Assessment of Water Quality, Road Runoff, and Bulk Atmospheric Deposition, Guanella Pass Area, Clear Creek and Park Counties, Colorado, Water Years 1995–97

By Michael R. Stevens

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U.S. DEPARTMENT OF THE INTERIOR
GALE A. NORTON, Secretary

U.S. GEOLOGICAL SURVEY
Charles G. Groat, Director

For additional information write to:

District Chief
U.S. Geological Survey
Box 25046, Mail Stop 415
Denver Federal Center
Denver, CO 80225–0046

Copies of this report can be purchased from:

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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATIONS

Multiply	By	To obtain
acre	0.00156	square mile
acre-foot (acre-ft)	1,233	cubic meter
acre-foot per square mile (acre-ft/mi^2)	0.000476	cubic hectometer per square kilometer
yard	0.9144	meter
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
inch	25.4	centimeter
mile	1.609	kilometer
square centimeter (cm^2)	0.1550	square inch (in^2)
square foot (ft^2)	0.0929	square meter
square mile (mi^2)	2.590	square kilometer (km^2)
ton, short	0.9072	megagram or metric ton
ton per day (T/d)	0.9072	megagram per day

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

$$°F = (1.8 \times °C) + 32$$

Sea level: In this report, “sea level” refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Additional Abbreviations

MCL	Maximum Contaminant Level
mg	milligrams
(mg/d)/ft^2	milligrams per day per square foot
mg/L	milligrams per liter
mm	millimeters
NTU	nephelometric turbidity units
ROE	residue on evaporation
µg/L	micrograms per liter
µm	micrometers
$\mu m^3/cm^2$	cubic micrometers per square centimeter
µS/cm	microsiemens per centimeter at 25 degrees Celsius

Assessment of Water Quality, Road Runoff, and Bulk Atmospheric Deposition, Guanella Pass Area, Clear Creek and Park Counties, Colorado, Water Years 1995–97

By Michael R. Stevens

Abstract

The Guanella Pass road, located about 40 miles west of Denver, Colorado, between the towns of Georgetown and Grant, has been designated a scenic byway and is being considered for reconstruction. The purpose of this report is to present an assessment of hydrologic and water-quality conditions in the Guanella Pass area and provide baseline data for evaluation of the effects of the proposed road reconstruction. The data were collected during water years 1995–97 (October 1, 1995, to September 30, 1997).

Based on Colorado water-quality standards, current surface-water quality near Guanella Pass road was generally acceptable for specified use classifications of recreation, water supply, agriculture, and aquatic life. Streams had small concentrations of dissolved solids, nutrients, trace elements, and suspended sediment. An exception was upper Geneva Creek, which was acidic and had relatively large concentrations of iron, zinc, and other trace elements related to acid-sulfate weathering. Concentrations of many water-quality constituents, especially particle-related phases and suspended sediment, increased during peak snowmelt and rainstorm events and decreased to prerunoff concentrations at the end of runoff periods. Some dissolved (filtered) trace-element loads in Geneva Creek decreased during rainstorms when total recoverable loads remained generally static or increased, indicating a phase change that might be explained by adsorption of trace elements to suspended sediment during storm runoff.

Total recoverable iron and dissolved zinc exceeded Colorado stream-water-quality standards most frequently. Exceedances for iron generally occurred during periods of high suspended-sediment transport in several streams. Zinc standards were exceeded in about one-half the samples collected in Geneva Creek 1.5 miles upstream from Grant.

Lake-water quality was generally similar to that of area streams. Nitrogen and phosphorus ratios calculated for Clear and Duck Lakes indicated that phytoplankton in the lakes were probably phosphorus-limited. Measures of trophic status (secchi depth, total phosphorus, and chlorophyll-*a*) indicated that Duck and Clear Lakes were oligotrophic in 1997.

Ground water had relatively low specific conductance (range 24 to 584 microsiemens per centimeter) and did not exceed U.S. Environmental Protection Agency drinking-water standards, except for samples collected from a single well, which exceeded the Proposed Maximum Contaminant Level for uranium.

Runoff from the Guanella Pass road enters streams through surface channels connected to culverts and roadside ditches. Fifty-six percent of the total number of culvert and roadside-ditch drainage features on the Guanella Pass

road showed evidence of recent surface runoff connection to an adjacent stream. Road runoff is generated during snowmelt and during summer rainstorms.

At a road cross-drain culvert monitored continuously for discharge (water years 1996–97), most runoff (77 to 96 percent) was a result of snowmelt, and runoff from the road preceded the basinwide peak streamflow, resulting in sediment and water-quality constituent inputs to the stream when the stream's capacity for dilution of the road runoff was low. Specific conductance of road-runoff samples ranged from 14 to 468 microsiemens per centimeter. Major-ion composition of some samples indicated effects from deicing salt (sodium chloride) and dust inhibitor (magnesium chloride) applied to sections of the road, but changes in the stream concentrations that might be attributed to the runoff were brief and relatively small.

Nutrients were commonly measured in road-runoff samples at larger concentrations than in streamflow. Concentrations of nitrate and ammonia, especially during rainfall-generated road runoff, were more similar to the concentrations in precipitation than to the concentrations in stream water. Concentrations of ammonia plus organic nitrogen (total as N) (range less than 0.2 to 24 milligrams per liter) and total phosphorus (range 0.024 to 7.2 milligrams per liter) in road runoff were generally large in snowmelt and rainstorm samples and were related to abundant particulate organic material and suspended sediment in the road runoff.

Trace-element data indicated that total recoverable trace-element concentrations in road runoff were substantially larger (by several times) than dissolved trace-element concentrations, indicating that most trace elements were particulate. Most of the stream trace-element standards would not likely be exceeded as a result of road-runoff constituents discharged into streams because the standards apply primarily to dissolved-phase (filtered) constituents, and the predominant phase associated with Guanella Pass road runoff is particulate.

The suspended-sediment concentrations in snowmelt-generated road runoff ranged from 66 to 7,360 milligrams per liter. Rainstorm-runoff concentrations ranged from 34 to 38,800 milligrams per liter. The sediment was primarily fine grained, which facilitated transport of the sediment. The median percentage of silt and clay (finer than 0.062 millimeter) in road-runoff samples analyzed for size fractions was greater than 90 percent for snowmelt samples and 88 percent for rainstorm samples.

Dilution of estimated road runoff to South Clear Creek upstream from Naylor Creek as a result of snowmelt on the road in early May (prior to peak watershed streamflows) ranged from approximately 10 to 100 times. During peak snowmelt in the watershed (early June), dilution of road runoff was estimated to be greater than 1,000 times. Dilution factors for late-summer-rainstorm road runoff were in the range of 10 to 500 times. Given the large concentrations of suspended sediment in road runoff, the potential water-quality effects of road runoff could be substantial during the low streamflows of early snowmelt and late summer base flow (low dilution capacity) but inconsequential during high streamflows (high dilution capacity).

The median bulk deposition rate of filterable solids is probably related to dust deposition from roads. The median deposition rate at sites near unpaved roads was 105 times the median rate at an undisturbed reference site (located at least 500 feet away from a road), and the rate at sites near paved roads was 3 times the undisturbed reference site median rate. During August to September 1997, bulk atmospheric deposition directly on the active channel of a reach of Geneva Creek was estimated to be 1.7 tons, or about 1 percent of the estimated 165 tons of suspended sediment transported past the nearby stream-monitoring site near Grant during the same period. The estimate of 1.7 tons indicates little potential effect from direct settling of bulk atmospheric solids on suspended-sediment transport in Geneva Creek, a stream that closely parallels the Guanella Pass road.

INTRODUCTION

The Guanella Pass road between Georgetown and Grant, Colo. (fig. 1), has been designated a scenic byway and is being considered for reconstruction. The mountainous area along the road is drained by South Clear Creek north of the pass and by Geneva Creek south of the pass (fig. 1). The area drained by these two streams and their tributaries is an important natural area that is used for clean-water supplies, recreation, and wildlife habitat.

The existing road was constructed during the 1950's and 1960's. The road consists of a series of paved and unpaved (dirt and gravel) sections, with road cuts and fills that were left to revegetate naturally. The proposed road reconstruction has several alternatives ranging from complete reconstruction and paving to leaving the road in the present form (Federal Highway Administration, 1993). The proposed road reconstruction may add new features, such as new asphalt paving, retaining walls, changes in drainage features, and revegetated slopes. The reconstruction of the Guanella Pass road may affect the chemical quality and sediment loading of the adjacent streams. However, an erosion-resistant road surface, engineered drainage system, and revegetation efforts might reduce the long-term amount of eroded sediment in the streams.

To characterize existing conditions and provide a basis for evaluation of the effects of the proposed road reconstruction, the U.S. Geological Survey (USGS), in cooperation with the Federal Highway Administration (FHWA) and Clear Creek County, conducted a study during water years (WY) 1995–97 (October 1, 1995, to September 30, 1997).

Purpose and Scope

The purpose of this report is to present an evaluation of hydrologic and water-quality conditions in the Guanella Pass area based on the data collected during water years 1995–97. Objectives of the study are to (1) describe existing hydrology, water quality, suspended sediment, and dust conditions in the Guanella Pass road area; (2) collect sufficient data for comparison of conditions during the preconstruction period to the construction and postconstruction periods if the road is reconstructed; and (3) assess general effects of the present road on hydrology, water quality, sediment, and dust.

Seventy-seven sites were established in the study area to facilitate hydrologic characterization of streams, lakes and reservoirs, ground water, road runoff, and bulk deposition related to the current road. Data were collected mostly in the South Clear Creek and Geneva Creek Basins, although sites in the West Chicago Creek and Deer Creek Basins were added as undisturbed reference sites.

This report focuses on documenting and describing the water resources (streams, lakes and reservoirs, and ground water) in the study area in terms of onsite measurements, concentrations of major and trace constituents, nutrients, and suspended sediment and compares water quality to applicable standards and guidelines. In the "Characterization of Guanella Pass Road Runoff" sections of the report, background information, chemical and sediment characteristics, sources, delivery to streams, and some potential effects of road runoff on water resources are discussed. In the "Bulk Atmospheric Deposition" sections, effects of road-surface type, distribution characteristics, and estimates of bulk atmospheric-deposition contributions from an unpaved road to a stream are discussed.

Acknowledgments

The assistance of others during this study was invaluable. The author thanks Historic Georgetown, Inc., Public Service Company of Colorado, William and Julia Holmes, Clear Creek and Park Counties, and the U.S. Department of Agriculture Forest Service for access to property for sampling and installation of equipment.

DESCRIPTION OF STUDY AREA

The Guanella Pass road, located approximately 40 miles west of Denver, Colo. (fig. 1), connects U.S. Interstate 70 at Georgetown with U.S. Highway 285 at Grant. The northern 13.1 miles is known as Clear Creek County Road 381, and the southern 10.4 miles is known as Park County Road 62 (Federal Highway Administration, 1993). The road ranges in altitude from about 8,600 ft at Georgetown and Grant to 11,699 ft at the top of the pass and consists of several paved and unpaved sections; the paved sections total 11.4 miles and the unpaved sections total 12.1 miles (Federal Highway Administration, 1993).

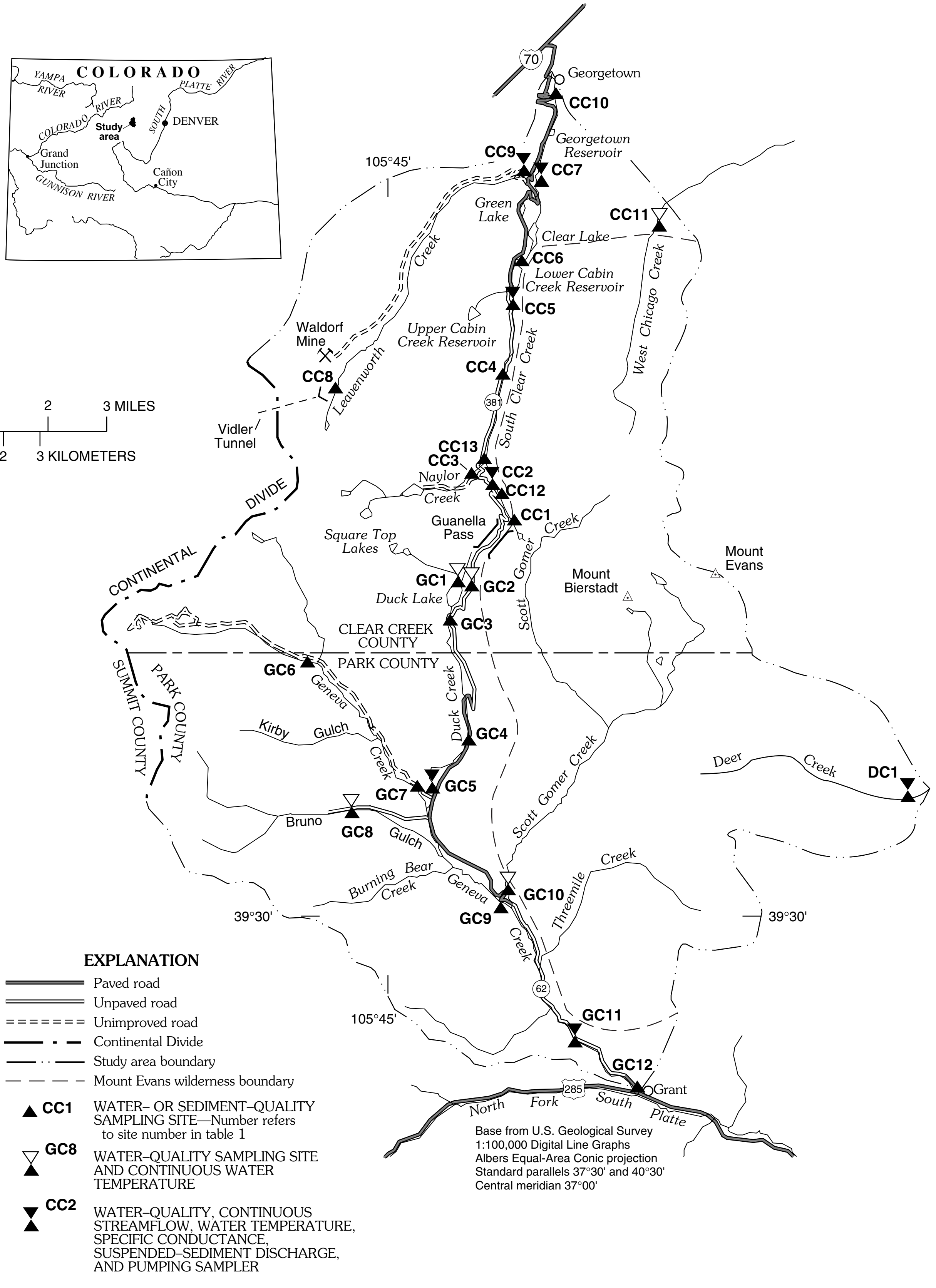


Figure 1. Location of Guanella Pass study area and stream data-collection sites.

The road section in Clear Creek County (fig. 1) is maintained year round; the road section in Park County is not maintained in winter but seldom is impassable. In Clear Creek County, a salt (sodium chloride) and sand mixture is applied to road sections in winter, and a magnesium chloride dust inhibitor is sometimes applied to unpaved road sections (Jim Cannedy, Clear Creek County, oral commun., 1997).

The study area includes the watersheds of South Clear Creek and Geneva Creek and part of the West Chicago Creek and Deer Creek watersheds (which do not drain areas along the Guanella Pass road). The Guanella Pass road parallels South Clear Creek from the pass to Georgetown; south of the pass, the road parallels Duck and Geneva Creeks to the southern terminus at Grant. The Continental Divide forms the western boundary of the study area, and the eastern one-half of the study area includes the Mount Evans Wilderness Area. Annual precipitation in the study area ranges from about 12 to 16 inches near Georgetown and Grant to about 40 to 50 inches in the higher mountains (Colorado Climate Center, 1984). Vegetation includes conifer and aspen forest at low altitudes and alpine tundra above timberline, which is about 11,500 ft.

Precambrian granite, gneiss, and schist compose the bedrock in the study area. Geology consists mainly of these three bedrock types; most basins have a mix of two or all three (Tweto, 1979). The metamorphic rocks are metasediments (metamorphic rock related to sedimentary parent material) and metavolcanics (metamorphic rock related to volcanic parent material). Both rock types are gneissic and are different mainly in the mafic mineral composition. Both rock types also are intruded and partly melted by granite from a large intrusion centered in the Mount Evans area. Small intrusions of Tertiary age in the headwaters of Geneva and Leavenworth Creeks cover a relatively small area.

Glaciers deposited drift in the valleys of Duck, Geneva, and South Clear Creeks (Tweto, 1979). The drift composes substantial portions of many of the unconsolidated deposits in the valleys. Armoring of the streambed by cobbles and boulders seems to reduce active channel erosion of the glacial drift. Many area lakes were created as a result of glacial activity.

Ore deposits were mined near the headwaters of Geneva and Leavenworth Creeks. These areas are known as the Geneva Creek and Argentine Districts (Davis and Streufert, 1990). Naturally occurring pyritic components of the intrusive rocks and mineral deposits become oxidized and produce acidic and mineralized ground water and surface water in the upper basin of Geneva Creek (Bassett and others, 1992) and Leavenworth Creek. This process is referred to as acid-sulfate weathering.

The primary land use is recreation. Most of the study area is managed by the U.S. Department of Agriculture, Forest Service (Forest Service). The Forest Service maintains five campgrounds in the area, two on the South Clear Creek side and three on the Geneva Creek side of Guanella Pass. Dispersed camping along the roadside is popular. Some livestock grazing occurs in the Geneva, Scott Gomer, and Duck Creek drainages. Although there was substantial logging in the area in the past (Nichols, 1992), there are no current (1999) logging operations. A few residences, some seasonal, are located at Duck and Naylor Lakes and along Duck, Geneva, and lower South Clear Creeks.

The Vidler Tunnel (fig. 1) diverts water from upper Peru Creek across the Continental Divide into the Leavenworth Creek Basin for downstream use. The Roberts Tunnel, a transmountain diversion of water from Dillon Reservoir to the North Fork of the South Platte River near Grant, conducts flows beneath the southwest corner of the study area. An aqueduct diverts water from Leavenworth Creek on a seasonal basis to maintain the water level in Green Lake, which is not located on a stream. Some of the natural lakes, such as Duck Lake, have been modified for increased storage by the construction of small dams. The Public Service Company of Colorado operates two reservoirs (Upper and Lower Cabin Creek Reservoirs) in the South Clear Creek Basin for a pumped-storage hydroelectric facility. Water is diverted from South Clear Creek at Georgetown Reservoir for drinking-water treatment and hydroelectric power generation in Georgetown.

MONITORING NETWORK AND QUALITY ASSURANCE

Seventy-seven sites were established in the study area for hydrologic characterization of streams, lakes and reservoirs, ground water, and road runoff and bulk deposition related to the current road. Data were collected mostly in the South Clear Creek and

Geneva Creek Basins, although sites in the West Chicago Creek (CC11) and Deer Creek (DC1) Basins were added as additional undisturbed reference sites. The locations of all sites are shown in figures 1–3, and the site names and identification numbers are listed in table 1. Data collected for the study period also are compiled in Stevens and others (1997), Stevens (1999), Stevens (2000), and Cox-Lillis (2000).

Continuous records of discharge, water temperature, specific conductance, and suspended sediment were collected at seven sites on perennial streams. These sites (CC2, CC5, CC7, CC9, GC5, GC11, and DC1) provided seasonal perspective and allowed computation of annual means and loads that can be used for comparisons between sites and between years at the same site.

Samples for surface-water quality were collected at 26 sites in WY’s 1995–97. In WY 1995, many sites were sampled at a reconnaissance level during high flow and low flow to determine the location of future sampling efforts. In WY’s 1996–97, the number of analytes was reduced along with the number of sites. Selected continuous-record sites (CC2, CC5, GC5, GC11, and DC1) were sampled approximately 20 times per year during the open-water season—approximately weekly from May through June and biweekly from July through August. A few samples were collected during low flow and storm runoff each year. Stream sites sampled for macroinvertebrates and algae (periphyton) are described in Cox-Lillis (2000). Water samples at these biological sites were collected at high flow and low flow in WY’s 1996–97 to characterize variability of water quality.

Water-quality samples, onsite-measurement profiles, and(or) bottom-sediment samples were collected from six lakes and reservoirs (fig. 2). In WY 1995, four lakes or reservoirs (L1, L2, L3, and L4) were sampled once for water chemistry in August. In WY 1996, L1 and L3 were sampled once for water chemistry during late summer. In WY 1997, L1 and L3 were sampled at least six times. Bottom-sediment chemical samples were collected each year from L1 and L3; one bottom-sediment chemical sample was collected during the study at L2, L4, L5, and L6.

Samples to assess ground-water quality were collected at 15 springs or wells (fig. 3). A single water sample was collected at campground wells and springs near the road to indicate the quality of water used for drinking and to indicate whether road-runoff chemical effects might be observed in sources near the road.

Road-runoff samples were collected at 17 sites (fig. 2) during WY’s 1995–97, mostly at cross-drain culverts or ditches at the roadside. Two chemical samples of full-depth composites of maximum-accumulation snowpack were collected in March (fig. 2) during WY’s 1995–97.

Bulk atmospheric-deposition samples were collected at 15 sites (fig. 3) during WY’s 1995–97. Differences in deposition between paved and unpaved road sites were assessed at 12 sites in August and September 1995. Site G was sampled intensively in August and September 1996 to assess deposition characteristics. Sites L, M, and N were sampled in August and September 1997 to compute an estimate of bulk deposition contributions to the active channel of Geneva Creek.

The types of hydrologic and water-quality data collected from streams, lakes, reservoirs, ground water, and road runoff in WY 1995 are onsite measurements (water discharge, water temperature, specific conductance, pH, turbidity, and dissolved oxygen); concentrations of major ions and dissolved solids (calcium, magnesium, sodium, potassium, alkalinity, sulfate, chloride, fluoride, silica, and dissolved-solids residue); nutrients (nitrogen and phosphorus compounds); trace elements (cadmium, copper, iron, lead, manganese, mercury, and zinc); organic carbon; and suspended sediment. These data, the methods of data collection, and quality assurance are listed and described in Stevens and others (1997) and Stevens (2000).

Replicate and equipment blank samples were obtained for quality-assurance purposes. Replicate samples were collected to determine sampling and analytical precision. Replicates were obtained by collecting an extra sample immediately after the first sample. Field blank samples were collected to determine if field sampling and processing equipment biased constituent concentration through contamination; laboratory bias also is included in the results of a field blank. Field blanks were prepared by using certified inorganic and organic blank water that was passed through the sampling equipment and processed as a regular sample.

Percentiles of relative percent difference (RPD) were computed for replicate samples. Median concentrations are reported for field blanks in table 2. The replicate data indicate generally reproducible analytical results. Median RPD’s ranged from 0 to

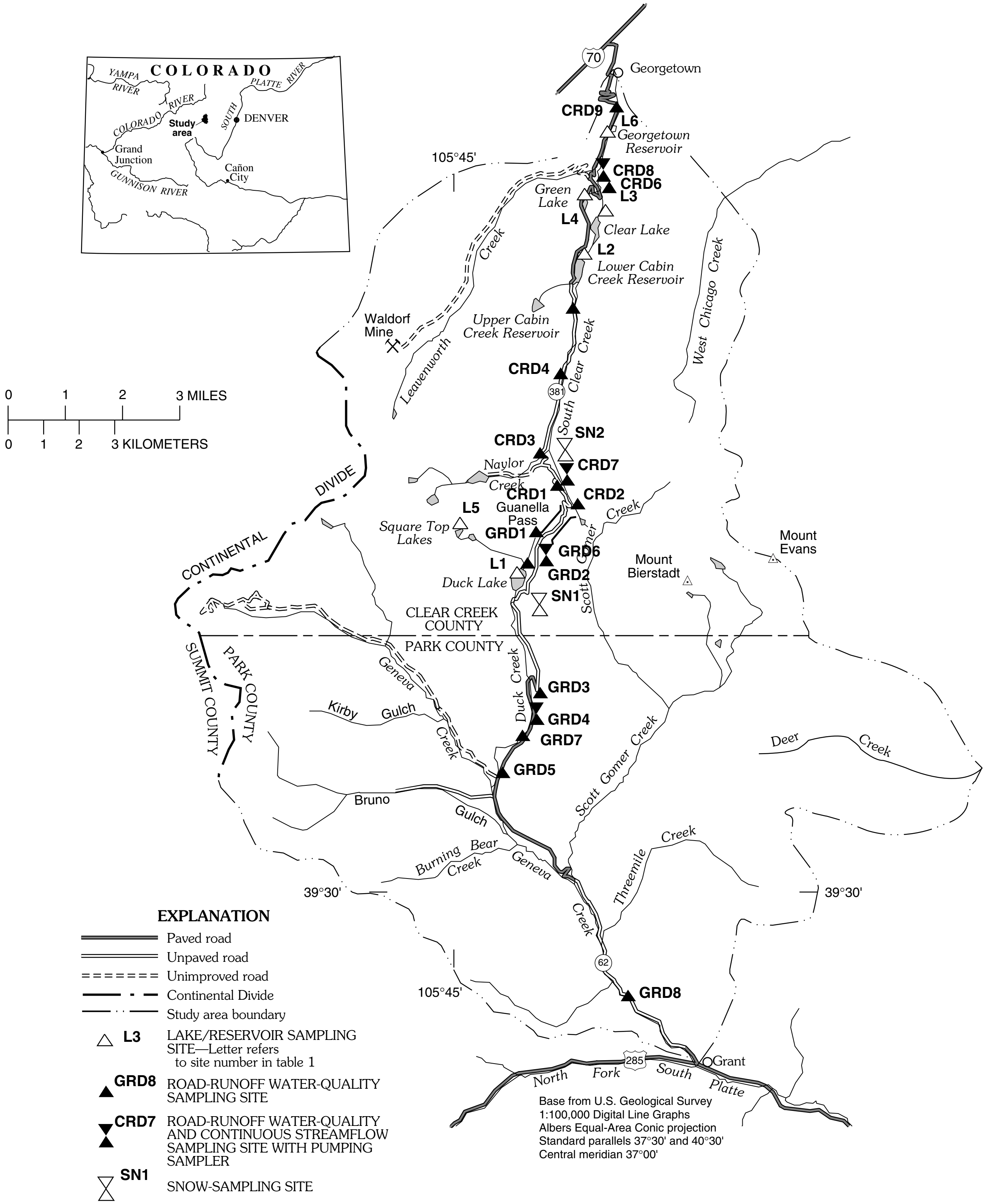


Figure 2. Location of lake, reservoir, road-runoff, and snow-sampling sites.

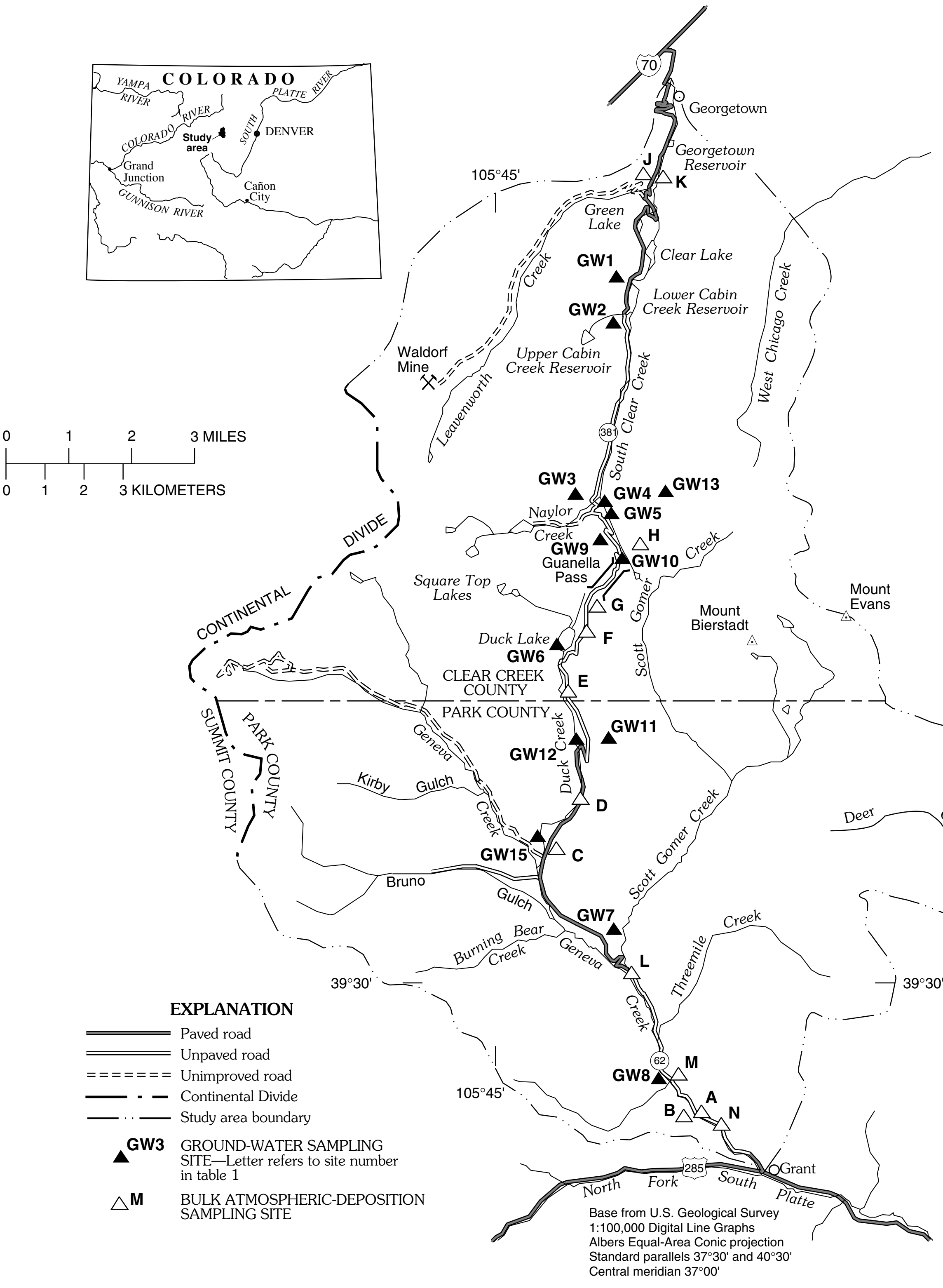


Figure 3. Location of ground-water and bulk atmospheric-deposition sampling sites.

Table 1. Data-collection sites

Site number (figs. 1–3)	U.S. Geological Survey identification number	Site name
CC1	393606105422118	South Clear Creek near Guanella Pass
CC2	393647105425317	South Clear Creek above Naylor Creek near Georgetown
CC3	393642105430416	Naylor Creek at mouth near Georgetown
CC4	393804105423413	South Clear Creek below Naylor Creek near Georgetown
CC5	06714400	South Clear Creek above Lower Cabin Creek Reservoir near Georgetown
CC6	393946105422203	South Clear Creek above Clear Lake near Georgetown
CC7	06714600	South Clear Creek above Leavenworth Creek near Georgetown
CC8	393819105452801	Leavenworth Creek above Waldorf Mine near Georgetown
CC9	06714800	Leavenworth Creek at mouth near Georgetown
CC10	394211105414100	South Clear Creek at Georgetown
CC11	394027105393900	West Chicago Creek near Idaho Springs
CC12	393619105423700	South Clear Creek above Naylor Creek at upper station near Georgetown
CC13	393649105425301	South Clear Creek near Guanella Pass Campground near Georgetown
GC1	393504105432312	Duck Creek above Duck Lake West Branch near Grant
GC2	393458105431511	Duck Creek above Duck Lake East Branch near Grant
GC3	393433105433210	Duck Creek below Duck Lake near Grant
GC4	393243105430814	Duck Creek above Mill Gulch near Grant
GC5	06704500	Duck Creek near Grant
GC6	393348105460415	Geneva Creek above Smelter Gulch near Grant
GC7	393153105440109	Geneva Creek above Duck Creek near Grant
GC8	393141105445808	Bruno Gulch above Geneva Park near Grant
GC9	393018105421707	Geneva Creek above Scott Gomer Creek near Grant
GC10	393028105421706	Scott Gomer Creek at mouth near Grant
GC11	06705500	Geneva Creek at Grant
GC12	392735105394705	Geneva Creek near Grant
DC1	393040105340400	Deer Creek near Bailey
GW1	393944105422500	Lower Cabin Creek Reservoir Dam spring
GW2	393904105422800	Clear Lake Campground well
GW3	393644105430400	Guanella Pass Campground west well
GW4	393638105425900	Guanella Pass Campground east well
GW5	393620105423900	Guanella Pass spring #1
GW6	393439105434200	Duck Lake spring
GW7	393052105423300	Burning Bear Campground well
GW8	392853105405800	Whiteside Campground well
GW9	393610105423900	Guanella Pass spring #2 near Georgetown
GW10	393616105423400	Guanella Pass spring #3 near Georgetown
GW11	393342105424800	Guanella Pass spring #4 near Grant
GW12	393335105431500	Guanella Pass spring #6 near Grant
GW13	393627105421800	Guanella Pass spring #7 near Grant
GW14	393036105340100	Deer Creek spring #1 near Bailey
GW15	393145105435300	Duck Creek Picnic Ground well near Grant
L1	393454105432900	Duck Lake near Grant
L2	393937105423900	Lower Cabin Creek Reservoir near Georgetown
L3	394011105425700	Clear Lake near Georgetown
L4	394032105421700	Green Lake near Georgetown
L5	393527105441900	Lower Square Top Lake near Grant
L6	394128105415300	Georgetown Reservoir near Georgetown

Table 1. Data-collection sites—Continued

Site number (figs. 1–3)	U.S. Geological Survey identification number	Site name
CRD1	393612105423800	Road ditch below Guanella Pass
CRD2	393602105423000	Road ditch near Guanella Pass
CRD3	393643105430200	Road ditch at Naylor Creek near Georgetown
CRD4	393643105425200	Road ditch above Lower Cabin Creek Reservoir near Georgetown
CRD5	393859105422700	Road ditch above Clear Lake Campground near Georgetown
CRD6	394036105415900	Road ditch below Green Lake near Georgetown
CRD7	393618105424200	Guanella Pass culvert #1 near Georgetown
CRD8	394043105420200	Guanella Pass culvert #4 near Georgetown
CRD9	394211105414300	Road ditch above Georgetown
GRD1	393516105430700	Road ditch near Duck Lake near Grant
GRD2	393506105430600	Road ditch above Duck Lake near Grant
GRD3	393309105430200	Road ditch near Geneva Mountain near Grant
GRD4	393244105430800	Road ditch below Duck Lake
GRD5	393152105434700	Road ditch below Mill Gulch near Grant
GRD6	393508105430600	Guanella Pass culvert #2 near Grant
GRD7	393243105430800	Campsite road runoff #1 near Grant
GRD8	393444105444100	Road ditch near Grant
A	392813105403200	Grant road site (bulk deposition) near Grant
B	392822105410600	Grant reference site (bulk deposition) near Grant
C	393152105434701	Road site below Mill Gulch (bulk deposition) near Grant
D	393300105431100	Road site above Mill Gulch (bulk deposition) near Grant
E	393413105432700	Geneva Basin Ski Area road site (bulk deposition) near Grant
F	393506105430601	Road site above Duck Lake (bulk deposition) near Grant
G	393516105430701	Road site near Duck Lake (bulk deposition) near Grant
H	393612105423801	Road site below Guanella Pass (bulk deposition) near Georgetown
J	394113105420000	Road site above Georgetown Reservoir (bulk deposition) near Georgetown
K	394116105414900	Clear Creek reference site (bulk deposition) near Georgetown
L		Geneva Creek bulk deposition site L near Grant
M		Geneva Creek bulk deposition site M near Grant
N		Geneva Creek bulk deposition site N near Grant

29 percent. Many of the larger RPD's are due to concentrations or values near the minimum reporting level (MRL), a range in which precision is expected to be poor. In these cases, concentrations may differ little but result in large RPD's. For example, a sample with a concentration of 0.01 mg/L and a replicate concentration of 0.02 mg/L would result in an RPD of 67 percent, but the difference might be considered to be within the precision of the method at that concentration. Data for individual replicate pairs and analytes, which are listed in Stevens (2000), can help determine if large RPD's are the result of substantial differences between replicate sample concentrations.

Median values or concentrations of field blanks indicated no substantial or systematic contamination bias during collection and processing of samples. Median concentrations for five analytes (table 2) were above the laboratory MRL (calcium, dissolved ammonia, dissolved aluminum, total organic carbon, and dissolved organic carbon). Calcium concentrations in blanks were far below most stream concentrations (median blank concentration was less than 10 percent of median stream concentrations, tables 34–47 in Appendix). Contamination bias in the other four analytes could affect the data in some samples containing small concentrations of those analytes.

Table 2. Summary of quality-assurance data, water years 1995–97

[mg/L, milligrams per liter; µg/L, micrograms per liter; --, no data; <, less than minimum reporting level; *, concentration in blank exceeds the laboratory minimum reporting level]

Property	Units	Number of pairs	Replicates (relative percent difference)			Blanks	
			10th percentile	50th percentile	90th percentile	Number of blanks	Median concentration
Calcium, dissolved	mg/L	4	0	0.7	1.5	8	*0.02
Magnesium, dissolved	mg/L	4	0	0	0	8	<.01
Sodium, dissolved	mg/L	4	0	0	0	8	<.02
Potassium, dissolved	mg/L	4	0	0	0	4	<.1
Sulfate	mg/L	6	0	0	5.0	6	<.1
Chloride	mg/L	6	0	0	93	6	<.1
Fluoride	mg/L	1	--	0	--	2	<.1
Silica	mg/L	4	0	0	1.0	8	<.02
Dissolved solids, residue at 180 degrees Celsius	mg/L	4	3.9	12	43	4	<1
Nitrogen, nitrite, dissolved as N	mg/L	--	--	--	--	4	<.01
Nitrogen, nitrite plus nitrate, dissolved as N	mg/L	7	0	4.9	13	9	<.05
Nitrogen, ammonia, dissolved as N	mg/L	5	0	0	0	7	*.004
Nitrogen, ammonia plus organic, dissolved as N	mg/L	--	--	--	--	1	<.2
Nitrogen, ammonia plus organic, total as N	mg/L	7	0	0	16	5	<.2
Phosphorus, total as P	mg/L	7	0	29	81	5	<.001
Phosphorus, dissolved as P	mg/L	--	--	--	--	2	<.01
Phosphorus, dissolved orthophosphate as P	mg/L	5	0	0	0	7	<.01
Aluminum, total recoverable as Al	µg/L	--	--	--	--	1	<10
Aluminum, dissolved as Al	µg/L	--	--	--	--	5	*.8
Antimony, dissolved as Sb	µg/L	--	--	--	--	5	<1
Arsenic, total recoverable as As	µg/L	--	--	--	--	1	<1
Barium, total recoverable as Ba	µg/L	--	--	--	--	1	<100
Barium, dissolved as Ba	µg/L	--	--	--	--	5	<1
Beryllium, total recoverable as Be	µg/L	--	--	--	--	1	<10
Beryllium, dissolved as Be	µg/L	--	--	--	--	5	<1
Cadmium, total recoverable as Cd	µg/L	--	--	--	--	1	<1
Cadmium, dissolved as Cd	µg/L	--	--	--	--	5	<1
Chromium, total recoverable as Cr	µg/L	--	--	--	--	1	<1
Chromium, dissolved as Cr	µg/L	--	--	--	--	5	<1
Cobalt, total recoverable as Co	µg/L	--	--	--	--	1	<1
Cobalt, dissolved as Co	µg/L	--	--	--	--	5	<1
Copper, total recoverable as Cu	µg/L	6	0	9	100	6	<1
Copper, dissolved as Cu	µg/L	6	0	0	54	10	<1
Iron, total recoverable as Fe	µg/L	6	3.3	12	31	6	<10
Iron, dissolved as Fe	µg/L	6	.5	6.4	21	10	<3
Lead, total recoverable as Pb	µg/L	6	0	0	0	6	<1
Lead, dissolved as Pb	µg/L	2	0	0	0	6	<1
Manganese, total recoverable as Mn	µg/L	6	0	0	43	6	<10
Manganese, dissolved as Mn	µg/L	6	0	0	3.8	10	<1
Mercury, total recoverable as Hg	µg/L	--	--	--	--	1	<.1
Molybdenum, total recoverable as Mo	µg/L	--	--	--	--	1	<1

Table 2. Summary of quality-assurance data, water years 1995–97—Continued

[mg/L, milligrams per liter; µg/L, micrograms per liter; --, no data; <, less than minimum reporting level; *, concentration in blank exceeds the laboratory minimum reporting level]

Property	Units	Number of pairs	Replicates (relative percent difference)			Blanks	
			10th percentile	50th percentile	90th percentile	Number of blanks	Median concentration
Molybdenum, dissolved as Mo	µg/L	--	--	--	--	5	<1
Nickel, total recoverable as Ni	µg/L	--	--	--	--	1	<1
Nickel, dissolved as Ni	µg/L	--	--	--	--	5	<1
Selenium, total recoverable as Se	µg/L	--	--	--	--	1	<1
Silver, total recoverable as Ag	µg/L	--	--	--	--	1	<1
Silver, dissolved as Ag	µg/L	--	--	--	--	5	<.2
Zinc, total recoverable as Zn	µg/L	6	0	0	0	6	<10
Zinc, dissolved as Zn	µg/L	6	0	13	54	10	<3
Uranium, natural, dissolved	µg/L	--	--	--	--	6	<1
Carbon, organic, total as C	mg/L	--	--	--	--	1	*.4
Carbon, organic, dissolved as C	mg/L	--	--	--	--	3	*.4

CHARACTERIZATION OF WATER RESOURCES

Characterization of existing water resources was necessary to document baseline preconstruction hydrologic and water-quality conditions and to provide a basis for evaluating possible effects of road runoff on the water resources. Information about precipitation, streams, lakes and reservoirs, and ground water in WY's 1995–97 was collected.

Precipitation

Precipitation in the study area falls primarily as snow during October through May. Short, locally intense thunderstorms occur in summer but usually cause only minor, short-duration rises in stream stage. Storm runoff from rainfall contributes relatively little to the total annual flow in streams and produces peak flows that are small compared to snowmelt peak flows. Average annual precipitation differs with altitude and position relative to major topographic features like the Continental Divide and Mount Evans. Average annual precipitation ranges from 12 to 16 inches near Georgetown and Grant, and 40 to 50 inches on Mount Evans and the Continental Divide (Colorado Climate Center, 1984).

Rainfall data were collected seasonally (April or May to September) by tipping-bucket recorders at streamflow gages, primarily for the purpose of activating storm-sampling equipment and for interpretation of water-quality data. The rainfall data indicate that 30 to 50 or more days with measurable rain can be expected from June to August each year. Rainstorms usually occur during afternoon to early morning. Daily precipitation seldom exceeded 0.5 inch but can exceed 1.5 inches (Stevens and others, 1997; Stevens, 2000). Measured precipitation totals in April, May, or September can be rain, melted snow, or both, depending upon air temperature. This can be important because raindrops have more erosive power than snow and cause faster surface-runoff response during a storm.

Snowpack chemical quality was analyzed once each year near the end of the snow accumulation season and before spring melting began (end of March) at two sites, one in South Clear Creek Basin (SN2) and one in Duck Creek Basin (SN1) (fig. 2). Because most of the water in the study area begins as snow, the chemical character of the snowpack is a useful initial geochemical baseline for the interpretation of water quality. In general, runoff derived from melted snow in the study area is dilute and slightly acidic (Stevens and others, 1997; Stevens, 2000). Specific conductance was generally less than 10 µS/cm, and pH ranged from 4.9 to 6.9. Major ion concentrations were small; calcium was the predominant cation, and sulfate was the predominant anion. Dissolved ammonia concentrations were generally less than 0.1 mg/L as N, dissolved nitrate concentrations were less than 0.20 mg/L as N, and dissolved orthophosphate concentrations were less than 0.02 mg/L as P. Aluminum, iron, manganese, and zinc were detected at small concentrations in the dissolved phase (less than 12 µg/L) (Stevens and others, 1997; Stevens, 2000).

Rainfall chemical quality was not analyzed in the study area, but regional precipitation quality is monitored by the National Atmospheric Deposition Program/National Trends Network (NADP/NTN) at several sites along the Colorado Front Range and is probably similar to precipitation quality in the Guanella Pass area. Precipitation-weighted-mean concentrations for winter and summer in 1997 at three sites (table 3, fig. 4) along the Front Range of Colorado are listed in table 4. Using precipitation-weighted-mean concentration ensures that the influence of the weekly composite concentration on the mean is proportional to the amount of precipitation that week. This concentration is computed as the sum of the weekly products of the precipitation volume multiplied by the composite concentration, and divided by the sum of all weekly precipitation volumes, for a particular season. For purposes of this study, winter included the months of December, January, and February, and summer included June, July, and August (National Atmospheric Deposition Program/National Trends Network, 1998).

Table 3. Selected National Atmospheric Deposition Program/National Trends Network sites in Colorado

Site number (fig. 4)	Site name	Latitude	Longitude	Altitude (feet)
P1	Loch Vale	40°17'16"	105°39'46"	10,364
P2	Niwot Saddle	40°03'19"	105°35'18"	11,549
P3	Manitou	39°06'04"	105°05'31"	7,749

Similar to snow chemistry of Guanella Pass samples, summer rainfall samples at the three NADP/NTN sites had low specific conductance, were slightly acidic, and had a low chloride concentration (table 4) (National Atmospheric Deposition Program/National Trends Network, 1998). Although concentrations of dissolved ammonia and nitrate are larger at the NADP/NTN sites than those measured in the snowpack on Guanella Pass, general patterns probably are similar. Despite a large range in mean concentrations among NADP/NTN sites, data indicate that dissolved inorganic nitrogen concentrations are larger in summer than winter. Also, the prevalence of relatively large inorganic nitrogen concentrations in rainfall is important to the interpretation of road-runoff nutrient chemistry because rapid conveyance of nutrient-laden runoff to streams bypasses soil processes that could remove nitrogen, resulting in larger stream nitrogen concentrations during rainstorm runoff.

Streams

Streams are the primary water resource in the Guanella Pass area. It is important to understand the hydrologic and water-quality aspects of study-area streams in order to characterize current conditions and establish a baseline for future comparisons.

Hydrology

Streamflow in the study area is affected by seasonal snow accumulation and melting (fig. 5). A winter base-flow period lasts from about mid-September to March and is characterized by low, stable flows that occur primarily beneath a cover of ice in midwinter and are supported by ground-water discharge. Particle transport is generally small and dissolved-solids concentrations are generally large during this period.

In April or early May, warm air temperatures can cause limited melting, especially at lower elevations, which causes small rises in streamflow and a flushing of sediment and chemical constituents that have accumulated on the streambed, in snowpack, and in soil or aquifer pore spaces. For sediment, the flushing is related to erosion by increased streamflow. For some dissolved chemical constituents, the flushing is related to the displacement of soil water and ground water (which are concentrated in dissolved solids due to longer contact time with soil and rock) into streams by meltwater (Hornberger and others, 1994) and to the selective release of chemical constituents from snowpack during the early period of snowpack

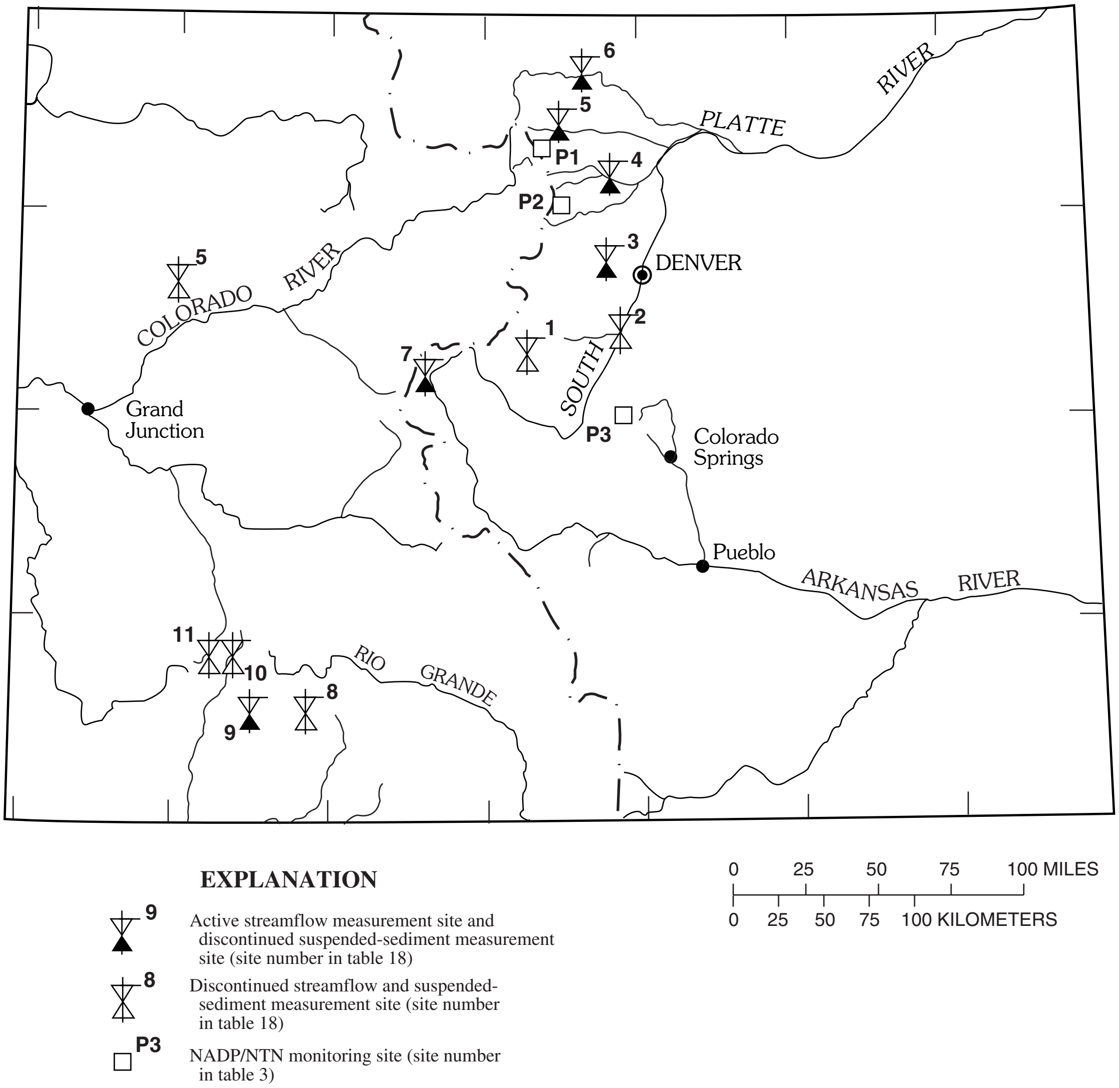


Figure 4. Location of selected precipitation and suspended-sediment sampling sites in Colorado.

melting (Davis and others, 1995). During this early melting period, the high-altitude snowpack reaches melting temperature, and meltwater infiltrates into the underlying soil and into ground water. This increases the ground-water hydraulic head under the snowpack, and ground water discharges to the streams.

During the rising limb of the hydrograph, streamflows increase rapidly but still fluctuate in response to changes in air temperature and spring storms. Streamflow fluctuates daily in response to melting (fig. 6), which can influence concentrations of water-quality constituents by dilution and physical suspension.

Peak streamflow typically occurs between late May and mid-June. Streamflows rapidly decrease after the peak, and the decline typically slows through July. Particle transport begins to decrease because of decreasing supply of sediment and energy for transport, and dissolved-solids concentrations generally increase because of less dilution by meltwater and changing sources of flow as the annual snowpack is depleted and streamflow is sustained by ground water. Rainstorms can occur from May to September but are most prevalent in July, August, and early September. In general, rainstorms cause small increases in streamflow but are not an important contributor to the annual total runoff.

Continuous streamflow was measured at seven sites in the study area (fig. 1). Annual stream-discharge data (Stevens and others, 1997; Stevens, 2000) are summarized in table 5. Differences in WY 1995–97 discharge for all sites are represented generally by the 1995–97 Geneva Creek (GC11) hydrograph shown in figure 7. The highest peak streamflows and annual runoff occurred in 1995 and the lowest occurred in 1996. Runoff measured at each site was generally proportional to drainage area, although the runoff per square mile differs (table 5) because of variations in precipitation with altitude. Annual runoff during the study period ranged from 1,220 acre-ft/yr (CC2 in 1996) to 59,510 acre-ft/yr (GC11 in 1995) (table 5; Stevens and others, 1997; Stevens, 2000).

Because the study period was only 3 years, the WY 1995–97 average runoff at streamflow-gaging stations with longer records might provide perspective in the context of long-term average runoff (table 6). In comparison to historical runoff at nearby gaging stations, WY 1995 was an exceptionally large runoff year. Flooding occurred in Georgetown, and some culvert and road damage resulted from peak flows in the Guanella Pass study area. Streamflow in water year 1996 was slightly above normal in some areas and below normal in other areas, while water year 1997 was above normal but less than WY 1995 high flows.

Flow-duration curves can be used to indicate which flow ranges were different in year-to-year comparisons. The Geneva Creek near Grant site (GC11) generally represents trends seen throughout the study area (fig. 8). The flow-duration curves show that the differences in flow among the 3 years occurred during the highest 10 to 20 percent of streamflows. These highest daily flows are representative of the peak snowmelt period and are important because generally most of the suspended-sediment and water-quality constituent loads are transported by the highest flows.

Water-Quality Characteristics

Water quality in the Guanella Pass study area was summarized using statistics, boxplots, and nonparametric correlations with streamflow, specific conductance, and suspended-sediment concentration. Evaluation of water quality with standards based on State of Colorado fixed and equation-derived values are described in the “Colorado Water-Quality Standards” section of this report. Methods of data collection, water-quality data, and daily mean data from continuously measured parameters are presented in Stevens and others (1997) and Stevens (2000). Statistical summaries of water-quality information are listed in table 7 for all sites and in Appendix tables 36–49 for individual sampling sites where more than two samples were collected.

Table 4. Rainfall chemical quality at selected Front Range of Colorado NADP/NTN sites in 1997 (National Atmospheric Deposition Program, 1998)

[NADP/NTN, National Atmospheric Deposition Program/National Trends Network; concentrations are precipitation-weighted-mean concentrations; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; winter includes December, January, February; summer includes June, July, and August]

Property or constituent	Loch Vale (P1)[1]		Niwot Saddle (P2)[1]		Manitou (P3)[1]	
	Winter	Summer	Winter	Summer	Winter	Summer
Specific conductance, µS/cm	4.8	7.6	4.9	9.6	8.7	12.6
pH, standard units	5.07	5.00	5.09	4.88	5.06	4.77
Calcium, dissolved, mg/L as Ca	.04	.09	.09	.11	.12	.19
Magnesium, dissolved, mg/L as Mg	.005	.012	.010	.014	.018	.026
Sodium, dissolved, mg/L as Na	.050	.033	.038	.031	.068	.049
Potassium, dissolved, mg/L as K	.011	.022	.015	.023	.042	.042
Chloride, dissolved, mg/L as Cl	.08	.05	.05	.06	.11	.08
Sulfate, dissolved, mg/L as SO_4	.28	.50	.26	.73	.31	.97
Nitrogen, ammonia, dissolved, mg/L as N	.03	.18	.03	.25	.21	.28
Nitrogen, nitrate, dissolved, mg/L as N	.41	.78	.52	1.08	1.18	1.41

[1] Sites are shown on map in figure 4.

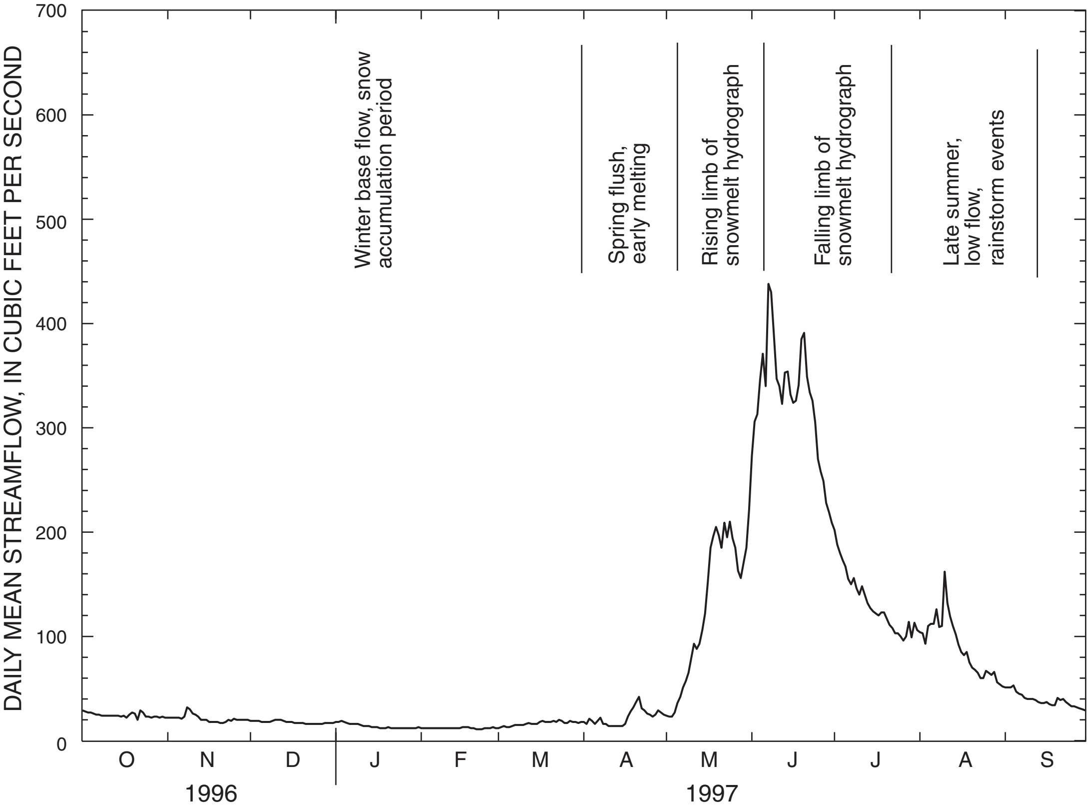


Figure 5. Generalized stream hydrograph divided into seasonal periods.

Onsite Measurements

Onsite measurements of water temperature, specific conductance, pH, and dissolved oxygen were made when water-quality samples were collected. Water temperature was measured continuously at sites CC2, CC5, CC7, CC9, CC11, GC1, GC2, GC5, GC8, GC10, GC11, and DC1, and specific conductance continuously at sites CC2, CC5, CC7, CC9, GC5, GC11, and DC1 (Stevens and others, 1997; Stevens, 2000).

Water temperature was measured continuously on a seasonal basis (May to September) at selected sites during WY's 1995–97 (Stevens and others, 1997; Stevens, 2000). Most sites had mean daily and instantaneous water temperatures within 1 or 2 degrees above 0°C from November to March. Summer monthly mean water temperatures for sites monitored in WY's 1996–97 with sufficient data are listed in table 8 and shown in figure 9. Summer water temperatures at all sites have a strong daily (diurnal) fluctuation influenced by air temperature, generally varying by as much as 5° to 10°C during the day. The warmest months of the year are July and August when monthly mean water temperatures ranged from 7.1° to 11.6°C; instantaneous high water temperatures during this period ranged from about 10° to 20°C (Stevens, 2000). Figure 9 indicates that monthly mean temperatures between sites vary by less than 5 degrees during the entire open-water season. In May, when there is no ice cover at low-elevation sites and ice cover is only beginning to melt in the high basins (GC1, GC2, CC2), a water-temperature gradient due to elevation (cooler at higher sites than at lower sites) is evident (table 8 and fig. 9). Through summer, the temperature differences between sites decrease.

Water chemistry in the streams of the Guanella Pass area changes seasonally with variations in water discharge (fig. 10). During the study period, water in the streams was relatively dilute, with specific-conductance values generally below 100 µS/cm. Specific conductance is strongly correlated with the amount of dissolved ionic compounds in water, making it useful for assessing the general amount of dissolved material that can degrade water when present in large concentrations (Hem, 1985). Median specific conductance at sites with computed statistics (table 7 and Appendix tables 36–49) ranged from 31 µS/cm at site GC1 to 87 µS/cm at site CC7. Less mineralized headwater sites (CC1, GC1, and GC2) had minimum specific conductances less than 30 µS/cm. Acid-sulfate weathering, caused by the oxidation of pyrite in the headwaters of Geneva and Leavenworth Creeks, was the source of relatively large specific conductances (greater than 100 µS/cm) measured during low flows along those streams. Large specific conductances also were measured at site CC2 at low flows and were due to the presence of springs located just upstream, which contribute water with specific conductances greater than 200 µS/cm (Stevens and others, 1997; Stevens, 1999).

Spearman correlation coefficients (Helsel and Hirsch, 1992) of specific conductance with selected constituents at selected sites were computed (table 9). Spearman's rho is a nonparametric measure of the strength of monotonic correlation between two variables using a rank procedure. Nonparametric statistics are less affected by non-normally distributed data than parametric statistics and can be used with data sets containing censored values (data reported as less than laboratory MRL). The correlation coefficient varies from minus 1 to plus 1, with the negative sign indicating a negative slope or decreasing dependent variable with an increasing independent variable, and the positive sign indicating a positive slope or increasing dependent variable with an increasing independent variable. Stronger correlation is indicated by values more positive or more negative than zero. The p-value is computed to indicate the significance level and two-tailed probability of error. For this study, Spearman's rho of greater than plus or minus 0.50 was considered at least moderately correlated. Also for this study, p-values less than 0.05 were considered highly significant and indicate a less than 5-percent statistical probability of error.

At all sites listed in table 9, specific conductance had a strong positive correlation with most of the major dissolved constituents (calcium, magnesium, sodium, alkalinity, sulfate, and silica), with the exception of potassium and chloride at three sites. Specific conductance generally was poorly and insignificantly correlated with nutrients. Trace elements were poorly

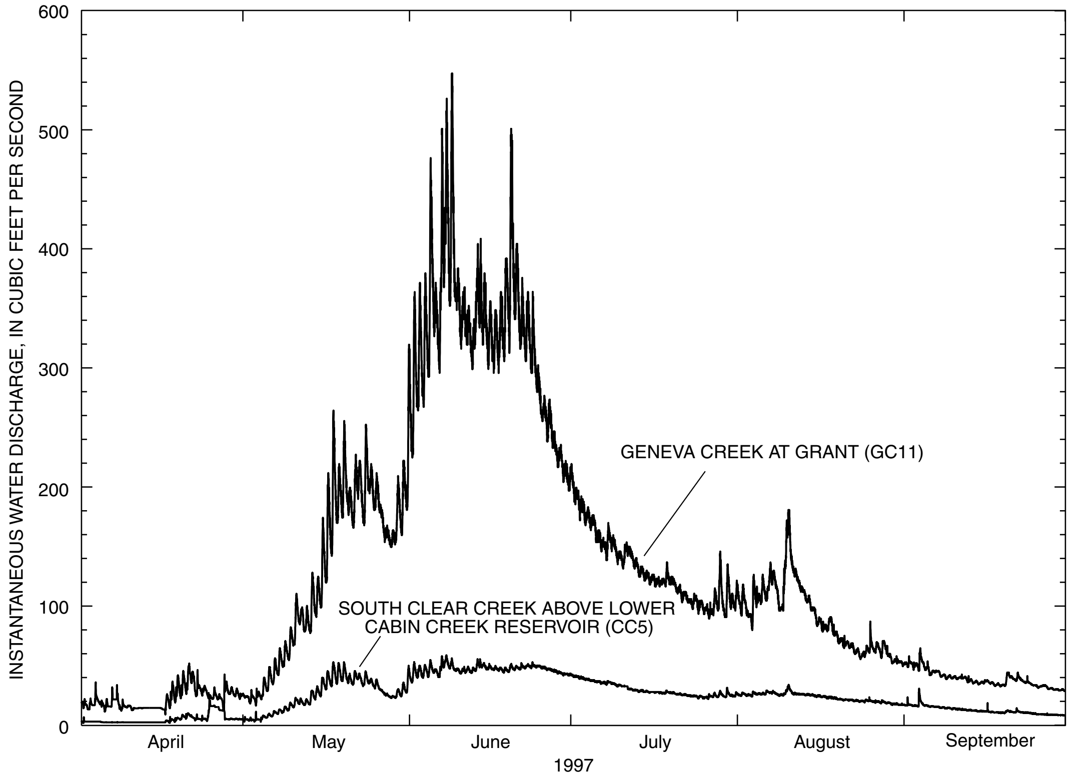


Figure 6. Fluctuations in instantaneous stream discharge at sites GC11 and CC5, April through September 1997.

Table 5. Stream discharge data for water years 1995–97 at sites with stream gages

[ft, feet; mi^2, square mile; ft^3/s, cubic feet per second; acre-ft, acre feet; site locations are shown in figure 1]

Measurement	CC2	CC5	CC7	CC9	GC5	GC11	DC1
Altitude of gage (ft)	10,710	10,100	9,280	9,280	9,750	8,760	9,280
Drainage area (mi^2)	2.19	11.8	16.0	12.0	7.78	74.6	13.4
Water year 1995							
Maximum daily discharge (ft^3/s)	--	107	147	125	78	746	--
Minimum daily discharge (ft^3/s)	--	1.6	3.6	1.2	0.46	7.4	--
Average daily discharge (ft^3/s)	--	15.3	21.2	17.7	7.33	82.2	--
Instantaneous peak flow (ft^3/s)	--	--	215	168	97	1,070	--
Annual runoff (acre-ft)	--	11,110	15,350	12,830	5,310	59,510	--
Annual yield (acre-ft/mi^2)	--	942	959	1,069	683	798	--
Water year 1996							
Maximum daily discharge (ft^3/s)	19	36	60	83	29	282	31
Minimum daily discharge (ft^3/s)	.17	2.5	3.4	1.3	.81	10	2.5
Average daily discharge (ft^3/s)	1.68	10.7	16.6	13.8	5.92	55.7	8.96
Instantaneous peak flow (ft^3/s)	--	42	64	100	32	357	--
Annual runoff (acre-ft)	1,220	7,770	12,080	10,020	4,300	40,470	6,510
Annual yield (acre-ft/mi^2)	557	658	755	835	553	542	486
Water year 1997							
Maximum daily discharge (ft^3/s)	19	54	113	100	36	438	103
Minimum daily discharge (ft^3/s)	.31	2.8	3.7	1.5	.60	11	2.4
Average daily discharge (ft^3/s)	2.21	14.0	18.4	15.3	6.60	70.2	16.7
Instantaneous peak flow (ft^3/s)	31	59	127	124	39	547	136
Annual runoff (acre-ft)	1,600	10,100	13,330	11,080	4,780	50,820	12,120
Annual yield (acre-ft/mi^2)	731	856	833	923	614	681	904

and insignificantly correlated with specific conductance with the exception of GC11, where manganese and zinc were moderately and positively correlated with specific conductance in both total recoverable and dissolved analyses. Suspended-sediment concentration generally had a weak inverse correlation with specific conductance; the negative slope reflects the opposite influences of streamflow on the two constituents (that is, specific conductance decreases with increasing streamflow, whereas suspended-sediment concentration generally increases with increasing streamflow).

Median specific conductance generally increased from site CC1 near the headwaters of South Clear Creek to CC7, just upstream from the confluence with Leavenworth Creek (fig. 11). Concentration by evapotranspiration, tributary inflow, or ground-water inflow might be the cause of the downstream upward trend.

Upstream/downstream comparisons in two reaches (CC1 to CC2, and CC13 to CC5, fig. 1) along South Clear Creek in water year 1997 also were used to determine whether specific conductance increases in a downstream direction in upper South Clear Creek, a stream reach that parallels the Guanella Pass road. Samples collected at paired upstream/downstream sites (sampled in downstream order, closely spaced in time) indicates that the upstream sites generally had smaller values of specific conductance on all of the sampling dates (fig. 12). Figure 12 also shows that water discharge increases in a downstream direction, indicating inflow from surface- and ground-water sources, which could explain the increase in specific conductance.

Specific conductance generally increased in a downstream direction along Duck Creek from GC1 to GC5 (fig. 11). Geneva Creek, a stream with relatively large concentrations of dissolved solids as a result of acid-sulfate weathering processes, tends to decrease in specific conductance in a downstream direction from GC7 to GC11 (fig. 11) due to dilution by less concentrated tributary flows.

Values of pH generally were neutral (between about 7 and 8) (fig. 11) except at GC7 and GC6, mineralized sites in the upper part of Geneva Creek (upstream from the moderating influence of Scott Gomer Creek), where pH values as low as 3.9 were measured (GC6). Annual fluctuations in pH at most sites were less than 1.0 pH unit. Although Leavenworth Creek is affected by mine drainage, pH was always neutral at the mouth (CC9). The low-flow sample in the upper part of the Leavenworth Creek Basin (CC8) in 1995 also had a near-neutral pH (7.2). The pH was not correlated with specific conductance (table 9) except at site GC11, where seasonal dilution by relatively alkaline snowmelt causes a weak but significant positive correlation with discharge and consequently a weak but highly significant negative correlation with specific conductance. Alkaline snowmelt might seem inconsistent because snow is weakly acidic, but exposure of the meltwater to soil and rock materials increases alkalinity of the runoff.

The solubility of dissolved oxygen is controlled by temperature and barometric pressure. Certain natural environments such as wetlands and the bottom water of lakes can be undersaturated in dissolved oxygen; but generally the turbulent, shallow, rapid-flowing streams of mountainous areas are well oxygenated. Temperature fluctuations and photosynthetic activity can result in temporary supersaturation of dissolved oxygen. Dissolved-oxygen concentrations during the study ranged from 6.7 mg/L (GC2) to 11.6 mg/L (CC5), and the median percentage of saturation of dissolved oxygen ranged from 99 (GC5, GC8) to 104 (GC10) (table 7, Appendix tables 36–49). No dissolved oxygen deficiencies (less than 6 mg/L; Colorado Department of Public Health and Environment, Water Quality Control Division, 1996) were measured in any streams during the study.

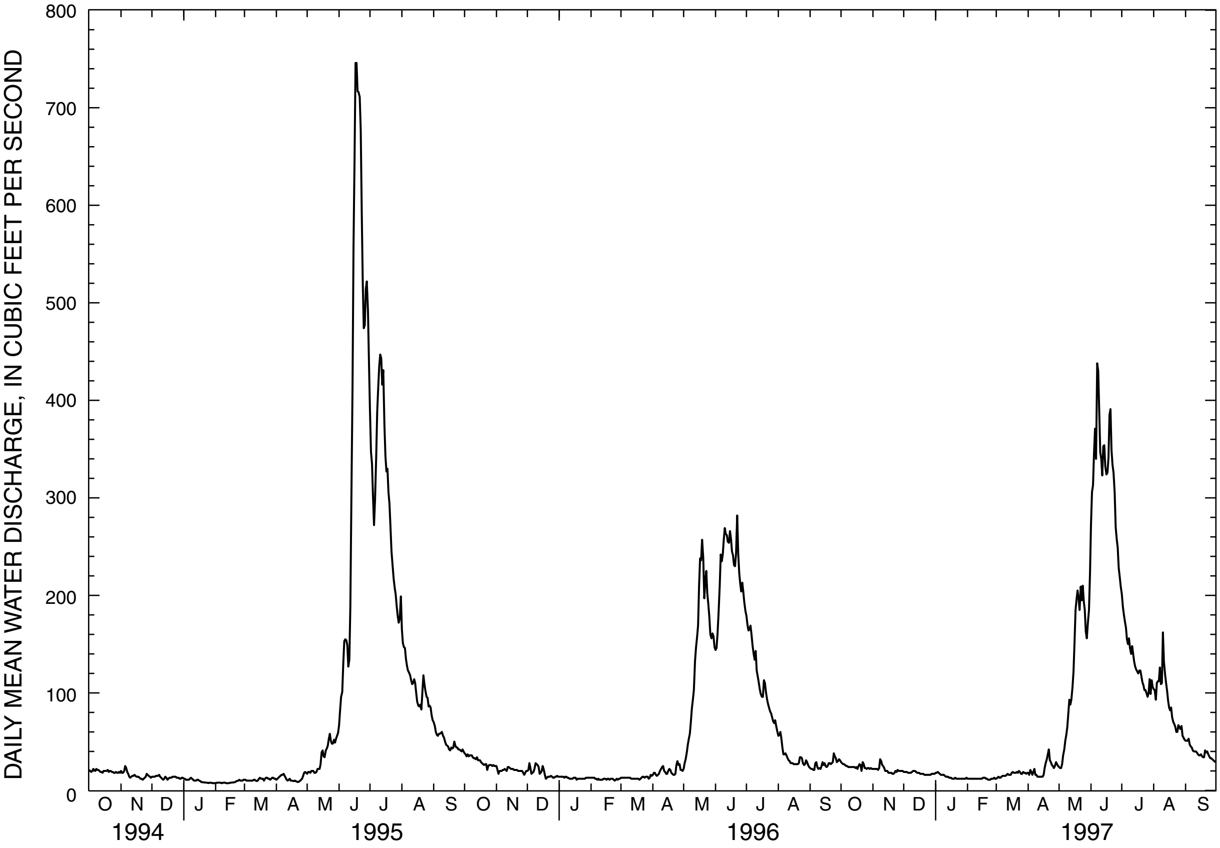


Figure 7. Daily mean water discharge at Geneva Creek at Grant (GC11), water years 1995–97.

Table 6. Percentage of average annual flow for streams near Guanella Pass study area, water years 1995–97

[Data from Crowfoot and others (1996–98); WY, water year; average annual runoff is for the period of record]

U.S. Geological Survey station number	Station name	Average annual runoff (acre-ft)	Percentage of average annual flow			Distance from study area
			WY 1995	WY 1996	WY 1997	
06716500	Clear Creek near Lawson	105,700	151	126	139	6 miles downstream from Georgetown
06710385	Bear Creek above Evergreen	29,330	157	77	119	21 miles east of Guanella Pass
06706000	North Fork South Platte River below Geneva Creek, at Grant[1]	52,240	155	106	137	1,500 feet downstream from confluence with Geneva Creek, at Grant

[1] Diversions from Roberts Tunnel have been subtracted.

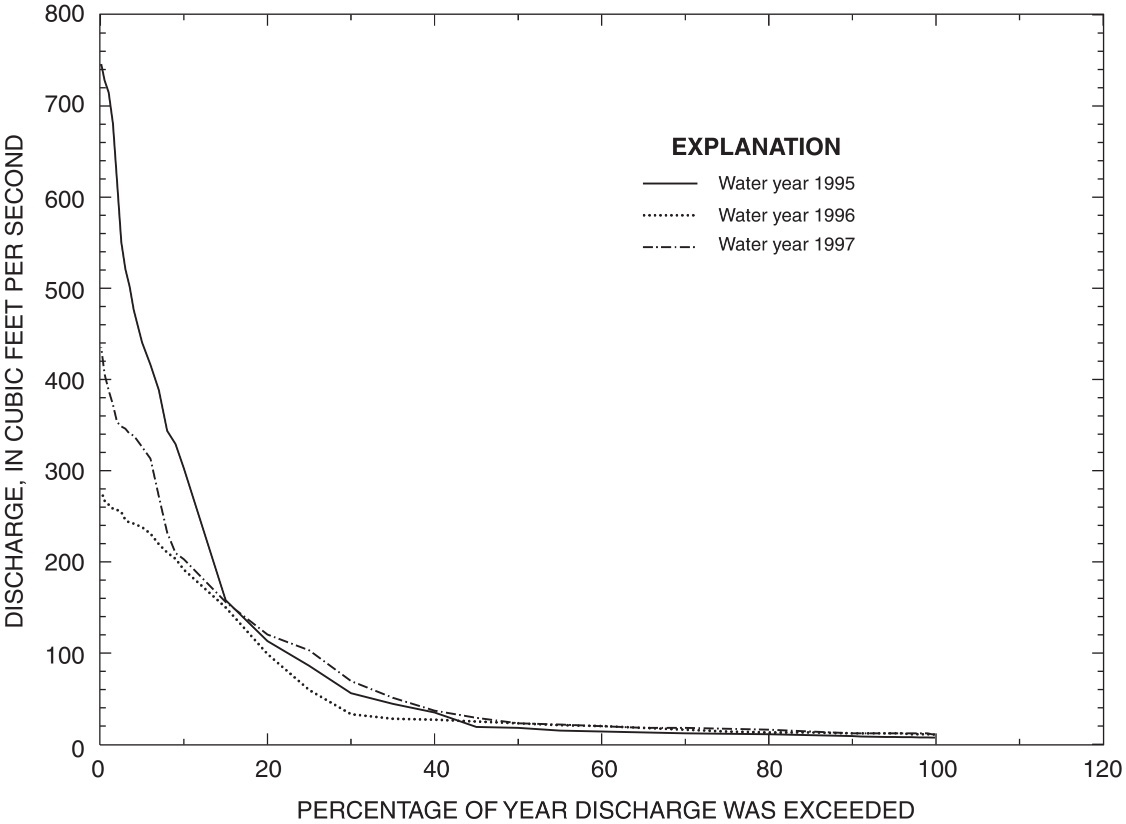


Figure 8. Flow-duration curves at Geneva Creek at Grant (GC11), water years 1995–97.

Table 7. Summary of stream-water-quality statistics, water years 1995–97

[--, insufficient data to calculate statistic; ranges of site data computed from all stream-water-quality sites; median statistics are a compilation of individual site summary statistics in the Appendix; **, 1995 data were at a higher minimum reporting limit (MRL) and are not included in computations; µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; mg/L, milligrams per liter; %, percentage; <, less than; µg/L, micrograms per liter; mm, millimeters; T/d, tons per day]

Property or constituent	Units	Data range		Summary of site median statistics		
		Minimum	Maximum	Minimum median	Median of medians	Maximum median
Specific conductance	µS/cm	23	210	31	44	87
pH	units	3.8	8.8	5.0	7.6	8.0
Turbidity	NTU	.2	2,140	.7	2.2	8.0
Dissolved oxygen	mg/L	6.7	11.6	7.7	8.8	9.8
Dissolved oxygen saturation	%	84	117	99	100	104
Hardness, as $CaCO_3$	mg/L	9	89	11	18	38
Calcium, dissolved	mg/L	2.6	16	3 3	5	10
Magnesium dissolved	mg/L	.6	12	.8	1.2	3.9
Sodium dissolved	mg/L	.7	5.6	.8	1.4	1.7
Potassium dissolved	mg/L	.2	2.0	.5	.6	1.2
Acid-neutralizing capacity, Alkalinity, lab, as $CaCO_3$	mg/L	<.1	61	4.6	16	41
Sulfate	mg/L	.8	90	1.4	3.3	23
Chloride	mg/L	<.1	36	.1	.3	1.2
Fluoride	mg/L	<.1	.4	.1	.2	.2
Silica	mg/L	4.1	13	4.4	6.8	9.2
Dissolved solids, residue at 180 degrees Celsius	mg/L	10	128	24	40	70
Nitrogen, nitrite, dissolved as N	mg/L	<.01	.01	--	--	--
Nitrogen, nitrite plus nitrate, dissolved as N**	mg/L	.005	.22	.011	.059	.1
Nitrogen, ammonia, dissolved as N**	mg/L	<.002	.036	<.002	<.002	<.002
Nitrogen, ammonia plus organic, dissolved as N	mg/L	<.2	.3	--	--	--
Nitrogen, ammonia plus organic, total as N	mg/L	<.2	4.3	<.2	<.2	.2
Phosphorus, total as P**	mg/L	<.001	3.2	.002	.009	.02
Phosphorus, dissolved as P	mg/L	<.01	.04	--	--	--
Phosphorus, dissolved orthophosphate as P**	mg/L	<.001	.02	<.001	.001	.002
Aluminum, total recoverable as Al	µg/L	20	11,000	--	--	--
Aluminum, dissolved as Al	µg/L	4	4,700	--	--	--
Antimony, dissolved as Sb	µg/L	<1	<1	--	--	--
Arsenic, total recoverable as As	µg/L	<1	<1	--	--	--
Barium, total recoverable as Ba	µg/L	<100	<100	--	--	--
Barium, dissolved as Ba	µg/L	16	38	--	--	--
Beryllium, total recoverable as Be	µg/L	<10	<10	--	--	--
Beryllium, dissolved as Be	µg/L	<1	<1	--	--	--
Cadmium, total recoverable as Cd	µg/L	<1	2	--	--	--
Cadmium, dissolved as Cd	µg/L	<1	2	--	--	--
Chromium, total recoverable as Cr	µg/L	<1	20	--	--	--
Chromium, dissolved as Cr	µg/L	<1	2	--	--	--
Cobalt, total recoverable as Co	µg/L	<1	10	--	--	--
Cobalt, dissolved as Co	µg/L	<1	8	--	--	--
Copper, total recoverable as Cu	µg/L	<1	92	<1	<1	17
Copper, dissolved as Cu	µg/L	<1	37	<1	<1	4
Iron, total recoverable as Fe	µg/L	10	110,000	80	460	1,200
Iron, dissolved as Fe	µg/L	<3	1,800	18	104	420

Table 7. Summary of stream-water-quality statistics, water years 1995–97—Continued

[--, insufficient data to calculate statistic; ranges of site data computed from all stream-water-quality sites; median statistics are a compilation of individual site summary statistics in the Appendix; **, 1995 data were at a higher minimum reporting limit (MRL) and are not included in computations; µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; mg/L, milligrams per liter; %, percentage; <, less than; µg/L, micrograms per liter; mm, millimeters; T/d, tons per day]

Property or constituent	Units	Data range		Summary of site median statistics		
		Minimum	Maximum	Minimum median	Median of medians	Maximum median
Lead, total recoverable as Pb	µg/L	<1	71	<1	<1	36
Lead, dissolved as Pb	µg/L	<1	2	<1	<1	2
Manganese, total recoverable as Mn	µg/L	<10	2,300	10	20	190
Manganese, dissolved as Mn	µg/L	<1	760	<1	5.5	190
Mercury, total recoverable as Hg	µg/L	<.1	.1	--	--	--
Molybdenum, total recoverable as Mo	µg/L	<1	2	--	--	--
Molybdenum, dissolved as Mo	µg/L	<1	<1	--	--	--
Nickel, total recoverable as Ni	µg/L	<1	17	--	--	--
Nickel, dissolved as Ni	µg/L	<1	17	--	--	--
Selenium, total recoverable as Se	µg/L	<1	<1	--	--	--
Silver, total recoverable as Ag	µg/L	<1	<1	--	--	--
Silver, dissolved as Ag	µg/L	<1	2	--	--	--
Zinc, total recoverable as Zn	µg/L	<10	430	<10	<10	190
Zinc, dissolved as Zn	µg/L	<3	320	<3	5.5	170
Uranium, natural, dissolved	µg/L	<1	2	--	--	--
Carbon, organic, total as C	mg/L	1.0	33	--	--	--
Carbon, organic, dissolved as C	mg/L	.5	3.3	--	--	--
Sediment, suspended	mg/L	<1	1,180	2	5.5	18
Sediment, suspended, % finer than 0.062 mm	%	14	100	44	69	83
Sediment, suspended, discharge	T/d	.001	1,370	.01	.19	1.8

Dissolved-Solids Loads

Dissolved-solids loads were computed for sites with continuous specific-conductance data (CC2, CC5, CC7, CC9, GC5, GC11, and DC1) by relating specific conductance to dissolved-solids (sum of constituents) concentration. The result of a regression of specific conductance (SC) with dissolved solids sum of constituents concentration (S_d) for all available data from all sites during the study was used to estimate daily mean dissolved-solids concentration from computed and estimated daily mean specific conductance at the selected sites. The data were transformed using the natural logarithm (LN) before doing an ordinary least-squares regression, then retransformed and multiplied by a bias transformation-correction factor. The regression is expressed as:

$$LN(S_d) = b + a\ LN\ (SC) \qquad (1)$$

where

a is the slope coefficient, and
b is the intercept coefficient for the regression.

