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Assessment of Hydrology, Water Quality, and Trace Elements in Selected Placer-Mined Creeks in the Birch Creek Watershed near Central, Alaska, 2001–05

Scientific Investigations Report 2007–5124

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

Cover: Harrison Creek fall colors, August 31, 2005. View is looking north across Harrison Creek in foreground. (Photograph taken by Ben W. Kennedy, U.S. Geological Survey.)

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Conversion Factors

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	0.00156	square mile (mi^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter (L)
gallon (gal)	0.003785	cubic meter (m^3)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Flow rate	
foot per second (ft/s)	0.3048	meter per second (m/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
inch per year (in/yr)	25.4	millimeter per year (mm/yr)
	Pressure	
atmosphere, standard (atm)	101.3	kilopascal (kPa)
bar	100	kilopascal (kPa)
inch of mercury at 60ºF (in. Hg)	3.377	kilopascal (kPa)

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

$$°C=(°F-32)/1.8.$$

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

$$°F=(1.8\times°C)+32.$$

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

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L), equivalent to parts per million (ppm), or micrograms per liter (µg/L), equivalent to parts per billion (ppb).

Datums

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

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

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

Abbreviations, Acronyms, and Definitions

AA	atomic absorption
ADEC	Alaska Department of Environmental Conservation
ADNR	Alaska Department of Natural Resources
ATSDR	Agency for Toxic Substances and Disease Registry
ATV	all-terrain vehicle
BLM	Bureau of Land Management
CaCO3	calcium carbonate
CB-PEC	consensus-based probable effect concentrations
CSG	crest-stage gage
CVAF	cold vapor atomic fluorescence
DGGS	Alaska Division of Geological and Geophysical Surveys
EWI	equal-width-increments
GFAA	graphite furnace atomic absorption
IC	ion chromatography
ICP	inductively coupled plasma
ICPMS	inductively coupled plasma mass spectrometry
LRL	laboratory reporting level
MRL	minimum reporting level
N	nitrogen
NAWQA	National Water-Quality Assessment
NWQL	National Water Quality Laboratory
NWIS	National Water Information System
P	phosphorus
SQG	sediment-quality guidelines
TMDL	total maximum daily load
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
mg	milligram
mm	millimeter
µg/g	microgram per gram
µm	micrometer, micron
µS/cm	microsiemens per centimeter at 25 degrees Celsius

p-value: A statistic term. A measure of probability that a difference between groups occurred by chance. For example, a p-value of .01 ($p = .01$) means there is a 1 in 100 chance the result occurred by chance. The smaller the p-value, the more likely it is that the difference between groups is caused by some other factor than random chance.

Water year: A continuous 12-month period selected to present hydrologic or meteorologic data including a complete annual hydrologic cycle. The water year used by the U.S. Geological Survey runs from October 1 through September 30 and is designated by the year it ends.

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Assessment of Hydrology, Water Quality, and Trace Elements in Selected Placer-Mined Creeks in the Birch Creek Watershed near Central, Alaska, 2001–05

By Ben W. Kennedy and Dustin E. Langley

Executive Summary

The U.S. Geological Survey, in cooperation with the Bureau of Land Management, completed an assessment of hydrology, water quality, and trace-element concentrations in streambed sediment of the upper Birch Creek watershed near Central, Alaska. The assessment covered one site on upper Birch Creek and paired sites, upstream and downstream from mined areas, on Frying Pan Creek and Harrison Creek. Stream-discharge and suspended-sediment concentration data collected at other selected mined and unmined sites helped characterize conditions in the upper Birch Creek watershed. The purpose of the project was to provide the Bureau of Land Management with baseline information to evaluate watershed water quality and plan reclamation efforts. Data collection began in September 2001 and ended in September 2005.

There were substantial geomorphic disturbances in the stream channel and flood plain along several miles of Harrison Creek. Placer mining has physically altered the natural stream channel morphology and removed streamside vegetation. There has been little or no effort to re-contour waste rock piles. During high-flow events, the abandoned placer-mine areas on Harrison Creek will likely contribute large quantities of sediment downstream unless the mined areas are reclaimed.

During 2004 and 2005, no substantial changes in nutrient or major-ion concentrations were detected in water samples collected upstream from mined areas compared with water samples collected downstream from mined areas on Frying Pan Creek and Harrison Creek that could not be attributed to natural variation. This also was true for dissolved oxygen, pH, and specific conductance—a measure of total dissolved solids. Sample sites downstream from mined areas on Harrison Creek and Frying Pan Creek had higher median suspended-sediment concentrations, by a few milligrams per liter, than respective upstream sites. However, it is difficult to attach much importance to the small downstream increase, less than 10 milligrams per liter, in median suspended-sediment concentration for either basin. During low-flow conditions in 2004 and 2005, previously mined areas investigated on Harrison Creek and on Frying Pan Creek did not contribute substantial suspended sediments to sample sites downstream from the mined areas. No substantial mining-related water- or sediment-quality problems were detected at any of the sites investigated in the upper Birch Creek watershed during low-flow conditions.

Average annual streamflow and precipitation were near normal in 2002 and 2003. Drought conditions, extreme forest fire impact, and low annual streamflow set apart the 2004 and 2005 summer seasons. Daily mean streamflow for upper Birch Creek varied throughout the period of record—from maximums of about 1,000 cubic feet per second to minimums of about 20 cubic feet per second. Streamflow increased and decreased rapidly in response to rainfall and rapid snowmelt events because the steep slopes, thin soil cover, and permafrost areas in the watershed have little capacity to retain runoff.

Median suspended-sediment concentrations for the 115 paired samples from Frying Pan Creek and 101 paired samples from Harrison Creek were less than the 20 milligrams per liter total maximum daily load. The total maximum daily load was set by the U.S. Environmental Protection Agency for the upper Birch Creek basin in 1996. Suspended-sediment paired-sample data were collected using automated samplers in 2004 and 2005, primarily during low-flow conditions. Suspended-sediment concentrations in grab samples from miscellaneous sites ranged from less than 1 milligram per liter during low-flow conditions to 1,386 milligrams per liter during a high-flow event on upper Birch Creek.

Streambed-sediment samples were collected at six sites on Harrison Creek, two sites on Frying Pan Creek, and one site on upper Birch Creek. Trace-element concentrations of mercury, lead, and zinc in streambed sediment were less than the consensus-based probable-effect concentrations for aquatic life protection published in MacDonald and others (2000). Elevated arsenic, chromium, and nickel concentrations detected in several bed sediment samples indicate sediment input from mineralized local bedrock.

Water samples were collected for analysis of mercury concentration at ten sites during August and September 2005. Total-recoverable and total-dissolved-mercury concentrations for all samples were less than State and Federal drinking-water standards of 2.0 micrograms per liter.

Monitoring of suspended-sediment concentration, water quality, and trace elements in streambed sediment are recommended for Harrison Creek to document conditions during moderate to high flows and to monitor downstream impacts of reclamation work. Continued seasonal operation of the upper Birch Creek stream gage and crest-stage gages on Harrison Creek are recommended to document streamflow and to aid in ongoing flood-plain restoration and design work.

Introduction

Historic placer-gold-mine operations have adversely affected water-quality and geomorphic conditions in the upper Birch Creek watershed near Central, Alaska. Birch Creek is a perennial clear-water stream that flows about 340 mi from its headwaters near Eagle Summit, through remote private, State, and Federal land in interior Alaska (fig. 1). In 1893, gold was discovered on Birch Creek in an area that later became famous as the Circle Mining District (Yeend and others, 1998). Placer-mine operations were active on the upper reaches of Birch Creek, and several of its tributaries in the Circle Mining District, from the 1890s until the beginning of World War II. Mining activity increased again in the mid-1970s with the rise in gold prices. The Alaska National Interest Land Conservation Act of 1980 designated a 126-mi section of Birch Creek as a component of National Wild and Scenic Rivers System. Through the same congressional action, large blocks of Federal land north and south of the wild-river corridor were converted to National Conservation Areas. The land and river corridor reclassifications limited mining operations in the Birch Creek watershed. The Bureau of Land Management (BLM) is tasked with assessment and reclamation of mined lands in the watershed with the goal of returning mined areas to a more scenic and natural state.

The U.S. Geological Survey (USGS), in cooperation with the BLM, completed an assessment of hydrology, water quality, and trace-element concentrations in streambed sediment for portions of Birch Creek, Harrison Creek, and Frying Pan Creek. The assessment studied one stream-gage site on upper Birch Creek and paired crest-stage gage sites, upstream and downstream from mined areas, on Harrison Creek and Frying Pan Creek (fig. 1). The Birch Creek site was downstream from several historic placer-mine operations with varied reclamation. Harrison and Frying Pan Creek are placer-mined tributaries to Birch Creek.

Description of Study Area

The upper Birch Creek study area encompasses an area of about 850 mi^2 (fig. 1). Elevations range from about 900 ft near Central to peaks more than 4,000 ft near Eagle Summit and the headwaters of Birch Creek. Many of the hills and ridges are rounded and sparsely vegetated—tree line is approximately 3,000 ft. Vegetation is primarily black and white spruce forest, with tundra at higher elevations. Willow and alder are common near streams. The highlands are underlain by Paleozoic schist and quartzite with Cretaceous and Tertiary granitic intrusions and minor mafic sills and dikes. The area has numerous high-angle northeast trending faults. Bedrock is mineralized (Wiltse and others, 1995). Upper Birch Creek and Frying Pan Creek are underlain by quartzite and quartzitic schist. The South Fork of Harrison Creek and Harrison Creek flow eastward along a gradational geologic contact with mafic schist to the north and quartzite/quartzitic schist to the south (Yeend, 1991).

The Circle Mining District is one of the richest placer-gold districts in Alaska, with an estimated total production of 1 million troy ounces since placer mining began in the late 1800s (Yeend, 1991). Widespread geochemical anomalies, and scattered mineral occurrences and prospects, indicate the region also may contain molybdenum porphyry, tungsten skarn, granite-related uranium deposits, lode tin deposits, platinum deposits of mafic igneous association, and sedimentary exhalative zinc-lead deposits (Foster and others, 1994). Silt and stream gravels cover much of the lowland areas. Permafrost is discontinuous but prevalent, especially in steep valleys and north facing slopes (Davis, 2001).

Annual precipitation in the area ranges from 10 to 20 in/yr (Jones and Fahl, 1994) with upland areas receiving more precipitation than lower areas. The seasonal precipitation pattern is normally at a minimum in spring and at a maximum in late summer. Summer thunderstorms are common over the hills and upland areas. Summer maximum temperatures range from the upper 70s °F with extreme readings in the 90s; winter temperatures may be minus 50°F or lower for 2 or 3 weeks at a time (Western Regional Climate Center, 2006). Snow cover and freezing temperatures typically persist from October through April. Daylight hours range from a minimum of about 4 hours in winter to more than 20 hours in summer.

Local rivers normally begin freezing by the first week of October; melting of the river ice generally occurs in May. Streams typically have two or more peak discharge periods during open-water season. The first peaks are associated with snowmelt in May or June and subsequent peak discharges are associated with heavy precipitation events during summer or autumn. Flows increase and decrease rapidly in response to rainfall or rapid snowmelt events because the relatively steep slopes, thin soil cover, and permafrost in the watershed have a low capacity for retaining precipitation or meltwater.

Naturally occurring events affecting water quality in the Birch Creek watershed include periodic heavy precipitation, forest fire activity, and landslides. During 2003, mid- and late-summer heavy precipitation resulted in extensive flooding in the Birch Creek watershed. The 2004 fire season was the worst on record in Alaska, approximately 6.5 million acres burned, with a majority of the large-fire activity occurring in central and eastern Alaska (National Climate Data Center, 2004). Only minor portions of the study area burned in 2004.

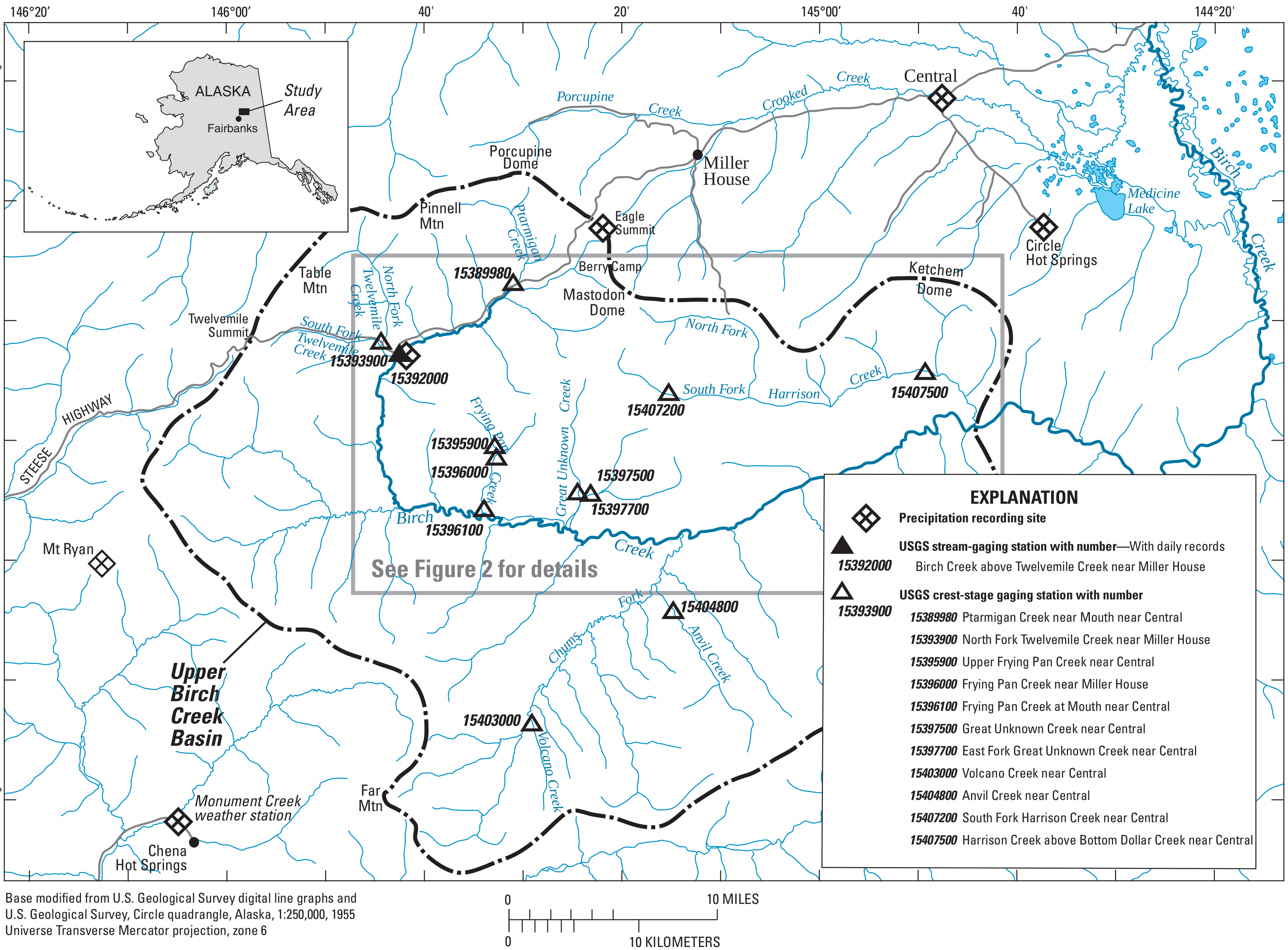


Figure 1. Location of stream-gage sites for the Birch Creek watershed study near Central, Alaska.

Widespread wildfire activity occurred in 2005 as well, more than 4.4 million acres burned across the State (National Climate Data Center, 2005). None of the study area burned during 2005. Smoke and particulate matter from the 2004 and 2005 wildfires spread and persisted over the study area as well as large regions of Alaska and Canada.

Placer Mining

Prior to initiation of regulatory controls, placer-mine operations often created stream channel disturbances (Madison, 1981). Placer-mining operations were responsible for generating large quantities of sediment and increasing concentration of heavy metals—including arsenic, copper, lead, and mercury—downstream from mining activities (U.S. Environmental Protection Agency [USEPA], 1994). Placer mining typically involves rerouting streamflow into bypass channels and stripping vegetation and overburden to reach gold-bearing streambed and flood-plain gravels. As much as 90 percent of gold recovered from stream placers is in the lowermost 3 ft of gravel and in cracks and holes in the uppermost foot of bedrock (Yeend and others, 1998). Many abandoned placer mines left streams in bypass channels that are neither stable nor representative of the natural morphology of undisturbed reaches. Draglines, bulldozers, and excavators were used to move bed material to large trommel and wash plants that fed into a sluice with trough and riffle networks. Waste material was discharged to a series of tailing piles and settling ponds that were formed as mining progressed along the stream channel.

Fine-grained materials were washed downstream or buried in settling ponds. Vegetation does not readily grow on coarse tailings left at the land surface. Even if the site is re-contoured, the lack of soil or other fine-grained materials severely affects the stability of the restoration and lengthens the time required for natural re-vegetation. Without a binding mat of vegetation on the flood plain the unconsolidated tailings do not constrain the channel during floods. This can result in high sediment loads from mined areas during moderate to high flows. Excess sediment can irritate or clog the gills of invertebrates and fish and fills voids in gravel necessary for fish to spawn. Excess sediment also can blanket or erode algae, the base of the food chain for invertebrates and fish.

In early placer-gold-mining operations, elemental mercury commonly was added to sluice-box troughs to increase recovery of fine-grained gold as placer ore was washed through ground sluices. Fine-grained gold amalgamates with mercury. Alpers and Hunerlach (2000) noted the estimated loss of mercury at historic placer-gold-mining operations in California was 10 to 30 percent per season, resulting in contaminated sediments at mine sites. Mercury was readily available to placer miners in Alaska. The Red Devil mine, near the town of Sleetmute on the Kuskokwim River, operated from 1933 until 1971 and at one time was the largest mercury mine in the United States (Alaska Department of Environmental Conservation [ADEC], 1999). There are no known reports of elevated mercury concentrations in water, sediment, or fish tissue for the Birch Creek watershed. However, the National Park Service detected high levels of mercury and lead in sediment and elevated concentrations of zinc in water at a previously mined site on Coal Creek, about 44 mi southeast of Circle (Alaska Department of Environmental Conservation, 2005). Other mining districts in Alaska have documented mercury contamination associated with placer mining. The Agency for Toxic Substances and Disease Registry (ATSDR) completed a public health assessment of the City of Nome and Alaska Gold Company site and determined arsenic and mercury contamination were widespread throughout the Nome, Alaska, area (Agency for Toxic Substances and Disease Registry, 1987). Preliminary sampling indicated arsenic and mercury contamination of water, sediment, and soil were attributable to gold extraction activities. On the other hand, there are areas in Alaska that have been mined extensively for placer gold, but do not have high mercury concentrations in water or sediment (MacFarlane, 2004). Nevertheless, based on the premise that procedures for early placer-mining operations in the upper Birch Creek watershed were similar to accepted practices of the time, and mercury was readily available in Alaska, some of the placer mines in the watershed probably used liquid mercury to increase recovery of fine-grained gold.

Mercury contamination poses a risk to human health and the environment. Concentrations of mercury in filtered natural river water typically are very low, rarely exceeding tenths of 1 microgram per liter (Hem, 1985). However, mercury may remain in soils and sediment for long periods, slowly releasing mercury compounds into the environment. Organic complexes such as methyl-mercury, CH_3Hg^+, and other similar forms can be produced by methane-generating bacteria in contact with metallic mercury in lake or stream sediment (Wood and others, 1968). Methyl-mercury is the compound most readily incorporated into biological tissues and is a potent neurotoxin that impairs the nervous system (Alpers and Hunerlach, 2000). Mercury methylation is controlled by sulfate-reducing bacteria and other environmental factors including temperature, dissolved organic carbon, salinity, pH, and oxidation-reduction conditions.

Previous Studies

Most previous studies of environmental effects associated with placer-mining activities in the Birch Creek watershed focused on surface-water-quality impacts that resulted from increased downstream sediment loads. Several studies of mined and unmined streams conducted in the Birch Creek watershed have shown suspended-sediment concentrations were elevated in placer-mined streams (Weber, 1986; Mack and others, 1988; Ray, 1993; Packee, 1994; Vohden, 1999). Weber (1986) investigated the effects of placer-mining effluent on downstream water quality and aquatic macroinvertebrate populations in the east side of the Birch Creek watershed. The investigation concluded that the effects of increased siltation from placer-mining effluent are not restricted to the area immediately below active mining. Placer mining in the Birch Creek watershed resulted in profound changes in turbidity and invertebrate densities that persisted far downstream from mining input (Weber, 1986). Ray (1993) also investigated stream-sediment loads related to placer mining in the upper Birch Creek basin. Ray noted extensively disturbed creeks with no active mining contributed sediment for transport at a higher rate than unmined streams, but not as high a rate as actively mined streams. The investigation also noted a large percentage of the sediment is transported in short periods during high streamflows (storm events). At most sites, 90 percent of the sediment was transported in 10 percent of the time. Additional hydrologic and water-quality investigations by Vohden (1999) also concluded that precipitation events played a major role in explaining elevated suspended-sediment concentrations at their sediment monitoring locations. In 1996, the USEPA issued a total maximum daily load (TMDL) for total suspended solids to meet water-quality standards for turbidity in Upper Birch Creek of 20 mg/L. Several tributaries in the Birch Creek drainage are listed in Section 303(d) as impaired waters because they exceeded water-quality criteria for turbidity (Alaska Department of Environmental Conservation, 2006).

The Alaska Division of Geological and Geophysical Surveys (DGGS) monitored streamflow in Birch Creek above Twelvemile Creek from 1986 through 1994. Reported average flow for the period of record was 89 ft^3/s (U.S. Environmental Protection Agency, 1996). The 2001 through 2005 USGS Birch Creek stream gage, site 15392000, was installed near the same location as the DGGS 1986 through 1994 Birch Creek stream gage. The DGGS reported a June 25, 1989, period-of-record peak flow of 1,940 ft^3/s for Birch Creek, with an estimated recurrence interval of 15 years (Ray, 1990). Peak flow was calculated using indirect methods.

Bjerklie and LaPerriere (1985) investigated surface and sub-surface waters in the Birch Creek basin in 1982. Their study reported mean levels of conductivity (113 µS/cm), alkalinity (51 mg/L), total hardness (72 mg/L), and pH (7.7) were not substantially different between Birch (mined) and Twelvemile (unmined) Creeks. However, concentrations of suspended solids, turbidity, and total iron were higher in Birch Creek than in Twelvemile Creek or Ptarmigan Creek before mining began. Mack and Moorman (1986) collected chemical and physical water-quality samples at 25 sites in the Birch Creek drainage. Analyses showed streams sampled above and below mining showed little, if any, lowering in pH, increase in sulfate concentration, or rise in specific conductivity below mined areas. Their findings indicated that the Alaska Department of Environmental Conservation (2003) maximum acceptable concentration of mercury for public drinking water (2 micrograms per liter [µg/L]) was exceeded slightly in both mined and unmined streams. Mack and Moorman (1986) suggested these findings might indicate slightly elevated levels of naturally occurring mercury in the area or laboratory analytical error.

During the summer of 1984, mined and unmined stream sections in the Birch Creek watershed were inventoried to collect data on fish presence, habitat quality, and the densities and community structure of benthic invertebrates (Weber and Post, 1985). Weber and Post concluded that placer mining in the Birch Creek watershed resulted in elimination of the riparian vegetation and a higher proportion of silt and sand deposited on the stream bottom downstream from mined areas. They further concluded placer mining caused elimination of fish habitat, depressed aquatic invertebrate populations, and elimination of all fish from mined streams and from streams above active mining.

Townsend (1996) revisited mined and unmined streams in the Birch Creek drainage and reported the numbers of Arctic grayling and streams containing Arctic grayling increased from 1984 to 1990 and from 1990 to 1995. It was postulated that increased presence of Arctic grayling and other fish species in the upper Birch Creek drainage was the result of improved water quality, better mining practices and fewer mines, reclamation of stream and riparian habitats, and enhanced fish passage in active mining areas. Further studies by Townsend (2000) reported 19 juvenile chinook salmon were captured in Birch Creek and Harrison Creek. The study concluded that the presence of juvenile chinook salmon in three areas along 80 mi of Birch Creek indicates chinook salmon spawn somewhere between Crooked Creek and Twelvemile Creek.

