Prepared in cooperation with the
National Park Service

Water Quality of the Crescent River Basin, Lake Clark National Park and Preserve, Alaska, 2003–2004

Scientific Investigations Report 2006–5151

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

Cover Photograph. Aerial photograph of Crescent Lake, August 18, 2004. Photograph taken by Timothy P. Brabets, U.S. Geological Survey.

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Conversion Factors, Datums, and Acronyms

SI to Inch/Pound

Multiply	By	To obtain
	Length	
inch (in)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	0.4047	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	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)
	Volume	
cubic foot (ft^3)	0.0283	cubic meter (m^3)

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

$$°F = (1.8 \times °C) + 32.$$

Vertical coordinate information is referenced to the North American Vertical Datum of 1929 (NAVD 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.

Acronyms used in this report:

ADCP	Acoustic Doppler Current Profiles
AFD&G	Alaska Department of Fish & Game
ANILCA	Alaska National Interest Lands Conservation Act
CCME	Canadian Council of Ministers of the Environment
CIRI	Cook Inlet Regional Incorporated
DOC	Dissolved Organic Carbon
ISQG	Interim Freshwater Sediment Quality Guideline
LACL	Lake Clark National Park and Preserve
LWD	Large Woody Debris
NAWQA	National Water-Quality Assessment Program
NPS	National Park Service
NWQL	National Water-Quality Laboratory
PEC	Probable Effect Concentration
PEL	Probable Effect Level
PPT	Parts per Thousand
QMH	Qualitative Multi-Habitat
TEC	Threshold Effect Concentration
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
YSI	Yellow Springs Instruments

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Water Quality of the Crescent River Basin, Lake Clark National Park and Preserve, Alaska, 2003-2004

By Timothy P. Brabets and Robert T. Ourso

Abstract

The U.S. Geological Survey and the National Park Service conducted a water-quality investigation of the Crescent River Basin in Lake Clark National Park and Preserve from May 2003 through September 2004. The Crescent River Basin was studied because it has a productive sockeye salmon run that is important to the Cook Inlet commercial fishing industry. Water-quality, biology, and limnology characteristics were assessed. Glacier-fed streams that flow into Crescent Lake transport suspended sediment that is trapped by the lake. Suspended sediment concentrations from the Lake Fork Crescent River (the outlet stream of Crescent Lake) were less than 10 milligrams per liter, indicating a high trapping efficiency of Crescent Lake. The North Fork Crescent River transports suspended sediment throughout its course and provides most of the suspended sediment to the main stem of the Crescent River downstream from the confluence of the Lake Fork Crescent River. Three locations on Crescent Lake were profiled during the summer of 2004. Turbidity profiles indicate sediment plumes within the water column at various times during the summer. Turbidity values are higher in June, reflecting the glacier-fed runoff into the lake. Lower values of turbidity in August and September indicate a decrease of suspended sediment entering Crescent Lake. The water type throughout the Crescent River Basin is calcium bicarbonate. Concentrations of nutrients, major ions, and dissolved organic carbon are low. Alkalinity concentrations are generally less than 20 milligrams per liter, indicating a low buffering capacity of these waters. Streambed sediments collected from three surface sites analyzed for trace elements indicated that copper concentrations

Figure 1. Location of the Crescent River and Lake Clark National Park and Preserve.

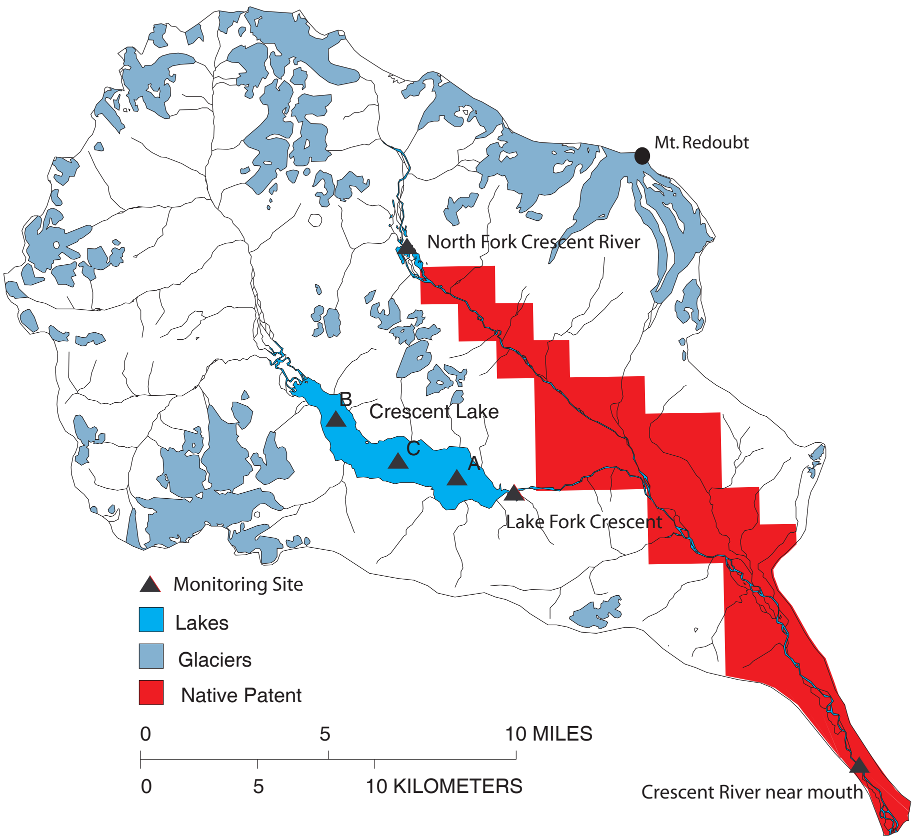

Figure 2. Crescent River Basin showing sampling sites and native inholdings.

at all sites were above proposed guidelines. However, copper concentrations are due to the local geology, not anthropogenic factors.

Zooplankton samples from Crescent Lake indicated the main taxa are *Cyclops sp.*, a Copepod, and within that taxa were a relatively small number of ovigerous (egg-bearing) individuals. *Cyclops sp.* are one of the primary food sources for rearing sockeye salmon juveniles and were most prevalent in the July sampling. Qualitative-Multi-Habitat algae samples were collected from two surface-water sites. A total of 59 taxa were found and were comprised of 4 phyla: Rhodophyta (red algae), Cyanophyta (blue-green algae), Chlorophyta (green algae), and Chrysophyta (diatoms). Twenty-two algal taxa were collected from the upper site, North Fork Crescent River, whereas twice as many taxa were collected from the downstream site, Crescent River near the mouth.

Introduction

The Crescent River watershed is approximately 250 square miles (mi^2) and is located on the west side of Cook Inlet in south-central Alaska in Lake Clark National Park and Preserve (fig. 1). There are two distinct tributaries to the main stem of the Crescent River (fig. 2). Lake Fork Crescent River drains Crescent Lake, a large approximately 6-mile long proglacial lake that is fed by snowmelt, glacier melt, and precipitation from the surrounding Chigmit Mountains. The North Fork Crescent River contains a few small lakes and is fed primarily from glacier melt, snowmelt, and precipitation.

The Crescent River system contains all five species of Pacific salmon with sockeye salmon the primary one. A strong sockeye salmon run is important to the Cook Inlet commercial salmon industry. Sport fishermen also target the fish, and local rural residents use the rivers as a traditional subsistence fishery. The Alaska Department of Fish and Game (ADF&G) has maintained a sonar fish counter on the river since 1979. Sockeye counts have ranged from about 20,000 salmon to about 130,000 salmon during this period (table 1). Most of the salmon travel up the Lake Fork Crescent River into Crescent Lake and spawn along its shores and tributaries.

The entire Crescent River watershed lies within Lake Clark National Park and Preserve (LACL). Public lands include Crescent Lake, the headwaters above the lake, and the upper portion of the North Fork Crescent River. Cook Inlet Region Incorporated (CIRI) and three Native village corporations own large tracts of inholdings in the watershed along the North Fork Crescent River and between Crescent Lake and Cook Inlet (fig. 2). Timber rights to approximately 42,000 acres of the lower Crescent River watershed were sold to a logging company in 1997. The timber company built a primary access road, airstrip, and log transfer facility, including a 550-foot (ft) causeway extending into Tuxedni Bay, in 1998-99. Secondary roads were built to harvest timber on the west side of the river; about 700 acres were harvested during 2000-2001 (fig. 3). Logging stopped in 2002 (Anchorage Daily News, January 11, 2004).

Table 1. Fish counts at Crescent River, 1979-2004.

[Data from Alaska Department of Fish and Game]

	Salmon Species				
Year	**Chinook**	**Coho**	**Chum**	**Pink**	**Sockeye**
	Oncorhynchus tshawytscha	*Oncorhynchus kisutch*	*Oncorhynchus keta*	*Oncorhynchus gorbuscha*	*Oncorhynchus nerka*
1979	122	0	95	3685	86654
1980	0	0	0	0	90863
1981	199	0	0	376	41213
1982	0	0	0	111	58957
1983	0	0	0	221	92122
1984	0	538	4880	0	118345
1985	0	850	505	984	128628
1986	0	0	0	0	20385
1987	552	552	7258	2044	120219
1988	549	245	3362	85	57716
1989	151	0	4392	354	71064
1990	21	73	7677	219	52238
1991	0	83	6080	322	44578
1992	171	303	6892	738	58241
1993	1619	0	1872	1976	37556
1994	7771	73	2939	657	30355
1995	4691	554	4583	1938	52311
1996	3487	52	2821	250	28729
1997	3092	0	1559	12428	70768
1998	1143	261	2439	1376	62257
1999	19325	0	1449	19748	66519
2000	2827	0	432	390	56599
2001	236	0	3022	5239	78082
2002	403	0	1129	345	62833
2003	1132	81	5739	2512	122457
2004	640	52	1134	1198	103201
Average	1851	143	2702	2200	69727
Total	48131	3717	70259	57196	1812890

The effects of logging on the water quality of streams are well documented in the literature. To briefly summarize, logging can result in the following impacts (Hartman and others, 1996).

Immediate: Stream temperature is increased due to increased sunlight; concentrations of nutrients and dissolved ions in streams change due to soil disturbance; fine sediment in streams is increased when slope soils, road cuts, and road ditches are exposed to erosion, and decreased stream detritus when riparian vegetation is removed.

Midterm (5 -10 years): Sediment production is increased due to hillslope failures and erosion when streambank integrity is lost. Streambed stability and channel diversity are reduced when more sediment enters streams, and composition of spawning gravel is changed when sediments are transported from upstream channels.

Long term: Structural and habitat features are changed due to the loss of large woody debris (LWD) in streams. For example, clear-cutting to the stream margin on the flood plain can cause destabilization of LWD, erosion of stream banks, entrainment of sediment, widening of the channel, and deposi-

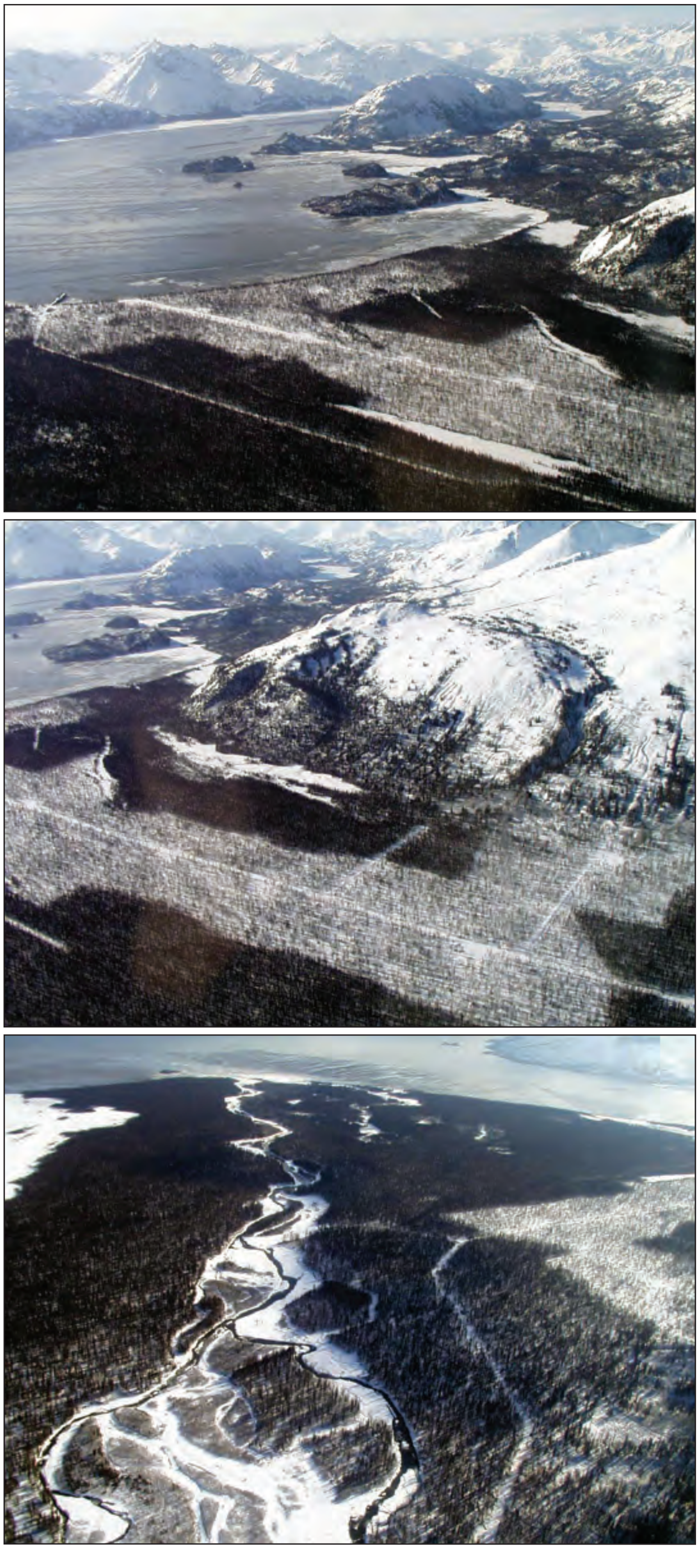

Figure 3. Aerial photographs showing logged areas of the Crescent River Basin, looking southeast to Cook Inlet. (Photographs taken by Penny Knuckles, National Park Service, 2002.)

tion of sediment in the lower reaches (Hartman and others, 1996). Channel diversity (e.g. pool volumes) and sediment storage are directly related to the LWD volume.

The National Park Service (NPS) has a responsibility to maintain the sockeye salmon habitat and protect the pristine quality of lakes and rivers within the LACL. These were the primary purposes mentioned in LACL's enabling legislation (Alaska National Interest Lands Conservation Act (ANILCA), 1980). If logging resumed at the planned scale, the harvest operations could pose an imminent threat to the water quality and fish habitat of the Crescent River watershed. Knowing the key water-quality effects from logging and identifying critical habitat areas in the Crescent River watershed would allow the NPS and state agencies to work with Native and village corporations to maintain the water quality and aquatic habitat of the Crescent River watershed. This information would also allow the NPS to develop land purchase priorities for LACA's Land Protection Plan, which is currently under development.

Purpose and Scope

Because the Crescent River is an important sockeye salmon river and logging may resume in the future, the U.S. Geological Survey (USGS), in cooperation with the NPS, conducted a study of the watershed in the summer months of 2003 and 2004. The purpose of this project was (1) to characterize the present water quality and aquatic habitat of the Crescent River watershed and (2) to identify the possible effects to water quality and aquatic habitat from any future logging in the watershed. This report presents the findings of that study.

Previous Studies

Previous water quality and biology studies in the Crescent River Basin have primarily been done by the Alaska Department of Fish and Game (ADF&G) (Koenings and others, 1985). The ADF&G has focused on assessing the fishery conditions of Crescent Lake since the early 1980s. The commercial fisheries division of ADF&G began monitoring the adult fish returns in 1979 to determine (1) magnitude of the escapement, (2) migrational timing, (3) stock composition of the sockeye harvest in the commercial fishery, and (4) age, length, sex, and scale characteristics.

