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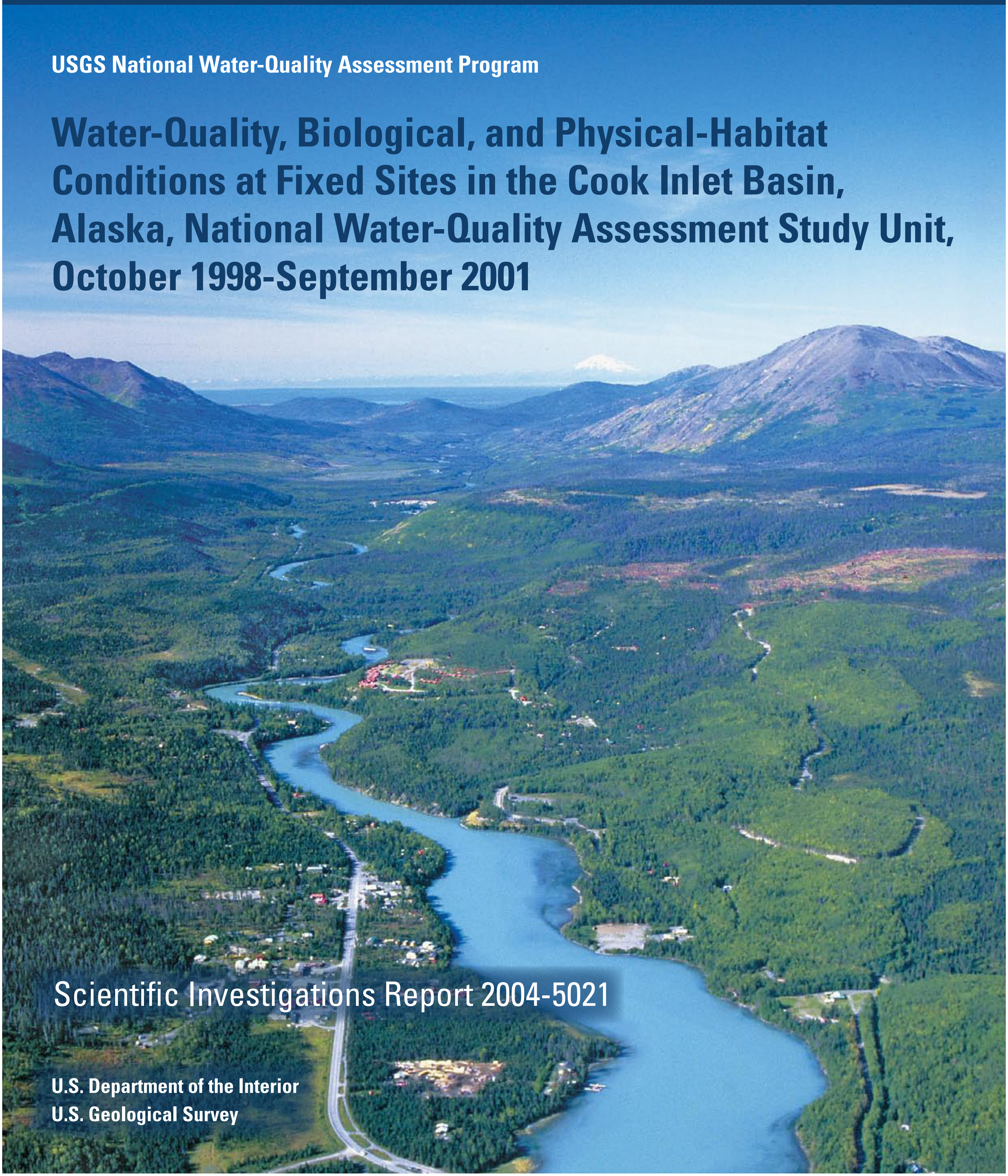
Water-Quality, Biological, and Physical-Habitat Conditions at Fixed Sites in the Cook Inlet Basin, Alaska, National Water-Quality Assessment Study Unit, October 1998-September 2001



Scientific Investigations Report 2004-5021

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

Cover: Photograph of the Kenai River at Cooper Landing looking west. Mt. Redoubt, an active volcano on the west side of Cook Inlet, is in the background. Photograph taken by Ken Graham of Accent Alaska (http://www.accentalaska.com).

Water-Quality, Biological, and Physical-Habitat Conditions at Fixed Sites in the Cook Inlet Basin, Alaska, National Water-Quality Assessment Study Unit, October 1998–September 2001

By Timothy P. Brabets and Matthew S. Whitman

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Foreword

The U.S. Geological Survey (USGS) is committed to serve the Nation with accurate and timely scientific information that helps enhance and protect the overall quality of life, and facilitates effective management of water, biological, energy, and mineral resources (http://www.usgs.gov/). Information on the quality of the Nation's water resources is of critical interest to the USGS because it is so integrally linked to the long-term availability of water that is clean and safe for drinking and recreation and that is suitable for industry, irrigation, and habitat for fish and wildlife. Escalating population growth and increasing demands for the multiple water uses make water availability, now measured in terms of quantity and quality, even more critical to the long-term sustainability of our communities and ecosystems.

The USGS implemented the National Water-Quality Assessment (NAWQA) Program to support national, regional, and local information needs and decisions related to water-quality management and policy (http://water.usgs.gov/nawqa/). Shaped by and coordinated with ongoing efforts of other Federal, State, and local agencies, the NAWQA Program is designed to answer: What is the condition of our Nation's streams and ground water? How are the conditions changing over time? How do natural features and human activities affect the quality of streams and ground water, and where are those effects most pronounced? By combining information on water chemistry, physical characteristics, stream habitat, and aquatic life, the NAWQA Program aims to provide science-based insights for current and emerging water issues and priorities. NAWQA results can contribute to informed decisions that result in practical and effective water-resource management and strategies that protect and restore water quality.

Since 1991, the NAWQA Program has implemented interdisciplinary assessments in more than 50 of the Nation's most important river basins and aquifers, referred to as Study Units (http://water.usgs.gov/nawqa/nawqamap.html). Collectively, these Study Units account for more than 60 percent of the overall water use and population served by public water supply, and are representative of the Nation's major hydrologic landscapes, priority ecological resources, and agricultural, urban, and natural sources of contamination.

Each assessment is guided by a nationally consistent study design and methods of sampling and analysis. The assessments thereby build local knowledge about water-quality issues and trends in a particular stream or aquifer while providing an understanding of how and why water quality varies regionally and nationally. The consistent, multi-scale approach helps to determine if certain types of water-quality issues are isolated or pervasive, and allows direct comparisons of how human activities and natural processes affect water quality and ecological health in the Nation's diverse geographic and environmental settings. Comprehensive assessments on pesticides, nutrients, volatile organic compounds, trace metals, and aquatic ecology are developed at the national scale through comparative analysis of the Study-Unit findings (http://water.usgs.gov/nawqa/natsyn.html).

The USGS places high value on the communication and dissemination of credible, timely, and relevant science so that the most recent and available knowledge about water resources can be applied in management and policy decisions. We hope this NAWQA publication will provide you the needed insights and information to meet your needs, and thereby foster increased awareness and involvement in the protection and restoration of our Nation's waters.

The NAWQA Program recognizes that a national assessment by a single program cannot address all water-resource issues of interest. External coordination at all levels is critical for a fully integrated understanding of watersheds and for cost-effective management, regulation, and conservation of our Nation's water resources. The Program, therefore, depends extensively on the advice, cooperation, and information from other Federal, State, interstate, Tribal, and local agencies, non-government organizations, industry, academia, and other stakeholder groups. The assistance and suggestions of all are greatly appreciated.

Robert M. Hirsch
Associate Director for Water

Contents

Figures

Tables

Tables at back of report (Excel files)

Conversion Factors and Datums

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter
inch (in.)	25.4	millimeter
inch per year (in/yr)	25.4	millimeter per year
mile (mi)	1.609	kilometer
	Area	
square mile (mi^2)	259.0	hectare
square mile (mi^2)	2.590	square kilometer
acre-foot (acre-ft)	1.233	cubic meter
acre-foot per day (acre-ft/d)	0.01427	cubic meter per second
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year
foot per day (ft/d)	0.3048	meter per day
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
cubic foot per second (ft^3/s)	724	acre-foot per year
cubic foot per day (ft^3/d)	0.02832	cubic meter per day
	Volume	
gallon (gal)	3.785	liter
	Flow rate	
gallon per minute (gal/min)	0.06309	liter per second
gallon per day (gal/d)	0.003785	cubic meter per day
gallon per minute per foot [(gal/min)/ft]	0.2070	liter per second per meter
foot per hour (ft/hr)	0.3048	meter per day

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

$$°F=1.8\ °C+32$$

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

$$°C=(°F-32)/1.8$$

Datums

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

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

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

Water-Quality, Biological, and Physical-Habitat Conditions at Fixed Sites in the Cook Inlet Basin, Alaska, National Water-Quality Assessment Study Unit, October 1998–September 2001

By Timothy P. Brabets and Matthew S. Whitman

Abstract

The Cook Inlet Basin study unit of the U.S. Geological Survey National Water-Quality Assessment Program comprises 39,325 square miles in south-central Alaska. Data were collected at eight fixed sites to provide baseline information in areas where no development has taken place, urbanization or logging have occurred, or the effects of recreation are increasing. Collection of water-quality, biology, and physical-habitat data began in October 1998 and ended in September 2001 (water years 1999-2001).

The climate for the water years in the study may be categorized as slightly cool-wet (1999), slightly warm-wet (2000), and significantly warm-dry (2001). Total precipitation was near normal during the study period, and air temperatures ranged from modestly cool in water year 1999 to near normal in 2000, and to notably warm in 2001. Snowmelt runoff dominates the hydrology of streams in the Cook Inlet Basin. Average annual flows at the fixed sites were approximately the same as the long-term average annual flows, with the exception of those in glacier-fed basins, which had above-average flow in water year 2001.

Water temperature of all streams studied in the Cook Inlet Basin remained at 0 ^{o}C for about 6 months per year, and average annual water temperatures ranged from 3.3 to 6.2 degrees Celsius. Of the water-quality constituents sampled, all concentrations were less than drinking-water standards and only one constituent, the pesticide carbaryl, exceeded aquatic-life standards. Most of the stream waters of the Cook Inlet Basin were classified as calcium bicarbonate, which reflects the underlying geology. Streams in the Cook Inlet Basin draining areas with glaciers, rough mountainous terrain, and poorly developed soils have low concentrations of nitrogen, phosphorus, and dissolved organic carbon compared with concentrations of these same constituents in streams in lowland or urbanized areas. In streams draining relatively low-lying areas, most of the suspended sediment, nutrients, and dissolved organic carbon are transported in the spring from the melting snowpack. The urbanized stream, Chester Creek, had the highest concentrations of calcium, magnesium, chloride, and sodium, most likely because of the application of de-icing materials during the winter. Several volatile organic compounds and pesticides also were detected in samples from this stream.

Aquatic communities in the Cook Inlet Basin are naturally different than similar sites in the contiguous United States because of the unique conditions of the northern latitudes where the Cook Inlet Basin is located, such as extreme diurnal cycles and long periods of ice cover. Blue-green algae was the dominant algae found at all sites although in some years green algae was the most dominant algae. Macroinvertebrate communities consist primarily of Diptera (true flies), Ephemeroptera (mayflies), and Plecoptera (stoneflies). Lowland areas have higher abundance of aquatic communities than glacier-fed basins. However, samples from the urbanized stream, Chester Creek, were dominated by oligochaetes, a class of worms. Most of the functional feeding groups were collector-gatherers. The number of taxa for both algae and macroinvertebrates were highest in water year 2001, which may be due to the relative mild winter of 2000–2001 and the above average air temperatures for this water year.

The streams in the Cook Inlet Basin typically are low gradient. Bank substrates consist of silt, clay, or sand, and bed substrate consists of coarse gravel or cobbles. Vegetation is primarily shrubs and woodlands with spruce or cottonwood trees. Canopy angles vary with the size of the stream or river and are relatively low at the smaller streams and high at the larger streams. Suitable fish habitat, such as woody debris, pools, cobble substrate, and overhanging vegetation, is found at most sites.

Of the human activities occurring in the fixed site basins — high recreational use, logging, and urbanization — based on the multiple lines of evidence used in the NAWQA program, only urbanization was noted to have measurably affected the water quality. High recreational use and logging may be affecting site-specific areas within the Kenai River and Ninilchik River basins, respectively, but these effects, if any, were not seen at the respective sampling sites.

Introduction

The long-term goals of the U.S. Geological Survey's (USGS) National Water-Quality Assessment (NAWQA) program are to describe the current water-quality and biological conditions for a large part of the Nation's freshwater streams and rivers, to describe how water quality is changing over time, and to improve understanding of the primary natural and human factors that affect water-quality conditions (Leahy and others, 1990). The NAWQA program includes 59 planned study units, and the first cycle of NAWQA began in 1991 with 20 study units. The remainder of the study-unit investigations began at 3-year intervals, with 20 new study units beginning in 1994 and 15 in 1997. The Cook Inlet Basin study unit, located in south-central Alaska (fig. 1), began in 1997.

The NAWQA program is designed to use multiple lines of evidence (chemical, biological, and physical) to assess water quality and stream conditions because conventional methods for sampling water may not provide enough information to make a complete assessment of water quality. Sampling several types of data at a site will provide a more complete description of water quality that may not be evident from one type of data. The types of data include (1) water chemistry; (2) trace-element and organic contamination in biota and streambed sediment; (3) biological information (algal, macroinvertebrate, and fish communities); and (4) stream-habitat characterization (Gurtz, 1994).

One of the basic building blocks of NAWQA study-unit sampling is a network of basic fixed sites (BFS). At BFS, a wide range of data are collected in order to provide the multiple lines of evidence about water quality. These data include, but are not limited to, continuous monitoring of streamflow and water temperature, water-quality sampling over a range of flow conditions, biological sampling, and physical-habitat surveys. In the Cook Inlet Basin, eight BFSs were selected (fig. 1, table 1). Sampling began at these sites in water year 1999 and continued through water year 2001.

Purpose and Scope

This report describes the water-quality, biological, and physical-habitat conditions at eight fixed sites in the Cook Inlet Basin. These fixed sites represent the different watersheds in the Cook Inlet Basin both from a 'natural' standpoint and a 'human' standpoint. Streamflow, field measurements, nutrients, organic carbon, major-ion chemistry, suspended sediment, biology, and physical-habitat data are presented and compared for the eight sites for water years 1999–2001.