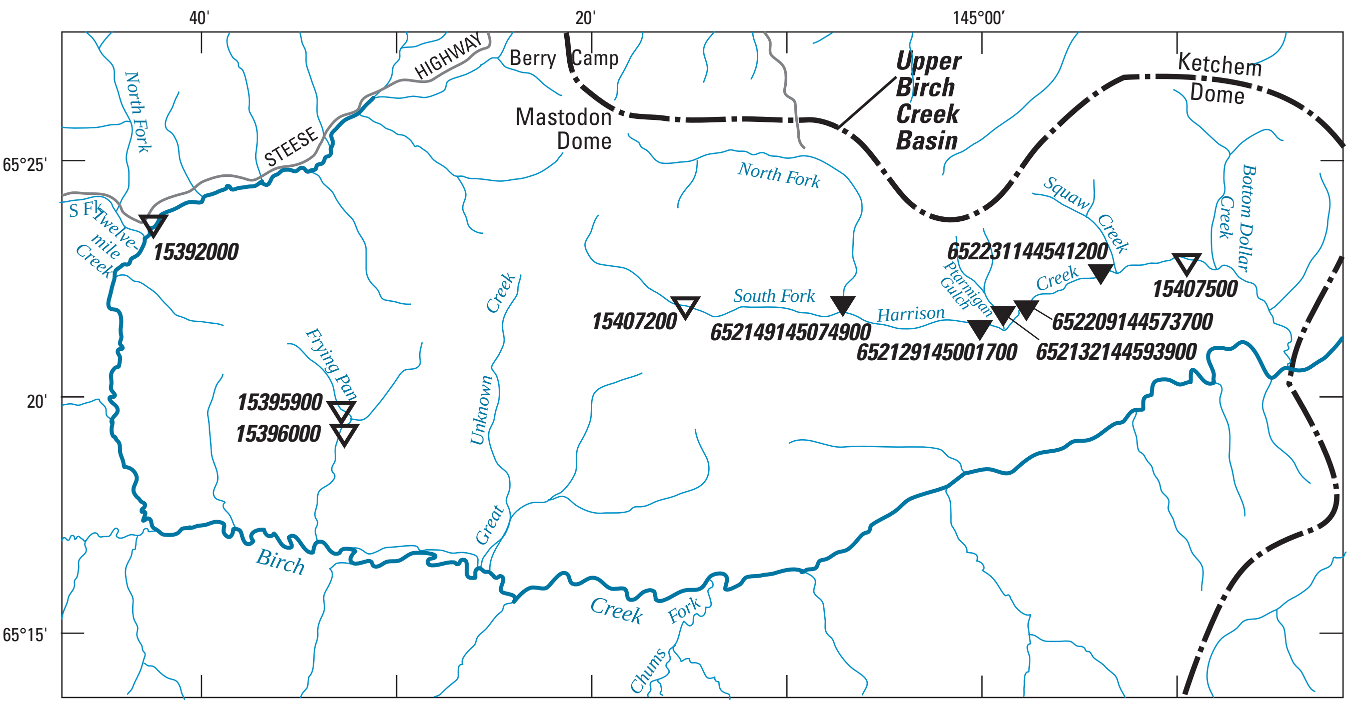
Purpose and Scope

The purpose of this report is to summarize hydrology, water-quality, and streambed-sediment data collected at one site on upper Birch Creek and at paired sites, upstream and downstream from mined areas on Frying Pan Creek and Harrison Creek. The report also summarizes stream discharge, water-quality, and trace-element-concentration data collected at miscellaneous mined and unmined sites. The purpose of the study was to provide the BLM with baseline information necessary to evaluate water-quality issues and to plan and evaluate reclamation of mined lands in the Birch Creek watershed. Data collection began in September 2001 and ended in September 2005.

Sampling sites (figs. 1 and 2) were located upstream and downstream from previously mined reaches to characterize differences and similarities of natural channels and channels disturbed by placer mining in the watershed. The Harrison Creek watershed was affected by large-scale placer mining and was scheduled for selected flood-plain reclamation work in 2006. Several miles of the creek have been mined with little or no reclamation of waste-rock. A relatively small reach (less than 0.5 mi) was mined in the Frying Pan Creek watershed. Tailings were contoured to natural topography; however, little vegetation has been established over the disturbed area. A daily stream gage with satellite telemetry was installed at the Birch Creek above Twelvemile Creek site to provide real-time streamflow data. The Birch Creek stream-gage site also was used as a miscellaneous water-quality and streambed-sediment sample site. Several tributaries, upstream from the Birch Creek stream gage, were mined previously. Specific objectives of the study were:

1. Characterize and compare variations in water chemistry, including major-ion, nutrient, mercury, and suspended-sediment concentrations, as well as water-quality field parameters of pH, dissolved oxygen, water temperature, and specific conductivity for selected sites upstream and downstream from previously mined areas on Harrison Creek and Frying Pan Creek.

2. Assess trace-element concentration levels in streambed sediments, particularly mercury because of its association with historic placer-gold-mine operations, and compare selected constituents to sediment-quality guidelines (SQG).



Base modified from U.S. Geological Survey digital line graphs and U.S. Geological Survey, Circle quadrangle, Alaska, 1:250,000, 1955
Universe Transverse Mercator projection, zone 6

0 10 MILES
0 10 KILOMETERS

EXPLANATION

Mercury sampling site with number

15392000 **Stream gaging site**

15392000	Birch Creek above Twelvemile Creek near Miller House
15395900	Upper Frying Pan Creek near Central
15396000	Frying Pan Creek near Miller House
15407200	South Fork Harrison Creek near Central
15407500	Harrison Creek above Bottom Dollar Creek near Central

652132144593900 **Miscellaneous sampling site**

652149145074900	North Fork Harrison Creek 0.1 mile above mouth near Central
652129145001700	Harrison Creek 0.4 mile above Ptarmigan Creek near Central
652132144593900	Ptarmigan Gulch 0.2 mile above mouth near Central
652209144573700	Harrison Creek 1.3 miles below Ptarmigan Gulch near Central
652231144541200	Harrison Creek 0.2 mile above Squaw Creek near Central

Figure 2. Location of water-quality and streambed-sediment sample sites in the upper Birch Creek watershed near Central, Alaska.

3. Document study area streamflow characteristics by maintaining a stream gage near the headwaters of Birch Creek, maintaining crest-stage gages on selected tributaries, and measuring streamflow during field visits.

During 2001 through 2003, project tasks included maintaining a daily stream gage near the headwaters of Birch Creek and collecting streamflow and suspended-sediment samples at 10 crest-stage gages on 5 paired stream sites (fig. 1). Crest-stage gage sites on each creek were paired. The first gage was located upstream from previously mined areas and was paired with a second gage, downstream from mined areas. Access to 6 of the 10 gage sites was by helicopter. Because of recurring logistical difficulties associated with accessing remote sites by helicopter during inclement weather, as well as extended periods of forest-fire activity and smoke cover, the areal extent of the project was reduced for the 2004 through 2005 field seasons. The daily stream gage with satellite telemetry was maintained near the headwaters of Birch Creek, site 15392000 (fig. 1). However, the number of crest-gage sites was reduced from 10 sites to 4: 2 paired sites on Harrison Creek and 2 paired sites on Frying Pan Creek (fig. 2) accessible by road or all-terrain vehicle (ATV).

Methods of Investigation

Field methods and data analysis methods are presented in this section of the report. The section, "Field Methods" describes field procedures for measurement and collection of data for discharge, water-quality parameters, water chemistry, suspended sediment, and trace elements in streambed sediment. The section, "Data Analysis" describes laboratory methods and procedures, data-set compilation and data comparison methods, and statistical summaries of data. Statistical summaries presented in this report are intended to provide the reader with convenient summaries and comparisons of selected data. Primary data were compiled in the data section in appendix A to provide additional detail.

Field Methods

Continuous-streamflow data were collected from September 2001 through September 2005 during open-water season, usually late May through September, at the Birch Creek stream gage above Twelvemile Creek, site 15392000 (table 1). The stream gage was equipped with satellite telemetry and recorded stage, precipitation, and air temperature. During site visits, field measurements of streamflow were made using a Price type AA or pygmy current meter and established procedures described in Rantz and others (1982). Streamflow data from field visits were used to develop a rating curve to compute streamflows from continuous-stage data recorded at the gage station following standard USGS procedures in Rantz and others (1982).

Crest-stage gage streamflow was monitored intermittently during open-water season at 10 crest-stage gage sites during 2001 through 2003, and regularly at 4 sites from 2004 through 2005 (table 1). Crest-stage gage records for selected sites were computed using standard USGS procedures (Rantz and others, 1982). Restricted access to remote sites prevented sufficient data records for calculation of peak streamflow for locations on Ptarmigan Creek site 15389980, North Fork of Twelvemile Creek site 15393900, Great Unknown Creek site 15397500, East Fork Great Unknown Creek site 15397700,Volcano Creek site 15403000, and Anvil Creek site 15404800 (table 1).

Channel cross-section geometry and water-surface profiles were determined by optical surveys for calculation of indirect discharge. Channel cross-section plots for South Fork of Harrison Creek (fig. A1) and Harrison Creek (fig. A2) crest-stage gage sites were included in appendix A for reference because flood-plain reclamation work was scheduled to begin in 2006 on Harrison Creek, below the confluence of the North Fork and South Fork of Harrison Creek (fig. 2).

Water-quality field parameters of water temperature, specific conductance, dissolved-oxygen concentration, and pH were measured using a multi-probe sonde during site visits at the Birch Creek stream gage site 15392000, at Frying Pan Creek sites 15395900 and 15396000, and at Harrison Creek crest-stage gage sites 15407200 and 15407500 (table 1). The multi-probe sonde was calibrated streamside during each field visit using standard solutions and adjusted according to procedures in Wagner and others (2000) as well as periodically checked in the lab with calibrated meters. Direct measurement of water-quality parameters were made following standard stabilization criteria (U.S. Geological Survey, 1998).

Nutrient, alkalinity, and major-ion water samples were collected during late summer 2004 at the Frying Pan and Harrison Creek crest-stage gage sites noted previously. Samples for nutrients, alkalinity, major ions, mercury in water, and selected trace elements in streambed sediment were collected at the same sites, as well as at the Birch Creek gage site, 15392000, during August and September 2005. Equipment blanks were sent to the National Water-Quality Laboratory (NWQL) for analysis at the beginning of the 2004 and 2005 field seasons. Four miscellaneous sites on Harrison Creek, 652149145074900, 652129145001700, 652132144593900, and 652209144573700, were sampled for mercury concentration in water and trace elements in streambed sediment (fig. 2) because these areas were scheduled for flood-plain reclamation work in 2006. Water samples for nutrients, alkalinity, major ions, and mercury were collected by equal-width-increment (EWI) methods using a handheld DH-81 sampler, with 1-liter (L) polyethylene sampler bottles, and a D-77 nozzle attachment. Samples were composited in a churn splitter made from inert material for dispensing sample aliquots to each analytical bottle (U.S. Geological Survey, 1998).

An automated water sampler was deployed to collect suspended-sediment samples at the Birch Creek gage site 15392000 in July 2003, but was lost during a late July high

Table 1. Description of stream-gage and water-quality sampling sites in the upper Birch Creek watershed near Central, Alaska, 2001–05.

[Latitude and longitude coordinates in North American Datum 1927 Alaska (NAD27AK) in degrees, minutes, and seconds. **Abbreviations:** USGS, U.S. Geological Survey; mi^2, square mile]

USGS site identification No.	Site name	Latitude	Longitude	Contributing drainage area (mi^2)	Remarks
15389980	Ptarmigan Creek near mouth, near Central, Alaska	65°26´24˝	145°31´34˝	19.2	Crest-stage gage—site not monitored in 2004–05
15392000	Birch Creek above Twelvemile Creek, near Miller House, Alaska	65°23´33˝	145°42´45˝	89.2	Stream gage with satellite telemetry, near Steese Hwy. mile 93. Mercury sample site—water and streambed sediment
15393900	North Fork Twelvemile Creek near Miller House, Alaska	65°24´03˝	145°44´18˝	23.2	Crest-stage gage—site not monitored in 2004–06
15395900	Upper Frying Pan Creek near Central, Alaska	65°19´37˝	145°33´01˝	8.1	Crest-stage gage above mined area. Mercury sample site—water and streambed sediment
15396000	Frying Pan Creek near Miller House, Alaska	65°19´18˝	145°33´02˝	14.7	Crest-stage gage below mined area, installed summer 2004. Mercury sample site—water and streambed sediment
15396100	Frying Pan Creek at mouth, near Central, Alaska	65°16´58˝	145°33´33˝	20.6	Crest-stage gage—remote site not accessed in 2004–05
15397500	Great Unknown Creek near Central, Alaska	65°17´38˝	145°24´00˝	18.6	Crest-stage gage—remote site not accessed in 2004–05
15397700	East Fork Great Unknown Creek near Central, Alaska	65°17´36˝	145°23´20˝	20.4	Crest-stage gage—remote site not accessed in 2004–05
15403000	Volcano Creek near Central, Alaska	65°08´09˝	145°28´39˝	5.6	Crest-stage gage—remote site not accessed in 2004–05
15404800	Anvil Creek near Central, Alaska	65°12´42˝	145°14´25˝	20.4	Crest-stage gage—remote site not accessed in 2004–05
15407200	South Fork Harrison Creek near Central, Alaska	65°21´52˝	145°15´25˝	9.1	Crest-stage gage site above mined area. Mercury sample site, water and streambed sediment
652149145074900	North Fork Harrison Creek 0.1 mile above mouth, near Central, Alaska	65°21´49˝	145°07´49˝	25.3	Placer mined tributary to Harrison Creek. Mercury sample site—water and streambed sediment
652129145001700	Harrison Creek 0.4 mile above Ptarmigan Gulch, near Central, Alaska	65°21´29˝	145°00´17˝	56.4	Mercury sample site—water and streambed sediment
652132144593900	Ptarmigan Gulch 0.2 mile above mouth, near Central, Alaska	65°21´32˝	144°59´39˝	3.9	Mercury sample site—water sample only
652209144573700	Harrison Creek 1.3 miles below Ptarmigan Gulch, near Central, Alaska	65°22´09˝	144°57´37˝	62.7	Mercury sample site—water and streambed sediment
652231144541200	Harrison Creek 0.2 mile above Squaw Creek, near Central, Alaska	65°22´31˝	144°54´12˝	67.5	Mercury sample site—water and streambed sediment
15407500	Harrison Creek above Bottom Dollar Creek, near Central, Alaska	65°22´45˝	144°49´58˝	71.6	Crest-stage gage site below mined area. Mercury sample site—water and streambed sediment

flow that undercut the stream bank where the sampler was deployed. During 2004 and 2005, automated samplers were deployed after spring snowmelt to collect daily suspended-sediment samples at two crest-stage gage sites on Frying Pan Creek (15395900 and 15396000) and two crest-stage gage sites on Harrison Creek (15407200 and 15407500) (fig. 2). Daily 1-L samples were collected at 10:00 p.m. The paired crest-stage gage sites were located upstream and downstream from placer-mined areas. Suspended-sediment EWI samples were collected during field visits to verify sample accuracy of the automated sampler. EWI sample concentrations were typically within ± 2 mg/L of automated sampler suspended-sediment concentration samples. Miscellaneous suspended-sediment grab (point) samples were collected from stream banks during high flows.

Streambed sediment samples for selected trace elements were collected to address concerns that substantial amounts of mercury in sediments may be disturbed during stream channel and flood plain reclamation work. Collection and field processing of streambed-sediment samples followed established USGS National Water-Quality Assessment (NAWQA) Program protocols (Shelton and Capel, 1994). Streambed sediments were collected from depositional zones selected to represent various streamflow regimes. Sampling was confined to the upper 1–4 in. of streambed sediment. At each sampling site, five to eight subsamples were collected, composited in a glass bowl, and passed through a 63-micron wet sieve. Eight replicate samples for total mercury were split and processed from the composite samples to evaluate sample mercury concentration variance. Samples were shipped overnight to the USGS NWQL in Arvada, Colorado, for analyses. Links to NWQL quality-assurance and analytical procedures are available at the NWQL Web page (http://wwwnwql.cr.usgs.gov/USGS/USGS_srv.html).

Data Analysis

Water samples collected for major-ion and nutrient analysis were analyzed at the USGS NWQL in Lakewood, Colorado, using standard analytical techniques described in Fishman (1993), Fishman and Friedman (1989), and Patton and Truitt (2000). Laboratory analysis of water samples collected for analysis of total mercury in filtered (0.45 µm) and unfiltered samples were analyzed at the USGS NWQL in Lakewood, Colorado, using standard analytical techniques described in Garbarino and Damrau (2001). Filtered (0.63 µm) streambed-sediment samples were collected and analyzed for selected trace elements at the USGS Central Mineral Resources Team-Analytical Chemistry, Denver, Colorado, using standard techniques described in Arbogast (1996), Taggart (2002), and Briggs and Meier (1999). Suspended-sediment concentration samples were analyzed at the USGS Cascades Volcano Observatory Sediment Laboratory in Vancouver, Washington, and analyzed according to methods described by Guy (1977).

Laboratory methods and minimum reporting limits for water and sediment samples collected during the study are listed in table 2. All stream discharge, water-quality, and streambed-sediment data are available to the public at the USGS National Water Information System (NWIS) at http://waterdata.usgs.gov/nwis.

Data Summary Methods

Hydrologic data were summarized using time-series plots of daily mean flow and box plots to characterized period-of-record, annual, and monthly flow statistics.

Water-quality data for field parameters, major ions, nutrients, suspended sediment, and mercury in water were summarized using descriptive statistics, piper plots, and box plots. Spatial differences for field parameters were summarized using a Wilcoxon rank-sum test. The Wilcoxon rank-sum test is a nonparametric test equivalent to the Mann-Whitney U test. It does not require a normal distribution to detect differences between two populations based on random samples from those populations (Helsel and Hirsch, 1992). Statistical comparisons were reported as significant for tests with calculated *p*-values less than or equal to 0.01. The *p*-value is a measure of probability that a difference between groups occurred by chance. For example, a *p*-value of 0.01 ($p = 0.01$) means there is a 1 in 100 chance the result occurred by chance. The smaller the *p*-value, the more likely the difference between groups was caused by some other factor than random chance.

Trace-element data were compiled using descriptive statistics and comparative tables. Histograms were used to illustrate variations in selected trace-element concentrations. National median trace-element concentrations for nine U.S. Environmental Protection Agency (1994) priority pollutants—arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, and zinc—were compared to study area sample results in a summary table.

Table 2. Laboratory methods and minimum reporting levels for samples collected in the upper Birch Creek watershed near Central, Alaska, 2003–05.

[MRL is defined by the NWQL as the smallest measured concentration of a substance that can be reliably measured by using a given analytical method. It is the “less-than” value reported when an analyte either is not detected or is detected at a concentration less than the MRL. Minimum reporting levels and reporting units given for NWQL Schedule constituents may vary from actual analytical results reported by NWQL for a particular sample as LRL because of instrument calibration, sample matrix interference, or other factors. **Method:** AA, atomic absorption; CVAF, cold vapor atomic fluorescence; EWI, equal-width-increment; GFAA, graphite furnace atomic absorption; IC, ion chromatography; ICP, inductively coupled plasma; ICPMS, inductively coupled plasma mass spectrometry. **Abbreviations**: LRL, laboratory reporting level; MRL; minimum reporting level; NWQL, National Water Quality Laboratory; ft^3/s, cubic foot per second; mg/L, milligram per liter; N, nitrogen: P, phosphorus; µg/L, microgram per liter; µg/g, microgram per gram; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25°C; $CaCO_3$, calcium carbonate; pct, percent]

Property or constituent	NWQL catalog units	Method		MRL/LRL
		Field	Analytical	
Field properties				
Discharge	ft^3/s	Current meter	Mid-interval	Variable
Specific conductance	µS/cm	Point/EWI	Electrode	1
pH	units	Point/EWI	Electrode	.1
Water temperature	mg/L	Point/EWI	Electrode	.1
Dissolved oxygen	mg/L	Point/EWI	Electrode	.1
Major ions: Schedule 2701 NWQL				
Calcium, dissolved	mg/L	EWI	ICP	0.02
Chloride, dissolved	mg/L	EWI	IC	.20
Fluoride, dissolved	mg/L	EWI	Ion selective electrode	.10
Iron, dissolved	µg/L	EWI	ICP	6
Magnesium, dissolved	mg/L	EWI	ICP	.008
Manganese, dissolved	µg/L	EWI	ICP	.6
Potassium, dissolved	mg/L	EWI	ICP	.16
Silica, dissolved	mg/L	EWI	ICP	.04
Sodium, dissolved	mg/L	EWI	ICP	.20
Sulfate, dissolved	mg/L	EWI	IC	.18
Acid-neutralizing capacity, lab as $CaCO_3$	mg/L	EWI	Titration	5
Nutrients: Schedule 1119 NWQL				
Nitrite, dissolved as N	mg/L	EWI	Colorimetry	0.002
Nitrite plus nitrate, dissolved as N	mg/L	EWI	Colorimetry	.016
Nitrogen, ammonia, dissolved as N	mg/L	EWI	Colorimetry	.010
Nitrogen, ammonia plus organic, dissolved as N	mg/L	EWI	Colorimetry	.10
Nitrogen, ammonia plus organic, total as N	mg/L	EWI	Colorimetry	.10
Phosphorus, total as P	mg/L	EWI	Colorimetry	.004
Phosphorus, dissolved as P	mg/L	EWI	Colorimetry	.004
Phosphorus, dissolved orthophosphate as P	mg/L	EWI	Colorimetry	.006
Mercury: Lab codes 2707, 2708 NWQL				
Mercury, dissolved	µg/L	EWI	CVAF	0.010
Mercury, total	µg/L	EWI	CVAF	.010
Streambed sediment trace elements: Schedule 2420 NWQL				
Aluminum (Al)	µg/g	Composite	ICPMS	50
Antimony (Sb)	µg/g	Composite	ICPMS	.04
Arsenic (As)	µg/g	Composite	ICPMS, GFAA	1
Barium (Ba)	µg/g	Composite	ICPMS	.2
Beryllium (Be)	µg/g	Composite	ICPMS	.03
Bismuth (Bi)	µg/g	Composite	ICPMS	.06
Cadmium (Cd)	µg/g	Composite	GFAA	.007
Calcium (Ca)	µg/g	Composite	ICPMS	100
Cerium (Ce)	µg/g	Composite	ICPMS	.1
Chromium (Cr)	µg/g	Composite	ICPMS	.5
Cobalt (Co)	µg/g	Composite	ICPMS	0.03

Table 2. Laboratory methods and minimum reporting levels for samples collected in the upper Birch Creek watershed near Central, Alaska, 2003-05.—Continued

Property or constituent	NWQL catalog units	Method		MRL/LRL
		Field	Analytical	
Streambed sediment trace elements: Schedule 2420 NWQL—Continued				
Copper (Cu)	µg/g	Composite	ICP, GFAA	2
Gallium (Ga)	µg/g	Composite	ICP, GFAA	.02
Iron (Fe)	µg/g	Composite	AA, ICP	50
Lanthanum (La)	µg/g	Composite	GFAA	.05
Lead (Pb)	µg/g	Composite	GFAA	.4
Lithium (Li)	µg/g	Composite	AA, ICP	.3
Magnesium (Mg)	µg/g	Composite	AA, ICP	6
Manganese (Mn)	µg/g	Composite	AA, ICP	.7
Mercury (Hg)	µg/g	Composite	CVAF	.020
Molybdenum (Mo)	µg/g	Composite	ICPMS	.50
Nickel (Ni)	µg/g	Composite	ICPMS	.3
Niobium (Nb)	µg/g	Composite	ICPMS	.1
Phosphorus (P)	µg/g	Composite	ICPMS	5
Potassium (K)	µg/g	Composite	ICPMS	20
Scandium (Sc)	µg/g	Composite	ICPMS	.04
Selenium (Se)	µg/g	Composite	ICPMS	.1
Silver (Ag)	µg/g	Composite	ICPMS	2
Sodium (Na)	µg/g	Composite	ICPMS	20
Strontium (Sr)	µg/g	Composite	ICPMS	.8
Sulfur (S)	pct	Composite	ICPMS	.05
Thallium (Tl)	µg/g	Composite	ICPMS	.08
Thorium (Th)	µg/g	Composite	ICPMS	1.0
Titanium (Ti)	µg/g	Composite	ICPMS	.005
Uranium (U)	µg/g	Composite	ICPMS	.1
Vanadium (V)	µg/g	Composite	ICPMS	2
Yttrium (Y)	µg/g	Composite	ICPMS	1
Zinc (Zn)	µg/g	Composite	ICP, AA	2
Organic carbon	pct	Composite	ICPMS	.01
Inorganic carbon	pct	Composite	ICPMS	.01
Organic plus inorganic carbon, total	pct	Composite	ICPMS	.01
Sediment				
Sediment, suspended, concentration	mg/L	Point/grab/EWI	Gravimetric	1

Results

Study results are divided into two sections. The first section describes overall trends in the data set. The second section compares samples from paired sites, upstream and downstream from mined areas on Frying Pan Creek and Harrison Creek.