Description of Study Area

Located on the west side of Cook Inlet, altitudes in the Crescent River Basin range from sea level to the summit of the Mt. Redoubt volcano at 10,197 ft (fig. 2). Precipitation averages about 70 inches over the entire basin, with approximately half of that falling as snow. Soils consist

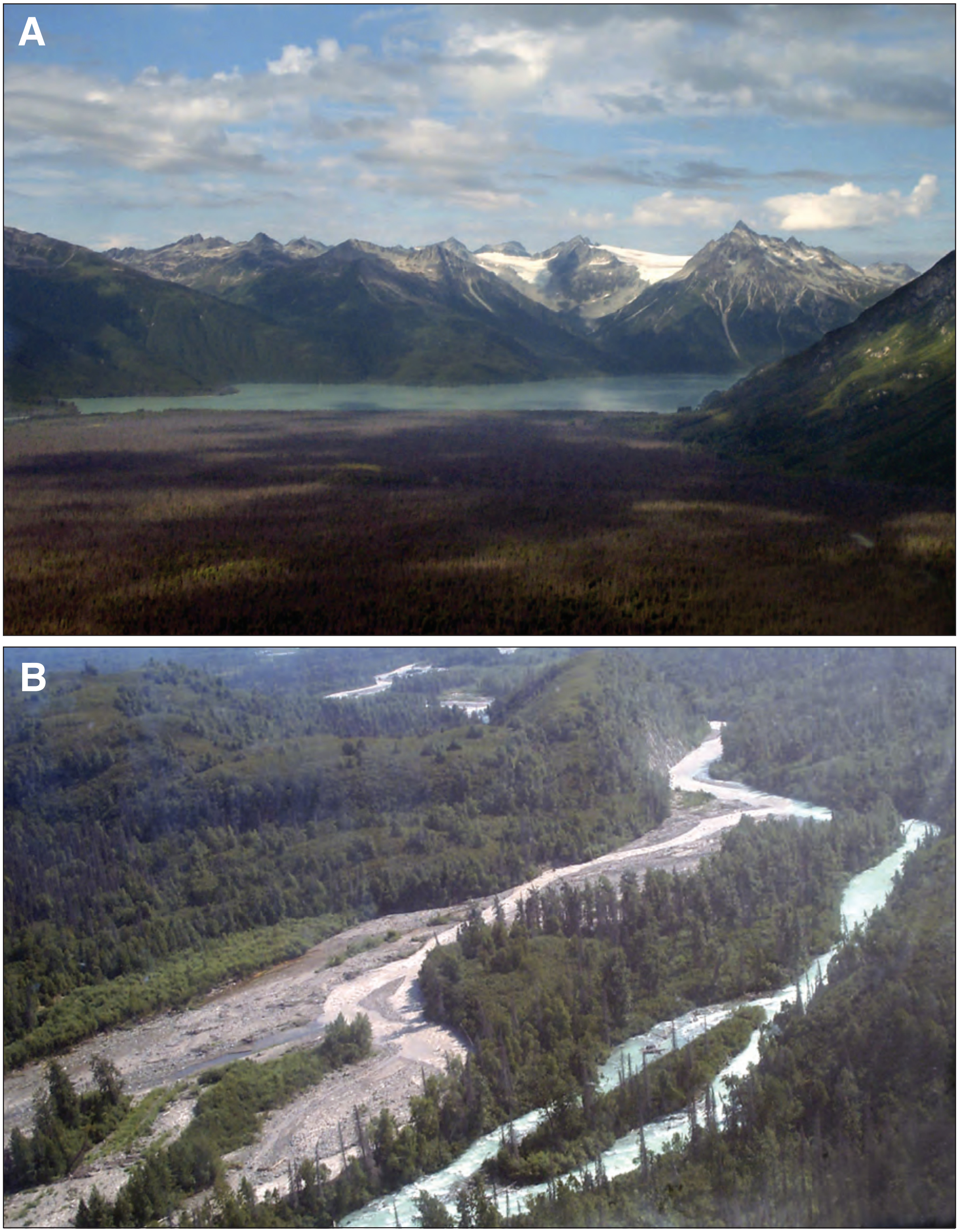

Figure 4. Aerial photographs of the Crescent River Basin: A. Outlet of Crescent Lake and B. North Fork Crescent River (left) and Lake Fork Crescent River (right). (Photographs taken by Timothy P. Brabets, U.S. Geological Survey, August 11, 2004.)

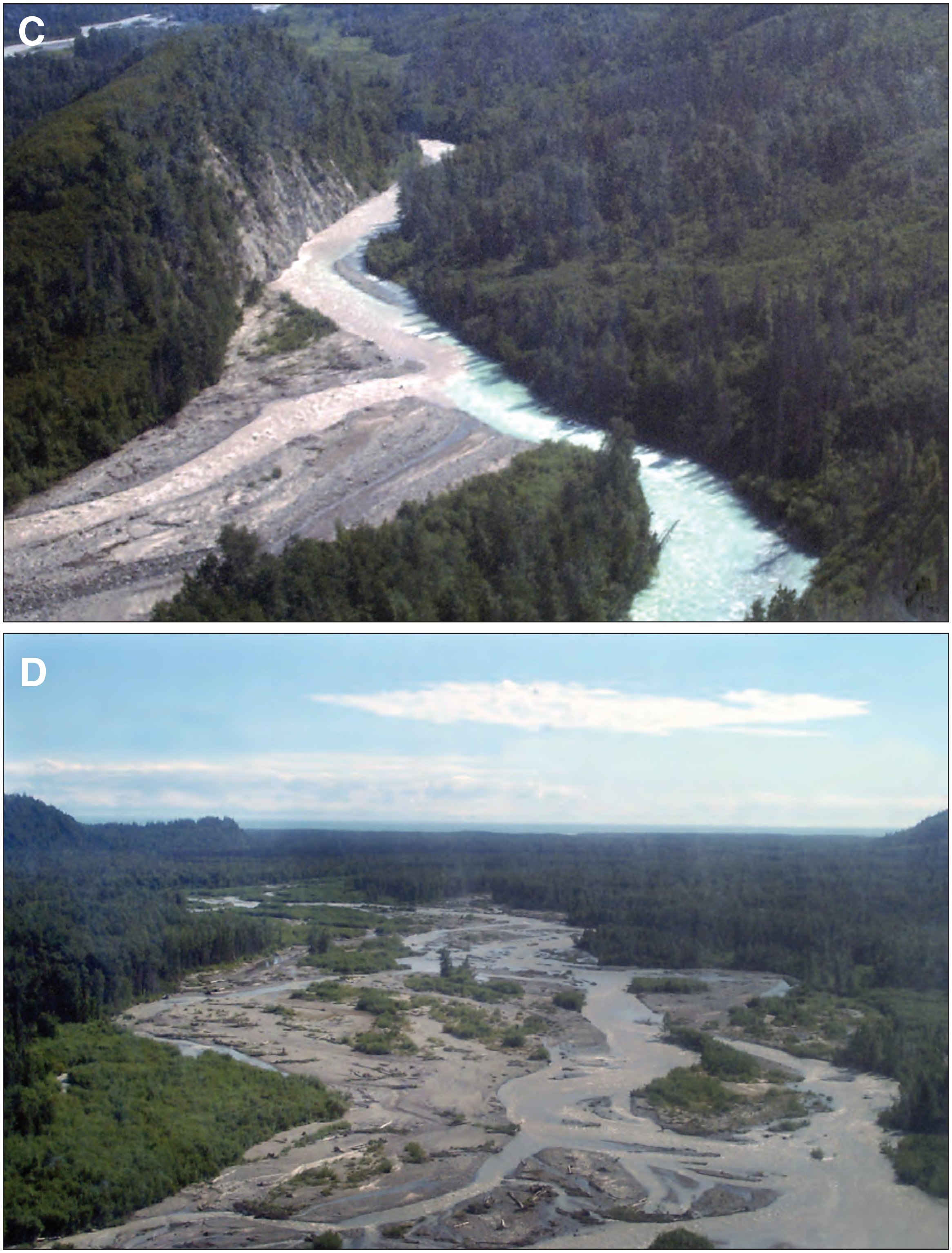

Figure 4 C. Confluence of North Fork Crescent River and Lake Fork Crescent River, and D. Crescent River near mouth. (Photographs taken by Timothy P. Brabets, U.S. Geological Survey, August 11, 2004.)—Continued

mostly of inceptisols with the lower part of the basin near the mouth primarily entisols. The physiographic characteristics of the basin are primarily those of moderately high, rugged mountains. Bedrock consists of sedimentary and metamorphic rocks. Land cover is primarily alpine tundra and bare soil (44 percent), spruce forest (31 percent), and permanent ice and snow (18 percent).

Lake Fork Crescent River drains an area of 125 mi^2 (fig. 2, table 2). Notable features in this watershed are glaciers, which comprise about 16 percent of the basin and Crescent Lake (fig.4A). Crescent Lake is approximately 6 mi long and slightly more than 1 mi wide. The average depth of the lake is about 75 ft, and the deepest part is about 100 ft (fig. 5). The lake is oligotrophic; its open-water period lasts about 5 months-from June through October. Thermally, Crescent Lake is a dimictic lake—it circulates twice a year—in the spring and the fall. It is directly stratified during summer and inversely stratified during winter. Surface temperatures characteristically reach 10 to 12°C during the open-water period. Annual water-residence time or flushing rate is estimated to be 0.7 to 0.8 years. Most of the inflow comes from overland runoff and snowmelt. Inflow from definable streams consists of meltwater from glaciers on the southwest side of the basin, at mid-lake. The other major tributary is at the upper end of the lake. Because Crescent Lake is glacier-fed, the lake and its outflow have the characteristic turquoise color (fig. 4A). However, Crescent Lake does trap much of the suspended sediment that enters the lake.

The North Fork Crescent River drains an area of about 75 mi^2. Approximately 23 percent of the basin consists of glaciers. The North Fork channel is relatively steep, and during open water is characterized by the typical turbid color of glacier-fed streams (fig. 4B). The confluence of the North Fork and Lake Fork Crescent Rivers forms the mainstem of the Crescent River (fig. 4C). In this section, the streambed channel becomes braided, and the channels constantly scour and shift (fig. 4D).

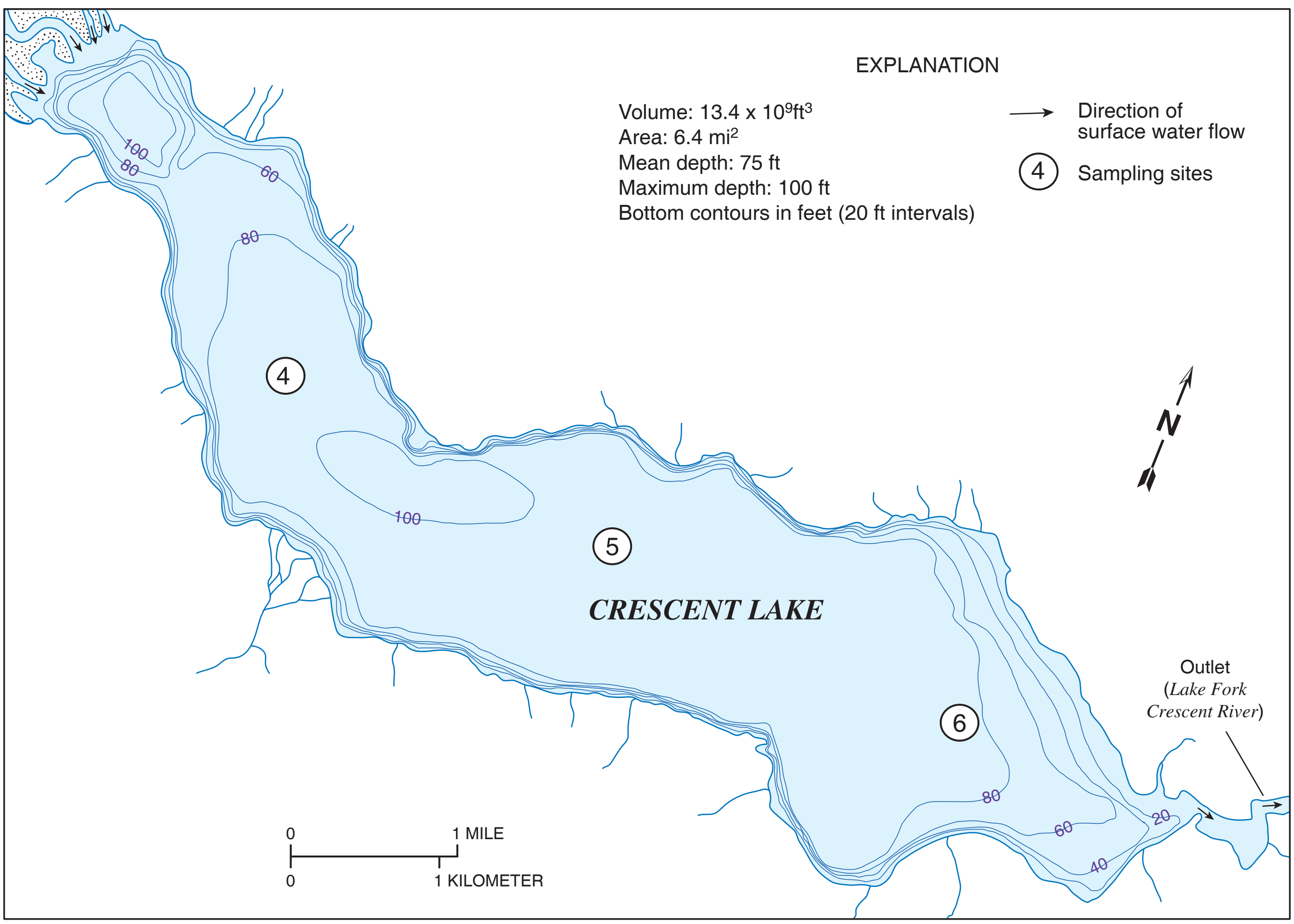

Figure 5. Bathymetric map of Crescent Lake showing sampling sites 4, 5, and 6. (Modified from Koenings and others, 1985).

Table 2. Water-quality sites, Crescent River Basin.

Map Number (figure 2)	Latitude/longitude or USGS station number	Station Name - Surface Water Sites	Area (mi^2)	Glaciers (mi^2)	Lakes (mi^2)
1	15294630	North Fork Crescent River near Tuxedni Bay	34.2	9.3	0.2
2	15294640	Lake Fork Crescent River near Tuxedni Bay	125.0	20.5	6.2
3	15294650	Crescent River near mouth near Tuxedni Bay	249.0	37.6	6.4
		Station Name - Lake Sites			
4	60°23'01" 152°58'52"	Crescent Lake 4.6 miles above outlet near Tuxedni Bay			
5	60°22'12" 152°56'13"	Crescent Lake 2.8 miles above outlet near Tuxedni Bay			
6	60°21'37" 152°53'35"	Crescent Lake 1.2 miles above outlet near Tuxedni Bay			

Methods of Data Collection and Analysis

To adequately characterize the water quality of the Crescent River Basin, data were collected from both stream sites and lake sites. The six sites in the Crescent River Basin that were selected for sampling included three surface-water sites and three lake sites (fig. 2, table 2). The three surface-water sites were on the North Fork Crescent River, Lake Fork Crescent River, and the main stem of the Crescent River (fig. 2). The three lake sites were on Crescent Lake—in the upper part, the middle part, and the lower part. Various types of water-quantity, water-quality, and biological data were collected from these sites throughout the runoff periods of 2003 and 2004 to gain a better understanding of the water quality of the Crescent River Basin.

Water samples were collected at all sites during the open-water period (May through October) in 2003 and 2004. The samples collected from streams were analyzed for pH, specific conductance, water temperature, and dissolved-oxygen concentration in the field. Major ions and dissolved solids, nutrients, organic carbon, and suspended sediment were analyzed by the USGS National Water-Quality Laboratory (NWQL). The field-collection and processing equipment used was made from Teflon or glass to prevent sample contamination and to minimize analyte losses through adsorption. All sampling equipment was cleaned prior to use with a nonphosphate laboratory detergent, rinsed with deionized water, and finally with stream water just prior to sample collection. Depth-integrated water samples were collected across the stream by using the equal-width-increment method (http://water.usgs.gov/owq/FieldManual/) and processed in the field using methods and equipment described by Shelton (1994). Water samples were collected from Crescent Lake using a 6.2 liter acrylic Van Dorn sampler. Samples to be analyzed for dissolved constituents were filtered through 0.45 micrometer (µm) capsule filters. Water samples were sent to the NWQL for analysis using standard USGS analytical methods (Fishman and Friedman, 1989; Patton and Truitt, 1992; Fishman, 1993). A YSI meter was used to measure field parameters including water temperature, dissolved-oxygen concentration, specific conductance, pH, and turbidity at the time of sampling. Discharge measurements also were made at the time of sampling either by wading (using methods outlined by Rantz and others (1982)) or by boat using an acoustic Doppler current profiler (ADCP) manufactured by R. D. Instruments following the guidelines outlined by Oberg and others (2005).

Streambed sediments were sampled at the three surface-water sites and analyzed for trace elements one time in 2004. Sediments were collected from several depositional areas at each site using Teflon tubes or Teflon coated spoons and composited in glass bowls (Shelton and Capel, 1994). Because the concentration of trace elements on streambed materials is strongly affected by the particle-size distribution of the sample, only the portion of the sample that was finer than 63 µm was analyzed. Stream water was used for sieving the trace-element sample through a 63 µm mesh. Water included in the trace-element sample was decanted after very fine-grained sediments had settled (about 24 hours). Arbogast (1990) describes laboratory procedures followed for processing streambed samples for trace-element analysis. Trace elements in streambed sediments were analyzed following a total digestion procedure.

Water stage was measured on a continuous basis in 2003 at the North Fork Crescent River, Lake Fork Crescent River, and Crescent River sites. Good stage record was obtained at the Lake Fork Crescent River site; stage record at the North Fork Crescent River and mainstem Crescent River sites was considered poor, however, due to constantly shifting channels. The USGS gaging station operated on the Johnson River, about 20 miles southwest of the Crescent River (fig. 1), was used for comparative purposes because its size and basin characteristics are similar to those of the North Fork Crescent River.

Quantitative zooplankton samples were collected from the three sites in Crescent Lake in June, July, August, and September 2004. Samples were collected using a 1.6 ft diameter conical plankton tow net with a mesh size of 153 µm and a sample vial of 100 milliters. Tow times were kept consistent at 3 ft per second. The ADF&G analyzed the samples for taxa presence, abundance, and density at their laboratory in Soldotna, Alaska.

Algae samples were collected at the North Fork Crescent River and at the Crescent River near the mouth according to protocols outlined by Cuffney and others (1993) and Porter and others (1993). An assessment of the algal community was done to identify the species of algae present at stream reaches. Algae samples were collected using a method known as Qualitative Multi-Habitat (QMH). The QMH sample is collected from the variety of habitats present in the stream reach. Analysis of the algae samples was done by the Philadelphia Academy of Natural Science in Philadelphia, Pennsylvania.

After data collection and compilation was complete, concentrations of the various water-quality constituents were evaluated in relation to established water-quality criteria. Trace-element concentrations in streambed sediments were compared with those collected by the USGS, National Water-Quality Assessment (NAWQA) program and with guidelines established by the Canadian Council of Ministers of the Environment (1999). The algae and trace element data also were compared with the algae and trace element data collected from four sites in the Kijik River Basin, located in the western part of LACL. Trace element data collected from sites in the Johnson River Basin was also used in the data analysis.