Reports on other topics have been produced during the Cook Inlet NAWQA study. These reports deal with trace elements and organic compounds in streambed sediments and fish tissue (Frenzel, 2000; 2002), water temperature (Kyle and Brabets, 2001), urbanization (Ourso, 2001; Ourso and Frenzel, 2003), ground water (Glass, 2001a; 2001b), and mining (Brabets and Whitman, 2002; Brabets and Riehle, 2003). The reader is referred to these reports for specific information on these topics.

Acknowledgments

The authors acknowledge the assistance provided by several USGS colleagues. William Swenson and Charles Couvillion collected most of the flow and water-quality data. Their commitment to the Cook Inlet study unit provided representative samples and a complete set of data for analysis. Michael Dettinger analyzed the climate data for the Cook Inlet Basin, and Rebecca Kyle compiled and analyzed the quality assurance-quality control data and the physical-habitat data.

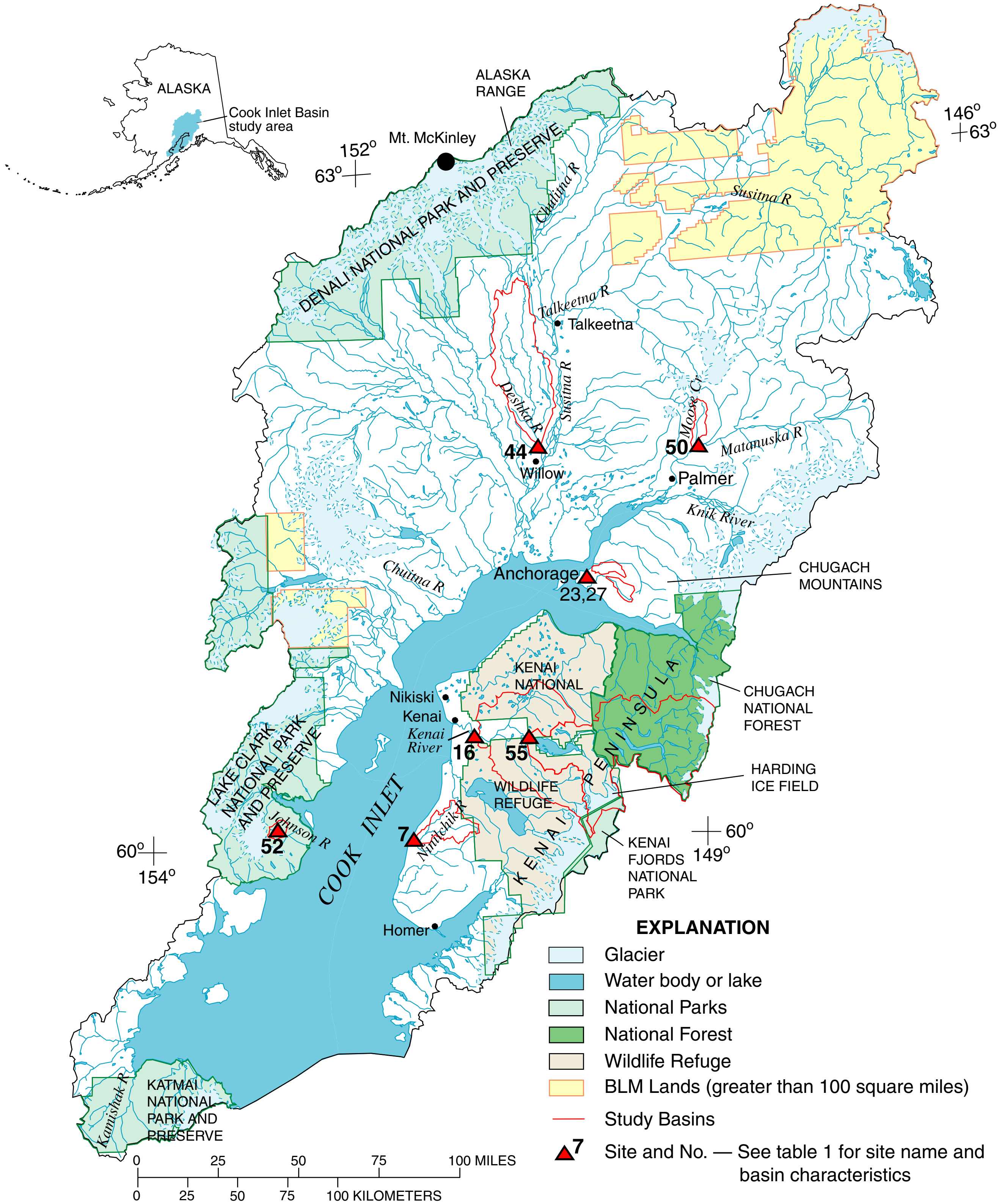

Figure 1. Location of fixed sites and their study basins in the Cook Inlet Basin study unit, Alaska.

Table 1. Basin characteristics of the basic fixed sites, Cook Inlet Basin study unit, Alaska

[**Basic Fixed Sites**: The Cook Inlet Basin NAWQA study unit established a uniform numbering system for all surface-water sites in the study basin. For a complete list of stations and numbers, see URL: http://ak.water.usgs.gov/Projects/Nawqa/water_sites.htm (accessed May 5, 2004). ft, foot; in., inch; ft^3/s, cubic foot per second; mi^2, square mile]

Characteristics	Basic Fixed Sites							
	Ninilchik River at Ninilchik (site 7)	Kenai River below Skilak Lake, near Sterling (site 55)	Kenai River at Soldotna (site 16)	South Fork Campbell Creek near Anchorage (site 23)	Chester Creek at Arctic Boulevard, at Anchorage (site 27)	Deshka River near Willow (site 44)	Moose Creek near Palmer (site 50)	Johnson River above Lateral Glacier, near Tuxedni Bay (site 52)
USGS ID (Station No.)	15241600	15266110	15266300	15274000	15275100	15294100	15283700	15294700
Drainage area (mi^2)	131	1,205	1,951	29.4	27.3	591	47.3	24.8
Mean altitude (ft)	676	2,228	1,788	2,664	682	492	3,210	2,349
Precipitation (in.)	21	84	65	25	22	29	47	70
Glaciers (mi^2)	0	171	199	0	0	0	1	8.5
Lakes (mi^2)	.2	83.5	103	.04	.1	14.4	.2	0
Wetlands (mi^2)	0	0	40.4	0	0	234	0	0
Primary soils (percentage in basin)								
Inceptisols	25	87	63	84	13	0	0	100
Spodosols	75	13	37	16	87	99	2	0
Entisols	0	0	0	0	0	0	27	0
No soils	0	0	0	0	0	0	71	0
Primary land cover (percentage in basin)								
Closed spruce shrub	73	15	15	25	27	0	0	0
Closed mixed forest	21	4	18	10	23	18	0	0
Open/closed mixed forest	0	0	0	0	22	0	0	0
Low shrub	0	0	0	0	8	0	0	0
Alpine tundra	0	18	13	35	0	0	35	57
Low/dwarf shrub	0	8	6	12	0	0	0	0
Spruce woodland and shrub	4	0	0	0	0	0	0	0
Closed spruce and hemlock	0	5	4	0	0	0	0	0
Closed broadleaf and closed mixed forest	0	0	0	0	0	75	32	0
Glaciers and snow	0	17	13	0	0	0	6	42
Physiographic region (percentage of basin)								
Moderately high rugged mountains	0	93	67	97	32	0	88	100
Low mountains	0	0	0	0	0	0	0	0
Plateaus and highlands	31	2	9	0	0	0	12	0
Plains and lowlands	69	5	24	3	68	100	0	0

Table 1. Basin characteristics of the basic fixed sites, Cook Inlet Basin study unit, Alaska—*Continued)*

[**Basic Fixed Sites**: The Cook Inlet Basin NAWQA study unit established a uniform numbering system for all surface-water sites in the study basin. For a complete list of stations and numbers, see URL: http://ak.water.usgs.gov/Projects/Nawqa/water_sites.htm (accessed May 5, 2004). ft, foot; in., inch; ft^3/s, cubic foot per second; mi^2, square mile]

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Flow characteristics (discharges in ft^3/s)								
Period of record	1964–85, 1999–present	1997–present	1965–present	1948–1971, 1999–2001	1966–1986, 1987–1993, 1999–present	1978–1986 1999–2001	1998–2001	1997–present
Mean annual discharge								
Period of record	107	5,180	5,910	38.1	20.0	870	103	565
1999	97.1	4,990	5,640	32.5	20.0	771	87	545
2000	106	4,740	5,300	42.1	25.7	916	125	459
2001	117	5,890	6,990	36.6	20.5	782	97	655
1999-2001	107	5,210	5,980	37.1	22.1	823	103	553
Lowest daily discharge								
1999	42	901	900	5.0	6.5	185	13	1.5
2000	42	915	1,300	6.3	14	260	15	20
2001	55	1,060	1,170	5.1	11	259	18	47
Highest daily discharge								
1999	417	14,400	15,500	139	91	5,560	508	2,810
2000	650	14,500	15,500	182	80	6,930	754	2,200
2001	689	18,300	19,400	160	70	3,495	564	2,960
Peak discharge								
1999	577	14,600	15,800	164	187	5,730	361	2,810
2000	692	14,600	15,900	225	168	7,030	1,080	2,200
2001	767	18,500	19,600	243	116	4,850	658	2,960

Methods of Data Collection and Analysis

All eight fixed sites were monitored using NAWQA sampling protocols that are consistent among all NAWQA sampling activities throughout the Nation. Various graphical and statistical methods were used to analyze water-quality data.

Data Collection

NAWQA protocols for fixed-site sampling are designed to assess the spatial and temporal distribution of water quality in relation to various streamflow conditions, and consist of water-quality sample collection at each fixed site approximately monthly or more frequently (Gilliom and others, 1995). Water samples collected at all fixed sites were analyzed for dissolved ions, nutrients, dissolved and suspended organic carbon, and suspended sediment (see appendix A for a complete list of all analyzed constituents). Field measurements of specific conductance, pH, water temperature, dissolved oxygen (DO), alkalinity, and bicarbonate were made onsite at the time of sample collection. All field measurements were completed according to NAWQA protocols (Shelton, 1994). Instantaneous discharge was obtained from continuous-recording, streamflow-gaging stations at or near each site, maintained by USGS personnel in accordance with standard USGS procedures (Rantz and others, 1982).

Most surface-water samples were obtained by collecting depth-integrating subsamples at equal-width increments across the stream channel by wading, or at equal-discharge increments from boats, using a US DH-81 or US D-77 sampler (Shelton, 1994). A weighted-bottle sampler was used separately to collect dissolved and suspended organic carbon samples in a baked amber glass bottle at the midpoint in the stream.

Water samples were processed in the field according to NAWQA protocols (Shelton, 1994). A cone splitter was used to composite most of the samples into Teflon® bottles. Samples analyzed for dissolved ions, nutrients, and field alkalinity were filtered through a 0.45-µm pore-size capsule filter, samples analyzed for dissolved and suspended organic carbon were filtered through a 0.45-µm pore-size silver filter, and samples analyzed for pesticides were filtered through 0.7-µm pore-size glass-fiber filter. Suspended-sediment samples were collected and processed according to methods described by Edwards and Glysson (1988) and shipped to the USGS Sediment Laboratory in Vancouver, Washington, for particle-size and concentration analysis. All other water-quality samples were shipped to the USGS National Water-Quality Laboratory (NWQL) in Denver, Colorado, for analysis. Water-quality data were published in the annual water-resources data reports for Alaska (U.S. Geological Survey, 1999–2001).

Samples for analysis of algae and macroinvertebrates were collected from each stream reach once each year during low-flow conditions. Each stream reach consisted of at least two sets of repeating geomorphic channel units (riffles, runs, or pools) and reach lengths were at least 150 m (meters) (about 500 ft) at wadeable sites and 750 m (about 2,500 ft) at nonwadeable sites. Collection and field processing of algae and macroinvertebrate communities followed NAWQA protocols (Cuffney and others, 1993). Three contrasting types of targeted habitats for algae and macroinvertebrate communities are defined in the NAWQA program: a qualitative multi-habitat (QMH), a richest-targeted habitat (RTH), and a depositional-targeted habitat (DTH). The QMH sample is collected from the variety of habitats present in the stream; the RTH sample represents that habitat in the reach, usually erosional riffles, where maximum taxa richness is likely to be observed; and the DTH sample represents low velocity habitats where sediments (silt and sand) are deposited. Macroinvertebrate and algae samples were collected in riffle areas of the stream reach to represent the RTH (Cuffney and others, 1993).

Fish and physical-habitat surveys were done once during 1999–2001 following NAWQA protocols (Meador and others, 1993; Fitzpatrick and others, 1998). Fish were collected by electrofishing the entire stream reach. Qualitative habitat measures (types and size of substrate, embeddedness of substrate, riffle, run, and pool ratios) were documented at 11 transects within the stream reach, and quantitative measures (stream width and depth, bank height and width, flood-plain width) were determined by a detailed survey of the entire stream reach. Complete lists of the algae and macroinvertebrate taxa and taxa densities and fish collected from the fixed sites during the sampling periods are in given in tables 15-20 (at back of report).

Quality Assurance

An important part of the NAWQA program is the collection and analysis of quality-control samples. Quality control consisted of analyses of blank, replicate, matrix-spiked replicate, and surrogate-compound samples. The quality-control data and discussion of the results are given in appendix B at back of report).

Quality-assurance and quality-control results for the macroinvertebrate samples were within the USGS NWQL quality-assurance guidelines of 20 percent for picking effectiveness (less than 6 percent for Cook Inlet samples). Picking effectiveness is a process to ensure that the original sample was identified adequately. Quality-assurance and quality-control results were within 10 percent for taxonomy identification (less than 7 percent for Cook Inlet samples). Taxonomy identification is the process in which macroinvertebrates are identified with the use of a microscope to the lowest taxonomic level, when applicable.

Data Analysis

The Statistica (StatSoft, Inc., 2001) software package was used for all statistical analysis. Nonparametric statistics were used on the assumption that the data were not normally distributed. Spearman rank-correlation analysis was used to compare major ions to specific conductance and suspended sediment to discharge. For this report, data were considered statistically correlated when the *rho* values (the Spearman rank correlation coefficient) were equal to or greater than 0.50 and probability was less than 0.005. The Kruskal-Wallis test was used to test for significant differences in median values among sites by performing a one-way analysis of variance on the ranks of the data. Data distribution of selected constituents for each site and among sites were displayed with boxplots (Helsel and Hirsch, 1992). Concentrations of the major ions in water samples are displayed on a trilinear diagram that helps display water-chemistry data in a manner to classify the chemical composition of the water (Drever, 1997). Data also were compared to drinking-water and aquatic-life standards (U.S. Environmental Protection Agency, 1986, 2000; Alaska Department of Environmental Conservation, 2003).