Overall Trends

Hydrology

Hydrologic characteristics of the Birch Creek watershed were compiled from stream-gage records, crest-stage gage records, discharge measurements, field-site inspections, and surveys of stream-channel cross sections. Generally, channels were alternating pool and riffle sequences with occasional deep reaches and gradients of about 2 percent or less. Bed material typically was coarse: pebble, cobble, and boulder, with only minor in-stream fine-grained sediments. Runoff intensity was high. Flows increased and decreased rapidly in response to major rainfall and snowmelt events because the relatively steep slopes, thin soil cover, and permafrost areas in the watershed had a low capacity for retaining precipitation or meltwater. Many of the drainages were split or single channels with relatively wide flood plains or incised channels with no flood plain (fig. A3).

Birch Creek Daily Stream Gage

Hydrologic data from the Birch Creek stream gage (site 15392000) were summarized using a time-series plot of daily mean streamflow (fig. 3) to characterize seasonal and long-term flow patterns. Seasonal discharges were highly variable.

Typically, there were two or more periods of sharp discharge peaks. The first peak flows were associated with snowmelt runoff. Magnitude of the snowmelt runoff peaks depended on the volume of accumulated winter snowpack, timing of snowpack melting, and precipitation events. Additional discharge peaks, of similar or greater magnitude, occurred after spring snowmelt and were related to the location, duration, and intensity of precipitation events.

Statistical summaries of the Birch Creek daily mean discharge data were compiled by year in table 3 and by month in table 4. Summary statistics and daily mean discharge values are also available online at the NWIS web site (http://waterdata.usgs.gov/nwis).

Daily mean peak discharges associated with snowmelt in late May and early June ranged from a minimum of about 400 ft^3/s in 2003 to maximums of about 1,000 ft^3/s in 2002 and 2005. Daily mean peak discharges associated with rainfall events were about 1,000 ft^3/s and occurred in June 2002, July and September 2003, and June 2005 (figs. 4 and 5). Spring discharges associated with snowmelt were low in 2003 because interior Alaska snowpack was less than 50 percent of average (Rozell, 2003). For 2004 and 2005 summer precipitation was less than normal (National Climate Data Center, 2005) and associated mid to late-summer discharge peaks were less than 600 ft^3/s. Maximum daily mean peak

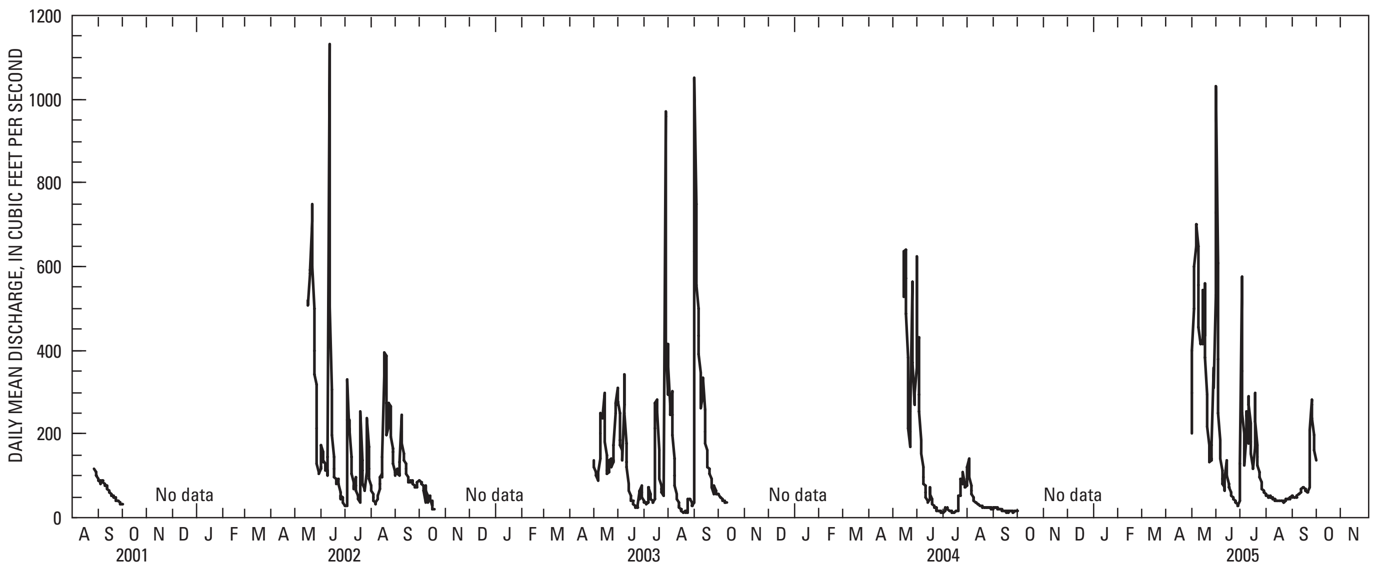


Figure 3. Daily mean streamflow for Birch Creek stream-gage site 15392000 near Central, Alaska, water years 2001–05.

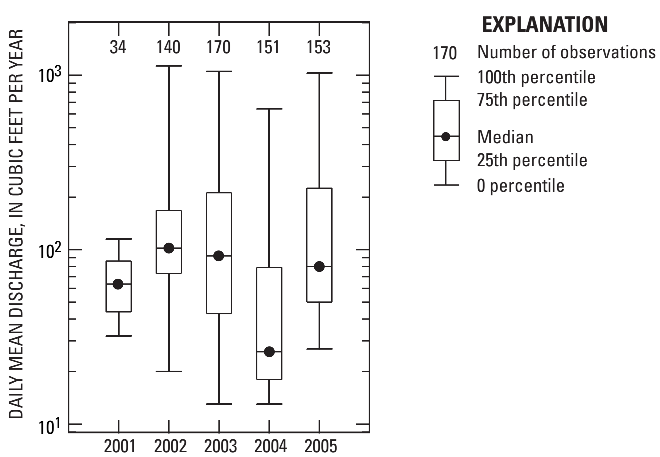


Figure 4. Distribution of daily mean discharge by year for stream gage (15392000) Birch Creek above Twelvemile Creek near Miller House, Alaska, water years 2001–05.

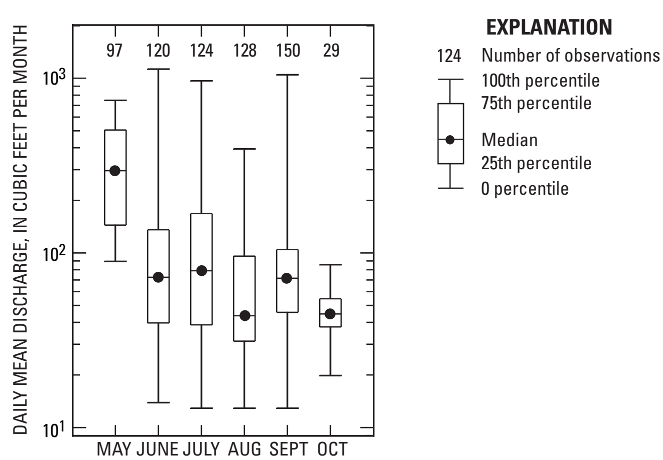


Figure 5. Distribution of daily mean discharge by month for stream gage (15392000) Birch Creek above Twelvemile Creek near Miller House, Alaska, water years 2001–05.

Table 3. Statistical summary of daily mean discharge by water year for stream gage (15392000), Birch Creek above Twelvemile Creek near Miller House, Alaska, 2001–05.

[Yearly streamflow recorded during open water season, May–October, does not include winter streamflow under ice cover. **Abbreviations:** ft^3/s, cubic foot per second]

Water year	Discharge (ft^3/s)					Number of days	Dates discharge recorded
	Minimum	25th Percentile	Median	75th Percentile	Maximum		
2001	32	48	68	87	115	34	Partial year: 34 days, 08-28 to 09-30
2002	27	79	108	194	1,130	140	Dates: 10-01 to 10-02; 05-16 to 09-30
2003	13	44	85	200	1,050	170	Dates: 10-01 to 10-17; 05-01 to 09-30
2004	13	18	28	76	641	151	Dates: 10-01 to 10-10; 05-13 to 09-30
2005	27	50	80	225	1,030	153	Dates: 05-01 to 09-30
					Total days	648	

Table 4. Statistical summary of daily mean discharge by month for stream gage (15392000), Birch Creek above Twelvemile Creek near Miller House, Alaska, water years 2001–05.

[**Abbreviation:** ft^3/s, cubic foot per second]

Month	Discharge (ft^3/s)					Number of observations	Notes
	Minimum	25th Percentile	Median	75th Percentile	Maximum		
May	90	145	297	508	750	97	Includes estimated data 05-01 to 05-07-03, 05-01 to 05-09-05; partial data 05-16 to 05-31-02, 05-13 to 05-31-04; and no data for May 2001.
June	14	40	73	136	1,130	120	Includes estimated data 06-20 to 06-24-02 and 06-29 to 06-30-05.
July	13	39	80	169	970	124	Includes estimated data 07-01 to 07-05-05.
August	13	32	44	96	395	128	Includes partial monthly data 08-28 to 08-31-01.
September	13	46	72	105	1,050	150	Includes estimated data 09-19 to 09-30-2004.
October	20	38	45	55	86	29	Includes partial monthly data 10-01 to 01-02-01; 10-01 to 10-17-02; 10-01 to 10-10-03; and no data for 2004.
					Total days	648	

discharges recorded during open-water season for 2002, 2003, and 2005 were comparable at approximately 1,000 ft^3/s (table 3; fig. 4). The maximum daily mean discharge peak during the drought year of 2004 was 641 ft^3/s (table 3), about 35 percent less than other years. For the period of record, peak discharges of about 1,000 ft^3/s occurred in June, July, and September. Minimum daily mean streamflows (~20 ft^3/s or less) occurred during June, July, August, September, and October (table 4; fig. 5). A maximum instantaneous discharge of 2,100 ft^3/s occurred July 27, 2003, from rainfall. Floodwaters over-topped the bank near the gage and flowed through heavily vegetated side channels behind the stream gage. An instantaneous discharge of 2,100 ft^3/s was calculated indirectly using the slope-area method as described in Dalrymple and Benson (1967). Field data used for flood discharge calculations included channel cross sections surveyed downstream from the gage location, water-surface slope from flagged high-water marks, and a Manning's streambed roughness coefficient (*n* value) of 0.040 determined from previous discharge measurements and observed channel characteristics. The roughness coefficient agrees with values for streams with similar morphology illustrated in Barnes (1967).

About 75 percent of the Birch Creek annual discharge, during 2002 through 2005, was at flows less than 200 ft^3/s (fig. 4). Median streamflow ranged from 28 ft^3/s in 2004 to 108 ft^3/s in 2002 (table 3). The statistical summary of daily mean discharge by month in table 4 and the boxplots of daily mean discharge by month (fig. 5) clearly illustrate the highly variable, precipitation-dependent, character of streamflow in the study area. Annual maximum and minimum discharges may occur during the same month.

The DGGS reported similar magnitude and variability in mean monthly streamflow and for instantaneous peak flow at the Birch Creek stream-gage site for 1986 through 1989. As an example, average monthly discharge for July 1987 was 147 ft^3/s; however, the July 1988 average discharge of 35.4 ft^3/s was substantially less than the previous year (Ray, 1990). DGGS also reported that an instantaneous peak flow of 1,940 ft^3/s occurred on June 25, 1989, with an estimated recurrence interval of 15 years (Ray, 1990). The magnitude of the calculated 1989 peak flow is similar to the maximum calculated instantaneous peak flow of 2,100 ft^3/s that occurred July 27, 2003, at the Birch Creek stream-gage site from a rainfall event. Except for the 2004 and 2005 summer drought periods, streamflow variability and magnitude in the upper Birch Creek watershed from 2001 through 2005 were similar to streamflow characteristics reported for the late 1980s.

Crest-Stage Gages

Water-year and period-of-record peak flows for Harrison Creek and Frying Pan Creek crest-stage gages for 2002 through 2005 were compiled in table 5.

A water-year maximum discharge and period-of-record maximum discharge of 244 ft^3/s for Upper Frying Pan Creek, site 15395900, occurred July 27, 2003, from rainfall. Discharge was calculated using the slope-area method (Dalrymple and Benson, 1967). The Manning's streambed roughness coefficient (*n* value) selected was 0.038. The downstream gage on Frying Pan Creek (site 15396000) was installed in July 2004. A maximum flow of 10.6 ft^3/s was measured August 3, 2004, during a field visit; however, no peak flows were recorded on the crest-stage gage during the 2004 drought. A water-year maximum, and period-of-record maximum, for Frying Pan Creek of 171 ft^3/s occurred May 30, 2005. The peak probably was affected by channel ice.

The period-of-record maximum discharge of 199 ft^3/s for South Fork of Harrison Creek site 15407200 also occurred May 30, 2005, and may have been affected by channel ice as well. A discharge of similar magnitude, 184 ft^3/s on July 27, 2003, was calculated using the slope-area method (Dalrymple and Benson, 1967). Selected Manning's roughness coefficients were 0.060 for the lower cross sections and 0.070 for the upstream section.

Table 5. Water-year and period-of-record maximum discharge for Harrison Creek and Frying Pan Creek crest-stage gages in the upper Birch Creek watershed near Central, Alaska, 2002–05.

[**Abbreviations:** ft^3/s, cubic foot per second; USGS, U.S. Geological Survey]

USGS site identification No. and name		Water year		Event type	Period of record	
		Date	Maximum discharge (ft^3/s)		Date	Maximum discharge (ft^3/s)
15395900	Upper Frying Pan Creek	06-11-02	83	Rainfall		
		07-27-03	244	Rainfall; ice affected	07-27-03	244
		05-24-04	90	Rainfall; ice affected		
		05-30-05	109	Rainfall; ice affected		
15396000	Frying Pan Creek near Miller House	05-30-05	171	Rainfall; ice affected	05-30-05	171
15407200	South Fork Harrison Creek	07-27-03	184	Rainfall		
		05-30-05	199	Rainfall	05-30-05	199
15407500	Harrison Creek	06-11-02	877	Rainfall		
		07-27-03	1,320	Rainfall	07-27-03	1,320
		05-24-04	556	Rainfall; ice affected		
		05-30-05	492	Rainfall; ice affected		

The Harrison Creek site 15407500 water-year maximum and period-of-record maximum discharge of 1,320 ft^3/s occurred July 27, 2003, from a rainfall event. A discharge of similar magnitude, 913 ft^3/s, was calculated from the September 2, 2003, peak using the slope-area method and a Manning's roughness coefficient of 0.039.

Data were not adequate to develop peak flows by indirect methods or stage-discharge ratings for remote crest-gage sites on Volcano Creek site 15403000, Anvil Creek site 15404800, Great Unknown Creek sites 15397500 and 15397700, North Fork Twelvemile Creek site 15393900, and Ptarmigan Creek site 15389980.

Stream Discharge Measurements

Stream discharge measurements collected during the project are available online at http://waterdata.usgs.gov/nwis and associated daily mean discharge measurements were complied in appendix A (table A1). The discharge measurements were completed during open-water season. Most discharge measurements were obtained during low-flow conditions using a wading rod and current meter at measured discharges of 200 ft^3/s or less. Measured discharges at gage sites were compiled in table 6. During 2003, high-water marks were flagged on Birch Creek, Upper Frying Pan Creek, South Fork of Harrison Creek, and Harrison Creek. Associated discharges were calculated using channel cross-section survey data and indirect methods as outlined in (Dalrymple and Benson, 1967). The calculated instantaneous discharge for Birch Creek site 15392000 for July 27, 2003, was 2,100 ft^3/s. The calculated indirect discharges for the same date were 184 ft^3/s for South Fork of Harrison Creek, site 15407200, 1,320 ft^3/s for Harrison Creek site 15407500, and 244 ft^3/s for Upper Frying Pan Creek site 15395900.

Streamflow data from the Birch Creek stream gage, crest-gage data from Birch Creek tributaries, and discharge measurements at project stations can be used to estimate the magnitude and frequency of peak streamflows for ungaged sites on streams. Methods are outlined in Jones and Fahl (1994) and Curren and others (2003).

Water Quality

Water-quality data were collected during 2004 and 2005 for selected sites on Birch Creek, Frying Pan Creek, Harrison Creek, and South Fork of Harrison Creek. Data presented in this section cover four topics. First, data are presented for water-quality field parameters of pH, specific conductance, dissolved oxygen, and temperature collected during field visits. Water-chemistry data are covered for samples collected annually for major ions, nutrients, and alkalinity. Automated daily suspended-sediment concentration sample data for paired sites on Frying Pan Creek and Harrison Creek for selected periods, as well as miscellaneous suspended-sediment grab samples for selected sites are presented. Finally, this section presents data about mercury concentration in water samples collected during August and September 2005. These water-quality data provide quantitative information for assessing general environmental conditions as well as conditions for aquatic life.

Field Parameters

Water-quality field parameters of pH, specific conductance, dissolved oxygen, and temperature provide information on aquatic environmental conditions. The pH of water is a measure of its hydrogen-ion activity and can range from 0 (acidic) to 14 (alkaline) standard units. River water in areas not influenced by contaminants generally has a pH in the range 6.5 to 8.5 (Hem, 1985). Specific conductance is a measure of total dissolved solids. As ion concentrations increase, specific conductance of the solution increases. Higher forms of aquatic life require dissolved oxygen for survival. The equilibrium concentration of dissolved oxygen in water in contact with air is a function of temperature and pressure, and to a lesser degree, the concentration of other solutes (Hem, 1985). Water temperature is controlled by many factors.

Water-quality field parameters were measured at the Birch Creek stream gage site 15392000, at sites upstream and downstream from previously mined areas on Frying Pan Creek sites 15395900 and 15396000, as well as at South Fork of Harrison Creek site 15407200, Harrison Creek site 15407500, and several miscellaneous sites (table 6). Summary statistics for water-quality field parameters were compiled in table 7 and illustrated in figure 6.

Measured specific conductance for Birch Creek, Frying Pan Creek, and Harrison Creek sites ranged from a minimum 52 µS/cm, during a June 1, 2005, Birch Creek peak flow precipitation/snowmelt event, to a maximum of 312 µS/cm at Frying Pan Creek on September 24, 2004, during low-flow conditions. Median specific conductance values ranged from 96 µS/cm at South Fork Harrison Creek site 15407200 to 197 µS/cm at Frying Pan Creek site 15396000 (table 7).

The median specific conductance of 96 µS/cm for South Fork of Harrison Creek, site 15407200, was considerably lower than median values for other study sites. Mack and Moorman (1986) reported variation in specific conductance of 25 to 193 µS/cm for samples collected in several Birch Creek tributaries. Lower conductance values were associated with precipitation events or were measured in basin headwaters where water residence time was short or bedrock was resistant to chemical weathering.

Table 6. Streamflow, water-quality field parameters, and suspended-sediment concentrations at selected sites in the upper Birch Creek watershed near Central, Alaska, 2003–05.

[**Suspended sediment sampling method:** EWI, equal width increment; E, estimated. **Abbreviations:** ft^3/s, cubic foot per second; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25°C; mi, mile; mg/L, milligram per liter; <. less than; –, no data]

Date	Time (hours)	Instantaneous steamflow (ft^3/s)	Water temperature (°C)	Specific conductance at 25°C (µS/cm)	Dissolved-oxygen concentration (mg/L)	pH (standard units)	Suspended-sediment concentration (mg/L)	Suspended-sediment sampling method
15389980 (Ptarmigan Creek near mouth, near Central, Alaska)								
07-22-03	1340	15.5	–	–	–	–	1	Point
09-02-03	1711	236	–	–	–	–	56	EWI
15392000 (Birch Creek above Twelvemile Creek, near Miller House, Alaska)								
05-21-03	1515	161	–	–	–	–	90	EWI
08-05-03	1235	246	–	–	–	–	20	EWI
09-02-03	–	1,050	–	–	–	–	1,386	Point
06-09-04	1200	73.8	10.9	232	9.5	7.8	–	–
06-18-04	1245	38.3	10.8	189	10.0	7.6	–	–
07-09-04	1300	16.6	11.4	232	9.4	7.8	–	–
08-24-04	1400	25.3	8.9	216	9.6	7.6	–	–
09-01-04	1530	25.5	8.7	183	11.5	7.5	–	–
06-01-05	1208	1,030	3.4	52	11.7	7.3	785	Point
06-13-05	1240	142	–	–	–	–	17	EWI
06-27-05	1730	27.8	12.2	194	9.8	7.6	2	EWI
07-19-05	1844	200	12.4	125	7.3	7.5	–	–
07-28-05	1130	64.3	13.2	168	7.9	7.7	–	–
09-12-05	1730	60.0	7.9	187	10.2	7.6	–	–
15393900 (North Fork Twelvemile Creek near Miller House, Alaska)								
07-22-03	1235	6.54	–	–	–	–	4	Point
09-02-03	1451	247	–	–	–	–	83	EWI
15395900 (Upper Frying Pan Creek near Central, Alaska)								
09-04-03	–	–	–	–	–	–	26	EWI
06-10-04	1450	6.40	8.7	116	[1]6.22	7.2	–	–
08-03-04	1907	5.35	7.4	119	11.1	7.4	–	–
09-01-04	1400	E 1.49	5.6	234	11.4	6.9	1	EWI
09-24-04	1640	0.70	1.0	312	11.6	7.6	<1	EWI
06-15-05	1330	2.96	9.9	156	9.5	7.2	1	EWI
06-25-05	1400	1.24	–	–	–	–	1	EWI
07-19-05	1602	13.3	8.2	92	8.0	7.1	6	EWI
08-11-05	1736	2.04	10.8	214	9.9	7.2	1	EWI
09-04-05	1544	2.88	5.0	194	10.8	7.4	–	–
09-13-05	1700	7.19	4.3	124	11.7	7.3	1	EWI
15396000 (Frying Pan Creek near Miller House, Alaska)								
06-10-04	–	–	–	–	–	–	–	–
08-03-04	1500	–	8.3	123	11.1	7.4	–	–
09-01-04	1200	1.54	5.8	234	12.0	7.0	1	EWI
09-24-04	1323	1.05	1.8	312	12.0	7.4	1	EWI
06-15-05	1121	4.57	10.2	177	9.5	7.3	1	EWI
06-25-05	1250	1.93	–	–	–	–	<1	EWI
07-19-05	1228	27.90	7.5	97	8.2	7.1	10	EWI
08-11-05	1320	3.42	12.0	228	10.3	7.4	2	EWI
09-04-05	1659	4.60	6.2	216	10.8	7.6	–	–
09-13-05	1547	13.00	4.6	142	11.9	7.3	2	EWI
15396100 (Frying Pan Creek at mouth, near Central, Alaska)								
07-22-03	–	–	–	–	–	–	4	Point
08-07-03	1250	23.70	–	–	–	–	7	Point
09-18-03	1107	8.33	–	–	–	–	3	Point

Table 6. Streamflow, water-quality field parameters, and suspended-sediment concentrations at selected sites in the upper Birch Creek watershed near Central, Alaska, 2003–05.—Continued