A nonparametric bias correction factor, C_b, which is the mean of the exponentiated residuals from the regression (Duan, 1983), is expressed as:

$$C_b = [\Sigma\, e^{(r)}]/n \qquad (2)$$

where

e = 2.71828 (base for natural logarithms),
r = residuals of the regression, and
n = number of residuals.

The final form of the equation is:

$$S_d = e^{(a)} SC^{(b)} C_b \qquad (3)$$

The reduced form of the equation and regression information for the Guanella Pass data is:

$$S_d = (1.496)SC^{(0.7962)}; \quad r^2 = 0.95; \; p = <0.0001 \qquad (4)$$

where

r^2 is the correlation coefficient, and

p is the p-value indicating significance of the slope coefficient.

After computing daily dissolved-solids concentration from equation 3, the daily load of dissolved solids, L_{sd}, was computed from:

$$L_{sd} = (0.0027)QS_d \qquad (5)$$

where

Q is the daily mean water discharge, in cubic feet per second.

Annual dissolved-solids loads for available water years were calculated as the sum of the daily loads for selected sites (table 10). Annual loads ranged from 72.0 tons at site CC2 in water year 1996 to 2,800 tons at site GC11 in water year 1995. Flow-weighted-mean concentrations of dissolved solids (computed by dividing the annual load in tons by the mean annual flow in cubic feet per second and converting to milligrams per liter) among all sites ranged from 25 to 53 mg/L. These differences might be related to basin geology or land use. When loads were expressed as flow-weighted-mean annual concentrations and yields per unit of runoff, the concentrations and yields at a particular site were similar each year.

Major Ions

The inorganic dissolved constituents that compose most of the dissolved solids in natural waters are called major cations and anions. The major cations are calcium, magnesium, sodium, and potassium and have positive charges. Major anions are bicarbonate, sulfate, chloride, and fluoride and have negative charges. Bicarbonate concentration is computed from an alkalinity titration that measures the acid-neutralizing capacity (ANC) of the solutes in the water. Differences in the major-ion composition of water can indicate differences in water sources, geochemical processes, geology, and land use. A related property, hardness, is the sum of the milliequivalents of calcium and magnesium multiplied by 50 and is expressed as equivalent $CaCO_3$, in milligrams per liter (Hem, 1985). Hardness is used to compute the trace-element water-quality standards in Colorado. Summary statistics for major ions are

Table 8. Selected monthly mean water temperature in degrees Celsius for sites with continuous water-temperature measurement

[--, no data]

Site (see fig. 1)	Altitude (feet)	Water year 1996				Water year 1997			
		May	June	July	August	May	June	July	August
GC2	11,160	0.5	5.7	--	7.4	0.4	5.4	7.7	7.5
GC1	11,160	1.7	5.3	10.1	--	--	--	--	--
CC2	10,710	--	5.7	8.4	7.1	0.9	5.8	7.6	7.8
CC5	10,100	3.1	6.1	8.3	8.4	3.2	5.9	7.4	8.2
GC8	9,840	3.0	5.1	8.3	8.7	2.9	4.7	7.1	8.0
GC5	9,750	5.4	6.8	9.7	8.7	4.7	6.4	9.0	8.7
CC11	9,730	3.6	7.1	9.6	8.9	3.0	6.3	8.2	8.1
GC10	9,380	2.8	8.1	11.2	9.4	3.0	7.0	10.2	9.0
CC7	9,280	5.3	8.8	12.0	10.1	5.2	8.8	10.7	11.6
CC9	9,280	2.3	4.7	7.9	8.2	2.1	4.6	7.1	8.0
DC1	9,280	--	5.0	7.0	6.8	2.4	4.6	6.2	6.8
GC11	8,760	5.3	7.7	10.9	10.4	4.8	7.2	9.8	9.7

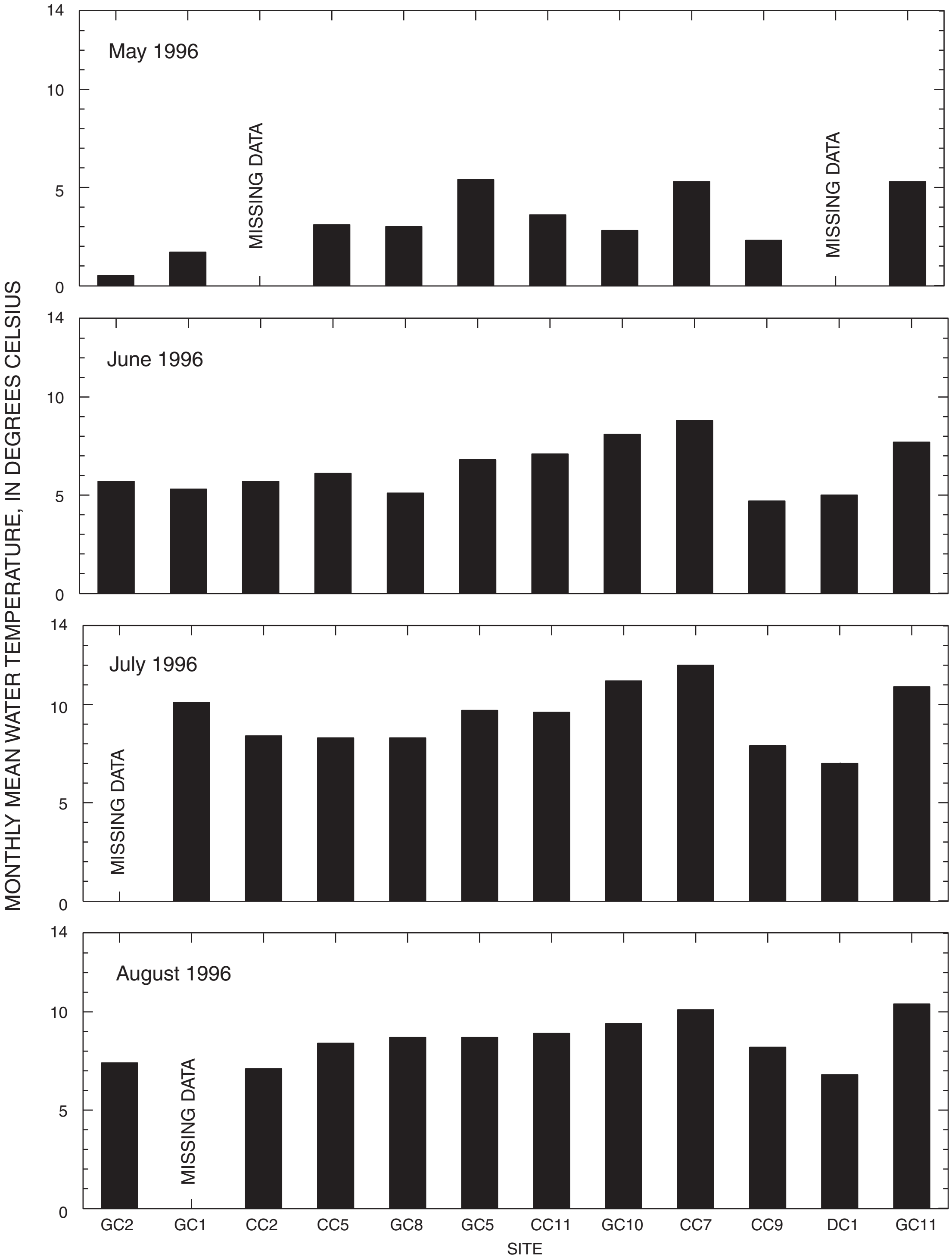


Figure 9. Monthly mean water temperature at selected sites, water years 1996–97.

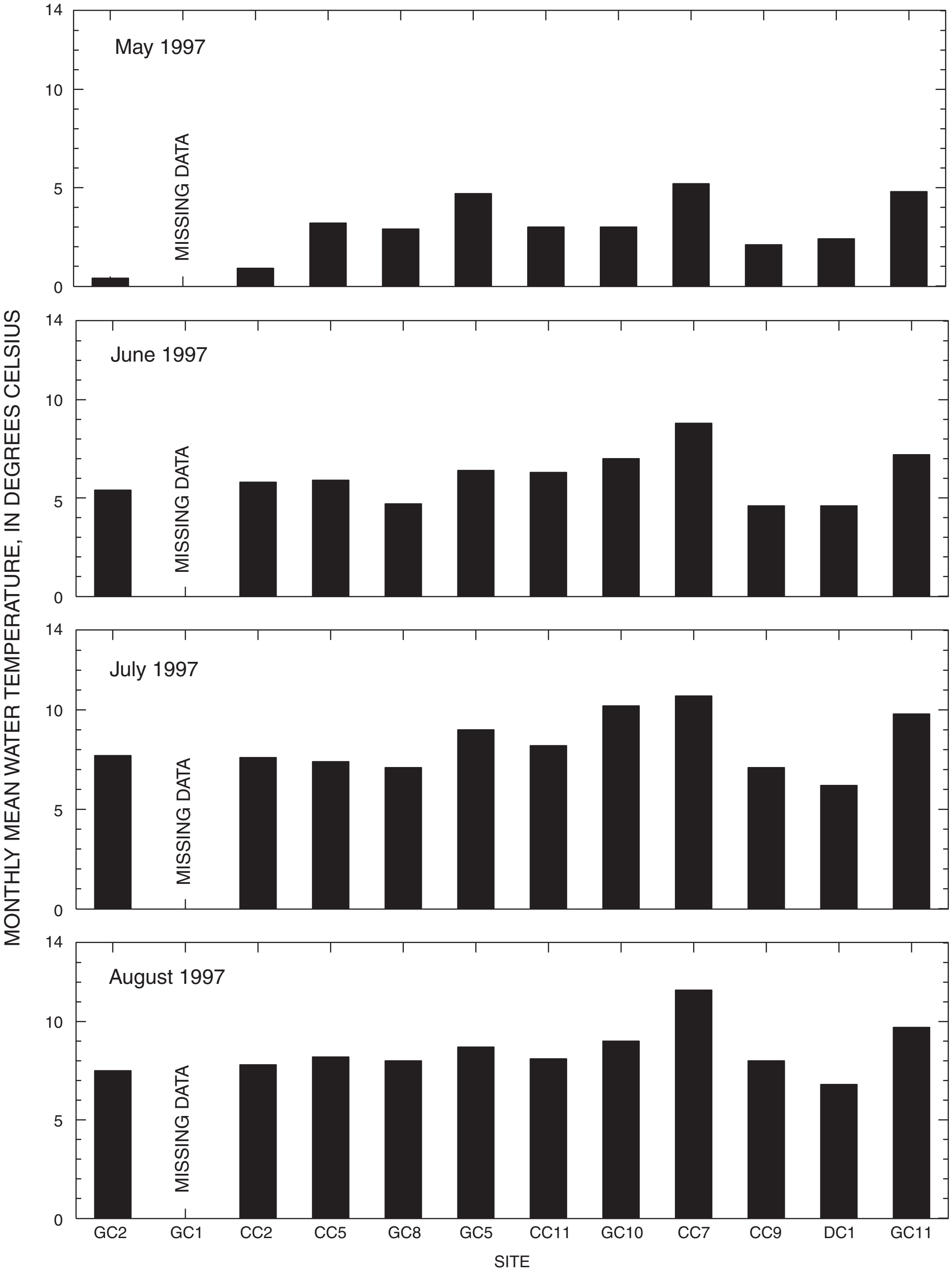


Figure 9. Monthly mean water temperature at selected sites, water years 1996–97—Continued.

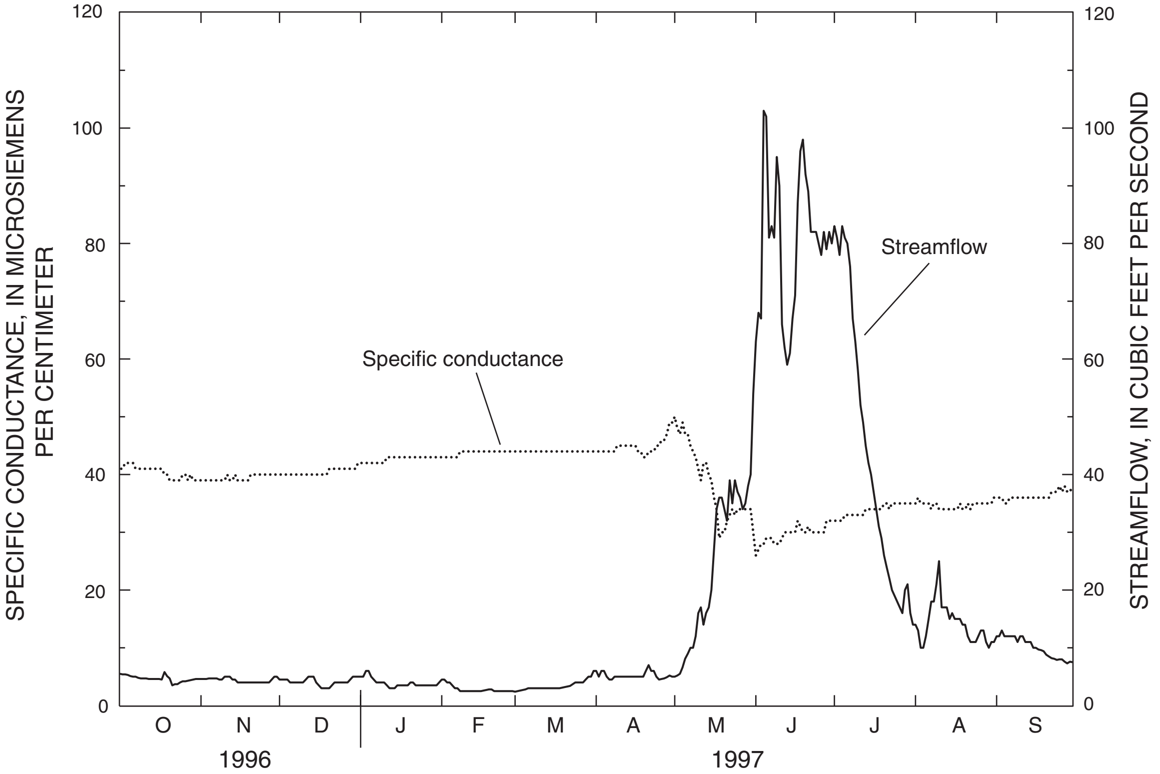


Figure 10. Seasonal variation of specific conductance and streamflow at site DC1, water year 1997.

listed in table 7 and the Appendix (tables 36–49). Boxplots of hardness, ANC (alkalinity), sulfate, and chloride for selected sites are shown in figure 11.

Stream chemistry was characterized by the predominance of calcium and bicarbonate (as indicated by acid-neutralizing capacity and the range in pH) at most sites (Stevens and others, 1997). The exceptions are the stream reaches where acid-sulfate weathering contributes enough sulfate to dominate the anions in stream water (upper Geneva and Leavenworth Creeks) (Stevens and others, 1997). When the mineral pyrite in bedrock or mine waste is oxidized, hydrogen ions (acid), sulfate, and iron hydroxide are produced. A summary of the reactions can be represented as follows (Moran and Wentz, 1974):

$$\begin{aligned} &FeS_2 + 3.75O_2 + 3.5H_2O \\ &\quad = Fe(OH)_3 + 2SO_4^{-2} + 4H^+ \end{aligned}$$

This acid-sulfate weathering process can result in lowering of pH, large sulfate and dissolved-solids concentrations, production of iron hydroxide (also known as yellow boy), and the release of trace elements such as copper, lead, and zinc associated with the pyrite or other minerals chemically weathered by the acidic water (Moran and Wentz, 1974).

Concentrations of major ions tended to be strongly and positively correlated with specific conductance (table 9), negatively correlated with water discharge (table 11), and poorly correlated with suspended sediment (table 12).

Possible Effects of Magnesium Chloride Applications on Major-Ion Chemistry in Streams

Because magnesium chloride (dust inhibitor) and sodium chloride (deicer) have been used on parts of the Guanella Pass road in Clear Creek County, chloride might be an indicator of road maintenance operations affecting surface water. Chloride concentrations in water are generally low in areas of crystalline bedrock geology because of the lack of minerals containing chloride. The primary source of chloride in these areas is precipitation and land use (such as deicers or dust inhibitors applied to a road).

Table 9. Spearman's coefficients of correlation for specific conductance (µS/cm at 25°C) and concentrations of selected water-quality constituents at selected sites, water years 1995–97

[rho, Spearman correlation coefficient; p-value, probability of a greater Spearman's rho; p-values <0.05 (2-tailed) are considered highly significant and are shaded, a light shade for positive, and a dark shade for negative correlations; Spearman's rho's greater than plus or minus 0.50 are shaded; NTU, nephelometric turbidity units; mg/L, milligrams per liter; µg/L, micrograms per liter; mm, millimeters; <, less than; correlations based on periodic water-quality samples]

Property or constituent	CC2		CC5		GC5		GC11		DC1	
	rho	p-value	rho	p-value	rho	p-value	rho	p-value	rho	p-value
pH, standard units	0.18	0.240	0.05	0.771	–0.12	0.420	–0.31	0.035	0.10	0.527
Turbidity, NTU	.19	<.001	–.11	.061	.05	.206	–.10	.005	–.02	.703
Oxygen, dissolved, mg/L	–.12	.487	.56	<.001	.49	.001	.34	.029	.40	.038
Hardness, total, mg/L as $CaCO_3$	.99	<.001	.92	<.001	.97	<.001	.94	<.001	.93	<.001
Calcium, dissolved, mg/L	.98	<.001	.89	<.001	.97	<.001	.93	<.001	.95	<.001
Magnesium, dissolved, mg/L	.99	<.001	.81	<.001	.95	<.001	.95	<.001	.92	<.001
Sodium, dissolved, mg/L	.96	<.001	.55	.029	.96	<.001	.83	<.001	.87	<.001
Potassium, dissolved, mg/L			.38	.143	.82	<.001	.41	.036	.38	.055
Alkalinity (acid-neutralizing capacity), mg/L as $CaCO_3$	.95	<.001	.91	<.001	.69	<.001	–.21	.307	.86	<.001
Sulfate, dissolved, mg/L	.96	<.001	.66	<.001	.82	<.001	.91	<.001	.54	<.001
Chloride, dissolved, mg/L	.79	<.001	.29	.101	.58	<.001	.19	.237	.30	.048
Silica, dissolved, mg/L	.64	<.001	–.34	.201	.92	<.001	.90	<.001	.66	<.001
Dissolved solids, sum of constituents, mg/L as N			.79	<.001	.91	<.001	.98	<.001	.89	<.001
Nitrogen, ammonia, dissolved, mg/L as N	.12	.635	.02	.925	.53	.022	.39	.110	–.28	.229
Nitrogen, ammonia plus organic, total, mg/L as N	–.45	.005	.21	.282	.15	.371	–.07	.689	.16	.310
Nitrogen, nitrite plus nitrate, dissolved, mg/L as N	–.01	.948	.25	.194	.49	.002	.15	.377	.15	.342
Phosphorus, total, mg/L as P	–.30	.074	–.16	.416	.04	.796	–.29	.084	.11	.466
Phosphorus, ortho, dissolved, mg/L as P	.02	.951	.15	.457	.15	.547	–.21	.398	.22	.359
Copper, dissolved, µg/L	.14	.386	–.04	.833	–.26	.099	–.07	.652	.21	.169
Copper, total recoverable, µg/L	.13	.427	–.16	.383	.13	.391	.33	.029	.19	.211
Iron, dissolved, µg/L	–.21	.181	–.17	.369	.47	.002	–.60	<.001	.13	.416
Iron, total recoverable, µg/L	–.19	.225	–.12	.502	.21	.163	–.34	.025	.13	.401
Lead, total recoverable, µg/L	.13	.394	–.14	.445	–.07	.630	–.06	.711	.15	.312
Manganese, dissolved, µg/L	–.19	.228	–.09	.624	.55	<.001	.82	<.001	.12	.443
Manganese, total recoverable, µg/L	–.11	.485	–.19	.295	.10	.508	.51	<.001	.13	.369
Zinc, dissolved, µg/L	–.26	.102	.23	.223	–.19	.237	.67	<.001	.18	.242
Zinc, total recoverable, µg/L	.21	.179	–.16	.369	–.14	.350	.60	<.001	.16	.288
Suspended sediment, percentage finer than 0.062 mm	.72	<.001	.34	.083	–.21	.789	.79	<.001	.61	.059
Suspended-sediment concentration, mg/L	–.74	<.001	–.30	.016	–.39	.077	–.40	.013	–.28	.117

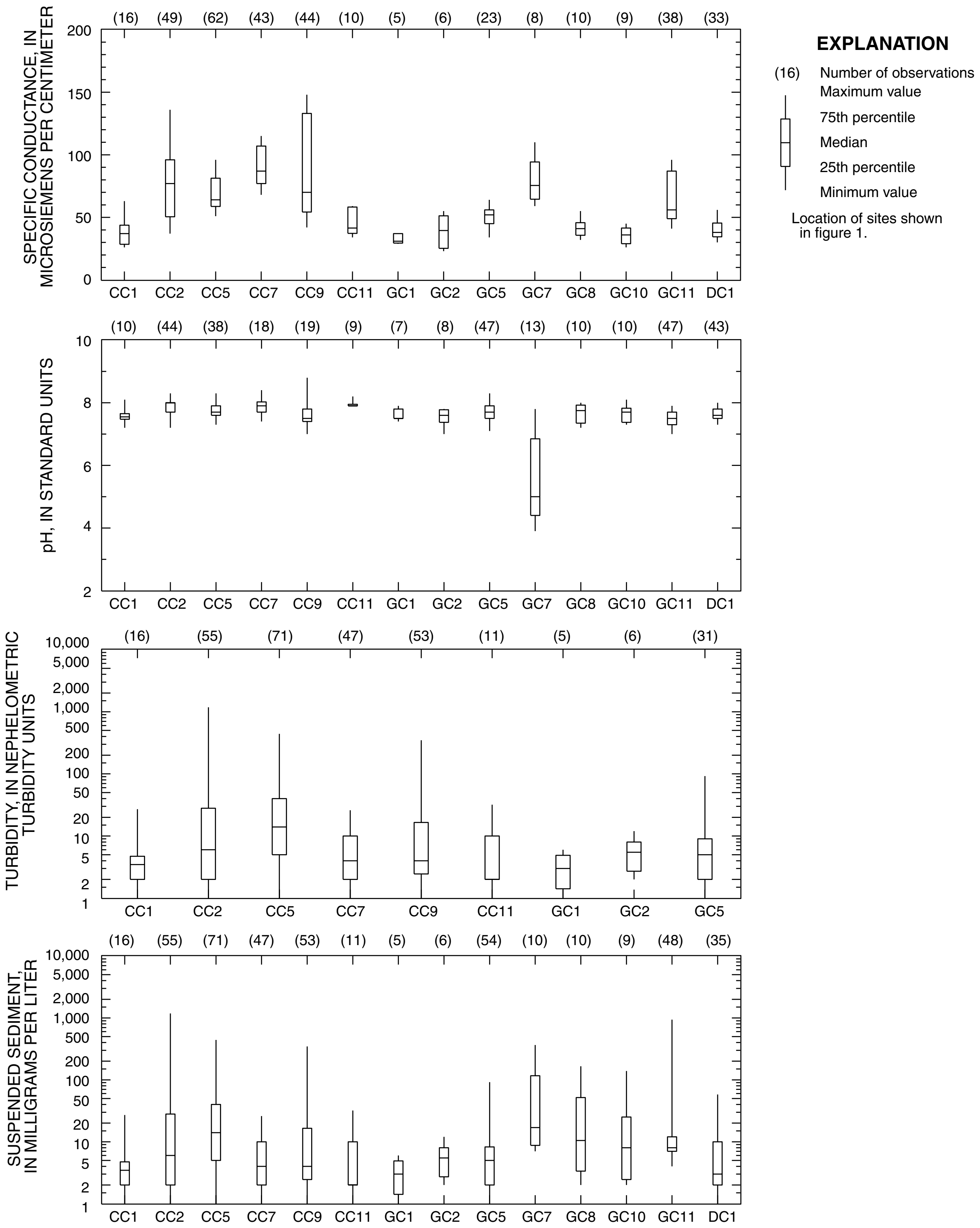


Figure 11. Distribution of concentrations and values of selected water-quality constituents at selected sites, water years 1995–97.

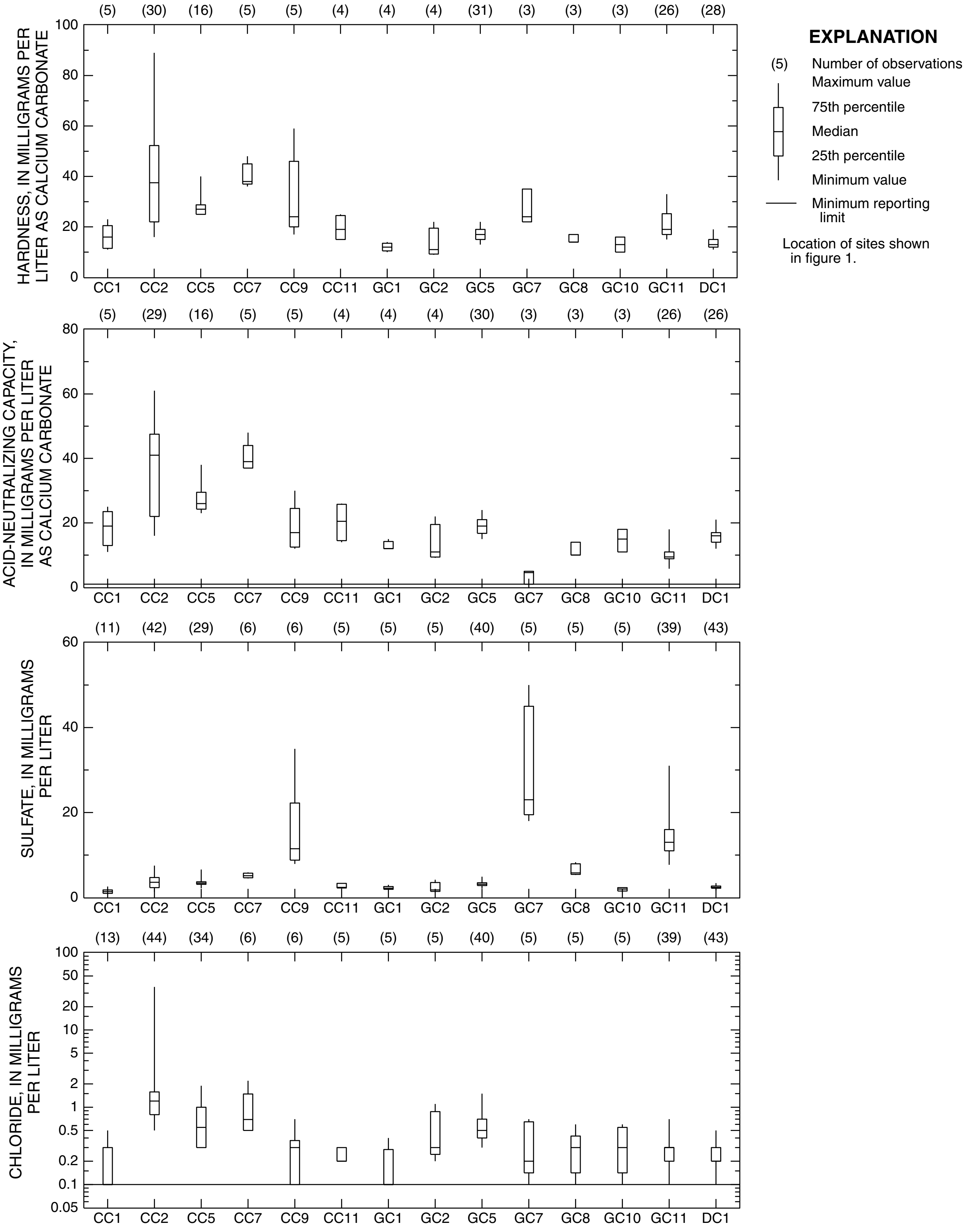


Figure 11. Distribution of concentrations and values of selected water-quality constituents at selected sites, water years 1995–97—Continued.

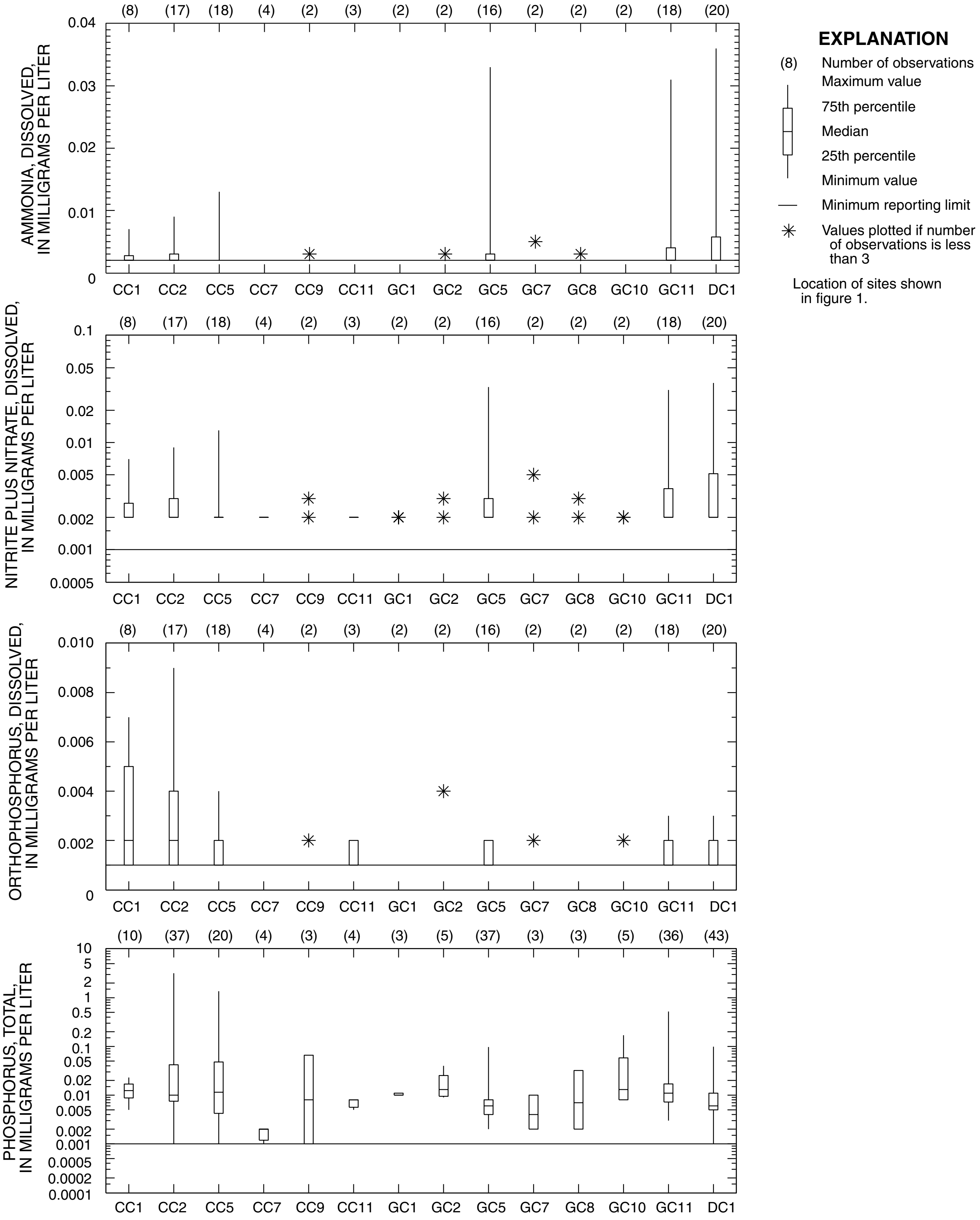


Figure 11. Distribution of concentrations and values of selected water-quality constituents at selected sites, water years 1995–97—Continued.

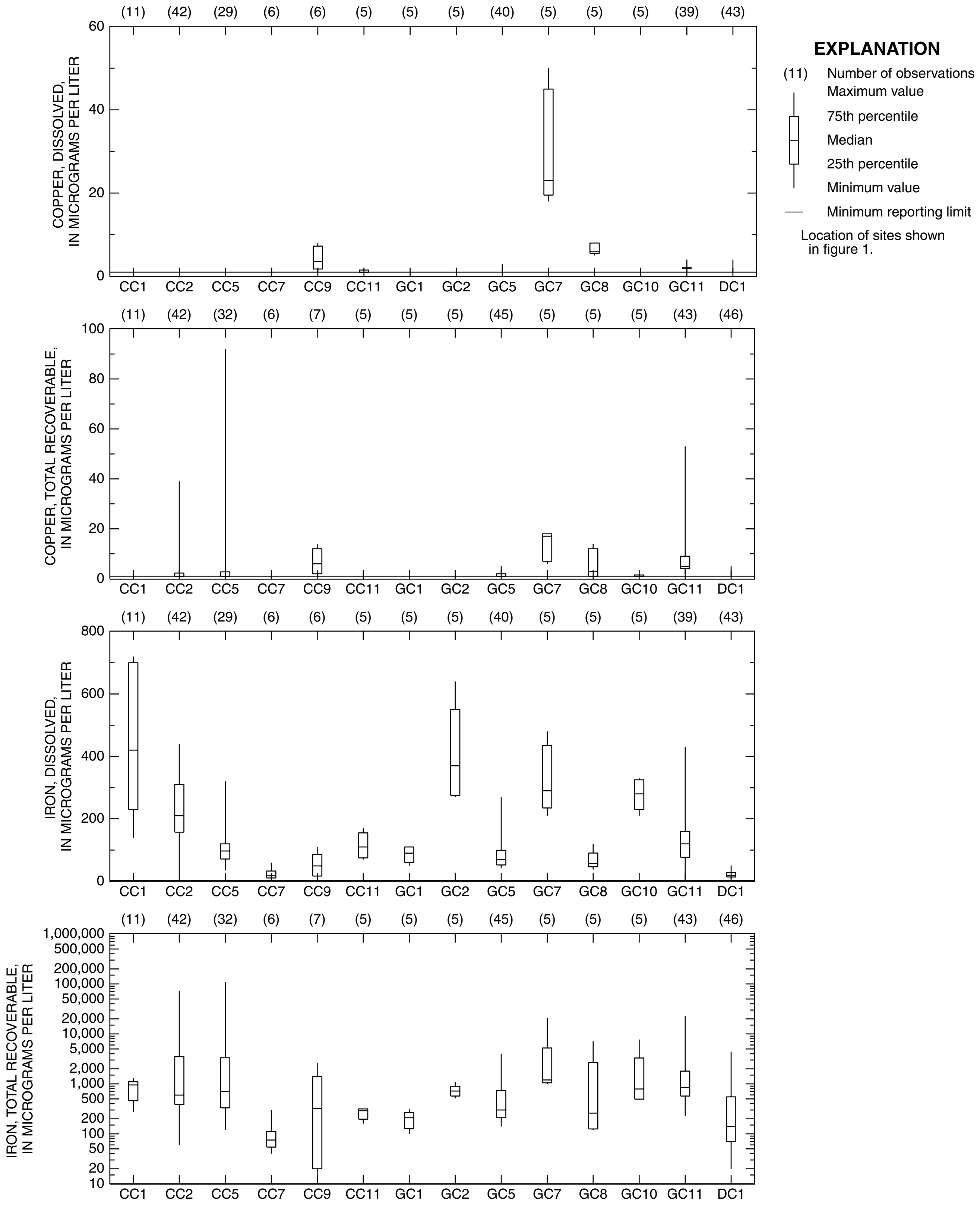


Figure 11. Distribution of concentrations and values of selected water-quality constituents at selected sites, water years 1995–97—Continued.

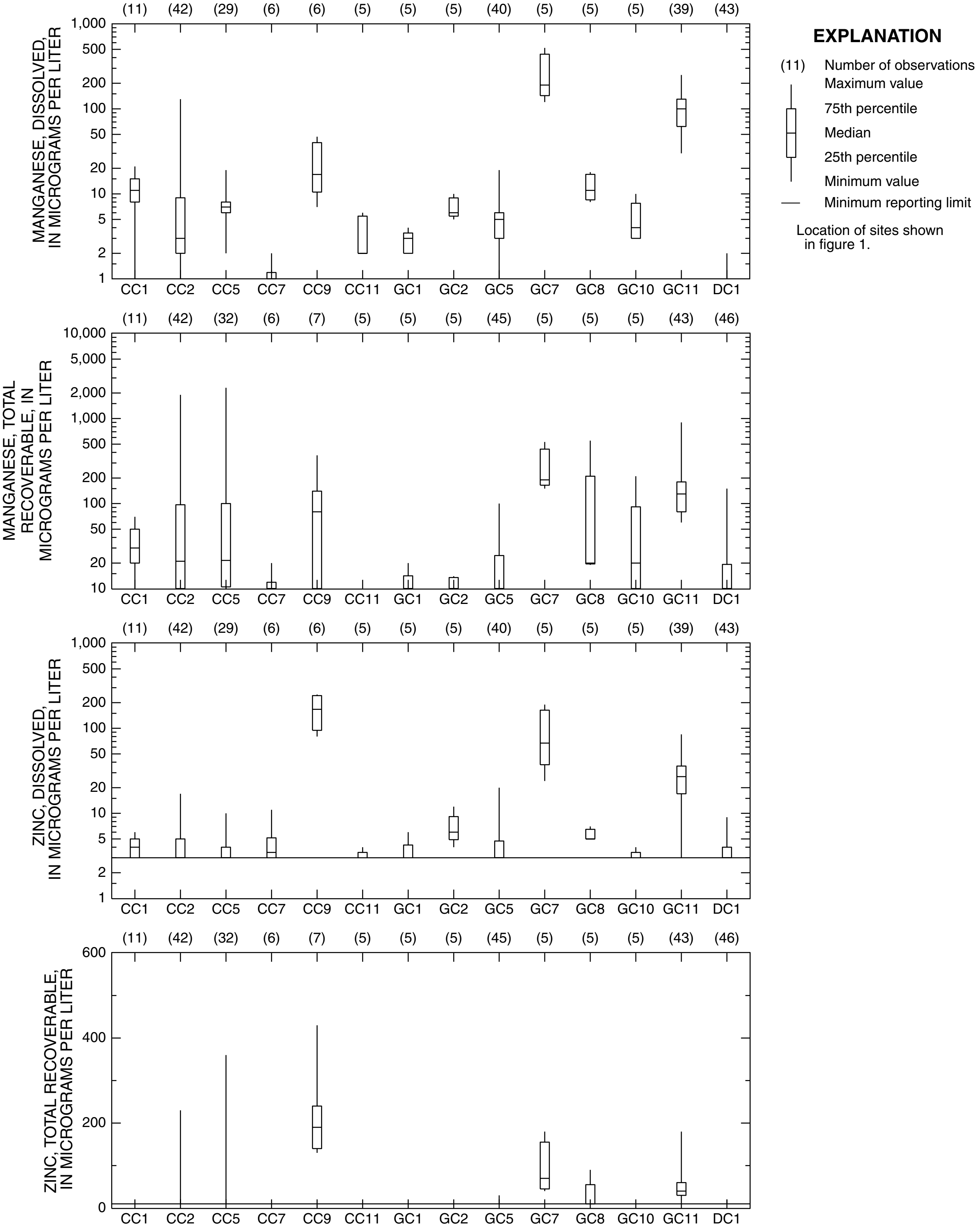


Figure 11. Distribution of concentrations and values of selected water-quality constituents at selected sites, water years 1995–97—Continued.

As mentioned previously, specific conductance increases downstream along South Clear Creek. Magnesium chloride or sodium chloride could increase specific conductance if supplied to the stream. Chloride concentrations in streams in the Guanella Pass area are generally less than 1 mg/L, a small proportion of the major-ion concentration. However, storm-related samples at CC2 had chloride concentrations up to 36 mg/L, and some road-runoff samples had predominantly magnesium and chloride or sodium and chloride major-ion compositions (Stevens and others, 1997). The downstream increase in specific conductance along South Clear Creek does not seem to be strongly related to chloride or any particular major inorganic constituent because major-ion composition tends to remain similar (figs. 13 and 14). Downstream increases in specific conductance are probably related to the concentration of dissolved solids by evapotranspiration.

Upstream/downstream comparisons in two reaches (CC1 to CC2, and CC13 to CC5, fig. 12) along South Clear Creek in water year 1997 were used to assess whether dissolved chloride concentrations were increasing in a downstream direction in upper South Clear Creek, a stream reach that runs parallel to the Guanella Pass road. Figure 12 indicates that the upstream sites for both pairs generally had smaller chloride concentrations during May and early June and in a rainstorm sample on July 28, 1997, for the CC1/CC2 pair. These dates correspond to the periods when road runoff is occurring, which is consistent with the migration of chloride in road runoff to streams. The downstream increases in concentration (fig. 12) could indicate effects from road runoff, which generally had larger concentrations of chloride than stream water (Stevens, 1999).

Clear Creek County applied magnesium chloride to the unpaved sections of the Guanella Pass road to control dust. During the study period, bighorn sheep were attracted to the salt residues and were frequently observed licking the treated portions of the road. The dust-control product applied is mainly $MgCl_2$ (30 percent by volume), SO_4 (less than 3.5 percent), K (less than 0.5 percent), Na (less than 0.7 percent), and H_2O (less than 69 percent) (John Millward, Great Salt Lake Minerals, written commun., 1997). Trace elements are listed as minor components of the product. The magnesium chloride product was initially applied in 1987 to the section of road between the end of pavement near Lower Cabin Creek Reservoir and Naylor Creek at a rate of 1.5 gallons per square yard, and to the section between timberline on the south side of the pass and a point just past the road to the Duck Lake residences at a rate of 0.5 gallon per square yard (Jim Cannedy, Clear Creek County, oral commun., 1998). In 1993, a second dust-control treatment was applied to the section of road between Naylor Creek and timberline on the south side of Guanella Pass at a rate of 0.5 gallon per square yard. A final application of magnesium chloride was made in 1996 to the unpaved portion of the road at a rate of 0.5 gallon per square yard (Jim Cannedy, Clear Creek County, oral commun., 1998).

To estimate if dissolved-solids loads might be sensitive to magnesium chloride applications, the mass of chloride applied to a section of road in a basin was compared to the estimated annual chloride load and the dissolved-solids load for a basin. The mass of chloride applied in the South Clear Creek Basin above Lower Cabin Creek Reservoir (CC5) was estimated using the application rates noted previously and a road width of 18 ft (table 13). The chloride load at CC5 was estimated using a relation of the natural logarithm of the chloride load and water discharge for WY's 1995–97 (fig. 15) and applying the resulting equation to daily mean discharge to compute daily chloride loads. Daily loads for the water year were summed to compute annual loads at CC5 for WY's 1995–97 (table 13).

The estimated mass of chloride from $MgCl_2$ applied to the road in the CC5 basin in 1987 (57.1 tons chloride), 1993 (11.5 tons), and 1996 (15.5 tons) ranged from 83 to 414 percent of the estimated average annual chloride load (13.8 tons per year) transported in South Clear Creek at CC5 during WY's 1995–97 (table 13).

To estimate how chloride applied to the road might affect concentrations in the stream, a hypothetical set of assumptions was used to compute changes in annual flow-weighted-mean concentrations (FWMC) of chloride transported from the CC5 basin. For the computation, it was assumed that the mass of chloride from the largest known application of $MgCl_2$ applied to the Guanella Pass road in the CC5 basin (57.1 tons in 1987) was added to the estimated annual chloride load for each year (1995–97) at CC5 (table 13). That load was then assumed to have been transported by the annual flow at CC5 that year and was converted to an annual FWMC of chloride (table 13). The FWMC that includes road-applied chloride could then be compared to the FWMC without road-applied chloride.

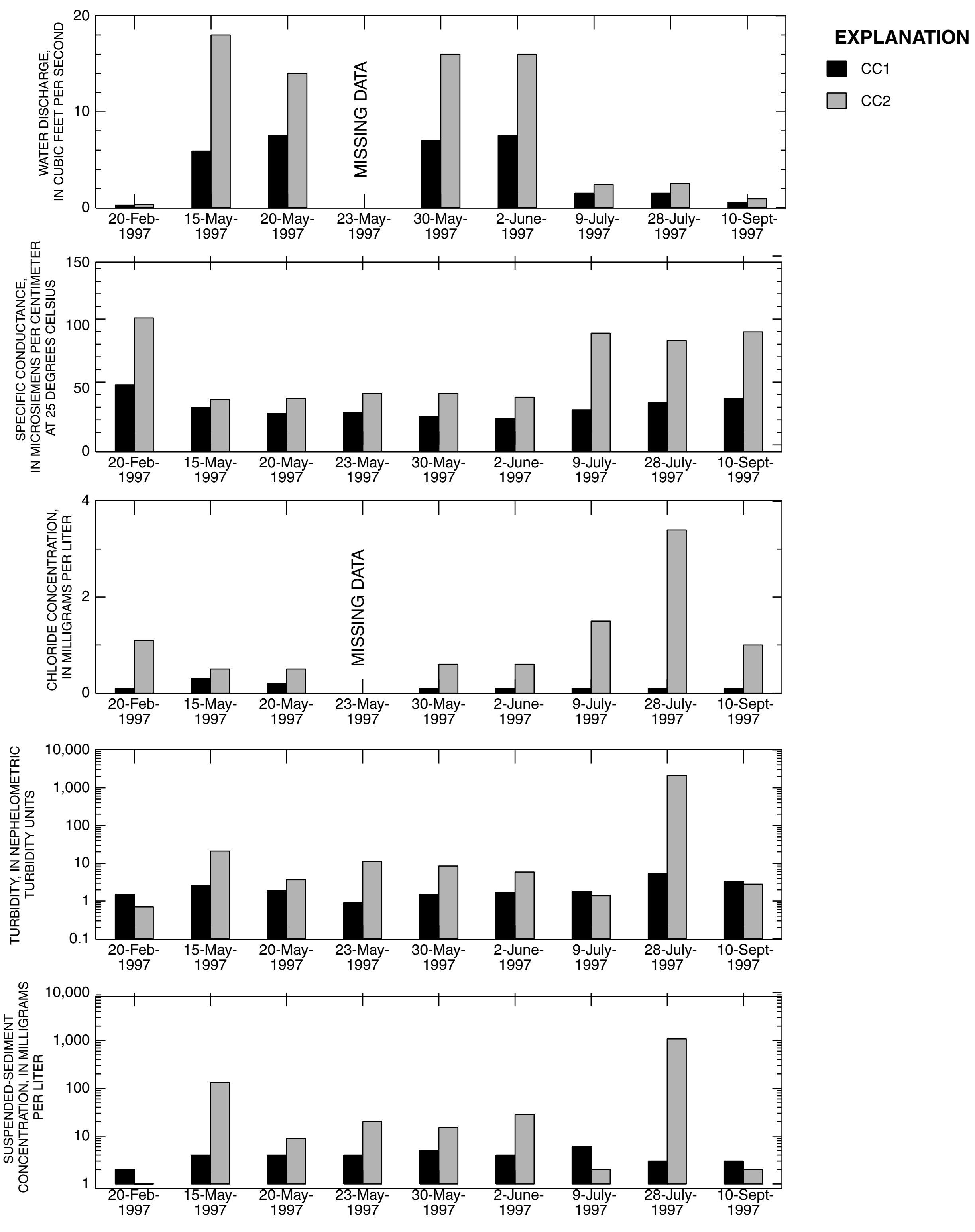


Figure 12. Comparison of water discharge, specific conductance, chloride concentration, turbidity, and suspended sediment at CC1 (upstream) and CC2 (downstream) and CC13 (upstream) and CC5 (downstream), in water year 1997.

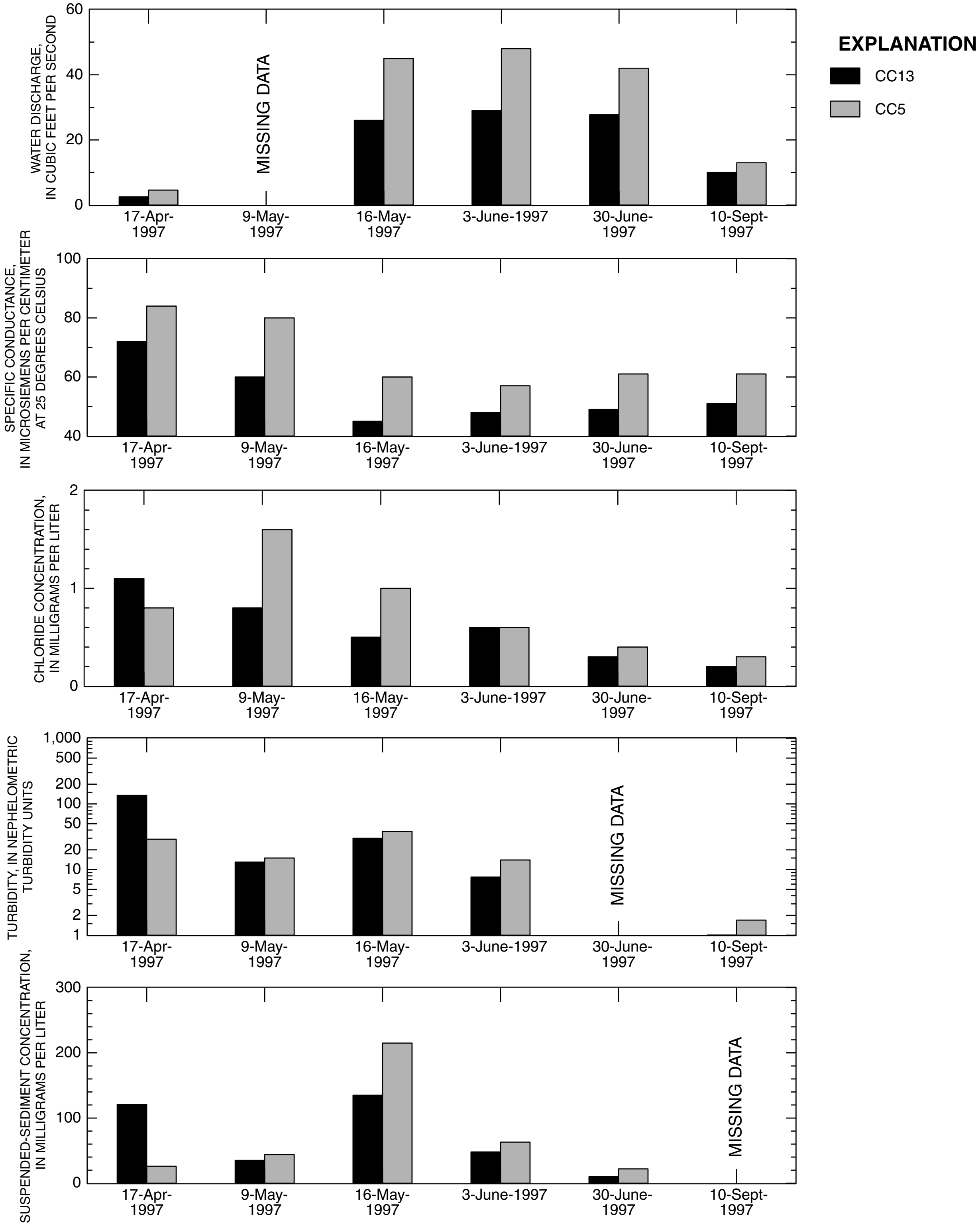


Figure 12. Comparison of water discharge, specific conductance, chloride concentration, turbidity, and suspended sediment at CC1 (upstream) and CC2 (downstream) and CC13 (upstream) and CC5 (downstream), in water year 1997—Continued.

Table 10. Dissolved-solids loads computed for selected sites, water years 1995–97

[mi^2, square mile; ft^3/s, cubic feet per second; acre-ft, acre-feet; mg/L, milligrams per liter]

Site (fig. 1)	Water year	Drainage area (mi^2)	Mean annual discharge (ft^3/s)	Annual discharge (acre-ft)	Annual dissolved-solids load (tons)	Flow-weighted mean dissolved-solids concentration (mg/L)	Dissolved-solids yield (tons/acre-ft)	Dissolved-solids yield (tons/mi^2)
CC2	1996	2.19	1.68	1,220	72.0	43	0.059	32.9
CC2	1997	2.19	2.21	1,600	88.7	41	.055	40.5
CC5	1995	11.8	15.3	11,100	597	40	.054	50.6
CC5	1996	11.8	10.7	7,750	437	41	.056	37.0
CC5	1997	11.8	14.0	10,100	554	40	.055	46.9
CC7	1995	16.0	21.2	15,400	1,070	51	.070	66.7
CC7	1996	16.0	16.6	12,100	864	53	.071	54.0
CC7	1997	16.0	18.4	13,300	933	51	.070	58.3
CC9	1995	12.0	17.7	12,800	670	38	.052	55.8
CC9	1996	12.0	13.8	10,000	547	40	.055	45.6
CC9	1997	12.0	15.3	11,100	602	40	.054	50.2
GC5	1995	7.78	7.33	5,310	219	30	.041	28.1
GC5	1996	7.78	5.92	4,300	169	29	.039	21.7
GC5	1997	7.78	6.60	4,780	189	29	.040	24.3
GC11	1995	74.6	82.2	59,500	2,800	35	.047	37.6
GC11	1996	74.6	55.7	40,500	2,100	38	.052	28.1
GC11	1997	74.6	70.2	50,800	2,420	35	.048	32.4
DC1	1996	13.4	8.97	6,510	239	27	.037	17.8
DC1	1997	13.4	16.7	12,100	404	25	.033	30.1

Results of the FWMC comparison indicate hypothetical increases in chloride from $MgCl_2$ ranging from about 3 to 12 times. In the case of the largest increase, the annual FWMC of chloride at CC5 in 1996 (0.5 mg/L) might increase 12 times (to 5.9 mg/L). Although this is a large percentage increase, the increased concentrations are still relatively minor, about 14 percent of the total dissolved solids FWMC of 41 mg/L at CC5 in 1996 (table 10). These increases are probably overestimates because it is unlikely that the entire mass of chloride applied would be flushed from the basin in a single year. If chloride applied to the road is not transported out of the basin within months of application, it could be stored in ground water or the soil material on the roadbed and might take years to leave the basin. Longer term monitoring is necessary to understand the fate of $MgCl_2$ applied to the Guanella Pass road.

Nutrients

Nitrogen and phosphorus compounds in water are important plant and algal nutrients. In excess concentrations, nutrients can produce a nuisance growth of algae in streams and lakes. Nutrient concentrations in stream water were generally small or less than the laboratory MRL. The distributions of ammonia, nitrite plus nitrate, orthophosphorus, and total phosphorus are shown in boxplots (fig. 11).

Table 11. Spearman's coefficients of correlation for instantaneous water discharge (cubic feet per second) and concentrations of selected water-quality constituents at selected sites, water years 1995–97

[rho, Spearman correlation coefficient; p-value, probability of a greater Spearman's rho; p-values <0.05 (2-tailed) are considered highly significant and are shaded, a light shade for positive, and a dark shade for negative correlations; Spearman's rho's greater than plus or minus 0.50 are shaded; µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; mg/L, milligrams per liter; µg/L, micrograms per liter; mm, millimeters; <, less than; correlations based on periodic water-quality samples]

Property or constituent	CC2		CC5		GC5		GC11		DC1	
	rho	p-value	rho	p-value	rho	p-value	rho	p-value	rho	p-value
Specific conductance, µS/cm	–0.95	<0.001	–0.74	<0.001	–0.76	<0.001	–0.93	<0.001	–0.76	<0.001
pH, standard units	–.21	.168	–.13	.450	.07	.620	.34	.020	–.08	.610
Turbidity, NTU	–.22	<.001	.30	<.001	.14	<.001	.10	.005	.06	.133
Oxygen, dissolved, mg/L	.10	.553	–.39	.023	–.69	<.001	–.37	.018	–.14	.471
Hardness, total, mg/L as $CaCO_3$	–.95	<.001	–.74	.001	–.83	<.001	–.95	<.001	–.80	<.001
Calcium, dissolved, mg/L	–.94	<.001	–.70	.002	–.83	<.001	–.94	<.001	–.83	<.001
Magnesium, dissolved, mg/L	–.95	<.001	–.70	.002	–.85	<.001	–.97	<.001	–.81	<.001
Sodium, dissolved, mg/L	–.93	<.001	–.24	.381	–.77	<.001	–.87	<.001	–.89	<.001
Potassium, dissolved, mg/L	–.21	.268	–.11	.670	–.62	<.001	–.45	.020	–.10	.624
Alkalinity (acid-neutralizing capacity), mg/L as $CaCO_3$	–.94	<.001	–.91	<.001	–.83	<.001	.20	.323	–.86	<.001
Sulfate, dissolved, mg/L	–.92	<.001	–.25	.194	–.57	<.001	–.91	<.001	–.46	.002
Chloride, dissolved, mg/L	–.69	<.001	.48	.004	–.17	.307	–.19	.255	–.05	.764
Silica, dissolved, mg/L	–.70	<.001	.52	.038	–.81	<.001	–.93	<.001	–.80	<.001
Dissolved solids, sum of constituents, mg/L	–.95	<.001	–.66	.005	–.80	<.001	–.98	<.001	–.93	<.001
Nitrogen, ammonia, dissolved, mg/L as N	–.05	.823	–.34	.163	–.17	.493	–.11	.638	–.08	.740
Nitrogen, ammonia plus organic, total, mg/L as N	.43	.007	.24	.219	–.23	.154	.15	.371	–.07	.649
Nitrogen, nitrite plus nitrate, dissolved, mg/L as N	–.03	.857	–.16	.408	–.21	.191	–.11	.490	–.21	.175
Phosphorus, total, mg/L as P	.30	.073	.52	.004	.06	.714	.27	.103	–.09	.555
Phosphorus, ortho, dissolved, mg/L as P	.01	.972	.29	.248	.40	.100	.13	.600	.18	.449
Copper, dissolved, µg/L	–.07	.643	.36	.056	.27	.091	–.01	.969	–.10	.535
Copper, total recoverable, µg/L	–.09	.571	.45	.009	.17	.264	–.26	.090	–.31	.032
Iron, dissolved, µg/L	.22	.161	.26	.174	–.41	.009	.61	<.001	.33	.028
Iron, total recoverable, µg/L	.21	.184	.59	<.001	.15	.330	.44	.003	.01	.971
Lead, total recoverable, µg/L	–.13	.403	.31	.086	.25	.095	.15	.338	–.29	.051
Manganese, dissolved, µg/L	.21	.173	.39	.034	–.59	<.001	–.85	<.001	–.13	.397
Manganese, total recoverable, µg/L	.10	.513	.57	.001	.17	.259	–.44	.003	–.17	.245
Zinc, dissolved, µg/L	.23	.142	–.18	.339	.34	.033	–.71	<.001	–.08	.600
Zinc, total recoverable, µg/L	–.21	.179	.22	.217	.24	.116	–.55	<.001	–.14	.343
Suspended sediment, percentage finer than 0.062 mm	–.70	<.001	–.77	<.001	–.49	.016	–.76	<.001	–.69	.013
Suspended-sediment concentration, mg/L	.69	<.001	.52	<.001	.57	<.001	.46	.001	.58	<.001

Table 12. Spearman's coefficients of correlation for suspended-sediment concentration and concentrations of selected water-quality constituents at selected sites, water years 1995–97

[rho, Spearman correlation coefficient; p-value, probability of a greater Spearman's rho; p-values <0.05 (2-tailed) are considered highly significant and are shaded, a light shade for positive, and a dark shade for negative correlations; Spearman's rho's greater than plus or minus 0.50 are shaded; µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; mg/L, milligrams per liter; µg/L, micrograms per liter; mm, millimeters; <, less than; correlations based on periodic water-quality samples]

Property or constituent	CC2		CC5		GC5		GC11		DC1	
	rho	p-value	rho	p-value	rho	p-value	rho	p-value	rho	p-value
Specific conductance, µS/cm	–0.32	0.034	0.01	0.945	–0.17	0.296	–0.25	0.105	–0.10	0.501
pH, standard units	–.55	<.001	–.26	.214	–.29	.110	–.58	<.001	–.55	<.001
Turbidity, NTU	.91	<.001	.78	<.001	.71	<.001	.87	<.001	.72	<.001
Oxygen, dissolved, mg/L	.32	.077	–.22	.361	.01	.963	.34	.068	.08	.705
Hardness, total, mg/L as $CaCO_3$	–.28	.148	–.62	.023	–.18	.369	–.23	.270	–.23	.241
Calcium, dissolved, mg/L	–.31	.105	–.63	.021	–.14	.500	–.21	.321	–.22	.270
Magnesium, dissolved, mg/L	–.24	.202	–.74	.004	–.21	.288	–.26	.217	–.18	.381
Sodium, dissolved, mg/L	–.25	.200	–.48	.096	–.10	.618	–.19	.366	–.35	.075
Potassium, dissolved, mg/L	.47	.010	–.03	.912	.14	.490	.27	.186	.16	.427
Alkalinity (acid-neutralizing capacity), mg/L as $CaCO_3$	–.44	.020	–.56	.048	–.33	.098	–.22	.294	–.42	.037
Sulfate, dissolved, mg/L	–.38	.017	–.53	.006	–.18	.286	–.10	.561	–.19	.220
Chloride, dissolved, mg/L	.07	.652	.75	<.001	–.03	.840	–.03	.868	–.10	.503
Silica, dissolved, mg/L	–.74	<.001	.07	.819	–.28	.160	–.39	.054	–.36	.064
Dissolved solids, sum of constituents, mg/L	–.26	.179	–.59	.034	–.21	.301	–.28	.181	–.36	.085
Nitrogen, ammonia, dissolved, mg/L as N	.09	.730	–.09	.737	–.03	.928	.28	.239	.21	.385
Nitrogen, ammonia plus organic, total, mg/L as N	.69	<.001	.57	.003	.30	.090	.32	.056	.50	<.001
Nitrogen, nitrite plus nitrate, dissolved, mg/L as N	.22	.195	–.35	.093	–.07	.700	–.21	.221	–.17	.289
Phosphorus, total, mg/L as P	.81	<.001	.89	<.001	.09	.614	.29	.086	.64	<.001
Phosphorus, ortho, dissolved, mg/L as P	.40	.113	.64	.005	.51	.064	.27	.255	.35	.138
Copper, dissolved, µg/L	.33	.040	.27	.198	.24	.163	.15	.367	.24	.126
Copper, total recoverable, µg/L	.67	<.001	.71	<.001	.51	<.001	.50	<.001	.54	<.001
Iron, dissolved, µg/L	.07	.659	.36	.078	–.01	.971	.18	.293	.38	.012
Iron, total recoverable, µg/L	.82	<.001	.91	<.001	.59	<.001	.80	<.001	.81	<.001
Lead, total recoverable, µg/L	.74	<.001	.70	<.001	.52	<.001	.75	<.001	.51	<.001
Manganese, dissolved, µg/L	.86	<.001	.44	.028	–.37	.026	–.25	.137	.37	.015
Manganese, total recoverable, µg/L	.82	<.001	.80	<.001	.59	<.001	.33	.031	.73	<.001
Zinc, dissolved, µg/L	.30	.057	–.11	.609	.32	.060	–.46	.004	.26	.086
Zinc, total recoverable, µg/L	.61	<.001	.64	<.001	.37	.016	.22	.158	.20	.177
Suspended sediment, percentage finer than 0.062 mm	–.18	.411	–.27	.156	–.65	<.001	.51	.024	–.46	.134

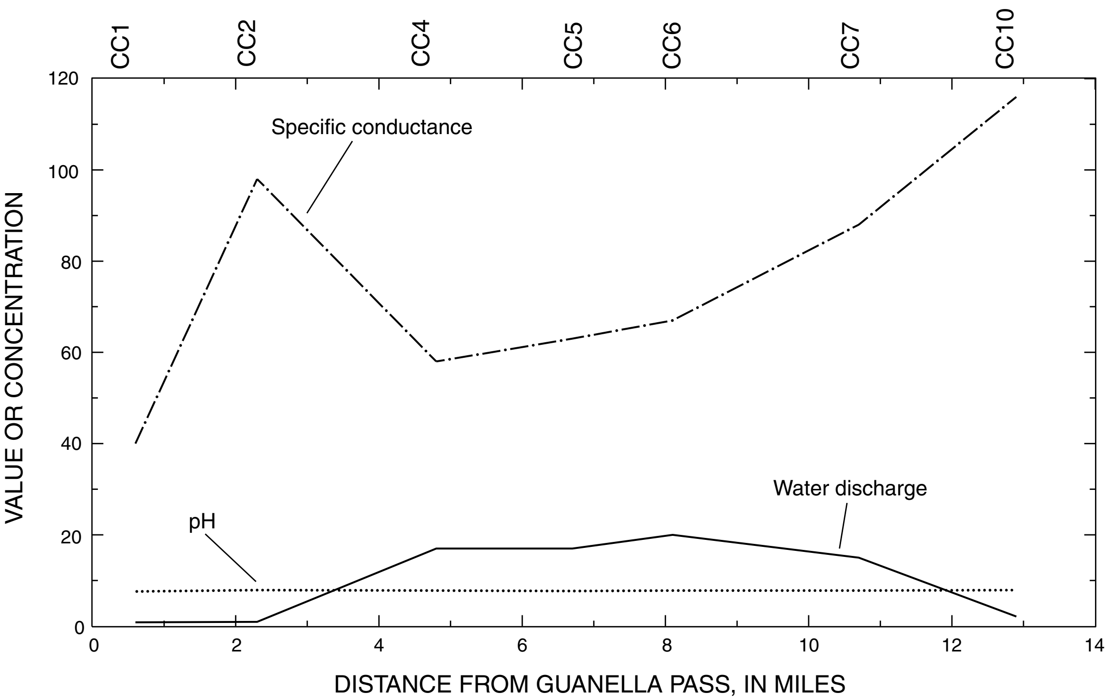


Figure 13. Values and concentrations of specific conductance (in microsiemens per centimeter at 25 degrees Celsius), pH (in standard units), and instantaneous water discharge (in cubic feet per second) at water-quality-sampling sites along South Clear Creek during low-flow synoptic sampling, September 6, 1995.

Dissolved ammonia concentrations generally were less than 0.01 mg/L as N. Dissolved nitrite plus nitrate concentrations generally were less than 0.10 mg/L as N. Concentrations of dissolved orthophosphate generally were less than 0.005 mg/L as P.

The largest nitrite plus nitrate and ammonia concentrations in alpine streams usually occur during winter low flow and early snowmelt (Stevens and others, 1997; Stevens, 2000). Most plants and bacteria that use nitrogen are inactive during winter, so nitrogen concentrations tend to be larger in streamflow during this period of the water year. Elution from snowpack and flushing of soil water high in nitrogen might be the cause of high nitrogen concentrations during early snowmelt (Campbell and others, 1995).

Nitrogen concentrations increase during rainfall runoff due to the larger nitrite plus nitrate and ammonia concentrations in precipitation (table 4) than streamflow. Selected Colorado atmospheric deposition stations in summer 1997 had more nitrate and ammonia as N (average nitrate 1.1 mg/L, average ammonia 0.24 mg/L, table 4) than typical stream-water concentrations (Guanella Pass stream median nitrite plus nitrate 0.059 mg/L, median ammonia less than 0.002 mg/L, table 7). When rainfall reaches the ground, nitrogen can be removed by plants and bacteria. Increases in nitrogen are expected in the stream because the plants and bacteria may not remove all the nitrogen before the runoff reaches the stream. Sites with large impervious drainage areas, such as roads and rock outcrops, may have larger nitrogen concentrations during runoff because the runoff gets to the stream more rapidly, retaining more nitrogen.

Total ammonia plus organic nitrogen and total phosphorus concentrations were highest during snowmelt runoff and summer storms (Stevens and others, 1997; Stevens, 2000). These analytes include the particulate contribution, which is large during periods of suspended-sediment transport. Total ammonia plus organic nitrogen concentrations usually did not exceed 1 mg/L as N except in some storm samples. Total phosphorus concentrations ranged from less than 0.001 to 3.2 mg/L as P; medians ranged from 0.002 to 0.020 mg/L as P (table 7, Appendix tables 36–49). Comparison of total and dissolved nutrient concentrations (Stevens and others, 1997) indicates that during snowmelt and storm events, particulate organic nitrogen and particulate phase phosphorus predominate. At low flows, nutrients were transported mainly in the dissolved phase in small concentrations.

Dissolved nutrients (nitrate, ammonia, and orthophosphorus) were not significantly correlated with specific conductance or streamflow (tables 9 and 11). Total ammonia plus organic nitrogen, however, which includes particulate-related nitrogen, had a significant but weak positive correlation with streamflow at site CC2 (table 11), a significant but

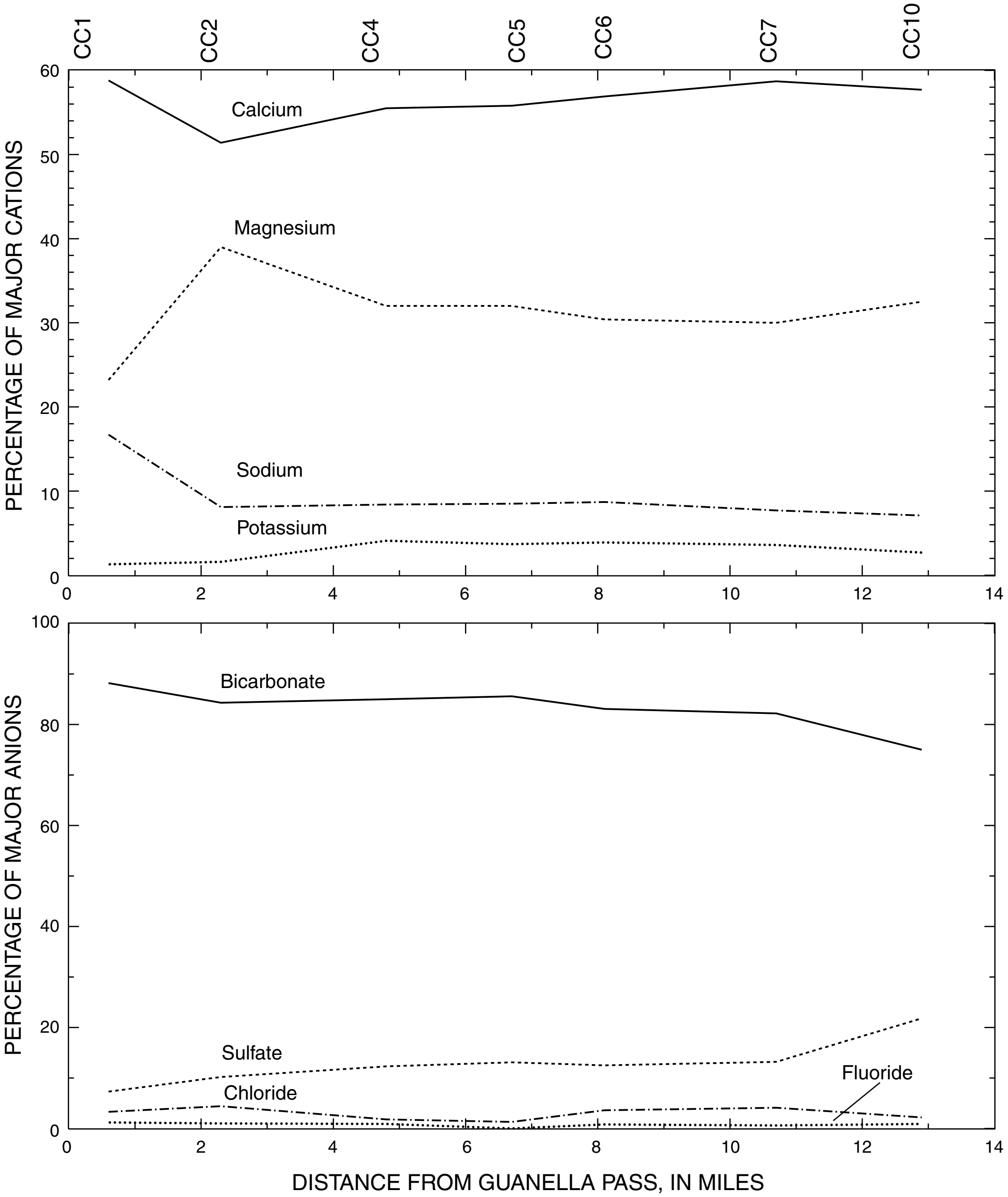


Figure 14. Percentages of major ions at water-quality-sampling sites along South Clear Creek during low-flow synoptic sampling, September 6, 1995.

Table 13. Estimates of mass of chloride in dust inhibitor applied to Guanella Pass road and annual chloride load and hypothetical concentration estimates in South Clear Creek at site CC5

[$MgCl_2$, magnesium chloride; WY, water year; loads are in tons; daily mean water discharge in cubic feet per second; FWMC is the annual flow-weighted-mean concentration in milligrams per liter, and is annual load (tons) divided by annual mean flow (ft^3/s) divided by 0.0027 divided by number of days in the year; Assumptions: Applied brine = 30% $MgCl_2$ by weight; density = 10.8 lbs/gal; pure $MgCl_2$ = 74.5% chloride by weight; County application rates and locations as described in this report; width of application on road = 18 feet]

	Mass of chloride in $MgCl_2$ applied in Guanella Pass area WY's 1995–97		
Year	1987	1993	1996
Load	79.3	22.2	24.1
	Mass of chloride in $MgCl_2$ applied to road in CC5 basin WY's 1995–97		
Year	1987	1993	1996
Load	57.1	11.5	15.5
	Annual chloride loads in South Clear Creek at site CC5		
Year	1995	1996	1997
Load	27.4	5.59	8.4
	Annual total dissolved solids loads in South Clear Creek at site CC5[a]		
Year	1995	1996	1997
Load	597	437	554

Year	Daily mean water discharge	Estimated actual chloride load	Estimated FWMC
	Annual flow-weighted-mean concentrations of chloride at site CC5		
1995	15.3	27.4	1.8
1996	10.7	5.59	0.5
1997	14.0	8.4	0.6

Year	Daily mean water discharge	Estimated 1996 chloride load plus 1987 chloride mass from applied $MgCl_2$	Hypothetical FWMC
	Hypothetical scenario using largest application and annual flows and chloride loads at CC5		
1995	15.3	84.5	5.6
1996	10.7	62.7	5.9
1997	14.0	65.5	4.7

[a]Data from table 10.

weak negative correlation with specific conductance at site CC2 (table 9), and significant positive correlations with suspended sediment at sites CC2, CC5, and DC1 (table 12). Total phosphorus, which also includes particulate-related phosphorus, had significant but weak positive correlations with streamflow at sites CC2 and CC5 (table 11), no significant correlations with specific conductance (table 9), and strong significant positive correlations with suspended sediment at sites CC2, CC5, and DC1 (table 12). The nutrient correlations at some sites (CC2, CC5, DC1) reinforce the indications that particulate nutrients are transported during periods of high flow when suspended-sediment concentrations are large, such as during snowmelt and storm runoff.

Trace Elements

Trace elements in this study are defined as inorganic chemical elements, excluding nutrients, found in natural water in small quantities, mostly less than 1 mg/L (Hem, 1985). Sometimes aluminum, barium, iron, and manganese exceeded 1 mg/L, but for the purposes of this study, they are still considered to be trace elements. The occurrence of trace elements can be separated into two types of sites: sites with acid-sulfate weathering processes in the watershed and sites unaffected by acid-sulfate weathering processes (table 14). If a site was located downstream from the mining areas on Geneva, Leavenworth, or South Clear Creeks, it was considered an affected site.

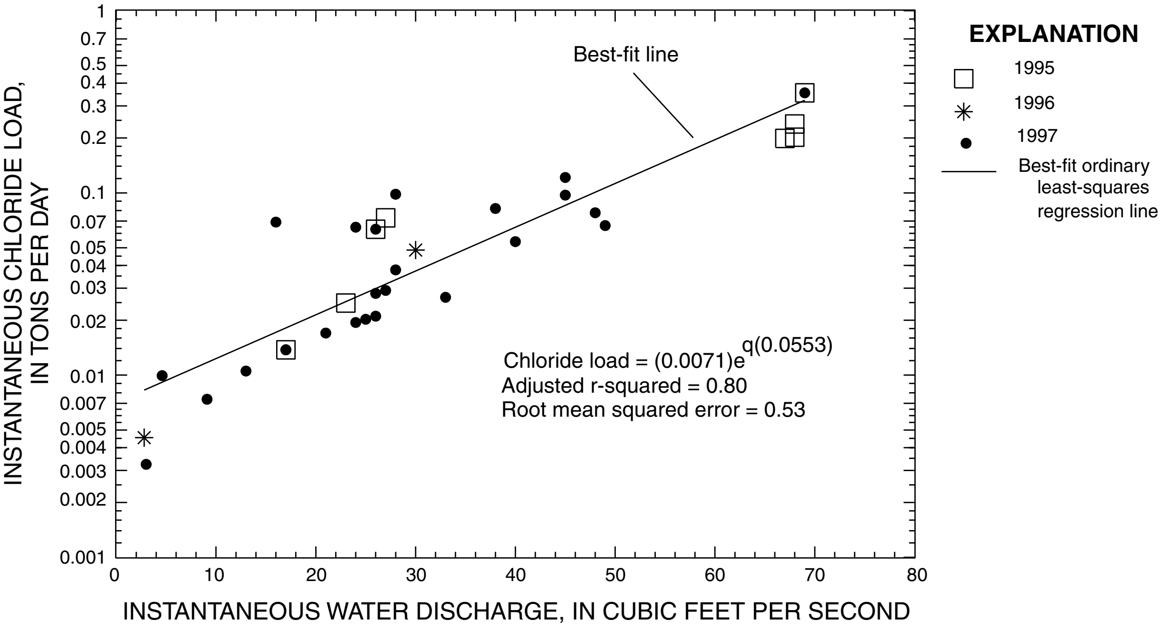


Figure 15. Relation of chloride load with instantaneous water discharge at site CC5, water years 1995–97.

In areas unaffected by acid-sulfate weathering, dissolved trace-element concentrations, excluding aluminum, barium, iron, and manganese, were small, generally less than 10 µg/L (Stevens and others, 1997; Stevens, 2000). The most frequently detected dissolved trace elements (excluding aluminum, barium, iron, and manganese) among streams unaffected by acid-sulfate weathering were zinc (range less than 3 to 20 µg/L) and copper (range less than 1 to 4 µg/L). Concentrations of dissolved lead and cadmium almost never exceeded the 1-µg/L laboratory MRL (Stevens and others, 1997; Stevens, 2000).

Streams located in areas of ore deposits and pyritic rocks are affected by acid-sulfate weathering: Geneva Creek (sites GC6, GC7, GC9, GC11, GC12), Leavenworth Creek (sites CC8 and CC9), and South Clear Creek downstream from Leavenworth Creek (site CC10). Characteristics of affected streams are large sulfate, iron, and other trace-element concentrations (table 14; Stevens and others, 1997). Acidic pH also is a characteristic, but it is not the defining factor. The pH can be neutralized downstream, but high concentrations of trace elements can persist, commonly in the suspended fraction or as streambed precipitates.

Total recoverable trace-element concentrations usually increase as the suspended-sediment concentration increases (table 12). This increase is due to total recoverable analyses incorporating the portion of the sample that is soluble in a mild-acid extraction. Thus, much of the trace element adsorbed to the suspended sediment will be a part of the concentration that would be removed by filtration in a dissolved analysis. In the Guanella Pass area, iron, manganese, barium, and aluminum occurred in large total recoverable concentrations (table 14).

Despite the presence of substantial trace-element sources in basins with pyritic rocks (upper Geneva Creek and Leavenworth Creek), maximum total recoverable trace-element concentrations were not always larger in streams affected by acid-sulfate weathering than those in unaffected streams (table 14). During snowmelt and rainstorm runoff, which are periods of large suspended-sediment concentrations, concentrations of total recoverable copper, chromium, iron, and manganese in some streams (CC2 and CC5) unaffected by acid-sulfate weathering exceeded maximum concentrations sampled in affected streams (table 14).