Load Estimator (LOADEST), a software program for estimating constituent loads in streams and rivers (R.L. Runkel, U.S. Geological Survey, written commun., 2003) was used to estimate annual and seasonal loads of the following constituents: suspended sediment, total nitrogen, total phosphorus, and dissolved organic carbon (DOC) (NOTE: In this report, total nitrogen is the sum of dissolved nitrite plus nitrate ($NO_2 + NO_3$) and total ammonia (NH_3) plus organic nitrogen). The output from LOADEST includes estimates of annual and seasonal loads. The user may select a rating-curve equation or allow the program to choose among eight alternative forms of the rating curve for the best regression equation describing the data. For estimating uncertainty in the average loads, the program uses the method described by Likes (1980), which provides a minimum-variance unbiased estimate of the variance of a sum of log-normal variables, and by Gilroy and others (1990), which calculates the exact variance of average constituent loads obtained by the rating-curve method when the rating-curve parameters and residual-error variance are known with certainty.

The algae and macroinvertebrate data provided the means of directly assessing the biological integrity of a fixed site. Algae and macroinvertebrates are continuously exposed to varying water-quality conditions, which allows these organisms to adapt to those conditions over time and provides for an indirect measure of water quality and habitat (Clements, 1994). Thus, these biological data provided information that reflects water quality over a period of time from months to years. Biological metrics (for example, taxonomic richness and composition measures) were used to relate macroinvertebrate communities to water quality. Each biological metric has an expected response to changes and differences in water quality (Barbour and others, 1997).

Description of Study Area

The Cook Inlet Basin covers 39,325 mi^2 in south-central Alaska (fig. 1). Altitude ranges from 0 ft above NGVD of 1929 to the highest point in North America, Mount McKinley, at 20,320 ft. Because of its large size and range in altitude, the Cook Inlet Basin has three climate zones: the Continental, Transitional, and Maritime Zones (fig. 2). The Continental Zone has greater temperature highs and lows than the other climate zones and is characterized by an average annual temperature of 22 ^oF (5.5 ^oC) (Brabets and others, 1999). Average annual temperature in the Transitional Zone is 23 ^oF (5 ^oC), and average annual temperature in the Maritime zone is 42 ^oF (5.6 ^oC). From season to season, and from year to year, temperatures in the Cook Inlet Basin vary considerably in response to local and regional weather patterns and the seasonal cycle. For example, at Anchorage, in the middle of the study region near the geographic center of the Transitional Zone, long-term average temperatures range from about 14 ^oF (10 ^oC) in winter to 59 ^oF (15 ^oC) in summer. In some winters, however, monthly temperatures fall to 5 ^oF (15 ^oC) or cooler, while in others, the monthly temperatures barely dip below freezing. Summer temperatures also vary from year to year, but much less so than do the winter temperatures. Annual-average temperature deviations from the long-term means at Anchorage have ranged between about -5 ^oF to 5 ^oF during the past 85 years.

Average precipitation rates vary widely across the basin, from about 16 in/yr (400 mm/yr) in the vicinity of Kenai to more than 240 in/yr (2,400 mm/yr) in parts of the Alaska Range, both located in the Transitional Zone (Daly and others, 1994; Simpson and others, 2002; see also URL: http://www.wrcc.dri. edu/pcpn/ak.gif, accessed February 10, 2003). The Continental Zone generally is drier than the Transitional Zone, which in turn is drier than the Maritime Zone (Hartman and Johnson, 1978). Average annual precipitation for the entire Cook Inlet Basin is about 44 in. High mountainous areas (which account for 58 percent of the Cook Inlet land area) receive the greatest amount of precipitation. From November to March, precipitation generally falls as snow. In extremely high mountains, snow is deposited year-round on glaciers and ice fields. The wettest months typically are August and September (Simpson and others, 2002), when temperatures are warm (and the atmosphere carries more water vapor) and when winds and storms are oriented directly along the southwest-northeast axis of Cook Inlet. In Anchorage, about three times as much precipitation falls during the August-September period as in the cooler seasons. Year-to-year precipitation variations are significant and, with a coefficient of variation of water-year precipitation totals at Anchorage of 20 percent, comparable to the scale of precipitation variations in much of British Columbia and the northwestern contiguous United States (Dettinger and Diaz, 2000).

Glaciers cover about 11 percent (4,200 mi^2) of the land area of Cook Inlet Basin. Most glaciers are located on the Alaska Range, the Harding Ice Field, and west of Cook Inlet (fig. 1). Year-round basal ice temperatures near 0 ^oC classify glaciers in the basin as temperate (Brabets and others, 1999). These glaciers store massive amounts of water as ice, and the amount of glacial melt depends on the extent of warm meteorological conditions. Characteristics of streams that have as little as 5-percent glacial ice within their basins are distinct from those of streams in basins with no glaciers (Glass, 1999). The most disparate feature is mean daily discharge. For example, in a comparison of basins with glaciers and basins without glaciers (fig. 3), both glacial and non-glacial streams have low discharge through the winter, primarily from the inflows of ground water. In April or May, rapid warming triggers ice breakup and snowmelt that increases streamflow.

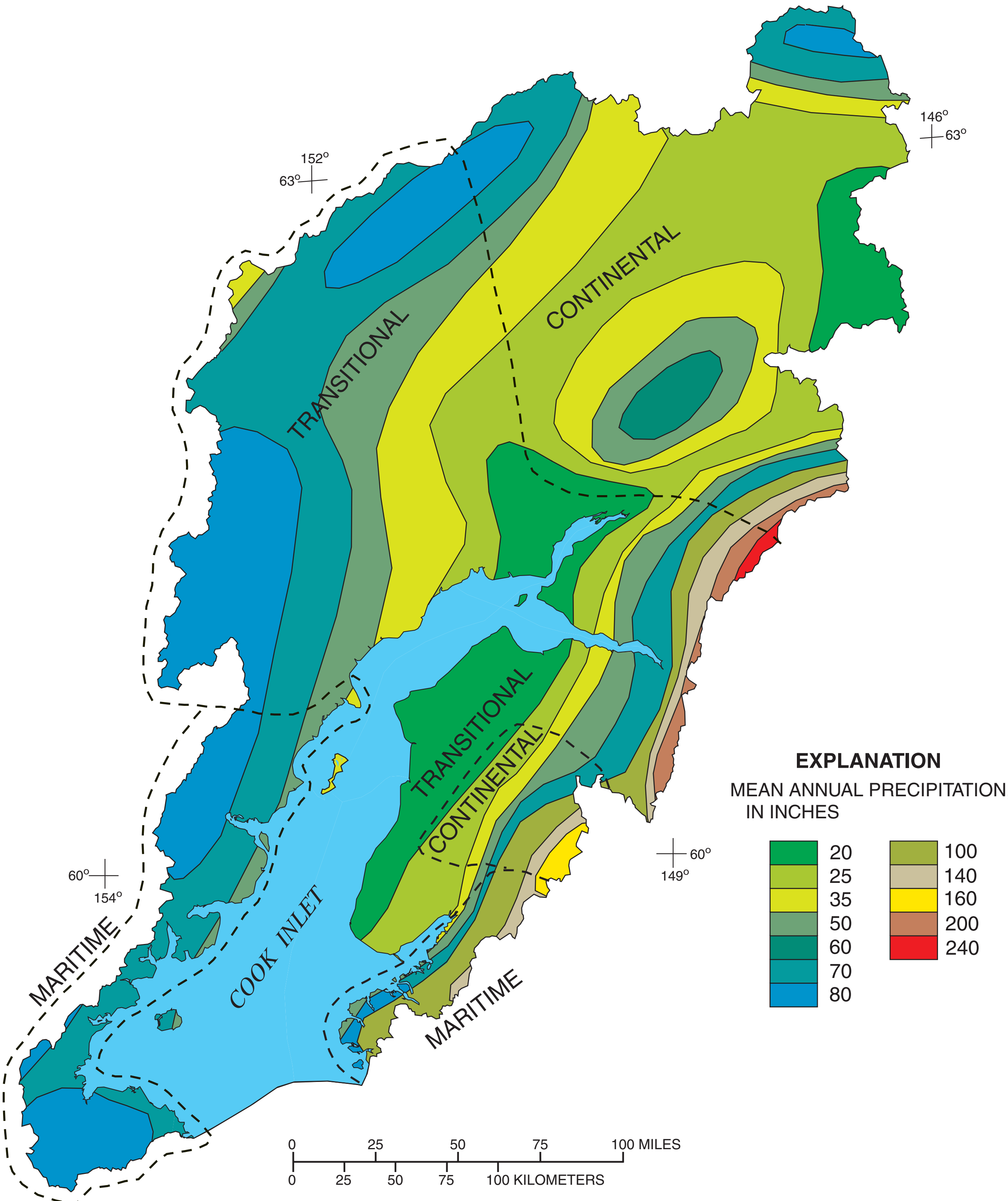

Figure 2. Climate and precipitation zones in the Cook Inlet Basin study unit, Alaska. Modified from Jones and Fahl (1994).

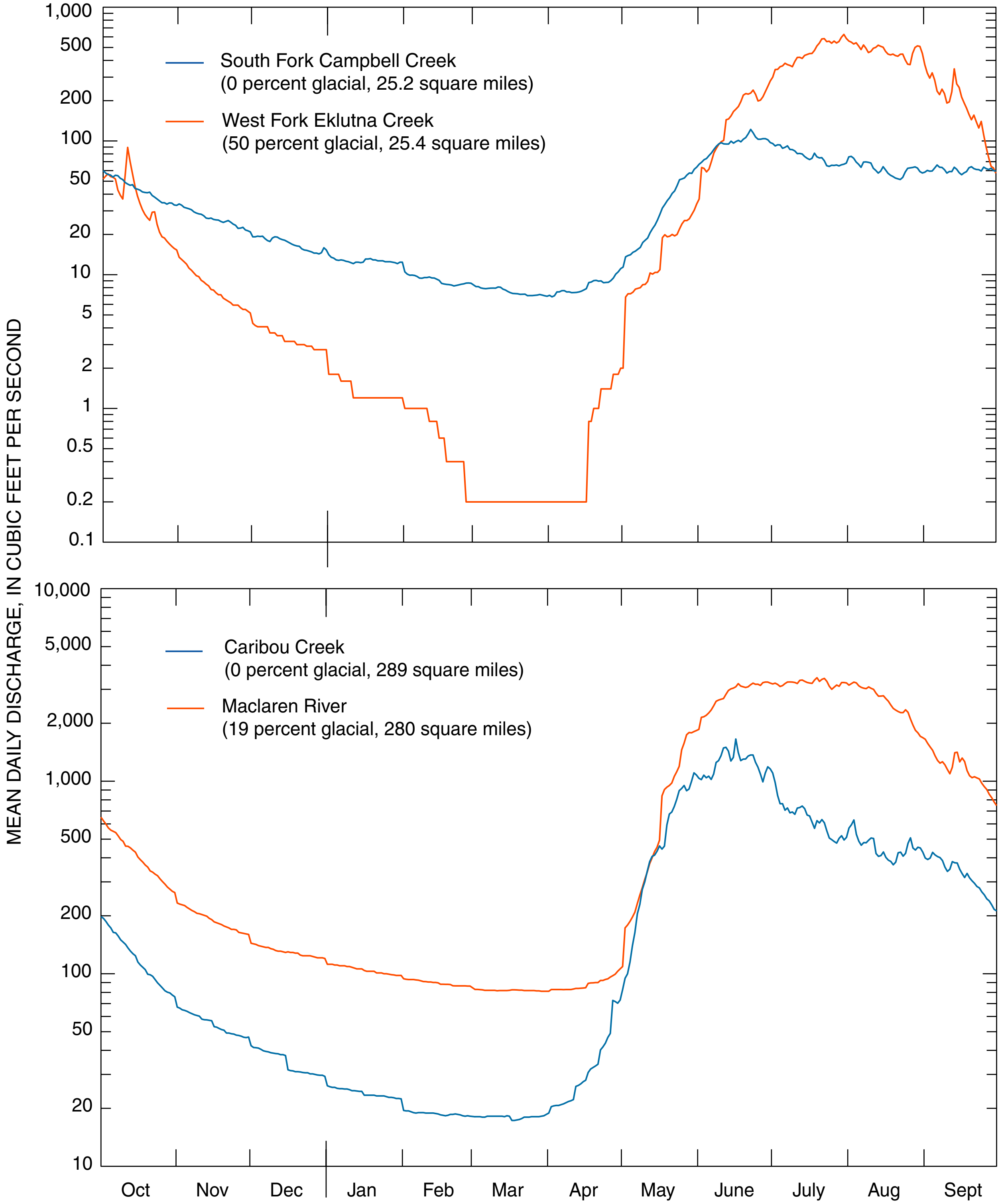

Figure 3. Comparison of discharge between glacial and non-glacial streams, Cook Inlet Basin study unit, Alaska.

During the warm and dry summer period, the discharge of nonglacial streams declines while the flow of glacier-fed streams remains high because of the continuous melting of snow and ice. Although glaciers delay the decline of high seasonal flows, the unit discharge for streams in basins with glacial ice coverage generally is larger than for streams in basins without glacial ice due to the melting of the ice.

Climate of the Cook Inlet Basin

Climatic fluctuations, large and small, cause variations in precipitation and temperature in the Cook Inlet Basin that may affect comparisons of the results of this study with observations in future sampling. Comparisons of water quality observed in 1999–2001 with those in future assessments may need to consider how the Pacific climate conditions during those sampling intervals compare to the conditions of the present study period, especially in water bodies and settings where temperatures play an important role.

The climate of the North Pacific Ocean basin underwent an important, related transition just before the study period, from a long-term (26-year) regime of North Pacific climate conditions that were characteristic of El Nino-like conditions (moderately warmer-than-normal sea-surface temperatures) to more La Nina-like conditions (moderately cooler-than-normal sea-surface conditions) that characterized the 1999–2001 period. Regimes of decadally persistent North Pacific climate conditions, reflecting either El Nino-like and El Nino-rich conditions or La Nina-like and La Nina-rich conditions for decades at a time (Zhang and others, 1997; Dettinger and others, 2001), are now commonly characterized in terms of a Pacific Decadal Oscillation (PDO) index (Mantua and others, 1997) (fig. 4*A*). These regimes are a common feature of the North Pacific-western North American climate (Biondi and others, 2001, D'Arrigo and others, 2001).