Acknowledgments

John Edmundson of the ADF&G, Soldotna, Alaska, analyzed the zooplankton samples from Crescent Lake at no cost to the project. David Westerman, also of the ADF&G, provided boat usage at the Crescent River sonar counter.

Water Quality of the Crescent River Basin

Water-quality data collected in the Crescent River Basin in 2003 and 2004 included field parameters (streamflow, specific conductance, pH, water temperature, dissolved-oxygen concentration, and turbidity), concentrations of suspended sediment, major inorganic ions, and nutrients. More specific data included water samples analyzed for dissolved organic carbon (DOC), chlorophyll-*a*, and the streambed sediments for trace elements. Biological data included samples of benthic algae from streams and samples of zooplankton from Crescent Lake. These data established a hydrologic data base of the Crescent River Basin and also provide insights as to whether the concentrations or values of certain constituents might be harmful to sockeye salmon.

Streamflow, Suspended Sediment, and Turbidity

In the Crescent River Basin, streamflow characteristics differ between the North Fork Crescent River and the Lake Fork Crescent River. For example, flow of the Lake Fork Crescent River reflects the affects of Crescent Lake. During the runoff season, the lake fills from rainfall, snowmelt, and ice melt. Once filled, Crescent Lake begins to empty, with the highest discharges occurring in July. Water levels at the Lake Fork Crescent River gradually rise and fall. Assuming the flow characteristics of the Johnson River are similar to those of the North Fork Crescent River, differences in the flow characteristics between the North Fork Crescent River and the Lake Fork Crescent River are notable (fig. 6). In the North Fork Crescent River (table 3), most runoff occurs from June through September. Following an intense rainfall however, there is a rapid rise and fall of water stage.

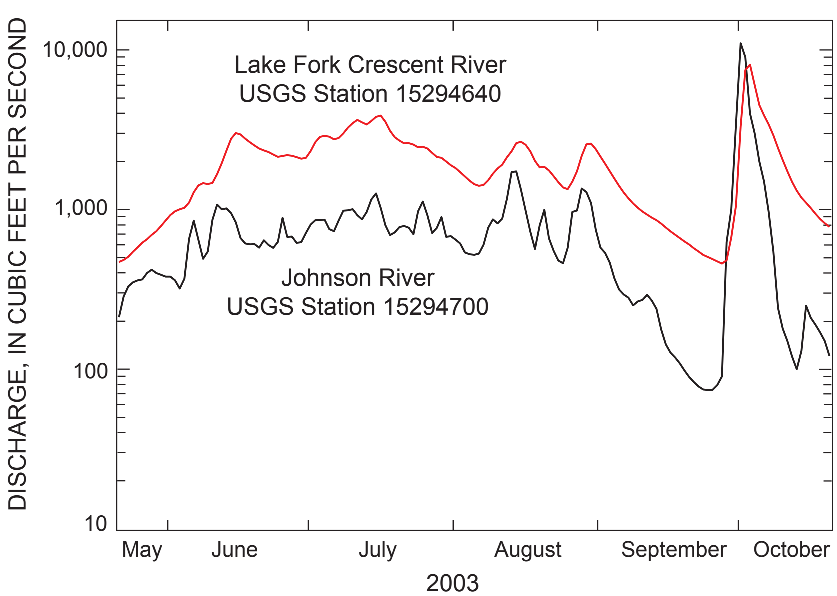

Figure 6. Discharge hydrographs of Lake Fork Crescent River and Johnson River, May 21 to October 2003.

Table 3. Physical field parameters and suspended sediment measured at surface sites in the Crescent River Basin.

[all values in milligrams per liter, mg/L, unless otherwise noted; °C, degrees Celsius; µs/cm at 25° Celsius, microsiemens per centimeter at 25° Celsius; <, less than; ft^3/s, cubic feet per second; $ft^3/s/mi^2$, cubic feet per second per square mile; NTU, Nephelometric Turbidity Unit; E, estimated; --, constituent not measured]

Date	Time	Discharge (ft^3/s)	Unit Discharge ($ft^3/s/mi^2$)	Dissolved Oxygen	pH (units)	Specific Conductance (µs/cm at 25° Celsius)	Water Temperature (°C)	Turbidity (NTU)	Suspended Sediment
North Fork Crescent River (site 1)									
5/16/2003	1330	89	2.6	9.3	7.0	55	8.0	4.1	20
7/2/2003	1630	E721	21.1	12.5	6.9	23	6.5	32.0	142
8/1/2003	1310	537	15.7	12.1	6.7	28	7.0	4.8	83
10/23/2003	1230	145	4.2	--	7.1	57	--	<2.0	11
8/11/2004	1350	501	14.6	12.8	6.0	25	8.2	54.0	318
9/8/2004	1350	E186	5.4	12.1	5.8	51	2.7	26.0	71
Lake Fork Crescent River (site 2)									
5/16/2003	1115	462	3.7	12.2	7.3	31	4.0	2.3	7.0
7/19/2003	1045	2730	21.8	10.8	6.7	26	10.0	7.1	10
8/14/2003	1025	2610	20.9	11.7	6.6	23	9.2	11.0	14
10/23/2003	1545	741	5.9	--	7.1	25	5.0	20.0	10
7/2/2003	1245	2140	17.1	13	6.3	31	9.6	16.0	13
7/29/2003	1130	2860	22.9	12.3	6.0	28	9.1	16.0	12
8/18/2003	1200	1380	11	9.8	6.2	25	13.2	13.0	11
9/13/2003	1225	560	4.5	10.8	6.0	24	9.5	--	8.0
Crescent River near mouth (site 3)									
5/16/2003	1615	742	3.0	13.6	8.0	58	7.9	3.7	10
7/2/2003	1120	E5250	21.1	10.9	7.1	34	10.0	20	277
8/1/2003	1730	3350	13.4	11.1	7.3	35	12.5	10	254
10/24/2003	1515	E1257	5.0	--	7.3	50	5.0	13	154
8/11/2004	1520	E3280	13.2	12.8	6.7	34	12.8	54	308
9/8/2004	1300	E1350	5.4	10.2	6.3	39	8.1	20	71

Recorded discharge at the Lake Fork Crescent River for the 2003 and 2004 runoff seasons ranged from about 500 cubic feet per second (ft^3/s) to about 4,000 ft^3/s with the exception of October 2003. A large flood occurred in the Crescent River Basin in October 2003 (fig. 6). Peak discharges of record were recorded at two USGS streamgaging stations on the west side of Cook Inlet near the vicinity of the Crescent River: Johnson River (USGS station 15294700) and the Iliamna River (USGS station 15300300). On the basis of water stage recorded at the Lake Fork Crescent River and a rating extension, the peak discharge at the Lake Fork Crescent River was estimated to be approximately 8,090 ft^3/s.

Measured discharges ranged from 89 ft^3/s to 721 ft^3/s at North Fork Crescent River, from 462 ft^3/s to 2,680 ft^3/s at Lake Fork Crescent River, and from 742 ft^3/s to 5,250 ft^3/s at the mainstem of the Crescent River. Unit runoff ranged from a low of 2.6 $ft^3/s/mi^2$ at North Fork Crescent River to a high of about 22.9 $ft^3/s/mi^2$ at Lake Fork Crescent River. During a given flow condition, unit runoff was approximately equal at all three sites (table 3).

Sediment in rivers is transported in suspension and as bedload. Suspended sediment generally consists of fine particles such as clay, silt, and fine sand that are transported in the stream while being held in suspension by the turbulence of flowing water. Bedload consists of coarse sediment particles such as coarse sands, gravels, and sometimes boulders that are transported along or near the streambed.

Measured values of suspended sediment in the Crescent River Basin varied at the three sites (table 3). The lowest concentrations of suspended sediment were measured at the Lake Fork Crescent River and ranged from 7 to 14 milligrams per liter (mg/L). Concentrations were low at this site because most of the suspended sediment is trapped by Crescent Lake. At the North Fork Crescent River site, suspended sediment concentrations ranged from 11 to 318 mg/L, typical for a glacier-fed stream. At Crescent River near the mouth, suspended

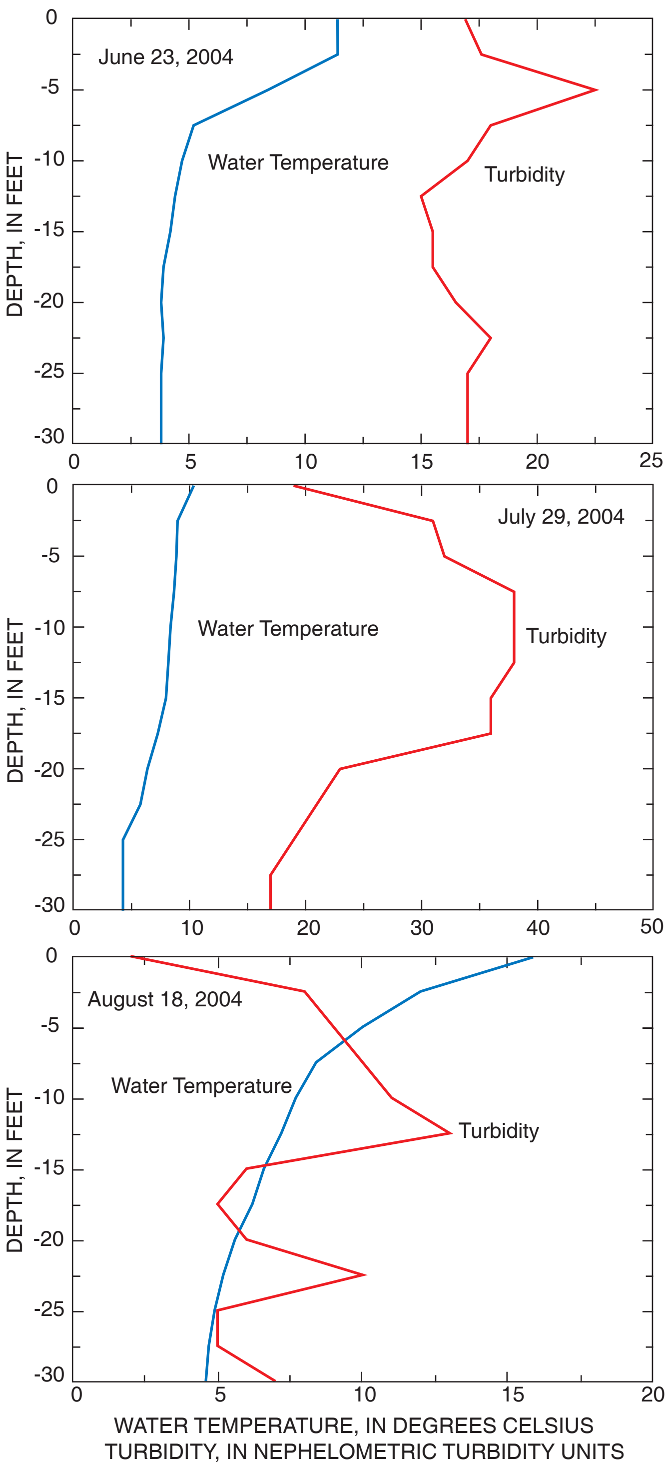

Figure 7. Water temperature and turbidity profiles of Crescent Lake, site 4.

sediment concentrations ranged from 10 to 308 mg/L, reflecting the influence of flows from the North Fork Crescent River. Because no logging has taken place immediately upstream of this site, the suspended sediment concentrations are more likely due to the natural channel characteristics such as steep slope and high velocities.

Turbidity, a measure of water clarity, is being used increasingly as a surrogate for suspended sediment concentrations (Gray and Glysson, 2003). At the Lake Fork Crescent River, turbidity values were all less than or equal to 20 Nephelometric Turbidity Units (NTU). At the North Fork Crescent River and Crescent River sites, turbidity values were as high as 54 NTU. Although no accurate statistical equation was found between suspended sediment and turbidity, higher suspended sediment concentrations usually corresponded to higher turbidity values.

Turbidity profiles were collected from Crescent Lake throughout 2004. The purpose for examining turbidity plumes is that light regimes that are altered by turbid inflows alter juvenile sockeye behavior relative to that observed in clear-water lakes. In Crescent Lake, turbidity profiles indicate sediment plumes moving through the lake (figs. 7-9, tables 4-6). In June, a plume in the upper part of the water column was present in the upper end of the lake (site 4). No plume was noted in the middle part of the lake (site 5), but a plume was noted in the lower part of the lake (site 6) in the lower portion of the water column. In July, a distinct sediment plume was evident in the upper and middle portions of Crescent Lake, though somewhat less evident in the lower portion of the lake. In August, there appeared to be two small sediment plumes in the upper part of the lake, but no other distinctions in the middle and lower portions of the lake.

Water Temperature

Water temperature is important in both physiochemical and biological processes such as oxygen solubility and fish metabolism and growth rates. Water temperature data collected at the three surface-water sites ranged from 2.7 to 13.2°C (table 3). At the Lake Fork Crescent River site, continuous records of water temperature showed a gradual warming from mid-May (about 4.0°C) to mid-August (about 13°C) and then gradual cooling. Although only two summers of data are available, the average water temperature for August 2004 was about 1.5°C higher than for August 2003 (fig. 10).

Previous work (Koenings and others, 1985) indicated that the water temperature of Crescent Lake under the ice during the winter period remained at 4°C. In 2004, depth profiles of water temperature of the Crescent Lake sites indicated different patterns throughout the summer (figs. 7-9). In June, the upper part of the water column is warmer throughout the lake. In July, Crescent Lake is fairly well mixed, and in August, the top part of Crescent Lake was warmer. In September, the lake was isothermal.

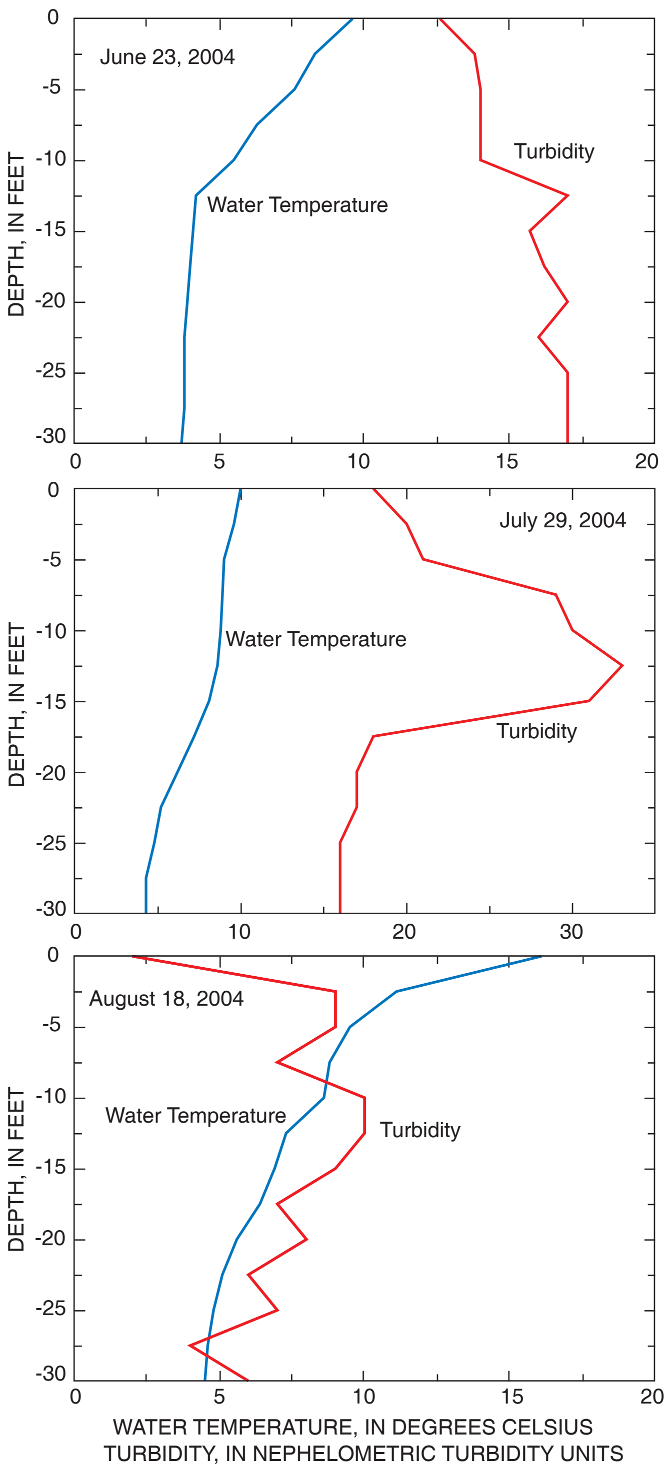

Figure 8. Water temperature and turbidity profiles of Crescent Lake, site 5.