The solubility of trace elements in water is affected by pH. Generally, the most soluble chemical forms of a trace element occur in acidic waters, whereas the most insoluble chemical forms occur in neutral or basic waters. The pH at which an element becomes soluble is different for each element. In the case of stream water, the stream pH may change from acidic to neutral as alkaline-tributary flows are added downstream. Elements that were soluble

Table 14. Summary of trace-element data ranges for sites that are affected and sites that are unaffected by acid-sulfate weathering in the watershed

[Affected sites: CC8, CC9, CC10, GC6, GC7, GC9, GC11, and GC12; unaffected sites: CC1, CC2, CC3, CC4, CC5, CC6, CC7, CC11, CC12, CC13, GC1, GC2, GC3, GC4, GC5, GC8, and DC1; data from Stevens and others (1997), Stevens (2000), and Appendix tables 34–47; multiple, many sites; µg/L, micrograms per liter; <, less than]

Constituent	Units	Acid-sulfate weathering				No acid-sulfate weathering			
		Maximum	Site	Minimum	Site	Maximum	Site	Minimum	Site
Aluminum, total recoverable as Al	µg/L	11,000	GC11	30	CC10	4,600	GC8	10	GC3
Aluminum, dissolved as Al	µg/L	4,700	GC6	6	CC10	140	GC8	3	CC3
Antimony, dissolved as Sb	µg/L	<1	multiple	<1	multiple	<1	multiple	<1	multiple
Arsenic, total recoverable as As	µg/L	<1	multiple	<1	multiple	<1	multiple	<1	multiple
Barium, total recoverable as Ba	µg/L	100	GC11	<100	multiple	100	GC8	<100	multiple
Barium, dissolved as Ba	µg/L	38	GC7	18	GC11	31	multiple	16	multiple
Beryllium, total recoverable as Be	µg/L	<10	multiple	<10	multiple	<10	multiple	<10	multiple
Beryllium, dissolved as Be	µg/L	<1	multiple	<1	multiple	<1	multiple	<1	multiple
Cadmium, total recoverable as Cd	µg/L	2	GC6, GC9	<1	multiple	<1	multiple	<1	multiple
Cadmium, dissolved as Cd	µg/L	2	GC6	<1	multiple	<1	multiple	<1	multiple
Chromium, total recoverable as Cr	µg/L	16	GC11	<1	multiple	20	CC2	<1	multiple
Chromium, dissolved as Cr	µg/L	<1	multiple	<1	multiple	2	GC5	<1	multiple
Cobalt, total recoverable as Co	µg/L	10	GC11	<1	multiple	10	GC8	<1	multiple
Cobalt, dissolved as Co	µg/L	8	GC6	<1	multiple	<1	multiple	<1	multiple
Copper, total recoverable as Cu	µg/L	53	GC11	1	CC9	92	CC5	<1	multiple
Copper, dissolved as Cu	µg/L	37	GC6	<1	CC10, GC11	4	DC1	<1	multiple
Iron, total recoverable as Fe	µg/L	47,000	GC6	10	CC9	110,000	CC5	20	DC1
Iron, dissolved as Fe	µg/L	1,800	GC6	<3	GC11	720	CC1	7	DC1
Lead, total recoverable as Pb	µg/L	71	CC9	<1	multiple	54	CC2	<1	multiple
Lead, dissolved as Pb	µg/L	2	CC9, GC12	<1	multiple	<1	multiple	<1	multiple
Manganese, total recoverable as Mn	µg/L	900	GC11	<10	CC9	2,300	CC5	<10	multiple
Manganese, dissolved as Mn	µg/L	760	GC6	2	CC10	130	CC2	<1	multiple
Mercury, total recoverable as Hg	µg/L	.1	GC6	<.1	multiple	<.1	multiple	<.1	multiple
Molybdenum, total recoverable as Mo	µg/L	2	multiple	<1	multiple	2	multiple	<1	multiple
Molybdenum, dissolved as Mo	µg/L	<1	multiple	<1	multiple	<1	multiple	<1	multiple
Nickel, total recoverable as Ni	µg/L	17	GC11	<1	CC10	17	GC8	<1	multiple
Nickel, dissolved as Ni	µg/L	17	GC6	<1	CC10	2	GC8	<1	multiple
Selenium, total recoverable as Se	µg/L	<1	multiple	<1	multiple	<1	multiple	<1	multiple
Silver, total recoverable as Ag	µg/L	<1	multiple	<1	multiple	<1	multiple	<1	multiple
Silver, dissolved as Ag	µg/L	1	GC12	<1	multiple	2	GC10	<1	multiple
Zinc, total recoverable as Zn	µg/L	430	CC9	<3	GC11	360	CC5	<10	multiple
Zinc, dissolved as Zn	µg/L	320	GC6	6	GC12	20	GC5	<3	multiple
Uranium, natural, dissolved	µg/L	2	GC6	<1	multiple	<1	multiple	<1	multiple

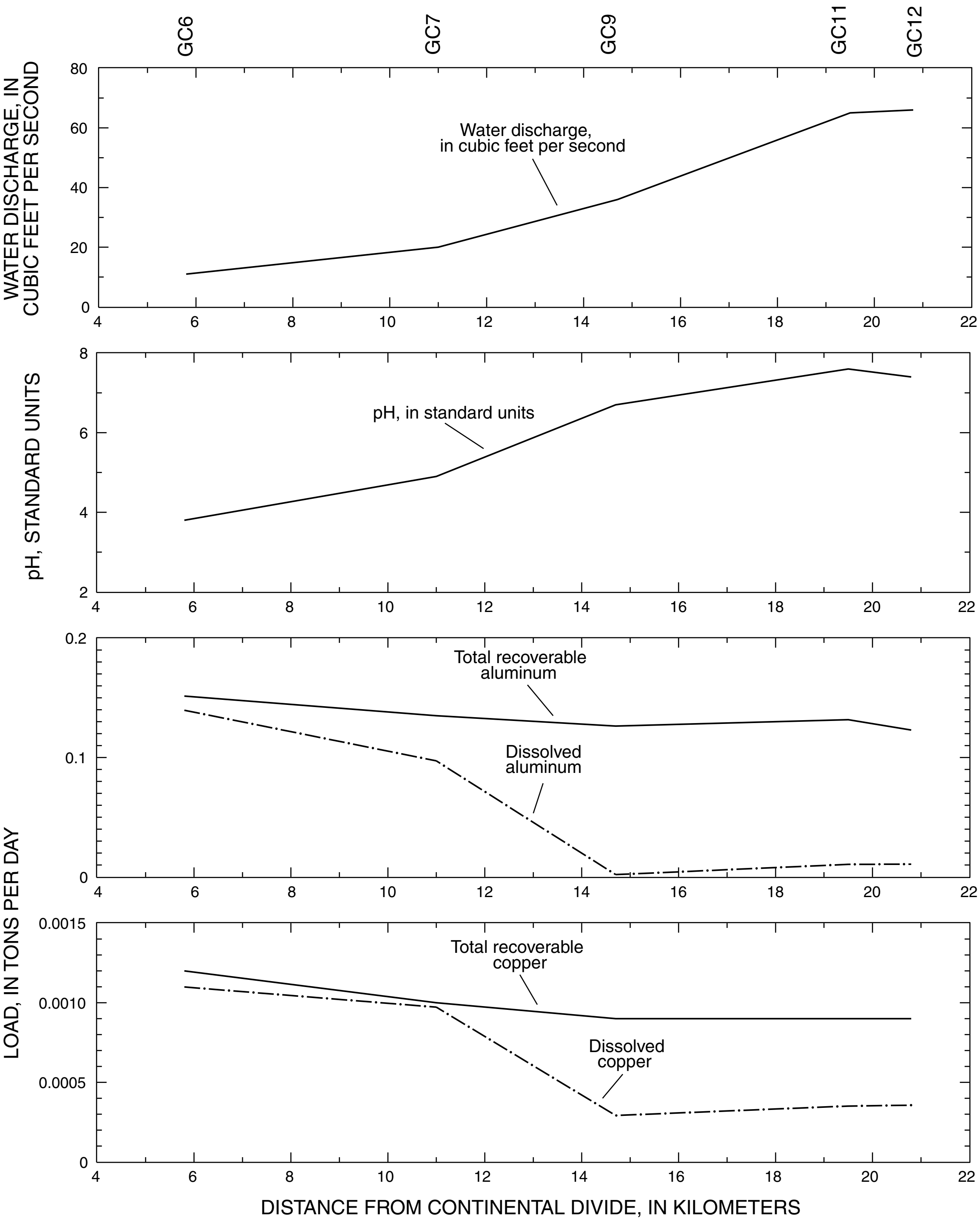


Figure 16. Variations in selected dissolved-phase and total recoverable trace-element loads along Geneva Creek from GC6 to GC12 during low-flow synoptic sampling, September 1995.

and in the dissolved phase (operationally defined as passing through a 0.45-µm filter) become insoluble and precipitate on the streambed or are transported downstream in the suspended fraction. In Geneva Creek, at site GC6 September 1995, most of the copper load was in the dissolved phase (fig. 16). As the stream flowed downstream from GC6 to GC12, the pH changed from 3.8 to 7.4. Dissolved copper decreased sharply in a downstream direction while total recoverable copper remained fairly steady,

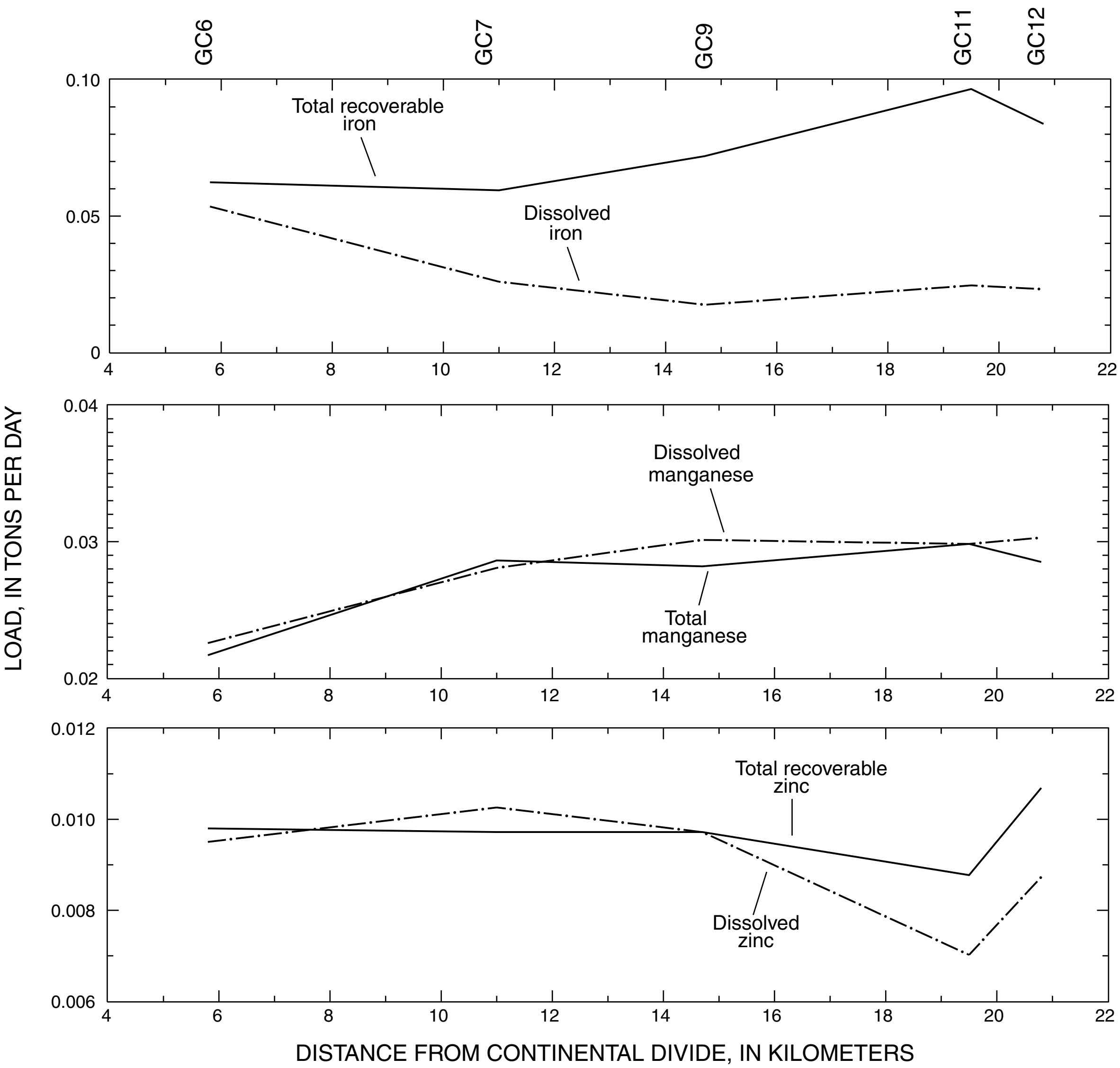


Figure 16. Variations in selected dissolved-phase and total recoverable trace-element loads along Geneva Creek from GC6 to GC12 during low-flow synoptic sampling, September 1995—Continued.

indicating that most of the copper changed to a suspended-solid phase. Most of the aluminum and iron were in the dissolved phase at site GC6, but both precipitated prior to reaching GC9. The pH change did not affect manganese and zinc as much because the data indicate that most of the loads remained in the dissolved phase from GC6 to GC12 (fig. 16).

Evidence of the trace-element phase change along Geneva Creek can be observed as orange and white precipitates, probably of iron and aluminum compounds, formed at confluences with tributaries and along the streambed as in other acidic/neutral-stream mixing zones in the region (Bassett and others, 1992; McKnight and others, 1992). Precipitates accumulate on the Geneva Creek streambed during low flow. These precipitates, whose smothering action causes a physical stress on aquatic life, can have a more negative effect than trace-element toxicity (Dev Niyogi, U.S. Geological Survey, oral commun., 1999). Then, during high flow, the precipitates on the streambed are scoured, representing a substantial source of particulate iron, aluminum, and other trace elements which are potentially adsorbed to the amorphous phases of iron and aluminum, suspended sediments, and organic particles dislodged from the streambed.

Spearman correlations of dissolved trace elements with streamflow (table 11) show that dissolved trace elements were sometimes significantly correlated.

The strongest correlations were negative or inverse and were at site GC11 for manganese and zinc; both elements transported mostly in the dissolved phase at GC11.

Dissolved trace elements were significantly correlated with specific conductance (table 9) at GC11 for iron (negative), manganese (positive), and zinc (positive). GC5 also had significant positive correlations with specific conductance for iron and manganese.

Dissolved trace elements were not generally correlated with suspended-sediment concentration (table 12). Dissolved manganese was significantly but weakly correlated with suspended sediment at CC5 (positive), GC5 (negative), and DC1 (positive) and was strongly and positively correlated at CC2.

Total recoverable trace elements and streamflow (table 11) were not well correlated at most sites. However, GC11, a site with large dissolved proportions of manganese and zinc, had negative correlations with streamflow for those elements, likely a result of dilution.

Total recoverable trace elements were significantly correlated with specific conductance (table 9) only at GC11 where there were significant positive correlations with manganese and zinc and a negative correlation with iron.

Spearman correlations of total recoverable trace elements with suspended-sediment concentrations (table 12) were significant and positive at all sites for copper, iron, lead, and manganese. Significant and positive correlations with suspended sediment were computed for zinc at CC2, CC5, and GC5. Positive correlation with suspended-sediment concentration was a result of the tendency for trace elements to be adsorbed to suspended sediment and for the majority of trace-element concentrations to be associated with the particulate phase (insoluble chemical forms) during periods of suspended-sediment transport.

Suspended Sediment, Turbidity, and Streambed-Particle Size

Monitoring of suspended sediment, turbidity, and streambed particle size was initiated because the existing road and the reconstruction project might cause erosion along the road and in receiving areas for road runoff, increase suspended-sediment transport, decrease water clarity, and contribute to deposits on the streambed. Some sites were intensely sampled with automated pumping samplers that produce detailed records of daily suspended-sediment discharge. At other sites, periodic samples of suspended sediment were manually collected to define a suspended-sediment transport relation. Streambed particle-size data were collected at selected sites.

Basin Characteristics of Suspended-Sediment Sites

Basin characteristics for Guanella Pass sediment-discharge computation sites are listed in table 15. Drainage areas for sediment-discharge computation sites ranged from 2.19 mi^2 (CC2) to 74.6 mi^2 (GC11). Several sites had similar drainage areas: CC5 (11.8 mi^2), CC7 (16.0 mi^2), CC9 (12.0 mi^2), and DC1 (13.4 mi^2). Road density in each of the basins varied from 0.0 mi/mi^2 (DC1 and CC1, roadless areas) to 1.05 mi/mi^2 (CC9, an area with a network of old mining roads). Other sites ranged from 0.23 mi/mi^2 (GC11) to 0.65 mi/mi^2 (CC2). The length of roads in a basin has been positively correlated with sediment yield in forested basins in Washington (Reid and Dunne, 1984).

Lakes, reservoirs, and beaver ponds can accumulate sediment and complicate basin sediment-yield computations by reducing downstream transport. All of the basins in the study area probably are affected to a degree by beaver dams. Upper Geneva Creek, Duck Creek, and upper South Clear Creek have large, active beaver dam complexes. Some of the observed beaver dams on active stream channels have large sediment deposits behind them. The trapping effect of beaver dams on sediment is probably less for suspended sediment than it is for bedload because of smaller grain sizes. Abandoned beaver dams show evidence of dissection of the dam and deposited sediment, which act as sediment sources as they are eroded. Duck Lake, Naylor Lake, Lower Cabin Creek Reservoir, and Clear Lake also trap portions of the sediment load from Duck Creek and South Clear Creek Basins and lessen the transport of sediment to downstream reaches.

The Vidler Tunnel diversions into Leavenworth Creek may affect the hydraulics and, thus, the sediment transport characteristics of Leavenworth Creek by importing water from Peru Creek. However, 1995–97 flow records show that Vidler Tunnel water was diverted mainly during July and August (Charles Schaffer, Colorado State Engineer's Office, written commun., 1999), when natural flows in Leavenworth Creek were rapidly receding, possibly increasing sediment transport. However, the tunnel water did not contribute to the highest flows in May and June, which transported the bulk of suspended-sediment loads.

Table 15. Basin characteristics of suspended-sediment discharge monitoring sites and upstream/downstream paired sites

[mi^2, square miles; ft, feet; <, less than; >, greater than; ≥, equal to or more than; valley trend is the general downstream bearing (map direction); basin gradient, basin relief divided by length of drainage basin; road density, length of roads in the basin divided by drainage area; CC1/CC2 and CC13/CC5 are upstream/downstream paired sites]

Site (fig. 1)	Drainage area (mi^2)	Valley trend	Range in altitude (ft)	Basin gradient (ft/ft)	Range in annual precipitation (inches)	Geology		Vegetation/ cover	Land-use factors	Road density (mi/mi^2)	Lakes/ reservoirs/ diversions
						Major	Minor				
CC1	1.1	northwest	12,988–11,200	0.19	30–40	granite	glacial drift, gneissic metasediments	tundra, conifer	primitive camping	0.0	none
CC2	2.19	northwest	12,988–10,710	.15	30–40	granite	glacial drift, gneissic metasediments	tundra, conifer	primitive camping, road	.65	none
CC5	11.8	north	13,794–10,200	.12	25≥30	gneissic metasediments	granite, glacial drift	aspen/ conifer, tundra	developed and primitive camping, road	.53	lakes
CC7	16.0	north	13,794–9,270	.10	16≥30	gneissic metasediments	granite, glacial drift	aspen/ conifer, tundra	developed and primitive camping, hydroelectric generation, road	.55	reservoirs
CC9	12.0	northeast	13,850–9,270	.13	16≥30	gneissic metavolcanics	glacial drift, gneissic metasediments	tundra, aspen/ conifer	primitive camping, mining, roads	1.05	Vidler Tunnel
CC13	7.2	north	13,794–10,705	.16	25≥30	gneissic metasediments	glacial drift, gneissic metasediments	aspen/ conifer, tundra	developed and primitive camping, road	.46	lakes
GC5	7.78	south	13,680–9,760	.35	20–30	gneissic metasediments	granite, glacial drift	aspen/ conifer, tundra	primitive camping, residential, grazing, road	.55	lakes
GC11	74.6	southeast	13,794–8,760	.21	<16–40	gneissic metasediments	granite, glacial drift	aspen/ conifer, tundra	primitive camping, mining, residential, grazing, road	.23	lakes
DC1	13.4	southeast	13,575–9,280	.15	20–30	gneissic metavolcanics	granite, glacial drift	aspen/ conifer, tundra	primitive camping	.0	none

Suspended-Sediment Concentrations and Loads

Suspended-sediment concentration data are listed in Stevens and others (1997) and Stevens (2000). Suspended sediment is defined as the particles (mostly rock fragments, soil, and some organic material) suspended in the water column by the turbulence of the water. Suspended-sediment discharge usually is only a portion of the total sediment discharge, which also includes the bedload. Bedload is the sediment transported by bouncing, rolling, and skidding along the streambed. Summary statistics of concentrations and percentage finer than 0.062 mm for each site with more than two samples are listed in Appendix tables 36–49 and table 7. Suspended-sediment concentrations vary by season—large (greater than 10 mg/L to hundreds of milligrams per liter) during snowmelt and rainstorm periods, small (less than 10 mg/L) during low-flow and winter periods. Suspended-sediment concentrations collected by equal-width integrated (EWI) methods (Edwards and Glysson, 1988) ranged from less than 1 mg/L at many sites during low flow to 1,180 mg/L at site CC2 during stormflow. Median suspended-sediment concentrations (EWI) were generally less than 20 mg/L (fig. 10). Larger concentrations occurred, indicated by sample concentrations from pumping samplers during rainstorms. Pumping samplers that collect stream water at a single point, however, do not average the variability in concentration at various depths and widths of the stream cross section. Thus, single-point samplers are less accurate and could under- or over-estimate suspended-sediment concentrations. An example of the seasonal and year-to-year variations, and the general positive correlation with streamflow of suspended-sediment concentration and discharge, is shown in figure 17 for Geneva Creek (GC11).

Sites on two reaches on South Clear Creek, CC1 to CC2 and CC13 to CC5 (fig. 12), during WY 1997 were used to examine the suspended-sediment concentration changes within a stream reach that closely parallels the Guanella Pass road. Samples were collected at the sites in downstream order, closely spaced in time. Upstream sites of each pair generally had smaller suspended-sediment concentrations than the downstream sites during May and early June and in a rainstorm sample on July 28, 1997 (CC1/CC2) (fig. 12). These dates correspond to the periods of road runoff.

Suspended-sediment discharge is the rate of suspended sediment transported by a stream (commonly expressed as tons per day). Incremental suspended-sediment discharges can be computed and summed to determine the weight of sediment transported in a period of time, typically a water year. In this study, suspended-sediment discharge was computed by two methods. One, selected sites were intensely sampled by automatic pumping samplers, and daily suspended-sediment discharge was computed using the SEDCALC program (Koltun and others, 1994). For this method, sufficient suspended-sediment concentration data are collected each day to compute an average daily suspended-sediment discharge. Daily mean suspended-sediment discharges computed by this method are listed in Stevens (2000).

A second method was used at sites where continuous water-discharge record was available and periodic suspended-sediment samples were collected. Transport relations were computed and sediment discharge estimated using instantaneous streamflows from the gaging station. One to three regression equations (table 16), bias corrected (Duan, 1983), were developed on the basis of hydrograph periods (fig. 5):

1. A rising-limb period was defined as the period between the day of the upturn in the hydrograph at the beginning of snowmelt to the day of the peak daily mean streamflow of the snowmelt period.
2. A falling-limb period was defined as the period from the day after the peak daily mean streamflow to the day when discharge decreases to 25 percent of the peak daily mean streamflow (generally near the end of July or early August).
3. Base flow (includes summer low flow) was defined as the period from the end of the falling-limb period to the beginning of the rising-limb period.
4. Storm days were assumed to be those days that had increases in streamflow or suspended-sediment concentrations related to rainstorms. Summer stormflow relations between suspended-sediment load and water discharge were poorly correlated and were not used. Not using the stormflow relations could underestimate the suspended-sediment contributions from rainstorms for the summer period. Suspended-sediment discharge computations and equations for this method are similar to those discussed previously in the “Dissolved-Solids Loads” section.

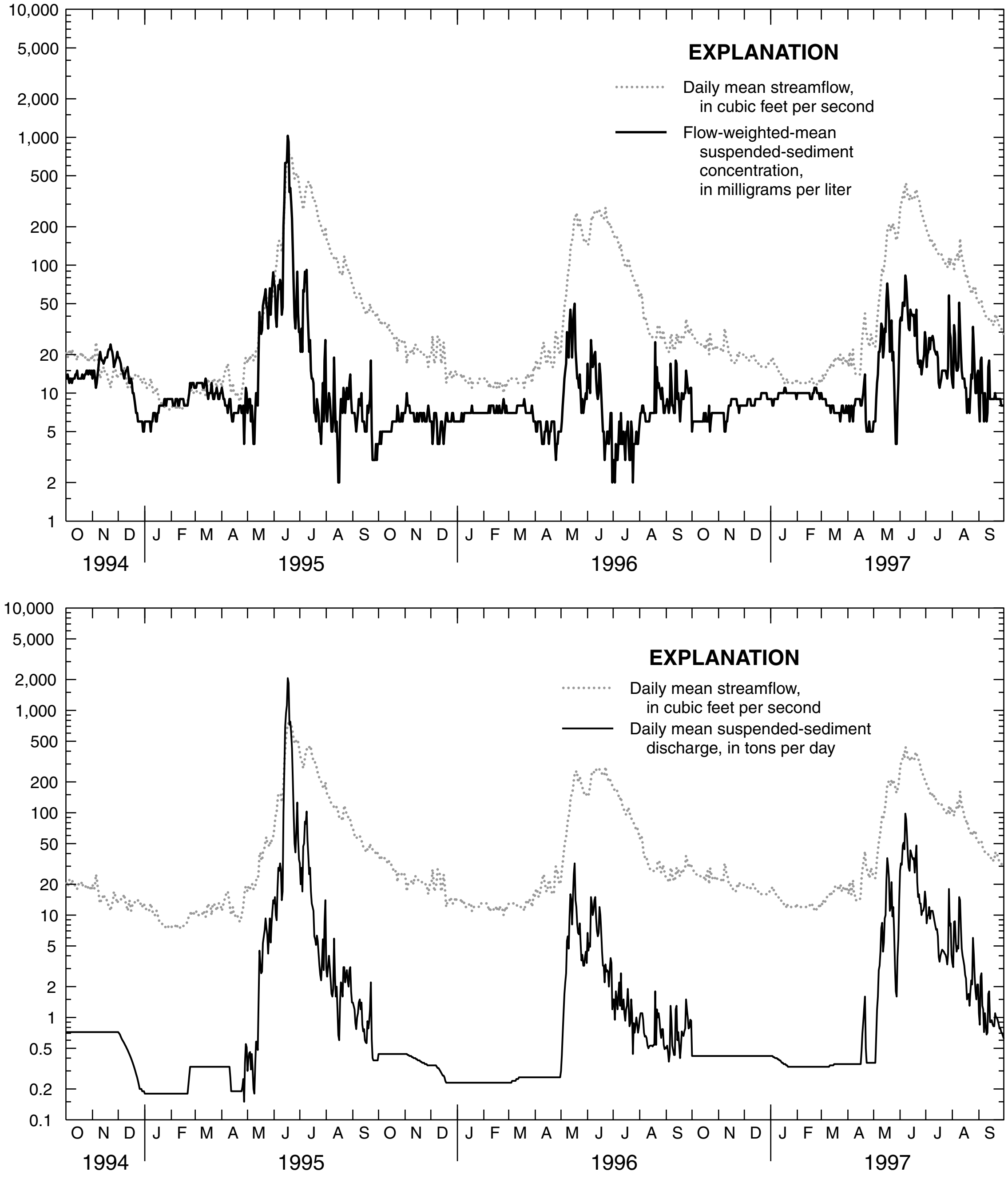


Figure 17. Variation in daily mean water discharge, daily flow-weighted-mean suspended-sediment concentration, and daily mean suspended-sediment discharge at site GC11, water years 1995–97.

Annual suspended-sediment discharges and yields computed by both methods for all sites, WY’s 1995–97, are listed in table 17. Suspended-sediment discharges were highly variable during the study period. Instantaneous suspended-sediment discharge (based on EWI samples) ranged from 0.001 T/d (CC1, CC2) to 1,370 T/d (GC11) (table 7). During WY’s 1995–97, annual suspended-sediment discharge ranged from 21.9 tons at CC2 (WY 1996) to 11,500 tons at GC11 (WY 1995). During water year 1995, suspended-sediment transport was more than an order of magnitude higher at some sites than transport during WY 1996. Relations between annual suspended-sediment discharge and annual streamflow (fig. 18) and between annual suspended-sediment discharge and drainage basin area (fig. 19) indicate

Table 16. Regression coefficients and information used to compute suspended-sediment loads at selected sites, water years 1996–97

[r, rising limb of annual snowmelt hydrograph; f, falling limb of annual snowmelt hydrograph; b, base-flow period; <, less than]

Site (fig. 1)	Hydrologic period	Water year	Number of samples	Natural logarithm form: $LN(L_s) = a + b\ LN\ (Q_w)$							Exponentiated form: $L_s = e^{(a)}Q_w^{(b)}C_b$
				Coefficient and p-values				Standard error	Coefficient of determination (r^2)	Bias correction factor (C_b)	
				a	p-value	b	p-value				
CC2	r	1996	13	–3.859	0.0044	1.568	0.0043	0.99	0.50	1.477	$L_s = (0.0312)Q_w^{(1.568)}$
CC2	f/b	1996	32	–5.112	<.0001	1.495	<.0001	.47	.93	1.098	$L_s = (0.0066)Q_w^{(1.495)}$
CC5	r	1996	17	–2.910	.0005	1.437	<.0001	.86	.74	1.358	$L_s = (0.0740)Q_w^{(1.437)}$
CC5	f/b	1996	47	–5.371	<.0001	1.505	<.0001	.70	.83	1.254	$L_s = (0.0058)Q_w^{(1.505)}$
CC7	r/f/b	1996–97	47	–5.048	<.0001	1.209	<.0001	.91	.62	1.471	$L_s = (0.0094)Q_w^{(1.209)}$
CC9	r	1997	17	–8.587	<.0001	2.439	<.0001	1.10	.73	1.765	$L_s = (0.00034)Q_w^{(2.439)}$
CC9	f/b	1997	36	–5.476	<.0001	1.453	<.0001	.84	.86	1.409	$L_s = (0.0059)Q_w^{(1.453)}$

Table 17. Summary of annual suspended-sediment discharges and suspended-sediment yields at selected sites, water years 1995–97

[tons/yr, tons per year; tons/mi^2, tons per square mile; tons/acre-ft, tons per acre-foot; --, no data]

Site (fig. 1)	Water year 1995			Water year 1996			Water year 1997		
	Suspended-sediment discharge (tons/yr)	Suspended-sediment yield (tons/mi^2)	Suspended-sediment yield (tons/acre-ft)	Suspended-sediment discharge (tons/yr)	Suspended-sediment yield (tons/mi^2)	Suspended-sediment yield (tons/acre-ft)	Suspended-sediment discharge (tons/yr)	Suspended-sediment yield (tons/mi^2)	Suspended-sediment yield (tons/acre-ft)
CC2	--	--	--	21.9	10.0	0.018	103	47.0	0.064
CC5	1,430	121	0.129	187	15.8	.024	319	27.0	.032
CC7	1,400	87.5	.091	112	7.00	.009	133	8.31	.010
CC9	1,760	147	.137	230	19.2	.023	278	23.2	.025
GC5	74.0	9.51	.014	29.7	3.82	.007	78.5	10.1	.016
GC11	11,500	154	.193	576	7.72	.014	1,760	23.6	.035
DC1	--	--	--	36.4	2.72	.006	326	24.3	.027

that annual suspended sediment at each site is proportional to annual flow, and large basins tend to produce large loads.

The relation between suspended-sediment yield (tons/mi^2) and water yield (fig. 20) indicates that annual yields in the South Clear Creek Basin (at CC5, basin area, 11.8 mi^2) tend to be larger than the Deer Creek Basin (at DC1, an undisturbed reference basin, area 13.4 mi^2) at equivalent annual flows, but are similar to the Leavenworth Creek Basin (at CC9, basin area 12.0 mi^2).

Comparison-Site Suspended-Sediment Yields

Guanella Pass suspended-sediment yields were compared to 11 mountainous stream sites with basins of crystalline (igneous or metamorphic) geology and mostly rural land uses in Colorado (Elliott and DeFeyter, 1986) to determine if Guanella Pass suspended-sediment yields were within the general range of computed yields of other basins with the similar general bedrock type, land use, and topography in the region. Generalized basin characteristics for these comparison sites are listed in table 18.

Streamflow and suspended-sediment yields for the sites are listed in table 19. The period of record for the comparison sites was not the same as the Guanella Pass study and could affect the suitability of the comparisons. Suspended-sediment yields per acre-foot of water discharge at Guanella Pass sites (table 17) were within the range of the mean yields of the comparison basins (table 19) except for water year 1995, when the Guanella Pass yields were much larger than the means but still within the range of the maximum yields.

Sediment Discharge by Hydrograph Period

The annual contribution of suspended-sediment load for three periods and the load contribution on days with summer storms (July to September) were computed (table 20) for the purpose of understanding how much suspended sediment each seasonal period contributes and whether those periods correspond to times when road runoff to streams occurs. The hydrograph periods (fig. 5) are the same as described in the previous discussion of sediment load computation: (1) Rising limb of the annual snowmelt water-discharge hydrograph, (2) falling limb, (3) base/summer low-flow period, (4) and summer stormflow.

Results indicate that approximately 80 percent or more of the suspended sediment was transported during the rising and falling limbs of the annual snowmelt hydrograph (about May to July). The shape of the hydrograph was important in that a sharp rise followed by a long, falling-limb recession produced a greater contribution for the falling limb despite larger flow-weighted-mean concentrations of suspended sediment during the rising limb. Guanella Pass suspended-sediment transport seems similar to many areas in Colorado in that suspended-sediment loads were generally larger during the rising-limb period than loads at the same discharge during the falling-limb period (Elliott and DeFeyter, 1986). This relation could indicate a limited supply of suspendable sediment that is exhausted during the rising portion of the annual snowmelt hydrograph. The annual contributions from low-flow and stormflow periods were relatively small, and stormflow contributions were generally smaller than those from low-flow periods.

Road runoff was produced by melting, primarily during the month of May, which corresponds to the rising-limb period of area stream hydrographs. By analyzing suspended-sediment discharge/water-discharge relations during the rising limb, differences

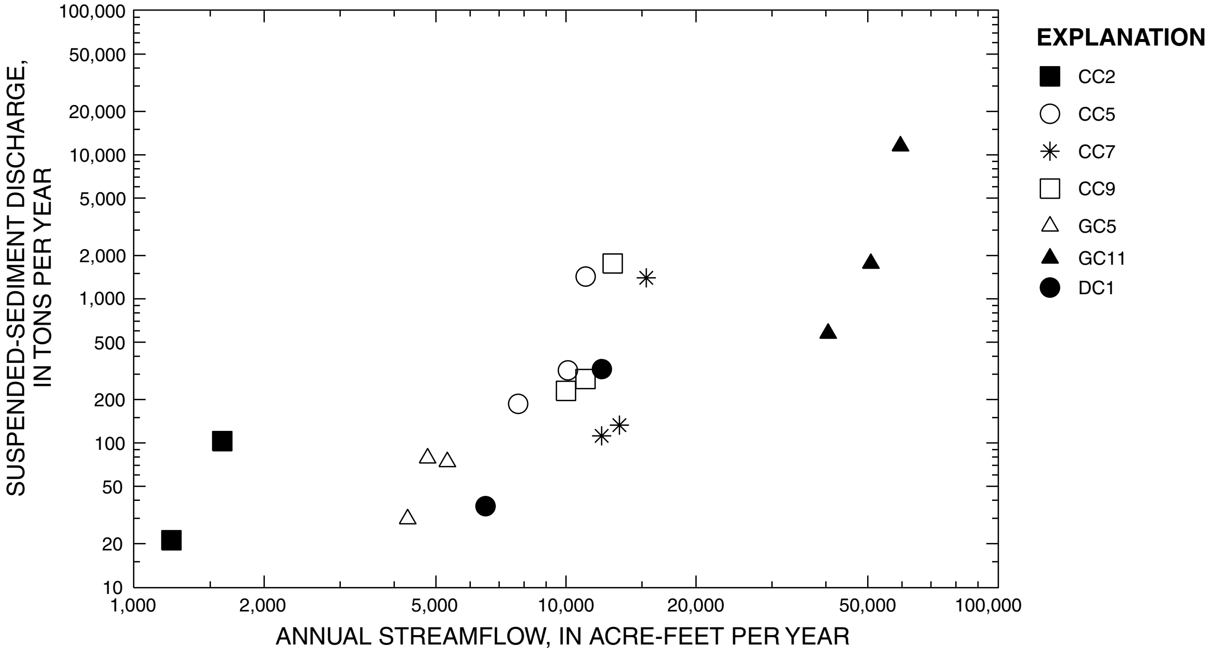


Figure 18. Relation of suspended-sediment discharge to annual streamflow for selected sites, water years 1995–97.

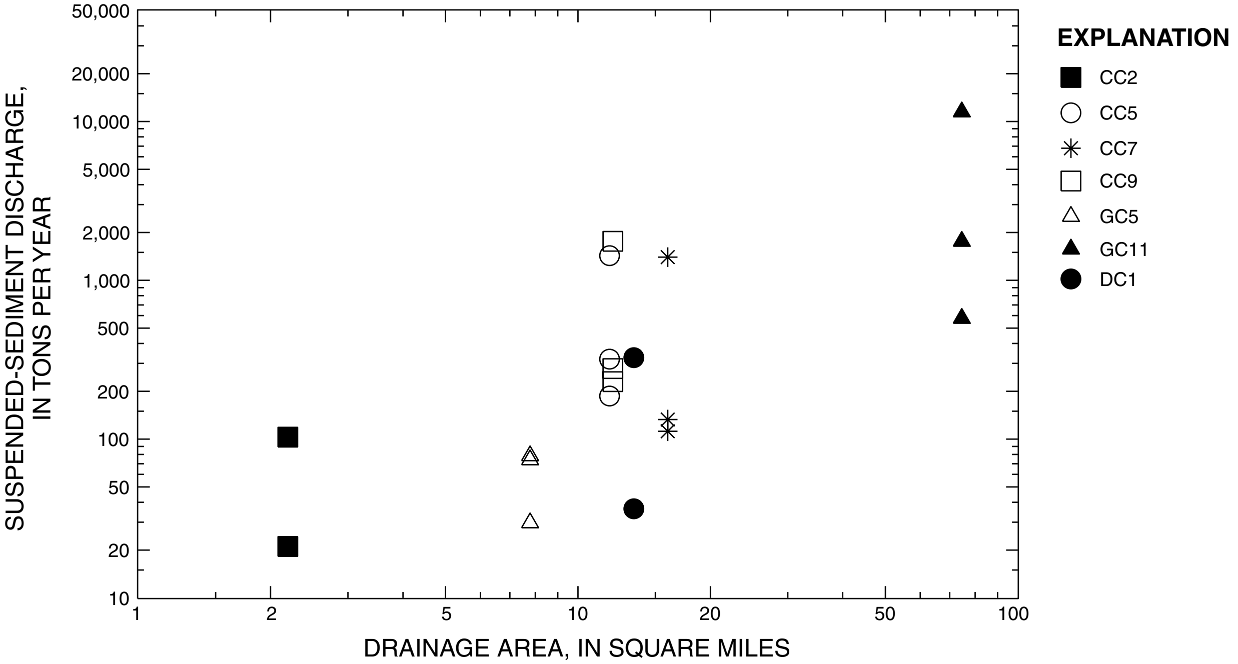


Figure 19. Relation of suspended-sediment discharge to drainage-basin area for selected sites, water years 1995–97.

in transport at sites receiving road runoff might be distinguished. Figure 21 shows sediment-transport relations (table 21) for the 1995–97 rising limb of the hydrograph at sites with annual suspended-sediment monitoring (CC2, CC5, CC7, CC9, GC5, GC11, and DC1). Site DC1 is considered to be a site with an undisturbed land use. Also, rising-limb suspended-sediment discharges, computed at sites with undisturbed land use (CC1, CC11, GC1, GC8, and GC10), were pooled to produce a regression line called REF (for undisturbed reference sites). These sites did not have enough data to compute a regression for each site.

Generally, most of the regression lines occupy a narrow band with a similar slope. The rising-limb transport relations for sites CC2 and CC5 indicate larger suspended-sediment discharge at a given streamflow than other sites in the study. CC2, a site with a small contributing drainage area, has steeper source areas and gradient, which might cause larger suspended-sediment discharges for a given water discharge. But results for site CC5, which has a similar contributing basin area as DC1 and CC9, indicate a larger rate of rising-limb suspended-sediment transport. Transport relations, yield comparisons, and peak rain-event suspended-sediment concentrations indicate that upper South Clear Creek, a basin receiving road runoff, had a larger rate of suspended-sediment transport than a similar-sized, undeveloped basin (Deer Creek near Bailey).

Turbidity

Turbidity is a measure of water clarity, which is affected primarily by the presence of suspended matter. Data documenting preconstruction variability in turbidity are important because turbidity could be used for project monitoring during construction. Turbidity was routinely measured with water-quality and suspended-sediment samples (Stevens and others, 1997; Stevens, 2000). Turbidity is easily measured and results are available immediately, allowing changes in water clarity to be identified. Increased turbidity is an indication of the reduction of light penetration crucial to sustaining periphyton (algae). Decreases in light penetration can reduce algal primary productivity and affect the feeding habits of fish (MacDonald and others, 1991).

Turbidity fluctuates with discharge (fig. 22). Understanding that turbidity fluctuates widely in short periods during runoff is important because preexisting fluctuation behavior could be mistaken for the effects of future construction near the stream. Continuous turbidity sensors such as the one that produced the data for figure 22 were tried at sediment-collection sites, but fouling and bubbles from turbulence affected the record. The use of continuous turbidity monitors to trigger sampling equipment under these conditions does not yet seem feasible.

Turbidity was generally measured with each suspended-sediment sample collected. The statistical summaries (table 7 and Appendix tables 36–49) include only turbidity measured simultaneously with periodic suspended-sediment samples because the entire data set of turbidity may overrepresent some flow regimes because of the differences in collection frequency of pumped suspended-sediment samples. In general, turbidity at low and winter flows was less than 5 nephelometric turbidity units (NTU). During the snowmelt period, turbidity was generally less than 100 NTU and often less than 20 NTU (Stevens and others, 1997; Stevens, 2000). A boxplot of turbidity values (EWI samples only) at selected sites is shown in figure 11 and indicates that median values were generally less than 10 NTU. As with suspended-sediment concentrations, the largest values of turbidity occurred on the rising limb of the snowmelt hydrograph. Peak rainstorm turbidity ranged from a few NTU's to more than 1,000 NTU's (Stevens and others, 1997; Stevens, 2000).

The upstream/downstream pairs (CC1 to CC2, and CC13 to CC5) (fig. 12) indicate a pattern of downstream increases in turbidity similar to suspended-sediment concentration. During the periods of early snowmelt (May to early June) and rainstorms (represented here by the July 28, 1997, sample at CC1/CC2), turbidity increased in a downstream direction.

Peak Suspended Sediment and Turbidity During Storms

Road runoff occurs during summer rainstorms, which contributes to large suspended-sediment concentrations in receiving streams. Table 22 is a compilation of peak suspended-sediment and turbidity data collected during rain events in the summer months of WY's 1995–97. Not all sites had equal sample coverage; pumping samplers were used, and sometimes only part of the rain event was adequately sampled. Ambient (nonstorm) conditions are represented by a sample unaffected by storm activity and collected within a few days of the event sample. Samples chosen to represent ambient conditions were limited by sample coverage and storm occurrence.

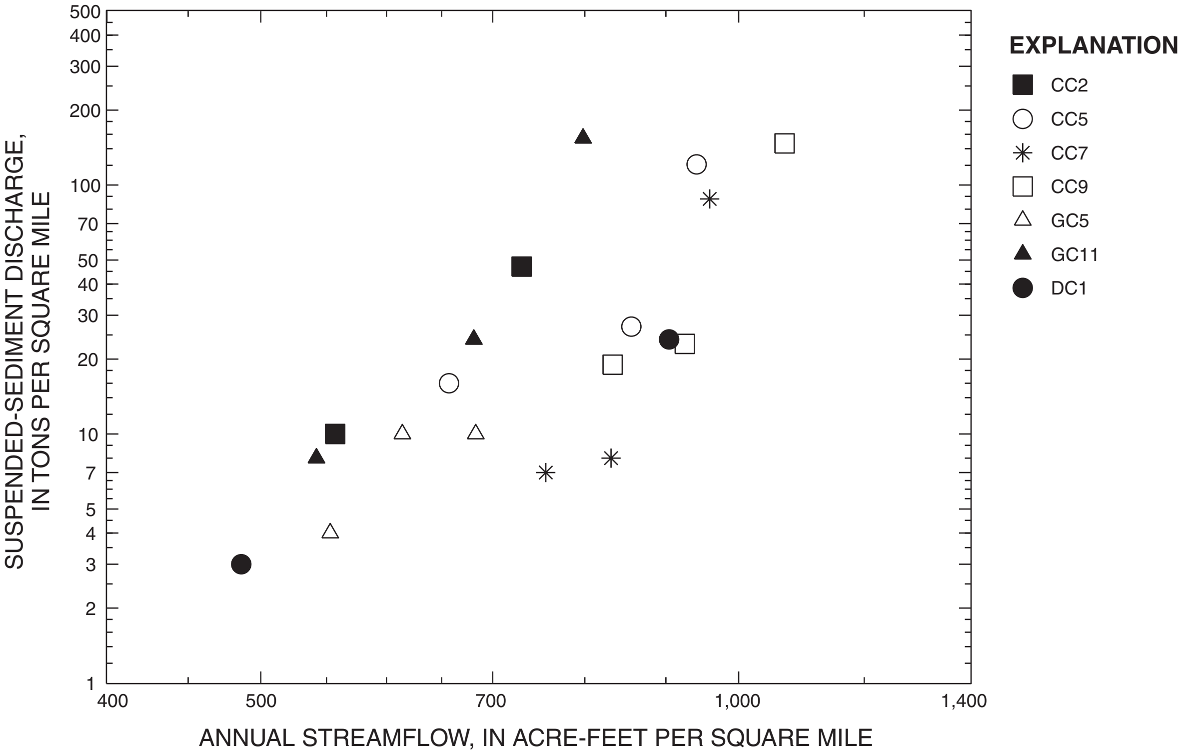


Figure 20. Relation of suspended-sediment yield per square mile to annual streamflow for selected sites, water years 1995–97.

Table 18. Generalized basin characteristics for suspended-sediment comparison sites located outside the study area

Site (fig. 4)	Site name	Drainage area (square miles)	Period of record (water years)	Generalized basin characteristics		
				Surface bedrock geology	Land use	Primary source of peak streamflow
1	Tarryall Creek near Jefferson	183	1978–81	crystalline/ sedimentary	rural, agriculture	snowmelt
2	North Fork South Platte River at South Platte	479	1950–82	crystalline	rural, developed	snowmelt
3	Clear Creek at Golden	400	1975–84	crystalline	rural, mining, developed	snowmelt
4	Saint Vrain Creek at Lyons	212	1950–84	crystalline	rural	snowmelt
5	Big Thompson River at Estes Park	137	1948–84	crystalline	rural, developed	snowmelt
6	Cache La Poudre River at mouth of canyon near Fort Collins	1,056	1950–84	crystalline	rural	snowmelt
7	Halfmoon Creek near Malta	23.6	1948–84	crystalline	rural	snowmelt
8	Middle Fork Piedra River near Pagosa Springs	32.2	1970–75	crystalline	rural	snowmelt
9	Vallecito Creek near Bayfield	72.1	1963–84	crystalline	rural	snowmelt
10	Animas River near Howardsville	55.9	1950–82	crystalline	rural, mining	snowmelt
11	Mineral Creek above Silverton	11.0	1969–75	crystalline	rural, mining	snowmelt

Analysis of the peak samples indicates that increases in suspended-sediment concentration and turbidity during a storm ranges from one to several orders of magnitude within a short period (table 22). At sites CC9, GC5, GC11, and DC1, measured peak concentrations did not exceed 400 mg/L. At sites CC2 and CC5, suspended-sediment concentrations exceeding 1,000 mg/L were sampled. The largest stream suspended-sediment concentration collected during the study period was 2,905 mg/L during a storm event (August 11, 1997) at site CC2. Data also indicate that suspended-sediment concentrations rapidly return to near prestorm concentrations after the storm (Stevens, 2000). Limited data for the percentage of silt/clay (finer than 0.062 mm) in the suspended sediment (table 22) indicate that during storms the material is fine grained, generally more than 90 percent silt/clay. This is probably due to the relatively small streamflow increases during rainstorm events that cannot transport large particles but can transport fine sediment detached by erosion resulting from the impact of rainfall on bare soil. If large particles are transported to the stream, they may settle on the streambed until being transported with high flows during the next snowmelt-runoff season.

Bed-Material Particle Size

Bed-material size distribution can indicate the condition of the stream substrate for biological integrity and show differences between sites that may indicate land-use effects. A study done in the Routt National Forest, in Colorado, which included an analysis of bed-material size and management activity, found a significant correlation between the number of particles less than 8 mm in diameter and the number of road crossings in granitic basins. Significant correlations between channel-condition indices with both the number of road crossings and the number of segments of road near the stream were also determined (Schnackenberg and MacDonald, 1998).

In the Guanella Pass study, pebble-count methods (Wolman, 1954; Bevenger and King, 1995) were used to evaluate substrate-size conditions at selected sites. The data (table 23) indicate that at most sites, sand-sized or smaller material accounts for less than 10 percent of the substrate and the silt/clay fraction accounts for less than 1 percent. This relatively coarse bed material is in contrast to the fine-grained character of stormflow suspended sediment, and it might indicate that fine sediment transported in stormflow does not form extensive deposits in these reaches and does not strongly influence bed-material composition. The boulder/cobble/gravel composition of area streams indicates that, in the areas sampled, fine materials, which can be poor habitat for algae, macroinvertebrates, and fish, were generally present in limited quantities, although fine sediments were observed in beaver ponds, debris dams, and stream-channel margins of most study-area streams.

Storm-Runoff Effects on Stream-Water Quality

Storm runoff can have an effect on stream-water chemistry and suspended-sediment transport in the study area. Water samples were collected at South Clear Creek above Naylor Creek (CC2) at base flow just before a thunderstorm (prestorm) and during stormflow (table 24). Water discharge increased from 0.54 to 0.71 ft^3/s. Specific conductance increased from 136 to 191 µS/cm, and the pH decreased from 8.0 to 7.6. Turbidity increased more than 600 times, indicating large concentrations of suspended particles. Most concentrations of major ions showed only minor changes, whereas the concentration of chloride increased 13 times, an indication that road applications of magnesium chloride (in 1993 and 1996 for this section of the road) could be affecting stormwater inflows to the stream. In contrast, the concentration of magnesium increased only slightly, perhaps a result of cation exchange with sodium and potassium, both of which also slightly increased.

The storm sample comparison at CC2 indicates that concentrations of nutrients, such as dissolved nitrite plus nitrate, total ammonia plus organic nitrogen, and total phosphorus, increased during the

Table 19. Summary of annual streamflow and suspended-sediment yields for selected comparison streams in Colorado with crystalline bedrock geology and Guanella Pass streams

[acre-ft, acre-foot; mi^2, square mile; $tons/mi^2$, tons per square mile]

Site (figs. 1, 5)	Annual streamflow: Maximum yield (acre-ft/mi^2)	Annual streamflow: Minimum yield (acre-ft/mi^2)	Annual streamflow: Mean yield (acre-ft/mi^2)	Suspended-sediment yield per square mile: Maximum yield (tons/mi^2)	Suspended-sediment yield per square mile: Minimum yield (tons/mi^2)	Suspended-sediment yield per square mile: Mean yield (tons/mi^2)	Suspended-sediment yield per acre-foot: Maximum yield (tons/acre-ft)	Suspended-sediment yield per acre-foot: Minimum yield (tons/acre-ft)	Suspended-sediment yield per acre-foot: Mean yield (tons/acre-ft)
Comparison sites (fig. 4) (data from Elliott and DeFeyter, 1986)									
1[a]	178	34	123	8.58	0.38	5.51	0.052	0.011	0.038
2	453	85	260	81.0	.58	22.0	.212	.007	.069
3	571	197	356	92.5	12.4	40.1	.162	.063	.103
4	750	158	406	21.6	2.28	9.24	.030	.014	.021
5	1,000	335	677	44.4	4.54	21.5	.045	.014	.030
6	611	88	227	48.7	2.05	10.8	.080	.022	.043
7	1,510	439	878	28.3	5.10	14.0	.020	.012	.016
8	1,540	458	983	59.3	7.02	31.9	.042	.015	.028
9	2,270	636	1,440	19.3	4.29	11.5	.009	.007	.008
10	1,940	594	1,240	356	3.35	79.1	.184	.006	.055
11	1,800	995	1,440	80.7	38.6	60.7	.045	.039	.042
Guanella Pass streams									
CC2[a]	731	557	644	47.0	10.0	28.5	.064	.018	.041
CC5[a]	942	657	819	121	15.8	54.6	.129	.024	.062
CC7[a]	959	756	849	87.5	7.00	34.3	.091	.009	.037
CC9[a]	1,069	833	942	147	19.2	63.1	.137	.023	.062
GC5[a]	683	553	617	10.1	3.82	7.81	.014	.007	.012
GC11[a]	798	542	674	154	7.72	61.8	.193	.014	.081
DC1[a]	904	486	695	24.3	2.72	13.5	.027	.006	.016

[a] Statistics are for periods less than 5 years and are presented for discussion only; not intended to represent long-term values.

Table 20. Summary of hydrograph period contributions for water discharge and suspended sediment at selected sites, water years 1995–97

[--, no data; periods are parts of the snowmelt hydrograph; flow-weighted-mean concentration is total suspended-sediment load for the period divided by total water discharge for the period converted to milligrams per liter; FWMC, flow-weighted-mean concentration of suspended sediment (in milligrams per liter)]

Characteristic	Water year 1995				Water year 1996				Water year 1997			
	Rising limb	Falling limb	Low flow	Rain-storm	Rising limb	Falling limb	Low flow	Rain-storm	Rising limb	Falling limb	Low flow	Rain-storm
Site CC2												
Percentage of water year	--	--	--	--	5	8	83	4	8	10	75	7
Percentage of discharge	--	--	--	--	21	43	49	2	14	53	26	6
Percentage of suspended-sediment load	--	--	--	--	63	25	8	4	18	69	.5	12
FWMC	--	--	--	--	40	8	3	21	59	61	1	96
Site CC5												
Percentage of water year	17	12	68	3	6	27	67	--	14	20	60	6
Percentage of discharge	20	48	26	6	9	60	31	--	23	47	19	10
Percentage of suspended-sediment load	34	56	1.7	8.1	57	37	6	--	49	35	2	14
FWMC	158	111	6	130	104	10	3	--	49	17	3	32
Site CC7												
Percentage of water year	13	13	74	--	24	15	61	--	16	17	67	--
Percentage of discharge	20	47	33	--	36	31	33	--	27	43	30	--
Percentage of suspended-sediment load	59	40	1.3	--	38	35	27	--	30	47	24	--
FWMC	193	57	3	--	7	8	6	--	8	8	6	--
Site CC9												
Percentage of water year	11	11	76	2	18	13	69	--	16	17	67	--
Percentage of discharge	20	53	21	5	31	46	23	--	23	56	21	--
Percentage of suspended-sediment load	27	71	.6	.7	59	39	2	--	51	42	6	--
FWMC	135	136	3	15	32	15	1	--	41	14	6	--
Site GC5												
Percentage of water year	15	10	75	--	21	13	64	2	15	13	68	4
Percentage of discharge	22	49	29	--	34	46	18	2	26	52	17	5
Percentage of suspended-sediment load	35	55	9	--	55	38	4.6	2.6	35	56	5	4
FWMC	16	12	3	--	8	4	1	5	16	13	4	10
Site GC11												
Percentage of water year	15	11	72	2	11	13	72	4	14	11	68	6
Percentage of discharge	18	55	24	3	32	37	27	4	26	39	26	8
Percentage of suspended-sediment load	48	50	1.5	.4	58	22	17	3	35	47	10	8
FWMC	378	130	9	15	19	6	7	9	34	30	10	26
Site DC1												
Percentage of water year	--	--	--	--	21	16	60	3	13	12	71	4
Percentage of discharge	--	--	--	--	35	31	31	3	18	53	25	4
Percentage of suspended-sediment load	--	--	--	--	46	33	9	12	58	38	3	1.4
FWMC	--	--	--	--	5	4	1	14	50	12	2	6

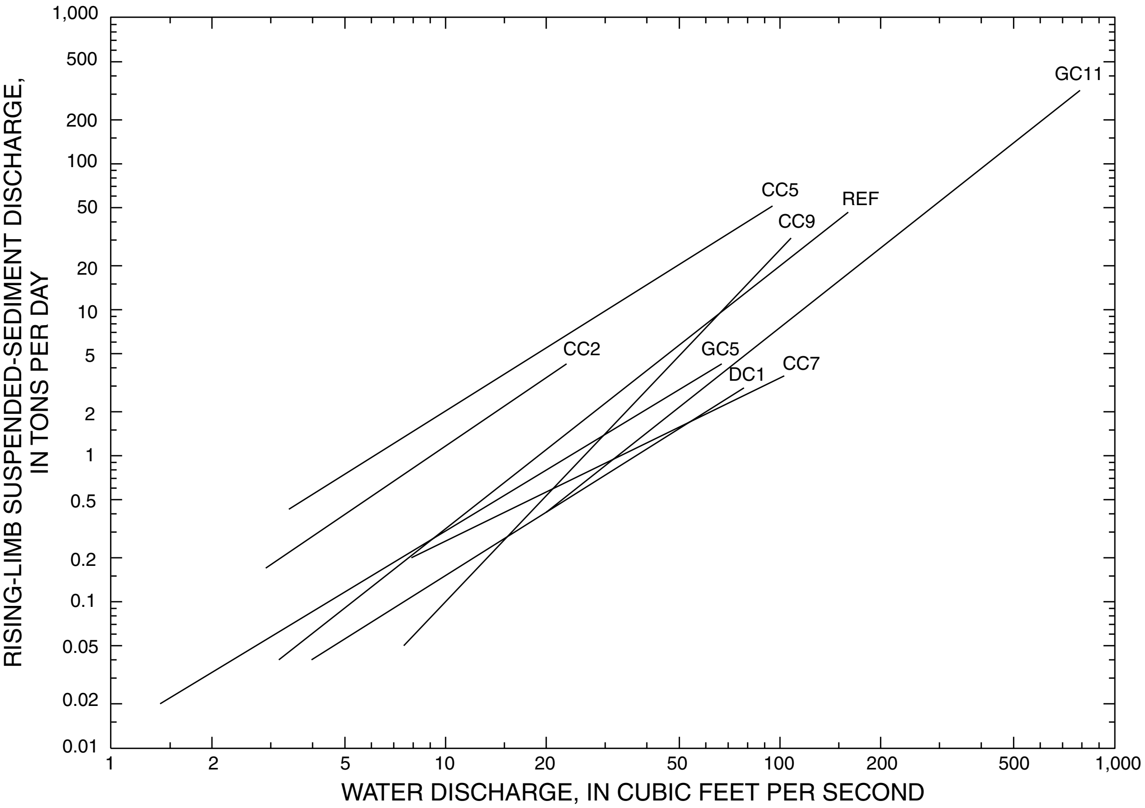


Figure 21. Relation of rising-limb suspended-sediment discharge and instantaneous water discharge for selected sites and a composite of undisturbed reference sites (REF), water years 1995–97.

Table 21. Regression equations and information for rising limb of snowmelt hydrograph at selected sites, water years 1995–97

[a, intercept coefficient; b, slope coefficient; Q_s, suspended-sediment discharge; Q_w, water discharge; LN, natural logarithm; REF, data from undisturbed land use reference sites excluding DC1; <, less than]

Site (fig. 1)	Number of samples	Natural logarithm form: $LN(Q_s) = b + a\ LN\ (Q_w)$							Exponentiated form: $Q_s = e^{(b)}Q_w^{(a)}C_b$
		Coefficients				Standard error	Adjusted coefficient of determination (r^2)	Bias correction factor (C_b)	
		a	p-value	b	p-value				
CC2	13	1.5684	0.0043	–3.8586	0.0044	0.987	0.50	1.477	$Q_s = (0.0312)Q_w^{(1.568)}$
CC5	17	1.4368	<.0001	–2.9098	.0005	.864	.74	1.358	$Q_s = (0.0740)Q_w^{(1.437)}$
CC7	14	1.1126	.0096	–4.2162	.0083	.899	.39	1.371	$Q_s = (0.0203)Q_w^{(1.113)}$
CC9	17	2.4386	<.0001	–8.5872	<.0001	1.102	.73	1.765	$Q_s = (0.00034)Q_w^{(2.439)}$
GC5	24	1.4329	<.0001	–4.9052	<.0001	.767	.80	1.387	$Q_s = (0.0103)Q_w^{(1.433)}$
GC11[a]	16	1.8111	<.0001	–7.1144	.0001	1.074	.76	2.190	$Q_s = (0.0018)Q_w^{(1.811)}$
DC1	19	1.4623	<.0001	–5.5047	<.0001	.684	.77	1.217	$Q_s = (0.0050)Q_w^{(1.462)}$
REF	20	1.8045	<.0001	–5.7564	<.0001	.985	.75	1.527	$Q_s = (0.0049)Q_w^{(1.805)}$

[a] Water years 1996–97 only.

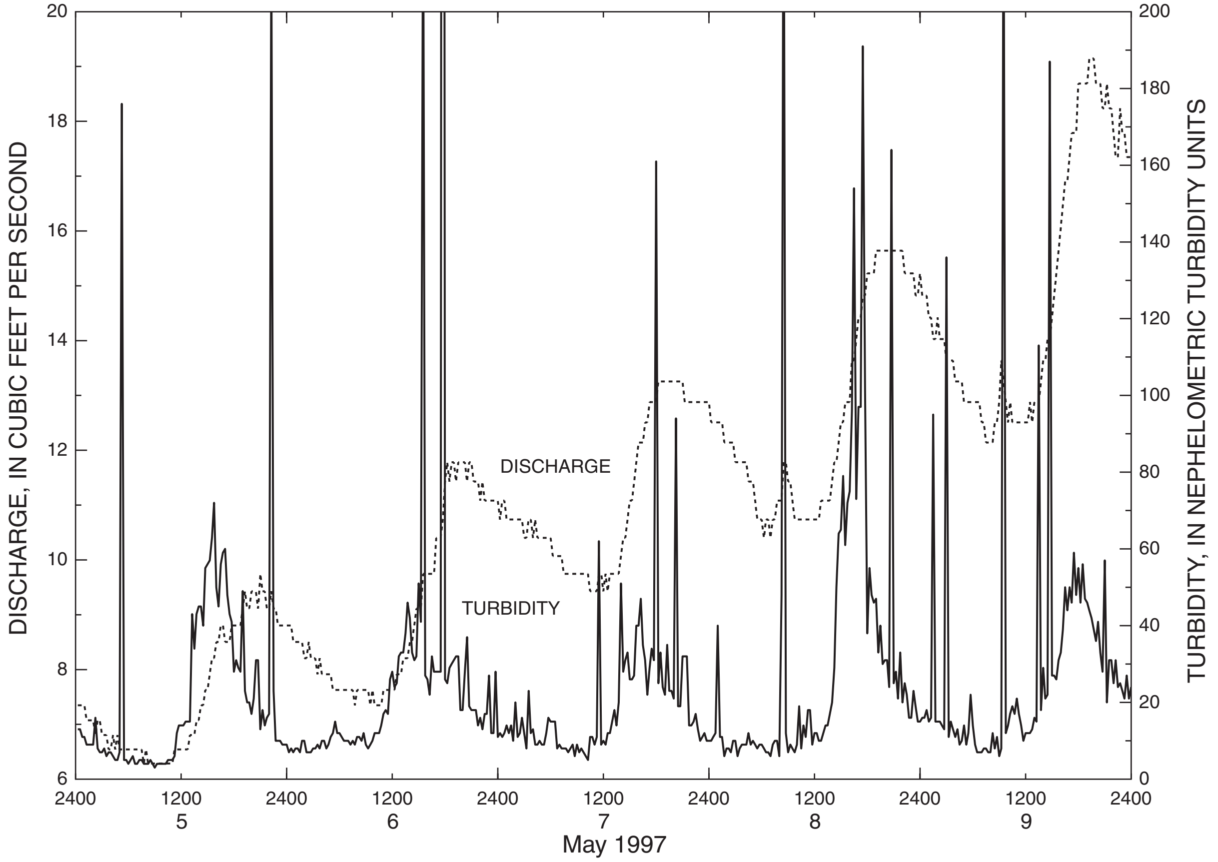


Figure 22. Daily fluctuations in instantaneous turbidity and water discharge at site CC5, May 5–9, 1997.

storm (table 24). Nitrate in precipitation (table 4) or dry-fall accumulations are possible sources of the temporary increase in concentration. The increases in total ammonia plus organic nitrogen and total phosphorus are likely related to the increases in suspended particles from erosion associated with the storm.

Prestorm and storm-runoff analytical results for trace-element analyses at CC2 (table 24) that are greater than the reporting limit indicate that total recoverable and dissolved concentrations were larger for the selected trace elements during storm-runoff conditions. The trace-element concentrations in the storm runoff are about 1 to 2 orders of magnitude larger than those measured in the prestorm conditions. The increase in total recoverable concentrations at CC2 is mostly the result of increases in suspended particles from erosion associated with the storm. The dissolved trace-element increases could be the result of an influx of trace-element-bearing surface runoff or ground water, colloids not removed by filtration, or instream geochemical processes involving sediment.

During storm runoff, the water discharge at CC2 (table 24) was only 31 percent higher than at prestorm conditions, whereas the sediment concentration increased more than 500 times. Sources of suspended sediment are bank and streambed erosion, surface runoff, and stormflow from the road. The small increase in streamflow seems insufficient to cause substantial increases in instream sediment-erosion processes. Although surface runoff is rare in forested basins (Luce, 1995), some sparsely vegetated areas exist in small areas near South Clear Creek that could contribute to suspended sediment if overland flow occurred. Storm runoff from the road is a likely source of the large increases in suspended-sediment concentration during the storm. During a different storm (July 28, 1997), field observation showed evidence of discharge to South Clear Creek upstream from CC2 originating at culverts and shoulder ditches on

Table 22. Ambient and rainstorm peak-measured suspended-sediment and turbidity data at sites with pumping samplers, water years 1995–97

[--, no data; ft^3/s, cubic feet per second; mg/L, milligrams per liter; mm, millimeters; NTU, nephelometric turbidity units; ambient samples represent nonstorm conditions preceding or following the indicated rainstorm peak concentration on the same line in the table; rainstorm peak-measured sample is the sample with the highest suspended-sediment concentration collected during a particular storm; sample coverage may not have been complete for any particular storm]

Site (fig. 1)	Rain-event peak-measured (sediment) sample						Representative ambient sample					
	Date	Time	Water discharge (ft^3/s)	Turbidity (NTU)	Suspended-sediment concentration (mg/L)	Percentage finer than 0.062 mm	Date	Time	Water discharge (ft^3/s)	Turbidity (NTU)	Suspended-sediment concentration (mg/L)	Percentage finer than 0.062 mm
CC9	08–01–95	1240	41	190	65	97	07–30–95	1900	49	1.9	2	--
CC9	08–23–95	1700	25	2.3	4	--	08–23–95	2400	23	1.0	1	--
CC9	08–28–95	1800	25	18	29	--	08–25–95	2100	23	.8	2	--
CC9	07–04–96	1700	64	.9	97	--	07–03–96	2400	52	.4	2	--
CC9	09–06–96	1430	--	--	27	--	09–05–96	1430	--	--	1	--
GC5	07–09–96	2015	20	11	35	90	07–08–96	2400	18	1.5	4	--
GC5	07–18–96	1358	31	8.2	29	69	07–16–96	2200	13	1.8	8	--
GC5	08–23–96	1428	2.1	4.2	10	--	08–22–96	2400	1.5	1.1	5	--
GC5	09–03–97	2115	8.6	7.6	64	--	09–03–97	1746	3.8	2.3	5	--
GC11	08–22–95	1800	127	8.7	19	--	08–20–95	1800	77	3.5	5	--
GC11	08–23–95	1600	105	9.0	20	--	08–20–95	1800	77	3.5	5	--
GC11	08–25–95	2100	110	4.1	40	--	08–25–95	2000	104	3.2	6	--
GC11	09–05–95	2400	54	11	27	--	09–05–95	2300	51	4.3	6	--
GC11	09–09–95	1800	61	4.4	17	--	09–07–95	1800	57	3.0	10	--
GC11	07–18–96	1245	112	27	44	85	07–17–96	2400	104	4.2	14	--
GC11	09–12–96	1844	26	83	100	98	09–12–96	1221	25	4.4	8	--
GC11	08–04–97	1630	109	98	143	--	08–03–97	1518	86	2.6	14	--
GC11	08–09–97	1715	118	140	329	--	08–11–97	1518	126	4.3	16	--
GC11	08–17–97	2045	83	18	39	--	08–18–97	1645	83	4.1	6	--
GC11	08–28–97	1500	67	40	56	--	08–29–97	1500	56	4.9	12	--
GC11	09–12–97	1859	--	--	66	--	09–12–97	1500	39	4.2	5	--
DC1	07–09–96	2200	29	4.4	27	--	07–09–96	1200	18	.4	2	--
DC1	07–18–96	1835	31	9.6	53	51	07–17–96	2200	14	1.0	3	--
DC1	08–21–96	1643	7.9	20	350	99	08–21–96	1620	7.2	1.2	4	81
DC1	08–23–96	1453	11	51	76	97	08–23–96	1430	8.7	2.9	5	76
DC1	09–12–96	1255	8.4	91	142	--	09–11–96	2200	5.4	.3	2	--
DC1	07–20–97	1345	58	2.5	14	--	07–19–97	1609	60	.5	4	--
DC1	08–03–97	2045	9.7	12	42	--	08–03–97	1845	9.7	4.0	5	--
DC1	08–04–97	1445	10	74	108	--	08–04–97	0145	9.7	1.0	10	--

Table 22. Ambient and rainstorm peak-measured suspended-sediment and turbidity data at sites with pumping samplers, water years 1995–97—Continued

[--, no data; ft^3/s, cubic feet per second; mg/L, milligrams per liter; mm, millimeters; NTU, nephelometric turbidity units; ambient samples represent nonstorm conditions preceding or following the indicated rainstorm peak concentration on the same line in the table; rainstorm peak-measured sample is the sample with the highest suspended-sediment concentration collected during a particular storm; sample coverage may not have been complete for any particular storm]

Site (fig. 1)	Rain-event peak-measured (sediment) sample						Representative ambient sample					
	Date	Time	Water discharge (ft^3/s)	Turbidity (NTU)	Suspended-sediment concentration (mg/L)	Percentage finer than 0.062 mm	Date	Time	Water discharge (ft^3/s)	Turbidity (NTU)	Suspended-sediment concentration (mg/L)	Percentage finer than 0.062 mm
DC1	08–09–97	1715	23	20	48	--	08–09–97	1345	16	1.4	3	--
DC1	08–31–97	1600	12	26	39	--	08–30–97	1600	11	1.0	3	--
CC5	07–03–95	1400	--	--	1,273	--	07–02–95	1400	--	--	55	--
CC5	07–04–95	1703	--	--	641	--	07–05–95	1747	--	--	35	24
CC5	07–30–95	1900	30	450	543	84	07–27–95	1720	--	--	28	--
CC5	08–20–95	1700	23	29	38	--	08–20–95	1500	20	1.2	5	--
CC5	08–22–95	1700	27	42	45	--	08–21–95	1500	21	2.3	6	--
CC5	08–28–95	1900	20	--	45	--	08–28–95	1800	22	--	6	--
CC5	08–30–95	1700	18	11	80	--	08–28–95	1700	21	3.8	10	--
CC5	07–28–97	1725	28	110	73	--	07–28–97	1435	26	--	4	84
CC5	08–09–97	1630	26	61	42	--	08–09–97	1400	26	2.3	5	--
CC5	08–10–97	1154	33	91	95	--	08–09–97	1154	25	1.8	5	--
CC5	08–11–97	1520	27	79	73	--	08–11–97	1154	26	3.2	8	--
CC5	08–26–97	1716	21	380	607	--	08–26–97	1201	20	1.5	3	--
CC5	09–01–97	1615	24	1,500	1,739	--	09–02–97	1845	16	1.3	4	--
CC2	07–18–97	1845	2.5	84	61	99	07–18–96	1800	2.4	1.9	1	--
CC2	08–03–96	1346	1.2	45	35	98	08–03–96	1416	1.1	6.1	4	--
CC2	08–21–96	1630	.71	2,500	1,510	100	08–21–96	1515	.54	4.0	3	93
CC2	08–27–96	1816	.71	870	450	100	08–27–96	1646	.58	--	4	--
CC2	09–06–96	1300	.82	1,500	773	100	09–06–96	1131	.52	4.6	6	--
CC2	09–14–96	2259	.63	420	180	100	09–14–96	2100	.58	2.7	3	--
CC2	09–15–96	0144	.73	99	52	--	09–15–96	0014	.66	3.0	3	--
CC2	07–18–97	1800	2.5	42	37	--	07–19–97	1800	1.7	4.5	2	--
CC2	07–28–97	1510	2.4	2,100	1,077	--	07–30–97	1800	2.1	6.1	7	--
CC2	08–09–97	1345	2.1	1,400	1,180	100	08–08–97	1830	1.8	3.5	3	--
CC2	08–11–97	1445	2.7	2,900	2,905	--	08–12–97	0300	2.4	8.1	6	--
CC2	09–03–97	1945	2.8	730	1,817	--	08–31–97	1800	1.2	1.7	2	--
CC2	09–19–97	2315	1.1	360	180	--	09–19–97	2131	.83	2.9	4	--

Table 23. Bed-material particle-size data collected at stream sites, Guanella Pass area

[<, less than]

Site (fig. 1)	Date	Percentage of particles less than size, in millimeters									
		256	64	8	4	2	1	0.5	0.25	0.125	0.062
CC11	07–15–97	73	43	8	6	6	4	2	1	<1	<1
CC9	07–17–97	93	47	6	5	4	4	3	2	1	<1
CC5	07–17–97	98	81	15	12	10	9	8	7	4	1
CC2	07–30–97	89	52	12	11	8	6	5	3	1	<1
CC12	10–01–96	91	51	4	4	4	3	2	2	1	1
CC1	08–22–97	93	40	<1	<1	<1	<1	<1	<1	<1	<1
GC1	08–01–97	81	57	8	8	4	2	1	1	<1	<1
GC2	08–01–97	80	36	10	10	7	5	3	2	1	<1
GC5	08–22–97	73	45	8	7	6	6	5	3	2	1
GC7	08–22–97	96	61	5	5	4	4	3	2	1	<1
GC8	08–22–97	89	45	3	3	3	2	1	1	<1	<1
GC10	08–20–97	82	39	2	2	2	2	1	1	<1	<1
GC11	08–12–97	72	29	3	3	3	2	2	1	1	<1
DC1	07–25–97	94	55	10	10	9	6	4	2	1	<1

the road. Discrete sources of sediment-laden discharge from the road were observed at several points along the stream during the short rainstorm. The velocity of the sediment plumes in the creek was slow because of low flow, resulting in alternating reaches of clear and turbid water. This non-steady-state condition might explain the large fluctuations in turbidity and suspended-sediment concentrations during some rain events at CC2 (Stevens, 2000) that are poorly correlated with streamflow.

A prestorm/storm-runoff sample set also was collected at Deer Creek near Bailey (DC1), which provides a storm-effects comparison at a site unaffected by roads or other land uses (table 24). The DC1 results might not be comparable to the CC2 results because of the difference in location and precipitation totals (CC2 = 0.25 inch, DC1 = 0.89 inch) (Stevens, 2000). Streamflow increased by 26 percent at DC1 between the prestorm and storm samples, indicating a minor effect on flow. Specific conductance and pH values, major ion and dissolved nitrite plus nitrate concentrations remained fairly stable. Particle-related analytes such as total ammonia plus organic nitrogen, total phosphorus, and total recoverable trace elements increased as a result of increased suspended-sediment concentrations (15 times the prestorm concentration). Overall, the increases in constituent concentrations at DC1 during the selected stormflows were smaller than at CC2 and might be a result of the lack of roads and development in the DC1 basin.

Evidence of trace-element phase changes during storms was indicated by comparing filtered and unfiltered samples collected during two storms at Geneva Creek at Grant (GC11) to samples collected during base-flow conditions (table 25). In the first sample set in table 25 (collected September 12, 1996, at 1716 and 1844 by pumping sampler), loads of suspended copper, iron, manganese, and zinc increased (increases ranging from 94 percent for copper to 10,000 percent for manganese) as a result of the storm runoff, whereas the dissolved-phase loads of copper and zinc decreased. Dissolved-phase loads of iron and manganese remained relatively unchanged. The decrease in percentage of some trace elements in the dissolved phase might be explained in part by a relative increase in particle-related phases (indicated by the increase in suspended sediment and turbidity) and by dilution from the increase in discharge. However, the decrease in dissolved-phase load between the base-flow condition and the storm condition for copper (–43 percent) and zinc (–60 percent) indicates that some of the dissolved phase might have been adsorbed to particles (sediment, organic material) transported during stormflow.

Table 24. Selected water-quality properties or constituents of water samples collected during prestorm (base flow) and storm runoff in South Clear Creek above Naylor Creek (CC2) on August 21, 1996, and Deer Creek near Bailey (DC1) on August 23, 1996

[ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; mg/L, milligrams per liter; µg/L, micrograms per liter; <, less than; mm, millimeters]

Property or constituent	CC2		DC1	
	Prestorm (1515 hours)	Storm runoff (1630 hours)	Prestorm (1430 hours)	Storm runoff (1453 hours)
Discharge, ft^3/s	0.54	0.71	8.7	11.0
pH, standard units	8.0	7.6	7.8	7.6
Specific conductance, µS/cm	136	191	39	43
Turbidity, NTU	4.0	2,500	2.9	51
Calcium, dissolved, mg/L as Ca	14	14	4.0	4.0
Magnesium, dissolved, mg/L as Mg	6.9	9.8	1.1	1.0
Sodium, dissolved, mg/L as Na	2.0	3.6	1.8	1.7
Potassium, dissolved, mg/L as K	.8	1.7	.6	.7
Alkalinity, total lab, mg/L as $CaCO_3$	60	44	17	17
Sulfate, mg/L as SO_4	6.6	7.1	2.7	2.5
Chloride, dissolved, mg/L as Cl	1.8	24	.2	.2
Dissolved solids, sum of constituents, mg/L	75	92	31	30
Nitrogen, nitrite plus nitrate, dissolved, mg/L as N	.016	.20	.063	.056
Nitrogen, ammonia plus organic, total, mg/L as N	.3	1.2	<.2	.5
Phosphorus, total, mg/L as P	.012	.23	.009	.077
Copper, total recoverable, µg/L as Cu	<1	39	<1	4
Copper, dissolved, µg/L as Cu	<1	1	<1	4
Iron, total recoverable, µg/L as Fe	390	66,000	180	3,100
Iron, dissolved, µg/L as Fe	240	59	12	34
Lead, total recoverable, µg/L as Pb	<1	48	<1	4
Manganese, total recoverable (µg/L as Mn)	<10	1,700	<10	100
Manganese, dissolved (µg/L as Mn)	<1	82	1	2
Zinc, total recoverable (µg/L as Zn)	<10	180	<10	<10
Zinc, dissolved (µg/L as Zn)	5	17	<3	<3
Sediment, suspended (mg/L)	3	1,510	5	76
Sediment, percentage finer than 0.062 mm	93	100	76	97

The second storm at GC11 (table 25) did not have a base-flow comparison sample immediately preceding the storm sample, but one sample collected 2 weeks before probably represents a suitable comparison. As with the 1996 sample, the storm sample collected on August 9, 1997 (pumping sampler), exhibited an increase in suspended sediment (2,600 percent) and turbidity (2,600 percent) relative to samples collected at the base-flow condition of July 27, 1997 (pumping sampler). Similar to the 1996 sample, the decrease in dissolved-phase loads of zinc transported during stormflow were greater than 94 percent. In contrast to the previous storm sample discussion, the dissolved copper load remained substantially unchanged (+5 percent), and dissolved manganese loads decreased substantially (–74 percent). The decreases in dissolved-phase loads of some trace elements indicate that sediment-laden stormflow may actually improve water quality from the standpoint of dissolved trace-element concentrations, which are a focus of State of Colorado water-quality standards (Colorado Department of Public Health and Environment, Water Quality Control Division, 1996).