The study period was marked by near-normal to dry conditions in much of the Cook Inlet Basin, with some localized areas of above-normal precipitation. Air temperatures ranged from modestly cool in water year 1999 to near normal in water year 2000, and to notably warm by water year 2001. Based on climate data from four long-term weather stations in the Cook Inlet Basin (table 2), water year 1999 was relatively cool because of a 'cold' February, whereas water year 2001 was notable for a warm winter and summer. Air temperatures during all three summers averaged close to the long-term normals. Precipitation measured at the climate stations varied from site to site. Extended winter storms occurred at Homer and Kenai but not at the other stations. This variation in precipitation is difficult to describe and explain in detail, because the number of long-term weather stations in the basin is limited and because large-scale precipitation maps developed by several investigators (Kalnay and others, 1996; Xie and Arkin, 1996; Huffman and others, 1997) from combinations of satellite, weather stations, and models do not agree.

Air temperatures during the study period ranged from –1 °F (–0.5 °C) cooler than the long-term average at Anchorage in 1999, to 1 °F (0.5 °C) warmer than normal in 2000, to 4 °F (2.2 °C) warmer than normal in 2001 (fig. 4*B*). Thus, whereas temperatures were near normal in water years 1999 and 2000, water year 2001 was substantially warmer, despite a moderate PDO value. Indeed, water year 2001 was the third warmest year on record in Anchorage.

In addition to the year-to-year and PDO-driven fluctuations, temperatures at Anchorage also have warmed significantly during the past 85 years, by about 3 °F (1.5 °C) per 100 years. Part of this warming is attributable to the interdecadal shifts of the PDO and its influence on Cook Inlet Basin temperatures, but most of the warming trend is not PDO-driven. Indeed, the warming trend in Anchorage temperatures is spread across a much longer "season" than is the PDO influence.

The historical sequence of water-year precipitation anomalies at Anchorage can be categorized in terms of warm-wet, cool-wet, warm-dry, and cool-dry years (fig. 4*C*). Water-year precipitation totals for all 3 study years were nearly normal. The study period years may be categorized as a slightly cool-wet year (1999), a slightly warm-wet year (2000), and a significantly warm-dry year (2001). Historically, cool-wet and, especially, cool-dry years have become much less common in the Cook Inlet Basin in recent decades. This shift reflects the warming trends described previously, which have resulted in fewer cooler years overall. Less notable but still significant, cool-dry years have occurred most frequently during the La Nina-like PDO regime. Thus, the La Nina-like PDO conditions that were established during the study period—if they persist in the future, as some have predicted (Hereford and others, 2002)—might be expected to bring a resurgence of cool-dry years, if the underlying non-PDO warming trends do not continue and preclude cool years altogether.

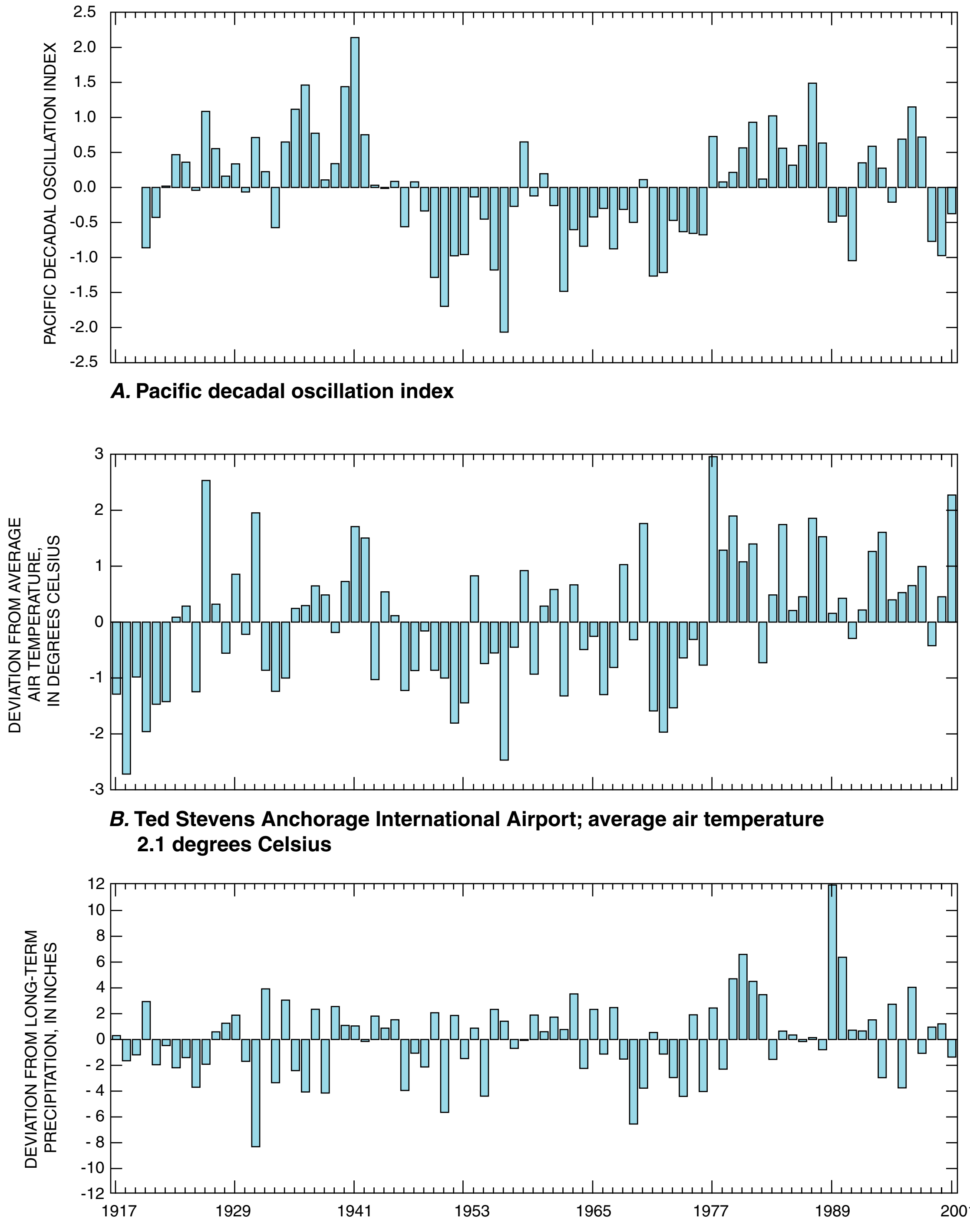

Figure 4. Pacific Decadal Oscillation, and deviation of air temperature and precipitation from average at Ted Stevens Anchorage International Airport, Cook Inlet Basin study unit, Alaska, 1917–2001.

Table 2. Precipitation totals and average temperatures and their deviations from normal at selected weather stations, Cook Inlet Basin study unit, Alaska, water years 1999–2001

[in., inch; °F, degree Fahrenheit]

Weather station	Precipitation		Air temperature	
	Total (in.)	Percentage of normal	Average (°F)	Deviation from normal (°F)
Water Year 1999				
Anchorage	16.1	101	34.7	–1.2
Homer	24.3	96	36.1	–1.2
Kenai	22.2	117	32.7	–1.0
Talkeetna	23.9	82	33.3	.2
Water Year 2000				
Anchorage	16.5	104	36.3	0.4
Homer	20.3	80	37.6	.2
Kenai	18.2	104	33.6	.0
Talkeetna	26.6	91	34.7	1.6
Water Year 2001				
Anchorage	12.8	80	39.6	4.0
Homer	37.0	146	41.4	4.0
Kenai	14.7	78	37.9	4.3
Talkeetna	23.3	80	38.3	5.2

In summary, the samples collected and measurements made during the study period represented mostly near-normal climate conditions. Only water year 2001 deviated much from long-term average conditions on the whole, with moderately dry conditions amid remarkable warmth. Because the glacial-fed rivers are more responsive to air-temperature fluctuations than to precipitation changes, the unusual warmth of 2001 may have affected flow and water quality in these rivers the most. Because glacial-fed streams are sensitive to air temperatures, which in turn are more reliably associated with the long-term states of the North Pacific climate (PDO) than are Cook Inlet Basin precipitation totals, results from the glacial-fed streams also may have been most biased by the persistence of La Nina-like (negative PDO) conditions throughout the study period. The period was one of consistently La Nina-like global and PDO conditions. Only the 1999 air temperatures, however, corresponded well with expectations based solely on the prevailing negative-PDO conditions.

Water-Quality, Biological, and Physical-Habitat Conditions at Fixed Sites

For the following discussion, the fixed sites were divided into three groups, based on their natural basin characteristics. Within each of these groups, one basin has been affected by manmade activities. This allowed a comparison between a pristine, undeveloped basin, and a basin that has been affected by human activity. The three groups and the associated manmade activity were (1) glacial and high-elevation basins and recreational use, (2) lowland basins and logging, and (3) urban basins, one basin affected by development and one basin not affected by development.

Glacial and High-Elevation Basins

Four of the eight fixed sites were considered to be in glacial or high-elevation basins. Two of the sites were on the Kenai River (sites 55 and 16, fig. 1), one site was on Moose Creek (site 50), and one site was on the Johnson River (site 52). The primary human activity that may affect the water quality is high-use recreational activity in the lower Kenai River. Brief descriptions of these sites follow (see table 1 for basin characteristics).

Kenai River below Skilak Lake, near Sterling, Alaska, Station 15266110

The Kenai River is in the southern part of the Cook Inlet Basin on the Kenai Peninsula and is one of the most popular destinations for sport fishing in Alaska. Most of the watershed is within the Chugach National Forest and the Kenai National Wildlife Refuge (fig. 1). The fixed site below Skilak Lake (fig. 5, site 55) represents the upper part of the Kenai River watershed, which is steep and rugged with glaciers present in the high mountains. Most of the runoff enters Kenai Lake. Downstream of Kenai Lake, the Kenai River flows through a relatively narrow canyon until it reaches Skilak Lake. Skilak Lake also is fed by runoff from the large glacier area of the Harding Ice Field. Drainage area of this site is 1,205 mi^2 and the streamflow-gaging station has been in operation since 1997.

Kenai River at Soldotna, Alaska, Station 15266300

The Kenai River at Soldotna fixed site is about 21 mi upstream from the mouth (fig. 1, site 16). The 745-mi^2 drainage area between this site and the site at the Kenai River below Skilak Lake is developed and is popular for sport fishing (fig. 5). This mostly lowland area consists of lakes (20 mi^2), wetlands (40.4 mi^2), and closed mixed forest (303 mi^2). Soils are predominantly spodosols. Daily streamflow records have been collected at this site since 1965.

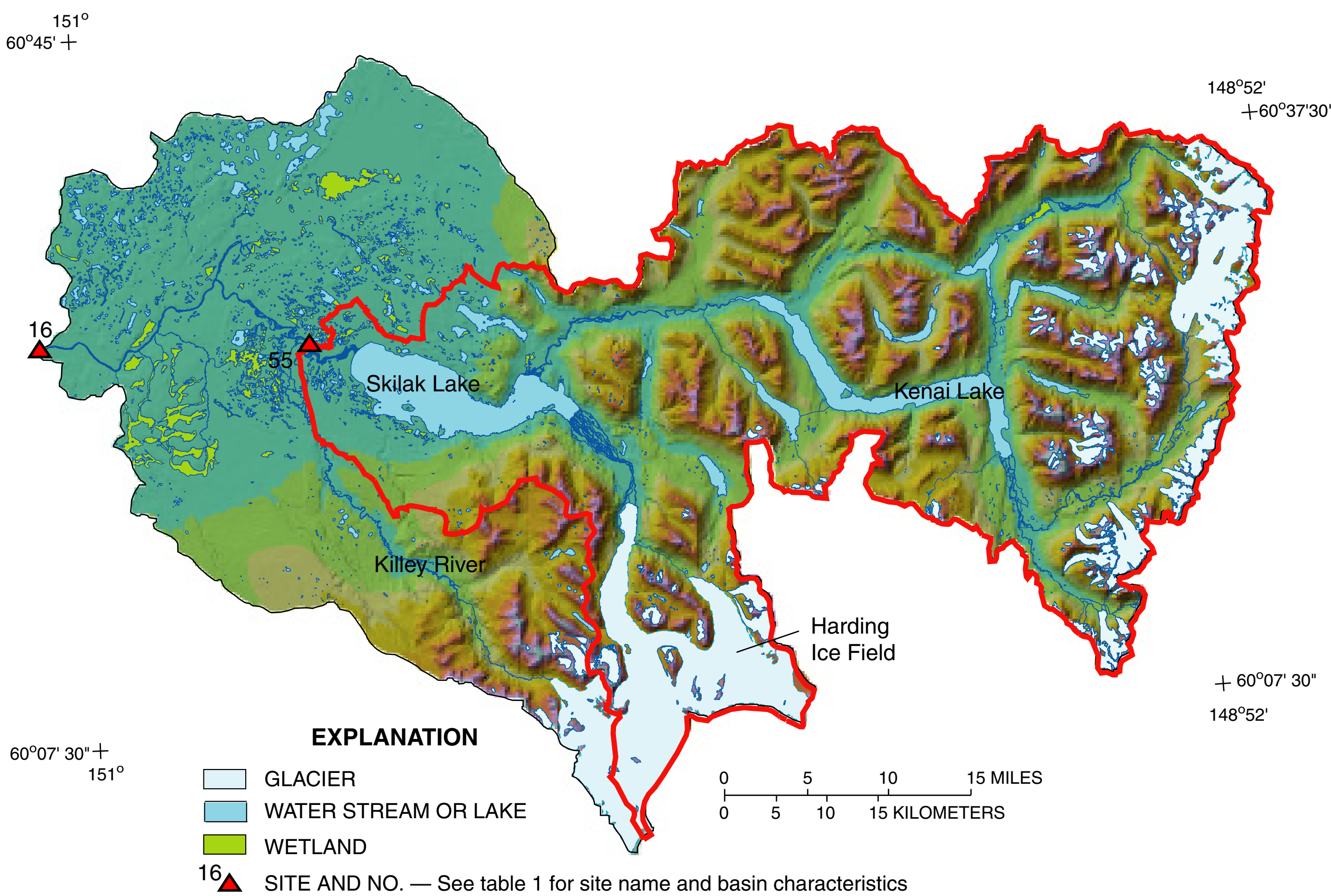

Figure 5. Shaded relief and location of the basic fixed sites and streamflow-gaging stations in the Kenai River Basin, Cook Inlet Basin study unit, Alaska.