Specific Conductance

Specific conductance is a measure of the ability of water to conduct an electric current. As the concentration of ions in solution increases or decreases, so does the conductance of the solution. It is a readily measured property that can be used to indicate the dissolved-solids or ion content of the water. Frequently a statistical relation can be developed between specific conductance and the concentration of ionic components making up the dissolved solids in water. During low flow, the specific conductance of a stream or river is generally the highest, indicating a greater component of ground-water inflow. Ground water has greater potential to dissolve minerals, having spent more time in contact with rocks and soil materials than rainwater or snowmelt. Periods of low specific conductance reflect runoff of rain or snowmelt, which typically contain small amounts of dissolved ions. Values of specific conductance during the study period were fairly consistent, with only slight variations among sites. Specific conductance at the three surface-water sites ranged from 23 to 58 microsiemens per centimeter at 25° Celsius (µs/cm at 25°C). The range of specific conductance values varied only slightly at Lake Fork Crescent River (23 to 31 µs/cm at 25°C) due to the moderating effects of flow from Crescent Lake. The ranges in conductance values were larger at the North Fork Crescent River and mainstem Crescent River, the higher values being measured during lower flow conditions (table 3). At Crescent Lake, depth profiles of specific conductance were fairly uniform throughout the water column and ranged from 20 to 39 µs/cm at 25°C (tables 4-6).

pH

The pH of water, a measure of its hydrogen-ion activity, can range from 0 (acidic) to 14 (alkaline) standard units. The pH of natural river water typically ranges between 6.5 and 8.0 standard units (Hem, 1985). During the study period, measured values of pH for all sites ranged from 5.8 to 8.0. Depth profiles of pH at the Crescent Lake sites varied slightly with depth, ranging from 5.8 to 6.7 (tables 4-6), within the typical range for fish growth and survival.

Dissolved Oxygen

The dissolved-oxygen concentration in a stream is controlled by several factors, including water temperature, air temperature and atmospheric pressure, hydraulic characteristics of the stream, photosynthetic or respiratory activity of stream biota, and the quantity of organic matter present (Hem, 1985). Salmon and other species of fish indigenous to southcentral Alaska streams require well-oxygenated water at every stage in their life history, as do many forms of aquatic invertebrates. Young fish tend to be more susceptible to oxygen deficiencies than adults. Dissolved-oxygen concentration at all surface-water sites during the study period

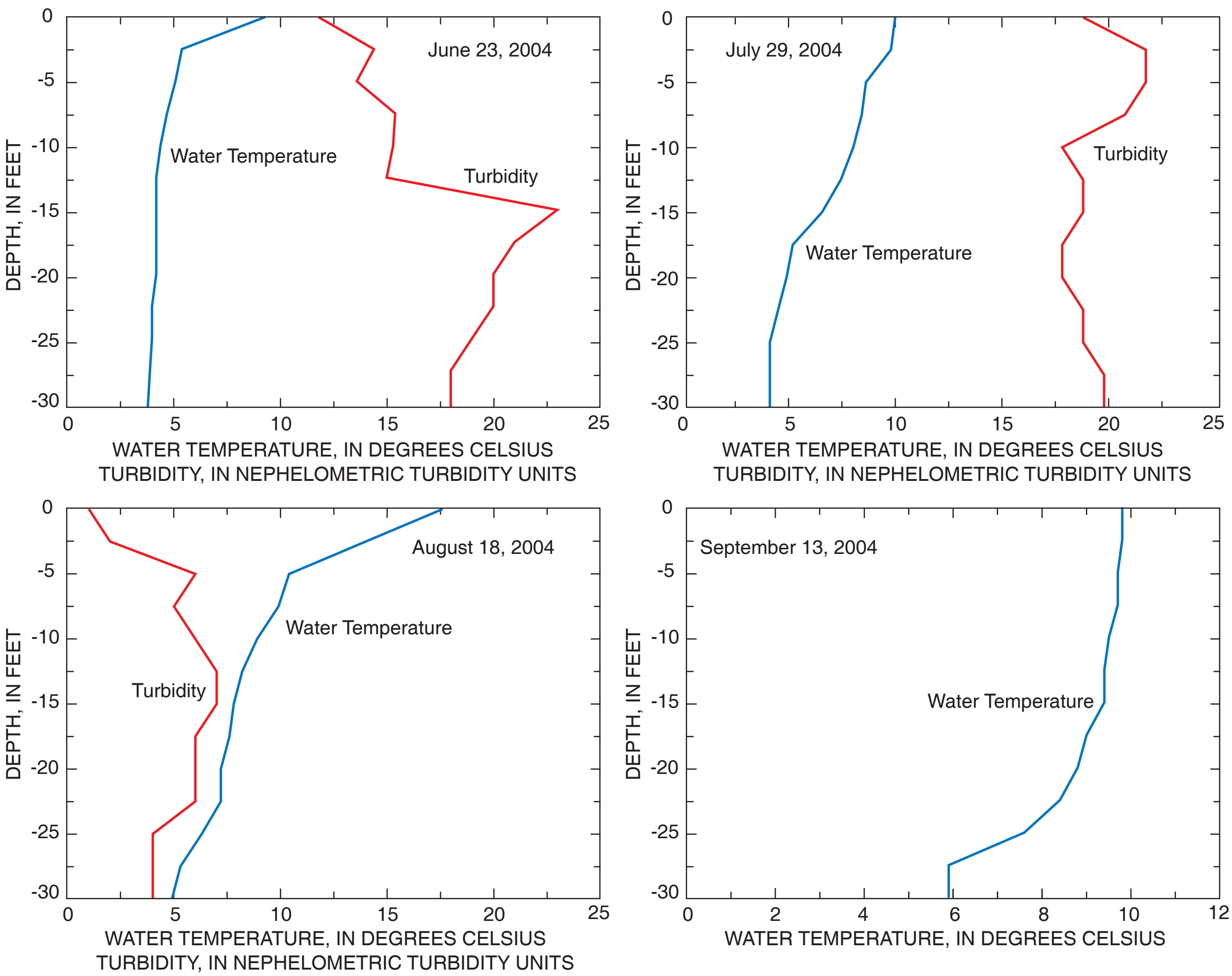

Figure 9. Water temperature and turbidity profiles of Crescent Lake, site 6.

ranged from 9.3 mg/L to 13.6 mg/L (table 3), the range of values being nearly identical at all stations. At Crescent Lake, depth profiles of dissolved-oxygen concentration indicated a minimum concentration of 8.4 mg/L and a maximum concentration of 14.2 mg/L. All measurements of dissolved-oxygen levels indicate adequate concentrations to support populations of salmonids. Dissolved oxygen was consistently greater than 74 percent of saturation during all dates and at all depths sampled. Increases or decreases in oxygen concentration were not biologically mediated; instead, these variations merely reflected a decrease or increase in water temperature (Koenings and others, 1985).

Alkalinity

Alkalinity is a measure of the capacity of the substances dissolved in water to neutralize acid. In most natural waters, alkalinity is produced mainly by bicarbonate and carbonate ions, which are formed when carbon dioxide or carbonate rocks dissolve in water (Hem, 1985). Alkalinity concentrations for all sites (reported as equivalent concentration of calcium carbonate ($CaCO_3$)) were all less than 20 mg/L (table 7). As expected, the Lake Fork Crescent River (site 2) had similar values of alkalinity to the site on Crescent Lake, ranging from 8 to 12 mg/L. The range of pH measured at all sites in the Crescent River Basin indicates that all of the alkalinity can be attributed to dissolved bicarbonate. Alkalinity measurements of this magnitude indicate that waters in the Crescent Lake Basin have a low buffering capacity. Lower alkalinity levels during August and September are dependent on the amount of glacial meltwater inflow.

Major Ions, Dissolved Solids, Iron, and Manganese

Water samples collected from Crescent Lake (site 5) and the three surface-water sites were analyzed for major ions and dissolved solids (table 7). Major ions and dissolved solids in

Table 4. Physical field parameters for Crescent Lake, site 4, 2004.

[mg/L, milligrams per liter; us/cm at 25° Celsius, microsiemens per centimeter at 25° Celsius; NTU, Nephelometric Turbidity Unit]

Date	Depth (feet)	Dissolved Oxygen (mg/L)	Percent Saturation (percent)	pH (units)	Specific Conductance (µs/cm at 25° Celsius)	Water Temperature (° Celsius)	Turbidity (NTU)
6/23/2004	0	10.8	100	6.3	33	11.4	16.9
	8	11.1	100	6.3	32	11.4	17.6
	16	11.7	100	6.4	32	8.4	22.5
	25	12.1	97	6.3	30	5.2	18.0
	33	12.2	95	6.2	34	4.7	17.0
	41	12.2	94	6.2	36	4.4	15.0
	49	12.1	93	6.1	38	4.2	15.5
	57	12.0	92	6.0	38	3.9	15.5
	66	12.0	91	6.0	39	3.8	16.5
	74	12.0	91	5.9	39	3.9	18.0
	82	11.8	91	5.9	39	3.8	17.0
	90	11.9	90	5.9	39	3.8	17.0
7/29/2004	0	10.2	91	6.3	26	10.4	19.0
	8	10.3	89	6.4	26	9.0	31.0
	16	10.3	89	6.4	26	8.9	32.0
	25	10.4	89	6.3	25	8.7	38.0
	33	10.4	89	6.4	25	8.4	38.0
	41	10.5	89	6.3	24	8.2	38.0
	49	10.6	89	6.2	25	8.0	36.0
	57	10.7	89	6.2	26	7.3	36.0
	66	10.8	88	6.2	31	6.4	23.0
	74	11.0	87	6.2	31	5.8	21.0
	82	11.0	86	6.2	33	5.3	19.0
	90	11.1	87	6.2	35	4.3	17.0
	98	11.3	86	6.1	35	4.3	17.0
8/18/2004	0	8.4	85	6.4	26	16.0	2.0
	8	9.0	83	6.5	25	12.0	8.0
	16	9.1	81	6.6	24	10.0	9.0
	25	9.2	79	6.6	25	8.4	10.0
	33	9.3	78	6.7	26	7.7	11.0
	41	9.3	77	6.7	27	7.2	13.0
	49	9.4	77	6.6	29	6.6	6.0
	57	9.5	77	6.7	30	6.2	5.0
	66	9.5	76	6.7	31	5.6	6.0
	74	9.6	75	6.7	32	5.2	10.0
	82	9.6	75	6.7	32	4.9	5.0
	90	9.6	74	6.6	33	4.7	5.0
	98	9.5	74	6.6	33	4.6	7.0

Table 5. Physical field parameters for Crescent Lake, site 5, 2004.

[mg/L, milligrams per liter; µs/cm at 25° Celsius, microsiemens per centimeter at 25° Celsius; NTU, Nephelometric Turbidity Unit; constituent not measured]

Date	Depth (feet)	Dissolved Oxygen (mg/L)	Percent Saturation (percent)	pH (units)	Specific Conductance (µs/cm at 25° Celsius)	Water Temperature (° Celsius)	Turbidity (NTU)
6/23/2004	0	11.8	100	6	34	9.6	12.6
	8	11.9	100	6	34	8.3	13.8
	16	12.0	100	6	34	7.6	14.0
	25	12.1	98	6	35	6.3	14.0
	33	12.2	97	6	36	5.5	14.0
	41	12.3	94	6	35	4.2	17.0
	49	12.1	92	6	35	4.1	15.7
	57	12.0	92	6	38	4.0	16.2
	66	11.9	91	6	38	3.9	17.0
	74	11.9	90	6	38	3.8	16.0
	82	11.9	90	6	38	3.8	17.0
	90	11.9	90	6	38	3.8	17.0
	98	11.8	90	6	39	3.7	--
7/29/2004	0	10.4	92	6.3	29	10.0	18.0
	8	10.5	91	6.3	29	9.6	20.0
	16	10.5	90	6.4	29	9.0	21.0
	25	10.5	90	6.3	28	8.9	29.0
	33	10.6	91	6.2	28	8.8	30.0
	41	10.7	91	6.2	32	8.6	33.0
	49	10.7	91	6.1	28	8.1	31.0
	57	10.9	90	6.1	31	7.2	18.0
	66	11.2	89	6.1	32	6.2	17.0
	74	11.3	87	6.2	34	5.2	17.0
	82	11.2	86	6.2	35	4.8	16.0
	90	11.2	86	6.3	36	4.3	16.0
	98	11.2	86	6.4	36	4.3	16.0
	0						
8/18/2004	0	10.1	100	6.5	28	16.1	2.0
	8	11.3	100	6.6	29	11.1	9.0
	16	11.5	100	6.6	30	9.5	9.0
	25	11.6	99	6.4	30	8.8	7.0
	33	11.7	99	6.4	31	8.6	10.0
	41	11.8	98	6.3	31	7.3	10.0
	49	11.9	98	6.2	31	6.9	9.0
	57	11.9	97	6.2	32	6.4	7.0
	66	12.0	96	6.2	34	5.6	8.0
	74	12.0	95	6.2	35	5.1	6.0

Table 5. Physical field parameters for Crescent Lake, site 5, 2004.—Continued

[mg/L, milligrams per liter; µs/cm at 25° Celsius, microsiemens per centimeter at 25° Celsius; NTU, Nephelometric Turbidity Unit; constituent not measured]

Date	Depth (feet)	Dissolved Oxygen (mg/L)	Percent Saturation (percent)	pH (units)	Specific Conductance (µs/cm at 25° Celsius)	Water Temperature (° Celsius)	Turbidity (NTU)
8/18/2004 Continued							
	82	12.1	94	6.3	35	4.8	7.0
	90	12.1	94	6.3	36	4.6	4.0
	98	12.1	94	6.3	36	4.5	6.0
9/13/2004	0	12.9	100	5.9	21	9.8	--
	8	12.0	100	5.9	21	9.8	--
	16	11.7	100	6	20	9.7	--
	25	11.6	100	6.1	20	9.7	--
	33	11.4	99	6.1	20	9.5	--
	41	11.3	99	6.1	20	9.4	--
	49	11.2	97	6.2	20	9.4	--
	57	11.2	97	6.3	20	9.0	--
	66	11.1	96	6.3	21	8.8	--
	74	11.1	95	6.3	21	8.4	--
	82	11.1	94	6.7	21	7.6	--
	90	11.3	92	6.7	25	5.9	--

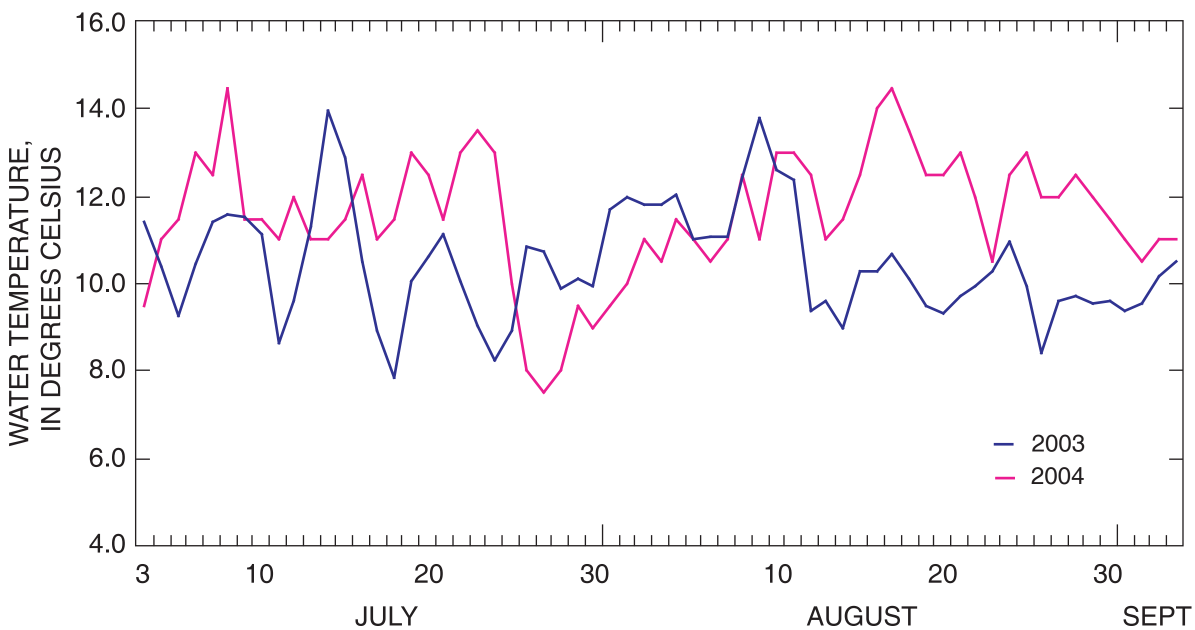

Figure 10. Continuous water temperature at Lake Fork Crescent River, July 3-September 3, 2003 and 2004.

Table 6. Physical field parameters for Crescent Lake, site 6, 2004.

[µs/cm at 25° Celsius, microsiemens per centimeter at 25° Celsius; mg/L, milligrams per liter; NTU, Nephelometric Turbidity Unit; constituent not measured]

Date	Depth (feet)	Dissolved Oxygen (mg/L)	Percent Saturation (percent)	pH (units)	Specific Conductance (µs/cm at 25° Celsius)	Water Temperature (° Celsius)	Turbidity (NTU)
6/23/2004	0	--	--	5.9	34	9.3	11.8
	8	--	--	5.9	32	5.4	14.4
	16	--	--	5.9	31	5.1	13.6
	25	--	--	5.9	32	4.7	15.4
	33	--	--	5.9	33	4.4	15.3
	41	--	--	5.9	34	4.2	15.0
	49	--	--	5.9	32	4.2	23.0
	57	--	--	5.9	31	4.2	21.0
	66	--	--	5.9	32	4.2	20.0
	74	--	--	5.9	34	4.0	20.0
	82	--	--	5.8	36	4.0	19.0
	90	--	--	5.8	36	3.9	18.0
	98	--	--	5.8	37	3.8	--
7/29/2004	0	12.8	100	6.3	29	10.0	19.0
	8	13.0	100	6.3	29	9.8	22.0
	16	13.1	100	6.3	29	8.6	22.0
	25	13.1	100	6.2	30	8.4	21.0
	33	13.2	100	6.2	30	8.0	18.0
	41	13.5	100	6.2	31	7.4	19.0
	49	13.9	100	6.2	32	6.5	19.0
	57	13.9	100	6.2	34	5.1	18.0
	66	13.9	100	6.2	35	4.8	18.0
	74	14.0	100	6.2	36	4.4	19.0
	82	13.9	100	6.3	36	4.0	19.0
	90	13.9	100	6.4	36	4.0	20.0
	98	14.2	100	6.5	37	4.2	--
8/18/2004	0	10.2	100	6.2	29	17.6	1.0
	8	10.9	100	6.4	28	14.0	2.0
	16	11.2	100	6.5	29	10.4	6.0
	25	11.1	100	6.5	29	9.9	5.0
	33	11.3	98	6.5	30	8.9	6.0
	41	11.4	97	6.5	30	8.2	7.0
	49	11.4	96	6.5	30	7.8	7.0
	57	11.5	96	6.5	31	7.6	6.0
	66	11.5	95	6.5	32	7.2	6.0
	74	11.6	96	6.5	32	7.2	6.0
	82	11.6	93	6.5	34	6.3	4.0
	90	11.6	91	6.5	35	5.3	4.0
	98	11.7	91	6.5	36	4.9	4.0

Table 7. Concentrations of major ions and trace elements iron and manganese in water samples collected in the Crescent River Basin.