Table 25. Comparison of selected water-quality constituents and trace-element phase changes at Geneva Creek (GC11) between two storm-event samples (09–12–96 and 08–09–97) and corresponding base-flow reference samples

[NA, not applicable; --, no data; ft^3/s, cubic feet per second; NTU, nephelometric turbidity units; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; >, greater than; <, less than; ≥, greater than or equal to]

Property or constituent	Base-flow reference		Stormflow		Percentage change in discharge-weighted value or load between base flow and stormflow
	Value or concentration	Percentage in suspended[1] or dissolved[2] phase	Value or concentration	Percentage in suspended[1] or dissolved[2] phase	
Date, time	09–12–96 at 1716		09–12–96 at 1844		
Discharge, ft^3/s	23	N/A	26	N/A	[3]13
Turbidity, NTU	4.8	N/A	83	N/A	[3]1,900
Specific conductance, µS/cm	87	100	86	100	[3]12
pH, standard units	7.2	N/A	7.3	N/A	N/A
Chloride, mg/L	.3	100	.3	100	[4]13
Sulfate, mg/L	29	100	28	100	[4]9
Copper, suspended[1] as Cu, µg/L	7	78	12	92	[4]94
Copper, dissolved as Cu, µg/L	2	22	1	8	[4]–43
Iron, suspended[1] as Fe, µg/L	>427	>99	5,096	>99	<1,200
Iron, dissolved as Fe, µg/L	<3	<1	4	<1	--
Manganese, suspended[1] as Mn, µg/L	<1	0	90	28	[4]>10,000
Manganese, dissolved as Mn, µg/L	250	100	230	72	[4]4
Zinc, suspended[1] as Zn, µg/L	5	6	70	70	[4]1,500
Zinc, dissolved as Zn, µg/L	85	94	30	30	[4]–60
Suspended sediment, mg/L	10	100	100	100	[4]1,000
Date, time	07–27–97 at 2201		08–09–97 at 1715		
Discharge, ft^3/s	112	N/A	118	N/A	5
Turbidity, NTU	5.4	N/A	140	N/A	2,600
Specific conductance, µS/cm	59	100	57	100	2
pH, standard units	7.1	N/A	7.3	N/A	N/A
Chloride, mg/L	.2	100	.2	100	5
Sulfate, mg/L	14	100	14	100	5
Copper, suspended[1] as Cu, µg/L	5	71	10	83	110
Copper, dissolved as Cu, µg/L	2	29	2	17	5
Iron, suspended[1] as Fe, µg/L	765	91	7,260	98	900
Iron, dissolved as Fe, µg/L	75	9	140	2	97
Manganese, suspended[1] as Mn, µg/L	30	20	270	90	850
Manganese, dissolved as Mn, µg/L	120	80	30	10	–74
Zinc, suspended[1] as Zn, µg/L	3	5	>67	>96	>2,200
Zinc, dissolved as Zn, µg/L	57	95	<3	<4	≥94
Suspended sediment, mg/L	13	100	329	100	2,600

[1] Percentage suspended fraction was computed as the difference between the dissolved and total recoverable concentrations divided by the total recoverable concentration; suspended sediment was assumed to be 100 percent suspended.

[2] Percentage dissolved fraction computed as the dissolved concentration divided by the total recoverable concentration; specific conductance, chloride, and sulfate were assumed to be 100 percent dissolved.

[3] Percentage change in discharge-weighted value by comparison of base-flow and stormflow estimates.

[4] Percentage change in constituent load by comparison of base-flow and stormflow estimates.

Lakes and Reservoirs

Lakes and reservoirs in the Guanella Pass area are important resources for recreation, aquatic habitat, hydroelectric-power generation, irrigation storage, and drinking water. Lakes and reservoirs within the watersheds affected by the Guanella Pass road are receiving waters for road runoff. Selected lakes and reservoirs near the Guanella Pass road were sampled to document water-quality conditions. Green Lake, Clear Lake, Lower Cabin Creek Reservoir, and Duck Lake were sampled once in August 1995 as part of a reconnaissance-level assessment (Stevens, 1999). In water years 1996–97, sampling focused on Clear Lake and Duck Lake, prominent public and private water bodies near the Guanella Pass road. In 1997, bottom sediment was collected at Georgetown Reservoir and Lower Square Top Lake for comparison to the previously sampled lakes and reservoirs (Stevens and others, 1997; Stevens, 2000).

Duck Lake (L1, fig. 2) is a privately owned lake at 11,123 ft of altitude near the headwaters of Duck Creek. Duck Lake is more than 100 feet deep in places, and its natural capacity has been modified with a small dam that seasonally releases irrigation water into Duck Creek for downstream use.

Lower Cabin Creek Reservoir (L2, fig. 2) is a shallow reservoir on South Clear Creek at approximately 10,000 ft of altitude, operated by the Public Service Company of Colorado for the purpose of peak power generation. The water from Lower Cabin Creek Reservoir is pumped to Upper Cabin Creek Reservoir and released to generate power at peak demand through a powerplant at the edge of Lower Cabin Creek Reservoir. Normal streamflow patterns are maintained by releases from Lower Cabin Creek Reservoir and Clear Lake (also operated by the Public Service Company of Colorado).

Clear Lake (L3, fig. 2), which is more than 100 feet deep and whose natural capacity has been modified with a small dam, is located immediately downstream from Lower Cabin Creek Reservoir on South Clear Creek at 9,873 ft of altitude. Recreational facilities at the lake promote heavy visitor use. Fluctuations in water level are generally minimal. During water years 1996 and 1997, however, repairs and renovations to the dam required lowering water levels and pumping water over the dam while construction progressed.

Green Lake (L4, fig. 2), located west of Clear Lake, is owned by the Public Service Company of Colorado and is used for private recreation. The lake is small but deep (more than 50 ft), and its natural capacity is increased by a small dam, with storage augmented by flows piped from Leavenworth Creek on a seasonal basis. Aeration is used during winter to maintain adequate dissolved oxygen for fish populations.

Lower Square Top Lake (L5, fig. 2) is a natural lake lying at 12,046 ft of altitude at the headwaters of Duck Creek. The lake area gets heavy visitor traffic by hikers and fishermen but has no other upstream land-use factors.

Georgetown Reservoir (L6, fig. 2) is a small diversion structure that allows water to be diverted to a powerplant in Georgetown and the Georgetown water-treatment plant. The capacity of the detention structure is small and is severely limited by sediment accumulation. Water in Georgetown Reservoir, having a short residence time and a shallow depth, is likely to be similar in character to a mixture of Leavenworth and South Clear Creeks.

Vertical Profiles and Onsite Measurements

Lake and reservoir profiles of water temperature, specific conductance, pH, and dissolved oxygen were used to evaluate limnological characteristics. Profile measurements were collected once at Lower Cabin Creek Reservoir and Green Lake in water year 1995 and many times during the open-water season at Duck and Clear Lakes during water years 1996–97 (Stevens and others, 1997; Stevens, 2000). Seasonal air temperatures and lake stratification patterns indicate that the deep lakes (Duck Lake, Clear Lake, and Green Lake) are probably dimictic—temperature stratification forms in summer and winter, and the lake contents mix during overturn in the spring and fall (Cole, 1994). In these lakes, water temperature, specific conductance, pH, and dissolved oxygen varied with depth during the summer season. Lower Cabin Creek Reservoir probably does not stratify every year (no stratification was observed in August 1995) because of shallow depth and pumping of reservoir contents for hydroelectric-power generation. Seasonal profile patterns for the stratified lakes in the study area are exemplified by selected Duck Lake and Clear Lake profiles for WY 1997 (figs. 23 and 24).

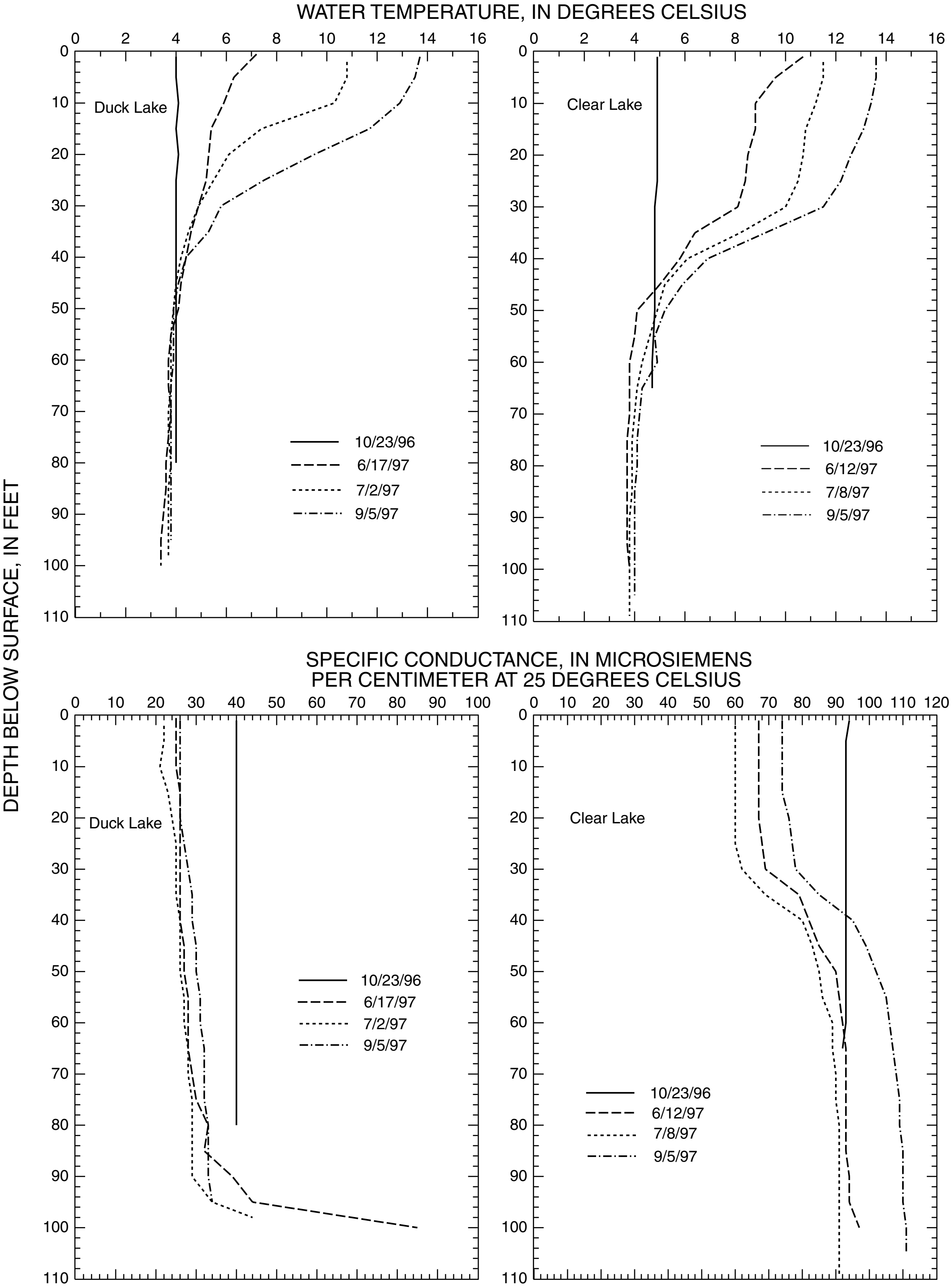


Figure 23. Profile of water-temperature and specific-conductance variation with depth in Duck Lake and Clear Lake on selected sampling dates during water year 1997.

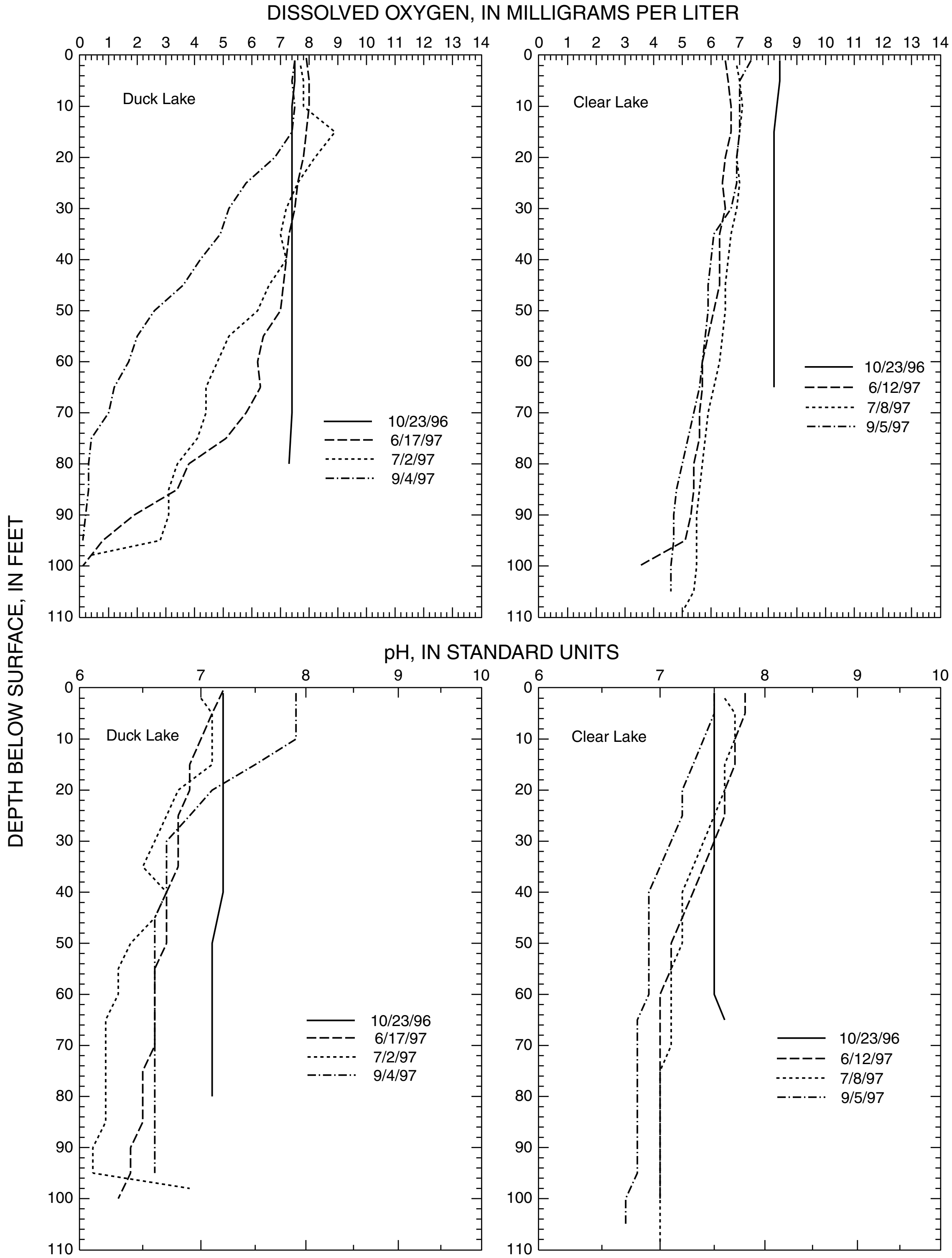


Figure 24. Profile of pH and dissolved-oxygen variation with depth in Duck Lake and Clear Lake on selected sampling dates during water year 1997.

In both Duck and Clear Lakes, minor thermal stratification was evident in June 1997, intensifying through the summer. The thermocline was located at about 20 to 30 ft below the surface in Duck Lake and 30 to 40 ft below the surface in Clear Lake (fig. 23). The surface temperatures throughout water year 1997 ranged from about 4° to 14°C, whereas the bottom temperatures were a fairly constant 4°C year round. Specific-conductance profiles (fig. 23) generally indicate increasing conductivity with depth, whereas pH profiles (fig. 24) generally indicate neutral but decreasing pH, with depth. Water temperature, specific conductance, and pH are generally uniform with depth in October 1996.

Dissolved-oxygen profiles at Duck and Clear Lakes (water year 1997) (fig. 24) generally indicate decreases with depth except October 1996 when mixing of lake or reservoir contents reoxygenated the entire water column of both lakes. Bottom-water hypoxia (low oxygen) was more pronounced in Duck Lake than in Clear Lake; minimum dissolved-oxygen concentrations in Duck Lake generally were less than 2 mg/L except for October 1996. Small concentrations of dissolved oxygen can restrict the vertical distribution of organisms that require oxygen. Clear Lake did not have dissolved-oxygen concentrations below 3.5 mg/L in water year 1997.

Transparency and Chlorophyll

Water transparency was assessed with secchi-disc measurements at the time of water-quality sampling. Transparencies at all sampling dates ranged from 9.0 ft (Clear Lake, 10–23–96) to 29.4 ft (Green Lake, 08–15–95). Most transparencies were in the 8- to 15-ft range in water years 1996–97 (Stevens and others, 1997; Stevens, 2000).

Chlorophyll-*a* can be used as an indicator of algal productivity. Chlorophyll-*a* concentrations were analyzed from photic-zone composite samples from Duck and Clear Lakes in water years 1996–97 (Stevens and others, 1997; Stevens, 2000). The photic zone was estimated at the time of sampling to be twice the secchi-disc depth. Chlorophyll-*a* concentrations in Duck Lake in water years 1996–97 ranged from 0.5 mg/L (09–4–96, data from Stevens [2000]) to 3.2 mg/L (08–12–97). Chlorophyll-*a* concentrations in Clear Lake in water years 1996–97 ranged from 0.2 mg/L (09–05–97, 06–12–97) to 0.5 mg/L (07–23–97) (table 27).

Water-Column Major Ions, Nutrients, and Trace Elements

Chemical characteristics of lake and reservoir water were generally similar to those of the streams that flow into them. In the case of Green Lake, chemical characteristics are influenced by the diversion water from Leavenworth Creek that maintains the lake level. Some lake and reservoir bottom-water samples indicate that reducing conditions develop as a result of seasonal oxygen deficits (Stevens and others, 1997; Stevens, 2000).

Specific conductance ranged from 22 µS/cm at the surface of Duck Lake (07–02–97) to 212 µS/cm near the bottom of Green Lake (08–15–95). As in most area stream waters, pH was neutral and major-ion chemistry was predominantly calcium and bicarbonate at all lakes and reservoirs sampled. Chloride concentrations were small, generally less than 1 mg/L (Stevens and others, 1997; Stevens, 2000).

Nutrient concentrations were small; nitrogen species consisted mainly of dissolved ammonia and dissolved nitrite plus nitrate. Ammonia can be released from bottom sediment during periods of hypoxia. The largest concentration of ammonia (0.722 mg/L as N) was determined for near-bottom water of Duck Lake in the June 17, 1997, sample. Most bottom-water samples had concentrations of dissolved ammonia less than 0.2 mg/L as N. Surface or photic-zone composite samples had dissolved ammonia concentrations less than 0.01 mg/L as N. Duck Lake tended to have dissolved ammonia concentrations that were larger than those from Clear Lake (Stevens and others, 1997; Stevens, 2000), a consequence of more extreme reducing conditions caused by more intense hypoxia.

Nitrite plus nitrate, along with ammonia, are considered to be the most bioavailable forms of nitrogen in water (Woods, 1992). Nitrite plus nitrate was present in the inflows to lakes but also may be formed from the oxidation of ammonia. Nitrite plus nitrate concentrations in surface, or photic-zone composite, samples ranged from less than 0.005 mg/L as N (Duck Lake, 09–04–97) to 0.11 mg/L as N (Clear Lake, 08–16–95, and Lower Cabin Creek Reservoir, 08–15–95). Nitrite plus nitrate concentrations in near-bottom samples ranged from 0.013 mg/L as N (Duck Lake, 06–17–97) to 0.21 mg/L as N (Duck Lake, 09–04–96). Generally, larger surface-water and near-bottom-water concentrations of nitrite plus nitrate occurred in Clear Lake than in Duck Lake in water year 1997, probably because of inflows of surface water containing large concentrations (Stevens and others, 1997; Stevens, 2000).

Phosphorus is the other major nutrient of concern in lakes and reservoirs and is of particular interest because it usually is the limiting nutrient for algal growth. Total phosphorus concentrations ranged from 0.001 to 0.18 mg/L as P in surface and photic-zone composite samples, and 0.001 to 0.094 mg/L as P in near-bottom samples. The large concentration at the surface was measured when shore erosion increased suspended particles, a result of the drawn-down condition of Clear Lake at the time of sampling. Dissolved orthophosphorus, the most bioavailable form of phosphorus (Woods, 1992), ranged from less than 0.001 to 0.002 mg/L as P in surface or photic-zone composite samples, and less than 0.001 to 0.038 mg/L as P in near-bottom water samples (Stevens and others, 1997; Stevens, 2000). The larger concentrations of phosphorus in near-bottom water samples of Duck and Clear Lakes than in the photic zone may indicate that phosphorus is being released from bottom sediment, especially in Duck Lake. Because the near-bottom water-sample concentrations are so large, the difference between near-surface and near-bottom samples does not seem to be a result of algal consumption of phosphorus near the surface.

Nitrogen (N) to phosphorus (P) mass ratios have been used to characterize the limiting nutrient for algal growth present in water (Britton and Gaggiani, 1987; Woods, 1992). If a nutrient is limiting, the hypothesis is that the addition of that nutrient would then cause an increase in algal production (in the absence of other limiting factors) (Britton and Gaggiani, 1987; Woods, 1992). A mass ratio of about 7N:1P (dissolved inorganic nitrogen to dissolved orthophosphorus) is the theoretical boundary between N and P limitation (Redfield, 1958). In practice, N:P ratios below 5 are thought to represent nitrogen-limiting situations, whereas N:P ratios above 10 represent phosphorus-limiting conditions. Nitrogen to phosphorus ratios between 5 and 10 could indicate nitrogen or phosphorus limitation (Britton and Gaggiani, 1987; Woods, 1992).

Nitrogen to phosphorus ratios for Duck and Clear Lakes for WY 1997 are listed in table 26. Some nutrient concentrations were less than the MRL, but in most cases this fact did not prevent assessment of the

Table 26. Mass ratio computations of nitrogen to phosphorus and limiting nutrients in Duck Lake (L1) and Clear Lake (L3) surface or photic-zone composite samples, water year 1997

[All concentrations dissolved in mg/L; P, phosphorus; all phosphorus concentrations are orthophosphorus as P; N, nitrogen; DIN, dissolved inorganic nitrogen, the sum of $NO_2 + NO_3$ and ammonia; DIN:P, dissolved inorganic nitrogen to orthophosphorus ratio; limiting nutrient, algal growth limited by concentration of nitrogen or phosphorus; $(NO_2 + NO_3)$:P, ratio of nitrate plus nitrite to orthophosphorus, used when ammonia is a censored value; DIN:P ratio is preferred, but $(NO_2 + NO_3)$:P ratio along with the reporting limit of ammonia is used to estimate a range, which often determines a limiting nutrient; ?, inconclusive; --, not computed; <, less than; >, greater than]

Site	Date	Phosphorus, ortho as P	Nitrogen, $NO_2 + NO_3$ as N	Nitrogen, ammonia as N	DIN	Percentage of ammonia in DIN	DIN:P	Limiting nutrient by DIN:P	$(NO_2 + NO_3)$:P	Limiting nutrient by $(NO_2 + NO_3)$:P
L1	10–23–96	<0.001	0.014	<0.002	<0.016	<13	?	?	>14	P
L1	06–17–97	<.001	.019	<.002	<.021	<10	?	?	>19	P
L1	07–02–97	.001	.005	.002	.007	29	7	N or P	?	?
L1	07–14–97	<.001	.006	<.002	<.008	<25	?	?	>6	N or P, or P
L1	07–24–97	<.001	.012	.007	.019	37	>19	P	?	?
L1	08–12–97	.001	.007	<.002	<.009	<22	?	?	7	N or P
L1	09–04–97	.002	<.005	.002	<.007	29	<3.5	N	?	?
L3	10–23–96	<.001	.062	<.002	<.064	<3	?	?	>62	P
L3	06–12–97	<.001	.061	<.002	<.063	<3	?	?	>61	P
L3	07–08–97	<.001	.080	<.002	<.082	<2	?	?	>80	P
L3	07–23–97	<.001	.083	.002	.085	2	>85	P	--	--
L3	08–08–97	.001	.075	<.002	<.077	<3	?	?	75	P
L3	09–05–97	.001	.073	<.002	<.075	<3	?	?	73	P

ranges in ratios. If ammonia concentration was less than the reporting limit, generally the proportion of ammonia was too small to affect the N:P ratio. If the orthophosphorus or nitrite plus nitrate concentration was less than the MRL, an evaluation of the possible concentrations would usually allow an estimate of a range for the N:P ratio, which determined the limiting nutrient. For Duck Lake, 43 percent of the samples indicated phosphorus limitation (table 26); for 43 percent of the samples, limitation status could not be determined because of concentrations below the MRL, and 14 percent of the samples indicated nitrogen limitation. For Clear Lake, all samples during WY 1997 indicated phosphorus limitation.

Concentrations of dissolved and total recoverable trace elements in all lakes were small, with only aluminum, iron, manganese, and zinc consistently higher than the laboratory MRL (Stevens and others, 1997; Stevens, 2000). Copper occasionally exceeded the laboratory MRL. Iron and manganese concentrations were almost always higher in the near-bottom sample than in the surface or photic-zone composite sample, except after fall overturn when surface and bottom concentrations were nearly equal for total recoverable and dissolved concentrations. Near-bottom water-sample concentrations of total recoverable iron ranged from less than 10 μg/L (Green Lake, 08–15–95) to 2,500 μg/L (Duck Lake, 08–16–95). Near-bottom water-sample concentrations of total recoverable manganese ranged from less than 10 mg/L (several samples) to 540 mg/L (Duck Lake, 08–16–95) (Stevens and others, 1997; Stevens, 2000). Iron and manganese become more soluble and can be released from bottom sediments under reducing conditions caused by hypoxia. Lower Cabin Creek Reservoir may release these hypoxic waters periodically. Orange-red, flocculated material accumulated on the streambed downstream from the reservoir. The material probably consists of iron and manganese hydroxides precipitated as the water from the reservoir was reoxygenated in the stream (see streambed-sediment chemical data for site CC6 just downstream from Lower Cabin Creek reservoir [Stevens, 2000]).

Nutrient Limitation and Trophic Status

The relative fertility of a lake or reservoir can be evaluated by assessing the trophic status. Oligotrophic (nutrient-poor) lakes have characteristics such as high transparency, small organic-matter content, relatively large dissolved-oxygen concentrations, small nutrient concentrations, and small algal biomass. Eutrophic (nutrient-rich) lakes have the opposite characteristics (Woods, 1992). On the basis of data collected in water year 1997, Duck Lake and Clear Lake were assessed using the method developed by Carlson (1977).

Trophic-state index (TSI) values were calculated from the following equations:

$$\mathrm{TSI(SD)} = 60 - 14.41(\ln \mathrm{SD}) \tag{6}$$

$$\mathrm{TSI(TP)} = 14.42(\ln \mathrm{TP}) + 4.15 \tag{7}$$

$$\mathrm{TSI(CHLA)} = 8.23(\ln \mathrm{CHLA}) + 33.3 \tag{8}$$

where

SD = secchi-disc depth, in meters;

TP = total phosphorus concentration, in micrograms per liter;

CHLA = chlorophyll-*a* concentration, in micrograms per liter; and

ln = the natural logarithm of the indicated variable.

Trophic-state index values were calculated for each sampling date and for the mean values in water year 1997 (table 27). The Carlson (1977) index assumes phosphorus limitation. The boundary between oligotrophic (nutrient-poor) and mesotrophic (moderate nutrients) is a TSI value of 41. The boundary between mesotrophic and eutrophic (nutrient-rich) is a TSI value of 51. Both Duck and Clear Lakes generally remained in the oligotrophic category in water year 1997 for the three trophic indices. Annual mean TSI values were oligotrophic for both lakes.

Bottom-Sediment Chemistry

Bottom sediments in lakes and reservoirs can accumulate nutrients and trace elements that can be toxic to sediment-dwelling organisms and can be remobilized under certain geochemical conditions. Bottom sediments also can integrate years of chemical conditions and provide an indication of watershed chemical influences that are sometimes difficult to detect in water-column samples. A surficial sample

Table 27. Trophic-state index computations for Duck Lake (L1) and Clear Lake (L3), water year 1997

[TSI, trophic state index (Carlson, 1977); SD, secchi-disc depth; TP, total phosphorus as P; CHLA, chlorophyll-*a*; --, no data; WY, water year; m, meter; µg/L, micrograms per liter; all data are for surface or photic-zone composites]

Site (fig. 2)	Date	SD (m)	TSI (SD)	TP (µg/L)	TSI (TP)	CHLA (µg/L)	TSI (CHLA)
L1	10–23–96	4.0	40	6	30	0.8	28
L1	06–17–97	3.2	43	8	34	1.5	35
L1	07–02–97	--	--	6	30	1.9	37
L1	07–14–97	4.6	38	4	24	.8	28
L1	07–24–97	4.6	38	4	24	1.3	33
L1	08–12–97	4.2	39	14	42	3.2	42
L1	09–04–97	3.6	41	7	32	1.8	36
L1	Mean for WY 1997	4.0	40	7	31	1.6	34
L3	10–23–97	2.7	45	3	20	.3	19
L3	06–12–97	--	--	6	30	.2	15
L3	07–08–97	3.4	42	5	27	.4	22
L3	07–23–97	4.1	40	1	4	.5	24
L3	08–08–97	4.5	38	3	20	.4	22
L3	09–05–97	6.0	34	2	14	.2	15
L3	Mean for WY 1997	4.2	40	3	19	.3	20

(less than 10 cm of depth) of bottom sediment was collected by surface dredge (petite ponar type) once in four water bodies (L2, L4, L5, and L6) (fig. 2). At Duck Lake (L1) and Clear Lake (L3), bottom-sediment samples were collected each water year, 1995–97. Trace-element analyses were completed on all samples (less than 63-µm fraction). Nutrient analyses were completed on samples from sites L1, L3, and L4. Selected organic analyses (including herbicides and pesticides) were completed on samples from sites L1, L2, and L3 (Stevens and others, 1997; Stevens, 2000).

Selected trace-element, nutrient, and trace-organic concentrations in bottom sediment are listed in table 28. Among the sites sampled for nutrient content, Duck Lake (L4) had the largest concentrations of ammonia, ammonia plus organic nitrogen, and phosphorus. Because little of the ammonia plus organic nitrogen concentration is ammonia, organic nitrogen is the predominant form of nitrogen in bottom sediments at all of the lakes and reservoirs.

Among the lakes and reservoirs sampled for bottom-sediment trace elements (all sites), Green Lake (L4) and Georgetown Reservoir (L6) generally had the largest concentrations of zinc and lead (table 28). The large concentrations of these trace elements in sediment at these sites are related to sources of trace elements in the Leavenworth Creek Basin, which is a water source to both water bodies. The relatively large concentrations of trace elements in the bottom of Georgetown Reservoir (L6) could be a concern if the reservoir is dredged or decommissioned.

Among the sites sampled for selected trace-organic constituents, Duck Lake (L1) and Lower Cabin Creek Reservoir (L2) bottom sediment contained small concentrations of PCB's (polychlorinated biphenyls). Dichlorodiphenyldichloroethylene (DDE), also a decay product of DDT, was detected in Lower Cabin Creek Reservoir bottom sediment. Also, 1,1-dichloro-2,2-bis p-chlorophenylethane (DDD), a decay product of DDT, was detected in Duck Lake bottom sediment (table 28). The small concentrations of DDD and DDE in bottom sediment could be the result of bulk atmospheric deposition resulting from the past widespread use of DDT, and their presence does not necessarily indicate a source in the basin. These organic chemicals are environmentally persistent and readily partition into a sorbed phase such as bottom sediment.

Ground Water

Ground-water samples were collected at springs and USDA Forest Service campground handpumps in the Guanella Pass study area during a reconnaissance study of ground-water quality (fig. 3) to assess conditions in WY's 1995–97. Ground-water analytical data are presented in Stevens and others (1997) and Stevens (2000). Statistical summaries of ground-water chemical data are presented in Appendix table 50.

Ground-water sources in nearby crystalline bedrock areas are generally from fractures in bedrock or alluvium, soil, or glacial material in valleys (Hofstra and Hall, 1975). Because snow is the primary form of precipitation in the area, recharge in the bedrock areas is probably from infiltration of melted snow. Alluvium in the valleys is probably shallow and hydraulically connected to the stream. Available well-construction information (Stevens, 2000) indicates that some wells are relatively shallow (30 to 265 ft depth) and are screened in bedrock (screened depth ranging from 15 to 160 ft below surface).

Onsite Measurements and Major Ions

The specific conductance of ground-water samples ranged from 24 to 584 µS/cm, with a median value of 104 µS/cm (Appendix table 50), which is generally greater than the range in surface-water medians, 31 to 87 µS/cm (table 7). The pH ranged from 6.5 to 8.3, a generally neutral range. Turbidity was low, ranging from 0.2 to 20 NTU. The predominant cation in all of the ground-water samples was calcium, and the predominant anion was bicarbonate (fig. 25). The median concentration of chloride was 0.6 mg/L, and concentrations ranged from less than 0.1 to 18 mg/L (table 50). Natural background concentrations of chloride are generally low in the mountainous, crystalline bedrock setting (Hofstra and Hall, 1975).

Hofstra and Hall (1975) analyzed ground-water samples from the mountainous part of Jefferson County, an area of similar geology near the study area, and used a chloride concentration of 4 mg/L or greater to indicate chloride concentrations above background levels. Only two sites (fig. 3, GW4 and GW5) exceeded this criterion (Stevens and others, 1997). Because these sites are downslope from parts of the

Table 28. Selected bottom-sediment chemical concentrations for lake and reservoir sites, water years 1995–97

[--, no data; mg/kg, milligrams per kilogram; µg/g, micrograms per gram; <, less than; if more than one sample was collected, maximum concentration is listed]

Constituent	Units	Station (fig. 2)					
		L1	L2	L3	L4	L5	L6
Nitrogen, ammonia total as N	mg/kg	280	--	50	94	--	--
Nitrogen, ammonia plus organic total as N	mg/kg	9,200	--	1,900	3,900	--	--
Phosphorus, total as P	mg/kg	8,000	--	910	800	--	--
Arsenic, total as As	µg/g	13	2	3	7	<10	<10
Cadmium, total as Cd	µg/g	2	--	<2	--	<2	3
Copper, total as Cu	µg/g	49	60	73	160	3	31
Iron, total as Fe	µg/g	130,000	6,100	79,000	55,000	9,300	29,000
Lead, total as Pb	µg/g	90	30	63	330	18	450
Manganese, total as Mn	µg/g	4,700	1,200	2,300	650	170	1,800
Mercury, total as Hg	µg/g	.05	.05	.53	.28	--	--
Zinc, total as Zn	µg/g	170	180	210	2,000	28	1,000
PCB,[1] total	µg/kg	10	22	<2	--	--	--
DDE[2]	µg/kg	<.9	.7	<.2	--	--	--
DDD[3]	µg/kg	.9	<.4	<.2	--	--	--

[1] polychlorinated biphenyl.

[2] dichlorodiphenyldichloroethylene.

[3] 1,1-dichloro-2,2-bis(p-chlorophenyl)ethane.

Guanella Pass road treated with magnesium chloride ($MgCl_2$), this applied dust inhibitor is a likely source of chloride that has migrated into the ground water.

Scatterplots of major ionic constituents and specific conductance in ground-water samples might show outliers that could relate to applications of magnesium or sodium chloride. A scatterplot of magnesium with specific conductance (fig. 26) shows that magnesium concentration correlates well with specific conductance except at GW5, which tends to have a larger magnesium concentration than the specific-conductance correlation would predict. The chloride concentration at GW5, 5.8 mg/L, also is the second largest among all sampled ground-water sites. Sodium concentration has a poorer relation with specific conductance than the relation between magnesium concentration and specific conductance (fig. 26). Sampling site GW3 has a higher sodium concentration than the specific-conductance relation would predict, but the chloride concentration is too small to indicate any possible effect of NaCl applications. Chloride concentration is not well correlated with specific

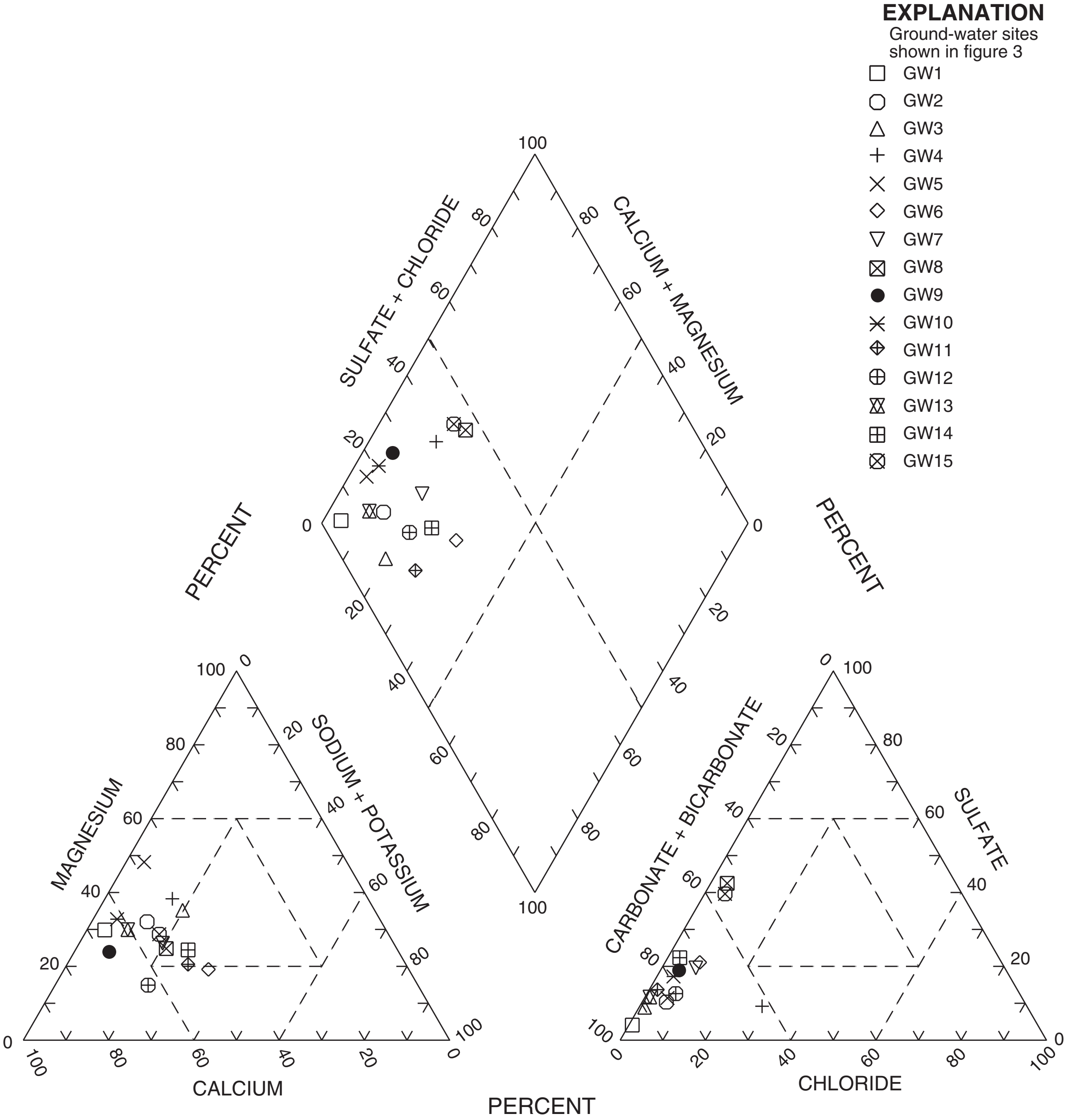


Figure 25. Chemical composition of ground-water samples collected during water years 1995–97.

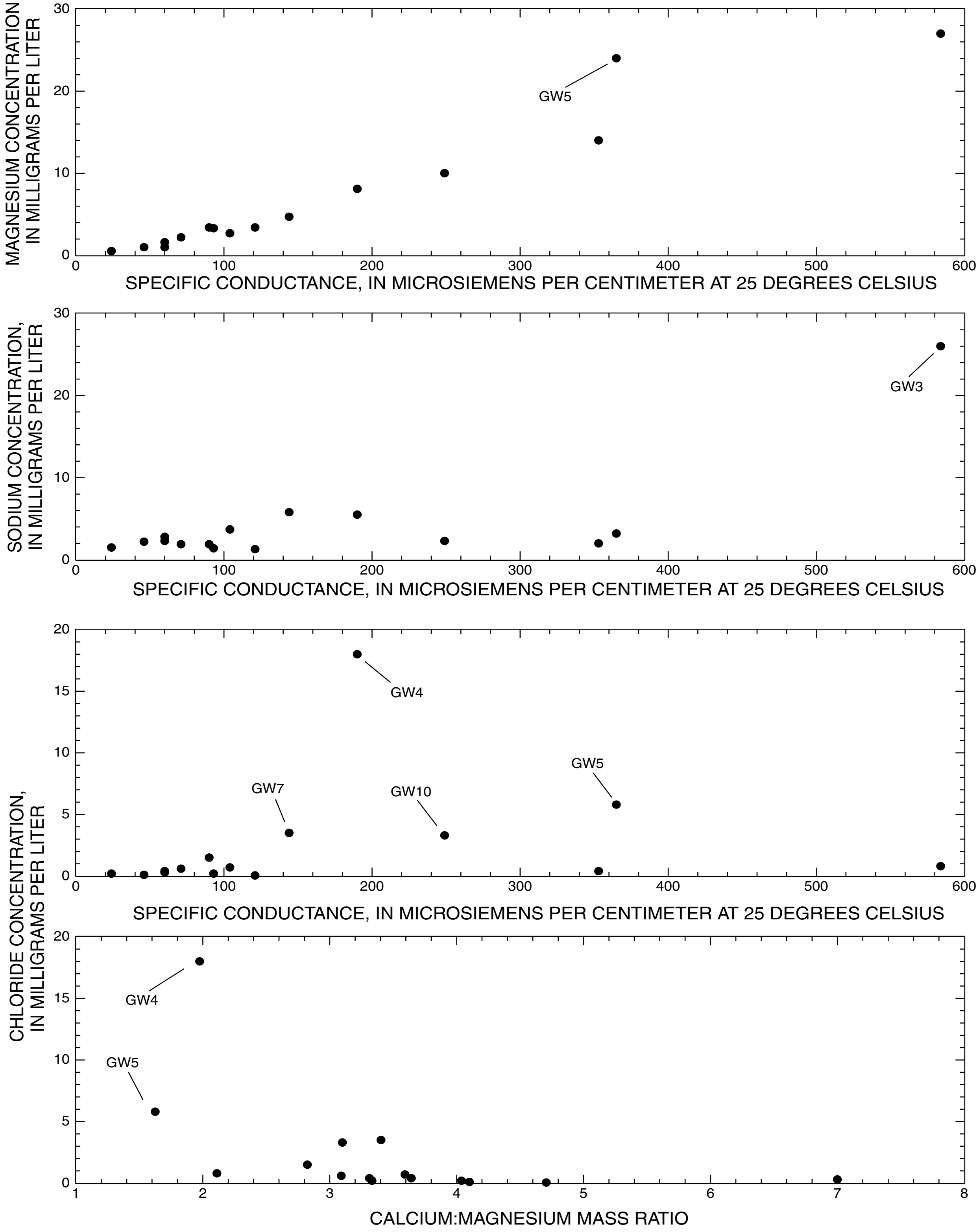


Figure 26. Relations of magnesium, sodium, and chloride concentrations and specific conductance, and the relation of chloride concentration and the mass ratio of calcium to magnesium, for ground-water samples collected during water years 1995–97.

conductance (fig. 26) probably because the source of chloride is precipitation or runoff, not rock weathering, in this geologic setting (Bassett and others, 1992). Chloride concentrations from two sampling sites were larger than 4 mg/L: GW4 and GW5 (Stevens and others, 1997). Both sampling sites are downslope from sections of roads treated with magnesium chloride ($MgCl_2$).

A scatterplot of chloride to calcium:magnesium ratio (Ca:Mg) (fig. 26) shows that the two largest chloride concentrations correspond to samples with low Ca:Mg ratios. Large chloride to Ca:Mg ratios could indicate influence by $MgCl_2$ runoff. Because the mass of chloride in $MgCl_2$ is almost three times greater than magnesium, the increase in chloride concentrations will be more obvious than the increase in magnesium.

Nutrients

Nutrient concentrations in ground water were small (Appendix table 50) and similar to those measured in mountainous areas of similar geology (Hofstra and Hall, 1975). Dissolved nutrient concentrations also were similar to concentrations measured in stream water. Dissolved nitrite plus nitrate was the nutrient species most frequently reported at concentrations greater than the laboratory MRL, with a median concentration of 0.08 mg/L as N and a range of less than 0.05 to 0.15 mg/L as N (table 50). Water from wells GW8 and GW10 (fig. 3) had the largest dissolved ammonia concentrations of 0.02 mg/L (Stevens and others, 1997; Stevens, 2000). Total or dissolved ammonia plus organic nitrogen was not detected at concentrations greater than laboratory MRL. Total phosphorus concentrations also were small, ranging from less than 0.01 to 0.03 mg/L as P (table 50). All dissolved orthophosphate concentrations were less than the MRL except at GW5 (0.001 mg/L as P), GW9 (0.002 mg/L as P), and GW10 (0.01 mg/L as P) (Stevens and others, 1997; Stevens, 2000). However, there were two reporting limits (0.001 and 0.01 mg/L), and many samples were analyzed at the higher reporting limit.

Trace Elements

Compared to the dissolved phase, particulate-phase concentrations of trace elements were relatively small, as indicated by differences between total recoverable and dissolved concentrations (Stevens and others, 1997; Stevens, 2000). Dissolved-phase concentrations were small except for occasional large concentrations of iron, manganese, and zinc. Large dissolved zinc (4,600 µg/L) and dissolved copper (9 µg/L) concentrations in campground wells could indicate a bias from trace elements leaching into well water from handpump or well materials. Concentrations of zinc and copper in samples collected from campground sites (GW2, GW3, GW4, GW7, GW8, and GW15) were all larger than in samples collected from springs (all others). Dissolved uranium was present in a few samples. In 1995, a relatively large concentration of 67 µg/L of uranium was determined in a sample from a campground well (GW3). The next largest uranium concentration in the 1995 sample set, however, was 5 µg/L (GW1), so the large concentration does not seem representative of uranium concentrations in the area. In 1997, a sample from GW3 had a uranium concentration of 44 µg/L, basically confirming the relatively large concentration in the 1995 sample. A possible source of uranium is groundwater contact with uranium-bearing rocks that are present in some crystalline rocks of the Colorado Front Range (Hills and others, 1982).

Comparisons with Water-Quality Standards

Stream and ground-water standards are used in this report to assess water quality. Water-quality standards for Colorado and other applicable guidelines are used to evaluate streams near the Guanella Pass road. Ground-water quality is evaluated on the basis of Colorado and U.S. Environmental Protection Agency (USEPA) drinking-water standards.

Streams

Water-quality standards for streams in Colorado are based on use classifications such as aquatic life, recreation, water supply, and agriculture.

Colorado Water-Quality Standards

In Colorado, water-quality standards are determined by the State Water Quality Control Commission and consist of a narrative or numeric restriction established to protect the beneficial uses of water. Some water-quality standards for streams are set to specific values or concentrations (such as dissolved oxygen, pH, nitrite, nitrate, chloride, sulfate, iron, and manganese). Others, un-ionized ammonia and some trace elements, are usually site specific and use hardness data and equations for each element to calculate standards (Colorado Department of Public Health and Environment, Water Quality Control Division, 1996). In certain cases (such as Leavenworth Creek CC9), fixed numeric standards have been established that reflect site-specific conditions and may specify trace-element phases and analytical techniques (such as dissolved or total recoverable methods).

Trace-element concentrations are assumed to be dissolved unless designated otherwise by the numeric standards (Colorado Department of Public Health and Environment, Water Quality Control Division, 1996). Acute standards are values or concentrations not to be exceeded for 1 day. Chronic standards are not to be exceeded by the 85th percentile of sample concentrations in a representative period. Extraordinary ephemeral or seasonal conditions do not constitute violations. Stream standard concentrations and values are not to be exceeded more than once every 3 years on the average (Colorado Department of Public Health and Environment, Water Quality Control Division, 1996). Thus, continued systematic monitoring is needed to determine compliance with or exceedance of a standard.

The State of Colorado specifies that hardness concentrations used to calculate the trace-element standards be computed from the lower 95-percent confidence limit of the mean hardness at the periodic low-flow criteria determined from regression analysis of site-specific or regional data. In this study, however, the length of record and current data were insufficient for this method. Therefore, hardness concentrations were determined from analysis of water samples collected at the time of sampling or were estimated from a site-specific hardness logarithmic regression with specific conductance (table 29). Hardness at CC9 was estimated from a regression that included all hardness concentrations for study area streams because insufficient site-specific hardness data were available for the site.

Preliminary estimates of the Colorado water-quality standards for six stream-sampling sites adjacent to the Guanella Pass road (table 30) were calculated on the basis of numeric fixed standards or equations (Table of Value Standards [TVS]) for each element (Colorado Department of Public Health and Environment, Water Quality Control Division, 1996). Laboratory MRL's for trace elements such as cadmium, mercury, silver, and lead were commonly too high to determine concentrations at the level of the standard. These constituents might be present in the sample at concentrations lower than the laboratory MRL but higher than the standard. Certain constituents listed in the Colorado water-quality standards were not analyzed in the samples (for example, chlorine, cyanide, sulfide, and boron).

Based on all samples collected in water years 1995–97, standards for dissolved oxygen, pH, chloride, sulfate, un-ionized ammonia, nitrate, total recoverable arsenic, and total recoverable chromium were not exceeded at any of the sampling sites along the Guanella Pass road (table 30).

Concentrations of water-quality constituents from South Clear Creek above Naylor Creek (CC2) exceeded both the dissolved and total recoverable fixed chronic standards for iron and manganese (table 30) at certain times. At South Clear Creek above Lower Cabin Reservoir (CC5), dissolved and total-recoverable iron and total recoverable manganese also exceeded the fixed chronic standard in some samples.

Table 29. Regression equations and information used to compute hardness concentrations at selected sites, water years 1995–97

[a, intercept coefficient; b, slope coefficient; H, hardness; SC, specific conductance; C_b, bias correction factor; all sites, a regression of available hardness and specific-conductance data at all sites; <, less than]

Site (fig. 1)	Water year	Number of samples	Natural logarithm form: LN(H) = b + a LN (SC)							Exponentiated form: $H = e^{(b)}SC^{(a)}C_b$
			Coefficients				Standard error	Adjusted coefficient of determination (r^2)	Bias correction factor (C_b)	
			a	p-value	b	p-value				
CC2	1995–97	29	1.0170	<0.0001	–0.9070	<0.0001	0.074	0.98	1.002	$H = (.4047)SC^{(1.017)}$
CC5	1995–97	15	.9166	<.0001	–.5019	.1140	.039	.92	1.001	$H = (.6060)SC^{(.9166)}$
GC5	1995–97	31	1.0093	<.0001	–1.0205	.0002	.045	.89	1.001	$H = (.3608)SC^{(1.009)}$
GC11	1995–97	26	.9447	<.0001	–.8391	<.0001	.044	.96	1.001	$H = (.4325)SC^{(.9447)}$
All study sites	1995–97	165	1.0840	<.0001	–1.2825	<.0001	.097	.95	1.005	$H = (.2786)SC^{(1.0840)}$

Table 30. Water-quality standards for selected stream-sampling sites along the Guanella Pass road for constituents and properties sampled

[mg/L, milligrams per liter; --, no data or no standard; <, less than; µg/L, micrograms per liter; ?, reporting limit above standard or part of range in standard; max, maximum; min, minimum; standards from Colorado Department of Public Health and Environment, Water Quality Control Commission (1996)]

Property or constituent	Total number of samples	Max or Min standard	Range of concentration		Range of standard		Number of exceedances	
			Min	Max	Chronic	Acute	Chronic	Acute
Site CC2								
Dissolved oxygen, mg/L	38	Min	6.8	11.5	6.0	--	0	--
pH, standard units	44	Min/max	7.2	8.3	6.5–9.0	--	0	--
Chloride, dissolved, mg/L	44	Max	.5	36	250	--	0	--
Sulfate, dissolved, mg/L	42	Max	1.3	7.5	250	--	0	--
Un-ionized ammonia, mg/L	17	Max	.000005	.00006	.02	0.03–0.10	0	0
Nitrate, dissolved, mg/L	37	Max	<.005	.12	10	10	0	0
Arsenic, total recoverable, µg/L	2	Max	<1	<1	--	50	--	0
Cadmium, dissolved, µg/L	2	Max	<1	<1	.3–.6	.5–1.6	?	?
Chromium III, dissolved, µg/L	2	Max	--	--	--	--	--	--
Chromium III, total recoverable, µg/L	2	Max	<1	20	--	50	--	0
Copper, dissolved, µg/L	42	Max	<1	2	2–11	3–16	0	0
Iron, dissolved, µg/L	42	Max	26	440	300	--	11	--
Iron, total recoverable, µg/L	42	Max	60	72,000	1,000	--	16	--
Lead, dissolved, µg/L	8	Max	<1	<1	5	5–34	0	0
Manganese, dissolved, µg/L	42	Max	<1	130	50	--	2	--
Manganese, total recoverable, µg/L	42	Max	<10	1,900	1,000	--	4	--
Mercury, total recoverable, µg/L	2	Max	<.1	<.1	.01	--	?	--
Nickel, dissolved, µg/L	2	Max	<1	<1	24–51	230–496	0	0
Selenium, total recoverable, µg/L	2	Max	<1	<1	10	--	0	--
Silver, dissolved, µg/L	2	Max	<1	<1	.003–.018	.09–.50	?	?
Zinc, dissolved, µg/L	42	Max	2	17	22–96	25–106	0	0
Site CC5								
Dissolved oxygen, mg/L	31	Min	7.1	11.6	6.0	--	0	--
pH, standard units	38	Min/max	7.3	8.3	6.5–9.0	--	0	--
Chloride, dissolved, mg/L	34	Max	.3	1.9	250	--	0	--
Sulfate, dissolved, mg/L	29	Max	2.2	6.6	250	--	0	--
Un-ionized ammonia, mg/L	26	Max	.000008	.0002	.02	.04–.12	0	0
Nitrate, dissolved, mg/L	28	Max	.048	.18	10	--	0	--
Arsenic, total recoverable, µg/L	8	Max	<1	<1	--	50	--	0
Cadmium, dissolved, µg/L	8	Max	<1	<1	.4–.4	.8–.9	?	?
Chromium III, dissolved, µg/L	8	Max	--	--	--	--	--	--
Chromium III, total recoverable, µg/L	8	Max	<1	8	--	50	--	0
Copper, dissolved, µg/L	29	Max	<1	2	3–5	4–7	0	0
Iron, dissolved, µg/L	29	Max	35	320	300	--	1	--
Iron, total recoverable, µg/L	32	Max	120	110,000	1,000	--	14	--
Lead, dissolved, µg/L	13	Max	<1	<1	5	10–18	0	0
Manganese, dissolved, µg/L	29	Max	2	19	50	--	0	--
Manganese, total recoverable, µg/L	32	Max	<10	2,300	1,000	--	1	--
Mercury, total recoverable, µg/L	8	Max	<.1	<.1	.01	--	?	--
Nickel, dissolved, µg/L	8	Max	<1	1	33–35	323–342	0	0
Selenium, total recoverable, µg/L	8	Max	<1	<1	10	--	0	0
Silver, dissolved, µg/L	8	Max	<1	<1	.007–.008	.2–.2	?	?
Zinc, dissolved, µg/L	29	Max	1	10	29–49	33–54	0	0

Table 30. Water-quality standards for selected stream-sampling sites along the Guanella Pass road for constituents and properties sampled—Continued

[mg/L, milligrams per liter; --, no data or no standard; <, less than; µg/L, micrograms per liter; ?, reporting limit above standard or part of range in standard; max, maximum; min, minimum; standards from Colorado Department of Public Health and Environment, Water Quality Control Commission (1996)]

Property or constituent	Total number of samples	Max or Min standard	Range of concentration		Range of standard		Number of exceedances	
			Min	Max	Chronic	Acute	Chronic	Acute
Site CC9								
Dissolved oxygen, mg/L	16	Min	8.4	11.3	6.0	--	0	--
pH, standard units	19	Mini/max	7.0	8.8	6.5–9.0	--	0	--
Chloride, dissolved, mg/L	6	Max	.1	.7	250	--	0	--
Sulfate, dissolved, mg/L	6	Max	7.9	35	250	--	0	--
Un-ionized ammonia, mg/L	5	Max	.000003	.0002	.02	0.03–0.07	0	0
Nitrate, dissolved, mg/L	6	Max	.044	.11	10	--	0	--
Arsenic, total recoverable, µg/L	3	Max	<1	<1	--	50	--	0
Cadmium, total recoverable, µg/L	3	Max	<1	2	0.4	--	1	--
Chromium III, dissolved, µg/L	--	Max	--	--	--	--	--	--
Chromium III, total recoverable, µg/L	3	Max	<1	4	--	50	--	0
Copper, total recoverable, µg/L	7	Max	1	14	50	--	0	--
Iron, dissolved, µg/L	6	Max	4	110	300	--	0	--
Iron, total recoverable, µg/L	7	Max	10	2,600	1,000	--	2	--
Lead, total recoverable, µg/L	7	Max	2	71	4	--	5	--
Manganese, dissolved, µg/L	6	Max	7	47	50	--	0	--
Manganese, total recoverable, µg/L	7	Max	<10	370	1,000	--	0	--
Mercury, total recoverable, µg/L	3	Max	<.1	<.1	.05	--	?	--
Nickel, total recoverable, µg/L	3	Max	1	4	50	--	0	--
Selenium, total recoverable, µg/L	3	Max	<1	<1	10	--	0	--
Silver, total recoverable, µg/L	3	Max	<1	<1	.1	--	?	--
Zinc, total recoverable, µg/L	7	Max	130	430	450	--	0	--
Site CC10								
Dissolved oxygen, mg/L	2	Min	8.2	9.1	6.0	--	0	--
pH, standard units	2	Min/max	7.9	8.0	6.5–9.0	--	0	--
Chloride, dissolved, mg/L	2	Max	.9	1.5	250	--	0	--
Sulfate, dissolved, mg/L	2	Max	9	12	250	--	0	--
Un-ionized ammonia, mg/L	2	Max	.0002	.0003	.02	.09–.10	0	0
Nitrate, dissolved, mg/L	2	Max	.06	.09	10	--	0	--
Arsenic, total recoverable, µg/L	2	Max	<1	<1.	--	50	--	0
Cadmium, dissolved, µg/L	2	Max	<1	<1.	.5–.6	1.2–1.7	?	0
Chromium III, dissolved, µg/L	2	Max	--	--	--	--	--	--
Chromium III, total recoverable, µg/L	2	Max	<1	1	--	50	--	0
Copper, dissolved, µg/L	2	Max	1	4	5–6	7–9	0	0
Iron, dissolved, µg/L	2	Max	9	66	300	--	0	--
Iron, total recoverable, µg/L	2	Max	40	740	1,000	--	0	--
Lead, dissolved, µg/L	2	Max	<1	1	5	18–28	0	0
Manganese, dissolved, µg/L	2	Max	2	23	50	--	0	--
Manganese, total recoverable, µg/L	2	Max	10	90	1,000	--	0	--
Mercury, total recoverable, µg/L	2	Max	<.1	<.1	.01	--	?	--
Nickel, dissolved, µg/L	2	Max	<1	2	44–54	426–521	0	0
Selenium, total recoverable, µg/L	2	Max	<1	<1	10	--	0	0
Silver, dissolved, µg/L	2	Max	<1	<1	.01–.02	.4–.6	?	?
Zinc, dissolved, µg/L	2	Max	42	130	45–56	49–62	1	1

Table 30. Water-quality standards for selected stream-sampling sites along the Guanella Pass road for constituents and properties sampled—Continued

[mg/L, milligrams per liter; --, no data or no standard; <, less than; µg/L, micrograms per liter; ?, reporting limit above standard or part of range in standard; max, maximum; min, minimum; standards from Colorado Department of Public Health and Environment, Water Quality Control Commission (1996)]

Property or constituent	Total number of samples	Max or Min standard	Range of concentration		Range of standard		Number of exceedances	
			Min	Max	Chronic	Acute	Chronic	Acute
Site GC5								
Dissolved oxygen, mg/L	42	Min	7.2	10.4	6.0	--	0	--
pH, standard units	47	Mini/max	7.1	8.3	6.5–9.0	--	0	--
Chloride, dissolved, mg/L	--	Max	--	--	--	--	--	--
Sulfate, dissolved, mg/L	--	Max	--	--	--	--	--	--
Un-ionized ammonia, mg/L	18	Max	.000009	.0004	.02	.06–.12	0	0
Nitrate, dissolved, mg/L	--	Max	--	--	--	--	--	--
Arsenic, total recoverable, µg/L	2	Max	<1	<1	100	--	0	--
Cadmium, dissolved, µg/L	2	Max	<1	<1	.3–.3	.6–.6	?	?
Chromium III, dissolved, µg/L	2	Max	<1	2	51–55	426–465	0	0
Chromium III, total recoverable, µg/L	--	Max	--	--	--	--	--	--
Copper, dissolved, µg/L	40	Max	<1	3	2–3	3–4	1	1
Iron, dissolved, µg/L	40	Max	43	270	300	--	0	--
Iron, total recoverable, µg/L	45	Max	140	4,000	1,000	--	7	--
Lead, dissolved, µg/L	8	Max	<1	<1	.3–.4	6–7	?	0
Manganese, dissolved, µg/L	--	Max	--	--	--	--	--	--
Manganese, total recoverable, µg/L	45	Max	<10	100	1,000	--	0	--
Mercury, total recoverable, µg/L	2	Max	<.1	<.1	.01	--	?	--
Nickel, dissolved, µg/L	2	Max	<1	<1	26–28	251–272	0	0
Selenium, total recoverable, µg/L	2	Max	<1	<1	17	135	0	--
Silver, dissolved, µg/L	2	Max	<1	1	.004–.005	.11–.13	1	1
Zinc, dissolved, µg/L	40	Max	2	10	19–29	21–32	0	0
Site GC11								
Dissolved oxygen, mg/L	40	Min	7.2	10.9	6.0	--	0	--
pH, standard units	47	Min/max	7.0	7.9	6.5–9.0	--	0	--
Chloride, dissolved, mg/L	--	Max	--	--	--	--	--	--
Sulfate, dissolved, mg/L	--	Max	--	--	--	--	--	--
Un-ionized ammonia, mg/L	18	Max	.000005	.00008	.02	.04–.11	0	0
Nitrate, dissolved, mg/L	--	Max	--	--	--	--	--	--
Arsenic, total recoverable, µg/L	2	Max	<1	<1	100	--	0	--
Cadmium, dissolved, µg/L	3	Max	<1	<1	.3–.4	.5–.8	?	?
Chromium III, dissolved, µg/L	2	Max	<1	<1	44–64	367–540	0	0
Chromium III, total recoverable, µg/L	--	Max	--	--	--	--	--	--
Copper, dissolved, µg/L	39	Max	1	4	2–5	2–6	1	1
Iron, dissolved, µg/L	39	Max	<3	430	300	--	1	--
Iron, total recoverable, µg/L	43	Max	230	23,000	1,000	--	19	--
Lead, dissolved, µg/L	7	Max	<1	1	.3–.8	4–16	1	0
Manganese, dissolved, µg/L	--	Max	--	--	--	--	--	--
Manganese, total recoverable, µg/L	43	Max	60	900	1,000	--	0	--
Mercury, total recoverable, µg/L	2	Max	<.1	<.1	.01	--	?	--
Nickel, dissolved, µg/L	2	Max	1	3	23–32	219–313	0	0
Selenium, total recoverable, µg/L	2	Max	<1	<1	17	135	0	0
Silver, dissolved, µg/L	2	Max	<1	<1	.003–.006	.08–.17	?	?
Zinc, dissolved, µg/L	39	Max	<3	85	16–41	17–46	21	17

At site CC9, Leavenworth Creek at the mouth, the total recoverable cadmium, lead, and iron (chronic) fixed standards were exceeded (table 30). Only total recoverable analyses are specified at site CC9. The few cadmium and lead exceedances may be related to ore deposits and acid-sulfate weathering processes. At site CC10, South Clear Creek at Georgetown, dissolved zinc exceeded the chronic and acute standards. Sources of zinc that contribute to exceedance of the standard at CC10 are Leavenworth Creek and possibly the mines on the hillsides downstream from the South Clear Creek/Leavenworth Creek confluence.

At site GC5, Duck Creek near Grant, dissolved copper and silver concentrations each exceeded acute and chronic standards in one of two samples. The chronic standard for total recoverable iron also was exceeded in 7 of 45 samples (table 30).

At site GC11, on Geneva Creek, dissolved copper exceeded the acute and chronic standards in a single sample. Dissolved iron and lead each exceeded the chronic standard in a single sample. Total recoverable iron concentrations at GC11 exceeded the 1,000-mg/L chronic standard in 19 of 43 samples. Dissolved zinc concentrations exceeded the standards in numerous samples at GC11: chronic 54 percent, and acute 44 percent of all samples (table 30).

The zinc exceedances at GC11 are associated with low-flow periods when the contributions from ground water are a larger percentage of flow and the dilution and neutralizing effect of nonacidic tributaries is small. Acid-sulfate weathering (Bassett and others, 1992) at the headwaters of Geneva Creek is the major source of the trace elements (copper, iron, lead, and zinc).

Total recoverable iron in streams can exceed chronic standards during snowmelt or stormflow due to the increase in iron associated with suspended-sediment during these periods (Gaggiani and others, 1987). Therefore, large suspended-sediment concentrations may cause exceedance of standards because of total recoverable iron content. The relation of total recoverable iron concentration and associated suspended-sediment concentration for samples collected during the high-flow sampling (1995) in Stevens (1999) indicates that the total recoverable iron standard of 1,000 μg/L would commonly be exceeded in the range of suspended-sediment concentrations measured. This relation of mainly particulate iron with suspended sediment and the presence of large concentrations of suspended sediment in road-runoff samples indicates that road runoff to streams could contribute to seasonally large concentrations of total recoverable iron. A similar effect could exist for manganese. Provisions for seasonal exceedance incorporated into the water-quality standards might disqualify naturally occurring suspended-sediment-related exceedances. Also, the use of the 85th percentile of the water-year data for comparison to the chronic standard will reduce the influence of large, seasonal concentrations.

Acid-sulfate weathering in upper Geneva Creek also produces large concentrations of total recoverable iron (Stevens and others, 1997) that may contribute to water-quality-standard exceedance in affected streams. For about the same suspended-sediment concentration, total recoverable iron concentrations from upper Geneva Creek sites (GC6, GC7, and GC9) were much larger than from all other sites sampled during high-flow (Stevens, 1999). Precipitating ferric iron along Geneva Creek is probably the cause of the iron-rich sediment.

Most of the stream trace-element standards are not likely to be exceeded as a result of road-runoff discharged into streams because the standards specify primarily dissolved phases, and the predominant phase associated with road runoff in the study area seems to be particulate (Stevens, 1999). Some of the trace elements associated with particles are probably adsorbed to sediment. But without lowering the pH, these trace elements are not likely to be desorbed or weathered from particles (Davis and others, 1991). Stream reaches that are paralleled by the Guanella Pass road are generally of neutral pH, although Geneva Creek is slightly acidic between Duck and Scott Gomer Creeks. If desorption is contributing trace elements to neutral-pH streams, the effect is small because concentrations in these streams are small. If the desorbed trace elements substantially alter water quality in neutral-pH streams, then larger dissolved trace-element concentrations than those measured would be evident, particularly in streams that receive road runoff.

Other Guidelines

Suspended-sediment concentration and turbidity were not regulated by the State of Colorado during 1995–97. However, FHWA does have a Special Contract Requirement (SCR) that normally contains the following statement whenever a project might affect an adjacent stream (Robert Nestel, Federal Highway Administration, written commun., 1998):

> The construction project engineer will be responsible for monitoring turbidity during the construction of this project to assure compliance with state water quality standards. The turbidity will be measured using an HF-DRT 15 turbidimeter or equivalent. Measurements will be taken upstream from the project area (as a control) and 150 m (500 feet) downstream in the area of highest turbidity whenever noticeable turbidity is being generated from the project. If these measurements show an increase of 10 Nephelometric Turbidity Units (NTU) or more, the Engineer shall suspend construction operations in the vicinity of the problem area and modify the erosion control plan to eliminate the cause of high turbidity.

Fluctuations in turbidity of Guanella Pass streams can exceed 10 NTU in a day (see fig. 22). Careful monitoring would be necessary to quantify the difference between naturally occurring and road-construction-related increases in turbidity during snowmelt and rainfall.

For nutrients in streams, USEPA recommends that eutrophication risk be controlled by limiting total phosphates to less than 0.05 mg/L (as phosphorus) in a stream at the point where it enters a lake or reservoir. Moreover, total phosphorus (as phosphorus) should be limited to concentrations less than 0.1 mg/L in streams that do not discharge directly into lakes or reservoirs (U.S. Environmental Protection Agency, 1986). Although total phosphates were not determined, the dissolved orthophosphorus concentrations in the Guanella Pass area streams did not exceed 0.05 mg/L. During storm runoff, total phosphorus concentrations sampled in Guanella Pass streams occasionally exceeded the 0.1-mg/L guideline.

Ground Water

The Colorado ground-water standards (drinking-water related) were used to evaluate ground-water quality at sites where water is used for human consumption (Colorado Department of Public Health and Environment, Water Quality Control Commission, 1997; U.S. Environmental Protection Agency, 1996). Ground water is used for drinking at one spring (GW6) and at Forest Service campgrounds and picnic grounds (GW2, GW3, GW4, GW7, GW8, and GW15). Drinking-water-quality standards for selected constituents are presented in table 31. Primary maximum contaminant levels (MCL's) regulate the maximum permissible concentration of a contaminant in water at the tap, are health related, and are legally enforceable only when they pertain to a public water supply. Constituent concentrations were larger than the MCL only in a single well (GW3) for a single constituent (uranium) (data from Stevens and others, 1997; Stevens, 2000). Well GW3 (west loop of the Guanella Pass campground) contained 67 μg/L of uranium in August 1995 and 44 μg/L in September 1997 (Stevens and others, 1997), exceeding the USEPA-proposed primary MCL of 20 μg/L. The bedrock in the study area is similar to common metamorphic and igneous rocks of the Colorado Front Range where uranium occurs (Hofstra and Hall, 1975; Hills and others, 1982).

Table 31. Drinking-water-quality standards for selected constituents and properties

[Standards from U.S. Environmental Protection Agency (1996) and Colorado Department of Public Health and Environment, Water Quality Control Commission (1997); NTU, nephelometric turbidity units]

Water-quality constituent or property	Standards
Major inorganic constituents (milligrams per liter)	
Sulfate	[1]250
Chloride	[1]250
Fluoride	[2]4
Dissolved solids	[1]500
Nitrite plus nitrate	[2]10
Trace elements (micrograms per liter)	
Arsenic	[2]50
Barium	[2]2,000
Cadmium	[2]5
Chromium (total)	[2]100
Copper	[1]1000
Iron	[1]300
Lead	[2]15
Manganese	[1]50
Mercury	[2]2
Selenium	[2]50
Zinc	[1]5,000
Uranium	[2,4]20
Other	
Turbidity (NTU)	[2,3].5–1.0

[1] Secondary maximum contaminant level. These standards apply to constituents in drinking water that primarily affect the esthetic qualities relating to the public acceptance of drinking water and are not federally enforceable but are intended as guidelines for States.

[2] Primary maximum contaminant level. These regulations are the maximum permissible level of a contaminant in water at the tap and are health related. Standards only apply to public drinking-water supply systems.

[3] Performance standard.

[4] Proposed.

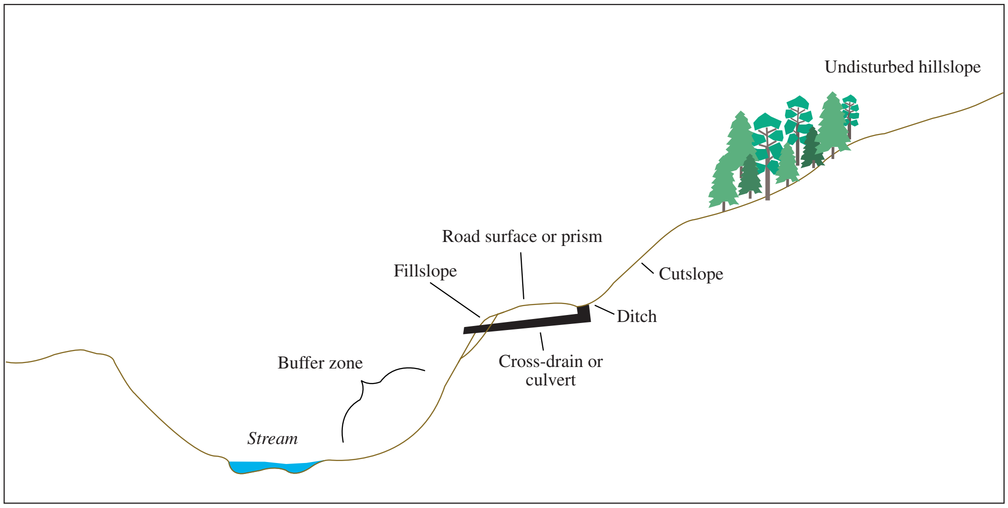


Figure 27. Schematic of a forest road.

Dissolved iron, manganese, and zinc concentrations approach or exceeded the secondary MCL's in some of the water samples from wells (data from Stevens and others, 1997; and Stevens, 2000). These constituents may affect the appearance and taste of water used for drinking. The turbidity in some samples from wells was greater than the standard, possibly because of precipitating iron during sample processing.

Water samples are routinely collected from Forest Service area campground wells by State, county, and private contractors for the analysis of nitrate, fecal coliform, and selected major ions and trace elements to assess drinking-water quality (Clear Creek Ranger District and South Platte Ranger District, written commun., 1995). Neither fecal coliform nor nitrate was reported at concentrations greater than the standards.

CHARACTERIZATION OF GUANELLA PASS ROAD RUNOFF

This section of the report presents a summary of selected references on the subject of forest road hydrology, hydrology and water quality of Guanella Pass road runoff, sources and transport of road runoff, and the potential effects of road runoff on receiving water.

Several components (cutslope, fillslope, road surface, and ditch) (fig. 27) of the Guanella Pass road contribute sediment and other water-quality constituents to streams from erosion. Hydraulic linkage is defined here as the surface-runoff connections between road-drainage features (roadside ditches and culverts) and streams or lakes. Less-direct transport to streams for dissolved constituents such as road salt can be caused by the infiltration of road runoff to ground water that then discharges to streams.

Background Information on Forest Road Hydrology

Although substantial work has been done on the effects of highway runoff on water quality (Dupuis and others, 1985; Young and others, 1996), forest roads are smaller in scale, have smaller traffic volume, and often are located in areas of more pristine water quality, which might not compare to highway-runoff studies in more urbanized areas. Hydrology and sediment transport related to forest roads, however, have been extensively studied. The effects studied are generally in the categories of water discharge, chemistry, sediment erosion, and biota. Forest road studies also generally emphasize erosion processes, sediment transport and delivery (both instream and through the buffer zone), and the effects of management practices.

Some studies found that road effects are related to changes in the timing and intensity of runoff in response to precipitation (King and Tennyson, 1984; Jones and Grant, 1996). Other studies reported no changes (Wright and others, 1990) or changes only when large areas were disturbed by roads (more than 12 percent of the basin area) (Harr and others, 1975). Changes in runoff are important because of the influence of runoff on sediment transport, channel stability, and substrate particle size (MacDonald and others, 1991). Roads affect watershed runoff by decreasing infiltration capacity, increasing runoff to the stream, intercepting subsurface drainage, and increasing rates of snowmelt. Wemple and others (1996) suggest that roads that are hydraulically linked to streams are extensions of the stream-channel network and efficiently collect and deliver water from precipitation to the stream, resulting in increased volume and a rapid response of runoff to precipitation. Road runoff reaches receiving water through the linkages (rills, gullies, or ephemeral channels) that cross the buffer zone between the road and stream or lake. While paved-surface roads are less permeable than gravel roads, the unit hydrographs for runoff from the two road surfaces, paved and in-use gravel, are practically the same in timing and peak flow, indicating that the effect of the surface type on water discharge may be small (Reid and Dunne, 1984).

The studies on the effects of forest management activities have focused primarily on the effects of silvicultural activities (such as timber harvest), not on road runoff exclusively. Dissolved oxygen, water temperature, and concentrations of nitrogen, phosphorus, and pesticides are recommended monitoring objectives to assess the effects of forest management activities (MacDonald and others, 1991). However, certain management activities such as mining or salt applications to roadways create the need for monitoring trace elements and major ions in surface water. Brown and Binkley (1994) analyzed available research for forested watersheds and concluded that water temperature generally increased, but dissolved oxygen, dissolved solids, nutrient, and pesticide/herbicide concentrations in surface water were generally not altered substantially by forest management activities.

The effect of sediment transport from forest roads is well documented. Many studies have concluded that increases in suspended-sediment concentration (Sullivan, 1985; Harr and Fredricksen, 1988; Davies and Nelson, 1993), turbidity (Anderson and Potts, 1987), and decreases in bed-material particle size (Eaglin and Hubert, 1993; Schnackenberg and MacDonald, 1998) are related to silvicultural activity. Several investigations have attempted to isolate the effects of roads and road construction alone (Brown and Krygier, 1971; Megahan and Kidd, 1972; Beschta, 1978; Woolridge and Larson, 1980; Anderson and Potts, 1987; Grayson and others, 1993; Cline and others, 1982). The effects in some cases are short in duration, and recovery occurs with time or at the conclusion of the construction activity (Beschta, 1978; Cline and others, 1982).

Research has provided information on erosional processes related to roads. Burroughs and King (1989) summarized erosion studies and management practices related to forest roads. They concluded that the road fillslope accounted for most (80 percent) of the sediment production immediately after road construction in an Idaho forest area, but that the road cutslope and roadside ditch became the primary source of sediment (83 percent) 4 years later. Fillslope sediment production is generally large immediately after construction and decreases exponentially over time (Burroughs and King, 1989). Sediment production sources and rates measured or estimated on forest roads by Reid and others (1981) indicate that cutslopes are a small source of sediment compared to the road surface for gravel roads, ranging from 0.4 percent (heavy-use roads) to 50 percent (light-use roads) in a basin in Washington. In a sensitivity analysis of the components of insloping forest roads, the Water Erosion Prediction Project (WEPP) model estimated that the road surface and roadside ditches are more important contributors to sediment yield than the cutslope (Tysdal and others, 1997). Road length between culverts, gradient, and soil type were important factors in erosion of the road surface, whereas the ditch length and channel roughness were important factors for the roadside ditch (Tysdal and others, 1997).

Choice of road surface type can have a strong influence on sediment production. Heavy-use gravel roads in a Washington forest were estimated to produce 250 times more sediment than paved roads on average (Reid and Dunne, 1984). Paving resulted in a 97-percent reduction of road-surface sediment production in an Idaho experiment (Burroughs and King, 1989). When crushed rock was applied to dirt roads in 3- to 6-inch lifts, road-surface sediment production was reduced by 70 to 92 percent compared to unprotected roads (Burroughs and King, 1989).

Burroughs and King (1989) reported on the results of many experiments in best management practices. Mulches, seeding, and filter windrows have been shown to reduce fillslope and cutslope sediment production substantially. Reductions in fillslope-sediment production ranged from 7 to more than 90 percent, depending on treatment and site conditions. Reductions in cutslope-sediment production ranged from 32 to 86 percent, depending on treatment and site conditions. The application of gravel riprap to the shoulder ditch reduced sediment production in simulated rainfall experiments by 24 percent. Overall, the recommended design of cutslope, ditch, and road surface was estimated to reduce sediment production by about 90 percent (Burroughs and King, 1989).

Other management practices such as the grading of roads and ditches are known to increase sediment yield (Grayson and others, 1993; Tysdal and others, 1997). Increasing traffic volume also increases sediment yields (Wald, 1975; Reid and Dunne, 1984; Foltz, 1996). Research on logging roads in Oregon indicated that reduction of logging truck tire pressure reduced sediment production by more than 80 percent on some roads (Moore and others, 1995). Erosion at culvert outlets in one study was proportional to culvert spacing (Piehl and others, 1988). Sediment production was 4 to 17 times more on a road with marginal-quality aggregate compared to good-quality aggregate (Foltz, 1996). Snowplowing was estimated to erode sediment from the road surface of the Pikes Peak road in Colorado, at the rate of 110 tons/acre (Chavez and others, 1993).

The biological effects of forest management activities that produce forest road runoff are not as well documented as the effects on sediment. Cline and others (1982) analyzed the effects of highway construction in a forest environment and determined that epilithic algae and benthic macroinvertebrates were adversely affected; however, these effects were short-lived and not severe. Eaglin and Hubert (1993) found positive correlation of fine sediment and embeddedness in streambeds with culvert density and a negative correlation of trout standing stocks with culvert density. In contrast, other studies indicate increases in primary productivity following forest disturbance, and this causes changes in algal and macroinvertebrate characteristics (Hansmann and Phinney, 1973; Newbold and others, 1980; Murphy and others, 1981). Lewis (1999) determined that the toxicity of magnesium chloride to boreal toads, rainbow trout, an invertebrate species, and an algal species was not substantial at the dilute concentrations estimated to be present after the road runoff is diluted by snowmelt. Reduction of light and siltation of substrate by sedimentation can reduce algae and macroinvertebrates by reducing primary productivity and preferred habitat (MacDonald and others, 1991).

Hydrology

Observations and monitoring of road runoff on Guanella Pass indicate that road runoff generally occurred during snowmelt and as a result of rainstorms. Ground-water seepage to the roadside ditches was rare, but small flows in spring and summer (May to August) were observed in a couple of small segments. Temperatures and solar radiation were low enough in September to allow snow accumulation on the road cutslopes and fillslopes, although melting occurred on warm days following the early fall snowstorms. Snowplowing generally kept the Guanella Pass road surface from becoming snowpacked until later in the fall. Plowed snow was stored in windrows mostly on the fillslope side, but some also was pushed to the cutslope side. Snowpack accumulation in the drainage area of the road (road surface, cutslopes and fillslopes, and roadside ditch) ranged from zero to several feet from September to May, depending upon altitude. At low-elevation road segments with southern exposure, melting commonly occurred on warm days all winter with little net accumulation. Elsewhere, melting of accumulated snow started at the lower elevations in March or April and progressed to higher altitudes in the following weeks.