[**Suspended sediment sampling method:** EWI, equal width increment; E, estimated. **Abbreviations:** ft^3/s, cubic foot per second; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25°C; mi, mile; mg/L, milligram per liter; <. less than; –, no data]

Date	Time (hours)	Instantaneous steamflow (ft^3/s)	Water temperature (°C)	Specific conductance at 25°C (µS/cm)	Dissolved-oxygen concentration (mg/L)	pH (standard units)	Suspended sediment concentration (mg/L)	Suspended sediment sampling method
15397500 (Great Unknown Creek near Central, Alaska)								
08-07-03	1515	28.10	–	–	–	–	5	Point
09-17-03	1100	19.50	–	–	–	–	2	Point
15397700 (East Fork Great Unknown Creek near Central, Alaska)								
08-07-03	1420	31.30	–	–	–	–	5	Point
09-17-03	1425	34.20	–	–	–	–	2	Point
15407200 (South Fork Harrison Creek near Central, Alaska)								
08-06-03	1438	35.80	–	–	–	–	1	Point
09-05-03	1550	41.20	–	–	–	–	3	EWI
07-08-04	1230	1.72	10.4	96	9.4	7.4	–	–
07-31-04	1510	–	9.9	95	10.2	7.5	1	Point
08-31-04	1350	1.57	7.5	110	11.9	7.2	<1	EWI
09-27-04	1354	2.14	0.4	113	14.7	7.2	<1	EWI
06-15-05	1753	5.98	11.0	84	9.2	7.4	5	EWI
06-27-05	1255	4.58	9.5	98	10.6	7.4	1	EWI
07-20-05	1245	11.70	8.6	76	10.1	7.4	<1	EWI
08-14-05	1855	5.02	11.6	96	10.7	7.3	1	EWI
08-18-05	1500	5.05	7.6	105	10.6	7.4	1	EWI
09-27-05	1340	24.00	2.6	66	12.4	7.3	<1	EWI
15407500 (Harrison Creek above Bottom Dollar Creek, near Central, Alaska)								
09-03-03	1515.00	411	–	–	–	–	67	EWI
06-17-04	1152	33.50	15.0	152	9.1	7.8	–	–
08-05-04	1155	18.11	15.9	216	9.7	7.9	–	–
08-30-04	1215	12.06	9.0	218	11.7	7.5	<1	Point
09-19-04	1410	9.83	4.4	221	13.7	7.7	<1	EWI
06-13-05	1725	46.2	17.8	–	–	–	2	EWI
06-28-05	1351	20.7	15.8	186	9.5	7.8	1	EWI
07-20-05	1944	[2]80-126 E	11.4	112	9.4	7.7	–	–
08-12-05	1451	36.2	14.0	191	9.7	7.9	1	EWI
08-17-05	1400	35.2	11.3	179	10.5	7.8	1	EWI
09-12-05	1455	53	7.4	176	11.5	7.7	1	EWI
Miscellaneous 2005 sample sites on Harrison Creek								
652149145074900 (North Fork Harrison Creek 0.1 mi above mouth, near Central, Alaska)								
08-18-05	1820	12.60	9.0	197	10.6	7.9	–	–
652129145001700 (Harrison Creek 0.4 mi above Ptarmigan Gulch, near Central, Alaska)								
08-31-05	1600	32.50	9.0	174	11.1	7.9	–	–
652132144593900 (Ptarmigan Gulch 0.2 mi above mouth, near Central, Alaska)								
08-31-05	1500	[3]<2 E	6.9	173	11.7	7.8	–	Center flow point
652209144573700 (Harrison Creek 1.3 mi below Ptarmigan Gulch, near Central, Alaska)								
08-31-05	1400	31.00	9.5	179	10.9	7.9	–	–
652231144541200 (Harrison Creek 0.2 mi above Squaw Creek, near Central, Alaska)								
08-17-05	1900	29.50	11.7	171	10.0	7.8	–	–

[1]Dissolved oxygen data suspect; no calibration in log book. Not used in summary statistics.

[2]Streamflow estimated at 80–126 ft^3/s. Used 103 ft^3/s as best estimate in table 7 summary statistics.

[3]Grab water sample for total mercury, discharge estimated at less than 2 ft^3/s, water-quality field parameters recorded: No sediment sample.

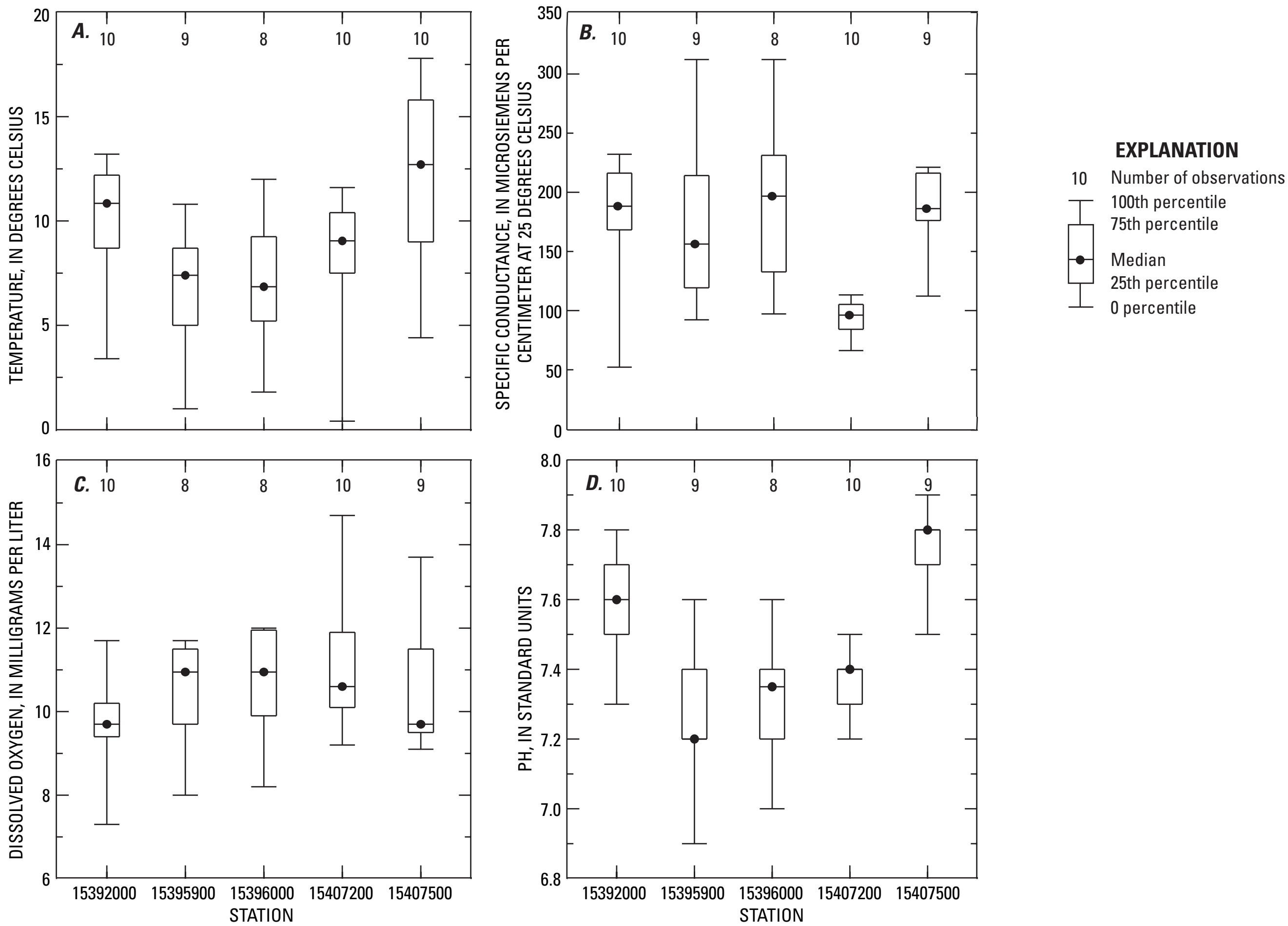


Figure 6. Distribution of water-quality field parameters for selected sites in the upper Birch Creek watershed near Central, Alaska, 2004 and 2005. (*A*) water temperature, in degrees Celsius, (*B*) specific conductance, in microsiemens per centimeter at 25 degrees Celsius, (*C*) dissolved oxygen, in milligrams per liter, and (*D*) pH, in standard units.

During open-water season, water temperatures are influenced by diurnal air temperature fluctuations. Summer diurnal water temperatures varied by 4 to 8°C. Higher water temperatures occurred in late afternoon to early evening. A maximum water temperature of 17.8°C was measured at Harrison Creek site 15407500 during summer low-flow conditions on June 13, 2005, in early evening. Water temperatures were near 0°C during spring May–June snowmelt and in late September as ice formed in stream channels. Median water temperatures during open-water season were between 7.4°C and 12.7°C (table 7).

Measured dissolved-oxygen concentrations ranged from 7.3 to 14.7 mg/L (table 7). Seasonal maximums were in late summer or early autumn, coincident with colder water temperatures, or during spring snowmelt and runoff. Median dissolved-oxygen concentrations for Birch Creek, Frying Pan Creek, and Harrison Creek ranged from 9.7 to 11.0 mg/L. (table 7). Brabets and others, (2000), reported a similar mean dissolved-oxygen concentration of 10.3 mg/L for interior highland streams of the Yukon basin.

Dissolved-oxygen concentrations measured at selected sample sites in the Birch Creek watershed were near equilibrium concentrations (U.S. Geological Survey, 1998) for the range of water temperatures, atmospheric pressures, and conductivities measured at sample sites. Hence, dissolved-oxygen concentrations at the Birch Creek study sites were not substantially depleted by processes that consume dissolved oxygen.

Measured pH was near neutral to moderately alkaline (6.9 to 7.9) (table 7). Median pH values for Birch Creek, Frying Pan Creek, and Harrison Creek, ranged from 7.2 to 7.8 standard units (table 7). The median pH for Upper Frying Pan Creek site 15395900 was 7.2. The median pH for Harrison Creek site 15407500 was 7.8. Bjerlkie and LaPerriere (1985)

Table 7. Statistical summary of water-quality field parameters at selected sites in the upper Birch Creek watershed near Central, Alaska, 2004 and 2005.

[**Abbreviations:** ft^3/s, cubic foot per second; µS/cm, microsiemens per centimeter at 25°C; °C, degrees Celsius; mg/L, milligram per liter; USGS, U.S. Geological Survey]

USGS site identification No.	Site name	Constituent or property	Minimum	25th percentile	Median	75th pecentile	Maximum	Number of samples
15392000	Birch Creek above Twelvemile Creek, near Miller House, Alaska	Discharge, instantaneous (ft^3/s)	16.6	30.4	69.1	190	1,050	14
		Water temperature °C	3.4	8.8	10.8	12.0	13.2	10
		Specific conductance (µS/cm at 25°C)	52	172	188	211	232	10
		Dissolved oxygen (mg/L)	7.3	9.4	9.7	10.1	11.7	10
		pH, field (standard units)	7.3	7.5	7.6	7.7	7.8	10
15395900	Upper Frying Pan Creek near Central, Alaska	Discharge, instantaneous (ft^3/s)	.70	1.63	2.92	6.14	13.3	10
		Water temperature °C	1.0	5.0	7.4	8.7	10.8	9
		Specific conductance (µS/cm at 25°C)	92	119	156	214	312	9
		Dissolved oxygen (mg/L)	8.0	9.8	10.9	11.5	11.7	8
		pH, field (standard units)	6.9	7.2	7.2	7.4	7.6	9
15396000	Frying Pan Creek near Miller House, Alaska	Discharge, instantaneous (ft^3/s)	1.10	1.83	4.00	6.70	27.9	8
		Water temperature °C	1.8	5.5	6.9	8.7	12.0	8
		Specific conductance (µS/cm at 25°C)	97	137	197	230	312	8
		Dissolved oxygen (mg/L)	8.2	10.1	11.0	11.9	12.0	8
		pH, field (standard units)	7.0	7.2	7.3	7.4	7.6	8
15407200	South Fork Harrison Creek near Central, Alaska	Discharge, instantaneous (ft^3/s)	1.57	3.36	5.05	17.9	41.2	11
		Water temperature °C	.4	7.5	9.0	10.3	11.6	10
		Specific conductance (µS/cm at 25°C)	66	87	96	103	113	10
		Dissolved oxygen (mg/L)	9.2	10.1	10.6	11.6	14.7	10
		pH, field (standard units)	7.2	7.3	7.4	7.4	7.5	10
15407500	Harrison Creek above Bottom Dollar Creek, near Central, Alaska	[1]Discharge, instantaneous (ft^3/s)	9.80	19.4	35.2	49.6	411	11
		Water temperature °C	4.4	9.6	12.7	15.6	17.8	10
		Specific conductance (µS/cm at 25°C)	112	176	186	216	221	9
		Dissolved oxygen (mg/L)	9.1	9.5	9.7	11.5	13.7	9
		pH, field (standard units)	7.5	7.7	7.8	7.8	7.9	9

[1] Includes 07-20-05 estimated discharge of 103 ft^3/s.

reported pH values of 6.6 to 7.8 for sites measured on Birch Creek, Twelvemile Creek, and Ptarmigan Creek. The pH range of 6.9 to 7.9 measured during the Birch Creek study are consistent with the near neutral to moderately alkaline pH values measured in mined and unmined streams in the upper Birch Creek watershed by the DGGS during 1984 (Mack and Moorman, 1986).

Generally, relatively low specific conductance and pH values were associated with peak flows. Higher water temperatures were associated with lower dissolved-oxygen levels. Discharge and specific conductance and discharge and pH were inversely related. Water-quality field parameters provide information on the aquatic environmental conditions. Changes in these characteristics along a stream reach or over time can help identify degraded habitat.

Major Ions

Major-ion compositions commonly vary temporally with changes in flow conditions, spatially with changes in geomorphic and geologic conditions, and with inputs from tributaries. Samples were collected at Harrison Creek sites 15407200 and 15407500, and at Frying Pan Creek sites 15395900 and 15396000, during late summer 2004, low-flow conditions. Samples were collected at the same sites during 2005 low-flow conditions, as well as at Birch Creek site 15392000 and two miscellaneous sites, 652129145001700, and 652209144573700, on Harrison Creek (fig. 2; table 8). The miscellaneous sites were located at the upstream and downstream margin of an area severely disturbed by mining. The area was scheduled for reclamation work during 2006.

Cation composition primarily was mixed calcium-magnesium with calcium predominant for all samples; anion compositions were mixed sulfate and bicarbonate or sulfate with minor bicarbonate for Frying Pan Creek and bicarbonate with minor sulfate for Birch Creek and Harrison Creek (fig. 7). Cation and anion compositions are similar to those reported by Brabets and others (2000). They determined the Yukon River tributaries were predominantly calcium-magnesium-bicarbonate waters with specific conductance ranging from 54 to 373 µS/cm.

Major-ion concentrations typically were greater for samples collected during the extended drought in 2004 than for samples collected during 2005 (table 8). Concentrations of major ions in water samples collected at Birch Creek site 15392000 during September 2005 were of similar magnitude as samples collected at study sites on Frying Pan Creek and Harrison Creek (fig. 8).

Nutrients

Nutrients were sampled at Harrison Creek sites 15407200 and 15407500 and at Frying Pan Creek sites 15395900 and 15396000 during late summer 2004, low-flow conditions. Samples were collected at the same sites during 2005 low-flow conditions, as well as at Birch Creek site 15392000 and two miscellaneous sites on Harrison Creek. Nutrient data were compiled and summarized in table 9.

Compounds of nitrogen and phosphorus are referred to as macronutrients because they are needed in relatively high concentrations for plant growth. In excess quantities, macronutrients can promote nuisance algae growth in streams and lakes causing eutrophication. Natural sources of nutrients include precipitation, rock weathering, and biochemical processes such as decomposition of organic matter.

Table 8. Summary of major-ion concentrations at selected sites in the upper Birch Creek watershed near Central, Alaska, 2004 and 2005.

[Concentrations are dissolved and in milligrams per liter unless otherwise noted. **Abbreviations:** USGS NWIS, U.S. Geological Survey National Water Information System; µg/L, microgram per liter; E, estimated; <, less than; –, no data]

USGS site identification No.	Sample date	Sample time (hours)	Constituent (USGS NWIS code)									
			Calcium (00915)	Magnesium (00925)	Sodium (00930)	Potassium (00935)	Chloride (00940)	Sulfate (00945)	Fluoride (00940)	Silica (00955)	Iron (01046) (µg/L)	Manganese (01056) (µg/L)
15392000	09-12-05	1730	24.9	8.21	0.89	0.69	E0.11	28.2	E0.05	5.10	19.0	11.0
15395900	09-01-04	1400	32.5	15.3	1.84	.61	<0.20	90.3	<.17	6.37	46.8	10.2
	09-04-05	1330	17.9	7.36	1.01	.34	<.20	48.0	<.10	5.03	54.0	7.30
15396000	09-01-04	1200	34.0	15.7	1.60	.65	<.20	81.1	<.17	6.03	24.7	248
	09-04-05	1630	25.2	11.4	1.16	.43	<.20	50.8	<.10	6.12	43.0	101
15407200	08-31-04	1500	19.5	1.94	.76	.53	E.14	11.8	<.17	5.96	<6.40	<.8
	08-18-05	1620	14.8	1.35	.74	.48	<.20	11.0	E.06	4.64	<6.00	.80
15407500	08-30-04	1300	37.2	6.07	1.24	.92	.27	37.5	<.17	5.24	E4.80	9.80
	08-17-05	1600	30.4	4.95	1.10	.87	<.20	27.0	<.10	5.48	12.0	5.70
652129145001700	08-31-05	1600	24.9	4.29	.86	.76	<.20	22.2	<.10	4.60	19.0	7.00
652209144573700	08-31-05	1400	25.2	4.34	.77	.75	<.20	24.2	<.10	4.85	16.0	15.0
		Minimum	14.8	1.35	0.74	0.34	<0.20	11	<0.10	4.6	<6	<0.8
		Maximum	37.2	15.7	1.84	.92	.27	90.3	<.17	6.37	54	248
		Median	25.2	6.07	1.01	.65	–	28.2	–	5.24	–	10.0

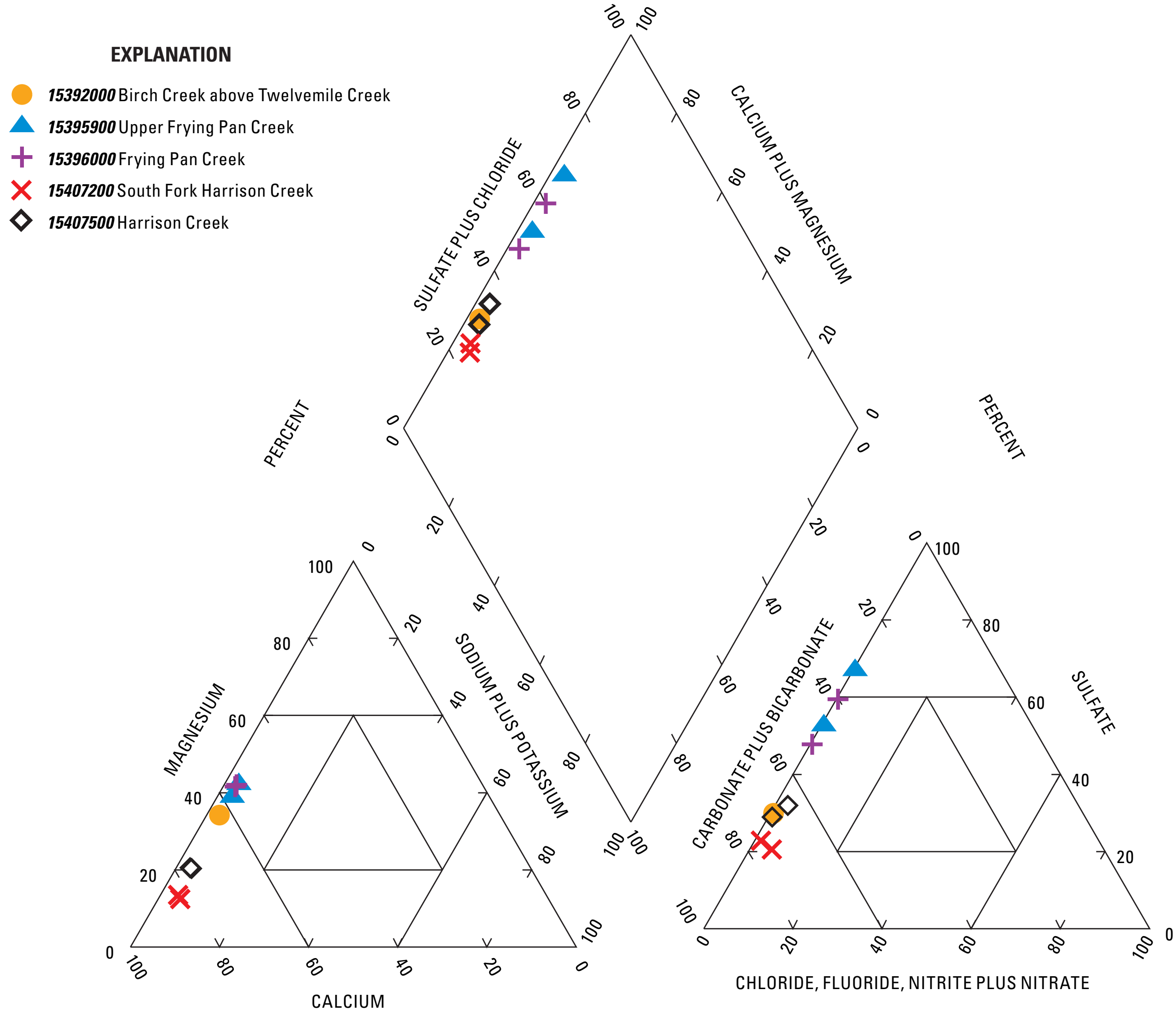


Figure 7. Major-ion composition of samples at selected sites in the upper Birch Creek watershed near Central, Alaska, 2004 and 2005.

Nutrient samples for this study were collected during low-flow conditions. Concentrations of macronutrients nitrogen and phosphorus were low, less than 0.3 mg/L (table 9). Total phosphorus concentrations typically were less than 0.004 mg/L, except for a concentration of 0.009 mg/L from sample site 15392000 (table 9). Median concentration of dissolved nitrite plus nitrate was 0.115 mg/L. The maximum concentration of dissolved nitrite plus nitrate was 0.218 mg/L. Brabets and others (2000) reported nitrogen and phosphorus concentrations of similar magnitude for the main stem of the Yukon River and Interior tributaries. Streams that drain mountainous terrain with poorly developed soils typically have low nutrient concentrations.