Moose Creek near Palmer, Alaska, Station 15283700

Moose Creek near Palmer is about 60 mi northeast of Anchorage (fig. 1, site 50). Extensive coal deposits in the basin may be mined in the future. The upper part of the Moose Creek Basin (above 2,000 ft elevation) consists of a long, steep canyon with a few glaciers. This part of the basin is steep, rugged terrain with very thin or absent soil. The lower part of the basin consists of plateaus, highlands, and valley alluvium. The site drains an area of 47.3 mi^2; the streamflow-gaging station was operated from 1998 to 2001.

Johnson River above Lateral Glacier, near Tuxedni Bay, Alaska, Station 15294700

The Johnson River above Lateral Glacier, near Tuxedni Bay is on the west side of Cook Inlet in the southern part of the Cook Inlet Basin (fig. 1, site 52). The watershed is 24.8 mi^2, is entirely within Lake Clark National Park and Preserve, and has altitudes ranging from 449 to 5,280 ft above NGVD 29. Glaciers and perennial snowfields cover 40 percent of the basin. The streamflow-gaging station has been operated since 1995.

The size of the basin drained by these four fixed sites range from 24.8 mi^2 (Johnson River) to 1,951 mi^2 (Kenai River at Soldotna) and each exhibits somewhat different runoff characteristics. Because the site at Skilak Lake is just below the lake outlet, the flow characteristics at the gaging station reflect both the effects of lake storage and runoff into the lake (from the surrounding basin). During the runoff season, Skilak Lake fills from snowmelt, rainfall, and ice melt. Once filled, it begins to empty, with the highest discharges occurring in August and September (fig. 6*A*). During the winter months, Skilak Lake provides a sustained discharge. The water is relatively warm and usually keeps the channel open and ice free. Flow at the Kenai River at Soldotna is similar to that at the upstream site below Skilak Lake, gradually rising during May and June, peaking during July and August, and then gradually receding during September to November (fig. 7*A*).

Most runoff from Moose Creek occurred from late April to late October. High flows from snowmelt were sustained in late June/early July (fig. 8*A*). Through the remainder of the runoff season, sharp and distinct peaks in the hydrograph were due to rainstorms. During the winter months, November through late April, flow in Moose Creek was primarily from ground water. At the Johnson River, observations of the snowpack and ice cover indicate there probably was little or no flow during winter months, but no measurements were made and no flow records were available. Low flows recorded in early May ranged from 1.5 to 85 ft^3/s. Most runoff occurred from May through October (fig. 9*A*).

Flows at these sites during 1999–2001 generally were within the 25th and 75th interquartile range (figs. 6-9). Average annual streamflows were near the long-term normal for the sites, with the exception of water year 2001 (table 1). At the Kenai River at Soldotna, average streamflow in water year 2001 was 6,990 ft^3/s, approximately18 percent above the long-term average (1965 to present). At the Johnson River, average streamflow for the May-to-October period was 655 ft^3/s, approximately 16 percent above the long-term average. Notable differences in streamflow at the Skilak Lake site were below average streamflow during the winter of 1999, above average during the winter of 2001, and above average during the summer of 2001 (due to above-average air temperatures) and during breakouts from glacier-dammed lakes in November 1999 and January 2001 (fig. 6*A*). In October 1999 and January 2001, there were sharp rises in flow at the Soldotna site because of a glacier dam outburst in the Killey River basin.

Water samples were collected at each of these four sites from October 1998 to September 2001 over a range of flows with exceedance probabilities ranging from less than 1 percent to greater than 90 percent (figs. 6-9). Because the sites on the Kenai River were funded from the USGS NAWQA program, more samples were collected at these sites than at Moose Creek and the Johnson River. However, the samples that were collected at Moose Creek and the Johnson River still covered a range of flows and provided good insight to the water quality of these streams.

Continuous water temperature records were collected at the two Kenai River sites. Water temperature in the Kenai River below Skilak Lake ranged from 0 to 14 ^oC (fig. 10). Notable features of the temperature record were the relatively mild temperatures (1.0 to 2.5 ^oC) during January 2001, reflecting the relatively mild winter. Water temperatures also reflect the effects of Skilak Lake, in that they gradually cool in the autumn and gradually rise in the spring. Average annual temperatures for water years 1999–2001 were 5.1, 5.2, and 6.2 ^oC (again, due to above-average air temperatures).

Water temperature of the Kenai River at Soldotna averaged 4.8, 4.9, and 5.5 ^oC, respectively for water years 1999–2001. These water temperatures are slightly cooler than the water temperatures at the upstream site, reflecting the cold water from the glacier-fed Killey River, which enters the Kenai River downstream of the Skilak Lake site. One notable feature was the effect of the mild winter of 2000–2001, when water temperatures frequently exceeded 0 ^oC throughout the winter (fig. 10). Highest average daily water temperatures measured during water years 1999–2001 were 14.0, 13.0, and 14.0 ^oC, respectively.

Specific-conductance values of the Kenai River, Moose Creek, and the Johnson River ranged from 32 to 155 µS/cm at 25 ^oC, with the values from the two Kenai River sites approximately equal (table 3). Concentrations of dissolved solids and dissolved elements were less than recommended levels for drinking water and aquatic life at all sites. Notable differences in the dissolved ions were the relatively high concentrations of iron and manganese found at the Kenai River at Soldotna, which were approximately twice as high as the concentrations of these ions found at the Kenai River below Skilak Lake. These higher concentrations probably are due to the effects of runoff from the lowland areas downstream of Skilak Lake.

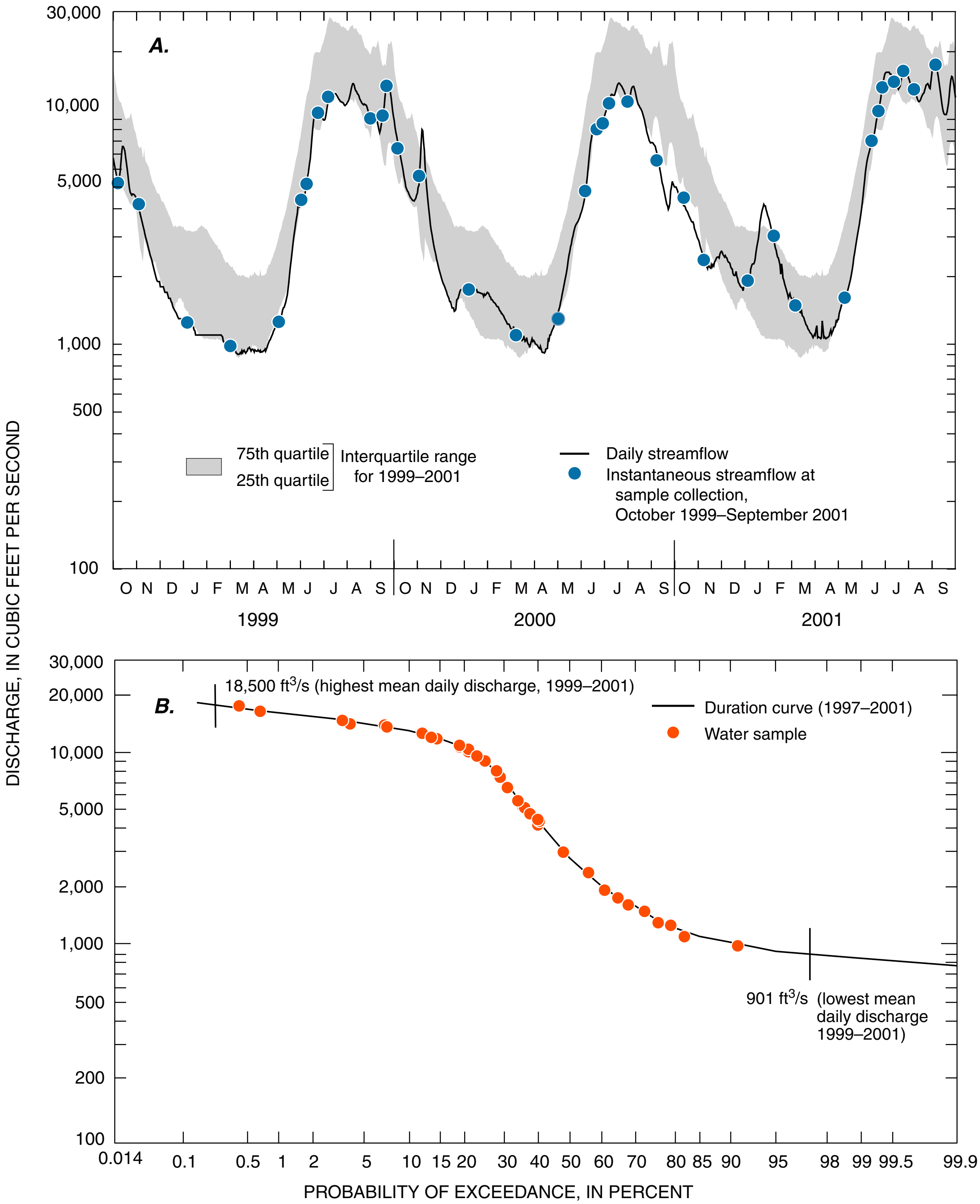

Figure 6. A. Daily and instantaneous streamflow at the time of sample collection, interquartile range of mean daily streamflows for the period of record, and B. Percentage of time indicated discharge was equaled or exceeded at the Kenai River below Skilak Lake, near Sterling (site 55), Cook Inlet Basin study unit, Alaska, water years 1999–2001.

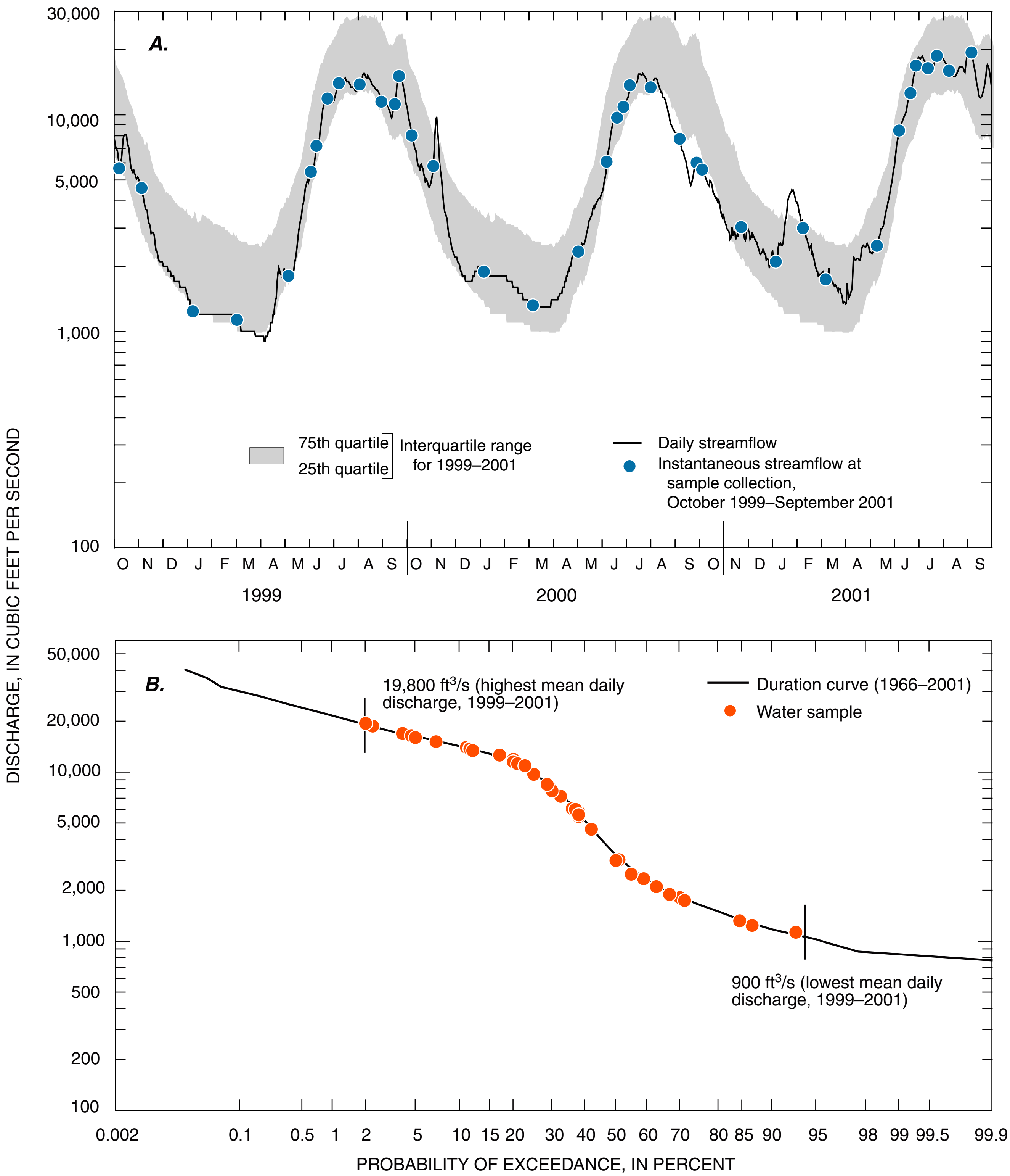

Figure 7. A. Daily and instantaneous streamflow at the time of sample collection, interquartile range of mean daily streamflows for the period of record, and B. Percentage of time indicated discharge was equaled or exceeded for the Kenai River at Soldotna (site 16), Cook Inlet Basin study unit, Alaska, water years 1999–2001.