At high altitude (greater than 10,000 ft), snow accumulated on the road drainage area until late April or early May when vigorous melting began to occur on warm days. Road runoff was usually finished on lower segments of the road when it was just starting on higher segments of the road. Almost all road-related runoff due to melting snow was complete by the end of May or early June (Stevens, 2000). Culvert flows generally peaked in May at altitudes above 10,000 ft, indicating that the bulk of road runoff occurs before the general watershed peak-flow period, which occurs between late May and mid-June (Stevens, 2000).

Depending upon conditions and location, ice accumulated in some culverts and did not thaw before spring snowmelt began on the road. Plowing often left the roadside ditch full of snow and ice at the beginning of the road snowmelt period, so early runoff occupied the road surface near the edge of the ditch, which caused erosion of the roadbed. As melting of the plowed snowbank progressed, the runoff flow migrated toward the ditch. If the culvert was clogged with ice or snow or runoff was diverted away from the entrance by debris, flow continued down the road to the next open culvert, diversion ditch, or swale in the road, where it flowed across the road and continued downslope. Rills and deep trenches, caused by overflow of roadside ditches, formed across the road at times during WY's 1995–97. After leaving the road, the runoff joined culvert or roadside-ditch flows and was diverted to the hillslope, where it flowed beneath the snowpack in the buffer zone.

Rainstorms usually occurred during June through September on Guanella Pass, and they were most common in July and August. The storms were generally of short duration, occurring in late afternoon or evening. Frontal storms occasionally produced several days of intermittent rain. During this study, observations during some rainstorms indicated that runoff began first on the road surface (gravel or paved). In some areas, infiltration seemed to be occurring in the ditch because flows sometimes disappeared as they flowed down the ditch. Only small amounts of surface flow were observed on the cutslopes, although small slumps of slope material into the ditch occurred during heavy rain. Rills on some steep cutslopes indicated that overland flow does occur at times. However, the rills may be eroded not only during intense rain, but also possibly beneath snowpack as early melting occurs.

Instantaneous water discharge measured at miscellaneous culvert and roadside ditch sites generally was small compared to stream discharge and ranged from 0.004 to 0.153 ft^3/s (Stevens and others, 1997; Stevens, 2000). A complete seasonal record of flow (WY's 1996–97) was collected at only one culvert-monitoring site, CRD7 (fig. 28). The flow on 86 percent of the days that had flow was due to snowmelt and 96 percent of the annual flow (0.408 acre-ft) was due to snowmelt. Maximum daily mean flow during WY 1996 was only 0.019 ft^3/s (Stevens, 2000). Site CRD7, draining an area of 0.687 acres, had flow for 43 days of a 144-day season in WY 1996 (Stevens, 2000). In WY 1997, CRD7 had flow for 48 days of a 138-day season (fig. 28). Flow on 58 percent of the days that had flow was due to snowmelt runoff, and 77 percent of the annual flow (0.665 acre-ft) was due to snowmelt. Maximum daily mean flow during WY 1997 was 0.029 ft^3/s (Stevens, 2000). During water years 1996–97, the peak snowmelt period at CRD7 preceded the general basin peak flows at CC2 and CC5, indicating that road runoff could enter streams when flow is low and dilution potential is smaller than that at peak streamflow (fig. 28).

Water-Quality Characteristics

Water quality of road runoff was characterized using summary statistics of a subset (20 samples) of all samples (47 total) collected. Because of the event-related nature of the sample collection and the intense sampling at certain sites (over one-half the samples were collected at GRD6 and CRD7), a subset of samples was chosen such that each site was represented by a maximum of one snowmelt sample and one rainfall sample to avoid bias in the statistics. For sites with more than a single sample, the sample chosen was based on these criteria: samples with a complete constituent list were preferred over a more limited constituent list; dip samples at the culvert end were preferred over pumped samples; and, all other factors being equal, the sample with the median suspended-sediment concentration was selected. The subset of water-quality data used is listed in Appendix table 51. Statistical summaries of the snowmelt and rainfall road-runoff data are listed in Appendix tables 52 and 53. The data set includes 8 snowmelt samples from 8 different sites and 12 rainfall samples from 12 different sites along the Guanella Pass road.

Onsite Measurements and Major Ions

For the snowmelt-runoff data set from the Guanella Pass road, specific conductance ranged from 14 to 301 μS/cm with a median of 38 μS/cm (Appendix table 52). For rainfall runoff, specific-conductance ranged from 19 to 468 μS/cm with a median of 78 μS/cm (Appendix table 53). The pH ranged from 6.1 to 8.5, and only three samples of road runoff had pH values below 7.0. The two lowest values were from rainfall runoff (Appendix table 51), but medians for snowmelt and rainfall were the same (7.2, tables 52, 53). Turbidity values were generally greater than 1,000 NTU for all samples. Samples collected during rainstorms generally had larger turbidity values than snowmelt samples.

As in stream water, ground water, and lake/reservoir water, the median major-ion concentrations in road runoff were dominated by calcium and bicarbonate. The maximum concentrations of anions were dominated by chloride (Appendix tables 52 and 53). Some samples exhibit major-ion compositions that indicate effects from deicing salt (NaCl) and dust inhibitor ($MgCl_2$) applied to sections of the road. The

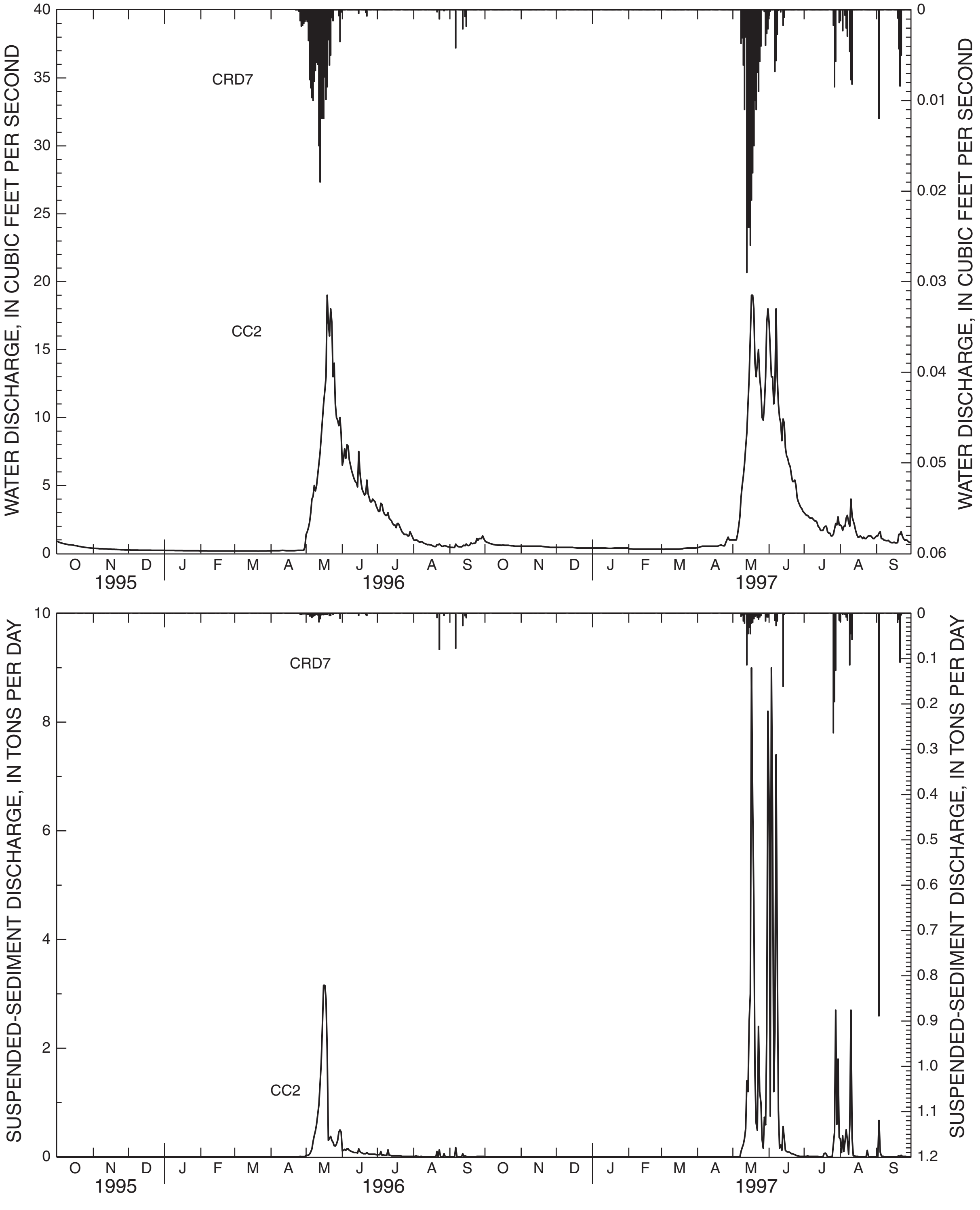


Figure 28. Variation in daily mean water discharge at CRD7 (road-runoff site) and CC2 (the potential receiving stream), water years 1996–97.

road-runoff sample for site CRD1 (rain-related) and CRD7 (rain-related) were dominated by concentrations of magnesium and chloride. The road-runoff sample for site CRD5 (rain-related) was dominated by concentrations of magnesium/calcium and chloride. The road-runoff sample for site CRD6 (snow-related) and CRD9 (rain-related) were dominated by concentrations of sodium and chloride (Appendix table 51). These five samples also had the largest dissolved-solids concentrations of all of the selected road-runoff samples (Appendix table 51). The samples with predominant magnesium are from sites along the unpaved section of road that had been treated with magnesium chloride. The samples with predominant sodium are from sites along the paved section of road north of Lower Cabin Creek Reservoir that receives sodium chloride in traction materials in winter (Jim Cannedy, Clear Creek County, oral commun., 1997). Not all samples collected in these areas clearly show NaCl and $MgCl_2$ effects. Those that do seem to be related to high dissolved-solids content and probably represent flushes of constituents previously applied to the road.

Nutrients

Nutrients (nitrogen and phosphorus compounds) were commonly detected at larger concentrations in road-runoff samples than in streamflow samples (Stevens and others, 1997; Stevens, 2000). Nitrite plus nitrate concentrations were generally larger than ammonia concentrations. Samples analyzed for dissolved nitrite plus nitrate collected during snowmelt had a median concentration of 0.095 mg/L as N, and concentrations ranged from 0.015 to 0.31 mg/L as N (Appendix table 52). Concentrations of dissolved nitrite plus nitrate collected during rain events were generally larger than in snowmelt-related samples, had a median concentration of 0.29 mg/L as N, and ranged from 0.055 to 1.2 mg/L as N (Appendix table 53). Samples collected for dissolved ammonia during snowmelt had a median concentration of 0.036 mg/L as N, and concentrations ranged from 0.010 to 0.080 mg/L as N (Appendix table 52). Rainfall-related ammonia concentrations had about the same median, 0.29 mg/L as N, but ranged to larger concentrations (maximum 0.20 mg/L as N). These forms of dissolved inorganic nitrogen are common chemical constituents in precipitation, and measured concentrations in rainfall-related road runoff (table 35) were larger than those measured in stream water (table 35) and similar to the concentrations in precipitation (table 4).

Dissolved ammonia plus organic nitrogen was infrequently detected (33 percent of snowmelt and 29 percent of rain-related samples) with a median concentration of 0.036 mg/L as N in snowmelt-related samples (Appendix tables 52 and 53). The concentrations of total ammonia plus organic nitrogen were larger in rainfall-related samples than snowmelt-related samples, ranging from less than 0.2 to 24 mg/L as N with a median of 3.5 mg/L as N (Appendix tables 52 and 53). The organic nitrogen in road runoff is probably related to organic material in suspended sediments in the road runoff.

Total phosphorus concentrations in road runoff were much larger than dissolved phosphorus or dissolved orthophosphorus concentrations. Rainfall-related concentrations for total phosphorus were generally larger than snowmelt-related runoff concentrations, ranging from 0.055 to 7.2 mg/L as P with a median of 1.4 mg/L as P, compared to 0.024 to 0.4 mg/L as P with a median of 0.060 mg/L as P for snowmelt (Appendix tables 52 and 53). Dissolved phosphorus and dissolved orthophosphorus median concentrations were 0.02 and 0.007 mg/L as P in snowmelt runoff samples, whereas the median concentrations were 0.01 mg/L as P in rainfall runoff samples (Appendix tables 52 and 53). Large total phosphorus concentrations with small dissolved phosphorus concentrations indicate that much of the phosphorus is associated with suspended sediment in road-runoff samples. Dissolved phosphorus can be readily adsorbed to sediment, which may account for the small concentrations of dissolved phosphorus in these samples. Only a portion of the total phosphorus is available to plant life (Sharpley and others, 1991; Parker, 1991) because much of the element is either associated with mineral grains of low solubility or is strongly sorbed to sediment.

A pumping sampler was used to collect some water-quality samples. Because power was not available, these samples were not refrigerated at the time of collection, and nutrient data need to be interpreted with caution because the concentrations could be affected and reactions between sediment and water could have occurred in the bottle.

Trace Elements

The trace elements in largest concentrations in road-runoff samples were aluminum, iron, and manganese (Appendix table 51). Other trace elements with median concentrations greater than the laboratory reporting limit were total recoverable and dissolved barium, total recoverable cadmium (rainfall only), total recoverable chromium, total recoverable cobalt, total recoverable and dissolved copper, total recoverable lead, total recoverable mercury (rainfall only), total and dissolved molybdenum (rainfall only), total recoverable nickel, and total recoverable and dissolved zinc. Total recoverable arsenic, dissolved chromium (rainfall only), dissolved nickel, total recoverable selenium, and dissolved uranium (rainfall only) were detected but did not have median concentrations greater than the laboratory reporting limit (Appendix tables 52 and 53). In general, rainfall-related concentrations were larger than snowmelt concentrations.

Analytical results of water samples from runoff from the Guanella Pass road indicate that total recoverable trace-element concentrations were substantially larger (by several times) than dissolved trace-element concentrations (Appendix table 51), indicating that most trace elements are in the suspended phase. The particulate trace elements are components of the rock and soil composing the roadbed, ditches, and cutslopes. Vehicle emissions and wear products (brake linings, tires, vehicle body, fluids) also contribute to trace elements (such as cadmium, copper, iron, lead, manganese, nickel, and zinc) available on the road for erosion (Young and others, 1996).

Organic Carbon and Trace-Organic Constituents

Dissolved organic-carbon concentrations in road runoff ranged from 2.3 to 3.8 mg/L (tables 35, 52, and 53). Total organic carbon in snowmelt runoff samples had a median concentration of 9.4 mg/L and a range in concentrations of 4.7 to 16 mg/L. Rainstorm runoff concentrations ranged from 5.6 to 150 mg/L, with a median of 94 mg/L (tables 35, 52, and 53). The large total organic-carbon concentrations in a few samples are probably related to plant detrital material. Two road-runoff samples collected during snowmelt and analyzed for trace-organic substances (organic chemicals normally present in small concentrations in the environment) had no detections of volatile or semivolatile organic substances greater than the laboratory reporting limits (Stevens and others, 1997).

Suspended Sediment and Particle Size

Suspended-sediment concentrations in snowmelt road runoff ranged from 66 to 7,360 mg/L, with a median concentration of 1,510 mg/L (Appendix table 52). Rainstorm-runoff concentrations were generally larger than those in snowmelt runoff and ranged from 34 to 38,800 mg/L, with a median of 7,190 mg/L (Appendix table 53). The sediment was primarily fine grained. More than 90 percent of suspended sediments from snowmelt samples and 88 percent from rainstorm samples were finer than 0.062 mm. This fine-grained character facilitates transport of the sediment and diminishes the likelihood that settling or deposition of the sediments would occur prior to reaching a stream. Fine sediment usually contains a larger proportion than coarse sediment of trace elements, nutrients, and oxygen-consuming substances (Horowitz, 1995), which can degrade water quality. Suspended sediments that subsequently settle out in streams can contribute to the reduction of suitable fish-spawning areas and filling of pool habitat (MacDonald and others, 1991). The fine-grained character of the road-related sediment, however, might indicate that high flows could easily resuspend the sediment deposited during lower flows.

Sources and Transport of Sediment in Road Runoff

Information about source areas and depositional areas of sediment, road-runoff linkages to receiving waters, and seasonal transport characteristics is helpful for understanding sediment transport related to road runoff.

Sources and Deposits of Sediment

Natural sources of sediment to streams in montane or alpine locations are primarily streambed and streambank erosion (Leaf, 1996) because overland flow, which could erode and transport sediment from the nonchannel sources, is rare in the natural setting. Sediment sources include intermittent and ephemeral channels that may contribute only during runoff periods. In some areas, mass wasting processes (such as landslides or soil creep) are important sources (Luce, 1995).

With the introduction of roads into mountainous areas, sediment may be introduced to streams by cutslopes, fillslopes, the road surface, and ditches (fig. 27). Many of the road cuts on the existing Guanella Pass road either have failed to revegetate naturally or support only marginal amounts of vegetation. When the road was originally constructed, many of the road cuts into the hillside were overly steep and are eroding into the hillslope. Soil materials slide or are washed downslope by rainfall and snowmelt. In some areas, road maintenance has removed vegetation and coarse materials at the toe of the cuts, which causes cutslope instability.

Cutslope instability may be related to the character of soils and can increase sediment supply to road runoff. The low-cohesion soils on the south side of Guanella Pass in the Duck Lake area contribute to cutslope instability and inhibit revegetation of the slopes. In dry weather, sandy slope material exposed to the weather was observed to be eroded by wind. The eroded slope material generally accumulates in the roadside ditch. During snowmelt and rainstorms, large boulders eroding out of the slopes were observed on the roadway in several areas (fig. 29). Evidence of large landslides near the road, however, was not observed.

Although moderate erosion occurs along the entire road, the most extreme examples are associated with the steepest cutslopes. Cutslope erosion was observed as rilled, sparsely vegetated areas in the switchback areas just above Georgetown, the switchbacks below Green Lake (fig. 30), the switchbacks along South Clear Creek above Naylor Creek (fig. 31), much of the section of the road from the top of Guanella Pass to the beginning of the paved section below the Geneva Basin Ski area, and the Falls Hill section (fig. 32). These areas are potentially large sources of sediment to road runoff.

Fillslopes on the Guanella Pass road generally do not seem to concentrate runoff enough to transport sediment to streams. Rilling of the fillslopes is limited by vegetation and coarse slope material in much of the area. However, where Geneva Creek closely follows the Guanella Pass road from near Grant to Threemile Creek, high flows are concentrated directly on sidecast material and the fillslope, and those materials are eroded by and transported in Geneva Creek (fig. 33). Sidecast material is replenished after repair and regrading of the road (fig. 34). Concentrated runoff from culvert outflows (fig. 35) and flow concentrated at the outside edge of the road prism by windrows of plowed material from grading also were observed to cause erosion of fillslope material.

During many storms and during the snowmelt period on the road, the road surface was observed to be disturbed by vehicle tires (fig. 36). Flow in ruts and overland flow on the road surface was observed to erode material off the road and transport sediment to the roadside ditches. Damage to the road surface was evident in some areas but generally did not concentrate flow enough to transport the sediment far into the buffer zone below the road.

Figure 29. Boulders eroded from cutslope on Guanella Pass road near disused ski area, May 1996.

Figure 30. Cutslope just north of Green Lake along Guanella Pass road, May 1994.

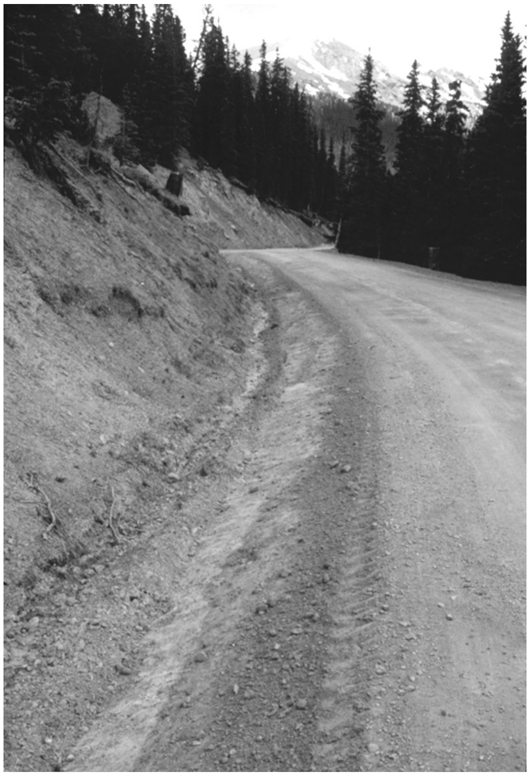


Figure 31. Cutslope along Guanella Pass road in the switchback road segment above Naylor Creek north of Guanella Pass, July 1995.

Figure 32. Cutslope along Guanella Pass road in the Falls Hill segment just north of the Scott Gomer Creek crossing, January 1994.

Figure 33. Erosion of fillslope and side-cast material by Geneva Creek, high streamflow, June 1995.

Figure 34. Appearance of fillslope at low streamflow in Geneva Creek after repair and regrading of road, August 1995.

Figure 35. Culvert outflow concentrating road runoff onto the fillslope in the switchback road segment above South Clear Creek, upstream from Naylor Creek, July 1995.

Figure 36. Rutting and erosion of the road surface just south of Naylor Creek.

Ditches that channel runoff on the shoulder of the road were eroded in some areas, mobilizing sediment that was transported by road runoff (fig. 37). Ditch erosion was often observed during snowmelt on the road when clogged ditches and culverts caused alternative flow paths for road runoff. Repairs to ditches were made by grading, which can loosen and replenish the loose sediment on the ditch bottom that can be eroded during subsequent runoff.

Sediment can be trapped in the buffer zone between the road and a potential receiving stream by physical obstructions, vegetation, or changes in slope. The buffer zone sometimes reduces transport of sediment in road runoff by promoting sedimentation or allowing infiltration of the water fraction. The deposited sediment sometimes buries the buffer-zone flora.

Two small but extreme examples of this type of deposit were observed. One is in the switchback road segment along South Clear Creek upstream from Naylor Creek where flow from a culvert eroded an area approximately 150 ft long, up to 15 ft wide, and 10 ft deep in colluvium on the slope (fig. 38). The eroded material was deposited as an alluvial fan at the base of the slope in a wetland area (fig. 39). Another area receiving large amounts of sediment is located approximately 1 mile south of Guanella Pass. A culvert discharges sediment onto an area of willows and tundra vegetation. The deposit of sand and gravel is approximately 10 to 50 ft wide and extends about 200 ft down the slope. Low tundra vegetation is covered (fig. 40), and even willows do not grow on the thickest part of the deposit. There was no evidence, however, that eroded sediment had reached the stream.

Fine-sediment deposits on streambeds were observed in only a few areas. In general, the stream gradient in the area is steep, which maintains velocities sufficient to keep finer grain sizes in suspension. Beaver ponds, pools created by large woody debris, lakes, and reservoirs trap some of the large grain-size particles. The beaver ponds in the active channel of South Clear Creek downstream from Naylor Creek show some signs of filling by sediment. One large pond is completely full of sediment and was abandoned by the beaver (fig. 41). The sediment is eventually released downstream when the structural components of the dam begin to decay and the stream erodes through the previously deposited material. Along South Clear Creek many ponds in the active channel have been filled and sediments behind the dam are eroding and being transported downstream (fig. 42). The sediments could move downstream, potentially settling in the next pond downstream. The revegetation of the ponded sediments is too slow a process, once the dam is breached, to prevent the accumulated sediments from being eroded. If the channel shifts away from a dam and does not destroy it, or if the dam is off the main channel, vegetation may eventually stabilize the sediments.

Alluvial fans at the stream inlets to lakes or reservoirs were only conspicuous in one area. Where South Clear Creek enters Georgetown Reservoir upstream from Georgetown, a large delta has accumulated material ranging in size from sand to cobble-sized material (fig. 43). The rate of accumulation is not known, but the deposit could eventually disrupt the operation of the reservoir for diversion of water to the powerplant and water-treatment plant in Georgetown. When the reservoir is drained for maintenance, accumulated sediments could be eroded and released to South Clear Creek downstream from the impoundment. The likely source of the sediments is Leavenworth Creek because the other tributary stream, South Clear Creek, is located downstream from Lower Cabin Creek Reservoir and Clear Lake, which probably trap much of the sediment from the upper part of the basin.

A possible source of the accumulated material in Georgetown Reservoir is a large mine dump that shows evidence of erosion where Leavenworth Creek passes underneath the Guanella Pass road. In addition, high, eroding stream cutbanks, which are composed of mine waste materials, contribute sediment to Leavenworth Creek in many areas between the Guanella Pass road and the confluence of Leavenworth Creek with South Clear Creek (fig. 44).

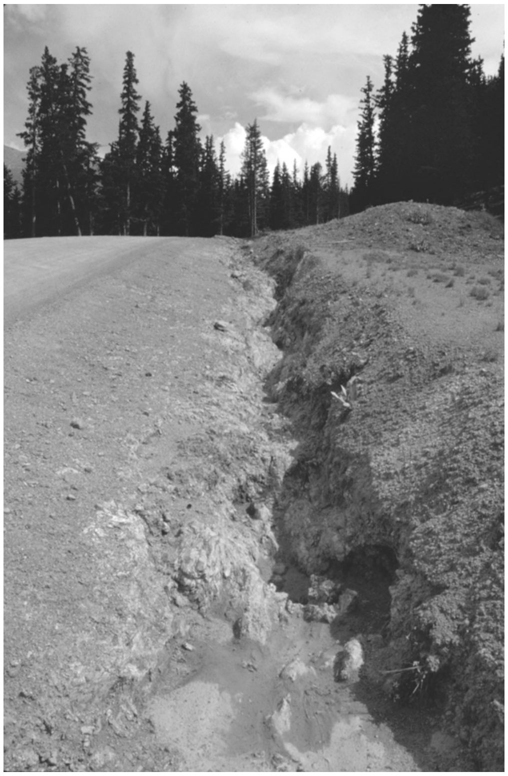


Figure 37. Ditch erosion in the switchback road segment, south of Naylor Creek, August 1998.

Figure 38. Eroded road-runoff channel about 200 feet below the Guanella Pass road, located in the switchback road segment south of Naylor Creek, August 1996.

Road Drainage and Stream Linkage

One of the ways that road runoff can enter streams is by surface flow from culvert and roadside-ditch drainage, which is referred to as a linkage in the following discussion. The concentrated flow in these drainage features can cross the buffer zone between a road and a stream or lake, contributing water-quality constituents and sediment. Evaluations of road-drainage features and their interaction with the buffer zone are described in Bilby and others (1989); Ohlander (1994); Snyder (1996); and Wemple and others (1996).

Figure 39. Alluvial fan of material eroded from a channel cut by road runoff on the slope above South Clear Creek upstream from Naylor Creek, August 1996.

Figure 40. Deposit of road-runoff sediment covering tundra vegetation just north of Duck Lake, near the summit of Guanella Pass, July 1995.

Figure 41. Abandoned beaver pond filled with sediment on South Clear Creek upstream from Lower Cabin Creek Reservoir, June 1996.

Figure 42. Sediments behind beaver dam (shown in figure 41) that is being eroded by South Clear Creek, June 1998.

Figure 43. Alluvial fan at the inlet of South Clear Creek to Georgetown Reservoir, just downstream from the confluence with Leavenworth Creek, September 1995.

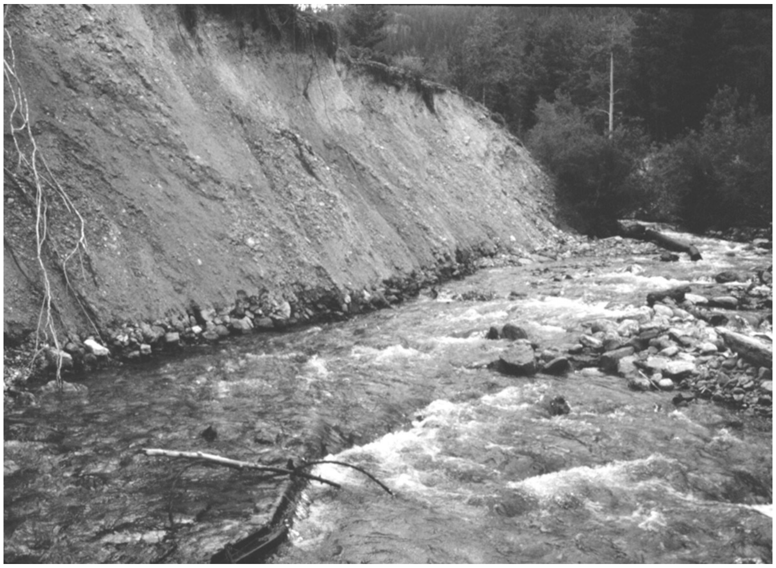
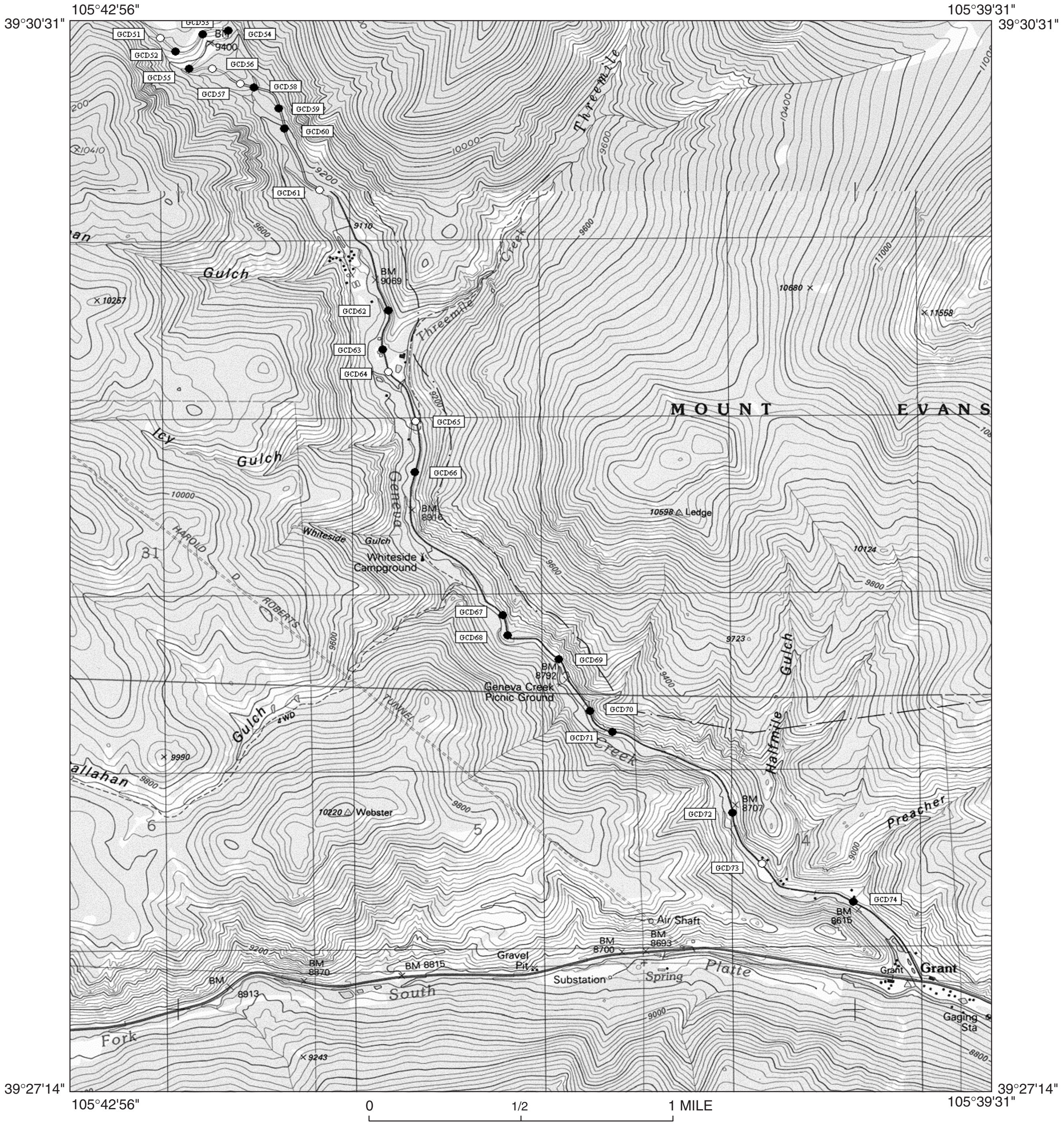


Figure 44. Cutbank in mine waste along Leavenworth Creek between Guanella Pass road and the confluence with South Clear Creek, August 1995.

Whether or not cross-drain culvert and roadside-ditch drainage reached streams was determined for the existing Guanella Pass road (1997) by walking each culvert or roadside-ditch outflow until the deposition point or receiving water was located (Appendix table 54). If evidence that the runoff from the drainage feature such as sediment or a channel leading to the stream or lake edge was found, a linkage was noted in Appendix table 54. Other descriptive information also was noted, such as contributing ditch length, buffer-zone vegetation, buffer-zone sediment grain size, buffer-zone topography, buffer-zone drainage-channel characteristics, obstructions, sediment travel distance, largest grain-size transported to stream, and the receiving stream name. The location of drainage features and their linkage to receiving waters are shown in figure 45.

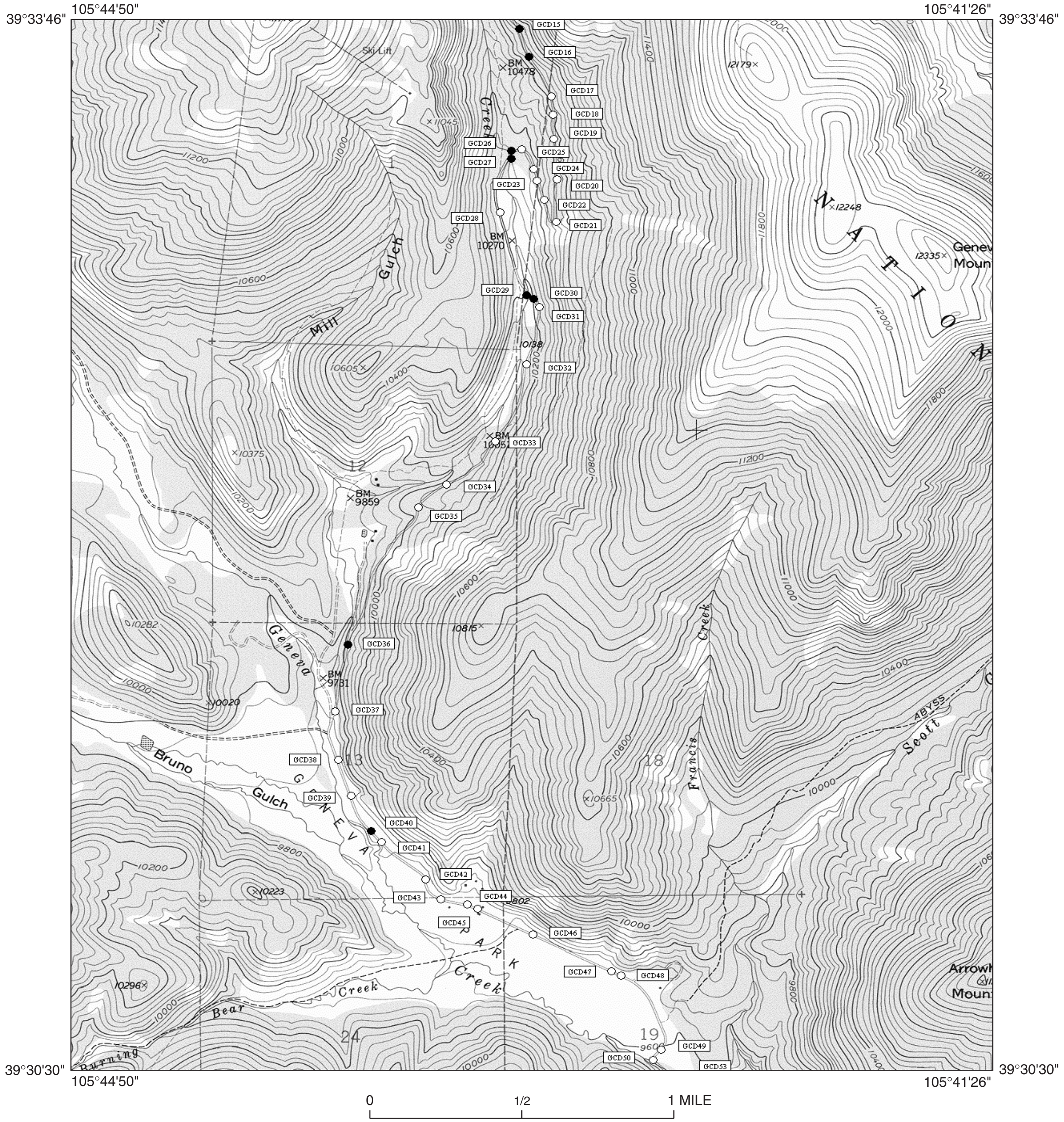


EXPLANATION

GCD74 ● Location and site number (table 54) of drainage feature (culvert of roadside ditch) that flows into a stream or lake

GCD73 ○ Location and site number (table 54) of drainage feature (culvert of roadside ditch) that does not flow into a stream or lake

Figure 45. Location and identification of drainage features (roadside ditches and culverts) that showed evidence of sediment reaching a stream.

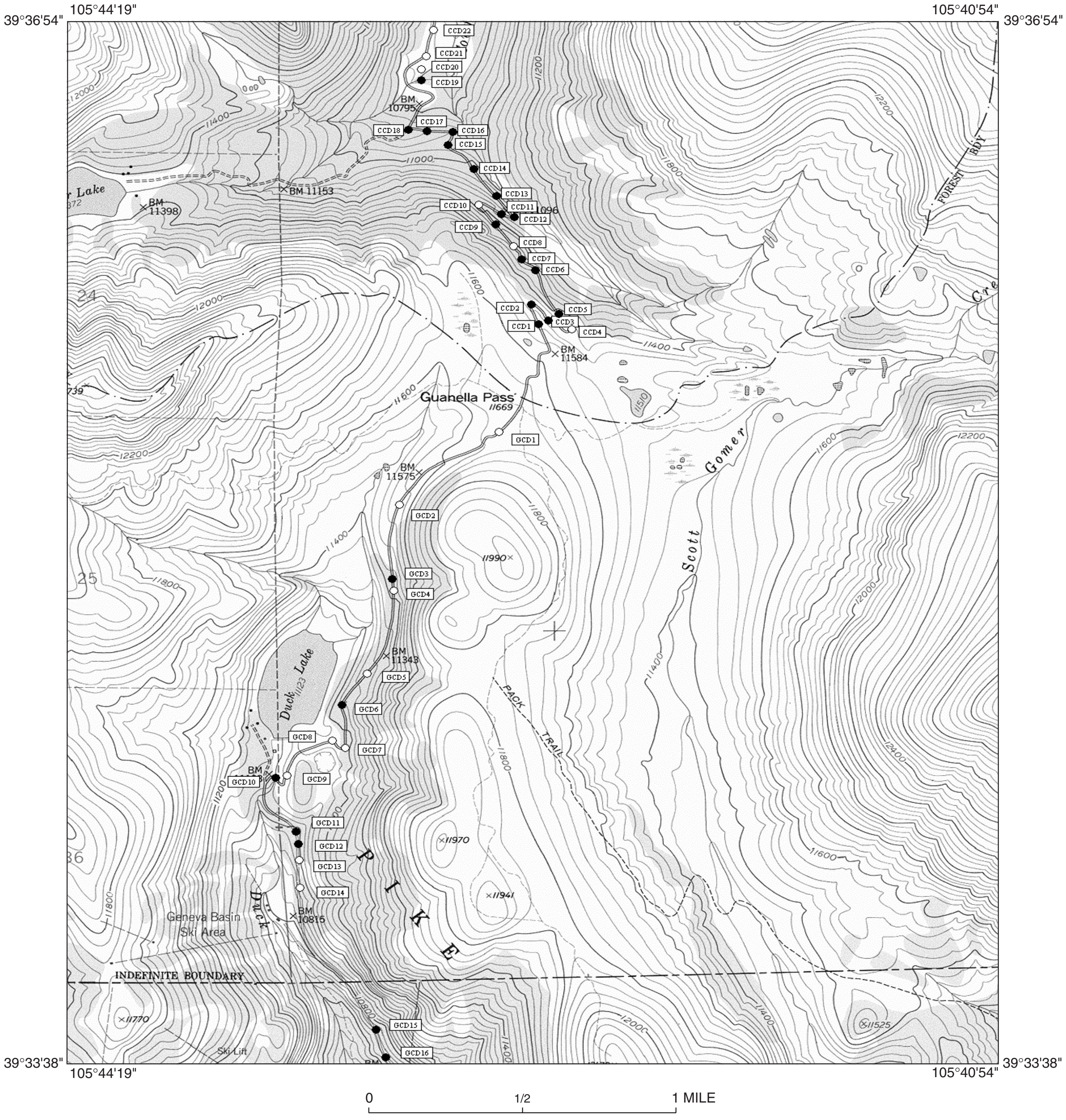


EXPLANATION

GCD40 ● Location and site number (table 54) of drainage feature (culvert of roadside ditch) that flows into a stream or lake

GCD41 ○ Location and site number (table 54) of drainage feature (culvert of roadside ditch) that does not flow into a stream or lake

Figure 45. Location and identification of drainage features (roadside ditches and culverts) that showed evidence of sediment reaching a stream—Continued.

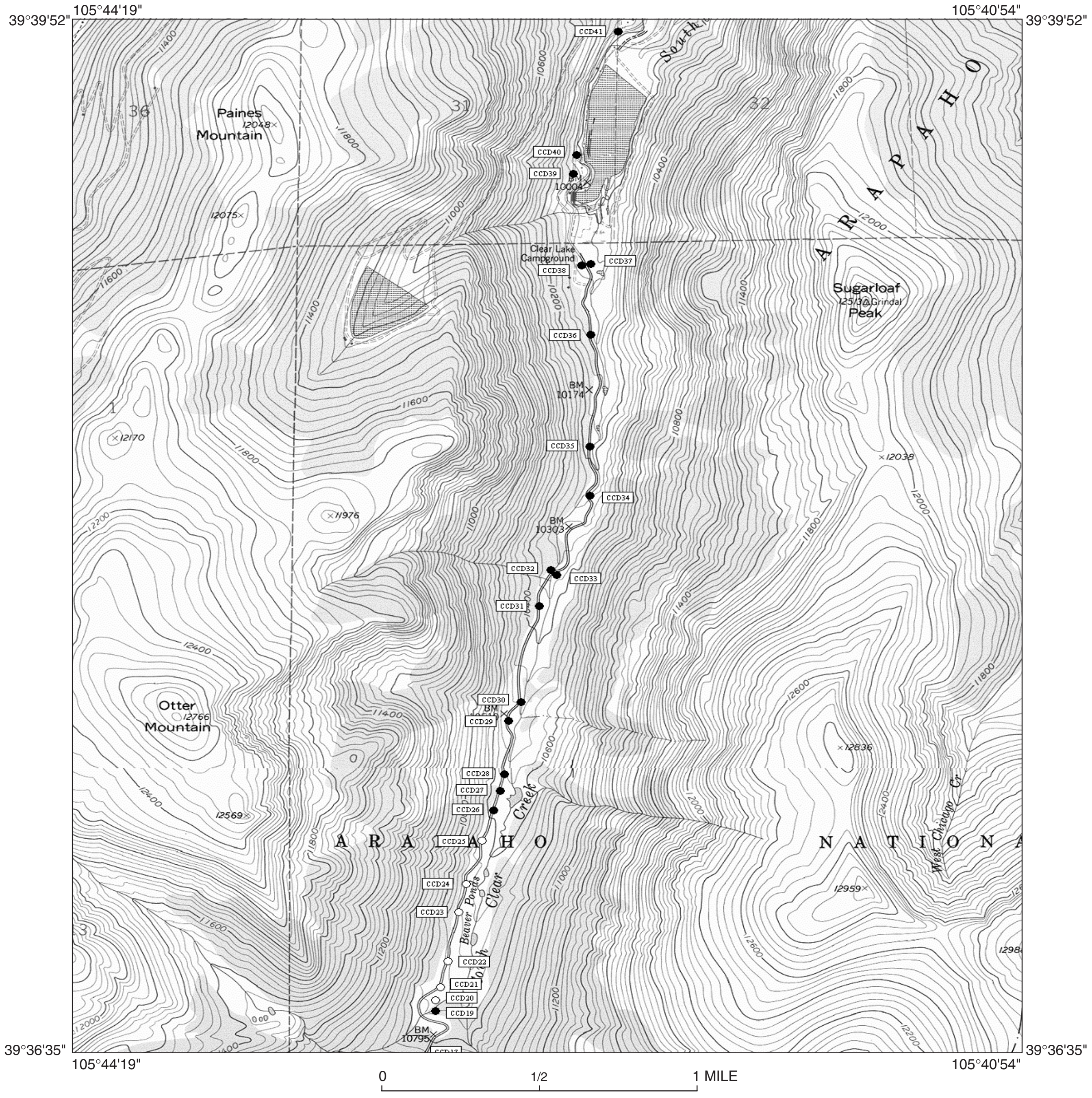


EXPLANATION

GCD16 ● Location and site number (table 54) of drainage feature (culvert of roadside ditch) that flows into a stream or lake

GCD14 ○ Location and site number (table 54) of drainage feature (culvert of roadside ditch) that does not flow into a stream or lake

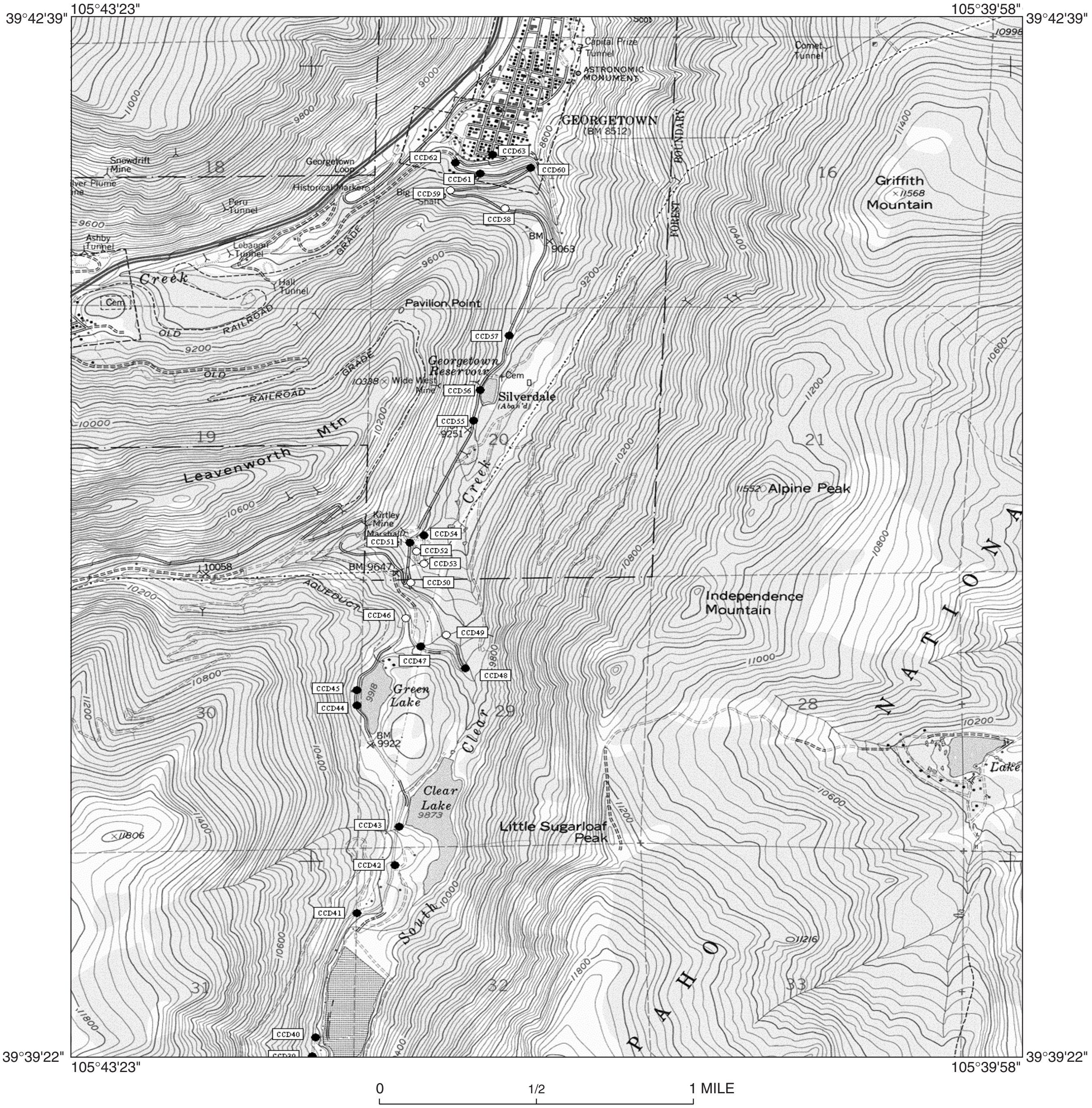
Figure 45. Location and identification of drainage features (roadside ditches and culverts) that showed evidence of sediment reaching a stream—Continued.



EXPLANATION

CCD19 ●	Location and site number (table 54) of drainage feature (culvert of roadside ditch) that flows into a stream or lake
CCD20 ○	Location and site number (table 54) of drainage feature (culvert of roadside ditch) that does not flow into a stream or lake

Figure 45. Location and identification of drainage features (roadside ditches and culverts) that showed evidence of sediment reaching a stream—Continued.



EXPLANATION

CCD40 ●	Location and site number (table 54) of drainage feature (culvert of roadside ditch) that flows into a stream or lake
CCD49 ○	Location and site number (table 54) of drainage feature (culvert of roadside ditch) that does not flow into a stream or lake

Figure 45. Location and identification of drainage features (roadside ditches and culverts) that showed evidence of sediment reaching a stream—Continued.

A total of 137 drainage features were located and described over the approximately 23.5 miles of the existing Guanella Pass road, 63 in the South Clear Creek drainage and 74 in the Geneva Creek drainage (Appendix table 54). Culverts accounted for 67 percent of the drainage features on the South Clear Creek side and 84 percent on the Geneva Creek side of Guanella Pass. Fifty-six percent of the total number of drainage features had direct connection to the stream during a past runoff event. In the South Clear Creek drainage, 75 percent of the drainage features had a direct connection, and 40 percent in the Geneva Creek drainage had a direct connection (Appendix table 54).

Road-drainage density in selected study-area basins were computed to indicate relative effects of the Guanella Pass road. The estimate was enhanced by using the length of ditch with a direct connection to the stream in the basin instead of the road length. This was estimated by computing the length of linked road ditch per square mile of drainage area upstream from the sampling site (table 32). Sites with the highest road-drainage density might be most affected by the present road and would probably be most affected by any reconstruction activities. In the Leavenworth Creek and upper Geneva Creek Basins (CC9 and GC11), secondary roads also could have the same potential effects as the Guanella Pass road, but their road-runoff linkages were not determined. Even if all the secondary road segments in the GC11 basin were connected to streams, the large drainage-basin area would result in a relatively small road-drainage density. But for CC9, secondary road-drainage connections have the potential of relatively large road-drainage density. Of the selected sampling sites, CC9 had the smallest road-drainage density from the Guanella Pass road (94 ft/mi^2), CC12 (South Clear Creek at upper station, above Naylor Creek) had the largest (3,126 ft/mi^2). In general, the smallest headwater drainage basins had the largest connected road-drainage densities. The large road-drainage density, combined with larger annual precipitation, indicate that the greatest effects of Guanella Pass road reconstruction on road runoff could occur in headwater basins.

Surface-runoff connections between the road drainage features and receiving waters depend upon the effectiveness of the buffer zone to attenuate runoff. The average sediment travel distance into the buffer zone of the road runoff that was stopped by the vegetative buffer (excluding blocked culverts) was 184 ft but ranged from less than 5 to 1,295 ft (Appendix table 54). The average travel distance of the road runoff that was not stopped by the buffer (distance from road to the point of entry in a stream or lake) also was 184 ft and ranged from 0 to 990 ft (Appendix table 54). These distances are for a single drainage feature and do not include flows from one feature to another.

Seasonal Characteristics of Sediment and Dissolved Solids in Road Runoff

To understand the seasonal characteristics of road runoff, four sites were instrumented with continuous water-stage recorders and automatic pumping samplers (Stevens, 2000). Three of the sites produced only partial water-discharge and suspended-sediment sample record (GRD4, GRD6, and CRD8) because of instrument malfunction. Water and suspended-sediment discharge record for site CRD7 was complete for the runoff seasons of WY’s 1996 and 1997. Characteristics of the four runoff monitoring sites are listed in table 33. Data and methods of sample collection at these sites are presented in Stevens (2000).

By using sediment and dissolved-solids budgets for the culvert-monitoring site CRD7 and the small watershed upstream from CC2 (South Clear Creek above Naylor Creek), which includes the CRD7 segment, the influence of road runoff on a headwater basin was evaluated. Three comparisons were made: (1) the estimated annual road-runoff sediment discharge in the CC2 basin was compared to the estimated annual suspended-sediment discharge at CC2; (2) the daily sediment discharges from road runoff were compared to daily suspended-sediment discharges at CC2 and expressed as a percentage (tables 55 and 56); and (3) the potential increase in suspended-sediment concentration at CC2 due to road runoff was determined by computing a concentration of suspended sediment from the road-runoff sediment discharge and the water discharge at CC2 (tables 55 and 56). The same comparisons were made for dissolved solids. Assumptions for the budgets are the following: (1) the length of Guanella Pass road in the watershed upstream from CC2 had a similar yield of sediment and dissolved solids per foot of road ditch (estimated from the yield per foot of road ditch

Table 32. Road-runoff linkages and road-drainage density in basins of selected stream-sampling sites

[ft, feet; mi^2, square miles; roadside ditch drainage density was computed by dividing the length of roadside ditch directly connected to the stream by the basin drainage area contributing to flow at the stream site]

Site (fig. 1)	Altitude (ft)	Sampling site drainage area (mi^2)	Total roadside ditch length (ft)	Total stream-linked roadside ditch length (ft)	Percentage stream-linked roadside ditch	Roadside ditch drainage density (ft/mi^2)
CC12	11,030	1.45	6,009	4,533	75	3,126
CC2	10,710	2.19	7,459	5,983	80	2,732
CC5	10,100	11.8	18,525	13,992	76	1,186
CC9	9,280	12.0	1,404[a]	1,129[a]	80	94[a]
GC2	11,160	.79	4,631	1,416	31	1,792
GC5	9,750	7.78	22,782	10,112	44	1,300
GC11	8,760	74.6	52,859[a]	26,647[a]	50	357[a]

[a] Computations include only Guanella Pass Road. Extensive secondary roads are present in CC9 (about 12.6 mi) and GC11 (about 8.6 mi).

Table 33. Characteristics of road-runoff monitoring sites

[ft, feet]

Site number (fig. 2)	Length of road segment (ft)	Average road width (ft)	Average cutslope width (ft)	Average fillslope width (ft)	Average cutslope slope (degrees)	Culvert diameter (ft)	Soil type on cutslope	Vegetation on cutslope
CRD7	565	24	29	26	30	1.25	decayed, granitic gravel and soil	sparse grasses, moss
GRD6	1,416	26	30	43	29	1.25	sandy, loose, decayed granite and rock fragments	sparse grasses
GRD4	1,134	21	18	18	20	1.5	gravelly soil with rock fragments	grass; some aspen/conifer
CRD8	754	28	27	49	35	no culvert	soil, some gravel and rock fragments	grasses; some conifer

draining to CRD7); and (2) the entire daily yield of sediment and dissolved solids from road ditches linked to the stream was transported to the stream instantaneously and then to CC2 without any loss of mass.

Because only suspended sediment was measured at CC2 and equipment used to sample suspended sediment is not able to collect large grain sizes, the coarse sediment fraction (sediment trapped behind the weir at CRD7) from the road-runoff budget was not included in the sediment-discharge computations. This is probably a reasonable assumption because coarse material is less likely to be transported to the stream and more likely to be deposited in the buffer zone. Duncan and others (1987) measured sediment delivery through an ephemeral headwater stream segment in a forested area of Washington and found that 40 to 100 percent of sediment less than 0.063 mm was transported downstream whereas less than 10 to 40 percent of sediment between 0.063 and 2 mm was transported. Particle-size data for sediment samples collected at the CRD7 weir indicate a predominance of the less than 0.062-mm fraction (average 91 percent of total). Particle-size data for bulk sediment trapped in the box at site CRD7 indicate almost no sediment less than 0.062 mm (percentage finer than 0.062 mm averaged 3.6) (Stevens and others, 1997; Stevens, 2000). The data indicate that most of the sediment transported past the weir at CRD7 is less than 0.062 mm, and very little of the sediment less than 0.062 mm is trapped.

Sediment

The CRD7 water and sediment-discharge results for water years 1996–97 are listed in table 34. In water year 1996, about 0.41 acre-ft of runoff was produced from the approximately 0.69 acre of cutslope and road surface (380 acre-ft/mi^2); about 96 percent of runoff occurred during snowmelt. Total sediment yield measured at the culvert was about 0.61 ton (566 tons/mi^2, 1.49 tons/acre-ft), 56 percent during snowmelt. The flow-weighted-mean concentrations of the total sediment load were 639 mg/L for snowmelt and 11,770 mg/L for rainstorm runoff.

In water year 1997, about 0.66 acre-ft of runoff was produced from the approximately 0.69 acre of cutslope and road surface (612 acre-ft/mi^2), about 77 percent during snowmelt. Total sediment yield measured at the culvert was about 4.74 tons (4,400 tons/mi^2, 7.18 tons/acre-ft), 24 percent during snowmelt. The flow-weighted-mean concentrations of the total sediment load were 1,635 mg/L for snowmelt and 17,540 mg/L for rainstorm runoff (table 34).

Annual estimates of the sediment budget for the road length connected to South Clear Creek upstream from Naylor Creek by surface drainage (a road segment similar in character to the CRD7 segment) (fig. 46) were computed and compared to the suspended-sediment discharge at CC2. On an annual basis, although the road-runoff water yields (CRD7 culvert yield multiplied by a factor of 10.6) were only about 0.35 percent (1996) and 0.44 percent (1997) of the water yield at CC2 (tables 5 and 34), the road runoff total sediment yield (CRD7 culvert yield multiplied by a factor of 10.6) was 29 percent (1996) and 49 percent (1997) of the annual suspended-sediment load at CC2 (tables 17 and 34).

On a daily basis, suspended-sediment loads from road runoff in the CC2 basin also were compared to CC2 watershed suspended-sediment loads to estimate the potential effect on stream concentrations and to test the sediment budget assumptions (Appendix tables 55–56). Comparison of the daily suspended-sediment discharges attributed to the roads in the CC2 basin to the estimated daily suspended-sediment discharges at CC2 sometimes resulted in percentages greater than 100 percent, which implies that more road-sediment transport was estimated than was actually measured at CC2 (Appendix tables 55 and 56). This discrepancy might be attributed to the following: (1) a lack of similarity between CRD7 and the larger road segment; (2) sediment erosion on the buffer-zone slope; (3) erosion on the South Clear Creek streambed or streambanks; or (4) inaccuracies in suspended-sediment transport estimates for the road runoff and the stream.

The analysis, however, does indicate that road runoff was seasonal, occurring during snowmelt and rainstorms. Runoff from the road preceded the basin-wide peak flow from snowmelt, resulting in sediment and water-quality constituent inputs to the stream when the capacity for dilution was low. In late summer, peak flows in streams had subsided and short thunderstorms caused road runoff to enter streams when capacity for dilution was again low. This may have resulted in larger concentrations of suspended sediment in receiving water or deposition of material on the streambed.

During snowmelt in 1996 (04–25–96 through 05–31–96), road-runoff sediment discharge had the potential to cause suspended-sediment concentration increases in South Clear Creek upstream from CC2 ranging from less than 1 to 43 mg/L, which equates

Table 34. Water discharge, sediment transport, and dissolved-solids transport at site CRD7, water years 1996–97

[Flow-weighted-mean concentration = annual sediment discharge (in tons/day) divided by annual mean water discharge (in ft^3/s) divided by 0.0027]

Water year	Water discharge (acre-feet)		Sediment transported over the weir (tons)		Sediment in coarse-particle trap (tons)		Flow-weighted-mean sediment concentration[1] (milligrams per liter)		Dissolved solids (tons)	
	Snowmelt	Rainstorm runoff	Snowmelt	Rainstorm runoff	Snowmelt	Rainstorm runoff	Snowmelt	Rainstorm runoff	Snowmelt	Rainstorm runoff
1996	0.39	0.017	0.172	0.207	0.17	0.06	639	11,770	0.015	0.003
1997	.51	.15	.567	1.98	.57	1.62	1,635	17,540	.012	.050

[1] Flow-weighted-mean sediment concentration includes both sediment transported over the weir and sediment collected in the coarse-particle trap.

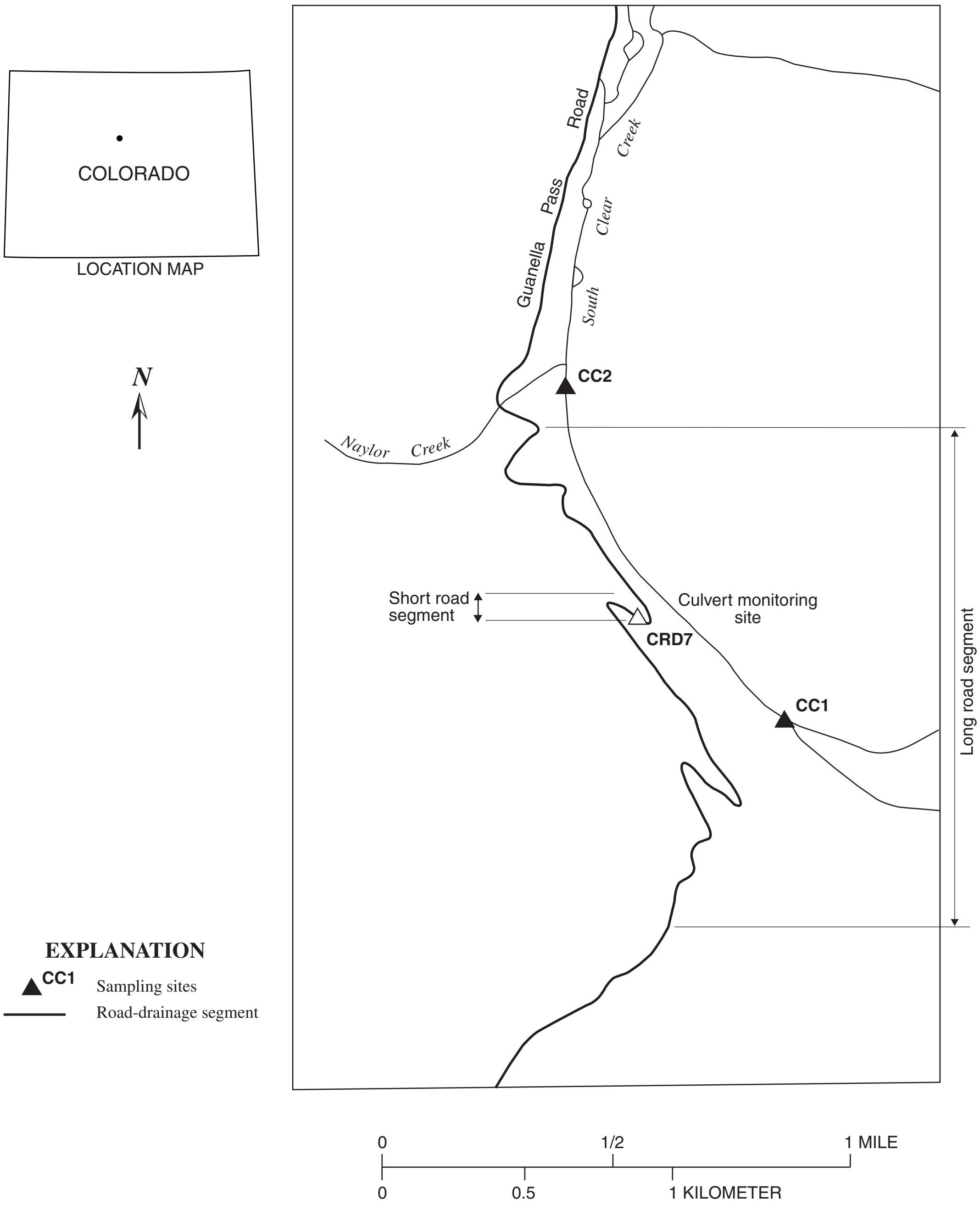


Figure 46. Location of culvert monitoring site and the segment of the road draining to the monitoring site (short segment), and the location of the segment of road draining to South Clear Creek upstream from the CC2 sampling site.

to 0.7 to more than 3,600 percent of the suspended-sediment discharges actually estimated at CC2 (table 55). Snowmelt road runoff during 1997 (05–08–97 through 06–02–97) in the CC2 basin had the potential to cause suspended-sediment concentration increases ranging from less than 1 to 50 mg/L, which equates to less than 1 to 86 percent of the suspended-sediment discharges estimated at CC2 (table 56). During rainstorms in 1996, road-runoff sediment discharge had the potential to cause suspended-sediment concentration increases in South Clear Creek upstream from CC2 ranging from 2 to 450 mg/L, which equates to 32 to 650 percent of the discharges estimated at CC2 (table 55). Rainstorm road runoff during 1997 in the CC2 basin had the potential to cause suspended-sediment concentration increases ranging from less than 1 mg/L to 2,330 mg/L, and the percentage difference of CRD7 to CC2 suspended-sediment discharge ranged from 1 to 11,400 percent (table 56).

Dissolved Solids

The CRD7 water discharge and dissolved-solids discharge results for WY's 1996–97 are listed in table 34. Dissolved-solids discharge in runoff for water year 1996 was about 0.018 ton, about 83 percent transported in snowmelt. Dissolved solids in runoff for WY 1997 was about 0.062 ton, about 19 percent transported in snowmelt.

Annual estimates of the dissolved-solids budget produced by the road length observed to be connected to South Clear Creek above Naylor Creek by surface drainage (fig. 46) were computed and compared to the dissolved-solids budget at CC2. On an annual basis, dissolved-solids discharges produced by road runoff draining to CC2 (CRD7 culvert yield multiplied by a factor of 10.6) were 0.3 (1996) and 0.7 percent (1997) of the dissolved-solids load estimated at CC2.

On a daily basis, dissolved-solids discharges from roads in the CC2 basin were compared to CC2 watershed dissolved-solids discharges to estimate the potential effect on stream concentrations. Potential increases in dissolved-solids concentration in South Clear Creek above Naylor Creek as a result of road runoff were small (Appendix tables 57 and 58). During snowmelt in 1996, road runoff to South Clear Creek (CC2) had the potential to cause dissolved-solids concentration increases ranging from less than 1 to 12 mg/L, which equates to less than 1 to about 16 percent of the estimated discharges at CC2 (Appendix table 57). Snowmelt road runoff during 1997 in the CC2 basin had the potential to cause dissolved-solids concentration increases ranging from less than 1 to about 1 mg/L, which equates to less than 1 to 2.4 percent of the estimated discharges at CC2 (Appendix table 58). During rainstorm road runoff in 1996, connected road-runoff contributions to South Clear Creek had the potential to cause dissolved-solids concentration increases ranging from less than 1 to 4 mg/L, which equates to less than 1 to 4.8 percent of the estimated discharges at CC2 (Appendix table 57). Rainstorm road-runoff during 1997 had the potential to cause dissolved-solids concentration increases ranging from less than 1 to 13 mg/L, which equates to less than 1 to about 24 percent of the estimated discharges at CC2 (Appendix table 58).

Although concentrations of dissolved solids in road runoff were sometimes larger than were measured at CC2, dilution decreases the likelihood of substantial increases in daily mean dissolved-solids concentration at CC2. Because this road segment has been treated with magnesium chloride, these estimates might be larger than those expected for a road not treated with the dust inhibitor.

Potential Effects of Road Runoff on Receiving Water

Receiving waters are the streams, ground water, and lakes and reservoirs into which road runoff flows. If road runoff flows into receiving waters in sufficient amounts, the effect could be an alteration of water quality. By comparing the chemistry of the road runoff to the chemistry of the receiving water, the potential effects of road runoff on the receiving water can be qualitatively evaluated.

Streams

The median concentrations for many constituents are larger in road runoff than in nearby streams, indicating that road runoff may increase stream concentrations (table 35). When compared to streams (Appendix tables 36–49), road runoff (Appendix tables 52 and 53) generally has larger median values of turbidity and larger median concentrations of sodium, chloride, dissolved nitrite plus nitrate, dissolved ammonia, total ammonia plus organic nitrogen, total phosphorus, dissolved phosphorus, total recoverable and dissolved aluminum, total recoverable barium, total recoverable chromium, total recoverable cobalt, total recoverable copper, total recoverable iron, total recoverable lead, total recoverable and dissolved manganese, total recoverable nickel, total recoverable zinc, total organic carbon, and suspended sediment. For these constituents, the median road-runoff values and concentrations range from 72 percent larger than stream values and concentrations for sodium (table 35) to more than 700 times larger for suspended sediment (table 35 and fig. 47).

Road runoff occurs during early spring from melting snow (often beginning before peak flow in streams) and during summer from afternoon and evening thunderstorms. Early snowmelt and thunderstorms often occur when streamflows are low

Table 35. Summary of stream and road-runoff water quality, water years 1995–97

[--, insufficient data to calculate statistic; ranges of site data computed from all stream-water-quality sites; stream median statistic is the median of all individual site medians from summary statistics in the Appendix; **, 1995 data at higher detection limit not included in computations; µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; >, greater than; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; %, percentage; mm, millimeters; T/d, tons per day]

Consituent or property	Units	Streams			Road runoff						
					Rainstorm-related			Snowmelt-related			Rain and snow
		Minimum	Median	Maximum	Minimum	Median	Maximum	Minimum	Median	Maximum	Median
Specific conductance, at 25 degrees Celsius	µS/cm	23	44	210	19	78	468	14	38	301	50
pH	units	3.8	7.6	8.8	6.1	7.2	8.5	6.9	7.2	7.5	7.2
Turbidity	NTU	.2	2.2	2,140	79	>1,000	>1,000	430	>1,000	>1,000	>1000
Dissolved oxygen	mg/L	6.7	8.8	11.6	--	--	--	6.7	9.4	10.2	9.4
Hardness, as $CaCO_3$	mg/L	9	18	89	1	17	160	5	15	49	16
Calcium, dissolved	mg/L	2.6	5	16	.2	5.2	20	1.5	3.4	11	3.4
Magnesium, dissolved	mg/L	.6	1.2	12	.06	.9	26	.2	1.6	5.1	1.1
Sodium, dissolved	mg/L	.7	1.4	5.6	.2	2.6	33	.5	1.4	54	2.4
Potassium, dissolved	mg/L	.2	.6	2.0	.5	2.8	5.6	.6	1.2	2.1	2.0
Acid-neutralizing capacity, lab, as $CaCO_3$	mg/L	<.1	16	61	5.4	22	59	4.8	14	43	20
Sulfate	mg/L	.8	3.3	90	.4	2.4	16	.4	1.2	4.4	1.6
Chloride	mg/L	<.1	.3	36	.4	2.8	120	.6	4.2	79	3.6
Fluoride	mg/L	<.1	.2	.4	<.1	.2	.4	<.1	.1	.2	.2
Silica	mg/L	4.1	6.8	13	.8	2.2	8.7	.6	3.2	7.1	2.4
Dissolved solids, residue at 180°C	mg/L	10	40	128	11	64	286	34	39	149	58
Nitrogen, nitrite, dissolved as N	mg/L	<.01	--	.01	<.01	.01	.06	<.01	<.01	<.01	.01
Nitrogen, nitrite plus nitrate, dissolved as N**	mg/L	.005	.059	.22	.055	.29	1.2	.015	.095	.31	.16
Nitrogen, ammonia, dissolved as N**	mg/L	<.002	<.002	.036	<.002	.040	.20	.010	.036	.080	.04
Nitrogen, ammonia plus organic, dissolved as N	mg/L	<.2	--	.3	<.2	<.2	.9	<.2	<.2	.2	<.2
Nitrogen, ammonia plus organic, total as N	mg/L	<.2	<.2	4.3	.3	3.5	24	<.2	.3	.6	.6
Phosphorus, total as P	mg/L	<.001	.009	3.2	.055	1.4	7.2	.024	.060	.40	.28
Phosphorus, dissolved as P	mg/L	<.01	--	.04	<.01	.01	.25	<.01	.02	.03	.01
Phosphorus, dissolved orthophosphate as P	mg/L	<.001	.001	.020	.003	.010	.22	.003	.007	.030	.01
Aluminum, total recoverable as Al	µg/L	20	--	11,000	41,000	50,000	130,000	550	14,000	120,000	41,000
Aluminum, dissolved as Al	µg/L	4	--	4,700	30	140	280	50	150	330	140
Antimony, dissolved as Sb	µg/L	<1	--	<1	<1	<1	<1	<1	<1	<1	<1
Arsenic, total recoverable as As	µg/L	<1	--	<1	<1	<1	2	<1	<1	1	<1
Barium, total recoverable as Ba	µg/L	<100	--	<100	700	1,800	2,600	100	200	2,500	700
Barium, dissolved as Ba	µg/L	16	--	38	9	20	48	7	16	41	16
Beryllium, total recoverable as Be	µg/L	<10	--	<10	<10	<10	<10	<10	<10	<10	<10

Table 35. Summary of stream and road-runoff water quality, water years 1995–97—Continued

[--, insufficient data to calculate statistic; ranges of site data computed from all stream-water-quality sites; stream median statistic is the median of all individual site medians from summary statistics in the Appendix; **, 1995 data at higher detection limit not included in computations; µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; >, greater than; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; %, percentage; mm, millimeters; T/d, tons per day]

Consituent or property	Units	Streams			Road runoff						
					Rainstorm-related			Snowmelt-related			Rain and snow
		Minimum	Median	Maximum	Minimum	Median	Maximum	Minimum	Median	Maximum	Median
Beryllium, dissolved as Be	µg/L	<1	--	<1	<1	<1	<1	<1	<1	<1	<1
Cadmium, total recoverable as Cd	µg/L	<1	--	2	<1	2	7	<1	<1	2	2
Cadmium, dissolved as Cd	µg/L	<1	--	2	<1	<1	<1	<1	<1	<1	<1
Chromium, total recoverable as Cr	µg/L	<1	--	20	89	120	200	<1	22	140	97
Chromium, dissolved as Cr	µg/L	<1	--	2	<1	<1	<1	<1	<1	1	<1
Cobalt, total recoverable as Co	µg/L	<1	--	10	20	80	110	<1	10	120	20
Cobalt, dissolved as Co	µg/L	<1	--	8	<1	<1	<1	<1	<1	<1	<1
Copper, total recoverable as Cu	µg/L	<1	<1	92	6	74	600	<1	31	250	57
Copper, dissolved as Cu	µg/L	<1	<1	37	<1	2	3	<1	1	3	1
Iron, total recoverable as Fe	µg/L	10	460	110,000	3,000	110,000	580,000	780	45,000	220,000	74,000
Iron, dissolved as Fe	µg/L	<3	104	1,800	17	63	520	46	220	1,100	110
Lead, total recoverable as Pb	µg/L	<1	<1	71	14	220	1,200	2	16	120	46
Lead, dissolved as Pb	µg/L	<1	<1	2	<1	<1	<1	<1	<1	<1	<1
Manganese, total recoverable as Mn	µg/L	<10	20	2,300	44	3,900	30,000	60	910	9,500	1,700
Manganese, dissolved as Mn	µg/L	<1	5.5	760	<1	22	1,700	4	46	72	36
Mercury, total recoverable as Hg	µg/L	<.1	--	.1	<.1	.1	.4	<.1	<.1	.1	<.1
Molybdenum, total recoverable as Mo	µg/L	<1	--	2	<1	1	2	<1	<1	1	<1
Molybdenum, dissolved as Mo	µg/L	<1	--	<1	<1	1	3	<1	<1	2	<1
Nickel, total recoverable as Ni	µg/L	<1	--	17	67	95	130	<1	16	140	70
Nickel, dissolved as Ni	µg/L	<1	--	17	<1	<1	1	<1	<1	2	<1
Selenium, total recoverable as Se	µg/L	<1	--	<1	<1	--	5	<1	<1	2	<1
Silver, total recoverable as Ag	µg/L	<1	--	<1	<1	<1	<1	<1	<1	<1	<1
Silver, dissolved as Ag	µg/L	<1	--	2	<1	<1	<1	<1	<1	<1	<1
Zinc, total recoverable as Zn	µg/L	<10	<10	430	40	460	2,200	<10	150	740	272
Zinc, dissolved as Zn	µg/L	<3	5.5	320	<1	2	44	<3	3	4	3
Uranium, natural, dissolved	µg/L	<1	--	2	<1	<1	3	<1	<1	<1	<1
Carbon, organic, total as C	mg/L	1.0	--	33	5.6	94	150	4.7	9.4	16	12
Carbon, organic, dissolved as C	mg/L	.5	--	3.3	2.4	3.2	3.7	2.3	3.0	3.8	3.2
Sediment, suspended	mg/L	<1	5.5	1,180	34	7,190	38,800	66	1,510	7,360	4,040
Sediment, suspended, % finer than 0.062 mm	%	14	69	100	35	88	100	37	90	97	90
Sediment, suspended, discharge	T/d	.001	.19	1,370	.0005	.16	13	.012	.16	2.9	.16

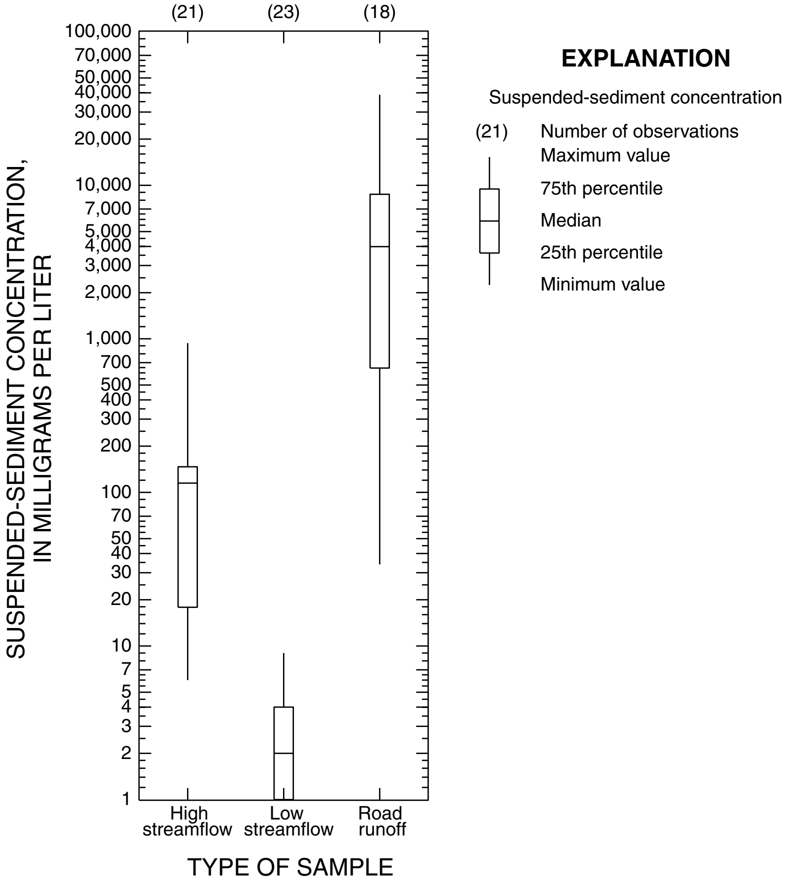


Figure 47. Distribution of suspended-sediment concentrations for high-streamflow, low-streamflow, and road-runoff samples.

and have a small capacity for dilution. For the WY 1996–97 estimates of road-runoff contributions to the CC2 basin, dilution of road-runoff water yield by South Clear Creek during rapid snowmelt on the road and early basin snowmelt (generally May) ranged from a factor of approximately 10 to 100 (dilution estimated from comparison of daily mean flow at CRD7 and CC2 in Stevens [2000]). During peak basin snowmelt (late May and early June), dilution factors of road runoff by snowmelt generally ranged from a few hundred to several thousand. Dilution factors for late-summer-rainstorm road runoff were in the range of 10 to 500 (Stevens, 2000). Thus, the potential water-quality effects of road runoff is more substantial during low streamflows and possibly inconsequential during high streamflows because of differences in dilution.

Concentrations of dissolved zinc and copper and total recoverable iron and manganese, trace elements that tended to exceed stream-water-quality standards at some stream sites along the Guanella Pass road, are present in road runoff. Rainstorm and snowmelt road-runoff median concentrations of dissolved copper (2 and 1 μg/L) and dissolved zinc (3 and 2 μg/L) (table 35) are generally below the range in standards (2 to 16 μg/L for copper, 16 to 106 μg/L for zinc) (table 30), indicating small potential influence on stream-water quality. Rainstorm and snowmelt road-runoff median concentrations of total recoverable iron and manganese (110,000 and 45,000 μg/L for iron; 3,900 and 910 μg/L for manganese) (table 35) are generally above the standards (1,000 μg/L for iron and manganese) (table 30), indicating a potential effect on stream concentrations.

The trace elements tend to be in particulate form, reducing the toxicity as defined by Colorado water-quality standards, which are primarily based on dissolved concentrations of trace elements (Colorado Department of Public Health and Environment, Water Quality Control Commission, 1996). Dissolved trace elements may be more bioavailable than particulate trace elements (Rainbow and Dallinger, 1993). The particle-related trace elements, however, may be transported to other geochemical environments (such as low pH) where they could become soluble and available to biota (Sundby, 1994).