Mercury

Filtered and unfiltered water samples were collected for analysis of mercury concentration at 10 sites during August and September 2005 because of concerns about possible mercury contamination associated with abandoned placer-gold-mine operations. Mercury concentrations were summarized in table 10 for one site on Birch Creek, two sites on Frying Pan Creek, six sites on Harrison Creek, and one site on Ptarmigan Gulch (fig. 2). Total-recoverable (unfiltered) concentrations and dissolved (filtered) concentrations were low, less than 0.01 µg/L at all sites, indicating the particulate-phase (greater than 0.45 µm) mercury concentrations were not substantial. All 2005 mercury samples collected were at

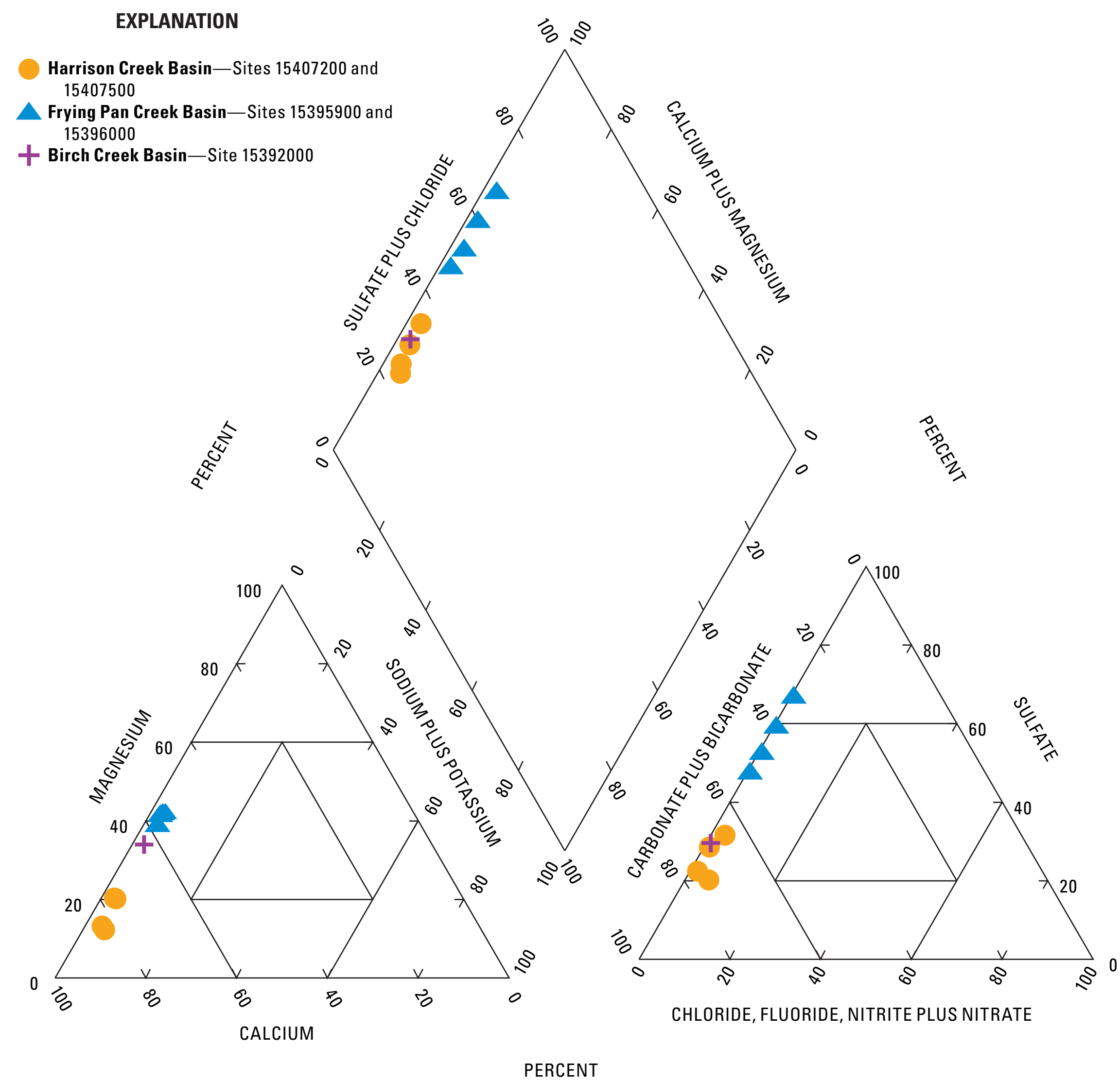


Figure 8. Major-ion composition of samples at selected sites by drainage basin in the upper Birch Creek watershed near Central, Alaska, 2004 and 2005.

concentrations less than the 2.0 µg/L maximum drinking water mercury contaminant level set by ADEC (Alaska Department of Environmental Conservation, 2003) and the National Primary Drinking Water Regulations (U.S. Environmental Protection Agency, 2003). Mack and Moorman (1986) investigated mercury concentration in water samples from several sites in the Birch Creek basin. Their results showed slightly elevated mercury concentrations of 6 µg/L or less. Mack and Moorman suggested their results may indicate naturally elevated mercury concentrations in mined as well as unmined areas, or the elevated values may represent analytical error rather than actual anomalies.

Suspended Sediment

For selected periods during the 2004 and 2005 field seasons, daily suspended-sediment samples were collected using automated samplers. The samples were used to document variations in suspended-sediment concentration at sites upstream and downstream from previously mined areas on Harrison Creek and Frying Pan Creek (table A1). Automated samplers collected daily samples at South Fork of Upper Frying Pan Creek site 15395900, and Frying Pan Creek site 15396000, Harrison Creek site 15407200, Harrison Creek site 15407500.

Table 9. Summary of nutrient concentrations at selected sites in the upper Birch Creek watershed near Central, Alaska, 2004 and 2005.

[Concentrations are dissolved and in milligrams per liter unless otherwise noted. **Abbreviations:** USGS NWIS, U.S. Geological Survey National Water Information System; µg/L, microgram per liter; E, estimated; <, less than; –, no data]

USGS site identification No.	Sample date	Sample time (hours)	Constituent (USGS NWIS code)							
			Phosphorus, total (00665)	Phosphorus (00666)	Ortho-phosphate phosphorus (00671)	Nitrate, as N (00613)	Nitrite-plus-nitrate, as N (00631)	Ammonia, as N (00608)	Ammonia plus organic, as N (00623)	Ammonia plus organic, as N, total (00625)
15392000	09-12-05	1730	0.009	0.01	<0.006	<0.002	0.110	<0.010	0.2	0.1
15395900	09-01-04	1400	E.002	<.004	<.006	E.001	.087	E.006	.2	.2
	09-04-05	1330	<.004	E.003	<.006	<.002	.104	E.006	.3	.3
15396000	09-01-04	1200	E.003	E.002	<.006	E.001	.115	.017	.2	.2
	09-04-05	1630	E.003	E.003	<.006	<.002	.113	E.009	.3	.2
15407200	08-31-04	1500	<.004	<.004	<.006	<.002	.098	<.010	<.1	<.1
	08-18-05	1620	<.004	<.004	<.006	.038	.133	<.010	<.1	E.06
15407500	08-30-04	1300	<.004	<.004	<.006	.002	.142	<.010	E.08	E.07
	08-17-05	1600	<.004	E.003	<.006	.002	.218	E.005	.1	.1
652129145001700	08-31-05	1600	.004	E.002	<.006	E.001	.185	<.010	.1	.1
652209144573700	08-31-05	1400	E.003	<.004	<.006	E.001	.205	<.010	.1	.1
		Minimum	E0.002	E0.002	<0.006	<0.002	0.087	<0.010	<0.1	<0.1
		Maximum	.009	.01	<.006	.038	.218	.017	.3	.3
		Median	–	–	–	–	.115	–	–	–

Table 10. Summary of mercury concentrations in water and streambed sediment at selected sites in the upper Birch Creek watershed near Central, Alaska, 2005.

[**Abbreviations:** USGS NWIS, U.S. Geological Survey National Water Information System; µg/L, microgram per liter; µg/g, microgram per gram; E, estimated; <, less than; –, no data]

USGS site identification No.	Sample date	Sample time (hours)	Mercury (USGS NWIS code)			
			Water, filtered (71890) (µg/L)	Water, unfiltered (71900) (µg/L)	Bed material, sieved (34910) (µg/g)	Bed material, sieved (replicate) (µg/g)
15392000	09-12-05	1730	<0.01	<0.01	–	0.05
15395900	09-04-05	1330	<.01	<.01	0.06	.03
15396000	09-04-05	1630	<.01	<.01	.05	.04
15407200	08-18-05	1620	<.01	<.01	.04	.04
15407500	08-17-05	1600	<.01	<.01	.05	.03
652149145074900	08-18-05	1820	<.01	<.01	.04	.03
652129145001700	08-31-05	1600	<.01	<.01	.03	.04
652132144593900	08-31-05	1500	<.01	<.01	–	–
652209144573700	08-31-05	1400	<.01	<.01	.04	.03
652231144541200	08-17-05	1900	<.01	<.01	.05	.03
		Minimum	<0.01	<0.01	0.03	0.03
		Maximum	<.01	<.01	.06	.05
		Median	<.01	<.01	.05	.03

Median suspended-sediment concentrations were less than 5 mg/L for the upstream and downstream Frying Pan Creek sites. Median sediment concentration was less than 15 mg/L for upstream and downstream sites on Harrison Creek (table 11). The maximum suspended-sediment concentrations collected using automated samplers on Frying Pan Creek and Harrison Creek were 816 and 290 mg/L, respectively.

Median suspended-sediment concentrations for the 115 paired samples from Frying Pan Creek and 101 paired samples from Harrison Creek were less than the 20 mg/L TMDL set by the U.S. Environmental Protection Agency (1996) for the upper Birch Creek basin (table 11; fig. 9). It is important to emphasize, however, that suspended-sediment paired samples were collected primarily during low-flow conditions. The U.S. Environmental Protection Agency (1996) reported that during low-flow conditions, the upper Birch Creek watershed generally met the turbidity criterion. They also reported most of the sediment load transported by the streams occurred over a short period—84 percent of the total sediment load for their 1993 study was transported in 1 day for Birch Creek at Twelvemile Creek. Similarly, Vohden (1999) concluded that rainfall events played a major role in explaining elevated suspended-sediment concentration values recorded at monitoring locations operated by the Alaska Department of Natural Resources (ADNR) on Birch Creek. Suspended-sediment paired-sample data collected during 2004 and 2005 summer drought conditions did not include high-flow samples. Hence, these data were not representative of associated high suspended-sediment concentrations that periodically occur in the watershed during a typical summer season.

Miscellaneous suspended-sediment samples were collected at selected sites on Birch Creek and several tributaries during 2003 through 2005 (table 6). Maximum recorded suspended-sediment concentration for miscellaneous grab samples collected during high water was 1,386 mg/L at Birch Creek station 15392000, on September 2, 2003 (table 6). Minimum suspended-sediment concentrations for several sites were less than 1 mg/L.

Suspended-sediment concentration generally increased with increased streamflow (tables 6 and A1). Sediment concentrations typically were higher at downstream sites than at upstream sites (table 11). There were, however, several elevated suspended-sediment concentrations in the 2004 through 2005 sediment record that were not associated with precipitation. Suspended-sediment samples collected at Harrison Creek on September 10, 2004, provide one example of an anomalous suspended-sediment concentration that may result from a localized in-stream disturbance. Suspended-sediment concentrations at the Harrison Creek downstream site (15407500) usually were greater than concentrations at the Harrison Creek upstream site (15407200). However, September 10, 2004, data show a sediment concentration of 158 mg/L at the upstream site (15407200) and only 13 mg/L at the downstream site (15407500) with no precipitation recorded at local climate stations (table A1).

Several factors may have had an adverse affect on the magnitude of suspended-sediment concentration in samples collected with automated samplers on Harrison Creek and Frying Pan Creek: (1) Access to Harrison Creek and Frying Pan Creek primarily was on established ATV trails that, at

Table 11. Statistical summary of daily suspended-sediment concentrations at selected sites in Frying Pan Creek and Harrison Creek near Central, Alaska, water years 2004 and 2005.

[Concentrations are in milligrams per liter. **Abbreviations:** <, less than]

USGS site identification No.	Site name	Number of paired sediment samples	Minimum	25th percentile	Median	75th percentile	Maximum
15395900	Upper Frying Pan Creek near Central, Alaska	115	1	1	2	4	107
15396000	Frying Pan Creek near Miller House, Alaska	115	<1	2	3	6	816
15407200	South Fork Harrison Creek near Central, Alaska	101	<1	1	1	2	158
15407500	Harrison Creek above Bottom Dollar Creek near Central, Alaska	101	1	4	7	14	290

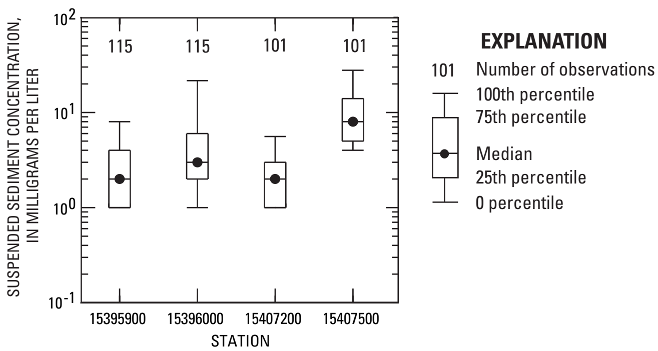


Figure 9. Distribution of daily suspended-sediment concentration data from automated samplers for selected sites in Frying Pan Creek and Harrison Creek near Central, Alaska, 2004 and 2005. (Values less than 1 milligram per liter are not shown.)

times, were used heavily by the public. Occasionally, ATVs were observed traveling in Harrison Creek and Frying Pan Creek upstream from automated sampler sites; (2) Localized heavy precipitation during the summer may affect suspended-sediment concentration at only one gage site in a particular basin. For example, table A1 shows more than 0.5 in. of precipitation recorded at Circle and Central on August 2, 2005, but only a trace at Birch Creek and none at Eagle Summit; (3) High suspended-sediment loads were observed for about 2 hours after collapse of a cut-bank upstream from Harrison Creek site 15407500; (4) Wildlife was active in the study area, and on occasion, likely disturbed fine-grain sediments upstream from sites, during or shortly before, collection of automated samples.

Suspended-sediment data collected using automated samplers, as well as concurrent daily precipitation and daily mean discharge recorded at Birch Creek station 15392000, were summarized in table A1 in appendix A. Daily precipitation recorded at nearby climate stations at Central, Circle Hot Springs, Eagle Summit, Mount Ryan, and Monument Creek at Chena Hot Springs (fig. 1) also were summarized in table A1 to facilitate comparison between daily suspended-sediment data and daily precipitation records from nearby climate stations.

Trace Elements in Streambed Sediment

Analysis of trace elements in streambed-sediment samples provides a reliable means for assessing the occurrence, concentration, and distribution of trace elements in an aquatic system. Most trace elements and many anthropogenic organic compounds are known to associate with fine-grained sediments (Van Metre and Callender, 1997). Consequently, even though the water may contain only small quantities of these constituents, suspended sediment and bed sediment may contain relatively large concentrations (Shelton and Capel, 1994). Accordingly, sampling and analysis of streambed-sediment material increases the likelihood that contaminants will be detected and that spatial distribution of trace elements in the aquatic environment can be evaluated.

Trace-Element Aquatic-Life Criteria

There are no official Federal or State of Alaska standards for trace-element concentrations in freshwater streambed sediments. However, sediment-quality guidelines (SQG) for a select number of elements have been proposed by several agencies and organizations to assess potential effects of sediment contamination on aquatic life. MacDonald and others (2000) compiled SQG and data from several sources and developed consensus-based probable effect concentration (CB-PECs) guidelines for freshwater ecosystems. Gilliom and others (1998) summarized aquatic-life criteria from various agencies and compiled National median values based on streambed-sediment data collected at 198 nonrandom sites by the USGS NAWQA program. Aquatic-life criteria and National data sets are useful for comparison purposes. They provide perspective for evaluation of the streambed-sediment data, but should be used only as indicators of potential sediment-quality problems that may warrant further examination. Alternatively, the absence of criteria for a particular contaminant, or the presence of contaminants that do not exceed one or more criteria, does not imply necessarily that there are no environmental issues of concern at that site. Mixtures of contaminants at some sites could behave synergistically to cause adverse biological effects that are not indicated by criteria developed for individual contaminants (U.S. Geological Survey, 1998). Elevated concentrations of trace elements in sediment may represent enrichment from natural or anthropogenic sources.

Selected Trace Elements

Streambed-sediment samples were collected during low-flow conditions at nine sites (fig. 2) in August and September 2005 because of concerns about elevated levels of heavy-metal contaminants, such as mercury, lead, and zinc, that may be associated with abandoned placer-mine operations. Because natural background levels for a particular contaminant may change substantially with changes in sediment-source geology, a suite of 40 trace elements were selected for analysis to document between-site variations in sediment constituents. Table 2 presents the list of trace elements, methods, reporting units, and minimum reporting limits.

Streambed-sediment samples were collected in Harrison Creek at the upstream site 15407200, at the downstream site 15407500, and at four intermediary sites in mined areas scheduled for reclamation work in 2006 (fig. 2).

Additional sediment samples were collected from Birch Creek site 15392000 and Frying Pan Creek sites 15395900 and 15396000 to document trace-element background levels in the study area.

Trace-element analytical results were compiled in appendix A (table A2). Statistical summaries of trace-element concentrations in streambed sediment were compiled in table 12. Streambed-sediment-quality guidelines for nine U.S. Environmental Protection Agency (1994) priority pollutants—arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, and zinc—were compared with trace-element concentrations for streambed-sediment samples collected from selected sites in table 13. Trace-element concentrations were not normalized for organic carbon content in the streambed sediments for comparison with sediment-quality guidelines. Organic carbon content was less than 5 percent for all samples (table A2). Median concentrations of mercury, lead, and zinc for all samples were less than the NAWQA National median concentrations compiled by Gilliom and others (1998) and less than the CB-PEC summarized by MacDonald and others (2000) (table 13). Averaged mercury concentrations ranged from 0.03 to 0.05 µg/g, lead concentrations ranged from 19.7 to 24 µg/g, and zinc concentrations ranged from 83.6 to 119 µg/g (table 12).

Median concentrations of arsenic, chromium, and nickel were greater than the NAWQA National median and several sample concentrations exceeded the CB-PEC (table 13). Arsenic concentrations ranged from 12 to 60 µg/g, chromium values varied from 49 to 55 µg/g, and nickel concentrations were 11.9 to 71.7 µg/g (table 12). Elevated arsenic concentrations in streambed sediment were expected because significant concentrations of arsenic are present in local bedrock (Foster and others, 1994; Newberry, 1996). Elevated chromium and nickel likely were associated with sediment input from weathered mafic-igneous rocks noted by Yeend (1991) and Foster and others (1994). Histograms showing streambed-sediment concentrations for selected sites in the upper Birch Creek watershed for the nine U.S. Environmental Protection Agency (1994) priority pollutants (table 13) and CB-PEC were compiled in figure 10.

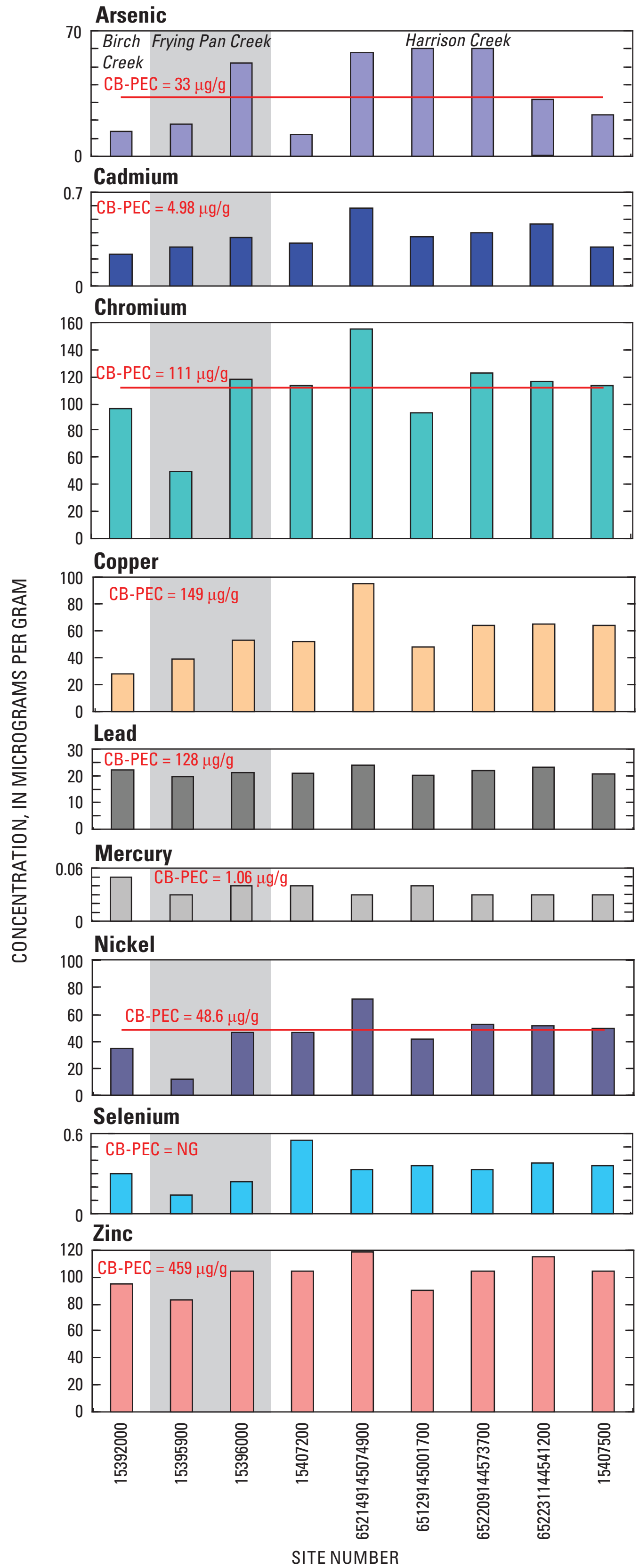


Figure 10. Histogram plots for nine priority-pollutant trace elements in selected streambed-sediment samples from the upper Birch Creek watershed near Central, Alaska, 2005. (CB-PEC, consensus based probable effect concentration [MacDonald and others, 2000]; µg/g, microgram per gram; NG, no guideline.)

Table 12. Statistical summary of trace-element concentrations in streambed sediment at selected sites in the upper Birch Creek watershed near Central, Alaska, 2005.

[Concentrations are in milligrams per gram unless otherwise indicated. **Abbreviation:** <, less than]

Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Number of samples
Mercury[1]	0.03	0.03	0.03	0.04	0.05	9
Selenium	.14	.3	.33	.36	.55	9
Sulfur, percent	.05	.06	.06	.09	.14	9
Total carbon, percent	1.52	2.15	3.18	3.6	4.79	9
Inorganic carbon, percent	.03	.05	.06	.1	.22	9
Organic carbon, percent	1.42	2	3.13	3.47	4.74	9
Thallium	.54	.61	.64	.65	.77	9
Antimony	1.1	1.2	1.4	1.7	7	9
Arsenic	12	18	31	58	60	9
Barium	615	685	697	797	875	9
Beryllium	1.6	1.7	1.8	1.8	1.9	9
Bismuth	.26	.29	.3	.33	.34	9
Cadmium	.24	.29	.36	.4	.58	9
Cerium	42.9	67.4	83.1	86.1	101	9
Chromium	49	96.3	114	118	155	9
Cobalt	18	20.6	23.2	24.7	31.1	9
Copper	27.8	47.6	53.4	64.4	95.2	9
Gallium	16	18	18	19	23	9
Lanthanum	33.9	36.6	43.8	44.1	48.2	9
Lead	19.7	20.6	21.1	22.2	24	9
Lithium	28.9	36.2	36.4	40.5	55.6	9
Manganese	582	787	1,150	2,040	3,080	9
Molybdenum	.67	.72	.8	.84	65.4	9
Nickel	11.9	41.6	46.2	52	71.7	9
Niobium	11	17	20	22	26	9
Scandium	8.9	18.5	21	22.1	28.3	9
Silver	<2	<2	<2	<2	<2	9
Strontium	149	153	165	201	355	9
Thorium	12.8	14	14.6	16.9	35.4	9
Uranium	2.8	3.2	3.3	3.9	194	9
Vanadium	117	155	158	160	531	9
Yttrium	12.6	21.9	23.3	25	28.6	9
Zinc	83.6	95	105	105	119	9
Aluminum	62,700	71,700	73,800	77,400	87,600	9
Calcium	11,100	12,400	13,000	14,100	16,000	9
Cesium	3.1	3.6	3.6	3.8	7	9
Iron	42,000	53,000	54,000	71,000	120,000	9
Magnesium	8,240	10,600	12,600	13,400	17,100	9
Phosphorus	430	790	860	890	1,100	9
Potassium	16,500	18,600	19,000	20,900	21,700	9
Rubidium	80.3	91.3	98.3	102	123	9
Sodium	7,620	8,270	8,320	10,600	18,100	9
Titanium	5,300	5,400	6,100	6,400	8,600	9

[1]Mercury concentration average of split (two) sample analysis from the same composite sample.

Table 13. Summary of streambed-sediment-quality guidelines for nine priority-pollutant trace elements in selected streambed-sediment samples from the upper Birch Creek watershed near Central, Alaska, 2005.