[all values in milligrams per liter unless otherwise noted; µg/L, micrograms per liter; --, constitutent not measured]

Date	Time	Alkalinity	Bicarbonate	Calcium	Chloride	Dissolved Solids	Fluoride	Iron (µg/L)	Magnesium	Manganese (µg/L)	Potassium	Silica	Sodium	Sulfate
North Fork Crescent River (site 1)														
5/16/2003	1330	19	25	7.4	1.8	47	<0.2	679	0.57	40.0	0.66	10.6	2.2	5.6
7/2/2003	1630	7	8	3.2	0.5	16	<0.2	37	0.22	3.3	0.40	4.9	1.0	2.4
8/1/2003	1310	8	10	3.8	0.6	22	<0.2	24	0.27	4.4	0.35	5.2	1.0	3.3
10/23/2003	1230	16	20	7.0	1.3	42	<0.2	204	0.51	14.0	0.66	10.7	2.2	6.5
8/11/2004	1350	7	9	2.9	0.5	11	<0.2	40	0.22	5.6	0.25	4.2	0.8	2.7
9/8/2004	1350	12	16	5.1	1.1	35	<0.2	76	0.39	7.8	0.52	7.2	1.5	4.4
Crescent Lake (site 5)														
6/23/2004	1635	9.5	13	3.7	0.57	27	<0.2	26	0.20	3.2	0.45	5.3	0.87	2.0
7/29/2004	1400	7.9	9	2.9	0.32	13	<0.2	16	0.14	2.6	0.43	3.6	0.58	1.5
8/18/2004	1415	9.2	10	3.2	0.37	22	<0.2	17	0.16	1.1	0.49	3.9	0.61	1.4
9/13/2004	1415	8.8	10	3.2	0.30	20	<0.2	30	0.16	1.1	0.45	4.0	0.56	1.8
Lake Fork Crescent River (site 2)														
5/16/2003	1115	12	16	4.0	0.51	27	<0.2	37	0.21	<2.0	0.47	5.5	0.95	2.3
7/19/2003	1045	9	12	3.4	0.47	18	<0.2	18	0.18	0.6	0.52	4.4	0.88	1.8
8/14/2003	1025	10	13	3.3	0.38	22	<0.2	18	0.16	1.1	0.36	3.9	0.67	1.7
10/23/2003	1545	8	10	3.3	0.33	25	<0.2	65	0.19	1.9	0.54	4.6	0.83	1.8
7/2/2004	1245	8	10	3.4	0.47	15	<0.2	19	0.17	3.1	0.41	4.4	0.71	1.9
7/29/2004	1130	8	10	3.2	0.38	26	<0.2	20	0.16	2.4	0.45	3.9	0.70	1.7
8/18/2004	1200	8	10	3.2	0.54	17	<0.2	24	0.16	--	0.53	3.7	0.55	1.3
9/13/2004	1225	8	10	3.3	0.32	17	<0.2	18	0.16	1.4	0.47	4.0	0.60	1.8
Crescent River near mouth (site 3)														
5/16/2003	1615	14	18	5.6	2.3	48	<0.2	44	0.70	4.2	0.64	11.7	2.3	5.3
7/2/2003	1120	8	10	4.0	1.0	24	<0.2	23	0.39	2.9	0.47	6.7	1.4	2.9
8/1/2003	1730	9	11	3.9	1.4	25	<0.2	16	0.42	3.9	0.57	6.3	1.6	3.1
10/24/2003	1515	12	15	5.2	2.0	36	<0.2	10	0.67	6.3	0.66	11.4	2.3	5.4
8/11/2004	1520	9	12	3.6	1.2	24	<0.2	20	0.42	5.8	0.37	6.7	1.4	3.5
9/8/2004	1300	10	13	--	--	--	--	--	--	--	--	--	--	--

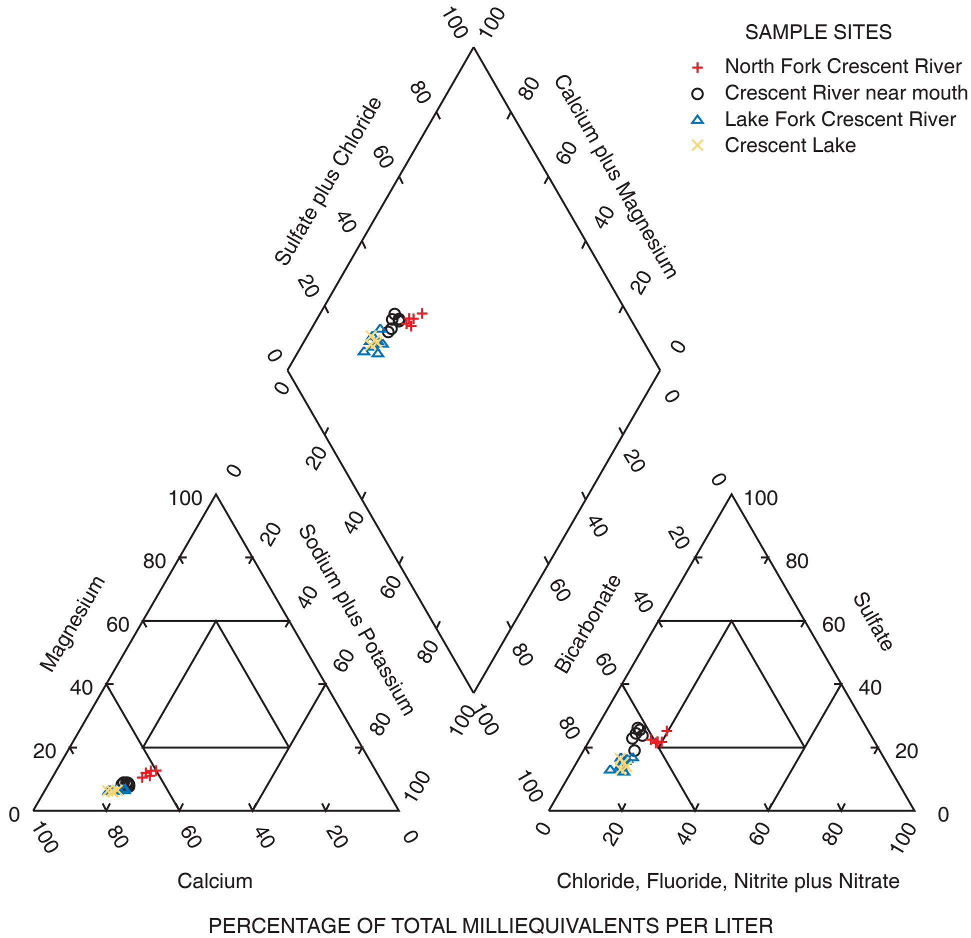

Figure 11. Trilinear diagram of water samples collected from the Crescent River Basin.

rivers consist of inorganic minerals derived primarily from soil and rock weathering. Dissolved cations that constitute a majority of the dissolved solids content in natural waters are calcium, magnesium, sodium, and potassium; the major anions are usually represented by sulfate, chloride, fluoride, nitrate, and those making up the alkalinity (Hem, 1985). Streams draining basins with rocks and soils containing insoluble minerals contain lower concentrations of dissolved solids. Analysis of water samples from the surface-water sites indicated that dissolved-solid concentrations were generally low, ranging from 11 to 48 mg/L (table 7). Dissolved-solids concentrations at Crescent Lake ranged from 13 to 27 mg/L (table 7). Low concentrations of dissolved solids such as these are representative of basins containing thin soils and rocks that are not easily dissolved or water that has had only brief contact time with more easily dissolved rocks.

Calcium and magnesium are both common alkaline-earth metals that are essential elements in plant and animal nutrition. Both elements are major components of the positively charged ions in most natural waters (Hem, 1985). Concentrations ranged from 2.9 to 7.4 mg/L for calcium and from 0.14 to 0.70 mg/L for magnesium. Concentrations of these constituents tended to be highest at the North Fork Crescent River and the mainstem Crescent River site. Sodium and potassium are both present in most natural waters, but usually in low concentrations in rivers. Sodium concentrations ranged from 0.55 to 2.3 mg/L at all sites sampled in the Crescent River Basin. Concentrations of sodium were all less than 1.0 mg/L at the Lake Fork Crescent River and Crescent Lake sites. Potassium concentrations ranged from 0.25 mg/L to 0.66 mg/L.

Bicarbonate was the dominant anion at both the surface-water and lake sites. Concentrations ranged from 8 to 25 mg/L at the surface water-sites and from 9 to 13 mg/L at the lake sites. Silica and sulfate, which are dissolved from rocks and soils, are the next most abundant anions, with concentrations ranging from 3.6 to 11.7 mg/L for silica and from 1.3 to 6.5 mg/L for sulfate. Chloride concentrations ranged from 0.3 to 2.3 mg/L.

Iron is dissolved from many rocks and soils and is an essential element in the metabolism of animals and plants. Iron in drinking water does not pose a health threat provided concentrations are less than 300 µg/L. Concentrations at all sites were less than or equal to 204 µg/L (table 7) with the exception of one sample at North Fork Crescent River that had a concentration of 679 μg/L. Manganese has chemistry similar to that of iron and concentrations should generally be less than 50 μg/L. All concentrations were less than or equal to 40 μg/L.

Trilinear diagrams were used to plot the major ions in milliequevalents per liter. The trilinear diagram permits the chemical composition of multiple samples to be represented on a single graph, and facilitates classification of the sample chemistry. On the basis of analyses of samples collected during this study, the water of the Crescent River sites and Crescent Lake can be classified as calcium bicarbonate water (fig. 11).

Nutrients and Organic Carbon

Nitrogen is an important water-quality constituent largely due to its role as a component of the protoplasm in aquatic biota, and thus it is an essential nutrient in lakes, streams, and rivers. In aquatic ecosystems, nitrogen commonly occurs in three ionic forms: ammonium (NH_4), nitrite (NO_2), and nitrate (NO_3). In the laboratory, ammonium is analyzed as ammonia (NH_3); thus nitrogen concentrations are reported as total and dissolved ammonia plus organic nitrogen, dissolved ammonia, dissolved nitrite plus nitrate, and dissolved nitrite. Nitrate is generally more abundant than nitrite in natural waters because nitrite readily oxidizes to nitrate in oxygenated water. Total ammonia plus organic nitrogen concentrations represent the ammonium and organic nitrogen compounds in solution and associated with colloidal material. Nitrate and nitrite are oxidized forms of inorganic nitrogen that make up most of the dissolved nitrogen in well-oxygenated streams such as the Crescent River. The dissolved concentrations represent the ammonium or nitrite plus nitrate in solution and are associated with material capable of passing through a 0.45-μm-pore filter.

All concentrations of the various nitrogen forms were low at less than 1 mg/L (table 8). Nitrate and nitrite concentrations were highest in the early spring. Lower concentrations were observed in July through September. Due to its toxicity to freshwater aquatic organisms, the U.S. Environmental Protection Agency (USEPA) (1976) suggests a limitation of 0.02 mg/L of ammonia as un-ionized ammonia for waters to be suitable for fish propagation. With the exception of one sample at the North Fork Crescent River (site 1), concentrations of ammonia (both ionized and unionized) were all below this level at all Crescent River and Crescent Lake sites.

Phosphorus is an element vital to all forms of aquatic biota because it is involved in the capture and transfer of chemical energy, and it is an essential element in nucleic acids (Gaudy and Gaudy, 1988). It occurs as organically bound phosphorus or as phosphate. Elevated concentrations of phosphorus in water are not considered toxic to human or aquatic life. Elevated concentrations can, however, stimulate the growth of algae in lakes and streams. Phosphorus concentrations are reported as total phosphorus and dissolved orthophosphate. Total phosphorus concentrations represent the phosphorus in solution, associated with colloidal material, and contained in or attached to biotic and inorganic particulate matter. Dissolved concentrations are determined from the filtrate that passes through a filter with a nominal pore size of 0.45 μm. The orthophosphate ion, PO_4, is a significant form of phosphorus because it is directly available for metabolic use by aquatic biota. Concentrations of total phosphorus, dissolved phosphorus and orthophosphate were typically low, with values near or below minimum reporting levels in nearly all Crescent River and Crescent Lake samples (table 8).

Phytoplankton (algae) can assimilate only three of the several different nutrient (nitrogen and phosphorus) compounds available in aquatic ecosystems. The only forms of nitrogen that phytoplankton can use for growth are nitrate, nitrite, and ammonia (inorganic nitrogen), whereas orthophosphate is the only form of phosphorus that phytoplankton can use for growth (Horne and Goldman, 1994). In general, a N:P ratio greater than 10 (by weight) indicates that phosphorus is the limiting nutrient, whereas a ratio less than 10 indicates that nitrogen is limiting (Horne and Goldman, 1994). For Crescent Lake N:P ratios ranged from 18 to 39, suggesting that phosphorus is the limiting nutrient.

DOC is commonly a major component of organic matter in aquatic ecosystems and is defined as organic carbon in the filtrate (dissolved and colloidal phases) that has passed through a 0.45-μm pore-size filter. Generally, DOC is in greater abundance than particulate organic carbon, accounting for about 90 percent of the total organic carbon of most waters (Aiken and Cotsaris, 1995). For the Crescent River and Crescent Lake sites, concentrations of DOC were all less than or equal to 1.1 mg/L.

Trace Elements in Streambed Sediments

Streambed sediments at the 3 surface-water sites in the Crescent River Basin were collected and analyzed for 39 trace elements (table 9). Most of the trace elements do not have an aquatic life standard. Thus, to provide a general comparison, the concentrations of trace elements in samples from the Crescent River Basin sites were compared to the concentrations of the NAWQA program data set, which consists of about 1,000 samples collected throughout the contiguous United States, Alaska, and Hawaii. Of these samples, about 250 samples represent reference or forested areas (V. Cory Stephens, U.S. Geological Survey, written commun. 2004). The concentrations of the Crescent River Basin data also were compared to concentrations of trace elements in streambed sediments collected from two other basins in Lake Clark National Park and Preserve: the Kijik River Basin and the Johnson River Basin. The 300 mi^2 Kijik River Basin is in the western part of the LACL, and is one of the key salmon spawning streams for Lake Clark. The 96 mi^2 Johnson River Basin is just south of the Crescent River Basin (fig. 1).

Most median concentrations of the trace elements collected in the Crescent River Basin were similar to the median concent rations for the NAWQA reference/forested sites, with

Table 8. Concentrations of nutrients and dissolved organic carbon in water samples collected in the Crescent River Basin.

[all values in milligrams per liter unless otherwise noted; <, less than; E, estimated; --, constituent not measured]

Date	Time	Dissolved Ammonia Nitrogen (NH_4)	Dissolved Nitrogen (NH_4+Org)	Total Nitrogen (NH_4 + Org)	Dissolved Nitrogen (NO_2+NO_3)	Dissolved Nitrogen (NO_2)	Dissolved Phosphorus	Dissolved Phosphorus Ortho	Total Phosphorus	N:P Ratio	Dissolved Organic Carbon
North Fork Crescent River (site 1)											
5/16/2003	1330	0.022	E0.06	E0.09	0.364	0.003	E0.002	<0.007	0.009		0.5
7/2/2003	1630	<0.015	E0.06	<0.10	0.055	<0.002	E0.003	<0.007	0.085		0.5
8/1/2003	1310	<0.015	<0.10	E0.05	0.039	<0.002	E0.003	<0.007	0.065		E0.2
10/23/2003	1230	E0.006	E0.06	<0.10	0.230	E0.001	E0.002	<0.006	0.010		0.5
8/11/2004	1350	<0.010	<0.10	<0.10	0.028	<0.002	0.005	E0.004	0.187		E0.2
9/8/2004	1350	E0.005	<0.10	E0.05	0.060	E0.001	0.004	<0.006	0.052		<0.3
Crescent lake (site 5)											
6/23/2004	1635	<0.010	<0.010	<0.01	0.221	<0.002	E0.002	<0.006	0.013	39	1.1
7/29/2004	1400	<0.010	<0.010	E0.05	0.097	E0.001	E0.002	<0.006	0.032	18	E0.2
8/18/2004	1415	<0.010	<0.010	<0.10	0.114	<0.002	<0.004	<0.006	0.016	39	E0.1
9/13/2004	1415	<0.010	<0.010	<0.10	0.094	E0.001	<0.004	<0.006	E0.010	18	0.4
Lake Fork Crescent River (site 2)											
5/16/2003	1115	<0.015	<0.10	<0.10	0.310	<0.002	<0.004	<0.007	<0.004		0.4
7/19/2003	1045	<0.015	<0.10	0.14	0.145	<0.002	<0.004	<0.007	0.008		0.4
8/14/2003	1025	E0.008	<0.10	<0.10	0.111	<0.002	<0.004	<0.007	0.014		E0.3
10/23/2003	1545	<0.010	<0.10	E0.06	0.157	E0.001	<0.004	<0.006	0.045		0.4
7/2/2004	1245	E0.005	<0.10	E0.05	0.154	<0.002	<0.004	<0.006	0.017		0.3
7/29/2004	1130	E0.007	<0.10	<0.10	0.126	<0.002	<0.004	<0.006	0.017		0.3
8/18/2004	1200	E0.005	<0.10	<0.10	0.092	E0.001	<0.004	<0.006	0.015		--
9/13/2004	1225	E0.006	<0.10	<0.10	0.094	E0.001	<0.004	<0.006	E0.009		0.4
Crescent River near mouth (site 3)											
5/16/2003	1615	<0.015	<0.10	E0.07	0.385	E.002	0.005	<0.007	0.008		0.6
7/2/2003	1120	<0.015	<0.10	E0.09	0.174	<0.002	E0.003	<0.007	0.127		0.4
8/1/2003	1730	0.040	0.23	0.26	0.101	<0.002	0.006	<0.007	0.079		1.0
10/24/2003	1515	<0.010	<0.10	<0.10	0.280	E0.001	0.005	E0.003	0.109		0.8
8/11/2004	1520	<0.010	E0.07	E0.06	0.118	E0.001	0.007	E0.004	0.197		E0.3
9/8/2004	1300	E0.006	E0.06	E0.06	0.146	E0.001	0.005	E0.003	0.052		E0.2

Table 9. Trace-element concentrations and percent organic carbon measured in streambed sediments.