Once a small sediment particle has become suspended in road runoff and enters a stream, it may not readily settle out of the water column. The particle-size data for road runoff (Stevens and others, 1997) indicates that the sediment eroding from the present road is primarily composed of fine particles. The median percentage of particles finer than 0.062 mm from 11 road-runoff samples (Stevens and others, 1997) was 84 percent. For six of the samples, smaller particle sizes were differentiated. Of those samples, an average of more than 20 percent of the particle weight was finer than 0.002 mm. These particles would have a settling time of more than 80 hours in 100 cm of still water at 20°C (Guy, 1969). The fine particle size decreases the likelihood that settling or filtration of the particle will occur in the buffer zone between the road and stream. The fine particle size also increases the likelihood that the particle will be transported in the stream and will not settle on the streambed. In some basins, this means transport out of the basin; in others, it means that particles may not settle out until they enter lakes or reservoirs.

Lakes and Reservoirs

Lakes and reservoirs may be long-term storage sites for many of the constituents in road runoff. In general, the lakes and reservoirs in the area had values and concentrations similar to low-flow stream concentrations (Appendix tables 36–49). Road runoff has the potential to alter lake and reservoir inflows, as described in the previous section, and to flow directly into lakes and reservoirs near the road. Increases in dissolved constituents or turbidity in inflows can promote stratification in lakes and reservoirs because of density differences between inflows and lake and reservoir water (Cole, 1994). Studies of Alaskan lakes indicate that an increase of as little as 5 NTU of turbidity in a clear lake can reduce the euphotic volume by as much as 80 percent (Lloyd and others, 1987). Increases in nutrients from road runoff may increase lake/reservoir algal productivity and accelerate eutrophication. Inputs of organic carbon from road runoff may increase oxygen demand and cause oxygen deficiencies in water at lake or reservoir bottoms. Low dissolved-oxygen concentrations near the bottom of lakes or reservoirs may promote the solubility of nutrients in the bottom sediments, creating a seasonal cycle of nutrient enrichment that could increase algal productivity (Cole, 1994). Trace elements, including some of the same trace elements delivered by road runoff, may become environmentally available during overturn of oxygen-depleted bottom waters of a lake or reservoir (Sundby, 1994). Excess sediment from road runoff may accumulate, causing a loss of reservoir capacity (MacDonald and others, 1991).

Georgetown Reservoir, the source of drinking water for Georgetown and water for the hydroelectric powerplant in Georgetown, may be sensitive to the effects of road runoff. Water that is relatively free of suspended sediment and turbidity is required for these uses. The large suspended-sediment concentrations and turbidity values in road runoff have the potential to degrade the quality of the water in the reservoir should the runoff reach the reservoir.

Ground Water

The potential effects of road runoff on ground water primarily result from dissolved constituents; most particulates would be removed as the water infiltrates through soil. Even if particle-related constituents reached the ground-water system, particulate matter would probably be decreased substantially by sedimentation, precipitation, and adsorption as the water moves through the system (Andrews and others, 1984). Of the dissolved constituents, median concentrations of hardness, alkalinity, the major ions (except sodium, potassium, and chloride), and dissolved solids are lower in road runoff (table 35) than in the ground water sampled (Appendix table 50), which indicates the potential for dilution of constituents in road runoff by ground water. The median concentrations of chloride, nitrite plus nitrate, ammonia, and dissolved aluminum, iron, and manganese were much larger in road runoff than ground water, indicating that ground-water concentrations of these constituents might increase with road-runoff infiltration. Wells near roads receiving sodium chloride or magnesium chloride treatments, such as the east well of Guanella Pass Campground, might be affected by the relatively large concentrations of infiltrating magnesium and chloride from road runoff.

BULK ATMOSPHERIC DEPOSITION

Bulk atmospheric-deposition samples were collected near the Guanella Pass road to assess particle-deposition (dust) conditions (table 1, fig. 3). Bulk atmospheric deposition was studied because the issue of dust deposition as a source of sediment to streams and lakes was considered important during initial discussions of the project. Deposited dust also can stress vegetation and alter acidic tundra soil chemistry near roadsides (Auerbach and others, 1997). Nutrients and organic chemicals from combustion engine emissions (from snowmobiles) have been shown to accumulate in roadside snowpack (Ingersoll, 1999). The bulk atmospheric deposition in this study was collected in open plastic buckets anchored to the ground and included precipitation, atmospheric particles, side-cast or wind-blown particles, loose particles bouncing downslope, raindrop-impact splash, throughfall from vegetation, vegetation debris, and insects.

Effect of Road-Surface Type

In 1995, 10 sites were chosen to represent the range of geographical and road-surface variation in the study area. Particles settling to the ground or deposited with precipitation were measured using open-bucket collectors placed along several paved and unpaved (gravel or dirt) sections of the Guanella Pass road and at reference sites located at least 500 ft away from any road. The collectors near the road were placed 15 ft (horizontal distance) from the edge of the road. At most sites, this distance from the road was near the edge of the disturbed zone (cut or fill area) along the road. The collectors accumulated particulate matter for 14 days in August and 21 days in October 1995. These time spans were long enough to include some dry periods and were chosen to include full weeks because more than twice the number of vehicles travel the road on weekend days than on weekdays. Just north of Grant, traffic counts during summer months averaged 2,935 vehicles per week; just south of Georgetown, traffic counts averaged 4,375 vehicles per week (Federal Highway Administration, 1998). Average deposition rates for each site for both periods were computed, and then all deposition rates, by site type, were grouped together for computation of median deposition rates (fig. 48).

The comparison of deposition rates indicates that unpaved roads produce substantially more bulk atmospheric deposition near the road than paved roads (fig. 48). The median deposition rate near unpaved (gravel or dirt) roads was about 105 times the median rate at reference sites (located at least 500 ft away

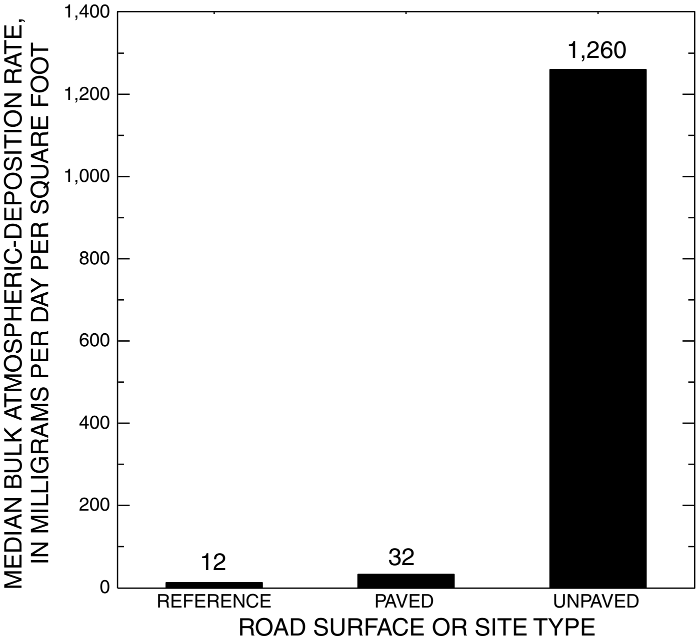


Figure 48. Comparison of median bulk atmospheric-deposition rates by type of site.

from a road). The median deposition rate near paved roads was about three times the median rate at reference sites. Because the weights of bulk deposition solids for the 21 days were smaller than the weights for the 14 days, other factors, such as precipitation or traffic levels, may have had a more important effect than the length of the collection period. A comparison of the deposition rates between individual sites and the deposition rates during the two sampling periods at the same site indicate that deposition rates are highly variable areally and temporally (Stevens, 1999).

Distribution Characteristics

The settling pattern of dust (less than 2 mm in diameter) near a section of gravel road on Guanella Pass was investigated for 56 days in August and September 1996 at site G (table 1, fig. 3) located near the summit of Guanella Pass in the Duck Creek drainage upstream from Duck Lake (Stevens, 2000). Bucket collectors placed at increasing distances from the edge of both sides of the road showed an exponential decrease in the amount of deposited material with increasing distance from the road (fig. 49).

Some chemical-distribution characteristics were analyzed from samples of bulk atmospheric deposition in 1995. The materials captured by a bulk atmospheric-deposition collector consisted of mostly inorganic particles (rock and soil dust) with some organic particles (leaves and insects). Sites E, F, G, H, and J are on road segments that have been treated with magnesium chloride or sodium chloride. The chloride deposition rates at sites E, F, G, H, and J (15 ft away from road) averaged 6.85 mg/d/ft^2. Chloride deposition rates for reference sites B, C, F, H, and K (at least 500 ft from the road) averaged 0.22 mg/d/ft^2 (Stevens and others, 1997). The large chloride deposition rates near the road indicate that some of the chloride is moving off the road in bulk atmospheric deposition.

Estimate of Bulk Atmospheric-Deposition Contributions from an Unpaved Road Section

To investigate the potential effect of bulk atmospheric deposition on suspended-sediment transport in a stream next to a unpaved (gravel) road, deposition rates in the flood plain of Geneva Creek were measured in August and September 1997 and compared to suspended-sediment load during the same period in adjacent Geneva Creek. Bucket collectors were placed at a range of locations from the road on the streamward

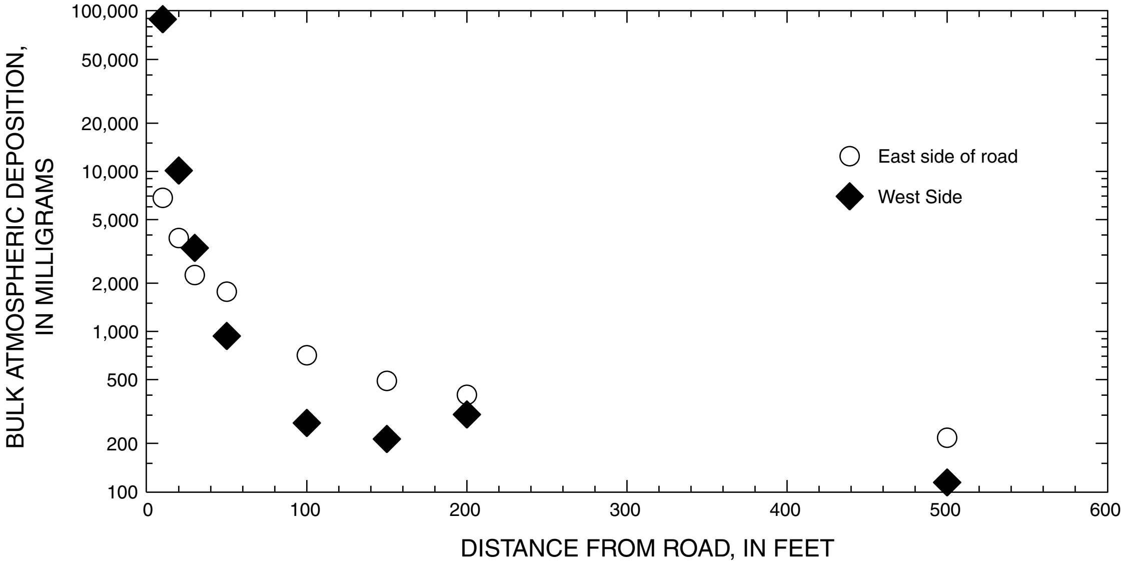


Figure 49. Distribution of bulk atmospheric deposition at site G, August through September 1996.

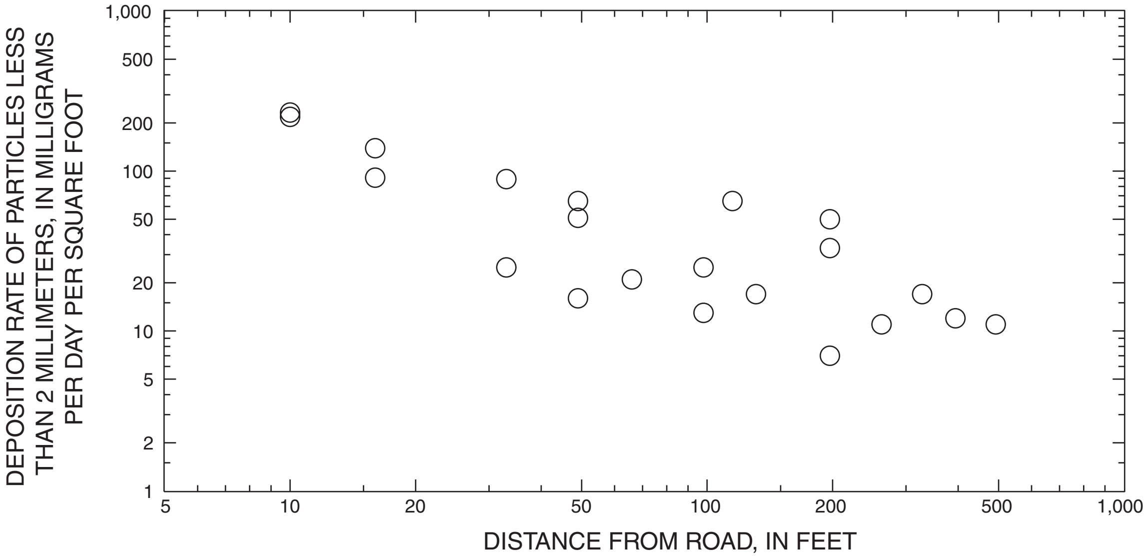


Figure 50. Relation of bulk atmospheric-deposition (less than 2 millimeters) rate and distance from the Guanella Pass road for data collected at sites L, M, and N, August through September 1997.

side at three locations (L, M, N, table 1, fig. 3). Deposition rates of particles passing a 2-mm sieve (to remove large detrital debris) were computed for 61 days during August 1 to September 30, 1997.

The natural logarithm of the deposition data for all three sites and the natural logarithm of distance from the road (fig. 50) were used to develop a linear regression equation. The equation was used to represent a deposition function for the streamward side of a 3.53-mile section of the Guanella Pass road (from the end of pavement just north of Grant to the end of gravel road just south of the Scott Gomer Creek road crossing). The road segment was divided into 39 subsections (most segments were 500 ft long). The distance from the road edge to the stream edge and the width of the stream at each subsection were measured from a map of the Guanella Pass Road corridor (Centennial Engineering, written commun., 1996). Numeric integration by Simpson's rule (Swokowski, 1979) was used to integrate the deposition equation (which is a function of distance from the road) over the width of the stream at the distance from the road where the active channel is located in each subsection. A midinterval method was then used to compute the deposition along the length of the stream, assuming that the length of the stream and the length of the road were similar.

Results indicate that bulk atmospheric deposition onto the active channel of Geneva Creek was inconsequential when compared to the low-flow suspended-sediment transport in Geneva Creek (site GC11) during August through September 1997. During the period, Geneva Creek transported an estimated 165 tons of suspended sediment (Stevens, 2000), whereas bulk deposition directly to the active channel during the same period was estimated to be 1.7 tons, about 1 percent of the stream suspended-sediment transport.

The differences in size between bulk atmospheric deposition and suspended sediment during August and September could affect an assumption of transport in the stream. The bulk deposition estimate was limited to the particle size less than 2 mm, and suspended sediment in Geneva Creek was usually near 100 percent finer than 0.062 mm during the low-flow season (Stevens and others, 1997). The percentage finer than 0.062 mm of nine bulk atmospheric-deposition samples collected 10 feet from the road ranged from 30 to 81, whereas at 49 feet from the road the percentage was generally greater than 80 percent (table 62 in Stevens [2000]). This indicates that sand-sized particles (greater than 0.062 mm) might be deposited in the sections of stream near the road and could remain on the stream bottom until higher flows transport them.

SUMMARY AND CONCLUSIONS

This study of water quality, road runoff, and bulk atmospheric deposition in the Guanella Pass area during WY's 1995–97 (October 1994 to September 1997) characterizes conditions in the South Clear Creek and Geneva Creek Basins about 40 miles west of Denver, Colorado, prior to a possible Guanella Pass road-reconstruction project.

During the study period, water in streams was relatively dilute, with specific-conductance values generally less than 100 µS/cm. The specific conductance of South Clear Creek generally increased in a downstream direction, possibly due to applications of magnesium chloride to portions of the Guanella Pass road, the effects of evapotranspiration, tributary inflow, or ground-water inflow. Specific conductance decreased in a downstream direction along Geneva Creek, a stream affected by acid-sulfate weathering, because of dilution from less concentrated tributary flows.

Values of pH generally were neutral (between about 7 and 8) except at GC7 and GC6, mineralized sites in the upper part of Geneva Creek, where pH values as low as 3.9 were measured. Dissolved oxygen ranged from 6.7 mg/L to 11.6 mg/L, and median percentages of dissolved oxygen saturation at each site ranged from 99 to 104.

Stream major-ion chemistry was characterized by the predominance of calcium and bicarbonate at most sites except the stream reaches where acid-sulfate weathering contributes enough sulfate to dominate the anions in stream water (upper Geneva and Leavenworth Creeks). Nutrient concentrations were generally small, except during high streamflow and storm runoff when particulate phases increased.

Dissolved trace-element concentrations in the Guanella Pass area (excluding aluminum, barium, iron, and manganese) were generally less than 10 µg/L, except in streams affected by acid-sulfate weathering. Total recoverable trace-element concentrations were generally larger than dissolved concentrations during snowmelt and stormflow, when suspended-sediment concentrations also were relatively large.

In Geneva Creek, at site GC6 September 1995, most of the copper load was in the dissolved phase. As the stream flowed downstream from GC6 to GC12, the pH changed from 3.8 to 7.4. Dissolved copper decreased sharply in a downstream direction while total recoverable copper remained fairly steady, indicating that most of the copper changed to a suspended-solid phase. Most of the aluminum and iron were in the dissolved phase at site GC6, but they precipitated prior to reaching GC9. The pH change did not affect manganese and zinc as much because the data indicate that most of the loads remained in the dissolved phase from GC6 to GC12.

Decreases in dissolved trace-element loads measured during rainstorms also were observed and might be explained by adsorption to suspended sediment. The decreases imply that sediment-laden stormflow may not degrade trace-element water quality because stream concentrations of dissolved trace elements decreased, improving water quality when compared to Colorado water-quality standards.

Suspended-sediment concentrations varied seasonally, being large during peak snowmelt and rainstorms and small during low flow and winter periods. Instantaneous suspended-sediment concentrations collected by equal-width-increment (EWI) methods ranged from less than 1 mg/L at many sites during low flow to 1,180 mg/L at a site on upper South Clear Creek. Median suspended-sediment concentrations (EWI's only) at most sites were generally less than 20 mg/L.

The relation of annual suspended-sediment discharge and annual streamflow to annual suspended-sediment discharge and drainage basin area indicates that annual suspended-sediment discharge at each site is proportional to annual flow and large basins tend to produce large loads. Suspended-sediment yields per acre-foot of water discharge at Guanella Pass sites were within the range of mean yields at crystalline bedrock comparison sites in Colorado except for water year 1995, when they were much larger than the means but still within the range of the comparison site maximum yields.

Generally, greater than 80 percent of suspended sediment was transported during the rising and falling limbs of the annual snowmelt hydrograph (about May to July). Transport during rainstorms only accounted for less than about 15 percent of the annual suspended-sediment discharge. Transport relations, yield comparisons, and peak rain-event suspended-sediment concentrations indicate that upper South Clear Creek, a basin receiving road runoff, had a larger rate of suspended-sediment transport than a similar-sized, undeveloped basin (Deer Creek near Bailey).

Bed-material particle-size data indicate that, at most sites, sand-sized or smaller material accounts for less than 10 percent, and the silt/clay fraction accounts for less than 1 percent of the streambed material. Therefore, bed-material composition for algae, macroinvertebrates, and fish, which prefer coarser materials, seems to be adequate habitat.

Seasonal stratification patterns indicate that the deeper (greater than 50 ft) lakes and reservoirs profiled (such as Duck Lake, Clear Lake, and Green Lake) are dimictic, with thermoclines forming in summer and winter, and the lake and reservoir contents mix and reoxygenate during overturn in the spring and fall. Bottom-water hypoxia (low oxygen) was more pronounced in Duck Lake than in Clear Lake; minimum dissolved oxygen concentrations in Duck Lake generally were less than 2 mg/L except in October 1996.

Concentrations of major ions, nutrients, and trace elements in lakes and reservoirs were generally similar to stream concentrations. However, the large concentrations of ammonia, phosphorus, iron, and manganese in bottom-water samples of Duck and Clear Lakes indicate release of these constituents from bottom sediment, especially in Duck Lake. Both Duck and Clear Lakes were classified as oligotrophic in water year 1997 according to Carlson's trophic state index.

Among lake and reservoir sites sampled for bottom-sediment trace elements, Green Lake and Georgetown Reservoir generally had the largest concentrations of zinc and lead. The larger concentrations of these trace elements in bottom sediment is related to sources of trace elements in the Leavenworth Creek Basin, which is the major water source to both impoundments.

Ground-water samples collected from sites downslope from parts of the Guanella Pass road that were treated with magnesium chloride showed chloride concentrations that were generally larger than concentrations at other sites. Dissolved nutrient concentrations in ground water were similar to concentrations in stream water. Nitrite plus nitrate was the dissolved nutrient detected most frequently, with a median concentration of 0.08 mg/L as N and a range of less than 0.05 to 0.15 mg/L as N. Trace-element concentrations in ground water generally were low except for some large concentrations of iron, manganese, and zinc at some wells.

Colorado water-quality standards for samples collected at six stream-sampling sites adjacent to the Guanella Pass road were based on numeric-fixed standards or standard equations and were used to evaluate stream concentrations. Generally, at the six sites evaluated, the total recoverable iron chronic standard was exceeded most frequently. Zinc standards (both acute and chronic) were exceeded numerous times at the Geneva Creek at Grant site (GC11). Total phosphorus concentrations in storm runoff of Guanella Pass occasionally exceeded the U.S. Environmental Protection Agency guideline of 0.1 mg/L as P for streams. An analysis of a ground-water sample from the well on the west loop of the Guanella Pass campground (GW3) contained 67 μg/L of uranium in August 1995 and 44 μg/L in September 1997, exceeding the U.S. Environmental Protection Agency proposed primary MCL of 20 μg/L.

Road runoff occurred during snowmelt and rainstorms. Individual culvert and ditch-water discharges generally were small compared to stream discharge. At one site monitored continuously for discharge (WY's 1996–97), most road runoff (77 to 96 percent) was a result of snowmelt. Runoff from the road preceded the basinwide peak streamflow, resulting in sediment and water-quality inputs to the stream when streamflow and the potential for dilution of the road runoff were low. For the WY 1996–97 estimates of road-runoff contributions to the CC2 basin, dilution of road-runoff water yield by South Clear Creek during rapid snowmelt on the road and early snowmelt in the watershed (generally early May) ranged from a factor of approximately 10 to 100 (dilution estimated from comparison of daily mean flow at CRD7 and CC2). During peak basin snowmelt (late May and early June), dilution factors of road runoff by snowmelt generally ranged from a few hundred to several thousand. Dilution factors for late-summer-rainstorm road runoff were in the range of 10 to 500. Thus, the potential water-quality effects of road runoff are more substantial during low streamflows and possibly inconsequential during high streamflows because of differences in dilution.

Specific conductance of road-runoff samples ranged from 14 to 468 μS/cm. The range of specific conductance of rainfall runoff was larger than values from snowmelt runoff. Major-ion composition of some samples indicated effects from deicing salt (NaCl) and dust inhibitor ($MgCl_2$) applied to sections of the road.

The estimated mass of chloride from $MgCl_2$ applied to the road for dust-suppressing purposes in the CC5 basin in 1987 (57.1 tons chloride), 1993 (11.5 tons), and 1996 (15.5 tons) ranged from 80 to 414 percent of the estimated average annual chloride load (13.8 tons per year) transported in South Clear Creek at CC5 during WY's 1995–97.

To estimate how chloride applied to the road might affect concentrations in the stream, a hypothetical set of assumptions were used to compute changes in annual flow-weighted-mean concentrations (FWMC) of chloride transported from the CC5 basin. For the computation, it was assumed that the mass of chloride from the largest known application of $MgCl_2$ applied to the Guanella Pass road in the CC5 basin (57.1 tons in 1987) was added to the estimated annual chloride load for each year 1995–97 at CC5. That load was then assumed to have been transported by the annual flow at CC5 that year and is converted to an annual FWMC of chloride. The FWMC that includes road-applied chloride could then be compared to the FWMC without road-applied chloride.

Results of the FWMC comparison indicate hypothetical increases in chloride from $MgCl_2$ ranging from about 3 to 12 times. In the case of the largest increase, the annual FWMC of chloride at CC5 in 1996 (0.5 mg/L) might increase 12 times (to 5.9 mg/L). Although this is a large percentage increase, the increased concentrations are still relatively minor, about 14 percent of the dissolved solids FWMC of 41 mg/L at CC5 in 1996.

Nutrients were commonly measured at larger concentrations in road-runoff samples than in streamflow. Concentrations of dissolved inorganic nitrogen (nitrate and ammonia) in rainfall-generated road runoff were more similar to the concentrations in precipitation than to the concentrations in stream water. Concentrations of total ammonia plus organic nitrogen (range less than 0.2 to 24 mg/L as N) and total phosphorus (range 0.024 to 7.2 mg/L as P) were generally large in snowmelt and rainstorm samples and were related to abundant particulate organic material and suspended sediment in the road runoff. In general, rainstorm-related median concentrations of total ammonia plus organic nitrogen and total phosphorus were at least an order of magnitude larger than snowmelt medians.

The largest concentrations of trace elements measured in road-runoff samples were for aluminum, iron, and manganese. Other trace elements with median concentrations greater than the laboratory MRL were total recoverable and dissolved barium, total recoverable cadmium (rainfall only), total recoverable chromium, total recoverable cobalt, total recoverable and dissolved copper, total recoverable lead, total recoverable mercury (rainfall only), total recoverable and dissolved molybdenum (rainfall only), total recoverable nickel, and total recoverable and dissolved zinc. In general, rainstorm-related concentrations were larger than snowmelt concentrations. Trace-element data indicate that total recoverable trace-element concentrations were substantially larger (by several times) than dissolved trace-element concentrations, indicating that most trace elements were particulate. This indicates that most of the stream trace-element standards would not likely be exceeded as a result of road-runoff constituents discharged into streams because the standards specify primarily dissolved phases, and trace elements in road runoff were primarily in the suspended phase. Two road-runoff samples collected during snowmelt and analyzed for trace-organic substances did not contain volatile or semivolatile organic substances greater than the laboratory MRL.

The suspended-sediment concentrations in snowmelt-generated road runoff ranged from 66 to 7,360 mg/L, with a median concentration of 1,510 mg/L. Rainstorm-runoff concentrations ranged from 34 to 38,800 mg/L, with a median of 7,190 mg/L. The sediment was primarily fine grained. More than 90 percent of suspended sediments from snowmelt samples and 88 percent from rainstorm samples were finer than 0.062 mm. This fine-grained character facilitates transport of the sediment and diminishes the likelihood that settling or deposition of the sediments would occur prior to reaching a stream.

Assessment of road-runoff effects depends on establishing a connection between erosion on the road and delivery of runoff to the adjacent stream. Fifty-six percent of the total number of culvert and roadside-ditch drainage features on the Guanella Pass road showed evidence of recent runoff connection to the stream. The average travel distance of road runoff that was stopped by the vegetative buffer between the road and adjacent stream was 184 ft but ranged from less than 5 to 1,295 ft.

The comparison of deposition rates indicates that unpaved roads produce substantially more bulk atmospheric deposition near the road than paved roads. The median deposition rate near unpaved (gravel or dirt) roads was about 105 times the median rate at reference sites (located at least 500 ft away from a road). The median deposition rate near paved roads was about three times the median rate at reference sites.

Bucket collectors placed at increasing distances from the edge of both sides of the road indicated an exponential decrease in the amount of deposited material with increasing distance from the road. During August to September 1997, bulk atmospheric deposition directly on the active channel of a reach of Geneva Creek was estimated to be 1.7 tons, or about 1 percent of the estimated 165 tons of suspended sediment transported past the nearby stream-monitoring site near Grant, indicating that bulk atmospheric deposition had little potential effect on suspended-sediment transport in Geneva Creek.

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APPENDIX—HYDROLOGIC AND WATER-QUALITY DATA

Table 36. Summary of water-quality statistics for analyses of samples collected, water years 1995–97, at CC1 (fig. 1)

[--, insufficient data to calculate statistic; statistics estimated using robust log-probability regression technique for censored data described in Helsel and Cohn (1988); **, 1995 data at higher detection limit not included in computations; µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; %, percentage; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; mm, millimeters; T/d, tons per day]

Property or constituent	Units	Number of samples	Percent detections	Mean	Standard deviation	Min-imum	10th percentile	25th percentile	Median	75th percentile	90th percentile	Max-imum	Lowest reporting limit
Specific conductance	µS/cm	16	100	37	11	26	27	28	34	42	56	63	1
pH	units	10	100	--	--	7.2	7.2	7.5	7.6	7.6	8.1	8.1	.1
Turbidity	NTU	16	100	2.4	1.2	.9	1.3	1.6	2	2.8	5.2	5.3	.1
Dissolved oxygen	mg/L	10	100	8.8	1	7.4	7.4	7.7	9.2	9.6	10	10	.1
Dissolved oxygen saturation	%	10	100	101	3.8	97	97	99	100	103	109	110	1
Hardness as $CaCO_3$	mg/L	5	100	16	4.8	11	--	--	16	--	--	23	1
Calcium, dissolved	mg/L	5	100	4.5	1.3	3.1	--	--	4.6	--	--	6.4	.1
Magnesium, dissolved	mg/L	5	100	1.1	.3	.8	--	--	1.1	--	--	1.6	.1
Sodium, dissolved	mg/L	5	100	1.3	.4	.8	--	--	1.5	--	--	1.6	.1
Potassium, dissolved	mg/L	5	100	.5	.2	.2	--	--	.5	--	--	.8	.1
Acid-neutralizing capacity, lab as $CaCO_3$	mg/L	5	100	18	6	11	--	--	19	--	--	25	1
Sulfate, dissolved	mg/L	11	100	1.5	.5	.8	.8	1	1.4	1.8	2.5	2.6	.1
Chloride, dissolved	mg/L	13	100	.2	.1	.1	.1	.1	.1	.3	.5	.5	.1
Fluoride, dissolved	mg/L	3	67	--	--	<.1	--	--	.1	--	--	.1	.1
Silica, dissolved	mg/L	5	100	6.7	1.6	4.9	--	--	7.5	--	--	8.3	.1
Dissolved solids, residue at 180 degrees Celsius	mg/L	7	100	35	9.3	24	--	--	35	--	--	48	1
Nitrite, dissolved as N	mg/L	2	50	--	--	<.01	--	--	--	--	--	.01	.01
Nitrite plus nitrate, dissolved as N	mg/L	**10	60	.021	.039	<.005	<.005	<.005	.011	.016	.119	.13	.005
Nitrogen, ammonia, dissolved as N	mg/L	**10	30	.002	.002	<.002	<.002	<.002	<.002	.002	.007	.015	.002
Nitrogen, ammonia plus organic, dissolved as N	mg/L	2	100	--	--	.2	--	--	--	--	--	.2	.2
Nitrogen, ammonia plus organic, total as N	mg/L	10	40	.2	.1	<.2	<.2	<.2	.2	.2	.3	.3	.2
Phosphorus, total as P	mg/L	**10	100	.013	.006	.005	.005	.009	.012	.017	.023	.023	.001
Phosphorus, dissolved as P	mg/L	2	100	--	--	.02	--	--	--	--	--	.02	.001
Phosphorus, dissolved orthophosphate as P	mg/L	**8	88	.003	.002	<.001	<.001	.001	.002	.005	.006	.01	.001
Aluminum, total as Al	µg/L	2	100	--	--	20	--	--	--	--	--	90	10
Aluminum, dissolved as Al	µg/L	2	100	--	--	20	--	--	--	--	--	30	1
Antimony, dissolved as Sb	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Arsenic, total as As	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Barium, total as Ba	µg/L	2	0	--	--	<100	--	--	--	--	--	<100	100
Barium, dissolved as Ba	µg/L	2	100	--	--	16	--	--	--	--	--	18	1
Beryllium, total as Be	µg/L	2	0	--	--	<10	--	--	--	--	--	<10	10

Table 36. Summary of water-quality statistics for analyses of samples collected, water years 1995–97, at CC1 (fig. 1)—Continued

[--, insufficient data to calculate statistic; statistics estimated using robust log-probability regression technique for censored data described in Helsel and Cohn (1988); **, 1995 data at higher detection limit not included in computations; µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; %, percentage; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; mm, millimeters; T/d, tons per day]

Property or constituent	Units	Number of samples	Percent detections	Mean	Standard deviation	Minimum	10th percentile	25th percentile	Median	75th percentile	90th percentile	Maximum	Lowest reporting limit
Beryllium, dissolved as Be	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Cadmium, total as Cd	µg/L	2	0	--	--	<1	--	--	<1	--	--	<1	1
Cadmium, dissolved as Cd	µg/L	2	0	--	--	<1	--	--	<1	--	--	<1	1
Chromium, total as Cr	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Chromium, dissolved as Cr	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Cobalt, total as Co	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Cobalt, dissolved as Co	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Copper, total as Cu	µg/L	11	18	--	--	<1	--	--	<1	--	--	1	1
Copper, dissolved as Cu	µg/L	11	27	--	--	<1	--	--	<1	--	--	1	1
Iron, total as Fe	µg/L	11	100	810	360	270	310	460	950	1,100	1,300	1,300	10
Iron, dissolved as Fe	µg/L	11	100	430	220	140	150	230	420	700	720	720	1
Lead, total as Pb	µg/L	11	0	--	--	<1	--	--	<1	--	--	<1	1
Lead, dissolved as Pb	µg/L	4	0	--	--	<1	--	--	<1	--	--	<1	1
Manganese, total as Mn	µg/L	11	91	40	20	<10	10	20	30	50	70	70	10
Manganese, dissolved as Mn	µg/L	11	91	11	5	<1	5	8	11	15	20	21	1
Mercury, total as Hg	µg/L	2	0	--	--	<.1	--	--	--	--	--	<.1	.1
Molybdenum, total as Mo	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Molybdenum, dissolved as Mo	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Nickel, total as Ni	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Nickel, dissolved as Ni	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Selenium, total as Se	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Silver, total as Ag	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Silver, dissolved as Ag	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Zinc, total as Zn	µg/L	11	0	--	--	<10	--	--	<10	--	--	<10	10
Zinc, dissolved as Zn	µg/L	11	54	4	1	<3	3	4	4	5	6	6	3
Uranium, natural dissolved	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Carbon, organic total as C	mg/L	2	100	--	--	6.4	--	--	--	--	--	6.7	.1
Carbon, organic dissolved as C	mg/L	1	100	--	--	3.3	--	--	--	--	--	3.3	.1
Sediment, suspended, concentration	mg/L	16	100	5	6	1	1	2	4	5	--	27	1
Sediment, suspended, % finer than 0.062 mm	%	3	100	--	--	35	--	--	55	--	--	100	1
Sediment, load	T/d	15	100	.10	.21	.001	.001	.002	.01	.08	.5	.8	.001

Table 37. Summary of water-quality statistics for analyses of samples collected, water years 1995–97, at CC2 (fig. 1)

[--, insufficient data to calculate statistic; statistics estimated using robust log-probability regression technique for censored data described in Helsel and Cohn (1988); µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; %, percentage; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; mm, millimeters; T/d, tons per day]

Property or constituent	Units	Number of samples	Percent detections	Mean	Standard deviation	Min-imum	10th percentile	25th percentile	Median	75th percentile	90th percentile	Maxi-mum	Lowest reporting limit
Specific conductance	µS/cm	49	100			37			77			136	1
pH	units	44	100	--	--	7.2			8			8.3	.1
Turbidity	NTU	44	100			.4			2.6			2,140	.1
Dissolved oxygen	mg/L	38	100	8.7	1.2	6.8	7	7.7	8.6	9.7	10.3	11.5	.1
Dissolved oxygen saturation	%	35	100	100	6.6	84	93	97	101	105	107	116	1
Hardness as $CaCO_3$	mg/L	30	100	39	19	16	16	22	38	52	63	89	1
Calcium, dissolved	mg/L	30	100	8.7	3.5	4.1	4.3	5.6	8.6	12	14	16	.1
Magnesium, dissolved	mg/L	30	100	4.2	2.6	1.4	1.5	2	3.9	5.5	7.4	12	.1
Sodium, dissolved	mg/L	30	100	1.8	.9	.8	1	1.1	1.6	1.9	2.9	5.6	.1
Potassium, dissolved	mg/L	30	100	.8	.4	.5	.6	.6	.7	.8	1.7	1.8	.1
Acid-neutralizing capacity, lab as $CaCO_3$	mg/L	29	100	36	14	16	16	22	41	48	55	61	1
Sulfate, dissolved	mg/L	42	100	3.8	1.6	1.3	1.9	2.4	3.6	4.7	6.4	7.5	.1
Chloride, dissolved	mg/L	44	100	2.8	6.3	.5	.6	.8	1.2	1.6	3.4	36	.1
Fluoride, dissolved	mg/L	5	80	--	--	<.1	--	--	.2	--	--	.2	.1
Silica, dissolved	mg/L	30	100	6.4	1.1	4.1	5	5.5	6.4	7.3	7.6	8.1	.1
Dissolved solids, residue at 180 degrees Celsius	mg/L	31	100	60	22	28	34	44	56	72	90	128	1
Dissolved solids, sum of constituents	mg/L	29	100	52	22	24	24	32	53	65	80	113	1
Nitrite, dissolved as N	mg/L	2	0	--	--	<.01	--	--	--	--	--	<.01	.01
Nitrite plus nitrate, dissolved as N	mg/L	37	86	.028	.031	<.005	.006	.01	.02	.03	.089	.12	.005
Nitrogen, ammonia, dissolved as N	mg/L	17	35	.002	.002	<.002	<.002	<.002	<.002	.003	.007	.03	.002
Nitrogen, ammonia plus organic, dissolved as N	mg/L	2	50	--	--	<.2	--	--	--	--	--	.2	.2
Nitrogen, ammonia plus organic, total as N	mg/L	37	43	.3	.8	<.2	<.2	<.2	<.2	.4	.5	4.3	.2
Phosphorus, total as P	mg/L	37	97	.21	.62	<.001	.006	.008	.01	.042	1	3.2	.001
Phosphorus, dissolved as P	mg/L	2	50	--	--	<.01	--	--	--	--	--	.02	.001
Phosphorus, dissolved orthophosphate as P	mg/L	17	88	.003	.002	<.001	<.001	.001	.002	.004	.007	.01	.001
Aluminum, total as Al	µg/L	2	100	--	--	60	--	--	--	--	--	1,300	10
Aluminum, dissolved as Al	µg/L	2	100	--	--	10	--	--	--	--	--	50	1
Antimony, dissolved as Sb	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Arsenic, total as As	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Barium, total as Ba	µg/L	2	0	--	--	<100	--	--	--	--	--	<100	100
Barium, dissolved as Ba	µg/L	2	100	--	--	18	--	--	--	--	--	31	1
Beryllium, total as Be	µg/L	2	0	--	--	<10	--	--	--	--	--	<10	10

Table 37. Summary of water-quality statistics for analyses of samples collected, water years 1995–97, at CC2 (fig. 1)—Continued

[--, insufficient data to calculate statistic; statistics estimated using robust log-probability regression technique for censored data described in Helsel and Cohn (1988); µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; %, percentage; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; mm, millimeters; T/d, tons per day]

Property or constituent	Units	Number of samples	Percent detections	Mean	Standard deviation	Min-imum	10th percentile	25th percentile	Median	75th percentile	90th percentile	Maxi-mum	Lowest reporting limit
Beryllium, dissolved as Be	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Cadmium, total as Cd	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Cadmium, dissolved as Cd	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Chromium, total as Cr	µg/L	2	50	--	--	<1	--	--	--	--	--	20	1
Chromium, dissolved as Cr	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Cobalt, total as Co	µg/L	2	50	--	--	<1	--	--	--	--	--	2	1
Cobalt, dissolved as Co	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Copper, total as Cu	µg/L	42	60	5	9	<1	<1	<1	1	2	20	39	1
Copper, dissolved as Cu	µg/L	42	57	1	.4	<1	1	1	1	1	2	2	1
Iron, total as Fe	µg/L	42	100	7,300	17,000	60	300	380	600	3,500	35,000	72,000	10
Iron, dissolved as Fe	µg/L	42	100	220	110	26	67	160	210	310	360	440	1
Lead, total as Pb	µg/L	42	31	5	12	<1	<1	<1	<1	2	20	54	1
Lead, dissolved as Pb	µg/L	8	0	--	--	<1	--	--	<1	--		<1	1
Manganese, total as Mn	µg/L	42	67	210	460	<10	1	3	21	98	970	1,900	10
Manganese, dissolved as Mn	µg/L	42	90	11	24	<1	1	2	3	9	23	130	1
Mercury, total as Hg	µg/L	2	0	--	--	<.1	--	--	--	--	--	<.1	.1
Molybdenum, total as Mo	µg/L	2	50	--	--	<1	--	--	--	--	--	1	1
Molybdenum, dissolved as Mo	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Nickel, total as Ni	µg/L	2	50	--	--	<1	--	--	--	--	--	6	1
Nickel, dissolved as Ni	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Selenium, total as Se	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Silver, total as Ag	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Silver, dissolved as Ag	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Zinc, total as Zn	µg/L	42	26	20	50	<10	<10	<10	<10	10	120	230	10
Zinc, dissolved as Zn	µg/L	42	40	3	3	<3	<3	<3	<3	5	7	17	3
Uranium, natural dissolved	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Carbon, organic total as C	mg/L	2	100	--	--	4.1	--	--	--	--	--	9.2	.1
Carbon, organic dissolved as C	mg/L	1	100	--	--	3.3	--	--	--	--	--	3.3	.1
Sediment, suspended, concentration	mg/L	55	94	93	270	<1	1	2	6	28	174	1,180	1
Sediment, suspended, % finer than 0.062 mm	%	22	100	66	24	34	35	42	65	87	100	100	1
Sediment, discharge	T/d	55	94	1.2	2.7	.001	.001	.01	.07	.52	6.6	13	.001

Table 38. Summary of water-quality statistics for analyses of samples collected, water years 1995–97, at CC5 (fig. 1)

[--, insufficient data to calculate statistic; statistics estimated using robust log-probability regression technique for censored data described in Helsel and Cohn (1988); **, 1995 data at higher detection limit not included in computations; µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; %, percentage; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; mm, millimeters; %, T/d, tons per day]

Property or constituent	Units	Number of samples	Percent detections	Mean	Standard deviation	Min-imum	10th percentile	25th percentile	Median	75th percentile	90th percentile	Max-imum	Lowest reporting limit
Specific conductance	µS/cm	62	100	69	13	51	55	59	64	81	87	96	1
pH	units	38	100	--	--	7.3	7.5	7.6	7.7	7.9	8.1	8.3	.1
Turbidity	NTU	49	100	22	36	.3	1.2	1.7	2.9	21	77	160	.1
Dissolved oxygen	mg/L	31	100	8.8	1	7.1	7.4	8	8.8	9.7	10.3	11.6	.1
Dissolved oxygen saturation	%	27	100	101	5	98	93	98	100	103	108	117	1
Hardness as $CaCO_3$	mg/L	16	100	28	4.2	25	25	25	27	29	36	40	1
Calcium, dissolved	mg/L	16	100	7	1	6.3	6.3	6.3	6.8	7.2	9.2	10	.1
Magnesium, dissolved	mg/L	16	100	2.5	.4	2.2	2.2	2.3	2.4	2.5	3.3	3.7	.1
Sodium, dissolved	mg/L	16	100	1.3	.2	1.1	1.2	1.2	1.2	1.3	1.5	1.8	.1
Potassium, dissolved	mg/L	16	100	.9	.3	.7	.7	.7	.9	1	1.4	2	.1
Acid-neutralizing capacity, lab as $CaCO_3$	mg/L	16	100	28	4.9	23	24	24	26	30	38	38	1
Sulfate, dissolved	mg/L	29	100	3.6	.9	2.2	2.9	3.1	3.4	3.7	4.3	6.6	.1
Chloride, dissolved	mg/L	34	100	.7	.4	.3	.3	.3	.6	1	1.3	1.9	.1
Fluoride, dissolved	mg/L	8	50	--	--	<.1	<.1	<.1	<.1	.1	.1	.1	.1
Silica, dissolved	mg/L	16	100	5.5	.5	4.3	4.6	5.2	5.5	5.9	6.1	6.1	.1
Dissolved solids, residue at 180 degrees Celsius	mg/L	30	100	45	9	23	34	39	44	52	61	64	1
Dissolved solids, sum of constituents	mg/L	16	100	39	5	35	36	37	37	39	46	53	1
Nitrite, dissolved as N	mg/L	8	12	--	--	<.01	<.01	<.01	<.01	<.01	.01	.01	.01
Nitrite plus nitrate, dissolved as N	mg/L	28	100	.09	.04	.048	.05	.06	.08	.11	.13	.2	.005
Nitrogen, ammonia, dissolved as N	mg/L	**18	28	<.002	.003	<.002	<.002	<.002	<.002	.002	.005	.02	.002
Nitrogen, ammonia plus organic, dissolved as N	mg/L	8	12	--	--	<.2	<.2	<.2	<.2	<.2	.3	.3	.2
Nitrogen, ammonia plus organic, total as N	mg/L	28	21	<.2	.3	<.2	<.2	<.2	<.2	<.2	.5	1.3	.2
Phosphorus, total as P	mg/L	28	96	.08	.25	.001	<.01	.01	.02	.07	.12	1.4	.001
Phosphorus, dissolved as P	mg/L	8	12	--	--	<.01	<.01	<.01	<.01	<.01	.01	.01	.001
Phosphorus, dissolved orthophosphate as P	mg/L	**18	50	.001	.001	<.001	<.001	<.001	.001	.002	.003	.02	.001
Aluminum, total as Al	µg/L	8	100	1,100	880	100	190	660	980	1,400	2,200	2,800	10
Aluminum, dissolved as Al	µg/L	8	100	45	35	7	16	28	35	52	78	120	1
Antimony, dissolved as Sb	µg/L	8	0	--	--	<1	--	--	<1	--	--	<1	1
Arsenic, total as As	µg/L	8	0	--	--	<1	--	--	<1	--	--	<1	1
Barium, total as Ba	µg/L	8	0	--	--	<100	--	--	<100	--	--	<100	100
Barium, dissolved as Ba	µg/L	8	100	28	1	27	27	27	28	28	29	30	1
Beryllium, total as Be	µg/L	8	0	--	--	<10	--	--	<10	--	--	<10	10

Table 38. Summary of water-quality statistics for analyses of samples collected, water years 1995–97, at CC5 (fig. 1)—Continued

[--, insufficient data to calculate statistic; statistics estimated using robust log-probability regression technique for censored data described in Helsel and Cohn (1988); **, 1995 data at higher detection limit not included in computations; µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; %, percentage; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; mm, millimeters; %, T/d, tons per day]

Property or constituent	Units	Number of samples	Percent detections	Mean	Standard deviation	Min-imum	10th percentile	25th percentile	Median	75th percentile	90th percentile	Max-imum	Lowest reporting limit
Beryllium, dissolved as Be	µg/L	8	0	--	--	<1	--	--	<1	--	--	<1	1
Cadmium, total as Cd	µg/L	11	0	--	--	<1	--	--	<1	--	--	<1	1
Cadmium, dissolved as Cd	µg/L	8	0	--	--	<1	--	--	<1	--	--	<1	1
Chromium, total as Cr	µg/L	8	75	3	3	<1	1	1	2	5	7	8	1
Chromium, dissolved as Cr	µg/L	8	12	--	--	<1	--	--	<1	--	--	1	1
Cobalt, total as Co	µg/L	8	62	2	1	<1	<1	1	2	3	3	3	1
Cobalt, dissolved as Co	µg/L	8	0	--	--	<1	--	--	<1	--	--	<1	1
Copper, total as Cu	µg/L	32	72	5	16	<1	<1	<1	1	3	6	92	1
Copper, dissolved as Cu	µg/L	29	24	1	<1	<1	<1	<1	<1	1	1	2	1
Iron, total as Fe	µg/L	32	100	5,400	1,900	120	250	330	700	3,400	7,500	110,000	10
Iron, dissolved as Fe	µg/L	29	100	110	63	35	54	72	97	120	200	320	1
Lead, total as Pb	µg/L	32	28	2	9	<1	<1	<1	<1	1	4	50	1
Lead, dissolved as Pb	µg/L	13	0			<1	<1	<1	<1	<1	<1	<1	1
Manganese, total as Mn	µg/L	32	88	130	400	<10	3	10	22	100	240	2,300	10
Manganese, dissolved as Mn	µg/L	29	100	7	3	2	4	6	7	8	12	19	1
Mercury, total as Hg	µg/L	8	0	--	--	<.1	--	--	<.1	--	--	<.1	.1
Molybdenum, total as Mo	µg/L	8	12	--	--	<1	--	--	<1	--	--	2	1
Molybdenum, dissolved as Mo	µg/L	8	0	--	--	<1	--	--	<1	--	--	<1	1
Nickel, total as Ni	µg/L	8	62	2	2	<1	<1	<1	1	4	4	5	1
Nickel, dissolved as Ni	µg/L	8	50	--	--	<1	--	--	1	--	--	1	1
Selenium, total as Se	µg/L	8	0	--	--	<1	--	--	<1	--	--	<1	1
Silver, total as Ag	µg/L	8	0	--	--	<1	--	--	<1	--	--	<1	1
Silver, dissolved as Ag	µg/L	8	0	--	--	<1	--	--	<1	--	--	<1	1
Zinc, total as Zn	µg/L	32	34	20	60	<10	<10	<10	<10	10	30	360	10
Zinc, dissolved as Zn	µg/L	29	55	3	3	<3	<3	<3	<3	4	7	10	3
Uranium, natural dissolved	µg/L	8	0	--	--	<1	--	--	<1	--	--	<1	1
Carbon, organic total as C	mg/L	7	100	4.6	3.7	2.1	--	--	3.5	--	--	13	.1
Carbon, organic dissolved as C	mg/L	4	100	1.6	.4	1.1	--	--	1.6	--	--	1.9	.1
Sediment, suspended, concentration	mg/L	71	100	38	69	1	3	5	14	40	85	441	1
Sediment, suspended, % finer than 0.062 mm	%	29	100	72	23	34	40	51	70	95	100	100	1
Sediment, load	T/d	71	100	4.1	14	.01	.02	.12	.57	2.7	6.4	113	.001

Table 39. Summary of water-quality statistics for analyses of samples collected, water years 1995–97, at CC7 (fig. 1)

[--, insufficient data to calculate statistic; statistics estimated using robust log-probability regression technique for censored data described in Helsel and Cohn (1988); **, 1995 data at higher detection limit not included in computations; µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; %, percentage; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; mm, millimeters; T/d, tons per day]

Property or constituent	Units	Number of samples	Percent detections	Mean	Standard deviation	Min-imum	10th percentile	25th percentile	Median	75th percentile	90th percentile	Max-imum	Lowest reporting limit
Specific conductance	µS/cm	43	100	92	15	68	--	--	87	--	--	115	1
pH	units	17	100	--	--	7.4	--	--	7.9	--	--	8.4	.1
Turbidity	NTU	26	100	3.1	4.6	.2	--	--	1.6	--	--	22	.1
Dissolved oxygen	mg/L	17	100	9.1	.8	7.6	--	--	9.1	--	--	11	.1
Dissolved oxygen saturation	%	12	100	103	7	93	--	--	101	--	--	116	1
Hardness as $CaCO_3$	mg/L	5	100	40	5	36	--	--	38	--	--	48	1
Calcium, dissolved	mg/L	5	100	11	1.4	9.7	--	--	10	--	--	13	.1
Magnesium, dissolved	mg/L	5	100	3.3	.4	3	--	--	3.1	--	--	3.8	.1
Sodium, dissolved	mg/L	5	100	1.5	.1	1.4	--	--	1.5	--	--	1.7	.1
Potassium, dissolved	mg/L	5	100	1.2	.1	1.1	--	--	1.2	--	--	1.3	.1
Acid-neutralizing capacity, lab as $CaCO_3$	mg/L	5	100	40	4.6	37	--	--	39	--	--	48	1
Sulfate, dissolved	mg/L	6	100	5.2	.6	4.5	--	--	5.2	--	--	5.9	.1
Chloride, dissolved	mg/L	6	100	1	.7	.5	--	--	.7	--	--	2.2	.1
Fluoride, dissolved	mg/L	4	100	.2	.1	.1	--	--	.2	--	--	.2	.1
Silica, dissolved	mg/L	5	100	6.4	.3	6.2	--	--	6.3	--	--	6.9	.1
Dissolved solids, residue at 180 degrees Celsius	mg/L	23	100	58	8	44	--	--	57	--	--	74	1
Dissolved solids, sum of constituents	mg/L	5	100	54	5	49	--	--	53	--	--	62	1
Nitrite, dissolved as N	mg/L	2	0	--	--	<.01	--	--	--	--	--	<.01	.01
Nitrite plus nitrate, dissolved as N	mg/L	6	100	.1	.01	.09	--	--	.1	--	--	.13	.005
Nitrogen, ammonia, dissolved as N	mg/L	**4	25	--	--	<.002	--	--	<.002	--	--	.002	.002
Nitrogen, ammonia plus organic, dissolved as N	mg/L	2	0	--	--	<.2	--	--	--	--	--	<.2	.2
Nitrogen, ammonia plus organic, total as N	mg/L	6	0	--	--	<.2	--	--	<.2	--	--	<.2	.2
Phosphorus, total as P	mg/L	**4	100	--	--	.001	--	--	.002	--	--	.002	.001
Phosphorus, dissolved as P	mg/L	2	0	--	--	<.01	--	--	--	--	--	<.01	.001
Phosphorus, dissolved orthophosphate as P	mg/L	**4	0	--	--	<.001	--	--	<.001	--	--	<.001	.001
Aluminum, total as Al	µg/L	2	100	--	--	30	--	--	--	--	--	90	10
Aluminum, dissolved as Al	µg/L	2	100	--	--	4	--	--	--	--	--	10	1
Antimony, dissolved as Sb	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Arsenic, total as As	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Barium, total as Ba	µg/L	2	0	--	--	<100	--	--	--	--	--	<100	100
Barium, dissolved as Ba	µg/L	2	100	--	--	26	--	--	--	--	--	29	1
Beryllium, total as Be	µg/L	2	0	--	--	<10	--	--	--	--	--	<10	10

Table 39. Summary of water-quality statistics for analyses of samples collected, water years 1995–97, at CC7 (fig. 1)—Continued

[--, insufficient data to calculate statistic; statistics estimated using robust log-probability regression technique for censored data described in Helsel and Cohn (1988); **, 1995 data at higher detection limit not included in computations; µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; %, percentage; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; mm, millimeters; T/d, tons per day]

Property or constituent	Units	Number of samples	Percent detections	Mean	Standard deviation	Min-imum	10th percentile	25th percentile	Median	75th percentile	90th percentile	Max-imum	Lowest reporting limit
Beryllium, dissolved as Be	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Cadmium, total as Cd	µg/L	2	0	--	--	<1	--	--	<1	--	--	<1	1
Cadmium, dissolved as Cd	µg/L	2	0	--	--	<1	--	--	<1	--	--	<1	1
Chromium, total as Cr	µg/L	2	50	--	--	<1	--	--	--	--	--	4	1
Chromium, dissolved as Cr	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Cobalt, total as Co	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Cobalt, dissolved as Co	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Copper, total as Cu	µg/L	6	0	--	--	<1	--	--	<1	--	--	<1	1
Copper, dissolved as Cu	µg/L	6	0	--	--	<1	--	--	<1	--	--	<1	1
Iron, total as Fe	µg/L	6	100	100	97	40	--	--	80	--	--	300	10
Iron, dissolved as Fe	µg/L	6	100	23	19	10	--	--	18	--	--	60	1
Lead, total as Pb	µg/L	6	17	--	--	<1	--	--	<1	--	--	1	1
Lead, dissolved as Pb	µg/L	4	0	--	--	<1	--	--	<1	--	--	<1	1
Manganese, total as Mn	µg/L	6	17	--	--	<10	--	--	<10	--	--	20	10
Manganese, dissolved as Mn	µg/L	6	33	--	--	<1	--	--	<1	--	--	2	1
Mercury, total as Hg	µg/L	2	0	--	--	<.1	--	--	--	--	--	<.1	.1
Molybdenum, total as Mo	µg/L	2	100	--	--	1	--	--	--	--	--	2	1
Molybdenum, dissolved as Mo	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Nickel, total as Ni	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Nickel, dissolved as Ni	µg/L	2	50	--	--	<1	--	--	--	--	--	1	1
Selenium, total as Se	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Silver, total as Ag	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Silver, dissolved as Ag	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Zinc, total as Zn	µg/L	6	0	--	--	<10	--	--	<10	--	--	<10	10
Zinc, dissolved as Zn	µg/L	6	66	--	--	<3	--	--	4	--	--	11	3
Uranium, natural dissolved	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Carbon, organic total as C	mg/L	2	100	--	--	2	--	--	--	--	--	2.2	.1
Carbon, organic dissolved as C	mg/L	1	100	--	--	1.2	--	--	--	--	--	1.2	.1
Sediment, suspended, concentration	mg/L	47	100	7	6	1	--	--	4	--	--	26	1
Sediment, suspended, % finer than 0.062 mm	%	13	100	71	21	26	--	--	69	--	--	100	1
Sediment, discharge	T/d	47	100	.59	.81	.01	--	--	.24	--	--	2.9	.001

Table 40. Summary of water-quality statistics for analyses of samples collected, water years 1995–97, at CC9 (fig. 1)

[--, insufficient data to calculate statistic; statistics estimated using robust log-probability regression technique for censored data described in Helsel and Cohn (1988); **, 1995 data at higher detection limit not included in computations; µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; %, percentage; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; mm, millimeters; T/d, tons per day]

Property or constituent	Units	Number of samples	Percent detections	Mean	Standard deviation	Min-imum	10th percentile	25th percentile	Median	75th percentile	90th percentile	Max-imum	Lowest reporting limit
Specific conductance	µS/cm	44	100	88	38	42	48	55	70	131	142	148	1
pH	units	19	100	--	--	7.0	7.2	7.4	7.5	7.8	8.2	8.8	.1
Turbidity	NTU	35	100	9.5	33	.2	.3	.6	1.5	2.8	9.2	190	.1
Dissolved oxygen	mg/L	16	100	9.7	.8	8.4	8.7	9.3	9.8	10.2	10.6	11.3	.1
Dissolved oxygen saturation	%	14	100	101	5.5	93	93	98	101	104	107	112	1
Hardness as $CaCO_3$	mg/L	5	100	31	17	17	--	--	24	--	--	59	1
Calcium, dissolved	mg/L	5	100	8.5	4.5	4.6	--	--	6.5	--	--	16	.1
Magnesium, dissolved	mg/L	5	100	2.4	1.3	1.3	--	--	2	--	--	4.7	.1
Sodium, dissolved	mg/L	5	100	1.3	.4	.9	--	--	1.1	--	--	2	.1
Potassium, dissolved	mg/L	5	100	.7	.2	.4	--	--	.6	--	--	1	.1
Acid-neutralizing capacity, lab as $CaCO_3$	mg/L	5	100	18	7	12	--	--	17	--	--	30	1
Sulfate, dissolved	mg/L	6	100	16	10	7.9	--	--	12	--	--	35	.1
Chloride, dissolved	mg/L	6	100	.3	.2	.1	--	--	.3	--	--	.7	.1
Fluoride, dissolved	mg/L	3	67	--	--	<.1	--	--	.2	--	--	.2	.1
Silica, dissolved	mg/L	5	100	6.2	1.2	4.8	--	--	5.9	--	--	8	.1
Dissolved solids, residue at 180 degrees Celsius	mg/L	28	100	55	18	32	--	--	51	--	--	97	1
Dissolved solids, sum of constituents	mg/L	5	100	48	23	28	--	--	37	--	--	86	1
Nitrite, dissolved as N	mg/L	2	0	--	--	<.01	--	--	--	--	--	<.01	.01
Nitrite plus nitrate, dissolved as N	mg/L	**3	100	--	--	.044	--	--	.085	--	--	.01	.005
Nitrogen, ammonia, dissolved as N	mg/L	**2	50	--	--	<.002	--	--	--	--	--	.003	.002
Nitrogen, ammonia plus organic, dissolved as N	mg/L	2	50	--	--	<.2	--	--	--	--	--	.2	.2
Nitrogen, ammonia plus organic, total as N	mg/L	6	0	--	--	<.2	--	--	<.2	--	--	<.2	.2
Phosphorus, total as P	mg/L	**3	67	--	--	<.001	--	--	.008	--	--	.066	.001
Phosphorus, dissolved as P	mg/L	2	0	--	--	<.01	--	--	--	--	--	<.01	.001
Phosphorus, dissolved orthophosphate as P	mg/L	**2	100	--	--	.001	--	--	.002	--	--	.002	.001
Aluminum, total as Al	µg/L	2	100	--	--	40	--	--	--	--	--	1,100	10
Aluminum, dissolved as Al	µg/L	2	100	--	--	20	--	--	--	--	--	100	1
Antimony, dissolved as Sb	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Arsenic, total as As	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Barium, total as Ba	µg/L	2	0	--	--	<100	--	--	--	--	--	<100	100
Barium, dissolved as Ba	µg/L	2	100	--	--	27	--	--	--	--	--	28	1
Beryllium, total as Be	µg/L	2	0	--	--	<10	--	--	--	--	--	<10	10

Table 40. Summary of water-quality statistics for analyses of samples collected, water years 1995–97, at CC9 (fig. 1)—Continued

[--, insufficient data to calculate statistic; statistics estimated using robust log-probability regression technique for censored data described in Helsel and Cohn (1988); **, 1995 data at higher detection limit not included in computations; µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; %, percentage; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; mm, millimeters; T/d, tons per day]

Property or constituent	Units	Number of samples	Percent detections	Mean	Standard deviation	Min-imum	10th percentile	25th percentile	Median	75th percentile	90th percentile	Max-imum	Lowest reporting limit
Beryllium, dissolved as Be	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Cadmium, total as Cd	µg/L	3	33	--	--	<1	--	--	<1	--	--	2	1
Cadmium, dissolved as Cd	µg/L	3	0	--	--	<1	--	--	<1	--	--	<1	1
Chromium, total as Cr	µg/L	2	50	--	--	<1	--	--	--	--	--	2	1
Chromium, dissolved as Cr	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Cobalt, total as Co	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Cobalt, dissolved as Co	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Copper, total as Cu	µg/L	7	100	7	5	1	--	--	6	--	--	14	1
Copper, dissolved as Cu	µg/L	6	83	--	--	<1	--	--	4	--	--	8	1
Iron, total as Fe	µg/L	7	100	760	970	10	--	--	320	--	--	2,600	10
Iron, dissolved as Fe	µg/L	6	100	52	39	4	--	--	50	--	--	110	1
Lead, total as Pb	µg/L	7	100	33	28	2	--	--	36	--	--	71	1
Lead, dissolved as Pb	µg/L	4	100	--	--	1	--	--	2	--	--	2	1
Manganese, total as Mn	µg/L	7	71	--	--	<10	--	--	80	--	--	370	10
Manganese, dissolved as Mn	µg/L	6	100	23	16	7	--	--	18	--	--	47	1
Mercury, total as Hg	µg/L	2	0	--	--	<.1	--	--	--	--	--	<.1	.1
Molybdenum, total as Mo	µg/L	2	50	--	--	<1	--	--	--	--	--	2	1
Molybdenum, dissolved as Mo	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Nickel, total as Ni	µg/L	2	100	--	--	1	--	--	--	--	--	3	1
Nickel, dissolved as Ni	µg/L	2	100	--	--	1	--	--	--	--	--	2	1
Selenium, total as Se	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Silver, total as Ag	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Silver, dissolved as Ag	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Zinc, total as Zn	µg/L	7	100	220	100	130	--	--	190	--	--	430	10
Zinc, dissolved as Zn	µg/L	6	100	170	72	80	--	--	170	--	--	250	3
Uranium, natural dissolved	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Carbon, organic total as C	mg/L	2	100	--	--	1.7	--	--	--	--	--	7.2	.1
Carbon, organic dissolved as C	mg/L	1	100	--	--	1.2	--	--	--	--	--	1.2	.1
Sediment, suspended, concentration	mg/L	53	94	20	51	<1	1	3	4	16	39	347	1
Sediment, suspended, % finer than 0.062 mm	%	19	100	51	24	22	27	33	44	62	91	100	1
Sediment, discharge	T/d	53	94	--	--	<.004	--	--	.23	--	--	91	.001

Table 41. Summary of water-quality statistics for analyses of samples collected, water years 1995–97, at CC11 (fig. 1)

[--, insufficient data to calculate statistic; statistics estimated using robust log-probability regression technique for censored data described in Helsel and Cohn (1988); **, 1995 data at higher detection limit not included in computations; µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; %, percentage; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; mm, millimeters; T/d, tons per day]

Property or constituent	Units	Number of samples	Percent detections	Mean	Standard deviation	Minimum	10th percentile	25th percentile	Median	75th percentile	90th percentile	Maximum	Lowest reporting limit
Specific conductance	µS/cm	10	100	46	10	34	35	38	42	58	59	59	1
pH	units	9	100	--	--	7.9	7.9	7.9	7.9	7.9	8	8.2	.1
Turbidity	NTU	10	100	1.4	.6	.8	.8	.9	1.3	1.8	2.4	2.5	.1
Dissolved oxygen	mg/L	10	100	8.8	.9	7.4	8.1	8.2	8.6	9.4	10.2	10.2	.1
Dissolved oxygen saturation	%	7	100	101	1	99	100	100	101	102	102	103	1
Hardness as $CaCO_3$	mg/L	4	100	20	5.3	15	--	--	19	--	--	25	1
Calcium, dissolved	mg/L	4	100	5.8	1.6	4.3	--	--	5.6	--	--	7.4	.1
Magnesium, dissolved	mg/L	4	100	1.2	.3	.9	--	--	1.2	--	--	1.5	.1
Sodium, dissolved	mg/L	4	100	1.6	.3	1.3	--	--	1.6	--	--	1.9	.1
Potassium, dissolved	mg/L	4	100	.7	.1	.6	--	--	.6	--	--	.8	.1
Acid-neutralizing capacity, lab as $CaCO_3$	mg/L	4	100	20	6	14	--	--	20	--	--	26	1
Sulfate, dissolved	mg/L	5	100	2.7	.6	2.1	--	--	2.4	--	--	3.4	.1
Chloride, dissolved	mg/L	5	100	.2	.06	.2	--	--	.2	--	--	.3	.1
Fluoride, dissolved	mg/L	2	100	--	--	.2	--	--	--	--	--	.3	.1
Silica, dissolved	mg/L	4	100	7.8	1.3	6.4	--	--	7.8	--	--	9.1	.1
Dissolved solids, residue at 180 degrees Celsius	mg/L	4	100	45	8.3	36	--	--	44	--	--	56	1
Dissolved solids, sum of constituents	mg/L	3	100	35	8	25	--	--	39	--	--	40	1
Nitrite, dissolved as N	mg/L	1	0	--	--	<.01	--	--	--	--	--	<.01	.01
Nitrite plus nitrate, dissolved as N	mg/L	5	100	.059	.016	.039	--	--	.058	--	--	.083	.005
Nitrogen, ammonia, dissolved as N	mg/L	**3	0	--	--	<.002	--	--	<.002	--	--	<.002	.002
Nitrogen, ammonia plus organic, dissolved as N	mg/L	1	0	--	--	<.2	--	--	--	--	--	<.2	.2
Nitrogen, ammonia plus organic, total as N	mg/L	5	20	--	--	<.2	--	--	<.2	--	--	.2	.2
Phosphorus, total as P	mg/L	**4	100	--	--	.005	--	--	.008	--	--	.008	.001
Phosphorus, dissolved as P	mg/L	1	0	--	--	<.01	--	--	--	--	--	<.01	.001
Phosphorus, dissolved orthophosphate as P	mg/L	**3	67	--	--	<.001	--	--	.001	--	--	.002	.001
Aluminum, total as Al	µg/L	1	100	--	--	20	--	--	--	--	--	20	10
Aluminum, dissolved as Al	µg/L	1	100	--	--	10	--	--	--	--	--	10	1
Antimony, dissolved as Sb	µg/L	1	0	--	--	<1	--	--	--	--	--	<1	1
Arsenic, total as As	µg/L	1	0	--	--	<1	--	--	--	--	--	<1	1
Barium, total as Ba	µg/L	1	0	--	--	<100	--	--	--	--	--	<100	100
Barium, dissolved as Ba	µg/L	1	100	--	--	17	--	--	--	--	--	17	1
Beryllium, total as Be	µg/L	1	0	--	--	<10	--	--	--	--	--	<10	10

Table 41. Summary of water-quality statistics for analyses of samples collected, water years 1995–97, at CC11 (fig. 1)—Continued

[--, insufficient data to calculate statistic; statistics estimated using robust log-probability regression technique for censored data described in Helsel and Cohn (1988); **, 1995 data at higher detection limit not included in computations; µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; %, percentage; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; mm, millimeters; T/d, tons per day]

Property or constituent	Units	Number of samples	Percent detections	Mean	Standard deviation	Min-imum	10th percentile	25th percentile	Median	75th percentile	90th percentile	Max-imum	Lowest reporting limit
Beryllium, dissolved as Be	µg/L	1	0	--	--	<1	--	--	--	--	--	<1	1
Cadmium, total as Cd	µg/L	1	0	--	--	<1	--	--	--	--	--	<1	1
Cadmium, dissolved as Cd	µg/L	1	0	--	--	<1	--	--	--	--	--	<1	1
Chromium, total as Cr	µg/L	1	0	--	--	<1	--	--	--	--	--	<1	1
Chromium, dissolved as Cr	µg/L	1	0	--	--	<1	--	--	--	--	--	<1	1
Cobalt, total as Co	µg/L	1	0	--	--	<1	--	--	--	--	--	<1	1
Cobalt, dissolved as Co	µg/L	1	0	--	--	<1	--	--	--	--	--	<1	1
Copper, total as Cu	µg/L	5	20	--	--	<1	--	--	<1	--	--	1	1
Copper, dissolved as Cu	µg/L	5	60	--	--	<1	--	--	1	--	--	2	1
Iron, total as Fe	µg/L	5	100	260	66	160	--	--	290	--	--	320	10
Iron, dissolved as Fe	µg/L	5	100	110	42	70	--	--	110	--	--	170	1
Lead, total as Pb	µg/L	5	0	--	--	<1	--	--	<1	--	--	<1	1
Lead, dissolved as Pb	µg/L	3	0	--	--	<1	--	--	<1	--	--	<1	1
Manganese, total as Mn	µg/L	5	40	--	--	<10	--	--	<10	--	--	10	10
Manganese, dissolved as Mn	µg/L	5	100	3	2	2	--	--	2	--	--	6	1
Mercury, total as Hg	µg/L	1	0	--	--	<.1	--	--	--	--	--	<.1	.1
Molybdenum, total as Mo	µg/L	1	100	--	--	2	--	--	--	--	--	2	1
Molybdenum, dissolved as Mo	µg/L	1	0	--	--	<1	--	--	--	--	--	<1	1
Nickel, total as Ni	µg/L	1	0	--	--	<1	--	--	--	--	--	<1	1
Nickel, dissolved as Ni	µg/L	1	0	--	--	<1	--	--	--	--	--	<1	1
Selenium, total as Se	µg/L	1	0	--	--	<1	--	--	--	--	--	<1	1
Silver, total as Ag	µg/L	1	0	--	--	<1	--	--	--	--	--	<1	1
Silver, dissolved as Ag	µg/L	1	0	--	--	<1	--	--	--	--	--	<1	1
Zinc, total as Zn	µg/L	5	0	--	--	<10	--	--	<10	--	--	<10	10
Zinc, dissolved as Zn	µg/L	5	20	--	--	<3	--	--	<3	--	--	4	3
Uranium, natural dissolved	µg/L	1	0	--	--	<1	--	--	--	--	--	<1	1
Carbon, organic total as C	mg/L	1	100	--	--	2.6	--	--	--	--	--	2.6	.1
Carbon, organic dissolved as C	mg/L	1	100	--	--	2.1	--	--	--	--	--	2.1	.1
Sediment, suspended, concentration	mg/L	11	91	6	9	<1	1	2	2	8	11	32	1
Sediment, suspended, % finer than 0.062 mm	%	3	100	--	--	36	--	--	67	--	--	77	1
Sediment, discharge	T/d	8	100	.16	.25	.004	.02	.03	.04	.13	.46	.71	.001

Table 42. Summary of water-quality statistics for analyses of samples collected, water years 1995–97, at GC1 (fig. 1)

[--, insufficient data to calculate statistic; statistics estimated using robust log-probability regression technique for censored data described in Helsel and Cohn (1988); **, 1995 data at higher detection limit not included in computations; µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; %, percentage; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; mm, millimeters; T/d, tons per day]

Property or constituent	Units	Number of samples	Percent detections	Mean	Standard deviation	Min-imum	10th percentile	25th percentile	Median	75th percentile	90th percentile	Max-imum	Lowest reporting limit
Specific conductance	µS/cm	5	100	33	4	29	--	--	31	--	--	37	1
pH	units	7	100	7.6	.2	7.4	7.5	7.5	7.5	7.7	7.8	7.9	.1
Turbidity	NTU	5	100	1.6	.5	1	--	--	1.5	--	--	2.1	.1
Dissolved oxygen	mg/L	8	100	7.7	.6	6.7	7.1	7.3	7.7	8.1	8.5	8.6	.1
Dissolved oxygen saturation	%	7	100	102	6	97	97	98	99	106	111	112	1
Hardness as $CaCO_3$	mg/L	4	100	--	--	10	--	--	12	--	--	14	1
Calcium, dissolved	mg/L	4	100	--	--	2.8	--	--	3.4	--	--	3.9	.1
Magnesium, dissolved	mg/L	4	100	--	--	.8	--	--	.9	--	--	1.1	.1
Sodium, dissolved	mg/L	4	100	--	--	.7	--	--	.8	--	--	1	.1
Potassium, dissolved	mg/L	4	100	--	--	.6	--	--	.6	--	--	.7	.1
Acid-neutralizing capacity, lab as $CaCO_3$	mg/L	4	100	--	--	12	--	--	12	--	--	15	1
Sulfate, dissolved	mg/L	5	100	2.3	.4	1.8	--	--	2.2	--	--	3	.1
Chloride, dissolved	mg/L	5	60	--	--	<.1	--	--	.1	--	--	.4	.1
Fluoride, dissolved	mg/L	3	33	--	--	<.1	--	--	<.1	--	--	.1	.1
Silica, dissolved	mg/L	4	100	--	--	4.1	--	--	4.4	--	--	5.6	.1
Dissolved solids, residue at 180 degrees Celsius	mg/L	4	100	--	--	16	--	--	24	--	--	27	1
Dissolved solids, sum of constituents	mg/L	3	100	--	--	20	--	--	20	--	--	25	1
Nitrite, dissolved as N	mg/L	2	50	--	--	<.01	--	--	--	--	--	.01	.01
Nitrite plus nitrate, dissolved as N	mg/L	**3	100	--	--	.02	--	--	.033	--	--	.039	.005
Nitrogen, ammonia, dissolved as N	mg/L	**2	0	--	--	<.002	--	--	--	--	--	<.002	.002
Nitrogen, ammonia plus organic, dissolved as N	mg/L	2	0	--	--	<.2	--	--	--	--	--	<.2	.2
Nitrogen, ammonia plus organic, total as N	mg/L	5	20	--	--	<.2	--	--	<.2	--	--	.2	.2
Phosphorus, total as P	mg/L	**3	100	--	--	.01	--	--	.01	--	--	.011	.001
Phosphorus, dissolved as P	mg/L	2	0	--	--	<.01	--	--	--	--	--	<.01	.001
Phosphorus, dissolved orthophosphate as P	mg/L	**2	100	--	--	.001	--	--	--	--	--	.001	.001
Aluminum, total as Al	µg/L	2	100	--	--	20	--	--	--	--	--	90	10
Aluminum, dissolved as Al	µg/L	2	100	--	--	5	--	--	--	--	--	30	1
Antimony, dissolved as Sb	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Arsenic, total as As	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Barium, total as Ba	µg/L	2	0	--	--	<100	--	--	--	--	--	<100	100
Barium, dissolved as Ba	µg/L	2	100	--	--	16	--	--	--	--	--	16	1
Beryllium, total as Be	µg/L	2	0	--	--	<10	--	--	--	--	--	<10	10

Table 42. Summary of water-quality statistics for analyses of samples collected, water years 1995–97, at GC1 (fig. 1)—Continued

[--, insufficient data to calculate statistic; statistics estimated using robust log-probability regression technique for censored data described in Helsel and Cohn (1988); **, 1995 data at higher detection limit not included in computations; µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; %, percentage; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; mm, millimeters; T/d, tons per day]

Property or constituent	Units	Number of samples	Percent detections	Mean	Standard deviation	Min-imum	10th percentile	25th percentile	Median	75th percentile	90th percentile	Max-imum	Lowest reporting limit
Beryllium, dissolved as Be	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Cadmium, total as Cd	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Cadmium, dissolved as Cd	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Chromium, total as Cr	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Chromium, dissolved as Cr	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Cobalt, total as Co	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Cobalt, dissolved as Co	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Copper, total as Cu	µg/L	5	20	--	--	<1	--	--	<1	--	--	1	1
Copper, dissolved as Cu	µg/L	5	20	--	--	<1	--	--	<1	--	--	1	1
Iron, total as Fe	µg/L	5	100	200	80	100	--	--	210	--	--	310	10
Iron, dissolved as Fe	µg/L	5	100	90	30	50	--	--	90	--	--	110	1
Lead, total as Pb	µg/L	5	0	--	--	<1	--	--	<1	--	--	<1	1
Lead, dissolved as Pb	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Manganese, total as Mn	µg/L	5	60	--	--	<10	--	--	10	--	--	20	10
Manganese, dissolved as Mn	µg/L	5	100	3	1	2	--	--	3	--	--	4	1
Mercury, total as Hg	µg/L	2	0	--	--	<.1	--	--	--	--	--	<.1	.1
Molybdenum, total as Mo	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Molybdenum, dissolved as Mo	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Nickel, total as Ni	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Nickel, dissolved as Ni	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Selenium, total as Se	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Silver, total as Ag	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Silver, dissolved as Ag	µg/L	2	50	--	--	<1	--	--	--	--	--	1	1
Zinc, total as Zn	µg/L	5	0	--	--	<10	--	--	<10	--	--	<10	10
Zinc, dissolved as Zn	µg/L	5	60	--	--	<3	--	--	<3	--	--	6	3
Uranium, natural dissolved	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Carbon, organic total as C	mg/L	2	100	--	--	1.9	--	--	--	--	--	3.1	.1
Carbon, organic dissolved as C	mg/L	1	100	--	--	1.1	--	--	--	--	--	1.1	.1
Sediment, suspended, concentration	mg/L	5	80	--	--	<1	--	--	3	--	--	6	1
Sediment, suspended, % finer than 0.062 mm	%	2	100	--	--	48	--	--		--	--	73	1
Sediment, discharge	T/d	5	80	--	--	<.003	--	--	.02	--	--	.1	.001

Table 43. Summary of water-quality statistics for analyses of samples collected, water years 1995–97, at GC2 (fig. 1)

[--, insufficient data to calculate statistic; statistics estimated using robust log-probability regression technique for censored data described in Helsel and Cohn (1988); **, 1995 data at higher detection limit not included in computations; µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; %, percentage; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; mm, millimeters; T/d, tons per day]

Property or constituent	Units	Number of samples	Percent detections	Mean	Standard deviation	Min-imum	10th percentile	25th percentile	Median	75th percentile	90th percentile	Max-imum	Lowest reporting limit
Specific conductance	µS/cm	6	100	39	14	23	--	--	40	--	--	55	1
pH	units	8	100	--	--	7	--	--	7.6	7.7	7.8	7.8	.1
Turbidity	NTU	6	100	3	.8	2	--	--	2.8	--	--	4.3	.1
Dissolved oxygen	mg/L	8	100	8.1	1	6.7	6.8	7.3	8.2	8.6	9.2	9.6	.1
Dissolved oxygen saturation	%	5	100	100	6	94	95	96	100	101	106	109	1
Hardness as $CaCO_3$	mg/L	4	100	--	--	9	--	--	11	--	--	22	1
Calcium, dissolved	mg/L	4	100	--	--	2.6	--	--	3	--	--	6.1	.1
Magnesium, dissolved	mg/L	4	100	--	--	.7	--	--	.8	--	--	1.6	.1
Sodium, dissolved	mg/L	4	100	--	--	.9	--	--	1	--	--	2	.1
Potassium, dissolved	mg/L	4	100	--	--	.5	--	--	.6	--	--	.7	.1
Acid-neutralizing capacity, lab as $CaCO_3$	mg/L	4	100	--	--	9	--	--	11	--	--	22	1
Sulfate, dissolved	mg/L	5	100	2.4	1.2	1.4	--	--	1.8	--	--	4.2	.1
Chloride, dissolved	mg/L	5	100	.5	.4	.2	--	--	.3	--	--	1.1	.1
Fluoride, dissolved	mg/L	2	100	--	--	.2	--	--	--	--	--	.4	.1
Silica, dissolved	mg/L	4	100	--	--	5.1	--	--	5.6	--	--	9.8	.1
Dissolved solids, residue at 180 degrees Celsius	mg/L	4	100	--	--	26	--	--	30	--	--	41	1
Dissolved solids, sum of constituents	mg/L	4	100	--	--	18	--	--	22	--	--	38	1
Nitrite, dissolved as N	mg/L	2	0	--	--	<.01	--	--	--	--	--	<.01	.01
Nitrite plus nitrate, dissolved as N	mg/L	**3	100	--	--	.017	--	--	.019	--	--	.029	.005
Nitrogen, ammonia, dissolved as N	mg/L	**2	100	--	--	.002	--	--	--	--	--	.003	.002
Nitrogen, ammonia plus organic, dissolved as N	mg/L	2	50	--	--	<.2	--	--	--	--	--	.3	.2
Nitrogen, ammonia plus organic, total as N	mg/L	5	80	--	--	<.2	--	--	.2	--	--	.3	.2
Phosphorus, total as P	mg/L	5	100	--	--	.009	--	--	.013	--	--	.04	.001
Phosphorus, dissolved as P	mg/L	2	50	--	--	<.01	--	--	--	--	--	.04	.001
Phosphorus, dissolved orthophosphate as P	mg/L	**2	100	--	--	.001	--	--	--	--	--	.004	.001
Aluminum, total as Al	µg/L	2	100	--	--	30	--	--	--	--	--	150	10
Aluminum, dissolved as Al	µg/L	2	100	--	--	20	--	--	--	--	--	30	1
Antimony, dissolved as Sb	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Arsenic, total as As	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Barium, total as Ba	µg/L	2	0	--	--	<100	--	--	--	--	--	<100	100
Barium, dissolved as Ba	µg/L	2	100	--	--	16	--	--	--	--	--	28	1
Beryllium, total as Be	µg/L	2	0	--	--	<10	--	--	--	--	--	<10	10