[**NAWQA National median**: National median concentrations from NAWQA sampling sites (Gilliom and others, 1998). **CB-PEC:** Consensus Based Probable Effect Concentration (MacDonald and others, 2000). **Abbreviations:** µg/g, microgram per gram, dry weight; NAWQA, National Water-Quality Assessment; NG, no guideline; USGS, U.S. Geological Survey; >, greater than; –, no data]

Constituent	Concentration (µg/g)			Birch Creek sample greater than CB-PEC (USGS site identification No.)	Concentration greater than CB-PEC (µg/g)
	Birch Creek watershed median	NAWQA National median	CB-PEC		
Arsenic	31	6.35	33	(15396000) Frying Pan Creek near Miller House, Alaska	52
				(652149145074900) North Fork Harrison Creek 0.1 mi above mouth, near Central, Alaska	58
				(652129145001700) Harrison Creek 0.4 mi above Ptarmigan Gulch, near Central, Alaska	60
				(652209144573700) Harrison Creek 1.3 mi below Ptarmigan Gulch, near Central, Alaska	60
Cadmium	.36	.4	4.98	None	–
Chromium	114	62	111	(15396000) Frying Pan Creek near Miller House, Alaska	118
				(15407200) South Fork Harrison Creek near Central, Alaska	114
				(652149145074900) North Fork Harrison Creek 0.1 mi above mouth, near Central, Alaska	155
				(652209144573700) Harrison Creek 1.3 mi below Ptarmigan Gulch, near Central, Alaska	123
				(652231144541200) Harrison Creek 0.2 mi above Squaw Creek, near Central, Alaska	116
				(15407500) Harrison Creek above Bottom Dollar Creek, near Central, Alaska	114
Copper	53.4	26	149	None	–
Lead	21.1	24.3	128	None	–
Mercury	[1].03	.06	1.06	None	–
Nickel	46.2	25	48.6	(652149145074900) North Fork Harrison Creek 0.1 mi above mouth, near Central, Alaska	71.7
				(652209144573700) Harrison Creek 1.3 mi below Ptarmigan Gulch, near Central, Alaska	53
				(652231144541200) Harrison Creek 0.2 mi above Squaw Creek, near Central, Alaska	52
				(15407500) Harrison Creek above Bottom Dollar Creek, near Central, Alaska	49.1
Selenium	.33	.7	NG	Sample concentrations do not exceed NAWQA median	–
Zinc	105	110	459	None	–

[1]Mercury concentration average of split (two) sample analysis from the same composite sample.

Comparison of Paired-Site Results

This section compares water-quality data and trace-element concentrations in streambed sediment for study sites located upstream and downstream from placer-mined areas on Frying Pan Creek, sites 15395900 and 15396000, and Harrison Creek, sites 15407200 and 15407500. Spatial differences for field parameters were summarized using a nonparametric Wilcoxon rank-sum test. Nonparametric tests do not require a normal distribution to detect differences between two populations based on random samples from those populations (Helsel and Hirsch, 1992). Statistical comparisons were reported as significant for tests with calculated *p*-values less than or equal to 0.01. Trace-element data were compiled using descriptive statistics and comparative tables. Histograms were used to illustrate between-site variations for selected trace elements (fig. 10).

Frying Pan Creek

Flow distance from the Upper Frying Pan Creek site 15395900 to the lower Frying Pan Creek site 15396000 is about 1 mi. One unnamed tributary joins Frying Pan Creek from the east between the upper and lower sites (fig. 2). Bedrock near Frying Pan Creek is primarily quartzite and quartzitic schist (Yeend, 1991). Frying Pan Creek has a placer-mined reach of about 0.25 mi between the upper and lower study sites. Placer mining physically altered the natural stream channel morphology and removed streamside vegetation. Gravel tailings were re-contoured, but only minor vegetation has been established on the contoured tailings (fig. 11). The placer-mined reach in Frying Pan Creek may contribute additional sediment downstream during high-flow events until adequate vegetation cover is established.

Figure 11. Reclaimed placer-mined area on Frying Pan Creek near Central, Alaska, June 2004. (Note cutbanks and sparse vegetation cover, center of photograph. View is looking downstream toward Frying Pan Creek station 15396000.)

Water Quality

There were no statistically significant differences ($p>0.01$) in water-quality field parameters of water temperature, pH, specific conductance, or dissolved oxygen between the Upper Frying Pan Creek site 15395900 and the downstream Frying Pan Creek site 15396000 (table 14). Total recoverable-mercury and dissolved-mercury concentrations in water were low, less than 0.01 µg/L at both the upstream and downstream sample sites (table 10). Mercury concentrations were less than the 2.0 µg/L State and Federal maximum concentration for safe drinking water.

Major-ion compositions did not vary substantially between upstream and downstream sites except for iron and manganese (table 15). Iron concentrations were lower at the downstream site. Manganese concentrations were an order-of-magnitude higher at the downstream site (15396000) and likely reflect ground-water input or increased manganese contribution from the unnamed east tributary. Sulfate was the dominant anion for Frying Pan Creek samples collected during 2004. Sulfate and bicarbonate concentrations in the Frying Pan Creek samples collected during 2005 were about equal, with bicarbonate concentrations greater than sulfate concentrations (fig. 8; table 15).

Nutrient concentrations were low with no major differences between samples from the upstream Frying Pan Creek site 15395900 and the downstream Frying Pan Creek site 15396000 (table 16).

One hundred fifteen paired suspended-sediment samples were collected in Frying Pan Creek (table A1). The maximum suspended-sediment concentration collected using automated samplers was 816 mg/L (table 11). The minimum suspended-sediment concentration was less than 1 mg/L. Upstream and downstream median suspended-sediment concentrations were less than 5 mg/L and were less than the 20 mg/L TMDL set by the U.S. Environmental Protection Agency (1996) for the upper Birch Creek basin.

Table 14. Statistical comparison of upstream and downstream water-quality field parameters at selected sites in Frying Pan Creek and Harrison Creek near Central Alaska, 2004 and 2005, by Wilcoxon rank-sum test.

[**Abbreviations:** µS/cm, microsiemens per centimeter at 25°C, mg/L, milligram per liter; °C, degrees Celsius]

Constituent or property	*p*-value	Significance greater than 99-percent confidence	Median	
			Upstream of mined area	Downstream of mined area
Frying Pan Creek				
			15395900	**15396000**
Water temperature (°C)	0.773	No	7.4	6.9
Specific conductance (µS/cm at 25°C)	.500	No	156	197
Dissolved oxygen (mg/L)	.562	No	10.9	11.0
pH, field (standard units)	.493	No	7.2	7.3
Harrison Creek				
			15407200	**15407500**
Water temperature (°C)	0.041	No	9.0	12.7
Specific conductance (µS/cm at 25°C)	.000	Yes	96	186
Dissolved oxygen (mg/L)	.391	No	10.6	9.7
pH, field (standard units)	.000	Yes	7.4	7.8

Table 15. Summary of upstream and downstream major-ion concentrations at selected sites in Frying Pan Creek and Harrison Creek near Central, Alaska, 2004 and 2005.

[Concentrations are dissolved and in milligrams per liter unless otherwise noted. **Abbreviations:** mg/L, milligram per liter; <, less than; µg/L, microgram per liter; E, estimated]

Constituent or property		2004 concentration		2005 concentration	
		Upstream	Downstream	Upstream	Downstream
Harrison Creek, August–September	**Site**	**15407200**	**15407500**	**15407200**	**15407500**
Calcium, dissolved (mg/L as Ca)		19.5	37.2	14.8	30.4
Magnesium, dissolved (mg/L as Mg)		1.94	6.07	1.35	4.95
Potassium, dissolved (mg/L as K)		.76	1.24	.74	1.10
Sodium, dissolved (mg/L as Na)		.53	.92	.48	.87
Chloride, dissolved (mg/L as Cl)		E0.14	.27	.06	.04
Sulfate, dissolved (mg/L as SO_4)		11.8	37.5	11.0	27.0
Fluoride, dissolved (mg/L as F)		<.17	<.17	.06	.02
Silica, dissolved (mg/L as SiO_2)		5.96	5.24	4.64	5.48
Iron, dissolved (µg/L as Fe)		<6.4	E4.8	3.45	11.6
Manganese, dissolved (µg/L as Mn)		<.8	9.80	.80	5.71
Bicarbonate, dissolved (mg/L as HCO_3)		54.2	96.4	46.3	82.8
Acid-neutralizing capacity, alkalinity (mg/L as Ca)		45	80	38	68
Frying Pan Creek, September	**Site**	**15395900**	**15396000**	**15395900**	**15396000**
Calcium, dissolved (mg/L as Ca)		32.5	34.0	17.9	25.2
Magnesium, dissolved (mg/L as Mg)		15.3	15.7	7.4	11.4
Potassium, dissolved (mg/L as K)		1.84	1.60	1.01	1.16
Sodium, dissolved (mg/L as Na)		.61	.65	.34	.43
Chloride, dissolved (mg/L as Cl)		.09	.09	.05	.00
Sulfate, dissolved (mg/L as SO_4)		90.3	81.1	48.0	50.8
Fluoride, dissolved (mg/L as F)		.03	.03	.05	.04
Silica, dissolved (mg/L as SiO_2)		6.37	6.03	5.03	6.12
Iron, dissolved (µg/L as Fe)		46.8	24.7	53.9	42.9
Manganese, dissolved (µg/L as Mn)		10.2	248	7.3	101
Bicarbonate, dissolved (mg/L as HCO_3)		55.4	69.4	53.9	69.7
Acid-neutralizing capacity, alkalinity (mg/L as Ca)		46	57	42	57

The suspended-sediment concentration samples were collected primarily during 2004 and 2005 low-flow drought conditions, and thus, were not representative of suspended-sediment concentrations that may be associated with moderate- to high-flow events. Although there were measurable differences in the paired low-flow suspended-sediment samples, they were minor—only a few milligrams per liter (tables 11 and A1). Therefore, it is difficult to attach much importance to the relatively small downstream increase in suspended-sediment concentration in Frying Pan Creek during low-flow conditions.

Table 16. Summary of upstream and downstream nutrient concentrations at selected sites in Frying Pan Creek and Harrison Creek near Central, Alaska, 2004 and 2005.

[Concentrations are in milligrams per liter unless otherwise noted. **Abbreviations:** mg/L, milligram per liter; <, less than; E, estimated]

Constituent	2004 concentration		2005 concentration	
	Upstream	Downstream	Upstream	Downstream
Harrison Creek, August–September Site	**15407200**	**15407500**	**15407200**	**15407500**
Phosphorus, total (mg/L as P)	<0.004	<0.004	<0.004	<0.004
Phosphorus, dissolved (mg/L as P)	<.004	<.004	<.004	E.003
Phosphorus, dissolved orthophosphate (mg/L as P)	<.006	<.006	<.006	<.006
Nitrogen, nitrite, dissolved (mg/L as N)	<.002	.002	.038	.002
Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)	.098	.142	.133	.218
Nitrogen, ammonia, dissolved (mg/L as N)	<.010	<.010	<.010	E.005
Nitrogen, ammonia plus organic, dissolved (mg/L as N)	<.1	E.08	<.1	.1
Nitrogen, ammonia plus organic, total (mg/L as N)	<.1	E.07	E.06	.1
Frying Pan Creek, September Site	**15395900**	**15396000**	**15395900**	**15396000**
Phosphorus, total (mg/L as P)	E0.002	E0.003	<0.004	E0.003
Phosphorus, dissolved (mg/L as P)	<.004	E.002	E.003	E.003
Phosphorus, dissolved orthophosphate (mg/L as P)	<.006	<.006	<.006	<.006
Nitrogen, nitrite, dissolved (mg/L as N)	E.001	E.001	<.002	<.002
Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)	.087	.115	.104	.113
Nitrogen, ammonia, dissolved (mg/L as N)	E.006	.017	E.006	E.009
Nitrogen, ammonia plus organic, dissolved (mg/L as N)	.2	.2	.3	.3
Nitrogen, ammonia plus organic, total (mg/L as N)	.2	.2	.3	.2

Trace Elements in Streambed Sediment

Streambed-sediment trace-element constituents generally were comparable for the Frying Pan Creek upstream site 15395900 and the downstream site 15396000, indicating streambed-sediment source material was similar for both sites (table 17). However, concentrations of several trace elements varied substantially between the upstream and downstream sites. Antimony, arsenic, and nickel concentrations were lower at the upstream site 15395900.

Molybdenum and uranium concentrations were higher at the upstream site 15395900, than at the downstream site 15396000. Foster and others (1994), reported the area was highly mineralized with scattered occurrences of molybdenum and uranium. The variation in molybdenum and uranium concentrations, as well as other trace elements, likely was related to variations in mineralized bedrock. Mercury and lead concentrations did not vary appreciably between the upstream and downstream sites. Zinc concentration increased slightly at the downstream site (fig. 10; table 17).

Table 17. Comparison of upstream and downstream trace-element concentrations in streambed sediment for selected sites in Frying Pan Creek near Central, Alaska, 2005.

[Concentrations are in micrograms per gram unless otherwise indicated. **Abbreviations:** <, less than; –, no data]

Constituent or property	Birch Creek watershed median concentration	Concentration		Percent change, upstream to downstream
		Upstream site 15395900	Downstream site 15396000	
Mercury	0.03	0.03	0.04	33
Selenium	.33	.14	.24	71
Sulfur, percent	.06	.06	.06	0
Total carbon, percent	3.18	2.19	3.18	45
Inorganic carbon, percent	.06	.03	.05	67
Organic carbon, percent	3.13	2.16	3.13	45
Thallium	.64	.77	.61	-21
Antimony	1.4	1.7	7.0	312
Arsenic	31	18	52	189
Barium	697	809	797	-1
Beryllium	1.8	1.9	1.8	-5
Bismuth	.30	.33	.26	-21
Cadmium	.36	.29	.36	24
Cerium	83.1	42.9	86.1	101
Chromium	114	49	118	141
Cobalt	23.2	18.0	21.5	19
Copper	53.4	38.9	53.4	37
Gallium	18	23	18	-22
Lanthanum	43.8	36.6	44.1	20
Lead	21.1	19.7	21.1	7
Lithium	36.4	55.6	31.8	-43
Manganese	1,150	582	787	35
Molybdenum	.80	65.4	.72	-99
Nickel	46.2	11.9	46.2	288
Niobium	20	11	22	100
Scandium	21	8.9	21	136
Silver	<2	<2	<2	–
Strontium	165	355	201	-43
Thorium	14.6	35.4	14.6	-59
Uranium	3.3	194	3.2	-98
Vanadium	158	531	155	-71
Yttrium	23.3	12.6	26.8	113
Zinc	105	83.6	105	26
Aluminum	73,800	87,600	75,700	-14
Calcium	13,000	16,000	14,300	-11
Cesium	3.6	7.0	3.6	-49
Iron	54,000	120,000	53,000	-56
Magnesium	12,600	8,240	12,400	50
Phosphorus	860	430	890	107
Potassium	19,000	18,200	18,700	3
Rubidium	98.3	123	89.4	-27
Sodium	8,320	18,100	10,600	-41
Titanium	6,100	5,500	6,300	15
			Minimum	-99
			Maximum	312
			Median	17
			Standard Deviation	89

Harrison Creek

Flow distance from the upstream site 15407200 on South Fork of Harrison Creek to the downstream site 15407500 on Harrison Creek above Bottom Dollar Creek is about 15 mi. Three tributaries join Harrison Creek from the north in the 15-mi reach between the upstream and downstream study sites. In downstream sequence, the three tributaries are North Fork of Harrison Creek, Ptarmigan Gulch, and Squaw Creek (fig. 1). From the confluence of the North Fork and South Fork, Harrison Creek flows eastward along a gradational geologic contact of mafic schist to the north and quartzite and quartzitic schist to the south (Yeend, 1991). The North Fork of Harrison Creek was mined extensively. Historic mining of unknown extent has occurred on Ptarmigan Gulch and Squaw Creek.

There are substantial geomorphic disturbances in the stream channel and flood plain from historic placer-mining activity along several miles of Harrison Creek (fig. 12). Placer mining physically altered the natural stream channel morphology and removed streamside vegetation (fig. A4). There has been little or no effort to re-contour waste-rock piles or remove mining debris. During high flow, the abandoned placer-mine areas on Harrison Creek likely will contribute large quantities of sediment downstream unless the mined areas are reclaimed. The BLM target for starting Harrison Creek reclamation work was 2006.

Figure 12. Waste-rock piles and debris from historic placer mining on Harrison Creek near Central Alaska, August 2005. (View is looking upstream toward Harrison Creek station 15407200.)

Water Quality

There are statistically significant differences in median specific conductance (*p*-value = 0.0003) and median pH (*p*-value = 0.0002) between the upstream South Fork Harrison Creek site 15407200 and downstream Harrison Creek site 15407500 (fig. 6; table 14). There were no significant differences in water temperature or dissolved oxygen. Median specific conductance for South Fork Harrison Creek, site 15407200, was 96 µS/cm, compared to 186 µS/cm for Harrison Creek site 15407500. Median pH for South Fork Harrison Creek site 15407200 was 7.4 standard units compared with Harrison Creek site 15407500 at 7.8 standard units.

The downstream increase in specific conductance and pH were driven primarily by surface water input from the North Fork of Harrison Creek as evidenced by field measurements (table 6). On August 18, 2005, at South Fork of Harrison Creek site 15407200, the measured discharge was 5.05 ft^3/s, specific conductance was 105 µS/cm, and pH was 7.4 standard units. In contrast, on the same date at North Fork of Harrison Creek site 652149145074900, the measured discharge was 12.6 ft^3/s, more than twice the measured streamflow in the South Fork. Specific conductance was 197 µS/cm, nearly twice the specific conductance measured in South Fork of Harrison Creek, and pH was 7.9, an increase of 0.5 standard units. Water-quality field parameters collected in August 2005 at selected Harrison Creek sites upstream and downstream from Ptarmigan Gulch and Squaw Creek show little change in specific conductance (171–179 µS/cm) and pH (7.8–7.9) as surface water flows through mined areas below the confluence of the North Fork and South Fork of Harrison Creek (table 6). The moderate range of specific conductance, from about 90 µS/cm in basin headwater areas of South Fork of Harrison Creek, to about 200 µS/cm at sites downstream from the North Fork of Harrison Creek, was typical of upland areas in the Yukon River basin. Similarly, downstream increases in pH from near neutral to more alkaline, likely reflect natural changes in hydrogen-ion activity rather than adverse changes to more acidic conditions that would be expected if substantial acid-mine drainage occurred in placer-mined areas. Bjerklie and LaPerriere (1985) detected comparable variations in specific conductance and pH for sites sampled in 1982 and 1983 in the upper Birch Creek watershed and also concluded the variations in specific conductance and pH were not a direct effect of placer mining.

Except for chloride, fluoride, and silica, major-ion concentrations for Harrison Creek were greater for the downstream site (15407500) than the upstream site (15407200) (table 15). Sulfate-bicarbonate compositions did not vary substantially between sites. However, there was a substantial increase in manganese concentration at the downstream site 15407500. The most common source of both iron and manganese in water is naturally occurring chemical weathering of iron and manganese-bearing bed material. Hence, concentrations of iron and manganese in ground water are generally higher than concentrations measured in surface waters. Increased manganese concentration at the downstream Harrison Creek site 15407500 likely reflects input from ground water as well as input from tributaries that drain mafic schist bedrock areas.

No major differences were detected in nutrient concentrations between the upstream South Fork of Harrison Creek and downstream Harrison Creek samples, although nitrogen, nitrite plus nitrate concentrations tended to be higher at the downstream Harrison Creek site 15407500 (table 16). Total-recoverable mercury concentrations and dissolved mercury concentrations were low, less than 0.01 µg/L, at the upstream South Fork of Harrison Creek sample site 15407200 and the downstream Harrison Creek sample site 15407500 (table 10). Mercury concentrations were less than the State and Federal maximum concentration for safe drinking water, 2.0 µg/L.

One hundred and one paired suspended-sediment samples were collected using automated samplers at South Fork of Harrison Creek site 15407200 and at Harrison Creek site 15407500 (table A1). The maximum suspended-sediment concentration collected using automated samplers was 290 mg/L (table 11). The minimum suspended-sediment concentration was less than 1 mg/L. Median suspended-sediment concentrations were less than 15 mg/L. The median suspended-sediment concentrations for the 101 paired samples from South Fork of Harrison Creek and Harrison Creek were less than the 20 mg/L TMDL set by the USEPA for the upper Birch Creek basin in 1996. However, suspended-sediment concentration samples were collected primarily during 2004 and 2005 low-flow drought conditions and thus, were not representative of suspended-sediment concentrations associated with higher flows. Differences of only a few milligrams per liter were measured in the paired low-flow suspended-sediment samples (tables 11 and A1). Thus, it is difficult to attach much importance to the relatively small downstream increase in suspended-sediment concentration in Harrison Creek during low-flow conditions.

Trace Elements in Streambed Sediment

Except for arsenic and manganese, concentrations of selected trace elements in streambed sediment varied by less than 36 percent between the upstream and downstream sites, indicating no significant change in streambed-sediment source between the sample sites (table 18). Manganese concentration was considerably higher at the downstream site indicating addition of manganese precipitate from ground water or changes in streambed-sediment source material. Arsenic concentrations were variable in the study area. Mercury, lead, and zinc concentrations did not vary appreciably between the upstream and downstream sites.

Table 18. Comparison of upstream and downstream trace-element concentrations in streambed sediment for selected sites in Harrison Creek near Central, Alaska, 2005.

[Concentrations are in micrograms per gram unless otherwise indicated. **Abbreviations:** <, less than; –, no data]

Constituent or property	Birch Creek watershed median concentration	Concentration		Percent change, upstream to downstream
		Upstream site 15407200	Downstream site 15407500	
Mercury	0.03	0.04	0.03	-25
Selenium	.33	.55	.36	-35
Sulfur, percent	.06	.06	.06	0
Total carbon, percent	3.18	4.79	4.00	-16
Inorganic carbon, percent	.06	.05	.06	20
Organic carbon, percent	3.13	4.74	3.94	-17
Thallium	.64	.64	.60	-6
Antimony	1.4	1.2	1.1	-8
Arsenic	31	12	23	92
Barium	697	753	638	-15
Beryllium	1.8	1.6	1.7	6
Bismuth	.30	.29	.31	7
Cadmium	.36	.32	.29	-9
Cerium	83.1	77.6	83.1	7
Chromium	114	114	114	0
Cobalt	23.2	20.6	23.2	13
Copper	53.4	52.3	64.1	23
Gallium	18	18	18	0
Lanthanum	43.8	43.8	42.3	-3
Lead	21.1	20.9	20.6	-1
Lithium	36.4	36.2	36.4	1
Manganese	1,150	742	1,030	39
Molybdenum	.8	.8	.7	-13
Nickel	46.2	46.2	49.1	6
Niobium	20	17	21	24
Scandium	21	20.3	21.8	7
Silver	<2	<2	<2	--
Strontium	165	149	151	1
Thorium	14.6	13.4	14.4	7
Uranium	3.3	3.3	2.8	-15
Vanadium	158	158	160	1
Yttrium	23.3	24.4	23.3	-5
Zinc	105	105	105	0
Aluminum	73,800	73,000	69,500	-5
Calcium	13,000	11,100	13,000	17
Cesium	3.6	3.7	3.5	-5
Iron	54,000	48,000	54,000	13
Magnesium	12,600	12,600	13,400	6
Phosphorus	860	870	790	-9
Potassium	19,000	19,000	18,600	-2
Rubidium	98.3	96.3	91.3	-5
Sodium	8,320	8,220	8,320	1
Titanium	6,100	5,400	6,900	28
			Minimum	-35
			Maximum	92
			Median	0
			Standard Deviation	20

Summary and Conclusions

The U.S. Geological Survey, in cooperation with the Bureau of Land Management, completed an assessment of hydrology, water quality, and trace-element concentrations in streambed sediment at one site on upper Birch Creek and at paired sites, upstream and downstream from mined areas on Frying Pan Creek and Harrison Creek, in anticipation of reclamation work scheduled to begin in 2006. Stream discharge, water-quality, and trace-element concentration data were collected at miscellaneous mined and unmined sites to assist in characterizing conditions in the upper Birch Creek watershed. Data collection began in September 2001 and ended in September 2005.