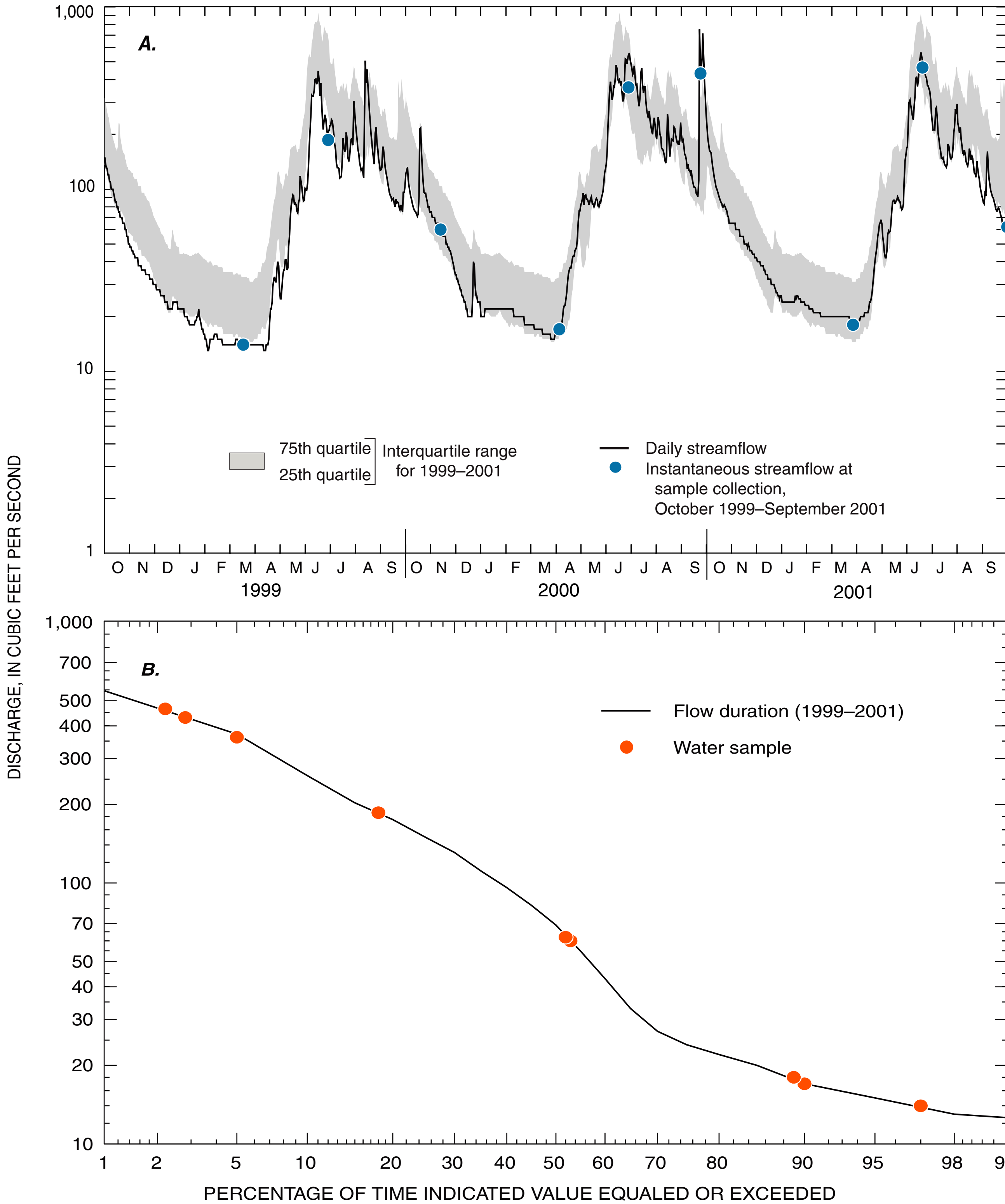

Figure 8. A. Daily and instantaneous streamflow at the time of sample collection, interquartile range of mean daily streamflows for the period of record, and B. Percentage of time indicated discharge was equaled or exceeded at Moose Creek near Palmer (site 50), Cook Inlet Basin study unit, Alaska, water years 1999–2001.

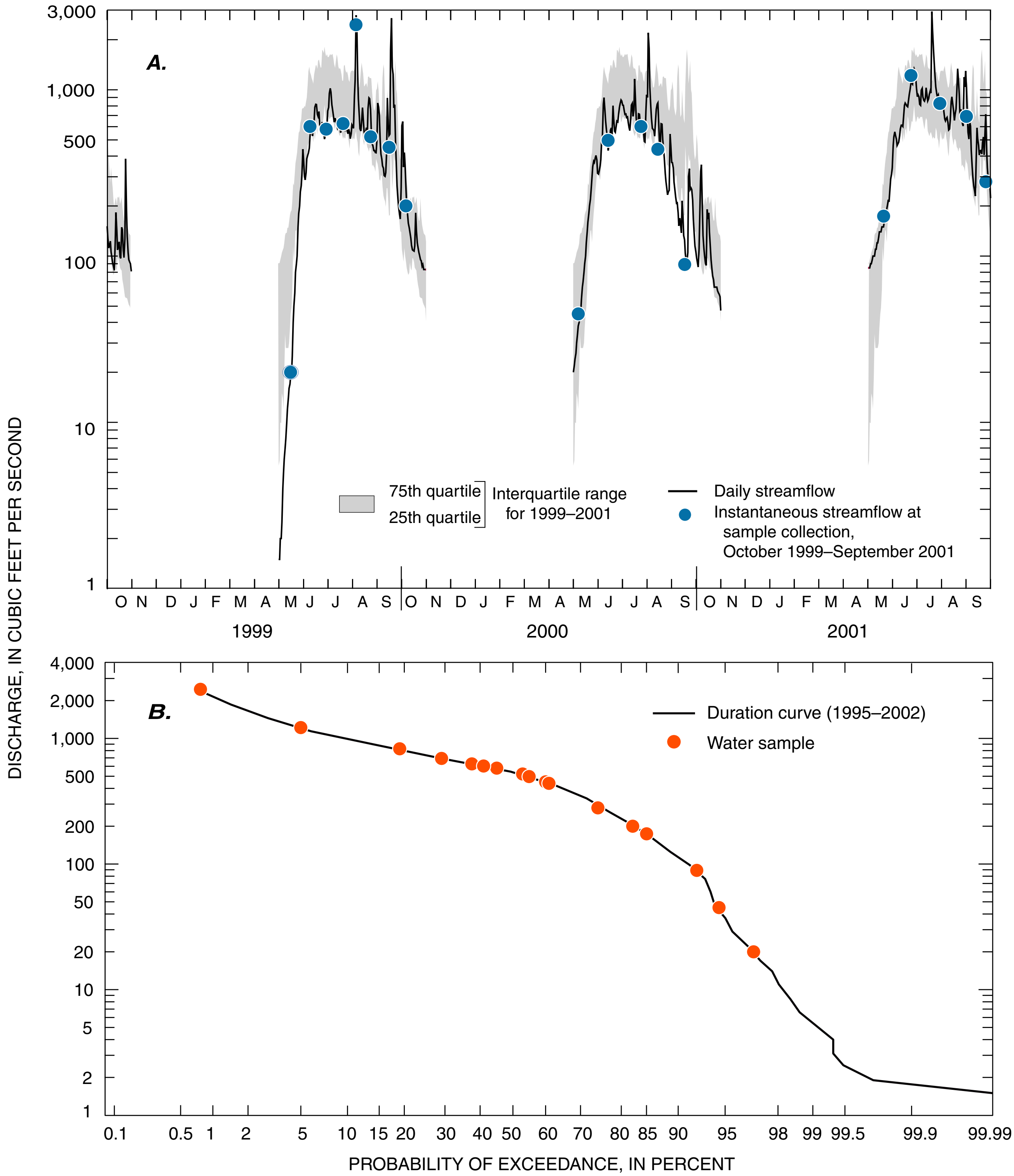

Figure 9. A. Daily and instantaneous streamflow at the time of sample collection, interquartile range of mean daily streamflows for the period of record, and B. Percentage of time indicated discharge was equaled or exceeded at Johnson River above Lateral Glacier, near Tuxedni Bay (site 52), Cook Inlet Basin study unit, Alaska, water years 1999–2001.

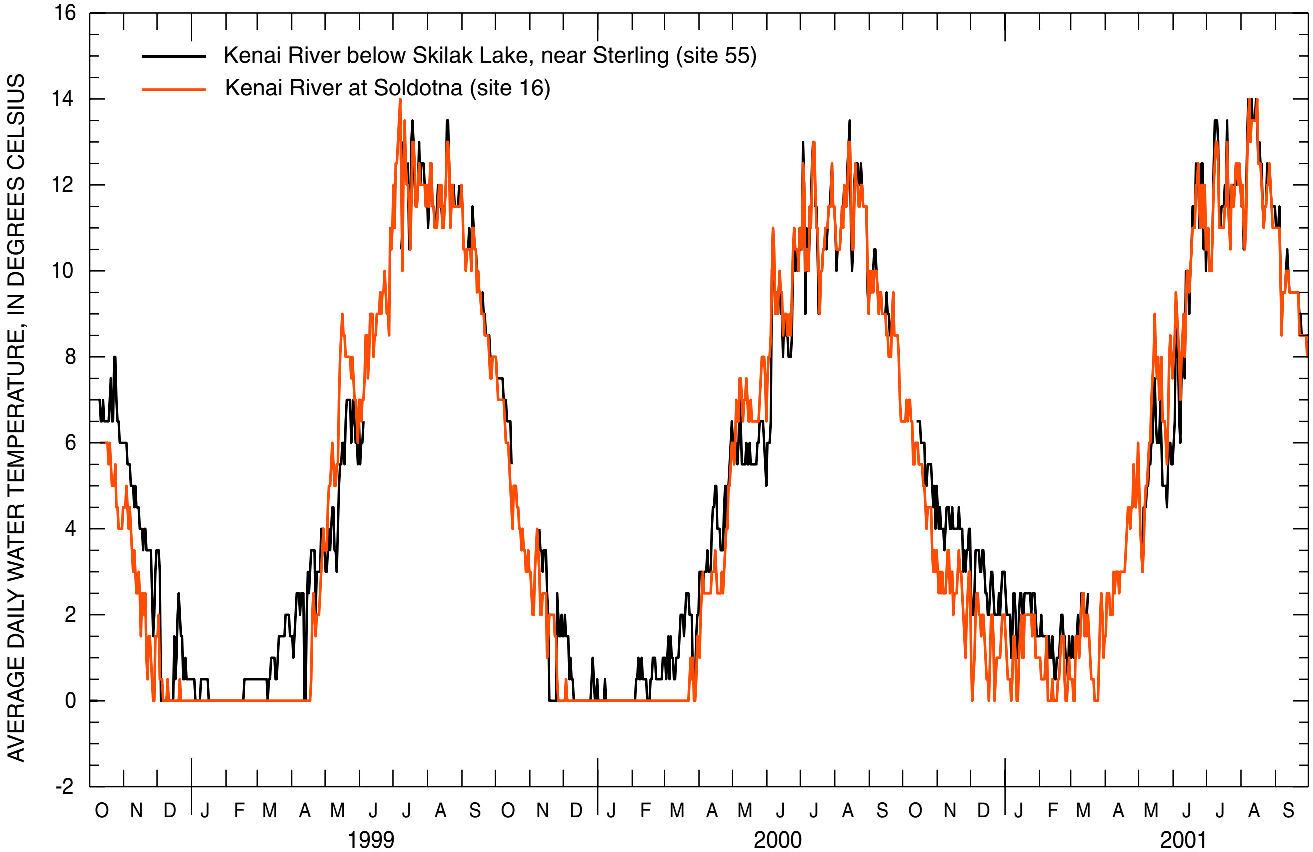

Figure 10. Average water temperature for two sites on the Kenai River in glacial and high-elevation basins, Cook Inlet Basin study unit, Alaska, water years 1999–2001.

Table 3. Summary of values of field measurements and concentrations of nutrients, major ions, organic carbon, and suspended sediment in water samples from fixed sites in glacial and high-elevation basins, Cook Inlet Basin study unit, Alaska, 1999–2001

[Locations of sites are shown in figure 1. Values are given in milligrams per liter unless otherwise noted. °C, degree Celsius; µS/cm, microsiemen per centimeter at 25 degrees Celsius; µg/L, microgram per liter. E, estimated; –, not determined; <, actual value is less than value shown]

Constituent	Minimum	Maximum	Mean	Median
Kenai River below Skilak Lake, near Sterling (site 55; 36 samples)				
Water temperature (°C)	0	15	7.7	8.0
Specific conductance (µS/cm at 25 °C)	53	70	62	62
pH	6.9	8.1	7.7	7.7
Dissolved oxygen	10.3	14.7	12.2	12.2
Ammonia nitrogen, dissolved	.001	.132	.002	.003
Ammonia-plus-organic nitrogen, dissolved	.056	.131	.095	.100
Ammonia-plus-organic nitrogen, total	.040	.148	.084	.080
Nitrite nitrogen, dissolved	.001	.004	.001	.001
Nitrite-plus-nitrate nitrogen, dissolved	.127	.189	.156	.156
Total nitrogen	.183	.337	.335	.236
Phosphorus, total	.003	.009	.006	.005
Phosphorus, dissolved	.001	.006	.005	.006
Orthophosphate phosphorus, dissolved	.001	.007	.003	.002
Alkalinity (as $CaCO_3$)	19	33	22	22
Bicarbonate (as $CaCO_3$)	23	41	27	27
Calcium	7.5	10.8	9.8	9.8
Magnesium	.6	.8	.7	.7
Sodium	.8	1.2	1.0	1.0
Potassium	.6	1.1	.8	.8
Sulfate	.8	6.9	5.8	6.1
Chloride	.1	1.0	.7	.7
Fluoride	<.1	<.1	<.1	<.1
Silica	2.4	3.2	2.8	2.8
Iron (µg/L)	10	90	12.6	10.0
Manganese (µg/L)	1.2	4.0	2.6	3.0
Dissolved solids, residue at 180 °C	33	64	41	40
Organic carbon, dissolved	.3	.6	.5	.5
Organic carbon, suspended	.1	.2	.2	.2
Suspended sediment	1	7	4	4
Kenai River at Soldotna (site 16; 38 samples)				
Water temperature (°C)	0	14	7.1	7.8
Specific conductance (µS/cm at 25 °C)	55	75	64	63
pH	7.1	8.1	7.6	7.6
Dissolved oxygen	9.6	14.3	11.9	11.8
Ammonia nitrogen, dissolved	.002	.14	.014	.003
Ammonia-plus-organic nitrogen, dissolved	.05	.11	.09	.10
Ammonia-plus-organic nitrogen, total	.04	.78	.11	.10
Nitrite nitrogen, dissolved	.001	.003	.001	.001
Nitrite-plus-nitrate nitrogen, dissolved	.07	.21	.14	.14
Total nitrogen	.11	.99	.25	.24
Phosphorus, total	.006	.213	.022	.011
Phosphorus, dissolved	.003	.014	.005	.006
Orthophosphate phosphorus, dissolved	.001	.013	.004	.004
Alkalinity (as $CaCO_3$)	20	30	24	23