Collected from sites located in the Crescent River Basin, September 2004. [values of carbon, aluminum, iron, and titanium in percent; all other values in micrograms per gram; <, less than]

Site #	Site name	Carbon (Organic)	Aluminum	Antimony	Arsenic	Barium	Berylium	Bismuth	Cadmium
1	North Fork Crescent River	1.9	9.1	0.3	4.7	600	0.8	<1	<.1
2	Lake Fork Crescent River	3	7.5	0.5	9	400	0.5	<1	0.2
3	Crescent River near mouth	7	8.4	0.3	2.9	430	0.5	<1	0.1

Site #	Site name	Cerium	Chromium	Cobalt	Copper	Europium	Gallium	Gold	Holmium
1	North Fork Crescent River	23	26	15	44	1	18	<1	<1
2	Lake Fork Crescent River	30	43	31	110	1	17	<1	1
3	Crescent River near mouth	22	20	31	72	1	20	<1	<1

Site #	Site name	Iron	Lanthanum	Lead	Lithium	Manganese	Mercury	Molybdenum	Neodymium
1	North Fork Crescent River	4.1	11	6	12	1000	0.02	1.1	14
2	Lake Fork Crescent River	7.9	13	8	16	1600	0.04	0.9	20
3	Crescent River near mouth	9.3	10	4	13	1700	<0.02	1.1	14

Site #	Site name	Nickel	Niobium	Scandium	Selenium	Silver	Strontium	Tantalum	Thallium
1	North Fork Crescent River	12	8	19	<.1	0.7	450	<1	<1
2	Lake Fork Crescent River	19	8	49	0.2	0.3	180	<1	<1
3	Crescent River near mouth	14	7	28	<.1	0.2	390	<1	<1

Site #	Site name	Thorium	Tin	Titanium	Uranium	Vanadium	Ytterbium	Yttrium	Zinc
1	North Fork Crescent River	3	1	0.37	1.2	130	2	19	72
2	Lake Fork Crescent River	6	2	0.7	2.9	220	4	13	120
3	Crescent River near mouth	2	1	0.87	1	380	2	19	150

the exception of higher concentrations of copper, scandium, and vanadium (table 10). Concentrations of cerium and lead in the Crescent River sites were lower than the NAWQA reference sites. Concentrations of most trace elements found in the Crescent, Johnson, and Kijik Rivers were similar. Notable exceptions were higher concentrations of arsenic, cerium, chromium, lanthanum, lithium, neodymium, thorium, and uranium found in the Kijik River samples. Concentrations of cadmium, lead, and zinc were higher at the Johnson River sites. Some of these sites, however, drain highly mineralized areas, which may explain these higher concentrations (Brabets and Riehle, 2003).

The focus in the literature on criteria for streambed sediments has been limited to nine trace elements: arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, and zinc. The Canadian Council of Ministers of the Environment (CCME) (1999) has established guidelines for some trace elements in unsieved streambed sediment. These guidelines use two assessment values: a lower value, called the "interim freshwater sediment quality guideline" (ISQG), is the concentration below which adverse effects are expected

Table 10. Comparison of concentrations of trace elements measured in streambed sediments from the USGS National Water-Quality Assessment program and range of concentrations from three surface water sites in the Crescent River Basin, four sites in the Kijik River Basin, and eight sites in the Johnson River Basin.

[values for aluminum, iron, and titanium in percent; all other values in micrograms per gram; <, less than; --, no data]

Trace element	NAWQA Reference Forested Sites (number of samples varies between 241 and 262)	Range in concentration from Kijik River sites	Range in concentration from Crescent River sites	Range in concentration from Johnson River sites
Aluminum	6.5	6.7-7.7	7.5-9.1	8.0-10
Antimony	0.7	1.1-2.0	0.3-0.5	0.4-10
Arsenic	7.0	24-32	2.9-9.0	16-64
Barium	470	680-850	400-600	200-1100
Berylium	2.0	2.0-2.4	0.5-0.8	0.2-1.0
Bismuth	--	<1	<1	<1
Cadmium	0.4	0.44-0.97	<0.1-0.2	<0.1-4.6
Cerium	70	66-82	22-30	21-36
Chromium	63	47-110	20-43	14-66
Cobalt	15	8.7-16	15-31	18-44
Copper	26	25-40	44-110	47-92
Europium	1.0	1.2-1.4	1	1.0-2.0
Gallium	16	18-20	17-20	15-20
Gold	--	<1	<1	<1
Holmium	--	1.0-1.3	<1-1	1.0-2.0
Iron	3.6	2.9-4.7	4.1-9.3	4.8-13
Lanthanum	--	36-43	10-13	8-15
Lead	24	24-32	4-8	4.0-230
Lithium	--	32-48	12-16	9-20
Manganese	955	720-1600	1000-1700	1200-2000
Mercury	0.07	<0.02-0.03	<0.02-0.04	0.10-0.93
Molybdenum	1	1.6-3.9	0.9-1.1	0.5-4.0
Neodymium	--	37-44	14-20	15-22
Nickel	26	14-32	12-19	4-25
Niobium	--	16-21	7-8	<4.0
Scandium	12	14-20	19-49	29-56
Selenium	0.7	0.11-0.95	<0.1-0.2	0.2-2.6
Silver	0.2	0.29-0.43	0.2-0.7	<0.1-0.8
Strontium	140	230-240	180-450	8.5-200
Tantalium	--	1.1-1.3	<1	<1
Thallium	--	<1	<1	<1-1.3
Thorium	12.0	7-12	2-6	<1-2
Tin	2.5	3.1-3.6	1-2	1-2
Titanium	0.37	0.41-0.59	0.37-0.87	0.5-0.8
Uranium	3.9	3.5-10	1-2.9	0.8-1.1
Vanadium	84	75-140	130-380	140-550
Ytterbium	--	2.6-3.3	2-4	3-4
Yttrium	--	28-34	13-19	27-43
Zinc	110	120-170	72-150	85-1800

Table 11. Comparison of streambed sediment quality guidelines to concentrations measured in streambed sediments in the Crescent River Basin for selected trace elements.

[Values in micrograms per gram; <, less than; --, no guideline established]

Trace Element	Interim Freshwater Sediment Quality Guideline (ISQG)[1]	Threshold Effect Concentration (TEC)[2]	Probable Effect Level (PEL)[1]	Probable Effect Concentration (PEC)[2]	Range in Crescent River samples
Arsenic	5.9	9.8	17.0	33.0	2.9 - 9
Cadmium	0.6	0.99	3.5	5.0	<.1 - .2
Chromium	37.3	43.4	90	111	20 - 43
Copper	35.7	31.6	197	149	44 - 110
Lead	35.0	35.8	91.3	128	4 - 8
Mercury	0.17	0.18	0.49	1.06	<0.02 – 0.04
Nickel	--	22.7	--	48.6	12 - 19
Selenium[3]	--	2.5	--	4.0	<.1 – .2
Zinc	123	121	315	459	72 - 150

[1] Canadian Council of Ministers of the Environment (1999)

[2] MacDonald and others (2000)

[3] Van Derveer and Canton (1997)

to occur rarely; and an upper value, called the "probable effect level" (PEL), is the concentration above which adverse effects are expected to occur frequently (table 11). Because trace-element samples for this study are from sediments finer than 0.063 mm, in which concentrations tend to be greatest, comparisons with the Canadian guidelines may overestimate the effects on aquatic organisms (Deacon and Stephens, 1998). However, it was felt that the PEL would be useful for comparative purposes when applied to the finer than 0.063-mm size fraction sediment samples analyzed for this study.

MacDonald and others (2000) proposed sediment quality guidelines for eight trace elements, and Van Derveer and Canton (1997) proposed guidelines for selenium. These guidelines use the following two concentrations for a given trace element: the threshold effect concentration (TEC) and the probable effect concentration (PEC) and assume a 1 percent organic carbon concentration. The TEC is the concentration below which sediment-dwelling organisms are unlikely to be adversely affected, and the PEC is the concentration above which toxicity is likely. In addition, MacDonald and others (2000) developed a Mean PEC Quotient, which is the toxicity of the combined trace- element concentrations. The Mean PEC Quotient is computed by summing the concentrations of all the trace elements analyzed and dividing by the number of elements. MacDonald and others (2000) found that sediments with mean PEC quotients less than 0.5 accurately predicted the absence of toxicity in 83 percent of the samples they examined. Mean PEC quotients greater than 0.5 accurately predicted toxicity in 85 percent of the samples.

When compared to the different guidelines, the concentration of chromium at the Lake Fork Crescent River, copper at all three stream sites, and zinc at the Crescent River near the mouth site exceeded the ISQG guidelines. Concentrations of copper at all sites and the concentration of zinc at the Crescent River near the mouth exceeded the TEC guidelines. All concentrations were below the PEL and PEC guidelines.

Comparison of the concentrations of the trace elements with the percent organic carbon and Mean PEC Quotient provides some insights about the bioavailability of these trace elements. The concentration of organic carbon in sediment is used to indicate the concentration of organic matter. The ability of organic matter to concentrate some trace elements in stream sediment is well recognized (Gibbs, 1973, Horowitz, 1991), and this ability varies with the type of organic matter. For example, complexation by organic matter, such as humic and fulvic acids, has generally been thought to reduce bioavailability (Spacie and Hamelink, 1985, Newman and Jagoe, 1994). Results of studies by Decho and Luoma (1994) and Winner (1985) suggest that organic carbon compounds may in some cases enhance uptake of certain trace elements. All three streambed sediment samples from the Crescent River had values of organic carbon greater than 1 percent (table 12). Compared to the percent organic carbon found in samples from the Kijik River and the Johnson River, most organic carbon values were less than 1 percent in the samples from the Crescent River. With the exception of one sample, the mean PEC quotient in the Johnson River samples was greater than 0.50, which would indicate some level of potential toxicity (table 12). As MacDonald and others (2000) noted, sites

Table 12. Concentrations of priority pollutant trace elements in streambed sediments finer than 0.063 mm for sites located in Lake Clark National Park and Preserve.

[concentrations in micrograms per gram, dry weight, organic carbon in percent; As, arsenic; Cd, cadmium; Cr, chromium; Cu, copper; Pb, lead; Hg, mercury; Ni, nickel; Se, selenium; Zn, zinc; <, less than; values in bold are concentrations that when normalized to one percent organic carbon, exceed Probable Effect Concentration (PEC), or for the mean PEC quotient, indicate toxicity for the sum of trace elements excluding selenium (MacDonald and others, 2000)]

Site #	Site name	Latitude	Longitude	Priority pollutant trace element										
				As	Cd	Cr	Cu	Pb	Hg	Ni	Se	Zn	Organic carbon	Mean PEC Quotient
	Crescent River Basin - Lake Clark National Park and Preserve													
1	North Fork Crescent River	602604	1525400	4.7	0.1	26	44	6	0.02	12	0.1	72	1.9	0.08
2	Lake Fork Crescent River	602129	1524907	9	0.2	43	110	8	0.04	19	0.2	120	3	0.09
3	Crescent River near mouth	601436	1523449	2.9	0.1	20	72	4	0.02	14	0.1	150	7	0.03
	Kijik River Basin - Lake Clark National Park and Preserve													
	Little Kijik River above Kijik Lake	601708	1542035	29	0.97	110	40	28	0.03	32	0.95	170	2.43	0.19
	Little Kijik River below Kijik Lake	601828	1541717	26	0.63	47	25	24	0.03	14	0.63	120	3.13	0.09
	Kijik River above Little Kijik River	601833	1541541	**24**	0.44	**62**	26	24	0.02	16	0.11	120	0.42	0.7
	Kijik River 1.5 miles above mouth	601801	1541436	32	0.73	69	34	32	0.02	20	0.25	150	1.06	0.35
	Johnson River Basin--Lake Clark National Park and Preserve													
	North Fork Ore Creek near mouth near Johnson Glacier	600658	1525814	**34**	<.1	**41**	**54**	<1	**0.53**	**15**	0.2	**120**	0.16	**2.21**
	East Fork Ore Creek near mouth near Johnson Glacier	600713	1525740	**64**	**4.3**	14	76	**230**	0.93	4	2.6	**1000**	1.00	**0.72**
	Ore Creek near mouth near Johnson Glacier	600715	1525728	**44**	**4.6**	23	**92**	**180**	**0.28**	8	1.2	**1800**	0.24	**4.60**
	Kona Creek 3 mi above mouth above Lateral Glacier	600826	1525544	**19**	<.1	**38**	**56**	6	**0.75**	11	0.6	**120**	0.25	**1.27**
	Kona Creek 2.5 mi above Lateral Glacier	600803	1525524	**18**	0.1	**42**	**57**	5	0.16	11	0.6	**140**	0.26	**0.98**
	Kona Creek 0.8 mi above mouth above Lateral Glacier	600636	1525514	**16**	0.4	48	63	17	0.28	14	0.7	150	0.49	**0.62**
	Unnamed tributary to Kona Creek above Lateral Glacier	600635	1525509	18	<.1	77	47	4	0.1	25	0.2	85	1.30	0.23
	Johnson River above Lateral Glacier	600541	1525438	**16**	0.2	**66**	**75**	4	**0.13**	17	0.3	**130**	0.05	**6.02**

Table 13. Macrozooplankton data for Crescent Lake.

[taxa in number per cubic meter; --, no data]

Date	*Cyclops*	Ovigerous Cyclops
Site 4		
6/23/2004	223	0
7/29/2004	2,145	0
Mean	1,184	0
Site 5		
6/23/2004	1,107	6
7/29/2004	524	--
8/18/2004	679	--
9/13/2004	28	1
Mean	584	4
Site 6		
6/23/2004	178	0
7/29/2004	1,992	18
Mean	1,085	9

Table 14. Seasonal means of length and biomass of zooplankton from Crescent Lake.

[Values in millimeters for length and milligrams per cubic meter for biomass]

	Mean Length	Weighted Length	Mean Biomass	Weighted Biomass
Site 4				
Cyclops	0.76	0.69	2	2
TOTAL			2	2
Site 5				
Cyclops	0.86	0.84	2	1
Ovigerous Cyclops	1.38	1.37	0.03	0.03
TOTAL			2.03	1.03
Site 6				
Cyclops	0.79	0.74	2	2
Ovigerous Cyclops	1.29	1.29	<1	<1
TOTAL			2	2

containing relatively low concentrations of organic carbon have higher potential toxicity. When normalized to percent organic carbon, no concentrations of trace elements in the Crescent River samples exceeded the PEC level.

Biology of the Crescent River Basin

Zooplankton

Zooplankton samples were collected in June and July 2004 at Crescent Lake sites 4 and 6 and in June, July, August, and September 2004 at site 5. The only genus identified was *Cyclops*, including a relatively small number of ovigerous *(egg-bearing) Cyclops* (table 13). *Cyclops* are one of the primary food sources for rearing sockeye salmon juveniles and were most prevalent in the July sampling. Sites 4 and 6 were very similar with regard to the length and the biomass of *Cyclops* (table 14). Site 5 exhibited *Cyclops* that were generally greater in length, but accounted for less in overall biomass.

Algae

Algae QMH samples were collected from Crescent River near the mouth (site 3) and the North Fork Crescent River (site 1). No quantitative data were collected at either of the Crescent River sites, so no quantitative assessments of biovolume or standing crop were performed. However, 59 species of algae were found within the 2 drainages, and several generalizations may be drawn from the simple presence/absence dataset (tables 15-18). Because of the complex response patterns of these metrics they are most useful for relative comparisons in larger datasets, although values do provide useful baseline measures. To further explain some of the observations, algae data that were collected in the Kijik River Basin in 2004 are also discussed in this section.

A total of fifty-nine taxa were found at the two Crescent River sites, and were comprised of four phyla (table 15): Rhodophyta (Red algae), Cyanophyta (blue-green algae), Chlorophyta (green algae), and Chrysophta (diatoms). Their general composition were: Rhodophyta (red algae), with one new individual yet to be fully described, Cyanophyta (blue-green algae) composed of one family containing two taxa, Chlorophyta (green algae) composed of two families, each with one taxa, and Chrysophyta (diatoms) which had the greatest number of taxa and was composed of seven families, four of which (Achnanthaceae, Diatomaceae, Naviculaceae, and Nitzschiceae) contained the vast majority of remaining taxa. Eight species—*Cymbella latens*, *Diatoma tenuis*, *Encyonema silesiacum*, *Fragilaria capucina*, *Fragilaria vaucheriae*,

Table 15. Algal taxa present for qualitative-multi-habitat (QMH) samples collected July-September 2004, at two stream sites in the Crescent River Basin and four stream sites in the Kijik River Basin.