Primary conclusions and characteristics of streamflow, water quality, and trace-element concentrations in streambed sediment for sites investigated during the study are summarized as follows.

1. Annual and monthly streamflow in the upper Birch Creek watershed were characterized as highly variable and precipitation dependent. Flows increased and decreased rapidly in response to rainfall and snowmelt events because the relatively steep slopes, thin soil cover, and permafrost areas in the watershed had a low capacity for retaining precipitation. Typically, there were two or more periods of relatively sharp discharge peaks. The first peak discharges were associated with snowmelt runoff. Additional discharge peaks, of similar or greater magnitude, occurred after spring snowmelt and were related to the location, duration, and intensity of precipitation.

   Daily mean peak discharges recorded at the Birch Creek stream gage for 2002, 2003, and 2005 were comparable at approximately 1,000 ft^3/s. Discharges associated with summer precipitation were low in 2004 and 2005 because of drought conditions in interior Alaska. Minimum daily mean streamflows of 22 ft^3/s or less were recorded during June, July, August, September, and October.

2. Water quality was generally good in Birch Creek, Harrison Creek, and Frying Pan Creek during the 2004 and 2005 field seasons. Median water temperatures during open-water season were between 7.4 and 12.7°C. Measured dissolved-oxygen concentrations were between 7.3 and 14.7 mg/L. Measured pH was near neutral to moderately alkaline ranging from 6.9 to 7.9 standard units. Specific conductance varied from a minimum 52 µS/cm during a June 1, 2005, peak flow on Birch Creek to a maximum of 312 µS/cm at Frying Pan Creek during late September 2004 low-flow conditions. Comparable water-quality field parameter values were reported for the upper Birch Creek watershed in the 1980s by the Alaska Department of Natural Resources (ADNR). Surface waters of the upper Birch Creek watershed were calcium-magnesium-bicarbonate waters and are typical of Yukon River basin waters. Cation compositions were mixed calcium-magnesium, but calcium was the predominant cation for all samples. Anion compositions for upper Birch Creek and Harrison Creek were primarily bicarbonate with minor sulfate; Frying Pan Creek anion compositions were mixed sulfate and bicarbonate or sulfate with minor bicarbonate. Concentrations of nutrients were low at all sample sites. All mercury samples collected were at concentrations below the 2.0 µg/L maximum drinking water mercury contaminant level set by Alaska Department of Environmental Conservation and the National Primary Drinking Water Regulations. Suspended-sediment concentrations were low on South Fork of Harrison Creek, Harrison Creek, and Frying Pan Creek during 2004 and 2005 and were less than the 20 mg/L total maximum daily load set by the U.S. Environmental Protection Agency in 1996 for the upper Birch Creek basin. Upstream suspended-sediment concentrations generally were less than downstream suspended-sediment concentrations and concentrations typically increased with increased streamflow. The maximum suspended-sediment concentration measured using automated samplers for Frying Pan Creek was 290 mg/L and for South Fork of Harrison and Harrison Creek was 816 mg/L.

3. Trace-element concentrations of mercury, lead, and zinc in streambed sediment were less than the National Water-Quality Assessment (NAWQA) National median concentrations. No mercury, lead, or zinc sample concentrations exceeded consensus-based probable effect concentrations (CB-PEC). Median concentrations of arsenic, chromium, and nickel were greater than the NAWQA National median concentrations and several sample concentrations exceeded the CB-PEC. Arsenic concentrations ranged from 12 to 60 µg/g, chromium varied from 49 to 155 µg/g, and nickel fluctuated from 11.9 to 71.7 µg/g. Elevated arsenic concentrations in streambed sediment were expected because previous geochemical analyses by the ADNR indicated significant concentrations of arsenic in local bedrock. Elevated chromium and nickel were likely associated with sediment input from weathered mafic-igneous rocks.

4. During 2004 and 2005, no substantial changes were detected in nutrient, major-ion, or mercury concentrations for water samples collected upstream from mined areas compared with water samples collected downstream from mined areas on Frying Pan Creek and Harrison Creek that could not be attributed to natural variation. This was also true for dissolved-oxygen concentration, pH, and specific conductance—a measure of total dissolved solids. Sample sites downstream from mined areas on Harrison Creek and Frying Pan Creek had higher median suspended-sediment concentrations, by a few milligrams per liter,

than respective upstream sites. However, it is difficult to attach much importance to the small downstream increase, less than 10 mg/L, in median suspended-sediment concentration for either basin. No significant mining-related water or sediment-quality problems were detected at study sites investigated in the upper Birch Creek watershed during low-flow conditions.

5. There are major geomorphic disturbances in the stream channel and flood plain along several miles of Harrison Creek. Placer mining has physically altered the natural stream channel morphology and removed streamside vegetation. Little or no effort has been made to re-contour waste-rock piles. During high-flow events the abandoned placer-mine areas on Harrison Creek will likely contribute large quantities of sediment downstream unless the mined areas are reclaimed.

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Appendix A. Hydrology, Water-Quality, and Trace-Element Data

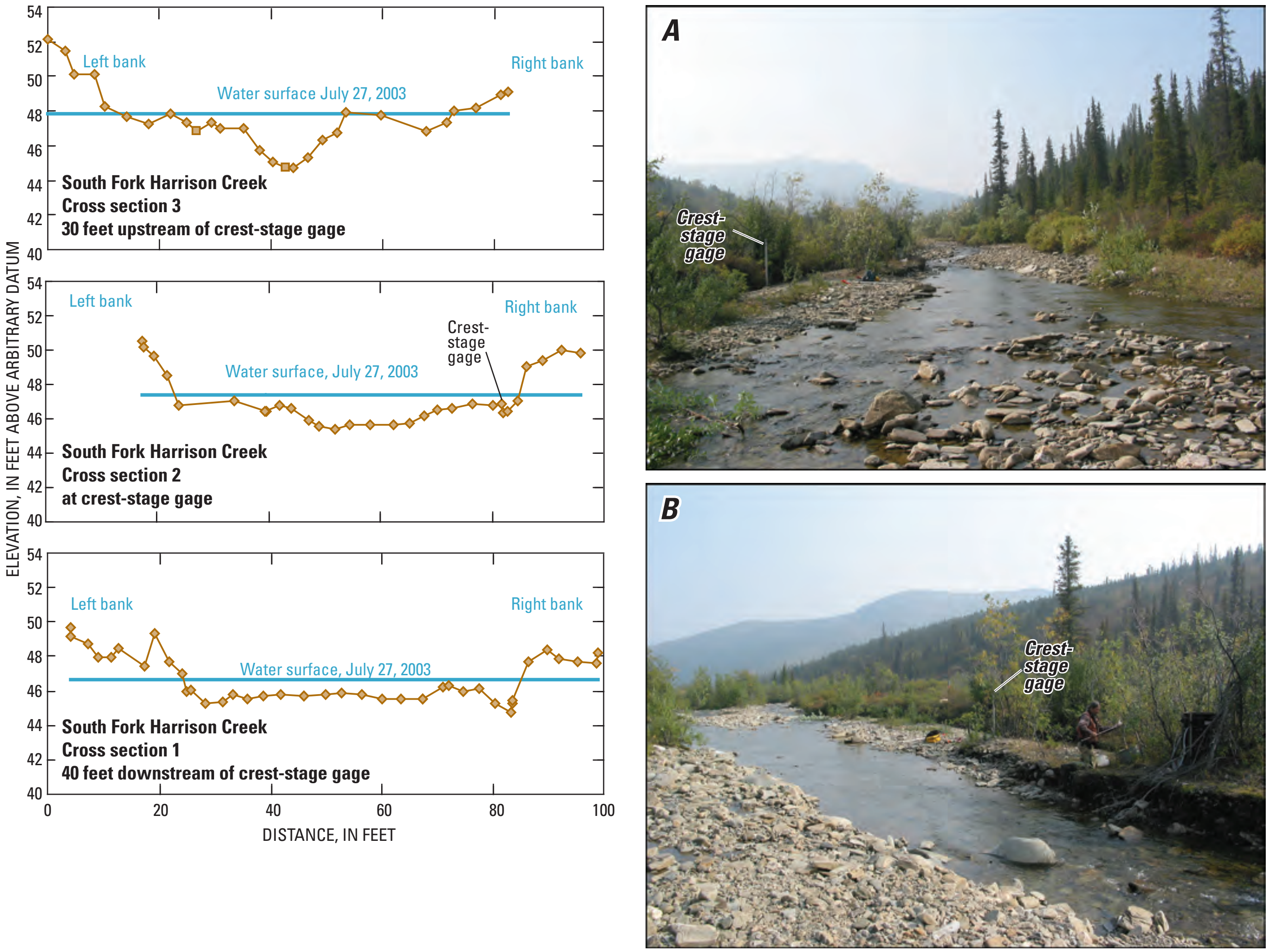

Figure A1. Stream channel cross-section plots and photographs showing (*A*) upstream channel and (*B*) downstream channel at South Fork Harrison Creek site 15407200 near Central, Alaska, August 2003. (An arbitrary elevation of 50 feet was assigned to a survey hub stake installed at the survey site for reference.)

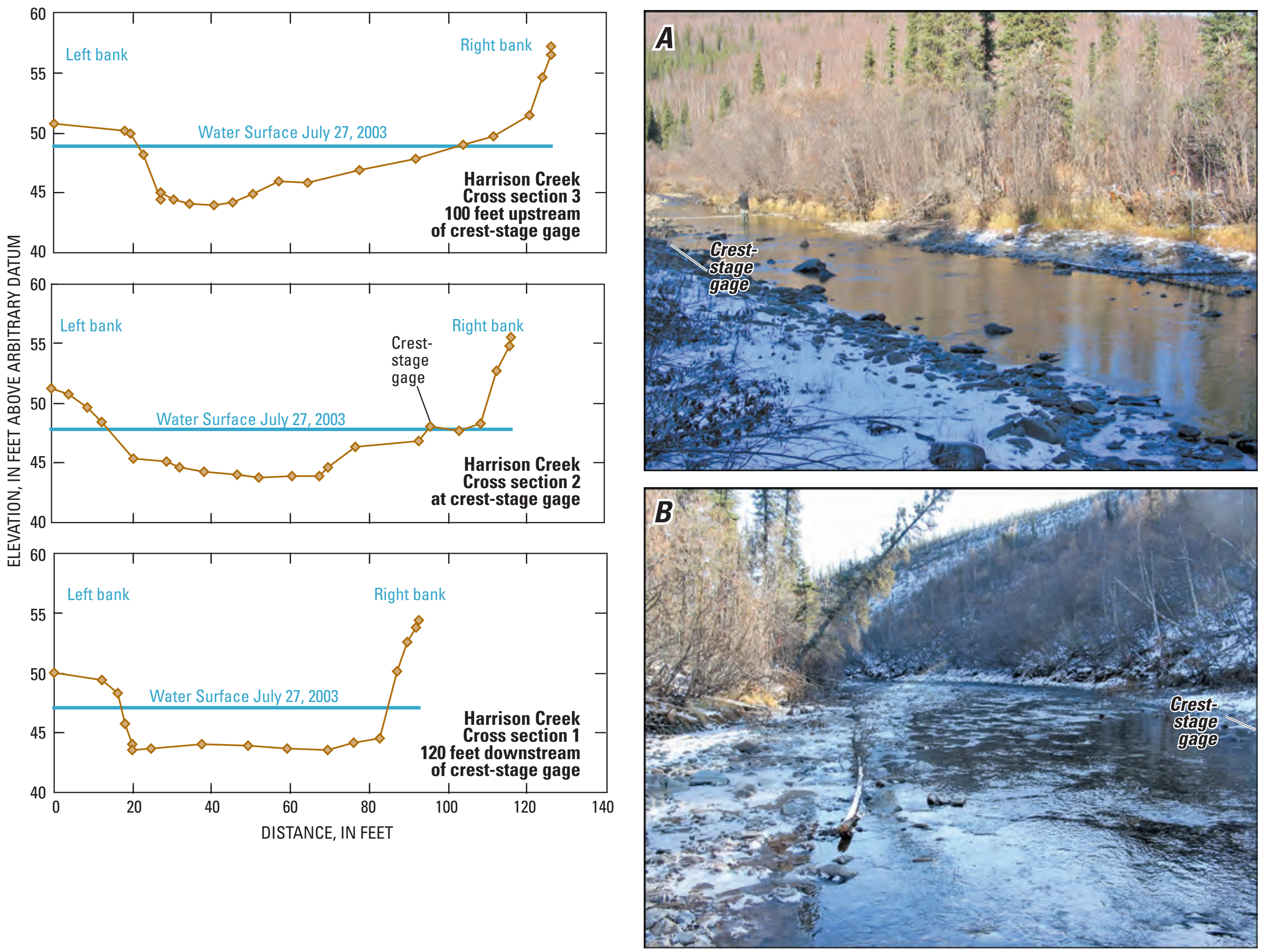

Figure A2. Stream channel cross-section plots and photographs showing (*A*) upstream channel and (*B*) downstream channel at Harrison Creek site 15407500 near Central, Alaska, September 2004. (An arbitrary elevation of 50 feet was assigned to a survey hub stake installed at the survey site for reference.)

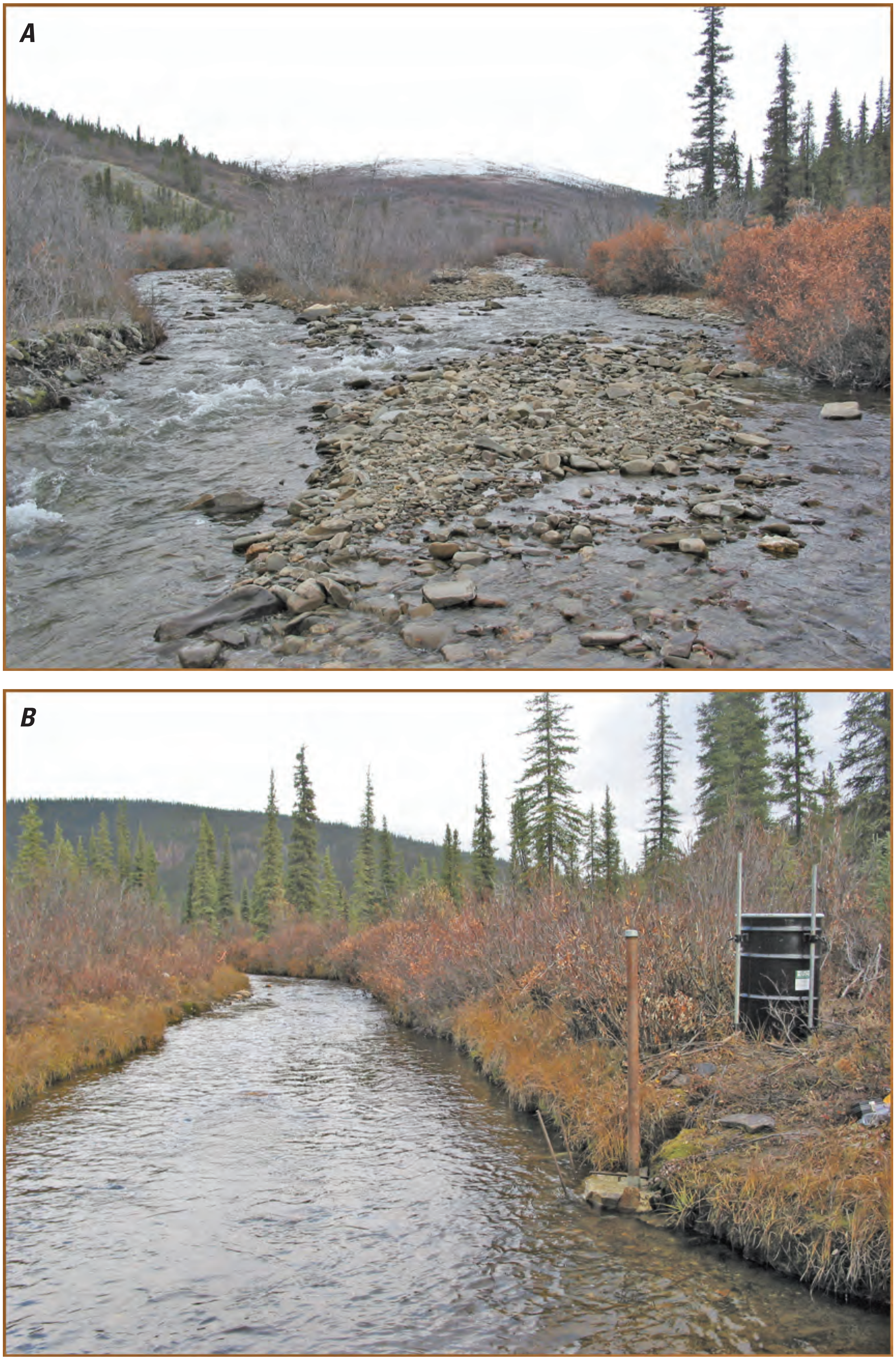

Figure A3. Photographs showing (*A*) split channel morphology at South Fork of Harrison Creek site 15407200 and (*B*) incised channel morphology at Frying Pan Creek site 15396000 near Central, Alaska, September 2005.)Views are looking upstream. Crest-stage gage and instrument shelter in right center of photograph *B*.)

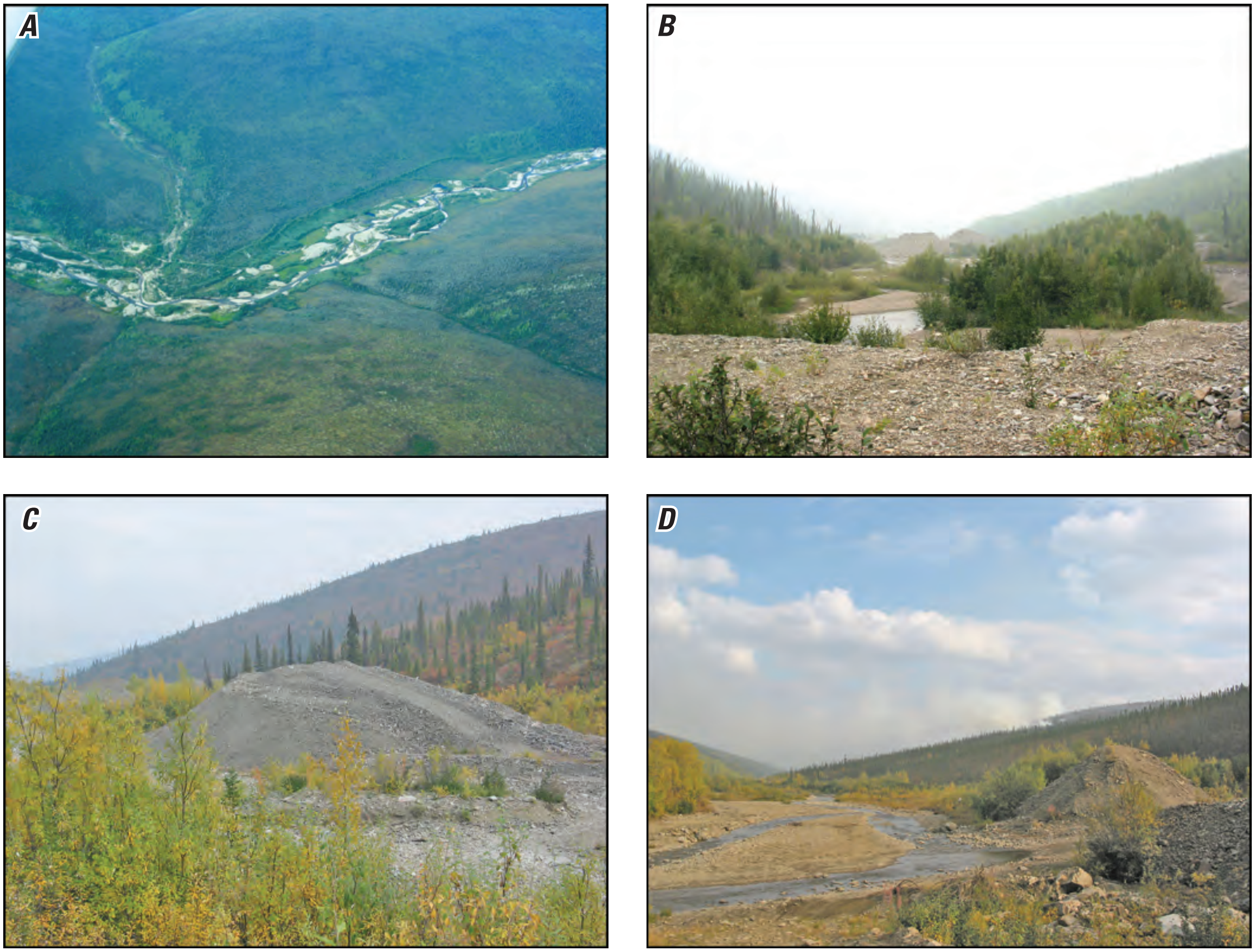

Figure A4. Photographs showing views of placer-mine tailings in Harrison Creek watershed near Central, Alaska. (*A*) Oblique aerial photograph of Harrison Creek placer-mine tailings, (*B*) Lower Harrison Creek placer-mine tailings, (*C*) South Fork Harrison Creek placer-mine tailings, and (*D*) South Fork Harrison Creek placer-mine tailings and stream channel.

Table A1. Summary of daily suspended-sediment concentration for selected sites in Frying Pan Creek and Harrison Creek with associated mean daily discharge at Birch Creek stream gage site 15392000 and daily precipitation from nearby climate stations near Central, Alaska, 2004 and 2005.