Table 3. Summary of values of field measurements and concentrations of nutrients, major ions, organic carbon, and suspended sediment in water samples from fixed sites in glacial and high-elevation basins, Cook Inlet Basin study unit, Alaska, 1999–2001—*Continued*

[Locations of sites are shown in figure 1. Values are given in milligrams per liter unless otherwise noted. °C, degree Celsius; µS/cm, microsiemen per centimeter at 25 degrees Celsius; µg/L, microgram per liter. E, estimated; –, not determined; <, actual value is less than value shown]

Constituent	Minimum	Maximum	Mean	Median
Kenai River at Soldotna (site 16; 38 samples)—*Continued*				
Bicarbonate (as $CaCO_3$)	22	36	29	28
Calcium	7.4	10.8	9.6	9.6
Magnesium	.7	1.3	.9	.8
Sodium	1.0	1.8	1.3	1.3
Potassium	.6	1.0	.8	.8
Sulfate	.8	6.4	5.6	5.8
Chloride	.1	1.3	.8	.8
Fluoride	<.1	<.1	<.1	<.1
Silica	2.9	5.4	3.8	3.5
Iron (µg/L)	10	180	35.5	20
Manganese (µg/L)	1.2	23.7	5.7	3.0
Dissolved solids, residue at 180 °C	33	58	42	42
Organic carbon, dissolved	.5	2.5	.9	.7
Organic carbon, suspended	.1	.5	.2	.2
Suspended sediment	2	88	19	14
Moose Creek near Palmer (site 50; 9 samples)				
Water temperature (°C)	0	11.1	3.9	3.2
Specific conductance (µS/cm at 25 °C)	61	155	105	96
pH	7.5	7.9	7.6	7.6
Dissolved oxygen	10.8	14.1	12.4	12.3
Ammonia nitrogen, dissolved	<.002	.03	.007	.002
Ammonia-plus-organic nitrogen, dissolved	<.10	E.08	–	–
Ammonia-plus-organic nitrogen, total	<.10	.11	.08	.08
Nitrite nitrogen, dissolved	<.001	.001	.001	.001
Nitrite-plus-nitrate nitrogen, dissolved	.099	.606	.27	.20
Total nitrogen	.199	.716	.35	.28
Phosphorus, total	.002	.013	–	–
Phosphorus, dissolved	.003	.006	–	–
Orthophosphate phosphorus, dissolved	.001	.007	.004	.002
Alkalinity (as $CaCO_3$)	21	52	35	34
Bicarbonate (as $CaCO_3$)	27	62	43	44
Calcium	8.1	19.4	13.3	12.6
Magnesium	.9	2.8	1.8	1.6
Sodium	1.3	6.2	3.5	3.2
Potassium	.3	.6	.4	.4
Sulfate	4.3	13.2	8.5	7.4
Chloride	.4	6.0	2.3	1.5
Fluoride	<.1	.2	<.1	<.1
Silica	3.7	7.1	5.2	5.2
Iron (µg/L)	8	16	11.4	10.0
Manganese (µg/L)	1.2	4.0	2.6	2.8
Dissolved solids, residue at 180 °C	34	90	62	58
Organic carbon, dissolved	.5	1.7	.9	.8
Organic carbon, suspended	.1	.5	.23	.20
Suspended sediment	1	30	8	2

Table 3. Summary of values of field measurements and concentrations of nutrients, major ions, organic carbon, and suspended sediment in water samples from fixed sites in glacial and high-elevation basins, Cook Inlet Basin study unit, Alaska, 1999–2001—*Continued*

[Locations of sites are shown in figure 1. Values are given in milligrams per liter unless otherwise noted. °C, degree Celsius; µS/cm, microsiemen per centimeter at 25 degrees Celsius; µg/L, microgram per liter. E, estimated; –, not determined; <, actual value is less than value shown]

Constituent	Minimum	Maximum	Mean	Median
Johnson River above Lateral Glacier, near Tuxedni Bay (site 52; 18 samples)				
Water temperature (degrees Celsius)	0	6.7	3.3	3.0
Specific conductance (µS/cm at 25 °C)	32	105	57	50
pH	6.9	7.9	7.3	7.2
Dissolved oxygen	11.5	15.3	13.2	13.2
Ammonia nitrogen, dissolved	.002	.077	.010	.003
Ammonia-plus-organic nitrogen, dissolved	.050	.147	.088	.100
Ammonia-plus-organic nitrogen, total	.055	.115	.092	.100
Nitrite nitrogen-dissolved	.001	.011	.002	.001
Nitrite-plus-nitrate nitrogen, dissolved	.014	.302	.084	.047
Total nitrogen	.069	.417	.176	.147
Phosphorus, total	.132	.594	.058	.021
Phosphorus-dissolved	.003	.010	.005	.006
Orthophosphate phosphorus, dissolved	.001	.010	.004	.002
Alkalinity (as $CaCO_3$)	10	21	14.4	14
Bicarbonate (as $CaCO_3$)	12	26	18	17
Calcium	5.3	15.0	8.3	7.3
Magnesium	.4	1.2	.7	.6
Sodium	.5	1.8	.9	.8
Potassium	.2	.5	.3	.3
Sulfate	.1	2.0	.7	.5
Chloride	3.7	18.0	9.2	7.7
Fluoride	<.1	<.1	<.1	<.1
Silica	1.8	5.6	3.1	2.7
Iron (µg/L)	10	30	11.3	10
Manganese (µg/L)	2.6	8.7	4.1	3.9
Dissolved solids, residue at 180 °C	20	68	35	34
Organic carbon, dissolved	.10	.89	.31	.30
Organic carbon, suspended	.20	.20	.20	.20
Suspended sediment	2	882	90	29

On the basis of Spearman's rank correlation coefficient (*rho*) and probability values less than 0.005, most of the dissolved constituents at Moose Creek and the Johnson River were significantly correlated with specific conductance (table 4). At the Kenai River below Skilak Lake (table 4), only calcium and sulfate indicated significant correlations with specific conductance. This trend also was apparent at the Kenai River at Soldotna (table 4), although more constituents were significantly correlated with specific conductance. The water at all four sites was classified as calcium bicarbonate type (fig. 11), though slightly higher values of chloride in the Johnson River were noted in the trilinear diagram.

Table 4. Relations between dissolved solids and major ions to specific conductance, and suspended-sediment concentration to discharge in water samples from fixed sites in glacial and high-elevation basins, Cook Inlet Basin, Alaska, October 1998 through September 2001

[Location of sites are shown in figure 1. Specific conductance in microsiemens per centimeter at 25 °C. Discharge in cubic feet per second. Spearman's rank correlation coefficients (*rho*) and probability values (*p*-values) are significant (in **bold**) when *rho* is greater than 0.5, and *p*-values are less than 0.005. <, actual value is less than value shown]

Water-quality constituent	*rho*	*p*-value
Moose Creek near Palmer (site 50; 9 samples)		
Calcium	**0.95**	**<0.0001**
Magnesium	**.99**	**<.0001**
Sodium	**.96**	**<.0001**
Bicarbonate	**.96**	**<.0001**
Silica	**.84**	**.0022**
Potassium	**.87**	**.0011**
Chloride	**.92**	**.0001**
Sulfate	**.99**	**<.0001**
Dissolved solids	**.98**	**<.0001**
Suspended sediment	**.88**	**.0006**
Johnson River above Lateral Glacier, near Tuxedni Bay (site 52; 18 samples)		
Calcium	**0.97**	**<0.0001**
Magnesium	**.98**	**<.0001**
Sodium	**.94**	**<.0001**
Bicarbonate	**.95**	**<.0001**
Silica	**.98**	**<.0001**
Potassium	.01	.9706
Chloride	**.79**	**<.0001**
Sulfate	**.98**	**<.0001**
Dissolved solids	**.75**	**.0004**
Suspended sediment	**.79**	**<.0001**
Kenai River below Skilak Lake, near Sterling (site 55; 36 samples)		
Calcium	**0.58**	**0.0002**
Magnesium	.28	.1001
Sodium	.31	.0670
Bicarbonate	.20	.2500
Silica	.37	.0250
Potassium	–.36	.0290
Chloride	.29	.0837
Sulfate	**.50**	**.0020**
Dissolved solids	.21	.2150
Suspended sediment	–.23	.1680
Kenai River at Soldotna (site 16; 38 samples)		
Calcium	0.46	0.0046
Magnesium	**.50**	**.0015**
Sodium	**.51**	**.0013**
Bicarbonate	.41	.0121
Silica	**.57**	**.0002**
Potassium	.24	.1550
Chloride	**.60**	**.0001**
Sulfate	.11	.4835
Dissolved solids	.28	.0968
Suspended sediment	**.66**	**<.0001**

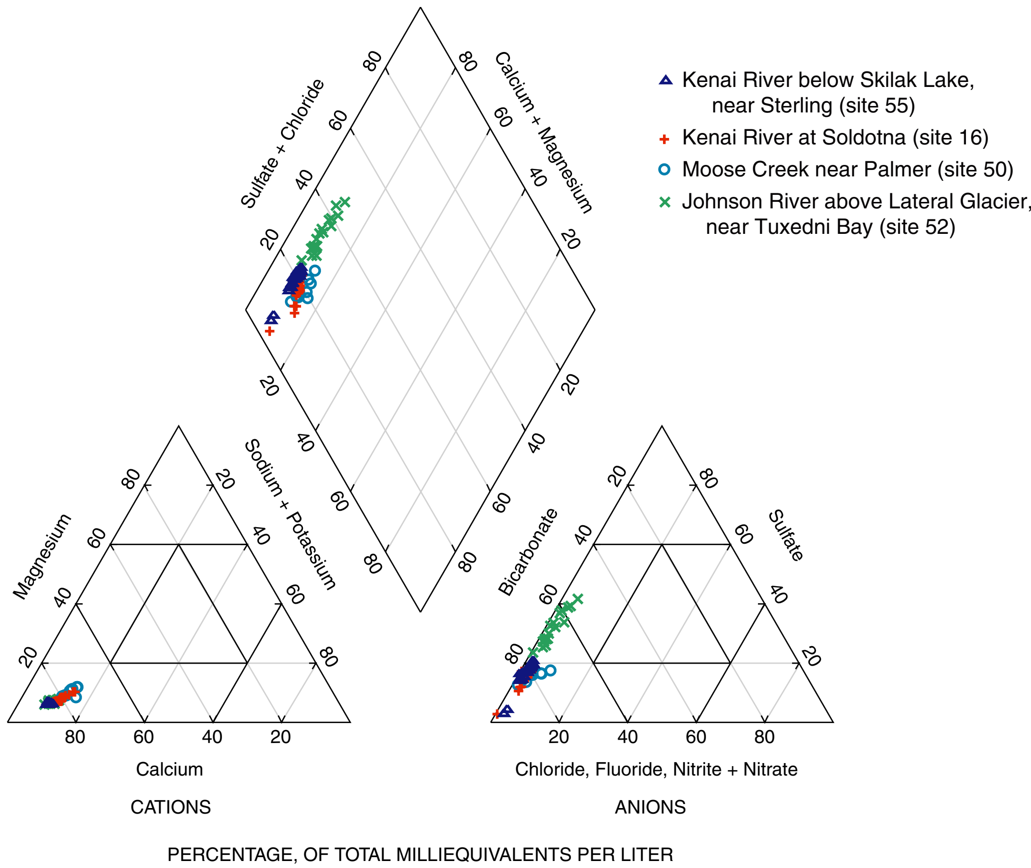

Figure 11. Concentrations of major ions in water samples from fixed sites in glacial and high-elevation basins, Cook Inlet Basin study unit, Alaska, water years 1999–2001.

Concentrations of suspended sediment at the four sites ranged from 1.0 to 882 mg/L (table 3) with the highest concentration noted from a high flow sample at the Johnson River. Based on Spearman's rank correlation coefficient (*rho*) and the probability values less than 0.005, suspended sediment was statistically correlated with discharge except at the Kenai River below Skilak Lake (table 4). Flow at this site was primarily outflow from Skilak Lake, and because most suspended sediment was trapped by the lake, a statistical correlation was not expected.

Sufficient discharge and suspended sediment data were available at the two Kenai River sites to utilize LOADEST. Equations produced by LOADEST (appendix C) indicated good correlations between suspended-sediment load and discharge. Estimated annual suspended-sediment load for 1999–2001 at the Kenai River below Skilak Lake was 18,000 ton/yr (table 5). Eighty percent of the total load was transported during the summer and autumn months (45 percent in summer, 35 percent in autumn). For the Kenai River at Soldotna, LOADEST estimated the annual suspended-sediment load transported past the Soldotna gage site at 129,000 ton/yr (table 5). The additional sediment load is most likely from the Killey River. Seventy-seven percent, or about 100,000 tons, was transported during the summer months. Only minor amounts, 1 and 4 percent respectively, were transported during winter and spring.