[X, species present. --, species not present]

Taxonomy	North Fork Crescent River	Crescent River near mouth	Little Kijik River above Kijik Lake	Little Kijik River below Kijik Lake	Kijik River above Little Kijik	Kijik River 1.5 miles above mouth
PHYLUM						
Family						
Genus species						
RHODOPHYTA (red algae)						
Unknown						
Unknown Rhodophyte Florideophycidae (chantransia)	X	--	--	--	--	--
CYANOPHYTA (blue-green algae)						
Borziaceae						
Komvophoron schmidlei	--	--	X	--	--	--
Merismopediaceae						
Merismopedia arctica	--	--	--	--	X	--
Oscillatoriaceae						
Oscillatoria lutea	--	--	X	--	X	--
Phormidiaceae						
Phormidium autumnale (CA Agardh) Gomont	--	--	X	--	X	--
Pseudanabaenaceae						
Geitlerinema splendidum	--	--	--	X	--	--
Homoeothrix sp.	--	X	X	--	X	--
Leptolyngbya sp.	X	--	--	--	--	--
Pseudanabaena sp.	--	--	X	--	X	X
Undetermined						
Unknown Cyanophyte coccoid	--	--	--	X	--	--
CHLOROPHYTA (green algae)						
Chaetophoraceae						
Stigeoclonium lubricum	--	--	--	X	--	--
Desmidiaceae						
Staurastrum sp.	--	--	X	--	--	X
Hydrodictyaceae						
Pediastrum boryanum	--	--	--	X	--	--
Scenedesmaceae						
Scenedesmus ecornis	--	--	X	--	--	--
Ulvaceae						
Schizomeris leibleinii	--	X	--	--	--	--
Volvocaceae						
Eudorina elegans	--	--	X	--	--	--
Zygnemataceae						
Mougeotia sp.	--	--	X	--	--	X

Table 15. Algal taxa present for qualitative-multi-habitat (QMH) samples collected July-September 2004, at two stream sites in the Crescent River Basin and four stream sites in the Kijik River Basin.—Continued

[X, species present. --, species not present]

Taxonomy	North Fork Crescent River	Crescent River near mouth	Little Kijik River above Kijik Lake	Little Kijik River below Kijik Lake	Kijik River above Little Kijik	Kijik River 1.5 miles above mouth
Spirogyra sp.	X	--	--	--	--	--
Zygnema sp.	--	--	--	X	X	--
CHRYSOPHYTA (diatoms)						
Achnanthaceae						
Achnanthes biasolettiana	--	X	--	--	--	--
Achnanthes kriegeri	--	--	X	--	--	X
Achnanthes lanceolata var. haynaldii	--	X	--	--	--	--
Achnanthes minutissima var. jackii	--	X	X	X	X	X
Achnanthes nodosa	--	X	X	X	--	--
Achnanthidium altergracillima	--	--	--	--	X	--
Achnanthidium kranzii	--	--	X	--	--	--
Achnanthidium minutissimum	--	X	X	X	--	--
Cocconeis placentula var. lineata	--	--	--	--	--	X
Eucocconeis flexella	--	X	X	--	X	X
Eucocconeis laevis	--	--	X	--	--	X
Planothidium frequentissimum	--	--	--	X	--	--
Planothidium lanceolatum	--	X	X	X	--	--
Psammothidium grischunum fo. Daonensis	--	--	--	X	--	--
Psammothidium helveticum	--	X	X	X	--	--
Psammothidium lacus-vulcani	--	--	--	X	--	--
Psammothidium subatomoides	--	--	--	X	--	--
Psammothidium ventralis	--	--	X	--	--	--
Rossithidium petersennii	--	X	X	X	--	X
Rossithidium pusillum	--	--	--	X	--	--
Diatomaceae						
Diatoma mesodon	X	--	X	--	--	--
Diatoma tenuis	X	X	X	--	X	X
Fragilaria capucina	X	X	--	X	X	--
Fragilaria capucina var. mesolepta	--	--	--	X	--	--
Fragilaria capucina var. rumpens	--	X	X	X	X	X
Fragilaria nanana	--	X	X	--	--	--
Fragilaria sp. 8 NAWQA EAM	--	--	X	X	--	--
Fragilaria tenera	--	--	X	--	--	--
Fragilaria vaucheriae	X	X	X	X	X	X
Fragilariforma bicapitata	--	--	X	--	--	--
Fragilariforma sp. 1 NAWQA EAM	--	--	X	--	--	--
Hannaea arcus	X	X	X	--	X	X
Hannaea arcus fo. recta	--	X	--	--	--	--

Table 15. Algal taxa present for qualitative-multi-habitat (QMH) samples collected July-September 2004, at two stream sites in the Crescent River Basin and four stream sites in the Kijik River Basin.—Continued

[X, species present. --, species not present]

Taxonomy	North Fork Crescent River	Crescent River near mouth	Little Kijik River above Kijik Lake	Little Kijik River below Kijik Lake	Kijik River above Little Kijik	Kijik River 1.5 miles above mouth
Meridion circulare	X	--	X	--	--	--
Meridion circulare var. constrictum	--	--	X	--	--	--
Opephora martyi	--	--	--	X	--	--
Pseudostaurosira pseudoconstruens	--	X	--	X	--	--
Pseudostaurosira robusta	--	--	--	X	--	--
Pseudostaurosira sp. 2 NAWQA EAM	--	--	--	X	--	--
Stauroforma exiguiformis	--	--	X	--	--	--
Staurosira construens	--	--	--	--	X	--
Staurosira construens var. binodis	X	--	--	X	X	--
Staurosira construens var. venter	--	--	--	X	--	--
Staurosira elliptica	--	X	X	X	--	--
Staurosirella lapponica	--	--	--	X	--	--
Staurosirella leptostauron var. rhomboides	--	--	--	X	--	--
Staurosirella pinnata	--	--	X	X	X	X
Staurosirella sp. 7 NAWQA EAM	--	--	--	X	--	--
Synedra amphicephala var. austriaca	--	--	--	X	X	X
Synedra delicatissima	--	--	--	X	X	X
Synedra delicatissima var. angustissima	--	--	--	X	--	--
Synedra ulna	X	--	X	--	X	X
Tabellaria fenestrata	X	--	X	--	--	--
Tabellaria flocculosa	X	X	X	X	X	X
Eunotiaceae						
Eunotia flexuosa	--	--	X	--	--	--
Eunotia minor	--	X	X	--	--	--
Eunotia paludosa	--	--	X	--	--	--
Naviculaceae						
Amphora pediculus	--	--	--	X	X	--
Amphora sp. 6 NAWQA EAM	--	X	--	X	X	--
Brachysira microcephala	--	X	X	X	X	X
Caloneis bacillum	--	--	--	X	--	--
Caloneis silicula	--	--	X	--	--	--
Cavinula pseudoscutiformis	--	--	--	X	--	--
Cymbella arctica	X	--	--	--	--	--
Cymbella cistula	X	--	--	X	--	--
Cymbella delicatula	--	--	--	X	X	--
Cymbella dorsenotata	--	--	--	--	--	X
Cymbella hilliardii	--	--	--	X	--	--

Table 15. Algal taxa present for qualitative-multi-habitat (QMH) samples collected July-September 2004, at two stream sites in the Crescent River Basin and four stream sites in the Kijik River Basin.—Continued

[X, species present. --, species not present]

Taxonomy	North Fork Crescent River	Crescent River near mouth	Little Kijik River above Kijik Lake	Little Kijik River below Kijik Lake	Kijik River above Little Kijik	Kijik River 1.5 miles above mouth
Cymbella latens	X	X	X	--	--	--
Cymbella mesiana	--	X	X	--	X	--
Cymbella naviculiformis	--	--	X	--	--	--
Cymbella stauroneiformis	--	--	X	--	--	--
Diadesmis confervacea	--	--	--	--	X	--
Diadesmis contenta	--	--	X	--	--	--
Didymosphenia geminata	--	X	--	--	X	--
Diploneis parma	--	--	--	X	--	--
Encyonema minutum	--	X	X	X	X	X
Encyonema reichardtii	--	--	X	--	--	--
Encyonema silesiacum	X	X	X	X	X	--
Encyonema triangulum	--	--	--	X	--	--
Encyonopsis aff. cesatii EAM	--	--	X	X	X	X
Encyonopsis cesatii	--	--	--	X	--	--
Encyonopsis descripta	--	--	--	X	--	--
Encyonopsis microcephala	--	--	--	X	X	--
Encyonopsis sp. 1 NAWQA EAM	--	X	--	X	X	--
Frustulia rhomboides var. viridula	X	--	--	--	--	--
Frustulia saxonica	--	--	--	X	--	--
Gomphonema angustatum	--	X	X	X	--	X
Gomphonema micropus	--	--	X	--	--	--
Gomphonema olivaceoides var. hutchinsoniana	--	X	--	--	--	--
Gomphonema olivaceum	--	X	--	--	X	X
Gomphonema productum	X	X	--	--	--	--
Gomphonema sarcophagus	--	--	X	--	--	--
Gomphonema sp. 3 Idaho SEH	X	--	--	--	--	--
Mayamaea atomus	--	X	--	--	--	--
Navicula arctotenelloides	--	X	--	--	--	--
Navicula cf. kriegerii NAWQA KM	--	--	--	--	--	X
Navicula cryptocephala	--	--	X	--	--	--
Navicula cryptotenella	--	X	--	X	--	X
Navicula hambergii	--	X	--	--	--	--
Navicula indifferens	--	--	--	X	--	--
Navicula sp. 44 NAWQA EAM	--	--	--	X	--	--
Navicula vulpina	--	--	--	X	--	--
Reimeria sinuata	--	X	X	--	--	X
Sellaphora pupula	--	--	--	X	--	--
Sellaphora seminulum	--	--	--	X	--	--

Table 15. Algal taxa present for qualitative-multi-habitat (QMH) samples collected July-September 2004, at two stream sites in the Crescent River Basin and four stream sites in the Kijik River Basin.—Continued

[X, species present. --, species not present]

Taxonomy	North Fork Crescent River	Crescent River near mouth	Little Kijik River above Kijik Lake	Little Kijik River below Kijik Lake	Kijik River above Little Kijik	Kijik River 1.5 miles above mouth
Stauroneis anceps	X	--	X	--	--	--
Nitzschiaceae						
Denticula kuetzingii	--	--	--	X	--	--
Denticula tenuis	--	X	--	X	X	X
Nitzschia angustata	--	--	--	X	--	--
Nitzschia dissipata	--	X	--	--	--	--
Nitzschia frustulum	--	X	--	X	X	--
Nitzschia linearis	--	--	X	--	--	--
Nitzschia modesta	X	--	--	--	--	--
Nitzschia palea	--	X	--	--	--	X
Nitzschia solita	--	--	X	--	--	--
Surirellaceae						
Surirella brebissonii	--	X	--	--	--	--
Thalassiosiraceae						
Aulacoseira crenulata	--	--	X	--	--	--
Aulacoseira granulata	--	--	X	--	--	--
Cyclotella ocellata	--	--	--	--	X	--
Cyclotella stelligera	--	X	--	--	X	X

Gomphonema productum, *Hannaea arcus*, and *Tabellaria flocculosa*—all diatoms, were common to both sites. Of these species, only *Hannaea arcus* is considered motile. The occurrence of motile species may be interpreted as a sign of a disturbed or highly variable environment, which would tend to favor motile species that, for example, may escape being covered by fine sediments that often occur in disturbed environments. Motile species are capable of movement over a surface or through the water column. None of these eight species fix nitrogen from the atmosphere, and all but one (*T. flocculosa*) are benthic (attached to the bottom) suggesting that the areas where they were collected are relatively stable or that these taxa may be capable of rapid recolonization after a perturbation. Most also tend to prefer neutral to slightly acidic conditions, though *D. tenuis* and *F. vaucheriae* are more tolerant of slightly basic conditions. Salinity values of less than 0.9 parts per thousand (ppt) were preferred by all but *D. tenuis*, which generally prefers slightly higher chloride concentrations, and subsequently, salinity values that typically range from 0.9-1.8 ppt (tables 16 and 17) (Stephen Porter, USGS, written commun. 2005).

The North Fork Crescent River (site 1) samples yielded 22 algal taxa (table 15). Nineteen were diatoms (80 percent), with one each of blue-green, green, and red algae. The red algae was an unknown taxa that was unique to the North Fork Crescent River site, even when considering the four nearby Kijik and Little Kijik River sites (likewise sampled for algae using the same protocol). Fourteen of the taxa found within the Crescent River basin were unique to the upper site. Eighty-one percent (table 18) of the unique taxa were non-motile (only three lived suspended in the water column), about 76 percent tended to prefer neutral to slightly basic pH, and about 90 percent preferred conditions ranging from <0.2 ppt to <0.9 ppt salinity. Many taxa found at this site were generally more tolerant to organically bound nitrogen, which suggests that this reach is also able to support some eutrophic species. Many algal taxa have minimum dissolved-oxygen saturation requirements. At the North Fork Crescent River, about 45 percent of the taxa require nearly 100 percent saturation. About 30 percent of the taxa require a minimum of 75 percent saturation, and the remaining taxa require at least 50 percent saturation. Finally, the trophic condition for the upstream site yielded only one taxa (*Frustulia rhomboides var. viridula*) considered to prefer oligotrophic conditions. The mean trophic condition for the site, excluding absence values and values meaning ubiquity across the ranges (in this case, the value “7” denotes a wide range of tolerance and are thus indifferent), was between oligo-mesotrophic and mesotrophic and indicated slightly higher nutrient enrichment than at the downstream site. Roughly 40 percent of the 22 taxa did not have a value

Table 16. Algal autecology characteristics and category values used to describe community structure at sample sites.

[<, less than; >, greater than; Stephen Porter, U.S. Geological Survey, written commun., 2002]

Characteristic	Category Code	Category Name	Category Description
Benthic-Sestonic Taxa	1	benthic	primarily or exclusively associated with benthic substrates
Benthic-Sestonic Taxa	2	sestonic	primarily or exclusively sestonic (planktonic taxa)
Motility	1	motile	taxa with capability of movement in the water column or on submerged surfaces
Motility	2	non-motile	taxa without capability of movement; attached to submerged surfaces
Nitrogen Fixers	1	Nitrogen Fixer	taxon is capable of fixing atmospheric nitrogen
Nitrogen Fixers	2	Not Nitrogen Fixer	taxon not capable of fixing atmospheric nitrogen
Nitrogen Uptake Metabolism	1	N autotroph - low org N	taxa generally intolerant to organically-bound nitrogen; some may be “oligotrophic” or “mesotrophic species
Nitrogen Uptake Metabolism	2	N autotroph - high org N	taxa tolerant to organically-bound nitrogen; some may be “eutrophic” taxa
Nitrogen Uptake Metabolism	3	N heterotroph - high org N (facultative)	taxa requiring periodic elevated concentrations of organically-bound nitrogen
Nitrogen Uptake Metabolism	4	N heterotroph - high org N (obligate)	taxa indicative of elevated concentrations of organically-bound nitrogen
Oxygen Requirement	1	always high	nearly 100% DO saturation
Oxygen Requirement	2	fairly high	> 75% DO saturation
Oxygen Requirement	3	moderate	> 50% DO saturation
Oxygen Requirement	4	low	> 30% DO saturation
Oxygen Requirement	5	very low	about 10% DO saturation or less
pH	1	acidobiontic	<7, optimum < 5.5
pH	2	acidophilous	<7, optimum < 7
pH	3	circumneutral	around 7
pH	4	alkaliphilous	>7, occurring ~ 7
pH	5	alkalibiontic	above 7
pH	6	indifferent	~ 7
Salinity	1	fresh	< 100 mg/L chloride; < 0.2 ppt salinity
Salinity	2	fresh brackish	< 500 mg/L chloride; < 0.9 ppt salinity
Salinity	3	brackish fresh	500 - 1000 mg/L chloride; 0.9 - 1.8 ppt salinity
Salinity	4	brackish	1000 - 5000 mg/L chloride; 1.8 - 9.0 ppt salinity
Trophic Condition	1	oligotrophic	
Trophic Condition	2	oligo-meso	
Trophic Condition	3	mesotrophic	
Trophic Condition	4	meso-eutrophic	
Trophic Condition	5	eutrophic	
Trophic Condition	6	polytrophic	
Trophic Condition	7	eurytrophic	wide range of tolerance to nutrient concentrations; indifferent

Table 17. Algal taxa autecology for taxa found at the two sites sampled within the Crescent River Basin, July 2004.