Table 43. Summary of water-quality statistics for analyses of samples collected, water years 1995–97, at GC2 (fig. 1)—Continued

[--, insufficient data to calculate statistic; statistics estimated using robust log-probability regression technique for censored data described in Helsel and Cohn (1988); **, 1995 data at higher detection limit not included in computations; µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; %, percentage; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; mm, millimeters; T/d, tons per day]

Property or constituent	Units	Number of samples	Percent detections	Mean	Standard deviation	Min-imum	10th percentile	25th percentile	Median	75th percentile	90th percentile	Max-imum	Lowest reporting limit
Beryllium, dissolved as Be	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Cadmium, total as Cd	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Cadmium, dissolved as Cd	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Chromium, total as Cr	µg/L	2	100	--	--	2	--	--	--	--	--	2	1
Chromium, dissolved as Cr	µg/L	2	50	--	--	<1	--	--	--	--	--	1	1
Cobalt, total as Co	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Cobalt, dissolved as Co	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Copper, total as Cu	µg/L	5	20	--	--	<1	--	--	<1	--	--	1	1
Copper, dissolved as Cu	µg/L	5	20	--	--	<1	--	--	<1	--	--	1	1
Iron, total as Fe	µg/L	5	100	740	220	510	--	--	720	--	--	1,100	10
Iron, dissolved as Fe	µg/L	5	100	400	150	270	--	--	370	--	--	640	1
Lead, total as Pb	µg/L	5	0	--	--	<1	--	--	<1	--	--	<1	1
Lead, dissolved as Pb	µg/L	3	0	--	--	<1	--	--	<1	--	--	<1	1
Manganese, total as Mn	µg/L	5	60	--	--	<10	--	--	10	--	--	10	10
Manganese, dissolved as Mn	µg/L	5	100	7	2	5	--	--	6	--	--	10	1
Mercury, total as Hg	µg/L	2	0	--	--	<.1	--	--	--	--	--	<.1	.1
Molybdenum, total as Mo	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Molybdenum, dissolved as Mo	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Nickel, total as Ni	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Nickel, dissolved as Ni	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Selenium, total as Se	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Silver, total as Ag	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Silver, dissolved as Ag	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Zinc, total as Zn	µg/L	5	0	--	--	<10	--	--	<10	--	--	<10	10
Zinc, dissolved as Zn	µg/L	5	100	7	3	4	--	--	6	--	--	12	3
Uranium, natural dissolved	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Carbon, organic total as C	mg/L	2	100	--	--	2.9	--	--	--	--	--	5.7	.1
Carbon, organic dissolved as C	mg/L	1	100	--	--	2.2	--	--	--	--	--	2.2	.1
Sediment, suspended, concentration	mg/L	6	100	6	4	2	--	--	6	--	--	12	1
Sediment, suspended, % finer than 0.062 mm	%	4	100	--	--	61	--	--	79	--	--	100	1
Sediment, discharge	T/d	5	100	.095	.12	.005	--	--	.01	--	--	.25	.001

Table 44. Summary of water-quality statistics for analyses of samples collected, water years 1995–97, at GC5 (fig. 1)

[--, insufficient data to calculate statistic; statistics estimated using robust log-probability regression technique for censored data described in Helsel and Cohn (1988); µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; %, percentage; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; mm, millimeters; T/d, tons per day]

Property or constituent	Units	Number of samples	Percent detections	Mean	Standard deviation	Min-imum	10th percent-ile	25th percent-ile	Median	75th percent-ile	90th percent-ile	Max-imum	Lowest reporting limit
Specific conductance	µS/cm	45	100			37			47			60	1
pH	units	47	100	--	--	7.1	--	--	7.7	--	--	8.3	.1
Turbidity	NTU	43	100			.9			2.3			100	.1
Dissolved oxygen	mg/L	42	100	8.4	.8	7.2	7.5	7.8	8.2	8.7	9.6	10.4	.1
Dissolved oxygen saturation	%	32	100	99	3	91	94	97	99	101	104	105	1
Hardness as $CaCO_3$	mg/L	31	100	17	2.4	13	15	15	17	19	20	22	1
Calcium, dissolved	mg/L	31	100	5.1	.7	3.8	4.3	4.4	5.1	5.8	6	6.4	.1
Magnesium, dissolved	mg/L	31	100	1.1	.1	.9	1	1	1.1	1.2	1.3	1.4	.1
Sodium, dissolved	mg/L	31	100	1.6	.2	1.2	1.3	1.4	1.7	1.8	1.9	1.9	.1
Potassium, dissolved	mg/L	31	100	.9	.1	.7	.7	.8	.9	1	1	1.1	.1
Acid-neutralizing capacity, lab as $CaCO_3$	mg/L	30	100	19	2	15	16	17	19	21	22	24	1
Sulfate, dissolved	mg/L	40	100	3.2	.7	2.1	2.3	2.8	3.2	3.5	4.5	4.9	.1
Chloride, dissolved	mg/L	40	100	.6	.2	.3	.3	.4	.5	.7	.8	1.5	.1
Fluoride, dissolved	mg/L	7	100	.2	.04	.2	.2	.2	.2	.2	.2	.3	.1
Silica, dissolved	mg/L	31	100	7.4	.5	6.3	6.6	7	7.3	8	8.1	8.2	.1
Dissolved solids, residue at 180 degrees Celsius	mg/L	31	100	37	13	10	22	28	36	45	55	70	1
Dissolved solids, sum of constituents	mg/L	30	100			25			32			37	1
Nitrite, dissolved as N	mg/L	2	0	--	--	<.01	--	--	--	--	--	<.01	.01
Nitrite plus nitrate, dissolved as N	mg/L	39	97	.048	.03	.006	.011	.023	.048	.065	.1	.11	.005
Nitrogen, ammonia, dissolved as N	mg/L	16	31	.006	.012	<.002	<.002	<.002	<.002	.003	.032	.033	.002
Nitrogen, ammonia plus organic, dissolved as N	mg/L	2	0	--	--	<.2	--	--	--	--	--	<.2	.2
Nitrogen, ammonia plus organic, total as N	mg/L	39	13	--	--	<.2	--	--	<.2	--	--	.4	.2
Phosphorus, total as P	mg/L	37	100	.011	.018	.002	.002	.004	.006	.008	.026	.097	.001
Phosphorus, dissolved as P	mg/L	2	0	--	--	<.01	--	--	--	--	--	<.01	.01
Phosphorus, dissolved orthophosphate as P	mg/L	16	75	.001	.001	<.001	.001	.001	.001	.002	.002	.01	.001
Aluminum, total as Al	µg/L	2	100	--	--	30	--	--	--	--	--	270	10
Aluminum, dissolved as Al	µg/L	2	100	--	--	6	--	--	--	--	--	30	1
Antimony, dissolved as Sb	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Arsenic, total as As	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Barium, total as Ba	µg/L	2	0	--	--	<100	--	--	--	--	--	<100	100
Barium, dissolved as Ba	µg/L	2	100	--	--	24	--	--	--	--	--	28	1
Beryllium, total as Be	µg/L	2	0	--	--	<10	--	--	--	--	--	<10	10

Table 44. Summary of water-quality statistics for analyses of samples collected, water years 1995–97, at GC5 (fig. 1)—Continued

[--, insufficient data to calculate statistic; statistics estimated using robust log-probability regression technique for censored data described in Helsel and Cohn (1988); µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; %, percentage; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; mm, millimeters; T/d, tons per day]

Property or constituent	Units	Number of samples	Percent detections	Mean	Standard deviation	Min-imum	10th percent-ile	25th percent-ile	Median	75th percent-ile	90th percent-ile	Max-imum	Lowest reporting limit
Beryllium, dissolved as Be	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Cadmium, total as Cd	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Cadmium, dissolved as Cd	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Chromium, total as Cr	µg/L	2	50	--	--	<1	--	--	--	--	--	3	1
Chromium, dissolved as Cr	µg/L	2	50	--	--	<1	--	--	--	--	--	2	1
Cobalt, total as Co	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Cobalt, dissolved as Co	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Copper, total as Cu	µg/L	45	38	1	1	<1	<1	<1	<1	2	2	5	1
Copper, dissolved as Cu	µg/L	40	22	1	.5	<1	<1	<1	<1	1	1	3	1
Iron, total as Fe	µg/L	45	100	650	850	140	170	210	300	740	2,000	4,000	10
Iron, dissolved as Fe	µg/L	40	100	84	47	43	45	52	70	99	140	270	1
Lead, total as Pb	µg/L	45	13	--	--	<1	--	--	<1	--	--	5	1
Lead, dissolved as Pb	µg/L	8	0	--	--	<1	<1	<1	<1	<1	<1	<1	1
Manganese, total as Mn	µg/L	45	62	20	20	<10	<10	<10	10	25	60	100	10
Manganese, dissolved as Mn	µg/L	40	98	6	4	<1	2	3	5	6	10	19	1
Mercury, total as Hg	µg/L	2	0	--	--	<.1	--	--	--	--	--	<.1	.1
Molybdenum, total as Mo	µg/L	2	100	--	--	1	--	--	--	--	--	1	1
Molybdenum, dissolved as Mo	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Nickel, total as Ni	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Nickel, dissolved as Ni	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Selenium, total as Se	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Silver, total as Ag	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Silver, dissolved as Ag	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Zinc, total as Zn	µg/L	45	9	--	--	<10	--	--	<10	--	--	30	10
Zinc, dissolved as Zn	µg/L	40	45	3	2	<3	<3	<3	<3	4	6	20	3
Uranium, natural dissolved	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Carbon, organic total as C	mg/L	2	100	--	--	2.3	--	--	--	--	--	4.7	.1
Carbon, organic dissolved as C	mg/L	1	100	--	--	1.4	--	--	--	--	--	1.4	.1
Sediment, suspended, concentration	mg/L	54	96	8.2	13	<1	1	2	5	8	17	92	1
Sediment, suspended, % finer than 0.062 mm	%	23	100	65	22	29	36	48	63	83	100	100	1
Sediment, discharge	T/d	54	100	.68	2.5	.003	.01	.01	.12	.42	1	17	.001

Table 45. Summary of water-quality statistics for analyses of samples collected, water years 1995–97, at GC7 (fig. 1)

[--, insufficient data to calculate statistic; statistics estimated using robust log-probability regression technique for censored data described in Helsel and Cohn (1988); **, 1995 data at higher detection limit not included in computations; µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; %, percentage; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; mm, millimeters; T/d, tons per day]

Property or constituent	Units	Number of samples	Percent detections	Mean	Standard deviation	Min-imum	10th percent-ile	25th percent-ile	Median	75th percent-ile	90th percent-ile	Max-imum	Lowest reporting limit
Specific conductance	µS/cm	8	100	79	18	59	62	66	76	87	102	110	1
pH	units	13	100	5.4	1.3	3.9	4	4.8	5	6.8	7.1	7.8	.1
Turbidity	NTU	8	100	24	33	.9	2.4	5.3	8	25	71	90	.1
Dissolved oxygen	mg/L	12	100	9.1	1.2	7.7	7.9	8.2	8.9	9.8	10.4	11.3	.1
Dissolved oxygen saturation	%	8	100	104	5.8	97	98	100	102	106	111	114	1
Hardness as $CaCO_3$	mg/L	3	100	--	--	22	--	--	24	--	--	35	1
Calcium, dissolved	mg/L	3	100	--	--	5.4	--	--	6.1	--	--	8.1	.1
Magnesium, dissolved	mg/L	3	100	--	--	2	--	--	2.2	--	--	3.5	.1
Sodium, dissolved	mg/L	3	100	--	--	1	--	--	1.2	--	--	1.4	.1
Potassium, dissolved	mg/L	3	100	--	--	.8	--	--	.9	--	--	.9	.1
Acid-neutralizing capacity, lab as $CaCO_3$	mg/L	3	100	--	--	<.1	--	--	4.6	--	--	5	1
Sulfate, dissolved	mg/L	5	100	30	14	18	--	--	23	--	--	50	.1
Chloride, dissolved	mg/L	5	100	.4	.3	.1	--	--	.2	--	--	.7	.1
Fluoride, dissolved	mg/L	2	50	--	--	<.1	--	--		--	--	.1	.1
Silica, dissolved	mg/L	3	100	--	--	5.8	--	--	7.2	--	--	9.5	.1
Dissolved solids, residue at 180 degrees Celsius	mg/L	3	100	--	--	41	--	--	70	--	--	79	1
Dissolved solids, sum of constituents	mg/L	2	100	--	--	37	--	--	--	--	--	45	1
Nitrite, dissolved as N	mg/L	2	0	--	--	<.01	--	--	--	--	--	<.01	.01
Nitrite plus nitrate, dissolved as N	mg/L	5	100	.075	.007	.07	--	--	.07	--	--	.085	.005
Nitrogen, ammonia, dissolved as N	mg/L	**2	50	--	--	<.002	--	--	--	--	--	.005	.002
Nitrogen, ammonia plus organic, dissolved as N	mg/L	2	0	--	--	<.2	--	--	--	--	--	<.2	.2
Nitrogen, ammonia plus organic, total as N	mg/L	5	20	--	--	<.2	--	--	<.2	--	--	.7	.2
Phosphorus, total as P	mg/L	**3	100	--	--	.002	--	--	.004	--	--	.01	.001
Phosphorus, dissolved as P	mg/L	2	0	--	--	<.01	--	--	--	--	--	<.01	.001
Phosphorus, dissolved orthophosphate as P	mg/L	2	50	--	--	<.001	--	--	--	--	--	.002	.001
Aluminum, total as Al	µg/L	2	100	--	--	2,500	--	--	--	--	--	3,600	10
Aluminum, dissolved as Al	µg/L	2	100	--	--	120	--	--	--	--	--	1,800	1
Antimony, dissolved as Sb	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Arsenic, total as As	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Barium, total as Ba	µg/L	2	0	--	--	<100	--	--	--	--	--	<100	100
Barium, dissolved as Ba	µg/L	2	100	--	--	30	--	--	--	--	--	38	1
Beryllium, total as Be	µg/L	2	0	--	--	<10	--	--	--	--	--	<10	10

Table 45. Summary of water-quality statistics for analyses of samples collected, water years 1995–97, at GC7 (fig. 1)—Continued

[--, insufficient data to calculate statistic; statistics estimated using robust log-probability regression technique for censored data described in Helsel and Cohn (1988); **, 1995 data at higher detection limit not included in computations; µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; %, percentage; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; mm, millimeters; T/d, tons per day]

Property or constituent	Units	Number of samples	Percent detections	Mean	Standard deviation	Min-imum	10th percent-ile	25th percent-ile	Median	75th percent-ile	90th percent-ile	Max-imum	Lowest reporting limit
Beryllium, dissolved as Be	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Cadmium, total as Cd	µg/L	2	50	--	--	<1	--	--	--	--	--	1	1
Cadmium, dissolved as Cd	µg/L	2	50	--	--	<1	--	--	--	--	--	1	1
Chromium, total as Cr	µg/L	2	50	--	--	<1	--	--	--	--	--	6	1
Chromium, dissolved as Cr	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Cobalt, total as Co	µg/L	2	100	--	--	2	--	--	--	--	--	5	1
Cobalt, dissolved as Co	µg/L	2	50	--	--	<1	--	--	--	--	--	5	1
Copper, total as Cu	µg/L	5	100	13	6	6	--	--	17	--	--	18	1
Copper, dissolved as Cu	µg/L	5	100	8	8	2	--	--	3	--	--	18	1
Iron, total as Fe	µg/L	5	100	5,100	8,900	1,000	--	--	1,200	--	--	21,000	10
Iron, dissolved as Fe	µg/L	5	100	330	110	210	--	--	290	--	--	480	1
Lead, total as Pb	µg/L	5	20	--	--	<1	--	--	<1	--	--	7	1
Lead, dissolved as Pb	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Manganese, total as Mn	µg/L	5	100	280	160	150	--	--	190	--	--	530	10
Manganese, dissolved as Mn	µg/L	5	100	270	170	120	--	--	190	--	--	520	1
Mercury, total as Hg	µg/L	2	0	--	--	<.1	--	--	--	--	--	<.1	.1
Molybdenum, total as Mo	µg/L	2	50	--	--	<1	--	--	--	--	--	1	1
Molybdenum, dissolved as Mo	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Nickel, total as Ni	µg/L	2	100	--	--	5	--	--	--	--	--	11	1
Nickel, dissolved as Ni	µg/L	2	100	--	--	2	--	--	--	--	--	11	1
Selenium, total as Se	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Silver, total as Ag	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Silver, dissolved as Ag	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Zinc, total as Zn	µg/L	5	100	90	60	40	--	--	70	--	--	180	10
Zinc, dissolved as Zn	µg/L	5	100	96	68	24	--	--	67	--	--	190	3
Uranium, natural dissolved	µg/L	2	50	--	--	<1	--	--	--	--	--	1	1
Carbon, organic total as C	mg/L	2	100	--	--	1	--	--	--	--	--	6.2	.1
Carbon, organic dissolved as C	mg/L	0	--	--	--	--	--	--	--	--	--	--	.1
Sediment, suspended, concentration	mg/L	10	100	70	112	7	8	9	18	94	144	365	1
Sediment, suspended, % finer than 0.062 mm	%	5	100	81	14	66	--	--	83	--	--	100	1
Sediment, discharge	T/d	8	100	9.6	16.9	.38	--	--	1.6	--	--	49	.001

Table 46. Summary of water-quality statistics for analyses of samples collected, water years 1995–97, at GC8 (fig. 1)

[--, insufficient data to calculate statistic; statistics estimated using robust log-probability regression technique for censored data described in Helsel and Cohn (1988); **, 1995 data at higher detection limit not included in computations; µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; %, percentage; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; mm, millimeters; T/d, tons per day]

Property or constituent	Units	Number of samples	Percent detections	Mean	Standard deviation	Min-imum	10th percentile	25th percentile	Median	75th percentile	90th percentile	Max-imum	Lowest reporting limit
Specific conductance	µS/cm	10	100	41	7	32	35	36	41	44	49	55	1
pH	units	10	100	--	--	7.2	7.2	7.4	7.8	7.9	8	8	.1
Turbidity	NTU	10	100	12	24	1	1.1	1.6	2.2	7.2	23	80	.1
Dissolved oxygen	mg/L	10	100	9	.9	7.7	8.1	8.5	8.7	9.2	10.3	10.7	.1
Dissolved oxygen saturation	%	5	100	101	4	96	97	99	99	103	105	107	1
Hardness as $CaCO_3$	mg/L	3	100	--	--	14	--	--	14	--	--	17	1
Calcium, dissolved	mg/L	3	100	--	--	3.5	--	--	3.6	--	--	4.5	.1
Magnesium, dissolved	mg/L	3	100	--	--	1.2	--	--	1.2	--	--	1.5	.1
Sodium, dissolved	mg/L	3	100	--	--	1	--	--	1.1	--	--	1.4	.1
Potassium, dissolved	mg/L	3	100	--	--	.5	--	--	.6	--	--	.8	.1
Acid-neutralizing capacity, lab as $CaCO_3$	mg/L	3	100	--	--	10	--	--	10	--	--	14	1
Sulfate, dissolved	mg/L	5	100	6.5	1.3	5.3	--	--	5.8	--	--	8.3	.1
Chloride, dissolved	mg/L	5	100	.3	.2	.1	--	--	.3	--	--	.6	.1
Fluoride, dissolved	mg/L	2	0	--	--	<.1	--	--	--	--	--	<.1	.1
Silica, dissolved	mg/L	3	100	--	--	5.8	--	--	6.1	--	--	8	.1
Dissolved solids, residue at 180 degrees Celsius	mg/L	3	100	--	--	34	--	--	37	--	--	52	1
Dissolved solids, sum of constituents	mg/L	3	100	--	--	25	--	--	25	--	--	33	1
Nitrite, dissolved as N	mg/L	2	0	--	--	<.01	--	--	--	--	--	<.01	.01
Nitrite plus nitrate, dissolved as N	mg/L	**3	100	--	--	.025	--	--	.051	--	--	.067	.005
Nitrogen, ammonia, dissolved as N	mg/L	**2	50	--	--	<.002	--	--	--	--	--	.003	.002
Nitrogen, ammonia plus organic, dissolved as N	mg/L	2	0	--	--	<.2	--	--	--	--	--	<.2	.2
Nitrogen, ammonia plus organic, total as N	mg/L	5	40	--	--	<.2	--	--	<.2	--	--	1.2	.2
Phosphorus, total as P	mg/L	**3	100	--	--	.002	--	--	.007	--	--	.032	.001
Phosphorus, dissolved as P	mg/L	2	50	--	--	<.01	--	--	--	--	--	.01	.001
Phosphorus, dissolved orthophosphate as P	mg/L	**2	50	--	--	<.001	--	--	--	--	--	.001	.001
Aluminum, total as Al	µg/L	2	100	--	--	100	--	--	--	--	--	4,600	10
Aluminum, dissolved as Al	µg/L	2	100	--	--	40	--	--	--	--	--	140	1
Antimony, dissolved as Sb	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Arsenic, total as As	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Barium, total as Ba	µg/L	2	50	--	--	<100	--	--	--	--	--	100	100
Barium, dissolved as Ba	µg/L	2	100	--	--	26	--	--	--	--	--	26	1
Beryllium, total as Be	µg/L	2	0	--	--	<10	--	--	--	--	--	<10	10

Table 46. Summary of water-quality statistics for analyses of samples collected, water years 1995–97, at GC8 (fig. 1)—Continued

[--, insufficient data to calculate statistic; statistics estimated using robust log-probability regression technique for censored data described in Helsel and Cohn (1988); **, 1995 data at higher detection limit not included in computations; µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; %, percentage; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; mm, millimeters; T/d, tons per day]

Property or constituent	Units	Number of samples	Percent detections	Mean	Standard deviation	Minimum	10th percentile	25th percentile	Median	75th percentile	90th percentile	Maximum	Lowest reporting limit
Beryllium, dissolved as Be	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Cadmium, total as Cd	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Cadmium, dissolved as Cd	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Chromium, total as Cr	µg/L	2	50	--	--	<1	--	--	--	--	--	9	1
Chromium, dissolved as Cr	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Cobalt, total as Co	µg/L	2	50	--	--	<1	--	--	--	--	--	10	1
Cobalt, dissolved as Co	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Copper, total as Cu	µg/L	5	100	6	6	1	1	1	3	10	12	14	1
Copper, dissolved as Cu	µg/L	5	40	--	--	<1	--	--	<1	--	--	2	1
Iron, total as Fe	µg/L	5	100	1,700	3,000	120	120	130	260	1,000	4,700	7,100	10
Iron, dissolved as Fe	µg/L	5	100	66	31	38	45	55	57	61	96	120	1
Lead, total as Pb	µg/L	5	20	--	--	<1	--	--	<1	--	--	5	1
Lead, dissolved as Pb	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Manganese, total as Mn	µg/L	5	100	140	230	20	20	20	20	80	360	550	10
Manganese, dissolved as Mn	µg/L	5	100	12	4	8	8	9	11	16	17	18	1
Mercury, total as Hg	µg/L	2	0	--	--	<.1	--	--	--	--	--	<.1	.1
Molybdenum, total as Mo	µg/L	2	100	--	--	1	--	--	--	--	--	2	1
Molybdenum, dissolved as Mo	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Nickel, total as Ni	µg/L	2	50	--	--	<1	--	--	--	--	--	17	1
Nickel, dissolved as Ni	µg/L	2	50	--	--	<1	--	--	--	--	--	2	1
Selenium, total as Se	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Silver, total as Ag	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Silver, dissolved as Ag	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Zinc, total as Zn	µg/L	5	60	--	--	<10	--	--	10	--	--	90	10
Zinc, dissolved as Zn	µg/L	5	100	--	--	5	--	--	5	--	--	7	3
Uranium, natural dissolved	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Carbon, organic total as C	mg/L	2	2	--	--	1.9	--	--	--	--	--	19	.1
Carbon, organic dissolved as C	mg/L	1	1	--	--	1.2	--	--	--	--	--	1.2	.1
Sediment, suspended, concentration	mg/L	10	10	37	55	2	2	4	10	37	110	166	1
Sediment, suspended, % finer than 0.062 mm	%	5	5	67	33	14	34	63	71	88	95	100	1
Sediment, discharge	T/d	7	7	3.4	7.3	.03	.042	.13	.4	1.7	9.2	20	.001

Table 47. Summary of water-quality statistics for analyses of samples collected, water years 1995–97, at GC10 (fig. 1)

[--, insufficient data to calculate statistic; statistics estimated using robust log-probability regression technique for censored data described in Helsel and Cohn (1988); **, 1995 data at higher detection limit not included in computations; µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; %, percentage; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; mm, millimeters; T/d, tons per day]

Property or constituent	Units	Number of samples	Percent detections	Mean	Standard deviation	Min-imum	10th percentile	25th percentile	Median	75th percentile	90th percentile	Max-imum	Lowest reporting limit
Specific conductance	µS/cm	9	100	36	7	26	27	31	36	40	43	45	1
pH	units	10	100	--	--	7.3	7.3	7.4	7.7	7.8	7.9	8.1	.1
Turbidity	NTU	9	100	5.5	7.6	1.5	1.7	2	2.2	5	11	25	.1
Dissolved oxygen	mg/L	10	100	9.1	1.1	7.4	8	8.4	9.1	9.6	10.2	11	.1
Dissolved oxygen saturation	%	7	100	103	5	97	98	98	104	106	108	110	1
Hardness as $CaCO_3$	mg/L	3	100	--	--	10	--	--	13	--	--	16	1
Calcium, dissolved	mg/L	3	100	--	--	2.9	--	--	4.1	--	--	4.8	.1
Magnesium, dissolved	mg/L	3	100	--	--	.6	--	--	.8	--	--	.9	.1
Sodium, dissolved	mg/L	3	100	--	--	.8	--	--	1.6	--	--	1.7	.1
Potassium, dissolved	mg/L	3	100	--	--	.6	--	--	.8	--	--	1.1	.1
Acid-neutralizing capacity, lab as $CaCO_3$	mg/L	3	100	--	--	11	--	--	15	--	--	18	1
Sulfate, dissolved	mg/L	5	100	2	.4	1.3	--	--	2	--	--	2.4	.1
Chloride, dissolved	mg/L	5	100	.3	.2	.1	--	--	.3	--	--	.6	.1
Fluoride, dissolved	mg/L	2	100	--	--	.1	--	--	--	--	--	.1	.1
Silica, dissolved	mg/L	3	100	--	--	4.4	--	--	8.7	--	--	8.8	.1
Dissolved solids, residue at 180 degrees Celsius	mg/L	3	100	--	--	26	--	--	29	--	--	34	1
Dissolved solids, sum of constituents	mg/L	3	100	--	--	19	--	--	28	--	--	31	1
Nitrite, dissolved as N	mg/L	2	0	--	--	<.01	--	--	--	--	--	<.01	.01
Nitrite plus nitrate, dissolved as N	mg/L	5	100	.05	.02	.033	--	--	.06	--	--	.071	.005
Nitrogen, ammonia, dissolved as N	mg/L	**2	0	--	--	<.002	--	--	--	--	--	<.002	.002
Nitrogen, ammonia plus organic, dissolved as N	mg/L	2	50	--	--	<.2	--	--	--	--	--	.2	.2
Nitrogen, ammonia plus organic, total as N	mg/L	5	60	--	--	<.2	--	--	.2	--	--	.7	.2
Phosphorus, total as P	mg/L	5	100	.04	.07	.008	--	--	.013	--	--	.17	.001
Phosphorus, dissolved as P	mg/L	2	50	--	--	<.01	--	--	--	--	--	.02	.001
Phosphorus, dissolved orthophosphate as P	mg/L	**2	100	--	--	.001	--	--	--	--	--	.002	.001
Aluminum, total as Al	µg/L	2	100	--	--	40	--	--	--	--	--	1,900	10
Aluminum, dissolved as Al	µg/L	2	100	--	--	10	--	--	--	--	--	40	1
Antimony, dissolved as Sb	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Arsenic, total as As	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Barium, total as Ba	µg/L	2	0	--	--	<100	--	--	--	--	--	<100	100
Barium, dissolved as Ba	µg/L	2	100	--	--	16	--	--	--	--	--	18	1

Table 47. Summary of water-quality statistics for analyses of samples collected, water years 1995–97, at GC10 (fig. 1)—Continued

[--, insufficient data to calculate statistic; statistics estimated using robust log-probability regression technique for censored data described in Helsel and Cohn (1988); **, 1995 data at higher detection limit not included in computations; µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; %, percentage; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; mm, millimeters; T/d, tons per day]

Property or constituent	Units	Number of samples	Percent detections	Mean	Standard deviation	Min-imum	10th percentile	25th percentile	Median	75th percentile	90th percentile	Max-imum	Lowest reporting limit
Beryllium, total as Be	µg/L	2	0	--	--	<10	--	--	--	--	--	<10	10
Beryllium, dissolved as Be	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Cadmium, total as Cd	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Cadmium, dissolved as Cd	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Chromium, total as Cr	µg/L	2	50	--	--	<1	--	--	--	--	--	3	1
Chromium, dissolved as Cr	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Cobalt, total as Co	µg/L	2	50	--	--	<1	--	--	--	--	--	2	1
Cobalt, dissolved as Co	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Copper, total as Cu	µg/L	5	20	--	--	<1	--	--	<1	--	--	2	1
Copper, dissolved as Cu	µg/L	5	0	--	--	<1	--	--	<1	--	--	<1	1
Iron, total as Fe	µg/L	5	100	2,200	3,100	480	--	--	790	--	--	7,700	10
Iron, dissolved as Fe	µg/L	5	100	280	50	210	--	--	280	--	--	330	1
Lead, total as Pb	µg/L	5	20	--	--	<1	--	--	<1	--	--	2	1
Lead, dissolved as Pb	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Manganese, total as Mn	µg/L	5	100	60	90	10	--	--	20	--	--	210	10
Manganese, dissolved as Mn	µg/L	5	100	5	3	3	--	--	4	--	--	10	1
Mercury, total as Hg	µg/L	2	0	--	--	<.1	--	--	--	--	--	<.1	.1
Molybdenum, total as Mo	µg/L	2	50	--	--	<1	--	--	--	--	--	1	1
Molybdenum, dissolved as Mo	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Nickel, total as Ni	µg/L	2	50	--	--	<1	--	--	--	--	--	2	1
Nickel, dissolved as Ni	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Selenium, total as Se	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Silver, total as Ag	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Silver, dissolved as Ag	µg/L	2	50	--	--	<1	--	--	--	--	--	2	1
Zinc, total as Zn	µg/L	5	0	--	--	<10	--	--	<10	--	--	<10	10
Zinc, dissolved as Zn	µg/L	5	60	--	--	<3	--	--	<3	--	--	4	3
Uranium, natural dissolved	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Carbon, organic total as C	mg/L	2	100	--	--	2.9	--	--	--	--	--	11	.1
Carbon, organic dissolved as C	mg/L	1	100	--	--	1.9	--	--	--	--	--	1.9	.1
Sediment, suspended, concentration	mg/L	9	100	26	44	2	2	3	8	21	52	139	1
Sediment, suspended, % finer than 0.062 mm	%	6	100	75	26	40	--	--	82	--	--	100	1
Sediment, discharge	T/d	7	100	9.7	22	.1	--	--	1.8	--	--	60	.001

Table 48. Summary of water-quality statistics for analyses of samples collected, water years 1995–97, at GC11 (fig. 1)

[--, insufficient data to calculate statistic; statistics estimated using robust log-probability regression technique for censored data described in Helsel and Cohn (1988); **, 1995 data at higher detection limit not included in computations; µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; %, percentage; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; mm, millimeters; T/d, tons per day]

Property or constituent	Units	Number of samples	Percent detections	Mean	Standard deviation	Min-imum	10th percentile	25th percentile	Median	75th percentile	90th percentile	Max-imum	Lowest reporting limit
Specific conductance	µS/cm	38	100	65	18	41	48	49	56	87	91	96	1
pH	units	47	100	--	--	7	7.1	7.3	7.5	7.7	7.8	7.9	.1
Turbidity	NTU	29	100	7.6	17	2.3	2.9	3.4	4.3	5.5	6.7	94	.1
Dissolved oxygen	mg/L	40	100	8.9	1	7.2	7.9	8.2	8.8	9.6	10.8	10.9	.1
Dissolved oxygen saturation	%	37	100	100	4.7	88	93	98	100	103	106	112	1
Hardness as $CaCO_3$	mg/L	26	100	21	5.3	15	16	17	19	25	30	33	1
Calcium, dissolved	mg/L	26	100	5.5	1.4	3.9	4.4	4.5	4.9	6.6	7.9	8.7	.1
Magnesium, dissolved	mg/L	26	100	1.7	.5	1.2	1.3	1.4	1.5	2.1	2.5	2.7	.1
Sodium, dissolved	mg/L	26	100	1.6	.5	1.2	1.2	1.3	1.4	2	2.5	2.9	.1
Potassium, dissolved	mg/L	26	100	.8	.2	.6	.6	.7	.8	.9	1.1	1.2	.1
Acid-neutralizing capacity, lab as $CaCO_3$	mg/L	26	100	9.8	2.2	5.8	7.2	8.9	9.4	11	12	18	1
Sulfate, dissolved	mg/L	39	100	15	6	7.7	9.7	11	13	16	28	31	.1
Chloride, dissolved	mg/L	39	97	.3	.1	<.1	.2	.2	.3	.3	.6	.7	.1
Fluoride, dissolved	mg/L	4	75	--	--	<.1	--	--	.2	--	--	.2	.1
Silica, dissolved	mg/L	26	100	8.1	1.5	6.3	6.6	6.9	7.4	9.4	11	12	.1
Dissolved solids, residue at 180 degrees Celsius	mg/L	26	100	47	15	28	33	36	43	54	72	86	1
Dissolved solids, sum of constituents	mg/L	25	100	41	11	29	32	33	35	48	57	64	1
Nitrite, dissolved as N	mg/L	2	0	--	--	<.01	--	--	--	--	--	<.01	.01
Nitrite plus nitrate, dissolved as N	mg/L	38	100	.06	.02	.024	.04	.05	.06	.07	.09	.13	.005
Nitrogen, ammonia, dissolved as N	mg/L	**18	50	.005	.008	<.002	<.002	<.002	<.002	.004	.022	.031	.002
Nitrogen, ammonia plus organic, dissolved as N	mg/L	2	50	--	--	<.2	--	--	--	--	--	.2	.2
Nitrogen, ammonia plus organic, total as N	mg/L	38	29	<.2	.1	<.2	<.2	<.2	<.2	.2	.3	.4	.2
Phosphorus, total as P	mg/L	36	100	.034	.09	.003	.004	.007	.011	.017	.054	.52	.001
Phosphorus, dissolved as P	mg/L	2	0	--	--	<.01	--	--	--	--	--	<.01	.001
Phosphorus, dissolved orthophosphate as P	mg/L	**18	72	.001	.001	<.001	<.001	.001	.001	.002	.002	.01	.001
Aluminum, total as Al	µg/L	2	100	--	--	750	--	--	--	--	--	11,000	10
Aluminum, dissolved as Al	µg/L	2	100	--	--	60	--	--	--	--	--	120	1
Antimony, dissolved as Sb	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Arsenic, total as As	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Barium, total as Ba	µg/L	2	50	--	--	<100	--	--	--	--	--	100	100
Barium, dissolved as Ba	µg/L	2	100	--	--	18	--	--	--	--	--	30	1
Beryllium, total as Be	µg/L	2	0	--	--	<10	--	--	--	--	--	<10	10

Table 48. Summary of water-quality statistics for analyses of samples collected, water years 1995–97, at GC11 (fig. 1)—Continued

[--, insufficient data to calculate statistic; statistics estimated using robust log-probability regression technique for censored data described in Helsel and Cohn (1988); **, 1995 data at higher detection limit not included in computations; µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; %, percentage; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; mm, millimeters; T/d, tons per day]

Property or constituent	Units	Number of samples	Percent detections	Mean	Standard deviation	Min-imum	10th percentile	25th percentile	Median	75th percentile	90th percentile	Max-imum	Lowest reporting limit
Beryllium, dissolved as Be	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Cadmium, total as Cd	µg/L	5	20	--	--	<1	--	--	<1	--	--	1	1
Cadmium, dissolved as Cd	µg/L	3	0	--	--	<1	--	--	<1	--	--	<1	1
Chromium, total as Cr	µg/L	2	50	--	--	<1	--	--	--	--	--	16	1
Chromium, dissolved as Cr	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Cobalt, total as Co	µg/L	2	100	--	--	1	--	--	--	--	--	10	1
Cobalt, dissolved as Co	µg/L	2	50	--	--	<1	--	--	--	--	--	1	1
Copper, total as Cu	µg/L	43	100	7	8	2	3	4	5	9	12	53	1
Copper, dissolved as Cu	µg/L	39	100	1.9	<1	1	1	2	2	2	2	4	1
Iron, total as Fe	µg/L	43	100	2,200	3,800	230	470	570	840	1,800	6,400	23,000	10
Iron, dissolved as Fe	µg/L	39	95	120	78	<3	12	77	120	160	210	430	1
Lead, total as Pb	µg/L	43	30	2	4	<1	<1	<1	<1	1	4	25	1
Lead, dissolved as Pb	µg/L	7	14	--	--	<1	--	--	--	--	--	1	1
Manganese, total as Mn	µg/L	43	100	160	130	60	70	80	130	180	270	900	10
Manganese, dissolved as Mn	µg/L	39	100	110	54	30	52	62	100	130	180	250	1
Mercury, total as Hg	µg/L	2	0	--	--	<.1	--	--	--	--	--	<.1	.1
Molybdenum, total as Mo	µg/L	2	100	--	--	1	--	--	--	--	--	2	1
Molybdenum, dissolved as Mo	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Nickel, total as Ni	µg/L	2	100	--	--	4	--	--	--	--	--	17	1
Nickel, dissolved as Ni	µg/L	2	100	--	--	1	--	--	--	--	--	3	1
Selenium, total as Se	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Silver, total as Ag	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Silver, dissolved as Ag	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Zinc, total as Zn	µg/L	43	100	50	29	<3	20	30	40	60	80	180	10
Zinc, dissolved as Zn	µg/L	39	97	31	18	20	13	17	27	36	57	85	3
Uranium, natural dissolved	µg/L	2	0	--	--	<1	--	--	--	--	--	<1	1
Carbon, organic total as C	mg/L	2	100	--	--	2.3	--	--	--	--	--	33	.1
Carbon, organic dissolved as C	mg/L	1	100	--	--	1.4	--	--	--	--	--	1.4	.1
Sediment, suspended, concentration	mg/L	48	100	38	140	4	6	7	8	12	22	939	1
Sediment, suspended, % finer than 0.062 mm	%	19	100	68	24	20	31	56	69	80	100	100	
Sediment, load	T/d	48	100	50	215	.2	.28	.43	1.8	5.7	18	1,370	.001

Table 49. Summary of water-quality statistics for analyses of samples collected, water years 1995–97, at DC1 (fig. 1)

[--, insufficient data to calculate statistic; statistics estimated using robust log-probability regression technique for censored data described in Helsel and Cohn (1988); µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; %, percentage; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; mm, millimeters; T/d, tons per day]

Property or constituents	Units	Number of samples	Percent detections	Mean	Standard deviation	Min-imum	10th percentile	25th percentile	Median	75th percentile	90th percentile	Max-imum	Lowest reporting limit
Specific conductance	µS/cm	33	100	40	7	30	32	34	38	46	52	56	1
pH	units	43	100	--	--	7.3	--	--	7.6	--	--	8	.1
Turbidity	NTU	29	100	2.4	5.4	.3	.4	.6	.7	1.7	6.3	29	.1
Dissolved oxygen	mg/L	27	100	9.1	.8	7.6	8	8.6	8.9	9.6	10.4	11	.1
Dissolved oxygen saturation	%	22	100	101	7	88	90	99	100	106	114	117	1
Hardness as $CaCO_3$	mg/L	28	100	14	2.1	11	11	12	13	15	18	19	1
Calcium, dissolved	mg/L	28	100	3.7	.5	3	3.1	3.3	3.7	4	4.7	5	.1
Magnesium, dissolved	mg/L	28	100	1	.2	.8	.8	.9	1	1.1	1.4	1.5	.1
Sodium, dissolved	mg/L	28	100	1.7	.2	1.4	1.5	1.5	1.6	1.8	1.9	2.2	.1
Potassium, dissolved	mg/L	28	100	.7	.1	.5	.5	.6	.6	.8	.8	1	.1
Acid-neutralizing capacity, lab as $CaCO_3$	mg/L	26	100	16	2.1	12	13	14	16	17	19	21	1
Sulfate, dissolved	mg/L	44	100	2.5	.4	1.7	2.1	2.2	2.4	2.7	3	3.4	.1
Chloride, dissolved	mg/L	44	98	.2	.1	<.1	.1	.2	.2	.3	.4	.5	.1
Fluoride, dissolved	mg/L	1	0	--	--	<.1	--	--	--	--	--	<.1	.1
Silica, dissolved	mg/L	28	100	9.1	.9	7.3	7.8	8.3	9.2	9.7	10	11	.1
Dissolved solids, residue at 180 degrees Celsius	mg/L	28	100	36	17	16	22	24	33	45	60	94	1
Nitrite, dissolved as N	mg/L	--	--	--	--	--	--	--	--	--	--	--	.01
Nitrite plus nitrate, dissolved as N	mg/L	43	100	.073	.035	.026	.04	.056	.066	.08	.1	.22	.005
Nitrogen, ammonia, dissolved as N	mg/L	20	35	.005	.01	<.002	<.002	<.002	<.002	.006	.023	.036	.002
Nitrogen, ammonia plus organic, dissolved as N	mg/L	--	--	--	--	--	--	--	--	--	--	--	.2
Nitrogen, ammonia plus organic, total as N	mg/L	43	26	<.2	<.2	<.2	<.2	<.2	<.2	.2	.4	.6	.2
Phosphorus, total as P	mg/L	43	100	.015	.023	.001	.003	.005	.006	.011	.045	.099	.001
Phosphorus, dissolved as P	mg/L	--	--	--	--	--	--	--	--	--	--	--	.001
Phosphorus, dissolved orthophosphate as P	mg/L	20	70	.001	.001	<.001	<.001	.001	.001	.002	.003	.003	.001
Aluminum, total as Al	µg/L	--	--	--	--	--	--	--	--	--	--	--	10
Aluminum, dissolved as Al	µg/L	--	--	--	--	--	--	--	--	--	--	--	1
Antimony, dissolved as Sb	µg/L	--	--	--	--	--	--	--	--	--	--	--	1
Arsenic, total as As	µg/L	--	--	--	--	--	--	--	--	--	--	--	1
Barium, total as Ba	µg/L	--	--	--	--	--	--	--	--	--	--	--	100
Barium, dissolved as Ba	µg/L	--	--	--	--	--	--	--	--	--	--	--	1
Beryllium, total as Be	µg/L	--	--	--	--	--	--	--	--	--	--	--	10
Beryllium, dissolved as Be	µg/L	--	--	--	--	--	--	--	--	--	--	--	1

Table 49. Summary of water-quality statistics for analyses of samples collected, water years 1995–97, at DC1 (fig. 1)—Continued

[--, insufficient data to calculate statistic; statistics estimated using robust log-probability regression technique for censored data described in Helsel and Cohn (1988); µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; %, percentage; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; mm, millimeters; T/d, tons per day]

Property or constituents	Units	Number of samples	Percent detections	Mean	Standard deviation	Min-imum	10th percentile	25th percentile	Median	75th percentile	90th percentile	Max-imum	Lowest reporting limit
Cadmium, total as Cd	µg/L	--	--	--	--	--	--	--	--	--	--	--	1
Cadmium, dissolved as Cd	µg/L	--	--	--	--	--	--	--	--	--	--	--	1
Chromium, total as Cr	µg/L	--	--	--	--	--	--	--	--	--	--	--	1
Chromium, dissolved as Cr	µg/L	--	--	--	--	--	--	--	--	--	--	--	1
Cobalt, total as Co	µg/L	--	--	--	--	--	--	--	--	--	--	--	1
Cobalt, dissolved as Co	µg/L	--	--	--	--	--	--	--	--	--	--	--	1
Copper, total as Cu	µg/L	47	34	1	1	<1	<1	<1	<1	1	3	5	1
Copper, dissolved as Cu	µg/L	44	25	1	1	<1	<1	<1	<1	1	1	4	1
Iron, total as Fe	µg/L	47	100	500	890	20	50	70	140	520	1,600	4,400	10
Iron, dissolved as Fe	µg/L	44	100	23	12	7	9	14	19	28	46	51	1
Lead, total as Pb	µg/L	46	24	1	1	<1	<1	<1	<1	1	3	6	1
Lead, dissolved as Pb	µg/L	4	0	--	--	<1	--	--	<1	--	--	<1	1
Manganese, total as Mn	µg/L	47	30	16	29	<10	<10	<10	<10	20	40	150	10
Manganese, dissolved as Mn	µg/L	44	20	1	1	<1	<1	<1	<1	1	2	2	1
Mercury, total as Hg	µg/L	--	--	--	--	--	--	--	--	--	--	--	.1
Molybdenum, total as Mo	µg/L	--	--	--	--	--	--	--	--	--	--	--	1
Molybdenum, dissolved as Mo	µg/L	--	--	--	--	--	--	--	--	--	--	--	1
Nickel, total as Ni	µg/L	--	--	--	--	--	--	--	--	--	--	--	1
Nickel, dissolved as Ni	µg/L	--	--	--	--	--	--	--	--	--	--	--	1
Selenium, total as Se	µg/L	--	--	--	--	--	--	--	--	--	--	--	1
Silver, total as Ag	µg/L	--	--	--	--	--	--	--	--	--	--	--	1
Silver, dissolved as Ag	µg/L	--	--	--	--	--	--	--	--	--	--	--	1
Zinc, total as Zn	µg/L	47	4	--	--	<10	--	--	<10	--	--	20	10
Zinc, dissolved as Zn	µg/L	44	41	3	2	<3	<3	<3	3	4	6	9	3
Uranium, natural dissolved	µg/L	--	--	--	--	--	--	--	--	--	--	--	1
Carbon, organic total as C	mg/L	--	--	--	--	--	--	--	--	--	--	--	.1
Carbon, organic dissolved as C	mg/L	--	--	--	--	--	--	--	--	--	--	--	.1
Sediment, suspended, concentration	mg/L	35	94	8	11	<1	1	2	3	10	17	58	1
Sediment, suspended, % finer than 0.062 mm	%	12	100	55	18	27	30	43	50	70	85	86	1
Sediment, discharge	T/d	35	100	.6	.95	.002	.01	.05	.15	.65	2.5	3.6	.001

Table 50. Summary of water-quality statistics for analyses of ground-water samples collected, water years 1995–97

[--, insufficient data to calculate statistic; statistics estimated using robust log-probability regression technique for censored data described in Helsel and Cohn (1988); °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter]

Property or constituent	Units	Number of samples	Percent detections	Mean	Standard deviation	Min-imum	10th percentile	25th percentile	Median	75th percentile	90th percentile	Max-imum	Lowest reporting limit
Water temperature	°C	7	100	5.6	1.9	3.0	--	--	5.5	--	--	8.6	0.1
Specific conductance	µS/cm	15	100	170	156	24	52	66	104	220	360	584	1
pH	units	15	100	--	--	6.5	6.9	7.0	7.3	7.6	7.8	8.3	.1
Turbidity	NTU	8	100	6	7.7	.2	.4	.9	1.9	9.1	17	20	.1
Hardness as $CaCO_3$	mg/L	15	100	77	77	7	16	24	41	96	200	250	1
Calcium, dissolved	mg/L	15	100	19	17	2.1	4.6	6.9	11	24	46	57	.1
Magnesium, dissolved	mg/L	15	100	7.1	8.4	.5	1.0	1.9	3.4	9.0	20	27	.1
Sodium, dissolved	mg/L	15	100	4.3	6.2	1.3	1.4	1.9	2.3	3.4	5.7	26	.1
Potassium, dissolved	mg/L	15	100	1.4	1	.4	.7	.9	1.1	1.4	2.4	4.6	.1
Acid-neutralizing capacity, lab as $CaCO_3$	mg/L	15	100	73	81	6.3	18	23	42	78	177	294	1
Sulfate, dissolved	mg/L	15	100	11	8.1	1.8	3.1	5	8.1	16	22	28	.1
Chloride, dissolved	mg/L	15	93	2.4	4.6	<.1	.1	.2	.6	3.3	11	18	.1
Fluoride, dissolved	mg/L	14	86	.3	.3	<.1	<.1	.1	.2	.6	1	1.1	.1
Silica, dissolved	mg/L	15	100	9.5	2.7	5.7	6.7	7.3	8.7	12	13	14	.1
Dissolved solids, residue at 180 degrees Celsius	mg/L	15	100	101	83	28	35	50	67	126	195	330	1
Dissolved solids, sum of constituents	mg/L	15	100	101	86	19	37	46	65	120	200	337	1
Nitrite, dissolved as N	mg/L	13	0	--	--	<.01	--	--	<.01	--	--	<.01	.01
Nitrite plus nitrate, dissolved as N	mg/L	15	80	.074	.043	<.05	.014	.032	.08	.11	.14	.15	.005
Nitrogen, ammonia, dissolved as N	mg/L	15	13	--	--	<.015	--	--	<.015	--	--	.02	.002
Nitrogen, ammonia plus organic, dissolved as N	mg/L	14	0	--	--	<.2	--	--	<.2	--	--	<.2	.2
Nitrogen, ammonia plus organic, total as N	mg/L	10	0	--	--	<.2	--	--	<.2	--	--	<.2	.2
Phosphorus, total as P	mg/L	10	70	.012	.011	<.01	.002	.003	.01	.022	.03	.03	.001
Phosphorus, dissolved as P	mg/L	14	29	--	--	<.01	--	--	<.01	--	--	.02	.001
Phosphorus, dissolved orthophosphate as P	mg/L	15	13	--	--	<.01	--	--	<.01	--	--	.01	.001
Aluminum, total as Al	µg/L	8	75	40	36	<10	<10	<10	40	60	100	110	10
Aluminum, dissolved as Al	µg/L	8	75	7	7	<1	<1	1	6	10	18	20	1
Antimony, dissolved as Sb	µg/L	8	0	--	--	<1	--	--	<1	--	--	<1	1
Arsenic, total as As	µg/L	8	0	--	--	<2	--	--	<2	--	--	<2	1
Barium, total as Ba	µg/L	8	0	--	--	<100	--	--	<100	--	--	<100	100
Barium, dissolved as Ba	µg/L	8	100	51	28	14	25	32	47	67	87	90	1

Table 50. Summary of water-quality statistics for analyses of ground-water samples collected, water years 1995–97—Continued

[--, insufficient data to calculate statistic; statistics estimated using robust log-probability regression technique for censored data described in Helsel and Cohn (1988); °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter]

Property or constituent	Units	Number of samples	Percent detections	Mean	Standard deviation	Minimum	10th percentile	25th percentile	Median	75th percentile	90th percentile	Maximum	Lowest reporting limit
Beryllium, total as Be	µg/L	8	0	--	--	<10	--	--	<10	--	--	<10	10
Beryllium, dissolved as Be	µg/L	8	0	--	--	<1	--	--	<1	--	--	<1	1
Cadmium, total as Cd	µg/L	9	11	--	--	<1	--	--	<1	--	--	2	1
Cadmium, dissolved as Cd	µg/L	9	11	--	--	<1	--	--	<1	--	--	2	1
Chromium, total as Cr	µg/L	8	0	--	--	<1	--	--	<1	--	--	<1	1
Chromium, dissolved as Cr	µg/L	8	0	--	--	<1	--	--	<1	--	--	<1	1
Cobalt, total as Co	µg/L	8	0	--	--	<1	--	--	<1	--	--	<1	1
Cobalt, dissolved as Co	µg/L	8	0	--	--	<1	--	--	<1	--	--	<1	1
Copper, total as Cu	µg/L	9	67	12	12	<1	1	2	5	23	30	30	1
Copper, dissolved as Cu	µg/L	14	57	2	3	<1	<1	<1	1	4	7	9	1
Iron, total as Fe	µg/L	9	89	660	940	<10	10	60	210	1,200	2,700	2,700	10
Iron, dissolved as Fe	µg/L	15	60	60	100	<3	<3	<3	13	41	300	320	1
Lead, total as Pb	µg/L	9	56	2	2	<1	1	1	2	4	6	6	1
Lead, dissolved as Pb	µg/L	9	11	--	--	<1	--	--	<1	--	--	2	1
Manganese, total as Mn	µg/L	9	67	40	70	<10	<10	<10	10	60	210	210	10
Manganese, dissolved as Mn	µg/L	15	60	25	60	<1	<1	<1	2	23	133	230	1
Mercury, total as Hg	µg/L	8	0	--	--	<.1	--	--	<.1	--	--	<.1	.1
Molybdenum, total as Mo	µg/L	8	88	2	1	<1	<1	1	2	2	4	4	1
Molybdenum, dissolved as Mo	µg/L	8	38	--	--	<1	--	--	<1	--	--	3	1
Nickel, total as Ni	µg/L	8	38	--	--	<1	--	--	<1	--	--	2	1
Nickel, dissolved as Ni	µg/L	8	50	1	1	<1	<1	<1	1	2	2	2	1
Selenium, total as Se	µg/L	8	0	--	--	<1	--	--	<1	--	--	<1	1
Silver, total as Ag	µg/L	8	0	--	--	<1	--	--	<1	--	--	<1	1
Silver, dissolved as Ag	µg/L	8	12	--	--	<1	--	--	<1	--	--	2	1
Zinc, total as Zn	µg/L	9	67	970	1,300	<10	40	110	470	1,400	4,100	4,100	10
Zinc, dissolved as Zn	µg/L	14	71	640	1,300	<3	<3	<3	4	860	3,200	4,600	3
Uranium, natural dissolved	µg/L	8	62	10	23	<1	<1	<1	2	4	60	67	1
Carbon, organic total as C	mg/L	8	100	2	1.2	.5	.7	1.5	1.8	2.2	3.5	4.3	.1
Carbon, organic dissolved as C	mg/L	8	100	1.4	.8	.5	.6	.8	1.2	1.9	2.5	2.6	.1

Table 51. Selected water-quality data collected at road-runoff sites, water years 1995–97

[--, no data; >, greater than; <, less than; d, dip method; p, pump sample; dfwm, daily flow-weighted-mean concentration; ft^3/s, cubic feet per second; deicer is NaCl historically applied to the road; dust suppressant is $MgCl_2$ historically applied; mm, millimeters; Hg, mercury; ft^3/s, cubic feet per second; NTU, nephelometric turbidity units; µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; µg/L, micrograms per liter; T/d, tons per day; P, paved; G, gravel]

Site number (fig. 2)	Date (mm/dd/yy)	Time (hhmm)	Water temperature (degrees Celsius)	Air pressure (mm of Hg)	Discharge, instantaneous (ft^3/s)	Turbidity (NTU)	Specific conductance (µS/cm at 25 degrees Celsius)	Oxygen, dissolved (mg/L)	pH, field (standard units)	Nitrite, dissolved (mg/L as N)	Nitrite plus nitrate (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)
CRD1	08/22/95	1200	--	--	0.007	>1,000	468	--	7.6	0.01	0.65	0.07
CRD2	06/10/95	1705	1	500	.144	430	44	10.2	7.3	<.01	.13	.04
CRD3	06/10/95	1510	20	510	.015	>1,000	56	6.7	7.5	<.01	.09	.05
CRD4	05/21/95	1305	4.5	510	.024	>1,000	107	9.9	7.3	<.01	<.05	.02
CRD5	08/30/95	1630	--	--	--	>1,000	264	--	8.5	.01	.43	.05
CRD6	04/06/95	1345	2	530	.008	--	301	9.2	7.2	<.01	.31	.08
GRD1	08/22/95	1230	--	--	.153	>1,000	19	--	7.2	<.01	.23	.04
GRD2	06/10/95	1305	4.5	500	.016	680	30	9.5	6.9	<.01	.1	.05
GRD3	08/22/95	1240	--	--	--	>1,000	51	--	7.3	<.01	.1	.03
GRD4	04/06/95	1655	.5	520	.066	--	14	9.2	7.2	.002	.015	.01
GRD5	08/23/95	1130	--	--	.004	>1,000	20	--	7	<.01	.17	.04
CRD7	08/21/96	1540	--	--	.014	61,000	455	--	6.4	--	1.2	--
CRD7	05/14/97	1700	--	--	.033	1,130	31	--	7.1	--	.11	.017
GRD6	08/23/96	1235	--	--	.088	32,000	105	--	8	--	.6	--
GRD6	05/10/97	1630	--	--	.043	1,430	32	--	7.3	--	.08	.032
GRD4	08/21/96	1611	--	--	.011	390	24	--	7	--	--	--
CRD8	08/06/97	1528	7.7	--	.005	79	45	--	7.7	--	.055	<.002
GRD8	08/04/97	1600	--	--	.012	10,000	113	--	8	--	.29	<.002
CRD9	10/16/96	1415	--	--	.019	3,400	244	--	7.1	.06	.75	.2
GRD7	07/09/96	1940	--	--	.035	>1,000	48	--	6.1	.02	.16	.09

Table 51. Selected water-quality data collected at road-runoff sites, water years 1995–97—Continued

[--, no data; >, greater than; <, less than; d, dip method; p, pump sample; dfwm, daily flow-weighted-mean concentration; ft^3/s, cubic feet per second; deicer is NaCl historically applied to the road; dust suppressant is $MgCl_2$ historically applied; mm, millimeters; Hg, mercury; ft^3/s, cubic feet per second; NTU, nephelometric turbidity units; µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; µg/L, micrograms per liter; T/d, tons per day; P, paved; G, gravel]

Site number (fig. 2)	Date (mm/dd/yy)	Time (hhmm)	Nitrogen, ammonia plus organic, total (mg/L as N)	Nitrogen, ammonia plus organic, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)	Hardness, total (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)
CRD1	08/22/95	1200	0.9	<0.2	1.5	<0.01	<0.01	160	20	26	12	4.6
CRD2	06/10/95	1705	.2	.2	.05	.02	.01	18	3.5	2.3	.9	.8
CRD3	06/10/95	1510	.6	<.2	.4	.01	.02	17	3.3	2.1	2.2	2.1
CRD4	05/21/95	1305	<.2	<.2	.03	<.01	<.01	49	11	5.1	1.9	2
CRD5	08/30/95	1630	6.1	<.2	6	.02	<.01	99	15	15	4.2	5.2
CRD6	04/06/95	1345	.3	<.2	.08	<.01	<.01	6	1.9	.4	54	1.6
GRD1	08/22/95	1230	.7	<.2	.33	.01	.01	6	1.9	.35	.5	1
GRD2	06/10/95	1305	.3	.2	.07	.03	.03	13	3.4	1.1	.9	.9
GRD3	08/22/95	1240	.6	<.2	.53	<.01	<.01	18	5.3	1.1	2.5	.8
GRD4	04/06/95	1655	<.2	<.2	.044	.03	<.01	5	1.5	.25	.5	.59
GRD5	08/23/95	1130	4.7	<.2	4	<.01	.02	8	2.4	.38	.2	.6
CRD7	08/21/96	1540	15	--	--	--	--	130	18	21	19	5.6
CRD7	05/14/97	1700	.3	--	.024	--	.003	--	--	--	--	--
GRD6	08/23/96	1235	3.5	--	.23	--	--	34	8.1	3.3	2.6	3.4
GRD6	05/10/97	1630	.4	--	.17	--	.01	--	--	--	--	--
GRD4	08/21/96	1611	--	--	--	--	--	6	1.7	.38	.3	2.2
CRD8	08/06/97	1528	.3	--	.055	--	.003	1	.2	.06	8.9	.5
GRD8	08/04/97	1600	5	--	3	--	.019	45	15	2	2.7	2.1
CRD9	10/16/96	1415	2.1	.7	1.3	.1	.11	16	5.2	.66	33	4.6
GRD7	07/09/96	1940	24	.9	7.2	.25	.22	11	3.4	.72	1.1	4.7

Table 51. Selected water-quality data collected at road-runoff sites, water years 1995–97—Continued

[--, no data; >, greater than; <, less than; d, dip method; p, pump sample; dfwm, daily flow-weighted-mean concentration; ft^3/s, cubic feet per second; deicer is NaCl historically applied to the road; dust suppressant is $MgCl_2$ historically applied; mm, millimeters; Hg, mercury; ft^3/s, cubic feet per second; NTU, nephelometric turbidity units; µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; µg/L, micrograms per liter; T/d, tons per day; P, paved; G, gravel]

Site number (fig. 2)	Date (mm/dd/yy)	Time (hhmm)	Acid-neutralizing capacity, water, unfiltered, titration to 4.5, lab (mg/L as $CaCO_3$)	Sulfate, dissolved, (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, residue on evaporation at 180 degrees Celsius, dissolved (mg/L)	Dissolved solids, sum of constituents (mg/L)	Aluminum, total (µg/L as Al)	Aluminum, dissolved (µg/L as Al)	Antimony, dissolved (µg/L as Sb)
CRD1	08/22/95	1200	19	6.1	120	0.3	1.9	286	206	42,000	30	<1
CRD2	06/10/95	1705	14	1.3	4.3	.1	2.5	39	25	6,600	130	<1
CRD3	06/10/95	1510	23	1.1	8.9	.1	4	34	39	120,000	170	<1
CRD4	05/21/95	1305	43	4.4	5.8	<.1	7.1	70	64	32,000	290	<1
CRD5	08/30/95	1630	42	5.8	60	.2	1.4	166	134	110,000	50	<1
CRD6	04/06/95	1345	10	3.2	79	<.1	1.2	149	147	12,000	50	<1
GRD1	08/22/95	1230	16	.4	.5	.2	1.4	11	18	130,000	280	<1
GRD2	06/10/95	1305	13	1.4	1.5	.2	3.9	34	22	17,000	330	<1
GRD3	08/22/95	1240	22	2.6	.5	.2	8.7	38	36	41,000	170	<1
GRD4	04/06/95	1655	4.8	.4	.6	.04	.62	--	7	550	50	<1
GRD5	08/23/95	1130	23	.6	.4	<.1	1.2	18	21	50,000	140	<1
CRD7	08/21/96	1540	14	6.3	120	--	4.7	276	210	--	--	--
CRD7	05/14/97	1700	--	1.2	4	--	--	--	--	--	--	--
GRD6	08/23/96	1235	35	3	14	--	2.6	58	61	--	--	--
GRD6	05/10/97	1630	--	1.1	1.1	--	--	--	--	--	--	--
GRD4	08/21/96	1611	5.4	1.4	.8	--	.8	16	11	--	--	--
CRD8	08/06/97	1528	15	1.7	3.1	.1	2.4	36	27	--	--	--
GRD8	08/04/97	1600	59	2.3	.8	.4	4.5	74	65	--	--	--
CRD9	10/16/96	1415	36	16	40	--	1.4	150	123	--	--	--
GRD7	07/09/96	1940	37	1.6	2.4	--	4.1	70	41	--	--	--

Table 51. Selected water-quality data collected at road-runoff sites, water years 1995–97—Continued

[--, no data; >, greater than; <, less than; d, dip method; p, pump sample; dfwm, daily flow-weighted-mean concentration; ft^3/s, cubic feet per second; deicer is NaCl historically applied to the road; dust suppressant is $MgCl_2$ historically applied; mm, millimeters; Hg, mercury; ft^3/s, cubic feet per second; NTU, nephelometric turbidity units; µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; µg/L, micrograms per liter; T/d, tons per day; P, paved; G, gravel]

Site number (fig. 2)	Date (mm/dd/yy)	Time (hhmm)	Arsenic, total (µg/L as As)	Barium, total (µg/L as Ba)	Barium, dissolved (µg/L as Ba)	Beryllium, total (µg/L as Be)	Beryllium, dissolved (µg/L as Be)	Cadmium, total (µg/L as Cd)	Cadmium, dissolved (µg/L as Cd)	Chromium, total (µg/L as Cr)	Chromium, dissolved (µg/L as Cr)	Cobalt, total (µg/L as Co)
CRD1	08/22/95	1200	<1	700	48	<10	<1	<1	<1	120	<1	80
CRD2	06/10/95	1705	<1	100	16	<10	<1	<1	<1	19	<1	9
CRD3	06/10/95	1510	<1	2,500	18	<10	<1	2	<1	140	<1	120
CRD4	05/21/95	1305	1	700	41	<10	<1	<1	<1	32	1	20
CRD5	08/30/95	1630	<2	2,600	48	<10	<1	4	<1	150	<1	110
CRD6	04/06/95	1345	<1	200	13	<10	<1	<1	<1	22	<1	10
GRD1	08/22/95	1230	1	2,100	9	<10	<1	2	<1	100	<1	90
GRD2	06/10/95	1305	<1	200	15	<10	<1	<1	<1	22	<1	10
GRD3	08/22/95	1240	<1	1,000	20	<10	<1	3	<1	97	<1	20
GRD4	04/06/95	1655	<1	<100	7	<10	<1	<1	<1	<1	<1	<1
GRD5	08/23/95	1130	2	1,800	10	<10	<1	2	<1	140	<1	50
CRD7	08/21/96	1540	--	--	--	--	--	--	--	--	--	--
CRD7	05/14/97	1700	--	--	--	--	--	--	--	--	--	--
GRD6	08/23/96	1235	--	--	--	--	--	--	--	--	--	--
GRD6	05/10/97	1630	--	--	--	--	--	--	--	--	--	--
GRD4	08/21/96	1611	--	--	--	--	--	<1	--	--	--	--
CRD8	08/06/97	1528	--	--	--	--	--	--	--	--	--	--
GRD8	08/04/97	1600	--	--	--	--	--	--	--	--	--	--
CRD9	10/16/96	1415	--	--	--	--	--	7	<1	200	--	--
GRD7	07/09/96	1940	--	--	--	--	--	3	--	89	--	--

Table 51. Selected water-quality data collected at road-runoff sites, water years 1995–97—Continued

[--, no data; >, greater than; <, less than; d, dip method; p, pump sample; dfwm, daily flow-weighted-mean concentration; ft^3/s, cubic feet per second; deicer is NaCl historically applied to the road; dust suppressant is $MgCl_2$ historically applied; mm, millimeters; Hg, mercury; ft^3/s, cubic feet per second; NTU, nephelometric turbidity units; µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; µg/L, micrograms per liter; T/d, tons per day; P, paved; G, gravel]

Site number (fig. 2)	Date (mm/dd/yy)	Time (hhmm)	Cobalt, dissolved (µg/L as Co)	Copper, total (µg/L as Cu)	Copper, dissolved (µg/L as Cu)	Iron, total (µg/L as Fe)	Iron, dissolved (µg/L as Fe)	Lead, total (µg/L as Pb)	Lead, dissolved (µg/L as Pb)	Manganese, total (µg/L as Mn)	Manganese, dissolved (µg/L as Mn)	Mercury, total (µg/L as Hg)
CRD1	08/22/95	1200	<1	75	<1	59,000	50	37	<1	3,900	120	<0.1
CRD2	06/10/95	1705	<1	10	1	220,000	230	6	<1	380	25	<.1
CRD3	06/10/95	1510	<1	250	1	220,000	1,100	120	<1	9,500	45	.1
CRD4	05/21/95	1305	<1	72	3	58,000	350	20	<1	1,400	72	<.1
CRD5	08/30/95	1630	<1	290	2	280,000	34	320	<1	13,000	26	.4
CRD6	04/06/95	1345	<1	44	1	32,000	46	49	<1	980	48	<.1
GRD1	08/22/95	1230	<1	100	<1	140,000	290	200	<1	7,300	17	.1
GRD2	06/10/95	1305	<1	25	1	32,000	370	13	<1	630	52	<.1
GRD3	08/22/95	1240	<1	61	2	56,000	150	36	<1	1,400	6	<.1
GRD4	04/06/95	1655	<1	<1	<1	0,780	46	2	<1	60	24	<.1
GRD5	08/23/95	1130	<1	72	<1	75,000	110	460	<1	3,400	7	.2
CRD7	08/21/96	1540	--	310	1	500,000	20	440	--	30,000	1,700	--
CRD7	05/14/97	1700	--	18	<1	23,000	220	13	--	840	51	--
GRD6	08/23/96	1235	--	560	2	580,000	110	610	--	24,000	72	--
GRD6	05/10/97	1630	--	37	1	72,000	160	42	--	1,700	4	--
GRD4	08/21/96	1611	--	14	1	16,000	25	41	<1	510	<1	--
CRD8	08/06/97	1528	--	6	2	3,000	55	14	--	44	3	--
GRD8	08/04/97	1600	--	51	2	85,000	17	160	--	2,700	5	--
CRD9	10/16/96	1415	--	600	--	170,000	71	1,200	<1	8,000	300	--
GRD7	07/09/96	1940	--	53	3	130,000	520	240	--	--	320	--

Table 51. Selected water-quality data collected at road-runoff sites, water years 1995–97—Continued

[--, no data; >, greater than; <, less than; d, dip method; p, pump sample; dfwm, daily flow-weighted-mean concentration; ft^3/s, cubic feet per second; deicer is NaCl historically applied to the road; dust suppressant is $MgCl_2$ historically applied; mm, millimeters; Hg, mercury; ft^3/s, cubic feet per second; NTU, nephelometric turbidity units; µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; µg/L, micrograms per liter; T/d, tons per day; P, paved; G, gravel]

Site number (fig. 2)	Date (mm/dd/yy)	Time (hhmm)	Molybdenum, total (µg/L as Mo)	Molybdenum, dissolved (µg/L as Mo)	Nickel, total (µg/L as Ni)	Nickel, dissolved (µg/L as Ni)	Selenium, total (µg/L as Se)	Silver, total (µg/L as Ag)	Silver, dissolved (µg/L as Ag)	Zinc, total (µg/L as Zn)	Zinc, dissolved (µg/L as Zn)	Uranium, dissolved (µg/L as U)
CRD1	08/22/95	1200	1	1	130	1	<2	<1	<1	180	<1	<1
CRD2	06/10/95	1705	<1	<1	15	1	<1	<1	<1	50	4	<1
CRD3	06/10/95	1510	<1	<1	140	<1	2	<1	<1	740	2	<1
CRD4	05/21/95	1305	<1	<1	23	2	<1	<1	<1	280	4	<1
CRD5	08/30/95	1630	1	1	120	<1	<1	<1	<1	900	<1	3
CRD6	04/06/95	1345	1	1	16	<1	<1	<1	<1	190	3	<1
GRD1	08/22/95	1230	<1	<1	95	<1	<10	<1	<1	550	1	<1
GRD2	06/10/95	1305	<1	<1	13	<1	<1	<1	<1	110	3	<1
GRD3	08/22/95	1240	2	2	70	<1	<1	<1	<1	200	<1	<1
GRD4	04/06/95	1655	<1	<1	<1	<1	<1	<1	<1	<10	2	<1
GRD5	08/23/95	1130	<1	<1	78	<1	5	<1	<1	490	2	<1
CRD7	08/21/96	1540	--	--	--	--	--	--	--	1,900	<3	--
CRD7	05/14/97	1700	--	--	--	--	--	--	--	80	<3	--
GRD6	08/23/96	1235	--	--	--	--	--	--	--	2,200	10	--
GRD6	05/10/97	1630	--	--	--	--	--	--	--	264	<3	--
GRD4	08/21/96	1611	--	--	--	--	--	--	--	160	16	--
CRD8	08/06/97	1528	--	--	--	--	--	--	--	45	<3	--
GRD8	08/04/97	1600	--	--	--	--	--	--	--	434	9	--
CRD9	10/16/96	1415	--	--	130	--	--	--	--	2,200	44	--
GRD7	07/09/96	1940	--	--	67	--	--	--	--	420	9	--

Table 51. Selected water-quality data collected at road-runoff sites, water years 1995–97—Continued

[--, no data; >, greater than; <, less than; d, dip method; p, pump sample; dfwm, daily flow-weighted-mean concentration; ft^3/s, cubic feet per second; deicer is NaCl historically applied to the road; dust suppressant is $MgCl_2$ historically applied; mm, millimeters; Hg, mercury; ft^3/s, cubic feet per second; NTU, nephelometric turbidity units; µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; µg/L, micrograms per liter; T/d, tons per day; P, paved; G, gravel]

Site number (fig. 2)	Date (mm/dd/yy)	Time (hhmm)	Carbon, organic, total (mg/L as C)	Carbon, organic, dissolved (mg/L as C)	Oil and grease, total (mg/L)	Sediment, suspended, concentration (mg/L)	Sediment, suspended, percent finer than 0.062 mm	Sediment, suspended, discharge (T/d)	Sampling method	Precipitation type	Road surface type	De-icer or dust suppressant
CRD1	08/22/95	1200	31	3.2	--	10,600	35	0.2	d	rain	G	$MgCl_2$
CRD2	06/10/95	1705	7.1	--	<1	7,360	90	2.86	d	snow	G	$MgCl_2$
CRD3	06/10/95	1510	16	--	<1	7,280	90	.29	d	snow	G	$MgCl_2$
CRD4	05/21/95	1305	11	--	<1	4,720	45	.31	d	snow	G	$MgCl_2$
CRD5	08/30/95	1630	130	3.7	--	8,190	88	--	d	rain	G	$MgCl_2$
CRD6	04/06/95	1345	10	2.3	<1	680	91	.015	d	snow	P	NaCl
GRD1	08/22/95	1230	140	2.4	--	30,800	37	12.7	d	rain	G	$MgCl_2$
GRD2	06/10/95	1305	8.9	--	<1	550	84	.024	d	snow	G	$MgCl_2$
GRD3	08/22/95	1240	12	2.4	--	1,120	100	--	d	rain	G	none
GRD4	04/06/95	1655	4.7	3.8	<1	66	37	.012	d	snow	P	none
GRD5	08/23/95	1130	140	3.5	--	6,190	42	.067	d	rain	P	none
CRD7	08/21/96	1540	--	--	--	38,800	100	1.47	p	rain	G	$MgCl_2$
CRD7	05/14/97	1700	--	--	--	973	91	.087	d	snow	G	$MgCl_2$
GRD6	08/23/96	1235	--	--	--	24,800	100	5.89	p	rain	G	$MgCl_2$
GRD6	05/10/97	1630	--	--	--	2,040	97	.24	p, dfwm	snow	G	$MgCl_2$
GRD4	08/21/96	1611	--	--	--	492	--	.015	p	rain	P	none
CRD8	08/06/97	1528	--	--	--	34	95	.0005	d	rain	P	NaCl
GRD8	08/04/97	1600	--	--	--	3,360	70	.11	d	rain	G	none
CRD9	10/16/96	1415	--	--	--	--	--	--	d	rain	P	NaCl
GRD7	07/09/96	1940	--	--	--	--	--	--	d	rain	G	none

Table 52. Summary of water-quality statistics for analyses of selected samples collected, water years 1995–97, at road-runoff sites during snowmelt

[--, insufficient data to calculate statistic; * indicates statistics estimated using robust log-probability regression technique for censored data described in Helsel and Cohn (1988); ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; >, greater than; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; %, percentage; mm, millimeters; T/d, tons per day]

Property or constituent	Units	Number of samples	Percent detections	Mean	Standard deviation	Minimum	10th percentile	25th percentile	Median	75th percentile	90th percentile	Maximum	Lowest reporting limit
Discharge	ft^3/s	8	100	0.044	0.045	0.008	0.013	0.016	0.029	0.144	0.001	0.144	0.001
Specific conductance	µS/cm	8	100	77	95	14	25	31	38	69	165	301	1
pH	units	8	100	--	--	6.9	--	--	7.2	--	--	7.5	.1
Turbidity	NTU	6	100	--	--	430	--	--	>1,000	--	--	>1,000	.1
Dissolved oxygen	mg/L	6	100	9.1	1.2	6.7	--	--	9.4	--	--	10.2	.1
Hardness as $CaCO_3$	mg/L	6	100	18	16	5	--	--	15	--	--	49	1
Calcium, dissolved	mg/L	6	100	4.1	3.5	1.5	--	--	3.4	--	--	11	.1
Magnesium, dissolved	mg/L	6	100	1.9	1.8	.2	--	--	1.6	--	--	5.1	.1
Sodium, dissolved	mg/L	6	100	10	22	.5	--	--	1.4	--	--	54	.1
Potassium, dissolved	mg/L	6	100	1.3	.7	.6	--	--	1.2	--	--	2.1	.1
Acid-neutralizing capacity, lab as $CaCO_3$	mg/L	6	100	18	14	4.8	--	--	14	--	--	43	1
Sulfate, dissolved	mg/L	8	100	1.8	1.3	.4	.9	1.1	1.2	1.8	3.6	4.4	.1
Chloride, dissolved	mg/L	8	100	13	27	.6	1.0	1.4	4.2	6.6	30	79	.1
Fluoride, dissolved	mg/L	6	67	--	--	<.1	--	--	.1	--	--	.2	.1
Silica, dissolved	mg/L	6	100	3.2	2.3	.6	--	--	3.2	--	--	7.1	.1
Dissolved solids, residue at 180 degrees Celsius	mg/L	5	100	65	49	34	--	--	39	--	--	149	1
Dissolved solids, sum of constituents	mg/L	6	100	51	51	7	--	--	32	--	--	147	1
Nitrite, dissolved as N	mg/L	6	17	--	--	<.01	--	--	<.01	--	--	<.01	.01
Nitrite plus nitrate, dissolved as N	mg/L	*8	88	.11	.091	.015	.015	.036	.095	.12	.28	.31	.005
Nitrogen, ammonia, dissolved as N	mg/L	8	100	.037	.023	.010	.015	.019	.036	.050	.059	.080	.002
Nitrogen, ammonia plus organic, dissolved as N	mg/L	6	33	--	--	<.2	--	--	<.2	--	--	.2	.2
Nitrogen, ammonia plus organic, total as N	mg/L	*8	75	.3	.15	<.2	<.2	<.2	.3	.4	.5	.6	.2
Phosphorus, total as P	mg/L	8	100	.110	.130	.024	.028	.041	.060	.10	.24	.40	.001
Phosphorus, dissolved as P	mg/L	6	67	--	--	<.01	--	--	.02	--	--	.03	.001
Phosphorus, dissolved orthophosphate as P	mg/L	*8	62	.01	.01	.003	.002	.003	.007	.018	.027	.03	.001
Aluminum, total as Al	µg/L	6	100	31,000	45,000	550	--	--	14,000	--	--	120,000	10
Aluminum, dissolved as Al	µg/L	6	100	170	120	50	--	--	150	--	--	330	1
Antimony, dissolved as Sb	µg/L	6	0	--	--	<1	--	--	<1	--	--	<1	1
Arsenic, total as As	µg/L	6	17	--	--	<1	--	--	<1	--	--	1	1
Barium, total as Ba	µg/L	6	83	--	--	100	--	--	200	--	--	2,500	100
Barium, dissolved as Ba	µg/L	6	100	18	12	7	--	--	16	--	--	41	1
Beryllium, total as Be	µg/L	6	0	--	--	<10	--	--	<10	--	--	<10	10

Table 52. Summary of water-quality statistics for analyses of selected samples collected, water years 1995–97, at road-runoff sites during snowmelt—Continued

[--, insufficient data to calculate statistic; * indicates statistics estimated using robust log-probability regression technique for censored data described in Helsel and Cohn (1988); ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; >, greater than; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; %, percentage; mm, millimeters; T/d, tons per day]