[**Abbreviations:** USGS Site_ID, U.S. Geological Survey site identification No.; NCDC_ID, Natural Climate Data Center climate station number; Snotel_ID, Natural Resources Conservation Service climate station number; in., inch; mg/L, milligram per liter; ft³/s, cubic foot per second; <, less than; E, estimated; –, no data]

Date	Suspended sediment concentration (mg/L)				Discharge (ft^3/s)	Precipitation (in.)					
	Upper Frying Pan Creek USGS Site_ID 15395900	Frying Pan Creek USGS Site_ID 15396000	South Fork Harrison Creek USGS Site_ID 15407200	Harrison Creek USGS Site_ID 15407500	Birch Creek USGS Site_ID 15392000	Birch Creek Precipitation USGS Site_ID 15392000	Central NCDC_ID 151466	Eagle Summit Snotel_ID AK45Q05S	Mt Ryan Snotel_ID AK46Q01S	Monument Creek Snotel_ID AK45Q02S	Circle Hot Springs NCDC_ID 501987
					2004						
08-01-04	–	–	2	33	122	0.31	0.20	–	0.5	–	0.13
08-02-04	–	–	1	24	140	.00	.02	–	.3	–	.03
08-03-04	9	14	–	–	98	.00	.00	–	.0	–	.00
08-04-04	13	5	1	26	76	.00	.00	–	–	–	.00
08-05-04	14	6	2	9	65	.00	.00	–	.1	–	.00
08-06-04	10	5	1	9	57	.02	.00	–	–	–	.00
08-07-04	8	3	1	8	50	.00	.00	–	–	–	.00
08-08-04	3	4	1	4	44	.00	.00	–	.1	–	.00
08-09-04	–	–	1	6	40	.00	.00	–	.0	–	–
08-10-04	3	2	1	7	38	.00	.00	–	–	–	.00
08-11-04	3	2	1	5	36	.00	.00	–	.0	–	.00
08-12-04	3	2	1	5	34	.00	.00	–	–	–	.00
08-13-04	4	3	–	–	32	.00	.00	–	–	–	.00
08-14-04	2	3	2	7	31	.04	.03	–	–	–	.00
08-15-04	4	2	<1	4	30	.00	.00	–	.0	–	.00
08-16-04	6	1	1	2	28	.00	.00	–	.0	–	.00
08-17-04	4	2	1	2	27	.00	.00	–	.0	–	.00
08-18-04	3	4	<1	5	27	.00	.00	–	–	–	.00
08-19-04	8	2	–	–	26	.00	.00	–	–	–	.00
08-20-04	2	2	–	–	25	.00	.00	–	–	–	.00
08-21-04	1	2	–	–	25	.00	.00	–	.0	–	.00
08-22-04	1	2	–	–	25	.00	.00	–	.0	–	.00
08-23-04	2	1	–	–	25	.00	.00	–	–	–	.00
08-24-04	3	1	–	–	25	.00	.00	–	–	–	.00
08-25-04	2	1	–	–	24	.00	.00	–	.0	–	.00
08-26-04	–	–	–	–	24	.00	.00	–	–	–	–
08-27-04	–	–	–	–	23	.00	.00	–	.0	–	–
08-28-04	–	–	–	–	23	.00	.00	–	.0	–	–
08-29-04	–	–	–	–	23	.00	.00	–	–	–	–
08-30-04	–	–	–	–	22	.00	.00	–	.0	–	–
08-31-04	–	–	2	7	21	.00	.00	–	.0	–	–
09-01-04	2	36	4	9	23	.20	.00	–	.0	–	.00
09-02-04	3	7	4	29	26	.06	.09	–	.3	–	.01
09-03-04	70	6	3	7	24	.00	.00	–	–	–	.00
09-04-04	5	1	19	8	23	.00	.00	–	–	–	.00
09-05-04	3	1	5	18	23	.00	.04	–	.3	–	.05
09-06-04	1	3	2	14	22	.00	.00	–	.0	–	.00
09-07-04	1	3	2	93	21	.00	.00	–	–	–	.00
09-08-04	2	20	2	15	21	.00	.00	–	.0	–	.00
09-09-04	1	4	2	7	20	.00	.00	–	.0	–	.00
09-10-04	1	5	158	13	19	.00	.00	–	.0	–	.00
09-11-04	14	6	12	44	19	.00	.00	–	.0	–	.00
09-12-04	107	5	2	7	18	.00	.00	–	.0	–	.00
09-13-04	8	3	1	5	18	.00	.00	–	.0	–	.00
09-14-04	4	4	2	9	18	.00	.00	–	.1	–	.00
09-15-04	–	–	6	9	16	.00	.00	–	–	–	.00
09-16-04	–	–	2	9	15	.00	.01	–	–	–	.00
09-17-04	2	2	3	3	15	.00	.00	–	–	–	.00
09-18-04	1	2	2	6	13	.00	.00	–	–	–	.00
09-19-04	1	1	–	–	14	.00	.00	–	–	–	.00

Table A1. Summary of daily suspended-sediment concentration for selected sites in Frying Pan Creek and Harrison Creek with associated mean daily discharge at Birch Creek stream gage site 15392000 and daily precipitation from nearby climate stations near Central, Alaska, 2004 and 2005.—Continued

[**Abbreviations:** USGS Site_ID, U.S. Geological Survey site identification No.; NCDC_ID, Natural Climate Data Center climate station number; Snotel_ID, Natural Resources Conservation Service climate station number; in., inch; mg/L, milligram per liter; ft^3/s, cubic foot per second; <, less than; E, estimated; –, no data]

Date	Suspended sediment concentration (mg/L)				Discharge (ft^3/s)	Precipitation (in.)					
	Upper Frying Pan Creek USGS Site_ID 15395900	Frying Pan Creek USGS Site_ID 15396000	South Fork Harrison Creek USGS Site_ID 15407200	Harrison Creek USGS Site_ID 15407500	Birch Creek USGS Site_ID 15392000	Birch Creek Precipitation USGS Site_ID 15392000	Central NCDC_ID 151466	Eagle Summit Snotel_ID AK45Q05S	Mt Ryan Snotel_ID AK46Q01S	Monument Creek Snotel_ID AK45Q02S	Circle Hot Springs NCDC_ID 501987
2004—Continued											
09-20-04	1	<1	–	–	15	0.04	0.00	–	0.0	–	0.01
09-21-04	1	1	–	–	15	.11	.14	–	.2	–	.19
09-22-04	1	2	–	–	15	.17	.04	–	.0	–	.03
09-23-04	1	1	–	–	15	.23	.00	–	.0	–	.00
09-24-04	3	2	–	–	15	.00	.38	–	.3	–	.21
09-25-04	–	–	–	–	14	.03	–	–	.1	–	.00
09-26-04	–	–	–	–	14	.35	.19	–	.1	–	.21
09-27-04	–	–	–	–	15	.00	.01	–	.1	–	.00
09-28-04	–	–	–	–	15	.00	.00	–	.0	–	.00
09-29-04	–	–	–	–	15	.00	.00	–	.0	–	.00
09-30-04	–	–	–	–	15	.02	.00	–	.1	–	.00
2005											
06-01-05	–	–	–	–	1030	0.31	0.48	0.60	0.6	1.00	1.20
06-02-05	–	–	–	–	609	.11	.23	.20	.0	.10	.27
06-03-05	–	–	–	–	380	.07	.02	.10	.0	.30	.09
06-04-05	–	–	–	–	249	.00	.01	.00	.0	.00	.08
06-05-05	–	–	–	–	184	.00	.00	.00	.0	.00	–
06-06-05	–	–	–	–	140	.00	.00	.00	.0	.00	–
06-07-05	–	–	–	–	112	.00	.00	.00	.1	.00	.00
06-08-05	–	–	–	–	93	.00	.00	.00	.0	.00	.00
06-09-05	–	–	–	–	80	.00	.00	.00	.0	.00	.00
06-10-05	–	–	–	–	71	.00	.00	.00	.0	.00	.00
06-11-05	–	–	–	–	66	.42	.00	.20	.4	.00	.00
06-12-05	–	–	–	–	93	.07	.00	.00	.2	.10	.19
06-13-05	–	–	–	–	137	.00	.10	.50	.0	.00	.01
06-14-05	–	–	–	–	100	.00	.00	.00	.0	.00	–
06-15-05	–	–	–	–	80	.00	.00	.00	.1	.00	.00
06-16-05	–	–	–	–	73	.98	.00	.00	.3	2.50	.00
06-17-05	–	–	–	–	71	.00	.02	.00	.0	.00	.00
06-18-05	–	–	–	–	61	.00	.00	.10	.0	.00	–
06-19-05	–	–	–	–	56	.13	.00	.00	.3	1.20	.00
06-20-05	–	–	–	–	54	.01	.00	.10	.0	.30	.00
06-21-05	–	–	–	–	49	.00	.00	.00	.0	.00	.00
06-22-05	–	–	–	–	45	.00	.00	.00	.1	.20	.00
06-23-05	–	–	–	–	41	.00	.03	.00	.0	.00	.03
06-24-05	–	–	–	–	37	.00	.00	.00	.1	.20	–
06-25-05	4	3	–	–	35	.01	.00	.00	.0	.00	–
06-26-05	5	2	–	–	32	.00	.00	.00	.0	.00	–
06-27-05	5	2	–	–	29	.00	.00	.00	.0	.10	.00
06-28-05	4	21	2	1	27	–	.00	.00	.0	.00	.00
06-29-05	2	2	2	2	40	–	.00	.00	.0	.00	.00
06-30-05	3	2	1	3	130	–	.00	.30	.1	.00	.00
07-01-05	11	56	1	31	574	–	.37	1.10	2.0	1.10	.38
07-02-05	5	39	1	79	350	–	.36	.00	.1	.10	.30
07-03-05	3	20	1	18	250	–	.18	.20	.0	.30	.50
07-04-05	3	6	3	105	200	–	.11	.40	.2	.20	.02
07-05-05	2	5	1	16	165	.00	.21	.00	.0	.10	.20
07-06-05	2	3	–	–	126	.00	.15	.00	.1	.00	–
07-07-05	5	26	3	290	194	.42	.38	.50	.4	1.20	.92

Table A1. Summary of daily suspended-sediment concentration for selected sites in Frying Pan Creek and Harrison Creek with associated mean daily discharge at Birch Creek stream gage site 15392000 and daily precipitation from nearby climate stations near Central, Alaska, 2004 and 2005.—Continued

[**Abbreviations:** USGS Site_ID, U.S. Geological Survey site identification No.; NCDC_ID, Natural Climate Data Center climate station number; Snotel_ID, Natural Resources Conservation Service climate station number; in., inch; mg/L, milligram per liter; ft^3/s, cubic foot per second; <, less than; E, estimated; –, no data]

Date	Suspended sediment concentration (mg/L)				Discharge (ft^3/s)	Precipitation (in.)					
	Upper Frying Pan Creek USGS Site_ID 15395900	Frying Pan Creek USGS Site_ID 15396000	South Fork Harrison Creek USGS Site_ID 15407200	Harrison Creek USGS Site_ID 15407500	Birch Creek USGS Site_ID 15392000	Birch Creek Precipitation USGS Site_ID 15392000	Central NCDC_ID 151466	Eagle Summit Snotel_ID AK45Q05S	Mt Ryan Snotel_ID AK46Q01S	Monument Creek Snotel_ID AK45Q02S	Circle Hot Springs NCDC_ID 501987
2005—Continued											
07-08-05	3	28	2	44	255	0.04	0.21	0.00	0.1	0.10	0.24
07-09-05	3	6	1	25	178	.27	.00	.80	.2	.10	–
07-10-05	13	74	2	58	290	.14	.14	.40	.3	.60	.00
07-11-05	6	25	2		269	.15	.00	.10	.2	.20	.02
07-12-05	4	10	2	13	225	.04	.00	.10	.1	.00	.00
07-13-05	4	6	3	12	183	.00	.07	.10	.0	.00	.10
07-14-05	3	4	1	14	152	.00	.00	.00	.0	.00	.00
07-15-05	6	5	1	11	122	.00	.00	.00	.0	.00	.00
07-16-05	4	12	5	19	118	.05	.00	.10	.1	.20	.00
07-17-05	3	7	2	26	170	.38	.79	.10	.6	.80	.31
07-18-05	91	816	2	57	300	.06	.66	.30	.7	.30	.75
07-19-05	3	23	2	76	230	.00	.02	.00	.0	.00	.00
07-20-05	8	45	<1	6	175	.00	.00	.00	.0	.10	.00
07-21-05	7	18	<1	28	146	.00	.00	.10	.0	.10	.00
07-22-05	3	13	<1	22	126	.00	.00	.00	.0	.00	.00
07-23-05	3	6	<1	10	109	.00	.00	.00	.0	.00	–
07-24-05	3	6	<1	11	95	.00	.00	.00	.0	.20	–
07-25-05	3	5	<1	8	85	.00	.00	.00	.0	.00	.00
07-26-05	2	6	3	9	76	.00	.00	.00	.0	.00	.00
07-27-05	3	4	<1	9	69	.00	.00	.00	.0	.10	.00
07-28-05	2	3	2	5	63	.00	.00	.00	.0	.10	.00
07-29-05	1	4	1	7	60	.06	.00	.10	.1	.10	–
07-30-05	2	2	3	6	59	.07	.10	.00	.1	.10	–
07-31-05	3	1	1	6	56	.00	.00	.20	.0	.10	.13
08-01-05	2	1	2	6	54	.00	.00	.10	.0	.10	.00
08-02-05	1	4	<1	8	53	.02	.58	.00	.0	.00	.53
08-03-05	1	2	1	5	50	.00	.11	.20	.0	.00	.13
08-04-05	1	3	2	6	48	.13	.00	.00	.1	.10	.00
08-05-05	2	2	1	4	50	.02	.00	.10	.1	.10	–
08-06-05	2	2	2	5	51	.08	.06	.10	.2	.60	–
08-07-05	2	2	1	3	49	.00	.01	.10	.0	.00	.04
08-08-05	2	4	1	5	47	.00	.00	.00	.0	.00	–
08-09-05	2	2	1	3	46	.00	.00	.00	.0	.00	–
08-10-05	2	2	1	11	44	.00	.00	.00	.0	.00	–
08-11-05	2	1	1	3	43	.00	.00	.00	.0	.00	–
08-12-05	1	2	1	1	42	.00	.00	.00	.0	.30	–
08-13-05	13	1	–	–	41	.00	.00	.00	.2	.00	–
08-14-05	1	5	2	2	40	.00	.00	.00	.0	.00	–
08-15-05	2	1	1	2	40	.00	.00	.00	.0	.00	–
08-16-05	1	2	1	3	39	.00	.00	.00	.0	.10	.00
08-17-05	1	2	2	2	40	.00	.00	–	.1	.10	.00
08-18-05	1	3	1	2	39	.00	.00	–	.0	.00	.00
08-19-05	1	5	1	3	39	.00	.00	–	5.7	.00	.00
08-20-05	1	1	2	2	39	.00	.00	.10	.0	.10	–
08-21-05	1	2	1	2	39	.01	.00	.10	.1	.10	–
08-22-05	1	1	1	2	38	.00	.02	.00	.0	.00	.00
08-23-05	1	2	1	2	38	.00	.00	.00	.0	.10	.00
08-24-05	2	2	1	3	41	.13	.00	.00	–	.00	.00
08-25-05	2	2	<1	3	44	.04	.14	.20	–	.30	.06

Table A1. Summary of daily suspended-sediment concentration for selected sites in Frying Pan Creek and Harrison Creek with associated mean daily discharge at Birch Creek stream-gage site 15392000 and daily precipitation from nearby climate stations near Central, Alaska, 2004 and 2005.—Continued

[**Abbreviations:** USGS Site_ID, U.S. Geological Survey site identification No.; NCDC_ID, Natural Climate Data Center climate station number; Snotel_ID, Natural Resources Conservation Service climate station number; in., inch; mg/L, milligram per liter; ft³/s, cubic foot per second; <, less than; E, estimated; –, no data]

Date	Suspended sediment concentration (mg/L)				Discharge (ft³/s)	Precipitation (in.)					
	Upper Frying Pan Creek USGS Site_ID 15395900	Frying Pan Creek USGS Site_ID 15396000	South Fork Harrison Creek USGS Site_ID 15407200	Harrison Creek USGS Site_ID 15407500	Birch Creek USGS Site_ID 15392000	Birch Creek Precipitation USGS Site_ID 15392000	Central NCDC_ID 151466	Eagle Summit Snotel_ID AK45Q05S	Mt Ryan Snotel_ID AK46Q01S	Monument Creek Snotel_ID AK45Q02S	Circle Hot Springs NCDC_ID 501987
2005—Continued											
08-26-05	2	5	1	19	43	0.00	0.11	–	–	0.10	0.15
08-27-05	2	1	1	5	44	.04	.01	.10	–	.00	.05
08-28-05	1	1	1	4	46	.00	.05	.00	1.0E	.00	.00
08-29-05	3	1	1	4	47	.00	.00	.00	.0	.00	.00
08-30-05	1	25	<1	4	46	.03	.00	–	.0	.00	–
08-31-05	1	3	1	6	49	.10	.00	.10	–	.00	.05
09-01-05	1	2	<1	5	51	.01	.10	.00	.5E	.00	–
09-02-05	1	2	1	6	51	.00	.00	.10	.0	.00	–
09-03-05	1	22	<1	5	50	.01	.02	–	.0	.00	–
09-04-05	–	–	<1	6	49	.01	.02	–	.0	.00	–
09-05-05	–	–	–	–	48	.00	.07	.10	.0	.00	–
09-06-05	–	–	–	–	48	.02	.00	.00	.0	.00	–
09-07-05	–	–	–	–	50	.07	.19	.10	–	.00	–
09-08-05	–	–	–	–	54	.00	.10	.20	.4	.00	–
09-09-05	–	–	–	–	56	.02	.00	.00	.0	.00	–
09-10-05	–	–	–	–	58	.00	.00	.10	.2	.00	–
09-11-05	–	–	–	–	58	.00	.00	.00	.0	.00	–
09-12-05	–	–	–	–	59	.13	.00	.00	.0	–	–
09-13-05	–	–	–	–	67	.02	.17	.10	.1	.10	–
09-14-05	–	–	–	–	72	.02	.04	.10	–	.10	–
09-15-05	–	–	–	–	73	.00	.05	.00	.1	–	–
09-16-05	–	–	–	–	72	.00	.00	.00	.0	–	–
09-17-05	–	–	–	–	69	.00	.00	.00	.0	.10	–
09-18-05	–	–	–	–	67	.01	.05	–	–	–	–
09-19-05	–	–	–	–	63	.00	.16	–	.2E	–	–
09-20-05	–	–	–	–	61	.01	.02	–	–	–	–
09-21-05	–	–	–	–	62	.01	.06	.40	–	.30	–
09-22-05	–	–	–	–	71	.06	.05	.10	.2	.10	–
09-23-05	–	–	–	–	96	.20	.07	.20	–	.40	–
09-24-05	–	–	–	–	210	.36	.17	.20	.5	.00	–
09-25-05	–	–	–	–	281	.03	.11	.50	.5	1.00	–
09-26-05	–	–	–	–	268	.01	.05	.10	–	.30	–
09-27-05	–	–	–	–	236	.00	.06	.10	–	–	–
09-28-05	–	–	–	–	197	.00	.14	.00	–	.40	–
09-29-05	–	–	–	–	160	.00	.41	.10	1.0E	.00	–
09-30-05	–	–	–	–	137	.04	.07	.00	.1	.10	–

Table A2. Summary of trace-element concentrations in streambed-sediment samples for selected sites in the upper Birch Creek watershed near Central, Alaska, 2005.

[Concentrations are in micrograms per gram unless otherwise indicated. **Bold** values indicate maximum. **Abbreviations:** <, less than; –, no data]

Constituent	NWIS parameter code	Sample reporting level	Site name (site identification No.)				
			Birch Creek above Twelvemile Creek near Miller House (15392000)	Upper Frying Pan Creek near Miller House (15395900)	Frying Pan Creek near Miller House (15396000)	South Fork Harrison Creek near Central (15407200)	North Fork Harrison Creek 0.1 mile above mouth near Central (652149145074900)
Mercury	34910	0.02	**0.05**	0.03	0.04	0.04	0.03
Selenium	34950	.1	.3	.14	.24	**.55**	.33
Sulfur, percent	34970	.05	.06	.06	.06	.06	.05
Total carbon, percent	49267	.01	1.52	2.19	3.18	**4.79**	1.66
Inorganic carbon, percent	49269	.01	.1	.03	.05	.05	.03
Organic carbon, percent	49266	.01	1.42	2.16	3.13	**4.74**	1.63
Thallium	4064	.08	.67	**.77**	.61	.64	.62
Antimony	34795	.04	2	1.7	**7**	1.2	1.7
Arsenic	34800	1	14	18	52	12	58
Barium	34805	.2	**875**	809	797	753	615
Beryllium	34810	.03	1.8	**1.9**	1.8	1.6	1.9
Bismuth	34816	.06	.28	.33	.26	.29	.33
Cadmium	34825	.007	.24	.29	.36	.32	**.58**
Cerium	34835	.1	91.9	42.9	86.1	77.6	**101**
Chromium	34840	.5	96.3	49	118	114	**155**
Cobalt	34845	.03	18.4	18	21.5	2.6	**31.1**
Copper	34850	2	27.8	38.9	53.4	52.3	**95.2**
Gallium	34860	.02	18	**23**	18	18	21
Lanthanum	34885	.05	46	36.6	44.1	43.8	**48.2**
Lead	34890	.4	22.2	19.7	21.1	2.9	**24**
Lithium	34895	.3	42.9	**55.6**	31.8	36.2	4.5
Manganese	34905	.7	2,040	582	787	742	1,150
Molybdenum	34915	.05	.67	**65.4**	.72	.8	.99
Nickel	34925	.3	34.6	11.9	46.2	46.2	**71.7**
Niobium	34930	.1	22	11	22	17	**26**
Scandium	34945	.04	16.7	8.9	21	2.3	**28.3**
Silver	34955	2	<2	<2	<2	<2	<2
Strontium	34965	.8	222	**355**	201	149	153
Thorium	34980	.1	17.2	**35.4**	14.6	13.4	16.9
Uranium	35000	.02	4.2	**194**	3.2	3.3	3.7
Vanadium	35005	.2	117	**531**	155	158	206
Yttrium	35010	.05	2.8	12.6	26.8	24.4	**28.6**
Zinc	35020	3	95	83.6	105	105	**119**
Aluminum	65170	50	77,400	**87,600**	75,700	73,000	79,500
Calcium	65171	100	11,400	**16,000**	14,300	11,100	14,100
Cesium	65172	.003	4	**7**	3.6	3.7	3.6
Iron	65173	50	42,000	**120,000**	53,000	48,000	68,000
Magnesium	65174	6	10,400	8,240	12,400	12,600	**17,100**
Phosphorus	65175	5	680	430	890	870	**1,100**
Potassium	65176	20	20,900	18,200	18,700	19,000	21,100
Rubidium	65177	.01	102	**123**	89.4	96.3	102
Sodium	65178	20	11,000	**18,100**	10,600	8,220	7,620
Titanium	65179	40	5,300	5,500	6,300	5,400	**8,600**

Table A2. Summary of trace-element concentrations in streambed-sediment samples for selected sites in the upper Birch Creek watershed near Central, Alaska, 2005.—Continued

[Concentrations are in micrograms per gram unless otherwise indicated. **Abbreviations:** <, less than; –, no data]

Constituent	Site name (site identification No.)				Minimum	Maximum	Median
	Harrison Creek 0.4 mile above Ptarmigan Gulch near Central (652129145001700)	Harrison Creek 1.3 miles below Ptarmigan Gulch near Central (652209144573700)	Harrison Creek 0.2 mile above Squaw Creek near Central (652231144541200)	Harrison Creek above Bottom Dollar Creek near Central (15407500)			
Mercury	0.04	0.03	0.03	0.03	0.03	0.05	0.03
Selenium	.36	.33	.38	.36	.14	.55	.33
Sulfur, percent	.13	**.14**	.09	.06	.05	.14	.06
Total carbon, percent	3.6	2.15	3.53	4	1.52	4.79	3.18
Inorganic carbon, percent	**.22**	.15	.06	.06	.03	.22	.06
Organic carbon, percent	3.38	**2**	3.47	3.94	1.42	4.74	3.13
Thallium	.54	.65	.64	.6	.54	.77	.64
Antimony	1.1	1.4	1.3	1.1	1.1	7	1.4
Arsenic	**60**	**60**	31	23	12	60	31
Barium	685	697	690	638	615	875	697
Beryllium	1.6	1.8	1.8	1.7	1.6	1.9	1.8
Bismuth	.29	.3	**.34**	.31	.26	.34	.3
Cadmium	.37	.4	.46	.29	.24	.58	.36
Cerium	67	67.4	85.7	83.1	42.9	101	83.1
Chromium	93.3	123	116	114	49	155	114
Cobalt	23.8	26	24.7	23.2	18	31.1	23.2
Copper	47.6	64.4	64.9	64.1	27.8	95.2	53.4
Gallium	16	19	18	18	16	23	18
Lanthanum	35.4	33.9	43.8	42.3	33.9	48.2	43.8
Lead	2.2	22	23.3	2.6	19.7	24	21.1
Lithium	28.9	37	36.4	36.4	28.9	55.6	36.4
Manganese	3,080	2,150	1,290	1,030	582	3,080	1,150
Molybdenum	.79	.84	.82	.7	.67	65.4	.8
Nickel	41.6	53	52	49.1	11.9	71.7	46.2
Niobium	17	19	20	21	11	26	20
Scandium	18.5	22.1	22.3	21.8	8.9	28.3	21
Silver	<2	<2	<2	<2	<2	<2	<2
Strontium	173	165	160	151	149	355	165
Thorium	12.8	14	15.8	14.4	12.8	35.4	14.6
Uranium	3	3.9	3.2	2.8	2.8	194	3.3
Vanadium	130	159	156	160	117	531	158
Yttrium	22.5	21.9	25	23.3	12.6	28.6	23.3
Zinc	89.8	104	115	105	83.6	119	105
Aluminum	62,700	73,800	71,700	69,500	62,700	87,600	73,800
Calcium	13,600	12,400	12,600	13,000	11,100	16,000	13,000
Cesium	3.1	3.6	3.8	3.5	3.1	7	3.6
Iron	71,000	78,000	54,000	54,000	42,000	120,000	54,000
Magnesium	10,600	14,300	12,600	13,400	8,240	17,100	12,600
Phosphorus	860	830	920	790	430	1,100	860
Potassium	16,500	**21,700**	19,900	18,600	16,500	21,700	19,000
Rubidium	8.3	102	98.3	91.3	8.3	123	98.3
Sodium	8,830	8,270	8,270	8,320	7,620	18,100	8,320
Titanium	5,400	6,100	6,400	6,900	5,300	8,600	6,100

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