[Taxa are sorted alphabetically. See Table 16 - Algal Autecology Values; taxa id from Philadelphia Academy of Natural Sciences]

FULLNAME	North Fork Crescent River	Crescent River near mouth	Taxon ID	Motility	Nitrogen Fixing	pH	Salinity	Organic Nitrogen	Oxygen Tolerance	Trophic	Benthic or Sestonic
Achnanthidium minutissimum (Kützing) Czarnecki	0	1	1,010	2	2	6	2	2	1	7	1
Achnanthes lanceolata var. haynaldii (Schaarschmidt) Cleve	0	1	2,017	2	2	4	2	2	3	7	1
Achnanthes nodosa Cleve	0	1	2,032	2	2						1
Achnanthes biasolettiana (Kützing) Grunow	0	1	2,053	2	2	4	2			3	1
Achnanthes minutissima var. jackii (Rabhenhost) Lange-Bertalot et Ruppel	0	1	2,176	2	2	3	2				1
Amphora sp. 6 NAWQA EAM	0	1	7,078								
Brachysira microcephala (Grunow) Compère	0	1	18,013	2	2						1
Cyclotella stelligera (Cleve et Grunow) Van Heurck	0	1	20,010	2	2	6	2				2
Cymbella cistula (Ehrenberg) Kirchner	1	0	23,005	2	2	4	2	1	2	5	1
Cymbella mesiana Cholnoky	0	1	23,127	2	2	4	2				1
Cymbella latens Krasske	1	1	23,163	2	2						1
Cymbella arctica (Lagerstedt) Schmidt	1	0	23,191	2	2						1
Denticula tenuis Kützing	0	1	25,002	1	2	4	1	1	1	3	1
Diatoma mesodon (Ehrenberg) Kützing	1	0	27,002	2	2	3	1	1	1	3	1
Diatoma tenuis Agardh	1	1	27,012	2	2	4	3	2	3	5	1
Eunotia minor (Kützing) Grunow	0	1	33,183	2	2	2	1				1
Fragilaria capucina Desmazières	1	1	34,006	2	2	3	2			3	1
Fragilaria vaucheriae (Kützing) Petersen	1	1	34,030	2	2	4	2	2	3	5	1
Fragilaria nanana Lange-Bertalot	0	1	34,088	2	2	3	1	1	1	2	1
Fragilaria capucina var. rumpens (Kützing) Lange-Bertalot	0	1	34,109	2	2	3	2			2	1
Frustulia rhomboides var. viridula (Brébisson) Cleve	1	0	35,006	1	2	2	1	1	1	1	1
Gomphonema angustatum (Kützing) Rabenhorst	0	1	37,003	2	2	4	2	1	1	1	1
Gomphonema productum (Grunow) Lange-Bertalot et Reichardt	1	1	37,055	2	2	3	2	2	1	2	1

Table 17. Algal taxa autecology for taxa found at the two sites sampled within the Crescent River Basin, July 2004.—Continued

[Taxa are sorted alphabetically. See Table 16 - Algal Autecology Values; taxa id from Philadelphia Academy of Natural Sciences]

FULLNAME	North Fork Crescent River	Crescent River near mouth	Taxon ID	Motility	Nitrogen Fixing	pH	Salinity	Organic Nitrogen	Oxygen Tolerance	Trophic	Benthic or Sestonic
Gomphonema olivaceum (Lyngbye) Kützing	0	1	37,065	2	2	5	2	2	2	5	1
Gomphonema olivaceoides var. hutchinsoniana Patrick	0	1	37,075	2	2						1
Gomphonema sp. 3 Idaho SEH	1	0	37,333								
Hannaea arcus (Ehrenberg) Patrick	1	1	39,001	1	2	6					1
Hannaea arcus fo. recta Cleve	0	1	39,003								
Meridion circulare (Greville) Agardh	1	0	45,001	2	2	4	2	2	2	7	2
Navicula hambergii Hustedt	0	1	46,356	1	2	2			1		1
Navicula cryptotenella Lange-Bertalot ex Krammer et Lange-Bertalot	0	1	46,527	1	2	4	2			7	1
Nitzschia dissipata (Kützing) Grunow	0	1	48,008	1	2	4	2	2	2	4	1
Nitzschia frustulum (Kützing) Grunow	0	1	48,013	2	2	4	3	4	3	5	1
Nitzschia palea (Kützing) Smith	0	1	48,025	2	2	3	2	4	4	6	1
Nitzschia modesta Hustedt	1	0	48,567	1	2						1
Reimeria sinuata (Gregory) Kociolek et Stoermer	0	1	55,002	2	2	3	2	2	1	3	1
Stauroneis anceps Ehrenberg	1	0	62,002	1	2	3	2	2	2	4	1
Surirella brebissonii Krammer et Lange-Bertalot	0	1	65,068	1	2	4	3				1
Synedra ulna (Nitzsch) Ehrenberg	1	0	66,024	2	2	4	2	2	3	7	1
Tabellaria fenestrata (Lyngbye) Kützing	1	0	67,002	2	2	3	1	1	1	2	2
Tabellaria flocculosa (Roth) Kützing	1	1	67,004	2	2	2	1	1	1	3	2
Pseudostaurosira pseudoconstruens (Marciniak) Williams et Round	0	1	73,002	2	2						1
Didymosphenia geminata (Lyngbye) Schmidt	0	1	81,001	2	2	6					1
Navicula arctotenelloides Lange-Bertalot et Metzeltin	0	1	93,188	1	2						1
Encyonema minutum (Hilse) Mann	0	1	110,004	2	2	3	2				1
Encyonema silesiacum (Bleisch) Mann	1	1	110,005	2	2	3	2	2	3	7	1
Planothidium lanceolatum	0	1	155,003	2	2	4	2	2	3	5	1

Table 17. Algal taxa autecology for taxa found at the two sites sampled within the Crescent River Basin, July 2004.—Continued

[Taxa are sorted alphabetically. See Table 16 - Algal Autecology Values; taxa id from Philadelphia Academy of Natural Sciences]

FULLNAME	North Fork Crescent River	Crescent River near mouth	Taxon ID	Motility	Nitrogen Fixing	pH	Salinity	Organic Nitrogen	Oxygen Tolerance	Trophic	Benthic or Sestonic
Staurosira construens var. binodis (Ehrenberg) Hamilton	1	0	172,005	2	2	4	2	2	1	4	1
Staurosira elliptica (Schumann) Williams et Round	0	1	172,007	2	2	4	2	1	1	4	1
Psammothidium helveticum (Hustedt) Bukhtiyarova et Round	0	1	186,003	2	2	4	1	2	2	3	1
Eucocconeis flexella (Kützing) Cleve	0	1	187,001	2	2	3	1	1	1	1	1
Rossithidium petersennii (Hustedt) Round et Bukhtiyarova	0	1	189,004	2	2	3	1	1	1	1	1
Encyonopsis sp. 1 NAWQA EAM	0	1	203,015								
Mayamaea atomus (Kützing) Lange-Bertalot	0	1	211,003	1	2	4	2	4	2	6	1
Schizomeris leibleinii Kützing	0	1	515,000	2	2						1
Spirogyra sp.	1	0	533,000	2	2						1
Homoeothrix spp	0	1	852,003	2	2						1
Leptolyngbya sp.	1	0	863,016	2	2						1
Unknown Rhodophyte Florideophycidae (chantransia)	1	0	1,599,006	2	2						1

associated with each of the autecological attributes discussed here.

The Crescent River at the mouth (site 3) provided habitat for about double the number of taxa (45) compared to the upstream site. Thirty-seven taxa represented algae not found at the upstream site. Nearly all of these taxa were diatoms (96 percent), except for one blue-green, and one green alga. Non-motile taxa made up about 80 percent of the algal community, whereas 20 percent were considered motile and all but 2 taxa were associated with benthic substrates (table 18). All taxa were categorized as unable to fix nitrogen from the atmosphere. The mean of the pH attributes suggested the algae preferred just slightly above circumneutral (~7) conditions, with four considered non-specific with respect to pH (these were not counted in the sum of values in the determination of the mean). Algal taxa exhibited a general salinity preference of <0.9 ppt, and <500 mg/L chloride. The downstream site (site 3) algal community's mean nitrogen uptake metabolism value was greater than the upstream site (site 1) community, although both sites would generally rank about the same on the attribute scale having taxa tolerant to organically bound nitrogen (table 18). Fifty percent of the taxa with assigned oxygen tolerance values required oxygen saturation to be near 100 percent. Eighteen percent required greater than 75 percent oxygen saturation, about 33 percent required less than 50 percent or less saturation, marking a shift downward in oxygen saturation requirements compared to the upper site. The mean trophic condition was within a range of oligo-meso- to meso-trophic conditions.

An exploratory comparative analysis of the two Crescent River sites and the four Kijik/Little Kijik River sites provides some insight into similarities and differences among the Crescent River sites and the Kijik and Little Kijik River basins. A cluster analysis based on the Raup-Crick similarity index for presence/absence data was used to group the sites according to similarities in each site's algal community (Hammer and others, 2001). The downstream Crescent River site was most similar to the 2 Kijik River sites (table 19), with respect to algal assemblages as the cophenetic correlation coefficient was 0.85, signifying that the cluster hierarchy of these sites accurately represented the original distances between points. These three sites have similar physical habitat characteristics: steep slopes (high streamflow velocity), small rocks as the bed substrate, and little or no bank vegetation. The North Fork Crescent River, Little Kijik River above Kijik Lake, and Little Kijik River below Kijik Lake show little similarity with respect to algal communities.

Table 18. Percentage calculations of algal autecology categories for the Crescent, Kijik, and Little Kijik Rivers.

Autecology Characteristic (category name - table 16)	North Fork Crescent River	Crescent River near mouth	Little Kijik River above Kijik Lake	Little Kijik River below Kijik Lake	Kijik above Little Kijik	Kijik 1.5 miles above mouth
Motile	19	19	4	11	18	11
NonMotile	81	81	96	89	82	89
Nitrogen Fixing	0	0	0	0	0	0
Non-Nitrogen Fixing	100	100	100	100	100	100
pHAcidobiontic	0	0	0	0	0	0
pHAcidophilous	13	9	11	6	6	6
pHCircumneutral	40	32	42	38	44	38
pHAlkaliphilous	40	44	37	50	31	31
pHAlkalibiontic	0	3	0	0	6	6
pHIndifferent	7	12	11	6	13	19
SalinityFresh	29	23	33	25	27	21
SalinityFreshBrackish	64	68	61	69	67	64
SalinityBrackishFresh	7	10	6	6	7	14
SalinityBrackish	0	0	0	0	0	0
OrgNAutoLow	38	33	46	45	50	38
OrgNAutoHigh	62	52	54	45	40	50
OrgNHeteroHighFacultative	0	0	0	0	0	0
OrgNHeteroHighObligate	0	14	0	9	10	13
OxyTolAlwaysHigh	46	50	62	55	60	38
OxyTolFairlyHigh	23	18	8	9	10	13
OxyTolModerate	31	27	31	36	20	50
OxyTolLow	0	5	0	0	10	0
OxyTolVeryLow	0	0	0	0	0	0
Oligotrophic	7	12	21	14	25	10
Oligomesotrophic	14	12	14	7	8	10
Mesotrophic	21	24	21	29	25	30
Mesoeutrophic	14	8	7	7	0	0
Eutrophic	21	20	21	21	25	40
Polytrophic	0	8	0	0	8	0
Eurytrophic	21	16	14	21	8	10
BenthicSpp	86	95	96	95	88	89
SestonicSpp	14	5	4	5	12	11
Counts of values						
FamRich	6	9	14	9	8	10
GenRich	16	29	38	31	23	27
SppRich	22	45	62	65	30	38

Table 19. Ramp-Crick similarity matrix for algal presence or absence data for Crescent, Kijik, and Little Kijik Rivers.

	Little Kijik River above Kijik Lake	Little Kijik River blw Kijik Lake	Kijik River abv Little Kijik River	Kijik River 1.5 miles abv mouth	North Fork Crescent River	Crescent River near mouth
Little Kijik River above Kijik Lake	1	0	0.93	0.17	0.32	0.34
Little Kijik River below Kijik Lake	0	1	0.1	0.45	0	0.08
Kijik River above Little Kijik River	0.93	0.09	1	1	0.23	0.98
Kijik River 1.5 miles above mouth	0.17	0.45	1	1	0.57	0.98
North Fork Crescent River	0.32	0	0.23	0.57	1	0.28
Crescent River near mouth	0.34	0.08	0.98	0.98	0.28	1

Possible Effects of Logging on Water Quality

Only a limited amount of logging has taken place in the Crescent River Basin in the area near the mouth of the river (fig. 3). Because the logging did not encroach along the riverbank and was primarily downstream of the Crescent River at the mouth site, no effects from this logging on the water quality of the Crescent River were detected in this study. However, based on the water quality and biology data collected in this study some general observations on possible effects of increased logging in the Crescent River Basin can be made.

The runoff characteristics in the Crescent River Basin are dominated by the Lake Fork Crescent River and the North Fork Crescent River. Crescent Lake essentially controls the runoff characteristics of the Lake Fork Crescent River and only natural factors will change these characteristics because there are no private lands above the outlet of Crescent Lake. Similarly, the runoff characteristics of the North Fork Crescent River above the sampling site will only change from natural factors because there are no private lands above the North Fork sampling site. Below the two sampling sites, setbacks of 66 ft on either side of the streambank are required (Alaska Department of Natural Resources, 2003). Thus, most likely, the present channel would not be altered and flow characteristics will remain essentially unchanged.

Previous studies have shown that logging can increase water temperature since the removal of the forest canopy exposes the watershed to more sunlight. In the Crescent River Basin water temperature is driven more by glacier melt, snowmelt, and the ambient air temperature. Thus, while logging would remove some of the forest canopy and thus expose more of the watershed to sunlight, most likely there would be no significant change in water temperature.

Presently, Crescent Lake traps most of the suspended sediment that enters the lake and thus the Lake Fork Crescent River has low suspended sediment concentrations. This feature is unlikely to change. Suspended sediment characteristics at the North Fork Crescent River site are typical of a glacier stream. Downstream of the North Fork and Lake Fork Crescent River sites, assuming that setbacks would be in place, suspended sediment would not increase from the main river channel or tributaries. However, there still will be relatively high suspended sediment concentrations downstream of the confluence of the North Fork and Lake Fork Crescent Rivers due to the channel characteristics (fig. 4).

Both the North Fork Crescent River and the Crescent River (site 1) at the mouth (site 3) showed relatively diverse aquatic habitat, typical for Alaska streams. The algal taxa found at both sites have adapted to the current suspended sediment characteristics of the Crescent River. However, if logging increased the suspended sediment supply to the Crescent River, these taxa could be covered by the fine sediment, and as a result the number of different taxa could decline. For example, the effects of logging on macroinvertebrate production have been shown to be detrimental to macroinvertebrate populations (Hartman and others, 1996). Densities of taxa were lower in clear-cut sections than in leavestrip sections. Total macroinvertebrate densities were reduced 41-50 percent when compared with densities during the prelogging phase and with densities from unlogged control sites. Most likely, increased transport of fine sediment reduced stability of the channel, and decreased input of leaf litter were responsible for this effect.

Concentrations of major ions, nutrients, and dissolved organic carbon are relatively low at all the sampling sites. Previous studies have shown that logging increases the concentrations of these constituents (Feller and Kimmins, 1984). Assuming the concentrations of these constituents do not change at the North Fork Crescent and Lake Fork Crescent River sites, the flows from these two sites could simply dilute any effect from downstream logging.

As an example watershed, the Ninilchik River, located on the east side of Cook Inlet (fig. 1) is a 130 mi^2 watershed that has been 70 percent logged. This basin was studied during the Cook Inlet Basin NAWQA study from 1998-2001. Results of the Cook Inlet Basin NAWQA (Brabets and Whitman, 2002) indicated no deterioration in water quality of this river. Setbacks were required in all logging areas of the Ninilchik River Basin, and the use of the setbacks most likely prevented degradation of water quality.

Summary

The Crescent River Basin, located on the west side of Cook Inlet in Lake Clark National Park and Preserve, drains an area of about 250 mi^2. Because the Crescent River supports a strong sockeye salmon fishery and a concern about the potential effects of logging in the basin, the water quality of the river and lake system were studied from 2003-2004. Major findings of the study include:

- The water type throughout the basin is calcium bicarbonate. Concentrations of nutrients, major ions, and dissolved organic carbon were low at all sites. Alkalinity concentrations are generally less than 10 mg/L, indicating a low buffering capacity of these waters.

- Glacier-fed streams that flow into Crescent Lake transport suspended sediment that is trapped by the lake. Suspended sediment concentrations from the Lake Fork Crescent River (the outlet stream of Crescent Lake) were less than 10 mg/L, indicating a high trapping efficiency of lake. The North Fork Crescent River transports suspended sediment throughout its course and provides most of the suspended sediment to the main stem of the Crescent River downstream from the confluence of the Lake Fork Crescent River. Given that only a small amount of logging has taken place in the Crescent River Basin, these suspended sediment concentrations are more likely due to the channel characteristics (steep slope and high velocities) than to logging.

- Three locations on Crescent Lake were profiled during the summer of 2004. Water temperature profiles indicate surface temperatures were as high as 18ºC while the bottom of the lake remained near 4ºC. Turbidity profiles indicate sediment plumes within the water column at various times during the summer. Turbidity values are higher in June, reflecting the glacier-fed runoff into the lake. Lower values of turbidity in August and September indicate a decrease of suspended sediment entering Crescent Lake.

- Streambed sediments collected from the Lake Fork Crescent River, North Fork Crescent River, and Crescent River mainstem were analyzed for trace elements. When compared to the different guidelines, the concentration of chromium at the Lake Fork Crescent River, copper at all three sites, and zinc at the Crescent River near the mouth site exceeded the ISQG. Concentrations of copper at all sites and zinc at the Crescent River near the mouth were above the TEC levels. All concentrations were below the PEL and PEC standards, and when normalized to percent organic carbon, all concentrations were less than the PEL and PEC levels.

- Zooplankton samples from Crescent Lake indicated the presence of the genus *Cyclops* and a relatively small number of ovigerous *Cyclops. Cyclops* are one of the primary food sources for rearing sockeye salmon juveniles and were most prevalent in the July sampling.

- QMH algae samples were collected from two stream sites. A total of 59 taxa were found and were comprised of 4 phyla: Rhodophyta (red algae), Cyanophyta (blue-green algae), Chlorophyta (green algae), and Chrysophyta (diatoms). Samples from the upper site, North Fork Crescent River, contained 22 algal taxa while samples from the downstream site, Crescent River near the mouth, contained twice as many taxa.

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