Property or constituent	Units	Number of samples	Percent detections	Mean	Standard deviation	Min-imum	10th percentile	25th percentile	Median	75th percentile	90th percentile	Max-imum	Lowest reporting limit
Beryllium, dissolved as Be	µg/L	6	0	--	--	<1	--	--	<1	--	--	<1	1
Cadmium, total as Cd	µg/L	6	17	--	--	<1	--	--	<1	--	--	2	1
Cadmium, dissolved as Cd	µg/L	6	0	--	--	<1	--	--	<1	--	--	<1	1
Chromium, total as Cr	µg/L	6	83	--	--	<1	--	--	22	--	--	140	1
Chromium, dissolved as Cr	µg/L	6	17	--	--	<1	--	--	<1	--	--	1	1
Cobalt, total as Co	µg/L	6	83	--	--	<1	--	--	10	--	--	120	1
Cobalt, dissolved as Co	µg/L	6	0	--	--	<1	--	--	<1	--	--	<1	1
Copper, total as Cu	µg/L	*8	88	57	81	<1	3	12	31	65	225	250	1
Copper, dissolved as Cu	µg/L	*8	75	1	.8	<1	<1	1	1	1	3	3	1
Iron, total as Fe	µg/L	8	100	82,000	88,000	780	16,000	30,000	45,000	110,000	220,000	220,000	10
Iron, dissolved as Fe	µg/L	8	100	320	340	46	46	130	220	360	590	1,100	1
Lead, total as Pb	µg/L	8	100	33	39	2	5	11	16	44	70	120	1
Lead, dissolved as Pb	µg/L	6	0	--	--	<1	--	--	<1	--	--	<1	1
Manganese, total as Mn	µg/L	8	100	1,900	3,100	60	280	570	910	1,500	4,000	9,500	10
Manganese, dissolved as Mn	µg/L	8	100	40	21	4	18	25	46	51	58	72	1
Mercury, total as Hg	µg/L	6	17	--	--	<.1	--	--	<.1	--	--	.1	.1
Molybdenum, total as Mo	µg/L	6	17	--	--	<1	--	--	<1	--	--	1	1
Molybdenum, dissolved as Mo	µg/L	6	17	--	--	<1	--	--	<1	--	--	2	1
Nickel, total as Ni	µg/L	6	83	--	--	<1	--	--	16	--	--	140	1
Nickel, dissolved as Ni	µg/L	6	33	--	--	<1	--	--	<1	--	--	2	1
Selenium, total as Se	µg/L	6	17	--	--	<1	--	--	<1	--	--	2	1
Silver, total as Ag	µg/L	6	0	--	--	<1	--	--	<1	--	--	<1	1
Silver, dissolved as Ag	µg/L	6	0	--	--	<1	--	--	<1	--	--	<1	1
Zinc, total as Zn	µg/L	*8	88	220	230	<10	<3	<3	150	280	660	740	10
Zinc, dissolved as Zn	µg/L	*8	75	3	.9	<3	<3	<3	3	4	4	4	3
Uranium, natural dissolved	µg/L	6	0	--	--	<1	--	--	<1	--	--	<1	1
Carbon, organic total as C	mg/L	6	100	9.6	3.8	4.7	--	--	9.4	--	--	16	.1
Carbon, organic dissolved as C	mg/L	2	100	--	--	2.3	--	--	3	--	--	3.8	.1
Oil and grease, total	mg/L	6	0	--	--	<1	--	--	<1	--	--	<1	1
Sediment, suspended, concentration	mg/L	8	100	2,960	3,050	66	405	648	1,510	5,360	7,300	7,360	1
Sediment, suspended, % finer than 0.062 mm	%	8	100	78	23	37	43	74	90	91	93	97	1
Sediment, discharge	T/d	8	100	.48	.97	.012	.014	.021	.16	.30	1.1	2.9	.001

Table 53. Summary of water-quality statistics for analyses of selected samples collected, water years 1995–97, at road-runoff sites during rainfall events

[--, insufficient data to calculate statistic; *, indicates statistics estimated using robust log-probability regression technique for censored data described in Helsel and Cohn (1988); ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; >, greater than; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; %, percentage; mm, millimeters; T/d, tons per day]

Property or constituent	Units	Number of samples	Percent detections	Mean	Standard deviation	Minimum	10th percentile	25th percentile	Median	75th percentile	90th percentile	Maximum	Lowest reporting limit
Discharge	ft^3/s	10	100	0.035	0.049	0.004	0.005	0.008	0.013	0.031	0.094	0.153	0.001
Specific conductance	µS/cm	12	100	155	165	19	20	40	78	249	436	468	1
pH	units	12	100	--	--	6.1	--	--	7.2	--	--	8.5	.1
Turbidity	NTU	12	100	--	--	79.	--	--	>1,000	--	--	>1,000	.1
Dissolved oxygen	mg/L	0	--	--	--	--	--	--	--	--	--	--	.1
Hardness as CaCO$_3$	mg/L	12	100	44	54	1	6	8	17	58	127	160	1
Calcium, dissolved	mg/L	12	100	8.0	7.1	.2	1.7	2.3	5.2	15	18	20	.1
Magnesium, dissolved	mg/L	12	100	5.9	9.2	.06	.4	.4	.9	6.2	20	26	.1
Sodium, dissolved	mg/L	12	100	7.2	9.9	.2	.3	1	2.6	9.7	18	33	.1
Potassium, dissolved	mg/L	12	100	2.9	2	.5	.6	1	2.8	4.6	5.2	5.6	.1
Acid-neutralizing capacity, lab as CaCO$_3$	mg/L	12	100	27	15	5.4	14	16	22	36	42	59	1
Sulfate, dissolved	mg/L	12	100	4.0	4.3	.4	.7	1.6	2.4	5.9	6.3	16	.1
Chloride, dissolved	mg/L	12	100	30	46	.4	.5	.7	2.8	45	114	120	.1
Fluoride, dissolved	mg/L	7	86	--	--	<.1	--	--	.2	--	--	.4	.1
Silica, dissolved	mg/L	12	100	2.9	2.3	.8	1.2	1.4	2.2	4.2	4.7	8.7	.1
Dissolved solids, residue at 180 degrees Celsius	mg/L	12	100	100	98	11	16	32	64	154	265	286	1
Dissolved solids, sum of constituents	mg/L	12	100	79	72	11	18	26	51	126	199	210	1
Nitrite, dissolved as N	mg/L	7	57	--	--	<.01	--	--	.01	--	--	.06	.01
Nitrite plus nitrate, dissolved as N	mg/L	11	100	.42	.35	.055	.10	.16	.29	.62	.75	1.2	.005
Nitrogen, ammonia, dissolved as N	mg/L	*9	78	.06	.06	<.002	.01	.023	.04	.08	.2	.2	.002
Nitrogen, ammonia plus organic, dissolved as N	mg/L	7	29	--	--	<.2	--	--	<.2	--	--	.9	.2
Nitrogen, ammonia plus organic, total as N	mg/L	11	100	5.7	7.4	.3	.6	.8	3.5	5.6	15	24	.2
Phosphorus, total as P	mg/L	10	100	2.4	2.6	.055	.21	.38	1.4	3.8	6.1	7.2	.001
Phosphorus, dissolved as P	mg/L	7	57	--	--	<.01	--	--	.01	--	--	.25	.001
Phosphorus, dissolved orthophosphate as P	mg/L	*9	78	.043	.075	.003	.001	.003	.01	.065	.22	.22	.001
Aluminum, total as Al	µg/L	5	100	75,000	42,000	41,000	--	--	50,000	--	--	130,000	10
Aluminum, dissolved as Al	µg/L	5	100	130	100	30	--	--	140	--	--	280	1
Antimony, dissolved as Sb	µg/L	5	0	--	--	<1	--	--	<1	--	--	<1	1
Arsenic, total as As	µg/L	5	40	--	--	<1	--	--	<1	--	--	2	1
Barium, total as Ba	µg/L	5	100	1,600	780	700	--	--	1,800	--	--	2,600	100
Barium, dissolved as Ba	µg/L	5	100	27	20	9	--	--	20	--	--	48	1
Beryllium, total as Be	µg/L	5	0	--	--	<10	--	--	<10	--	--	<10	10

Table 53. Summary of water-quality statistics for analyses of selected samples collected, water years 1995–97, at road-runoff sites during rainfall events—Continued

[--, insufficient data to calculate statistic; *, indicates statistics estimated using robust log-probability regression technique for censored data described in Helsel and Cohn (1988); ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; >, greater than; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; %, percentage; mm, millimeters; T/d, tons per day]

Property or constituent	Units	Number of samples	Percent detections	Mean	Standard deviation	Min-imum	10th percentile	25th percentile	Median	75th percentile	90th percentile	Max-imum	Lowest reporting limit
Beryllium, dissolved as Be	µg/L	5	0	--	--	<1	--	--	<1	--	--	<1	1
Cadmium, total as Cd	µg/L	*8	75	3	2	<1	1	1	2	4	6	7	1
Cadmium, dissolved as Cd	µg/L	6	0	--	--	<1	--	--	<1	--	--	<1	1
Chromium, total as Cr	µg/L	7	100	130	39	89	--	--	120	--	--	200	1
Chromium, dissolved as Cr	µg/L	5	0	--	--	<1	--	--	<1	--	--	<1	1
Cobalt, total as Co	µg/L	5	100	70	35	20	--	--	80	--	--	110	1
Cobalt, dissolved as Co	µg/L	5	0	--	--	<1	--	--	<1	--	--	<1	1
Copper, total as Cu	µg/L	12	100	180	210	6	18	52	74	300	540	600	1
Copper, dissolved as Cu	µg/L	*11	73	2	1	<1	1	1	2	2	3	3	1
Iron, total as Fe	µg/L	12	100	170,000	190,000	3,000	20,000	58,000	110,000	200,000	480,000	580,000	10
Iron, dissolved as Fe	µg/L	12	100	120	150	17	20	32	63	120	280	520	1
Lead, total as Pb	µg/L	12	100	310	340	14	36	40	220	440	600	1,200	1
Lead, dissolved as Pb	µg/L	7	0	--	--	<1	--	--	<1	--	--	<1	1
Manganese, total as Mn	µg/L	11	100	8,600	10,000	44	510	2,000	3,900	10,000	24,000	30,000	10
Manganese, dissolved as Mn	µg/L	*12	92	210	480	<1	1	5	22	260	1,300	1,700	1
Mercury, total as Hg	µg/L	5	60	--	--	<.1	--	--	.1	--	--	.4	.1
Molybdenum, total as Mo	µg/L	5	60	--	--	<1	--	--	1	--	--	2	1
Molybdenum, dissolved as Mo	µg/L	5	60	--	--	<1	--	--	1	--	--	3	1
Nickel, total as Ni	µg/L	7	100	99	28	67	--	--	95	--	--	130	1
Nickel, dissolved as Ni	µg/L	5	20	--	--	<1	--	--	<1	--	--	1	1
Selenium, total as Se	µg/L	5	20	--	--	<1	--	--	--	--	--	5	1
Silver, total as Ag	µg/L	5	0	--	--	<1	--	--	<1	--	--	<1	1
Silver, dissolved as Ag	µg/L	5	0	--	--	<1	--	--	<1	--	--	<1	1
Zinc, total as Zn	µg/L	12	100	810	810	40	160	200	460	1,200	2,200	2,200	10
Zinc, dissolved as Zn	µg/L	*12	58	8	13	<1	<1	<1	2	10	36	44	1
Uranium, natural dissolved	µg/L	5	20	--	--	<1	--	--	<1	--	--	3	1
Carbon, organic total as C	mg/L	8	100	83	63	5.6	10	26	94	140	140	150	.1
Carbon, organic dissolved as C	mg/L	5	100	3.0	.6	2.4	--	--	3.2	--	--	3.7	.1
Oil and grease, total	mg/L	0	--	--	--	--	--	--	--	--	--	--	
Sediment, suspended, concentration	mg/L	10	100	12,400	14,000	34	446	1,680	7,190	21,200	31,600	38,800	1
Sediment, suspended, % finer than 0.062 mm	%	9	100	74	29	35	37	42	88	100	100	100	1
Sediment, discharge	T/d	8	100	2.6	4.6	.0005	.01	.05	.16	2.6	7.9	13	.001

Table 54. Drainage-feature evaluation data

[--, no data; CCD, South Clear Creek drainage; GD, Geneva Creek drainage; n/a, not applicable; culvert refers to the end of a cross drain on the fillslope side; roadside ditch refers to the point where a ditch channels road runoff away from the road, such as at a switchback; note: table is in two parts and midway through this table a new set of column headings begins; predominant buffer zone grain size refers to soil or sediment cover on the slope where fine = sand/silt, medium = gravel and coarse = larger than gravel]

Site number (fig. 45)	Latitude (degrees minutes seconds)	Longitude (degrees minutes seconds)	Altitude (feet)	Type of feature	Contributing ditch length (feet)	Ditch length from other upslope culverts (feet)	Predominant buffer-zone vegetation	Slope material	Predominant buffer-zone grain size	Cutslope erosion	Slope topography
CCD1	39 35 57	105 42 35	11,512	culvert	790	--	alpine tundra	colluvium, soil	medium	moderately eroded, some vegetation	undulating
CCD2	39 36 01	105 42 37	11,486	roadside ditch	440	--	conifer	colluvium	medium	moderately eroded, some vegetation	smooth
CCD3	39 35 58	105 42 33	11,459	culvert	275	790	willow	colluvium	medium	highly eroded, little vegetation	smooth
CCD4	39 35 57	105 42 28	11,420	roadside ditch	571	--	willow	colluvium, soil	medium	highly eroded, little vegetation	undulating
CCD5	39 35 59	105 42 31	11,410	culvert	480	790+275	conifer	colluvium, soil	medium	highly eroded, little vegetation	smooth
CCD6	39 36 08	105 42 36	11,302	culvert	728	440	conifer	colluvium, soil	medium	moderately eroded, some vegetation	undulating
CCD7	39 36 10	105 42 39	11,295	culvert	526	--	willow	colluvium, soil	medium	highly eroded, little vegetation	undulating
CCD8	39 36 12	105 42 40	11,280	culvert	240	--	willow	colluvium, soil	medium	highly eroded, little vegetation	undulating
CCD9	39 36 16	105 42 45	11,266	culvert	475	--	conifer	colluvium, talus	coarse	highly eroded, little vegetation	undulating
CCD10	39 36 20	105 42 48	11,187	roadside ditch	665	--	conifer	colluvium, soil	medium	highly eroded, little vegetation	undulating
CCD11	39 36 18	105 42 43	11,144	culvert	565	--	conifer	colluvium	medium	highly eroded, little vegetation	undulating
CCD12	39 36 17	105 42 41	11,128	roadside ditch	254	475	conifer	colluvium, soil	medium	highly eroded, little vegetation	undulating
CCD13	39 36 21	105 42 45	11,108	culvert	492	565	willow	colluvium	medium	highly eroded, little vegetation	smooth
CCD14	39 36 27	105 42 50	11,020	culvert	668	--	conifer	colluvium, soil	medium	moderately eroded, some vegetation	smooth
CCD15	39 36 31	105 42 55	10,974	roadside ditch	720	--	conifer	colluvium, soil	medium	moderately eroded, some vegetation	undulating
CCD16	39 36 34	105 42 54	10,908	roadside ditch	290	--	conifer	colluvium, soil	medium	highly eroded, little vegetation	undulating

Table 54. Drainage-feature evaluation data—Continued

[--, no data; CCD, South Clear Creek drainage; GD, Geneva Creek drainage; n/a, not applicable; culvert refers to the end of a cross drain on the fillslope side; roadside ditch refers to the point where a ditch channels road runoff away from the road, such as at a switchback; note: table is in two parts and midway through this table a new set of column headings begins; predominant buffer zone grain size refers to soil or sediment cover on the slope where fine = sand/silt, medium = gravel and coarse = larger than gravel]

Site number (fig. 45)	Latitude (degrees minutes seconds)	Longitude (degrees minutes seconds)	Altitude (feet)	Type of feature	Contributing ditch length (feet)	Ditch length from other upslope culverts (feet)	Predominant buffer-zone vegetation	Slope material	Predominant buffer-zone grain size	Cutslope erosion	Slope topography
CCD17	39 36 34	105 43 00	10,882	culvert	579	720	conifer	colluvium, soil	medium	highly eroded, little vegetation	undulating
CCD18	39 36 34	105 43 04	10,872	culvert	416	--	conifer	soil	fine	highly eroded, little vegetation	smooth
CCD19	39 36 44	105 43 01	10,784	roadside ditch	610	--	willow	colluvium, soil	medium	moderately eroded, some vegetation	undulating
CCD20	39 36 46	105 43 01	10,777	culvert	305	--	willow	soil	fine	low erosion, revegetating	smooth
CCD21	39 36 48	105 43 00	10,764	culvert	197	--	willow	soil	fine	moderately eroded, some vegetation	smooth
CCD22	39 36 53	105 42 58	10,734	culvert	556	--	willow	soil, litter	fine	moderately eroded, some vegetation	smooth
CCD23	39 37 02	105 42 56	10,688	culvert	885	--	willow	soil	fine	moderately eroded, some vegetation	smooth
CCD24	39 37 08	105 42 54	10,662	culvert	903	--	willow	soil	fine	moderately eroded, some vegetation	smooth
CCD25	39 37 16	105 42 51	10,636	culvert	211	--	willow	soil, litter	fine	moderately eroded, some vegetation	smooth
CCD26	39 37 22	105 42 49	10,610	culvert	412	--	grass	soil, litter	fine	moderately eroded, some vegetation	smooth
CCD27	39 37 25	105 42 47	10,600	culvert	255	--	grass	soil	fine	moderately eroded, some vegetation	smooth
CCD28	39 37 28	105 42 46	10,583	culvert	220	--	grass	colluvium	medium	moderately eroded, some vegetation	smooth
CCD29	39 37 39	105 42 45	10,508	culvert	1270	--	willow	soil	fine	moderately eroded, some vegetation	smooth
CCD30	39 37 42	105 42 43	10,492	culvert	79	--	willow	colluvium	medium	moderately eroded, some vegetation	undulating
CCD31	39 38 00	105 42 39	10,393	culvert	777	--	conifer	soil	fine	low erosion, revegetating	smooth
CCD32	39 38 07	105 42 36	10,351	roadside ditch, bridge crossing	611	--	willow	colluvium	medium	low erosion, revegetating	undulating
CCD33	39 38 06	105 42 35	10,347	roadside ditch	297	--	willow	soil	fine	moderately eroded, some vegetation	smooth

Table 54. Drainage-feature evaluation data—Continued

[--, no data; CCD, South Clear Creek drainage; GD, Geneva Creek drainage; n/a, not applicable; culvert refers to the end of a cross drain on the fillslope side; roadside ditch refers to the point where a ditch channels road runoff away from the road, such as at a switchback; note: table is in two parts and midway through this table a new set of column headings begins; predominant buffer zone grain size refers to soil or sediment cover on the slope where fine = sand/silt, medium = gravel and coarse = larger than gravel]

Site number (fig. 45)	Latitude (degrees minutes seconds)	Longitude (degrees minutes seconds)	Altitude (feet)	Type of feature	Contributing ditch length (feet)	Ditch length from other upslope culverts (feet)	Predominant buffer-zone vegetation	Slope material	Predominant buffer-zone grain size	Cutslope erosion	Slope topography
CCD34	39 38 21	105 42 28	10,216	roadside ditch	1495	--	willow	soil	fine	moderately eroded, some vegetation	smooth
CCD35	39 38 31	105 42 28	10,206	culvert	988	--	conifer	colluvium	medium	moderately eroded, some vegetation	smooth
CCD36	39 38 52	105 42 28	10,081	culvert	2350	--	conifer	soil, litter	fine	moderately eroded, some vegetation	smooth
CCD37	39 39 05	105 42 28	10,013	roadside ditch	979	--	willow	colluvium, soil	medium	moderately eroded, some vegetation	smooth
CCD38	39 39 05	105 42 29	10,016	culvert (north and south ditches)	1794	--	willow	colluvium, soil	medium	moderately eroded, some vegetation	smooth
CCD39	39 39 23	105 42 31	10,045	culvert	467	--	grass	talus, colluvium, soil	coarse	highly eroded, little vegetation	undulating
CCD40	39 39 26	105 42 31	10,075	culvert	257	--	grass	talus, colluvium	coarse	highly eroded, little vegetation	rocky
CCD41	39 39 49	105 42 22	10,055	culvert	178	--	grass	talus, colluvium	coarse	moderately eroded, some vegetation	undulating
CCD42	39 39 59	105 42 14	9,963	culvert	1167	--	grass	talus, soil	coarse	moderately eroded, some vegetation	smooth
CCD43	39 40 06	105 42 13	9,931	culvert	1388	--	conifer	talus, colluvium	coarse	highly eroded, little vegetation	smooth
CCD44	39 40 29	105 42 22	9,917	culvert	105	--	grass	talus	coarse	moderately eroded, some vegetation	smooth
CCD45	39 40 32	105 42 21	9,927	culvert	136	--	grass	talus	coarse	moderately eroded, some vegetation	smooth
CCD46	39 40 46	105 42 11	9,809	roadside ditch	958	--	grass	rock, talus, colluvium	coarse	highly eroded, little vegetation	smooth
CCD47	39 40 40	105 42 09	9,776	culvert	731	--	grass	rock, talus, colluvium	coarse	moderately eroded, some vegetation	smooth
CCD48	39 40 36	105 41 59	9,727	roadside ditch	932	--	conifer	talus, colluvium	coarse	highly eroded, little vegetation	smooth

Table 54. Drainage-feature evaluation data—Continued

[--, no data; CCD, South Clear Creek drainage; GD, Geneva Creek drainage; n/a, not applicable; culvert refers to the end of a cross drain on the fillslope side; roadside ditch refers to the point where a ditch channels road runoff away from the road, such as at a switchback; note: table is in two parts and midway through this table a new set of column headings begins; predominant buffer zone grain size refers to soil or sediment cover on the slope where fine = sand/silt, medium = gravel and coarse = larger than gravel]

Site number (fig. 45)	Latitude (degrees minutes seconds)	Longitude (degrees minutes seconds)	Altitude (feet)	Type of feature	Contributing ditch length (feet)	Ditch length from other upslope culverts (feet)	Predominant buffer-zone vegetation	Slope material	Predominant buffer-zone grain size	Cutslope erosion	Slope topography
CCD49	39 40 42	105 42 03	9,655	roadside ditch	754	--	conifer	colluvium	medium	highly eroded, little vegetation	smooth
CCD50	39 40 52	105 42 10	9,547	roadside ditch	1134	--	conifer	colluvium, soil, litter	medium	low erosion, revegetating	smooth
CCD51	39 40 59	105 42 10	9,501	roadside ditch	815	--	none	talus, colluvium	coarse	moderately eroded, some vegetation	smooth
CCD52	39 40 58	105 42 09	9,478	culvert	105	--	aspen	colluvium	medium	moderately eroded, some vegetation	smooth
CCD53	39 40 56	105 42 07	9,442	roadside ditch	170	--	conifer	soil, litter	fine	moderately eroded, some vegetation	smooth
CCD54	39 41 01	105 42 07	9,415	roadside ditch	314	--	none	talus, colluvium	coarse	highly eroded, little vegetation	smooth
CCD55	39 41 23	105 41 57	9,274	culvert	1812	--	aspen	colluvium, soil	medium	moderately eroded, some vegetation	smooth
CCD56	39 41 28	105 41 55	9,183	culvert	269	--	none	colluvium	medium	moderately eroded, some vegetation	smooth
CCD57	39 41 39	105 41 49	9,173	culvert	1163	--	willow	rock, talus	coarse	moderately eroded, some vegetation	rocky
CCD58	39 42 03	105 41 50	8,927	culvert	2200	--	conifer	soil, litter	fine	moderately eroded, some vegetation	smooth
CCD59	39 42 06	105 42 02	8,864	roadside ditch	1085	--	conifer	rock, colluvium, soil	coarse	highly eroded, little vegetation	cliffs
CCD60	39 42 10	105 41 44	8,700	roadside ditch	1572	--	conifer	talus, colluvium	coarse	highly eroded, little vegetation	smooth
CCD61	39 42 09	105 41 55	8,677	culvert	597	--	conifer	colluvium, soil	medium	highly eroded, little vegetation	undulating
CCD62	39 42 11	105 42 01	8,661	culvert	715	--	conifer	colluvium, soil	medium	highly eroded, little vegetation	smooth
CCD63	39 42 13	105 41 53	8,546	roadside ditch	1100	1572+597	conifer	colluvium, soil	medium	moderately eroded, some vegetation	smooth
				Total ditch =	44,492						

Table 54. Drainage-feature evaluation data—Continued

[--, no data; CCD, South Clear Creek drainage; GD, Geneva Creek drainage; n/a, not applicable; culvert refers to the end of a cross drain on the fillslope side; roadside ditch refers to the point where a ditch channels road runoff away from the road, such as at a switchback; note: table is in two parts and midway through this table a new set of column headings begins; predominant buffer zone grain size refers to soil or sediment cover on the slope where fine = sand/silt, medium = gravel and coarse = larger than gravel]

Site number (fig. 45)	Latitude (degrees minutes seconds)	Longitude (degrees minutes seconds)	Altitude (feet)	Type of feature	Contributing ditch length (feet)	Ditch length from other upslope culverts (feet)	Predominant buffer-zone vegetation	Slope material	Predominant buffer-zone grain size	Cutslope erosion	Slope topography
GD1	39 35 37	105 42 44	11,666	culvert	747	--	tundra	soil	fine	moderately eroded, some vegetation	undulating
GD2	39 35 23	105 43 06	11,561	culvert	2330	--	tundra	colluvium, soil	medium	moderately eroded, some vegetation	undulating
GD3	39 35 09	105 43 07	11,496	culvert	1416	--	tundra	colluvium, soil	medium	highly eroded, little vegetation	undulating
GD4	39 35 07	105 43 07	11,482	culvert	138	--	conifer	colluvium	medium	highly eroded, little vegetation	smooth
GD5	39 34 52	105 43 13	11,315	culvert	1486	--	conifer	soil	fine	highly eroded, little vegetation	undulating
GD6	39 34 46	105 43 18	11,259	culvert	703	--	conifer	colluvium, soil	medium	moderately eroded, some vegetation	hummocky, large woody debris
GD7	39 34 38	105 43 18	11,233	roadside ditch	1010	--	conifer	talus, colluvium, soil	coarse	moderately eroded, some vegetation	smooth
GD8	39 34 39	105 43 20	11,217	roadside ditch	112	--	grass	talus, colluvium	coarse	moderately eroded, some vegetation	smooth
GD9	39 34 32	105 43 30	11,171	roadside ditch	400	--	none	rock, talus	coarse	moderately eroded, some vegetation	smooth
GD10	39 34 32	105 43 33	11,138	roadside ditch	190	--	conifer	colluvium	medium	moderately eroded, some vegetation	smooth
GD11	39 34 22	105 43 28	11,062	culvert	973	--	conifer	talus, colluvium	coarse	moderately eroded, some vegetation	undulating
GD12	39 34 20	105 43 28	11,049	culvert	283	--	conifer	talus, soil	coarse	moderately eroded, some vegetation	undulating
GD13	39 34 16	105 43 28	11,013	culvert	183	--	conifer	talus, colluvium	coarse	moderately eroded, some vegetation	undulating
GD14	39 34 11	105 43 28	10,977	culvert	703	--	conifer	colluvium, soil	medium	moderately eroded, some vegetation	smooth
GD15	39 33 45	105 43 11	10,761	culvert	2863	--	conifer	talus, colluvium, soil	coarse	highly eroded, little vegetation	smooth, large woody debris
GD16	39 33 39	105 43 09	10,656	culvert	645	--	conifer	talus, colluvium, soil	coarse	highly eroded, little vegetation	undulating, large woody debris

Table 54. Drainage-feature evaluation data—Continued

[--, no data; CCD, South Clear Creek drainage; GD, Geneva Creek drainage; n/a, not applicable; culvert refers to the end of a cross drain on the fillslope side; roadside ditch refers to the point where a ditch channels road runoff away from the road, such as at a switchback; note: table is in two parts and midway through this table a new set of column headings begins; predominant buffer zone grain size refers to soil or sediment cover on the slope where fine = sand/silt, medium = gravel and coarse = larger than gravel]

Site number (fig. 45)	Latitude (degrees minutes seconds)	Longitude (degrees minutes seconds)	Altitude (feet)	Type of feature	Contributing ditch length (feet)	Ditch length from other upslope culverts (feet)	Predominant buffer-zone vegetation	Slope material	Predominant buffer-zone grain size	Cutslope erosion	Slope topography
GD17	39 33 32	105 43 04	10,649	culvert	1062	--	conifer	rock, talus, soil	coarse	highly eroded, little vegetation	undulating, large woody debris
GD18	39 33 29	105 43 04	10,610	culvert	552	--	willow	talus, soil	coarse	moderately eroded, some vegetation	undulating, hummocky
GD19	39 33 24	105 43 03	10,639	culvert	390	--	conifer	talus, colluvium, soil	coarse	moderately eroded, some vegetation	undulating
GD20	39 33 16	105 43 03	10,554	culvert	815	--	conifer	colluvium, soil	medium	moderately eroded, some vegetation	smooth
GD21	39 33 08	105 43 03	10,492	roadside ditch	776	--	willow	talus	coarse	low erosion, revegetating	smooth
GD22	39 33 13	105 43 05	10,469	culvert	534	--	aspen	rock, talus, soil	coarse	low erosion, revegetating	undulating
GD23	39 33 16	105 43 07	10,413	culvert	170	815	aspen	talus, colluvium, soil	coarse	low erosion, revegetating	undulating
GD24	39 33 18	105 43 08	10,423	culvert	132	--	aspen	talus, colluvium, soil	coarse	low erosion, revegetating	undulating
GD25	39 33 22	105 43 10	10,390	culvert	640	1062	grass	soil	fine	low erosion, revegetating	undulating
GD26	39 33 22	105 33 13	10,373	roadside ditch	568	--	grass	colluvium, soil	medium	moderately eroded, some vegetation	smooth
GD27	39 33 20	105 43 13	10,357	roadside ditch	460	--	grass	colluvium, soil	medium	moderately eroded, some vegetation	smooth
GD28	39 33 10	105 43 15	10,314	culvert	904	--	grass	soil	fine	moderately eroded, some vegetation	smooth
GD29	39 32 55	105 43 09	10,246	roadside ditch	1135	--	grass	colluvium, soil	medium	low erosion, revegetating	smooth
GD30	39 32 54	105 43 08	10,239	culvert	222	--	willow	colluvium	medium	low erosion, revegetating	smooth
GD31	39 32 52	105 43 07	10,259	culvert	217	--	willow	soil	fine	low erosion, revegetating	smooth
GD32	39 32 42	105 43 09	10,157	culvert	1134	--	grass	soil	fine	moderately eroded, some vegetation	smooth
GD33	39 32 27	105 43 16	10,111	culvert	1499	--	willow	rock, colluvium, soil	coarse	moderately eroded, some vegetation	undulating

Table 54. Drainage-feature evaluation data—Continued

[--, no data; CCD, South Clear Creek drainage; GD, Geneva Creek drainage; n/a, not applicable; culvert refers to the end of a cross drain on the fillslope side; roadside ditch refers to the point where a ditch channels road runoff away from the road, such as at a switchback; note: table is in two parts and midway through this table a new set of column headings begins; predominant buffer zone grain size refers to soil or sediment cover on the slope where fine = sand/silt, medium = gravel and coarse = larger than gravel]

Site number (fig. 45)	Latitude (degrees minutes seconds)	Longitude (degrees minutes seconds)	Altitude (feet)	Type of feature	Contributing ditch length (feet)	Ditch length from other upslope culverts (feet)	Predominant buffer-zone vegetation	Slope material	Predominant buffer-zone grain size	Cutslope erosion	Slope topography
GD34	39 32 19	105 43 27	10,045	culvert	904	--	willow	soil	fine	moderately eroded, some vegetation	undulating
GD35	39 32 15	105 43 33	10,013	culvert	533	--	conifer	rock, colluvium, soil	coarse	moderately eroded, some vegetation	undulating
GD36	39 31 49	105 43 49	9,849	culvert	2773	--	conifer	colluvium, soil	medium	moderately eroded, some vegetation	undulating, large woody debris
GD37	39 31 37	105 43 52	9,799	culvert	1353	--	willow	soil	fine	moderately eroded, some vegetation	smooth
GD38	39 31 28	105 43 51	9,760	culvert	896	--	willow	soil	fine	low erosion, revegetated	smooth
GD39	39 31 21	105 43 48	9,747	culvert	700	--	willow	soil	fine	low erosion, revegetated	smooth
GD40	39 31 15	105 43 44	9,714	culvert	730	--	willow	soil	fine	low erosion, revegetated	smooth
GD41	39 31 13	105 43 41	9,717	culvert	515	--	willow	soil	fine	low erosion, revegetated	smooth
GD42	39 31 06	105 43 32	9,711	culvert	730	--	willow	soil	fine	low erosion, revegetated	smooth
GD43	39 31 02	105 43 28	9,698	culvert	513	--	willow	soil	fine	low erosion, revegetated	smooth
GD44	39 31 01	105 43 23	9,691	culvert	510	--	grass	soil	fine	low erosion, revegetated	smooth
GD45	39 31 00	105 43 20	9,694	culvert	144	--	grass	soil	fine	low erosion, revegetated	smooth
GD46	39 30 55	105 43 08	9,675	culvert	1680	--	grass	soil	fine	low erosion, revegetated	smooth
GD47	39 30 48	105 42 51	9,658	culvert	950	--	grass	soil	fine	low erosion, revegetated	smooth
GD48	39 30 47	105 42 48	9,658	culvert	250	--	grass	soil	fine	low erosion, revegetated	smooth
GD49	39 30 34	105 42 39	9,629	culvert	310	--	grass	soil	fine	low erosion, revegetated	smooth
GD50	39 30 32	105 42 41	9,632	roadside ditch	195	--	grass	soil	fine	low erosion, revegetated	smooth

Table 54. Drainage-feature evaluation data—Continued

[--, no data; CCD, South Clear Creek drainage; GD, Geneva Creek drainage; n/a, not applicable; culvert refers to the end of a cross drain on the fillslope side; roadside ditch refers to the point where a ditch channels road runoff away from the road, such as at a switchback; note: table is in two parts and midway through this table a new set of column headings begins; predominant buffer zone grain size refers to soil or sediment cover on the slope where fine = sand/silt, medium = gravel and coarse = larger than gravel]

Site number (fig. 45)	Latitude (degrees minutes seconds)	Longitude (degrees minutes seconds)	Altitude (feet)	Type of feature	Contributing ditch length (feet)	Ditch length from other upslope culverts (feet)	Predominant buffer-zone vegetation	Slope material	Predominant buffer-zone grain size	Cutslope erosion	Slope topography
GD51	39 30 28	105 42 36	9,570	culvert	725	--	grass	talus, colluvium	coarse	highly eroded, little vegetation	smooth
GD52	39 30 25	105 42 32	9,511	culvert	352	--	aspen	talus, colluvium	coarse	highly eroded, little vegetation	smooth
GD53	39 30 28	105 42 26	9,494	culvert	612	--	aspen	talus, colluvium	coarse	highly eroded, little vegetation	smooth
GD54	39 30 29	105 42 21	9,504	roadside ditch	400	--	conifer	colluvium	medium	highly eroded, little vegetation	rocky
GD55	39 30 22	105 42 29	9,399	roadside ditch	948	612	conifer	colluvium	medium	highly eroded, little vegetation	smooth
GD56	39 30 22	105 42 24	9,360	culvert	361	--	conifer	talus, colluvium, soil	coarse	low erosion, revegetating	hummocky
GD57	39 30 19	105 42 18	9,320	culvert	558	--	conifer	soil	fine	low erosion, revegetating	smooth
GD58	39 30 18	105 42 15	9,327	roadside ditch	279	--	none	rock, colluvium	coarse	low erosion, r evegetating	hummocky
GD59	39 30 15	105 42 09	9,347	culvert	635	--	conifer	soil	fine	low erosion, revegetating	smooth
GD60	39 30 11	105 42 08	9,314	culvert	287	--	conifer	soil	fine	low erosion, revegetating	smooth
GD61	39 30 00	105 42 00	9,199	culvert	323	--	conifer	colluvium, soil	medium	low erosion, revegetating	smooth
GD62	39 29 38	105 41 45	9,189	culvert	1,085	--	conifer	colluvium, soil	medium	moderately eroded, some vegetation	smooth
GD63	39 29 31	105 41 46	9,064	culvert	1,155	--	conifer	soil	fine	moderately eroded, some vegetation	smooth
GD64	39 29 27	105 41 45	9,019	culvert	394	--	conifer	soil	fine	low erosion, revegetating	smooth
GD65	39 29 17	105 41 39	8,992	culvert	920	--	conifer	soil	fine	moderately eroded, some vegetation	smooth
GD66	39 29 08	105 41 39	8,996	culvert	974	--	conifer	soil	fine	moderately eroded, some vegetation	smooth
GD67	39 28 42	105 41 19	9,009	culvert	3,140	--	conifer	soil	fine	moderately eroded, some vegetation	rocky

Table 54. Drainage-feature evaluation data—Continued

[--, no data; CCD, South Clear Creek drainage; GD, Geneva Creek drainage; n/a, not applicable; culvert refers to the end of a cross drain on the fillslope side; roadside ditch refers to the point where a ditch channels road runoff away from the road, such as at a switchback; note: table is in two parts and midway through this table a new set of column headings begins; predominant buffer zone grain size refers to soil or sediment cover on the slope where fine = sand/silt, medium = gravel and coarse = larger than gravel]

Site number (fig. 45)	Latitude (degrees minutes seconds)	Longitude (degrees minutes seconds)	Altitude (feet)	Type of feature	Contributing ditch length (feet)	Ditch length from other upslope culverts (feet)	Predominant buffer-zone vegetation	Slope material	Predominant buffer-zone grain size	Cutslope erosion	Slope topography
GD68	39 28 38	105 41 18	8,854	culvert	293	--	conifer	soil	fine	moderately eroded, some vegetation	hummocky
GD69	39 28 34	105 41 07	8,959	culvert	1,170	--	willow	talus, colluvium	coarse	moderately eroded, some vegetation	rocky
GD70	39 28 24	105 41 00	8,933	culvert	965	--	willow	talus, colluvium	coarse	moderately eroded, some vegetation	smooth
GD71	39 28 21	105 40 55	8,871	culvert	472	--	willow	talus, colluvium	coarse	moderately eroded, some vegetation	smooth
GD72	39 28 06	105 40 28	8,756	culvert	2,964	--	willow	colluvium, soil	medium	moderately eroded, some vegetation	smooth
GD73	39 27 56	105 40 22	8,697	culvert	1,515	--	willow	soil	fine	low erosion, revegetating	smooth
GD74	39 27 49	105 40 02	8,635	culvert	74	--	willow	colluvium, soil	medium	low erosion, revegetating	hummocky
				Total ditch =	59,679						

Site number (fig. 45)	Obstructions	Sediment travel distance into buffer zone (feet)	Natural or artificial channel	Channel width (feet)	Channel depth (feet)	Deposition or erosion in buffer zone	Largest particle size transported to stream	Runoff reaches stream or lake	Factors causing sediment to deposit in buffer zone	Name of receiving stream
CCD1	none	130 (to CCD3)	natural	1 to 2 ft	1 to 2 ft	erosion	gravel	always (via CCD3, CCD5)	not deposited	South Clear Creek
CCD2	fallen trees	360 (to CCD6)	natural	2 to 3 ft	0.5 ft	erosion	gravel	always (via CCD6)	not deposited	South Clear Creek
CCD3	none	150 (to CCD5)	natural	2 to 4 ft	1 to 2 ft	erosion	gravel	always (via CCD5)	not deposited	South Clear Creek
CCD4	fallen trees	210	natural	1.5 ft	0.5 ft	erosion	n/a	never	slope	South Clear Creek
CCD5	fallen trees	875	natural	2 to 4 ft	0.5 to 2 ft	both	gravel	always	not deposited	South Clear Creek
CCD6	fallen trees	650	artificial	2 to 20 ft	0.5 to 10 ft	erosion	gravel	always	not deposited	South Clear Creek
CCD7	fallen trees, rocks	710	natural	2 to 3 ft	1 to 2.5 ft	erosion	gravel	always	not deposited	South Clear Creek
CCD8	fallen trees	560	artificial	1 to 3 ft	1 to 3 ft	erosion	n/a	never	slope	South Clear Creek
CCD9	fallen trees, rocks	210 (to CCD12)	artificial	2 to 4 ft	0.5 ft	both	gravel	always (via CCD12)	not deposited	South Clear Creek
CCD10	fallen trees	495	artificial	1 to 3 ft	0.5 ft	both	n/a	never	slope	South Clear Creek
CCD11	fallen trees	170 (to CCD13)	artificial	2 to 3 ft	0.5 to 1 ft	both	gravel	always (via CCD13)	not deposited	South Clear Creek
CCD12	none	215	artificial	1 to 2 ft	0.5 to 1 ft	erosion	gravel	always	not deposited	South Clear Creek

Table 54. Drainage-feature evaluation data—Continued

[--, no data; CCD, South Clear Creek drainage; GD, Geneva Creek drainage; n/a, not applicable; culvert refers to the end of a cross drain on the fillslope side; roadside ditch refers to the point where a ditch channels road runoff away from the road, such as at a switchback; note: table is in two parts and midway through this table a new set of column headings begins; predominant buffer zone grain size refers to soil or sediment cover on the slope where fine = sand/silt, medium = gravel and coarse = larger than gravel]

Site number (fig. 45)	Obstructions	Sediment travel distance into buffer zone (feet)	Natural or artificial channel	Channel width (feet)	Channel depth (feet)	Deposition or erosion in buffer zone	Largest particle size transported to stream	Runoff reaches stream or lake	Factors causing sediment to deposit in buffer zone	Name of receiving stream
CCD13	fallen trees, rocks	75	artificial	2 to 4 ft	2 to 5 ft	erosion	cobble	always	not deposited	South Clear Creek
CCD14	none	195	artificial	2 ft	1 ft	both	gravel	always	not deposited	South Clear Creek
CCD15	fallen trees, rocks	322 (to CCD17)	artificial	1 to 2 ft	0.5 to 1 ft	erosion	gravel	always (via CCD17)	not deposited	Naylor Creek
CCD16	fallen trees	120	artificial	1 to 3 ft	0.5 ft	both	gravel	always	not deposited	South Clear Creek
CCD17	fallen trees	990	artificial	2 to 4	0.5	both	sand	always	not deposited	Naylor Creek
CCD18	fallen trees	345	natural and artificial	1 to 8	0.5–1	both	gravel	always	not deposited	Naylor Creek
CCD19	fallen trees	70	artificial	1 to 4	0.5–1	both	gravel	always	not deposited	Naylor Creek
CCD20	beaver dams	200	natural	1 to 2	0.5	both	n/a	probably not	obstructions (beaver dams)	South Clear Creek
CCD21	beaver dams	155	natural	1 to 2	<0.5	both	n/a	never	slope, vegetation, beaver dam	South Clear Creek
CCD22	beaver dams	170	artificial	1 to 3	0.5	both	n/a	never	slope, vegetation, beaver dam	South Clear Creek
CCD23	beaver dams	160	natural	1 to 3	0.5	both	n/a	never	slope, vegetation, beaver dam	South Clear Creek
CCD24	none	70	artificial	1 to 2	0.5	both	n/a	never	slope, vegetation, infiltration	South Clear Creek
CCD25	swale	25	natural	1	<0.5	deposition	n/a	never	slope, vegetation	South Clear Creek
CCD26	none	47	natural	1 to 2	0.5	both	sand	always	not deposited	South Clear Creek
CCD27	none	25	artificial	1 to 3	0.5	both	gravel	always	not deposited	South Clear Creek
CCD28	none	0	artificial	n/a	n/a	erosion	gravel	always	not deposited	South Clear Creek
CCD29	none	134	artificial	2 to 4	1	deposition	sand	always	not deposited	South Clear Creek
CCD30	rocks	35	natural	1 to 2	0.5	erosion	gravel	always	not deposited	South Clear Creek
CCD31	rocks	70	artificial	2	1	both	gravel	always	not deposited	South Clear Creek
CCD32	rocks	40	artificial	1 to 2	0.5–1	erosion	gravel	always	not deposited	South Clear Creek
CCD33	none	10	artificial	1 to 2	0.5	both	sand	always	not deposited	South Clear Creek
CCD34	none	25	artificial	1 to 2	0.5–1	both	gravel	always	not deposited	South Clear Creek
CCD35	none	15	artificial	1 to 2	1	erosion	gravel	always	not deposited	South Clear Creek
CCD36	closed drainages	153	artificial	1 to 10	0.5	both	silt/clay	sometimes	slope, vegetation, infiltration	South Clear Creek
CCD37	beaver dam	253	artificial	4 to 5	1 to 2	both	silt/clay	sometimes	beaver dam	South Clear Creek

Table 54. Drainage-feature evaluation data—Continued

[--, no data; CCD, South Clear Creek drainage; GD, Geneva Creek drainage; n/a, not applicable; culvert refers to the end of a cross drain on the fillslope side; roadside ditch refers to the point where a ditch channels road runoff away from the road, such as at a switchback; note: table is in two parts and midway through this table a new set of column headings begins; predominant buffer zone grain size refers to soil or sediment cover on the slope where fine= sand/silt, medium= gravel and coarse= larger than gravel]

Site number (fig. 45)	Obstructions	Sediment travel distance into buffer zone (feet)	Natural or artificial channel	Channel width (feet)	Channel depth (feet)	Deposition or erosion in buffer zone	Largest particle size transported to stream	Runoff reaches stream or lake	Factors causing sediment to deposit in buffer zone	Name of receiving stream
CCD38	beaver dam	253	artificial	1 to 5	1 to 2	both	silt/clay	sometimes	beaver dam	South Clear Creek
CCD39	none	200 (est)	artificial	unknown	unknown	unknown	unknown	probably	not deposited	Lower Cabin Creek Reservoir
CCD40	none	150 (est)	artificial	unknown	unknown	deposition	sand	always	not deposited	Lower Cabin Creek Reservoir
CCD41	rocks	250 (est)	natural	1 to 3	0.5	both	sand	always	not deposited	South Clear Creek
CCD42	none	800	natural	1 to 4	0.5	both	sand	always	not deposited	Clear Lake
CCD43	none	125	natural	1 to 3	1	erosion	gravel	always	not deposited	Clear Lake
CCD44	none	5	natural	1	<0.5	erosion	sand	always	not deposited	Green Lake
CCD45	none	5	natural	1	0.5	erosion	sand	always	not deposited	Green Lake
CCD46	rocks, closed drainages	120	artificial	1 to 3	0.5	both	n/a	never	obstructions, infiltration	South Clear Creek
CCD47	rocks	300	artificial	1 to 4	0.5	both	gravel	always	infiltration	South Clear Creek
CCD48	rocks	25	artificial	1 to 2	0.5–1	erosion	gravel	always	not deposited	South Clear Creek
CCD49	closed drainages	10	artificial	1 to 2	1	both	n/a	never	obstructions, infiltration	South Clear Creek
CCD50	none	75	artificial	1 to 3	0.5	deposition	n/a	never	slope	South Clear Creek
CCD51	none	50	artificial	2 to 10	2 to 5	erosion	gravel	sometimes	obstructions	Leavenworth Creek
CCD52	closed drainage	120	artificial	1	0–Jan	both	n/a	never	closed drainage	South Clear Creek
CCD53	none	25	artificial	1 to 2	0.5	both	n/a	never	slope, infiltration	South Clear Creek
CCD54	rocks	40	artificial	2 to 3	1 to 2	erosion	gravel	always	not deposited	Leavenworth Creek
CCD55	closed drainages	350	artificial	1 to 3	0.5	deposition	silt/clay	sometimes	slope, infiltration	South Clear Creek
CCD56	none	0	artificial	n/a	n/a	erosion	sand	always	not deposited	Georgetown Reservoir
CCD57	rocks	15	artificial	1 to 2	0.5	both	gravel	always	not deposited	South Clear Creek
CCD58	none	200	artificial	1 to 2	0.5	deposition	n/a	never	infiltration	South Clear Creek
CCD59	none	200 (est)	artificial	1 to 3	0.5–1	both	n/a	never	slope, infiltration	South Clear Creek
CCD60	rocks	250 (est)	artificial	1 to 2	1	both	gravel	always	not deposited	South Clear Creek
CCD61	none	150 to CCD62	artificial	1 to 2	0.5	both	sand	sometimes via CCD62	not deposited	Clear Creek
CCD62	sediment settling basin	(flows under road into ditch for CCD62)	artificial	n/a	n/a	deposition	silt/clay	sometimes via CCD62	lack of flow, sediment basin	Clear Creek

Table 54. Drainage-feature evaluation data—Continued

[--, no data; CCD, South Clear Creek drainage; GD, Geneva Creek drainage; n/a, not applicable; culvert refers to the end of a cross drain on the fillslope side; roadside ditch refers to the point where a ditch channels road runoff away from the road, such as at a switchback; note: table is in two parts and midway through this table a new set of column headings begins; predominant buffer zone grain size refers to soil or sediment cover on the slope where fine= sand/silt, medium= gravel and coarse= larger than gravel]

Site number (fig. 45)	Obstructions	Sediment travel distance into buffer zone (feet)	Natural or artificial channel	Channel width (feet)	Channel depth (feet)	Deposition or erosion in buffer zone	Largest particle size transported to stream	Runoff reaches stream or lake	Factors causing sediment to deposit in buffer zone	Name of receiving stream
CCD63	urban obstacles	n/a	artificial	n/a	n/a	both	sand	sometimes	n/a	Clear Creek
GD1	none	30	artificial	1	<0.5	deposition	n/a	never	slope, vegetation	Duck Creek
GD2	none	510	artificial	1 to 10	0.5–1.5	both	n/a	never	vegetation, infiltration	Duck Creek
GD3	rocks	405	artificial	1 to 8	0.5–3	erosion	gravel	always	not deposited	Duck Creek
GD4	fallen trees, rocks	155	artificial	1 to 3	0.5	deposition	n/a	never	slope, infiltration, vegetation	Duck Creek
GD5	closed drainages	240	artificial	1 to 3	0.5–1.0	both	n/a	never	obstructions, slope, infiltration	Duck Lake
GD6	fallen trees, rocks	390	artificial	1 to 4	<0.5	both	gravel	always	not deposited	Duck Lake
GD7	closed drainages	340	artificial	1 to 5	<0.5–1	erosion	n/a	never	closed drainage	Duck Creek
GD8	rocks, closed drainages	30	artificial	1	0.5	deposition	n/a	never	closed drainage	Duck Creek
GD9	rocks, closed drainages	20	artificial	1	0.5	deposition	n/a	never	closed drainage	Duck Creek
GD10	none	<5	artificial	2 to 3	0.5	erosion	gravel	always	not deposited	Duck Creek
GD11	fallen trees, rocks	770	both	1 to 3	0.5–1	both	sand	always	not deposited	Duck Creek
GD12	fallen trees, rocks	510	artificial	1 to 2	0.5	both	sand	always	not deposited	Duck Creek
GD13	fallen trees, rocks	50	artificial	1	0.5	deposition	n/a	never	infiltration	Duck Creek
GD14	fallen trees, rocks	1246	artificial	1 to 4	0.5–1	both	n/a	never	slope	Duck Creek
GD15	fallen trees rocks	775	natural	1 to 8	0.5–1.5	both	sand	always	not deposited	Duck Creek
GD16	fallen trees, rocks	760	artificial	1 to 8	0.5–1.5	both	sand	always	not deposited	Duck Creek
GD17	fallen trees, rocks	1295	natural	1 to 4	0.5–3	both	sand	never	slope, vegetation, infiltration	Duck Creek
GD18	fallen trees, rocks	295	natural	0.5 to 1	0.5–1.5	both	n/a	never	infiltration	Duck Creek
GD19	fallen trees, rocks	160	artificial	0.5–2	0.5–1	both	n/a	never	vegetation, infiltration	Duck Creek
GD20	fallen trees, rocks	175 (to GD23 ditch)	artificial	1 to 4	0.5–1	both	n/a	never (via GD25)	not deposited	Duck Creek
GD21	fallen trees, rocks	320	artificial	2 to 4	0.5–1	both	n/a	never	slope, infiltration	Duck Creek
GD22	fallen trees, rocks	335	artificial	1 to 2	0.5	both	n/a	never	slope	Duck Creek
GD23	fallen trees, rocks	250	artificial	1 to 5	0.5	both	n/a	never	slope	Duck Creek
GD24	fallen trees, rocks	60	artificial	1	0.5	both	n/a	never	slope	Duck Creek
GD25	rocks	545	natural	2 to 4	1 to 3	erosion	n/a	never	slope, vegetation, infiltration	Duck Creek
GD26	none	0	artificial	1 to 2	0.5	erosion	sand	always	not deposited	Duck Creek

Table 54. Drainage-feature evaluation data—Continued

[--, no data; CCD, South Clear Creek drainage; GD, Geneva Creek drainage; n/a, not applicable; culvert refers to the end of a cross drain on the fillslope side; roadside ditch refers to the point where a ditch channels road runoff away from the road, such as at a switchback; note: table is in two parts and midway through this table a new set of column headings begins; predominant buffer zone grain size refers to soil or sediment cover on the slope where fine= sand/silt, medium= gravel and coarse= larger than gravel]

Site number (fig. 45)	Obstructions	Sediment travel distance into buffer zone (feet)	Natural or artificial channel	Channel width (feet)	Channel depth (feet)	Deposition or erosion in buffer zone	Largest particle size transported to stream	Runoff reaches stream or lake	Factors causing sediment to deposit in buffer zone	Name of receiving stream
GD27	none	0	artificial	1 to 2	0.5	erosion	sand	sometimes	vegetation, infiltration	Duck Creek
GD28	closed drainages	20	artificial	1	0.5	deposition	n/a	never	closed drainage, vegetation, infiltration	Duck Creek
GD29	rocks	0	artificial	1.5	0.5	both	silt/clay	always	not deposited	Duck Creek
GD30	none	45	natural	4 to 6	0.5	erosion	silt/clay	always	not deposited	Duck Creek
GD31	closed drainages	200	natural	1 to 2	0.5 to 1	deposition	n/a	never	slope, vegetation, infiltration	Duck Creek
GD32	none	50	artificial	1	<0.5	deposition	n/a	never	slope, vegetation, infiltration	Duck Creek
GD33	fallen trees, rocks	80	artificial	1 to 2	<0.5	both	n/a	never	slope, vegetation, infiltration	Duck Creek
GD34	fallen trees, rocks	105	artificial	1	0.5	both	n/a	never	slope, vegetation, infiltration	Duck Creek
GD35	fallen trees, rocks	505	natural	1 to 3	0.5–1	both	n/a	never	obstructions, vegetation	Duck Creek
GD36	fallen trees, rocks	120	natural	1 to 2	0.5–1	both	sand	sometimes	infiltration	Duck Creek
GD37	none	165	artificial	1 to 3	0.5	both	n/a	never	slope, vegetation, infiltration	Geneva Creek
GD38	none	25	artificial	1	0.5	deposition	n/a	never	slope, vegetation, infiltration	Geneva Creek
GD39	culvert blocked	0	n/a	n/a	n/a	n/a	n/a	never	obstructions	Geneva Creek
GD40	none	15	artificial	1	0.5	erosion	sand	always	not deposited	Geneva Creek
GD41	none	5	artificial	1	0.5	both	n/a	never	slope, vegetation, infiltration	Geneva Creek
GD42	none	10	artificial	1	0.5	both	n/a	never	slope, vegetation, infiltration	Geneva Creek
GD43	none	<5	artificial	1	0.5	both	n/a	never	slope, vegetation, infiltration	Geneva Creek
GD44	none	<5	artificial	1	0.5	both	n/a	never	slope, vegetation, infiltration	Geneva Creek
GD45	none	10	artificial	1	0.5	both	n/a	never	slope, vegetation, infiltration	Geneva Creek
GD46	none	10	artificial	1	0.5	both	n/a	never	slope, vegetation, infiltration	Geneva Creek
GD47	none	45	artificial	1	0.5	both	n/a	never	slope, vegetation, infiltration	Geneva Creek

Table 54. Drainage-feature evaluation data—Continued

[--, no data; CCD, South Clear Creek drainage; GD, Geneva Creek drainage; n/a, not applicable; culvert refers to the end of a cross drain on the fillslope side; roadside ditch refers to the point where a ditch channels road runoff away from the road, such as at a switchback; note: table is in two parts and midway through this table a new set of column headings begins; predominant buffer zone grain size refers to soil or sediment cover on the slope where fine= sand/silt, medium= gravel and coarse= larger than gravel]

Site number (fig. 45)	Obstructions	Sediment travel distance into buffer zone (feet)	Natural or artificial channel	Channel width (feet)	Channel depth (feet)	Deposition or erosion in buffer zone	Largest particle size transported to stream	Runoff reaches stream or lake	Factors causing sediment to deposit in buffer zone	Name of receiving stream
GD48	none	10	artificial	1	0.5	both	n/a	never	slope, vegetation, infiltration	Geneva Creek
GD49	none	10	artificial	1	0.5	both	n/a	never	slope, vegetation, infiltration	Geneva Creek
GD50	rocks, closed drainages	95	artificial	1 to 2	0.5–1	both	n/a	never	obstructions, infiltration	Geneva Creek
GD51	culvert blocked	n/a	artificial	n/a	n/a	n/a	n/a	probably never	obstructions	Geneva Creek
GD52	rocks	300	artificial	1 to 5	0.5–1	both	gravel	always	not deposited	Geneva Creek
GD53	fallen trees, rocks	200	natural	1 to 2	0.5	both	gravel	always(via GD55)	not deposited	Geneva Creek
GD54	rocks	40	artificial	1	0.5	erosion	gravel	always	not deposited	Scott Gomer Creek
GD55	rocks	70	artificial	1 to 2	0.5	both	gravel	always	not deposited	Geneva Creek
GD56	rocks	30	artificial	1 to 2	0.5	both	n/a	never	obstructions, infiltration	Geneva Creek
GD57	none	55	artificial	1 to 2	0.5	both	n/a	never	slope, vegetation	Geneva Creek
GD58	rocks	20	artificial	1	0.5	erosion	sand	sometimes	not deposited	Scott Gomer Creek
GD59	none	10	artificial	0.5	<0.5	both	sand	always	not deposited	Geneva Creek
GD60	rocks	35	artificial	1 to 2	0.5	both	sand	always	not deposited	Geneva Creek
GD61	rocks	45	artificial	1 to 4	0.5	both	n/a	never	slope	Geneva Creek
GD62	rocks	40	artificial	1	0.5	both	gravel	always	not deposited	Geneva Creek
GD63	none	5	artificial	1 to 2	0.5	both	sand	always	not deposited	Geneva Creek
GD64	fallen trees	40	artificial	1 to 2	0.5–1	both	n/a	never	slope, obstructions, infiltration	Geneva Creek
GD65	none	90	artificial	1 to 4	<0.5	both	n/a	never	slope, obstructions, infiltration	Geneva Creek
GD66	rocks	50	artificial	1 to 2	0.5	both	sand	always	not deposited	Geneva Creek
GD67	rocks	3	artificial	1	<0.5	both	sand	always	not deposited	Geneva Creek
GD68	rocks	15	artificial	1	0.5	both	sand	always	not deposited	Geneva Creek
GD69	rocks	4	artificial	1	<0.5	erosion	sand	always	not deposited	Geneva Creek
GD70	rocks	8	artificial	1	0.5	erosion	gravel	always	not deposited	Geneva Creek
GD71	rocks	4	artificial	1	0.5	erosion	sand	always	not deposited	Geneva Creek
GD72	none	10	artificial	1 to 2	0.5	both	sand	always	not deposited	Geneva Creek
GD73	blocked culvert	n/a	artificial	n/a	n/a	n/a	n/a	n/a	n/a	Geneva Creek
GD74	rocks	40	natural	1	0.5	both	sand	sometimes	not deposited	Geneva Creek

Table 55. Suspended-sediment discharge from Guanella Pass road segment upstream from Naylor Creek expressed as a percentage of suspended-sediment discharge at CC2 and as a potential change in concentration at CC2, during CRD7 flow period, water year 1996

[Estimate of road runoff suspended-sediment discharge was based on CRD7 sediment discharge extrapolated by road length (CRD7 sediment discharge times 10.6, which is the ratio of the road length draining to CC2 and the road length draining to CRD7); concentration in milligrams per liter; road suspended-sediment discharge is expressed as percentage of suspended-sediment discharge measured at CC2, and the potential change in concentration under flow conditions at CC2 if the estimated road sediment discharge is added to that of CC2]

Date	Percentage of suspended-sediment discharge at CC2	Potential change in concentration at CC2 due to estimated road sediment discharge	Date	Percentage of suspended sediment discharge at CC2	Potential change in concentration at CC2 due to estimated road sediment discharge	Date	Percentage of suspended-sediment discharge at CC2	Potential change in concentration at CC2 due to estimated road sediment discharge
04/25/96	290	3	06/13/96	0.0	0	08/01/96	0.0	0
04/26/96	2,890	34	06/14/96	.0	0	08/02/96	.0	0
04/27/96	3,610	43	06/15/96	32	2	08/03/96	.0	0
04/28/96	2,080	25	06/16/96	.0	0	08/04/96	.0	0
04/29/96	1,920	23	06/17/96	.0	0	08/05/96	.0	0
04/30/96	630	11	06/18/96	.0	0	08/06/96	.0	0
05/01/96	26	4	06/19/96	.0	0	08/07/96	.0	0
05/02/96	26	4	06/20/96	.0	0	08/08/96	.0	0
05/03/96	29	5	06/21/96	56	3	08/09/96	.0	0
05/04/96	55	10	06/22/96	64	3	08/10/96	.0	0
05/05/96	36	8	06/23/96	.0	0	08/11/96	.0	0
05/06/96	37	9	06/24/96	.0	0	08/12/96	.0	0
05/07/96	22	6	06/25/96	.0	0	08/13/96	.0	0
05/08/96	14	4	06/26/96	.0	0	08/14/96	.0	0
05/09/96	12	3	06/27/96	.0	0	08/15/96	.0	0
05/10/96	5.2	1	06/28/96	.0	0	08/16/96	.0	0
05/11/96	8.2	3	06/29/96	.0	0	08/17/96	.0	0
05/12/96	34	11	06/30/96	.0	0	08/18/96	.0	0
05/13/96	18	6	07/01/96	.0	0	08/19/96	.0	0
05/14/96	4.0	2	07/02/96	.0	0	08/20/96	.0	0
05/15/96	2.7	1	07/03/96	.0	0	08/21/96	100	59
05/16/96	2.5	1	07/04/96	.0	0	08/22/96	.0	0
05/17/96	1.2	1	07/05/96	.0	0	08/23/96	650	450
05/18/96	1.5	1	07/06/96	.0	0	08/24/96	.0	0
05/19/96	.7	0	07/07/96	.0	0	08/25/96	.0	0
05/20/96	2.3	0	07/08/96	.0	0	08/26/96	.0	0
05/21/96	13	1	07/09/96	.0	0	08/27/96	78	31
05/22/96	11	1	07/10/96	.0	0	08/28/96	.0	0
05/23/96	1.3	0	07/11/96	.0	0	08/29/96	.0	0
05/24/96	7.3	1	07/12/96	.0	0	08/30/96	.0	0
05/25/96	.0	0	07/13/96	.0	0	08/31/96	.0	0
05/26/96	.0	0	07/14/96	.0	0	09/01/96	.0	0
05/27/96	.0	0	07/15/96	.0	0	09/02/96	.0	0
05/28/96	.0	0	07/16/96	.0	0	09/03/96	.0	0
05/29/96	2.5	0	07/17/96	.0	0	09/04/96	.0	0
05/30/96	56	4	07/18/96	.0	0	09/05/96	.0	0
05/31/96	3.0	0	07/19/96	.0	0	09/06/96	480	440
06/01/96	.0	0	07/20/96	.0	0	09/07/96	.0	0
06/02/96	.0	0	07/21/96	.0	0	09/08/96	.0	0
06/03/96	.0	0	07/22/96	.0	0	09/09/96	.0	0
06/04/96	.0	0	07/23/96	.0	0	09/10/96	.0	0
06/05/96	.0	0	07/24/96	.0	0	09/11/96	.0	0
06/06/96	.0	0	07/25/96	.0	0	09/12/96	480	190

Table 55. Suspended-sediment discharge from Guanella Pass road segment upstream from Naylor Creek expressed as a percentage of suspended-sediment discharge at CC2 and as a potential change in concentration at CC2, during CRD7 flow period, water year 1996—Continued

[Estimate of road runoff suspended-sediment discharge was based on CRD7 sediment discharge extrapolated by road length (CRD7 sediment discharge times 10.6, which is the ratio of the road length draining to CC2 and the road length draining to CRD7); concentration in milligrams per liter; road suspended-sediment discharge is expressed as percentage of suspended-sediment discharge measured at CC2, and the potential change in concentration under flow conditions at CC2 if the estimated road sediment discharge is added to that of CC2]

Date	Percentage of suspended-sediment discharge at CC2	Potential change in concentration at CC2 due to estimated road sediment discharge	Date	Percentage of suspended sediment discharge at CC2	Potential change in concentration at CC2 due to estimated road sediment discharge	Date	Percentage of suspended-sediment discharge at CC2	Potential change in concentration at CC2 due to estimated road sediment discharge
06/07/96	0.0	0	07/26/96	0.0	0	09/13/96	0.0	0
06/08/96	.0	0	07/27/96	.0	0	09/14/96	300	39
06/09/96	.0	0	07/28/96	.0	0	09/15/96	1,060	56
06/10/96	.0	0	07/29/96	.0	0	09/16/96	.0	0
06/11/96	.0	0	07/30/96	.0	0	09/17/96	.0	0
06/12/96	.0	0	07/31/96	.0	0			

Table 56. Suspended-sediment discharge from Guanella Pass road segment upstream from Naylor Creek expressed as a percentage of suspended-sediment discharge at CC2 and as a potential change in concentration at CC2, during CRD7 flow period, water year 1997

[Estimate of road runoff suspended-sediment discharge was based on CRD7 sediment discharge extrapolated by road length (CRD7 sediment discharge times 10.6, which is the ratio of the road length draining to CC2 and the road length draining to CRD7); concentration in milligrams per liter; road suspended-sediment discharge is expressed as percentage of suspended-sediment discharge measured at CC2, and the potential change in concentration under flow conditions at CC2 if the estimated road sediment discharge is added to that of CC2]

Date	Percentage of suspended-sediment discharge at CC2	Potential change in concentration at CC2 due to estimated road sediment discharge	Date	Percentage of suspended-sediment discharge at CC2	Potential change in concentration at CC2 due to estimated road sediment discharge	Date	Percentage of suspended-sediment discharge at CC2	Potential change in concentration at CC2 due to estimated road sediment discharge
05/08/97	70	6	06/26/97	0.0	0	08/14/97	0.0	0
05/09/97	25	3	06/27/97	.0	0	08/15/97	.0	0
05/10/97	78	12	06/28/97	.0	0	08/16/97	.0	0
05/11/97	69	13	06/29/97	.0	0	08/17/97	.0	0
05/12/97	2.9	1	06/30/97	.0	0	08/18/97	.0	0
05/13/97	86	50	07/01/97	.0	0	08/19/97	.0	0
05/14/97	40	16	07/02/97	.0	0	08/20/97	.0	0
05/15/97	13	9	07/03/97	.0	0	08/21/97	.0	0
05/16/97	16	11	07/04/97	.0	0	08/22/97	.0	0
05/17/97	2.6	5	07/05/97	.0	0	08/23/97	.0	0
05/18/97	3.3	4	07/06/97	.0	0	08/24/97	.0	0
05/19/97	2.7	3	07/07/97	.0	0	08/25/97	.0	0
05/20/97	4.5	2	07/08/97	.0	0	08/26/97	.0	0
05/21/97	9.9	2	07/09/97	.0	0	08/27/97	.0	0
05/22/97	20	3	07/10/97	.0	0	08/28/97	.0	0
05/23/97	5.7	3	07/11/97	.0	0	08/29/97	.0	0
05/24/97	7.2	2	07/12/97	.0	0	08/30/97	.0	0
05/25/97	5.8	2	07/13/97	.0	0	08/31/97	.0	0
05/26/97	.0	0	07/14/97	.0	0	09/01/97	.0	0
05/27/97	.0	0	07/15/97	.0	0	09/02/97	.0	0
05/28/97	.3	0	07/16/97	.0	0	09/03/97	1,410	2,330
05/29/97	30	5	07/17/97	.0	0	09/04/97	.0	0
05/30/97	3.6	2	07/18/97	.0	0	09/05/97	.0	0
05/31/97	1.1	2	07/19/97	.0	0	09/06/97	.0	0
06/01/97	.1	0	07/20/97	.0	0	09/07/97	.0	0

Table 56. Suspended-sediment discharge from Guanella Pass road segment upstream from Naylor Creek expressed as a percentage of suspended-sediment discharge at CC2 and as a potential change in concentration at CC2, during CRD7 flow period, water year 1997—Continued

[Estimate of road runoff suspended-sediment discharge was based on CRD7 sediment discharge extrapolated by road length (CRD7 sediment discharge times 10.6, which is the ratio of the road length draining to CC2 and the road length draining to CRD7); concentration in milligrams per liter; road suspended-sediment discharge is expressed as percentage of suspended-sediment discharge measured at CC2, and the potential change in concentration under flow conditions at CC2 if the estimated road sediment discharge is added to that of CC2]

Date	Percentage of suspended-sediment discharge at CC2	Potential change in concentration at CC2 due to estimated road sediment discharge	Date	Percentage of suspended-sediment discharge at CC2	Potential change in concentration at CC2 due to estimated road sediment discharge	Date	Percentage of suspended-sediment discharge at CC2	Potential change in concentration at CC2 due to estimated road sediment discharge
06/02/97	.2	0	07/21/97	0.0	0	09/08/97	0.0	0
06/03/97	.0	0	07/22/97	.0	0	09/09/97	.0	0
06/04/97	.0	0	07/23/97	.0	0	09/10/97	.0	0
06/05/97	.0	0	07/24/97	.0	0	09/11/97	.0	0
06/06/97	7.4	5	07/25/97	.0	0	09/12/97	.0	0
06/07/97	3.9	6	07/26/97	1,220	740	09/13/97	.0	0
06/08/97	4.7	5	07/27/97	460	420	09/14/97	.0	0
06/09/97	.2	0	07/28/97	50	220	09/15/97	.0	0
06/10/97	.0	0	07/29/97	.0	0	09/16/97	.0	0
06/11/97	2.2	0	07/30/97	.0	0	09/17/97	.0	0
06/12/97	.0	0	07/31/97	44.	28	09/18/97	.0	0
06/13/97	300	64	08/01/97	58.	34	09/19/97	2,120	98
06/14/97	6.4	1	08/02/97	.0	0	09/20/97	689	36
06/15/97	.0	0	08/03/97	6.8	6	09/21/97	11,400	303
06/16/97	.0	0	08/04/97	.0	0	09/22/97	130	9
06/17/97	.0	0	08/05/97	8.0	4	09/23/97	.0	0
06/18/97	.0	0	08/06/97	18.	13	09/24/97	.0	0
06/19/97	.0	0	08/07/97	50	21	09/25/97	.0	0
06/20/97	.0	0	08/08/97	.0	0	09/26/97	.0	0
06/21/97	.0	0	08/09/97	200	224	09/27/97	.0	0
06/22/97	.0	0	08/10/97	18	44	09/28/97	.0	0
06/23/97	.0	0	08/11/97	180	84	09/29/97	.0	0
06/24/97	.0	0	08/12/97	.0	0	09/30/97	.0	0
06/25/97	.0	0	08/13/97	.0	0			

Table 57. Dissolved-solids discharge from Guanella Pass road segment upstream from Naylor Creek expressed as a percentage of dissolved-solids discharge at CC2 and as a potential change in concentration at CC2, during CRD7 flow period, water year 1996

[Estimate of road runoff dissolved-solids (DS) discharge was based on CRD7 DS discharge extrapolated by road length (CRD7 DS times 10.6, which is the ratio of the road length draining to CC2 and the road length draining to CRD7); concentration in milligrams per liter; road DS is expressed as percentage of DS measured at CC2, and the potential change in concentration under flow conditions at CC2 if the estimated road DS is added to that of CC2]

Date	Percentage of DS discharge at CC2	Potential change in concentration at CC2 due to estimated road DS discharge	Date	Percentage of DS discharge at CC2	Potential change in concentration at CC2 due to estimated road DS discharge	Date	Percentage of DS discharge at CC2	Potential change in concentration at CC2 due to estimated road DS discharge
04/25/96	1.4	1	06/13/96	0.0	0	08/01/96	0.0	0
04/26/96	10.7	8	06/14/96	.0	0	08/02/96	.0	0
04/27/96	16.1	12	06/15/96	1.1	.4	08/03/96	.0	0
04/28/96	15.1	11	06/16/96	.0	0	08/04/96	.0	0
04/29/96	12.7	9	06/17/96	.0	0	08/05/96	.0	0
04/30/96	5.7	4	06/18/96	.0	0	08/06/96	.0	0
05/01/96	1.9	1	06/19/96	.0	0	08/07/96	.0	0

Table 57. Dissolved-solids discharge from Guanella Pass road segment upstream from Naylor Creek expressed as a percentage of dissolved-solids discharge at CC2 and as a potential change in concentration at CC2, during CRD7 flow period, water year 1996—Continued

[Estimate of road runoff dissolved-solids (DS) discharge was based on CRD7 DS discharge extrapolated by road length (CRD7 DS times 10.6, which is the ratio of the road length draining to CC2 and the road length draining to CRD7); concentration in milligrams per liter; road DS is expressed as percentage of DS measured at CC2, and the potential change in concentration under flow conditions at CC2 if the estimated road DS is added to that of CC2]

Date	Percentage of DS discharge at CC2	Potential change in concentration at CC2 due to estimated road DS discharge	Date	Percentage of DS discharge at CC2	Potential change in concentration at CC2 due to estimated road DS discharge	Date	Percentage of DS discharge at CC2	Potential change in concentration at CC2 due to estimated road DS discharge
05/02/96	1.5	.9	06/20/96	.0	0	08/08/96	.0	0
05/03/96	1.8	1	06/21/96	.3	.1	08/09/96	.0	0
05/04/96	3.1	2	06/22/96	.4	.2	08/10/96	.0	0
05/05/96	2.8	1	06/23/96	.0	0	08/11/96	.0	0
05/06/96	1.9	.9	06/24/96	.0	0	08/12/96	.0	0
05/07/96	1.3	.6	06/25/96	.0	0	08/13/96	.0	0
05/08/96	.8	.4	06/26/96	.0	0	08/14/96	.0	0
05/09/96	.9	.4	06/27/96	.0	0	08/15/96	.0	0
05/10/96	.7	.3	06/28/96	.0	0	08/16/96	.0	0
05/11/96	.8	.3	06/29/96	.0	0	08/17/96	.0	0
05/12/96	1.5	1.6	06/30/96	.0	0	08/18/96	.0	0
05/13/96	1.4	.6	07/01/96	.0	0	08/19/96	.0	0
05/14/96	.8	.3	07/02/96	.0	0	08/20/96	.0	0
05/15/96	.7	.2	07/03/96	.0	0	08/21/96	1.1	.8
05/16/96	.6	.2	07/04/96	.0	0	08/22/96	.0	0
05/17/96	.3	.1	07/05/96	.0	0	08/23/96	.5	.3
05/18/96	.4	.1	07/06/96	.0	0	08/24/96	.0	0
05/19/96	.3	.1	07/07/96	.0	0	08/25/96	.0	0
05/20/96	.1	.03	07/08/96	.0	0	08/26/96	.0	0
05/21/96	.2	.1	07/09/96	.0	0	08/27/96	.6	.4
05/22/96	.1	.04	07/10/96	.0	0	08/28/96	.0	0
05/23/96	.03	.01	07/11/96	.0	0	08/29/96	.0	0
05/24/96	.1	.02	07/12/96	.0	0	08/30/96	.0	0
05/25/96	.0	0	07/13/96	.0	0	08/31/96	.0	0
05/26/96	.0	0	07/14/96	.0	0	09/01/96	.0	0
05/27/96	.0	0	07/15/96	.0	0	09/02/96	.0	0
05/28/96	.0	0	07/16/96	.0	0	09/03/96	.0	0
05/29/96	.04	.01	07/17/96	.0	0	09/04/96	.0	0
05/30/96	.2	.05	07/18/96	.0	0	09/05/96	.0	0
05/31/96	.0	0	07/19/96	.0	0	09/06/96	4.2	3
06/01/96	.0	0	07/20/96	.0	0	09/07/96	.0	0
06/02/96	.0	0	07/21/96	.0	0	09/08/96	.0	0
06/03/96	.0	0	07/22/96	.0	0	09/09/96	.0	0
06/04/96	.0	0	07/23/96	.0	0	09/10/96	.0	0
06/05/96	.0	0	07/24/96	.0	0	09/11/96	.0	0
06/06/96	.0	0	07/25/96	.0	0	09/12/96	4.8	4
06/07/96	.0	0	07/26/96	.0	0	09/13/96	.0	0
06/08/96	.0	0	07/27/96	.0	0	09/14/96	1.0	.7
06/09/96	.0	0	07/28/96	.0	0	09/15/96	.0	0
06/10/96	.0	0	07/29/96	.0	0	09/16/96	.0	0
06/11/96	.0	0	07/30/96	.0	0	09/17/96	.0	0
06/12/96	.0	0	07/31/96	.0	0			

Table 58. Dissolved-solids discharge from Guanella Pass road segment upstream from Naylor Creek expressed as a percentage of dissolved-solids discharge at CC2 and as a potential change in concentration at CC2, during CRD7 flow period, water year 1997

[Estimate of road runoff dissolved-solids (DS) discharge was based on CRD7 DS discharge extrapolated by road length (CRD7 DS times 10.6, which is the ratio of the road length draining to CC2 and the road length draining to CRD7); concentration in milligrams per liter; road DS is expressed as percentage of DS measured at CC2, and the potential change in concentration under flow conditions at CC2 if the estimated road DS is added to that of CC2]

Date	Percentage of DS discharge at CC2	Potential change in concentration at CC2 due to estimated road DS discharge	Date	Percentage of DS discharge at CC2	Potential change in concentration at CC2 due to estimated road DS discharge	Date	Percentage of DS discharge at CC2	Potential change in concentration at CC2 due to estimated road DS discharge
05/08/97	0.5	0.2	06/26/97	0.0	0	08/14/97	0.0	0
05/09/97	.4	.1	06/27/97	.0	0	08/15/97	.0	0
05/10/97	.8	.3	06/28/97	.0	0	08/16/97	.0	0
05/11/97	1.5	.5	06/29/97	.0	0	08/17/97	.0	0
05/12/97	.3	.1	06/30/97	.0	0	08/18/97	.0	0
05/13/97	2.4	.8	07/01/97	.0	0	08/19/97	.0	0
05/14/97	1.4	.5	07/02/97	.0	0	08/20/97	.0	0
05/15/97	1.2	.4	07/03/97	.0	0	08/21/97	.0	0
05/16/97	.4	.1	07/04/97	.0	0	08/22/97	.0	0
05/17/97	.6	.2	07/05/97	.0	0	08/23/97	.0	0
05/18/97	.7	.2	07/06/97	.0	0	08/24/97	.0	0
05/19/97	.4	.1	07/07/97	.0	0	08/25/97	.0	0
05/20/97	.4	.1	07/08/97	.0	0	08/26/97	.0	0
05/21/97	.4	.1	07/09/97	.0	0	08/27/97	.0	0
05/22/97	.3	.1	07/10/97	.0	0	08/28/97	.0	0
05/23/97	.3	.1	07/11/97	.0	0	08/29/97	.0	0
05/24/97	.3	.1	07/12/97	.0	0	08/30/97	.0	0
05/25/97	.2	.1	07/13/97	.0	0	08/31/97	.0	0
05/26/97	.0	0	07/14/97	.0	0	09/01/97	.0	0
05/27/97	.0	0	07/15/97	.0	0	09/02/97	.0	0
05/28/97	.01	.004	07/16/97	.0	0	09/03/97	19.6	10
05/29/97	.3	.1	07/17/97	.0	0	09/04/97	.0	0
05/30/97	.1	.02	07/18/97	.0	0	09/05/97	.0	0
05/31/97	.05	.02	07/19/97	.0	0	09/06/97	.0	0
06/01/97	.02	.007	07/20/97	.0	0	09/07/97	.0	0
06/02/97	.01	.003	07/21/97	.0	0	09/08/97	.0	0
06/03/97	.0	0	07/22/97	.0	0	09/09/97	.0	0
06/04/97	.0	0	07/23/97	.0	0	09/10/97	.0	0
06/05/97	.0	0	07/24/97	.0	0	09/11/97	.0	0
06/06/97	.7	.2	07/25/97	.0	0	09/12/97	.0	0
06/07/97	.5	.2	07/26/97	5.5	3	09/13/97	.0	0
06/08/97	.4	.13	07/27/97	24.3	13	09/14/97	.0	0
06/09/97	.01	.004	07/28/97	7.2	4	09/15/97	.0	0
06/10/97	.0	0	07/29/97	.0	0	09/16/97	.0	0
06/11/97	.1	.025	07/30/97	.0	0	09/17/97	.0	0
06/12/97	.0	0	07/31/97	1.8	.9	09/18/97	.0	0
06/13/97	.3	.1	08/01/97	1.5	.7	09/19/97	1.7	1
06/14/97	.2	.06	08/02/97	.0	0	09/20/97	9.2	5
06/15/97	.0	0	08/03/97	2.6	1	09/21/97	10.4	5

Table 58. Dissolved-solids discharge from Guanella Pass road segment upstream from Naylor Creek expressed as a percentage of dissolved-solids discharge at CC2 and as a potential change in concentration at CC2, during CRD7 flow period, water year 1997—Continued

[Estimate of road runoff dissolved-solids (DS) discharge was based on CRD7 DS discharge extrapolated by road length (CRD7 DS times 10.6, which is the ratio of the road length draining to CC2 and the road length draining to CRD7); concentration in milligrams per liter; road DS is expressed as percentage of DS measured at CC2, and the potential change in concentration under flow conditions at CC2 if the estimated road DS is added to that of CC2]

Date	Percentage of DS discharge at CC2	Potential change in concentration at CC2 due to estimated road DS discharge	Date	Percentage of DS discharge at CC2	Potential change in concentration at CC2 due to estimated road DS discharge	Date	Percentage of DS discharge at CC2	Potential change in concentration at CC2 due to estimated road DS discharge
06/16/97	.0	0	08/04/97	.0	0	09/22/97	.4	.2
06/17/97	.0	0	08/05/97	.6	.3	09/23/97	.0	0
06/18/97	.0	0	08/06/97	1.9	.8	09/24/97	.0	0
06/19/97	.0	0	08/07/97	2.6	1	09/25/97	.0	0
06/20/97	.0	0	08/08/97	.0	0	09/26/97	.0	0
06/21/97	.0	0	08/09/97	4.5	2	09/27/97	.0	0
06/22/97	.0	0	08/10/97	3.1	1	09/28/97	.0	0
06/23/97	.0	0	08/11/97	4.4	2	09/29/97	.0	0
06/24/97	.0	0	08/12/97	.0	0	09/30/97	.0	0
06/25/97	.0	0	08/13/97	.0	0			