Table 5. Load estimates of suspended sediment, total nitrogen, total phosphorus, and dissolved organic carbon for two sites on the Kenai River in glacial and high-elevation basins, Cook Inlet Basin study unit, Alaska, water years 1999–2001

[Locations of sites are shown in figure 1. **Season:** Spring (March, April, May), Summer (June, July, August), Autumn (September, October, November), and Winter (December, January, February)]

Constituent and season	Load (tons per day)	Total load (year or season) (tons)	Upper 95th percent confidence limit (tons per day)	Lower 95th percent confidence limit (tons per day)	Standard error of prediction (tons per day)
Kenai River below Skilak Lake, near Sterling (site 55)					
Suspended sediment					
Average annual	49.2	17,960	58.2	41.3	4.3
Spring	14.8	1,360	20.0	10.7	2.4
Summer	88.2	8,110	109	70.4	9.8
Autumn	68.4	6,220	87.9	52.3	9.1
Winter	25.0	2,250	34.5	17.6	4.3
Total Nitrogen					
Average annual	1.2	438	1.3	1.1	0.06
Spring	.32	29.4	.37	.27	.02
Summer	2.53	233	2.86	2.23	.16
Autumn	1.45	132	1.61	1.30	.08
Winter	.39	35.1	.44	.33	.03
Total phosphorus					
Average annual	0.078	28.5	0.086	0.071	0.004
Spring	.025	2.3	.030	.021	.002
Summer	.15	13.8	.17	.13	.01
Autmn	.11	10.0	.12	.09	.01
Winter	.03	2.7	.036	.025	.003
Dissolved organic carbon					
Average annual	6.66	2,430	7.02	6.31	0.18
Spring	1.98	182	2.15	1.82	.08
Summer	14.66	1,350	15.69	13.67	.51
Autumn	7.62	693	8.06	7.21	.22

Table 5. Load estimates of suspended sediment, total nitrogen, total phosphorus, and dissolved organic carbon for two sites on the Kenai River in glacial and high-elevation basins, Cook Inlet Basin study unit, Alaska, water years 1999–2001—*Continued*

[Locations of sites are shown in figure 1. **Season:** Spring (March, April, May), Summer (June, July, August), Autumn (September, October, November), and Winter (December, January, February)]

Constituent and season	Load (tons per day)	Total load (year or season) (tons)	Upper 95th percent confidence limit (tons per day)	Lower 95th percent confidence limit (tons per day)	Standard error of prediction (tons per day)
Winter	2.26	203	2.43	2.10	.08
Kenai River at Soldotna (site 16)					
Suspended sediment					
Average annual	355	129,600	460	270	49
Spring	62.1	5,710	92.4	39.9	13.5
Summer	1,091	100,400	1,450	802	166
Autumn	240	21,840	332	167	42
Winter	17.9	1,610	28.1	10.7	4.5
Total nitrogen					
Average annual	1.7	620	2.0	1.4	0.1
Spring	.7	64.4	.96	.50	.1
Summer	3.60	331	4.42	2.90	.39
Autumn	1.99	181	2.54	1.53	.26
Winter	.40	36	.54	.29	.06
Total phosphorus					
Average annual	0.30	110	0.38	0.24	0.04
Spring	.15	13.8	.22	.09	.03
Summer	.74	68.1	.98	.54	.11
Autumn	.27	24.6	.38	.19	.05
Winter	.049	4.4	.077	.030	.012
Dissolved organic carbon					
Average annual	13.0	4,745	14.4	11.6	0.71
Spring	7.5	690	9.2	6.0	.82
Summer	26.8	2,470	30.7	23.3	1.9
Autumn	13.2	1,200	15.6	11.1	1.1
Winter	4.0	360	5.0	3.2	.44

Nitrogen, phosphorus, and dissolved-organic-carbon (DOC) concentrations were relatively low at all four sites although there are some differences. The highest concentration of total phosphorus, 0.59 mg/L, was detected at the Johnson River during a high water event in 1999 (table 3). The median concentrations of total phosphorus and orthophosphate at the Kenai River at Soldotna were at least twice as high as the median concentrations of these same constituents at the Kenai River below Skilak Lake (figs. 12-13, table 3). The Kruskal-Wallis test indicated a statistically significant difference in the median values. One possible reason for the difference might be the increased suspended sediment at the Soldotna site relative to the Skilak Lake site. Another reason may be the effects of wetlands and lowlands downstream of the Skilak Lake site. Another noteworthy feature was the relatively high concentration of DOC at the Kenai River at Soldotna every May (figs. 12-13). Whereas there was minimal variation in DOC concentrations at the Skilak Lake site, at Soldotna, concentrations of DOC were highest at this time of the year. These concentrations may reflect the ‘flushing’ of the remains of dead salmon carcasses.

Concentrations of nitrogen, phosphorus, and DOC showed only slight variation with discharge (figs. 12-13) with the exception of the DOC concentrations at Soldotna every May. Because sufficient data were available for the Kenai River sites, LOADEST was used to estimate annual loads of total nitrogen, total phosphorus, and DOC (appendix C, table 5). For the Kenai River below Skilak Lake, average annual loads of total nitrogen, total phosphorus, and DOC were 440, 28, and 2,400 tons, respectively (table 5). About 50 percent of the total load was transported during the summer season and about 30 percent was transported during autumn. For the Kenai River at Soldotna, the average annual loads of nitrogen, phosphorus, and DOC were 620, 110, and 4,700 tons, respectively (table 5). Similar to the upstream site, between 52 and 62 percent of the loads were transported in summer and between 22 and 30 percent of the loads were transported in autumn.

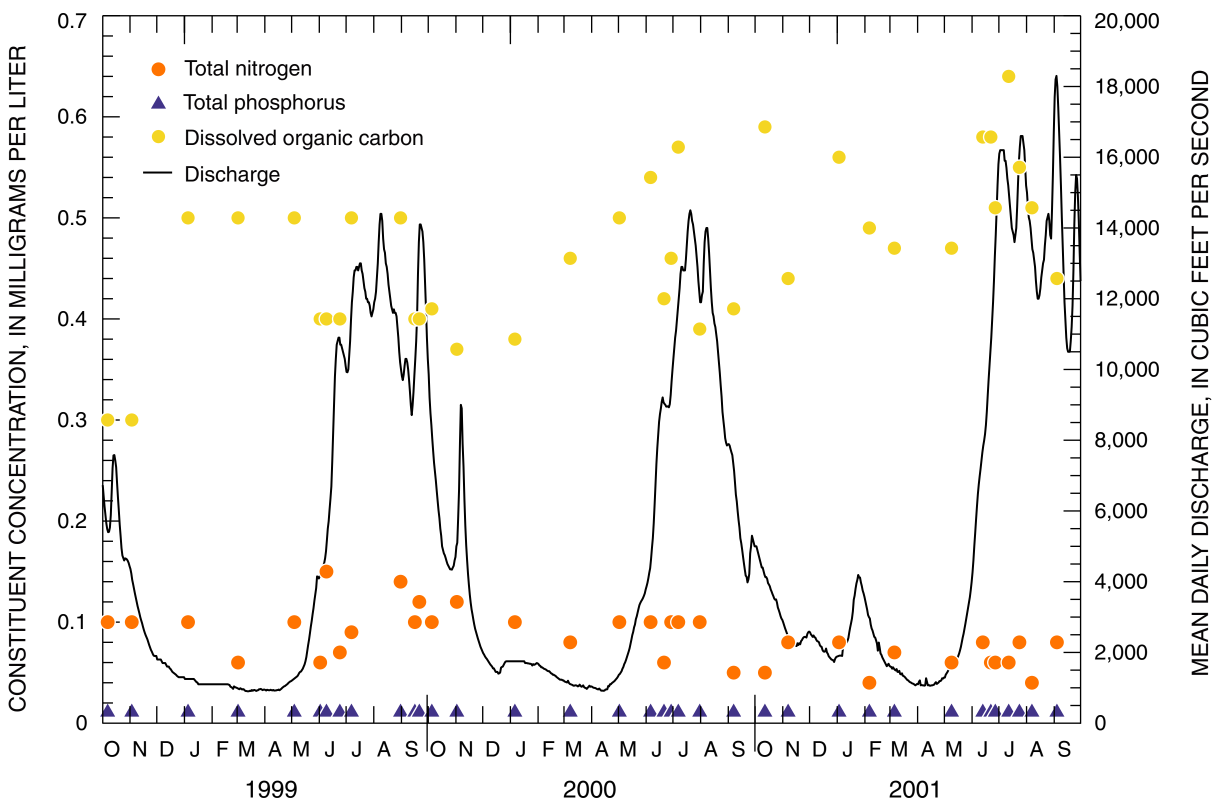

Figure 12. Variation in concentrations of total nitrogen, total phosphorus, and dissolved organic carbon with discharge for the Kenai River below Skilak Lake, near Sterling (site 55), Cook Inlet Basin study unit, Alaska, water years 1999–2001.

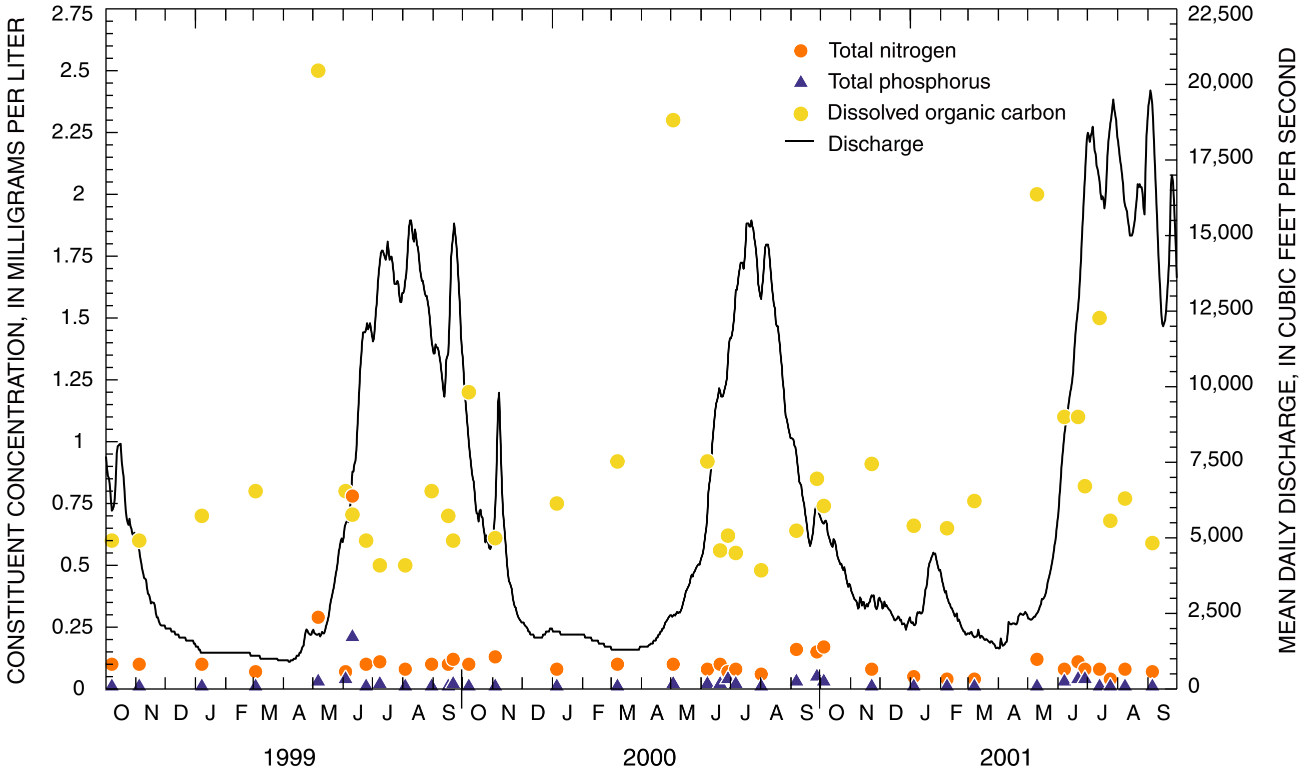

Figure 13. Variation in concentrations of total nitrogen, total phosphorus, and dissolved organic carbon with discharge for the Kenai River at Soldotna (site 16), Cook Inlet Basin study unit, Alaska, water years 1999–2001.

RTH and QMH samples for periphytic algae were collected one time from the Johnson River (August 1998) and from Moose Creek (May 1999) and three times (April 1999, May 2000, and May 2001) from the two Kenai River sites (tables 15-17). DTH samples were collected in 2000 at the Kenai River at Soldotna, and in 2001 at both Kenai River sites (tables 15-17). Attempts were made to collect DTH samples in 1999 at the Kenai River sites and in 2000 at the Kenai River below Skilak Lake. Due to the lack of access to depositional habitat at these sites, however, DTH samples could not be collected.

In the RTH samples, the lowest number of taxa were found at the Johnson River (14) and at Moose Creek (22). Blue-green algae were the only soft algae present in the samples, which was not unexpected, since it typically dominates nitrogen-poor water such as that in Moose Creek and the Johnson River (Bahls, 1993). At the Johnson River, the three most abundant diatoms in the RTH sample, composing nearly one-half of the diatom abundance, were *Hannaea arcus* and two taxa from the genera *Cymbella (Encyonema silesiacum and Reimeria sinuate)*. Both *Hannaea arcus* and *Cymbella* taxa are commonly abundant in arctic and alpine habitats with high water velocity and abrasive glacial silt (Hieber and others, 2001; Antoniades and Douglas, 2002). Stalk length of *Cymbella* also has been observed to increase as water velocity increases (Biggs and Hickey, 1994), possibly contributing to the high cell numbers in the Johnson River. At Moose Creek, a variety of *Cocconeis placentula* accounted for more than 60 percent of the diatom abundance in the RTH sample. This taxon is sensitive to organic enrichment (Bahls, 1993), and the genus *Cocconeis* is considered more sensitive than many other genera found in Cook Inlet Basin streams (Palmer, 1969).

At the Kenai River below Skilak Lake, an average of 44 species were identified in RTH samples, although this is skewed by the presence of 87 species in 2001: nearly four times the number found during other years. The identification of the 87 species in 2001 is believed to be accurate and possibly was due to the mild winter of 2000–2001. Seventy-three taxa were identified in the DTH sample. The relative abundance of soft algae in these samples by major algal division indicated only one division of soft algae in each of the quantitative samples from this site: blue-green algae in the 1999 RTH sample and both 2001 samples, and red algae in the 2000 RTH sample. Blue-green algae were expected since the nitrogen concentrations were low relative to phosphorous concentration. Red algae commonly dominate in cold, shaded water with high velocity, although nutrient and organic levels may vary. The population of diatoms making up more than 10 percent of the RTH samples varied each year, although most of the species present are similarly classified as intolerant to organic pollution (Bahls, 1993). An exception to this is the dominance by *Achnanthidium minutissium* in both the RTH and DTH samples from 2001. This taxon is indicative of substantial streambed scour events and is the likely cause for its high abundance at this site, considering the location of the site and dominance by the genus *Achnanthes* in 2000, which also is resilient to streambed scour (Stevenson and others, 1996; Hieber and others, 2001).

At the Kenai River at Soldotna, an average of 32 taxa were identified in RTH samples and 51 taxa in DTH samples. The relative composition of soft algae in RTH and DTH samples by major algal division varied greatly between years. In 1999, blue-green algae accounted for more than 90 percent of the soft algae abundance. Red algae dominated in 2000, and a sole euglenoid was the only soft algae in the 2001 sample. Blue-green algae and red algae are often abundant in clear, cold water with low nitrogen concentrations, whereas a high presence of euglenoids typically indicates organic enrichment (Bahls, 1993), implying degraded water-quality conditions around the time of sampling in 2001. Dominant diatom autecology for the RTH samples further suggests that the stream site may have been organically enriched in 2001, possibly from the decay of a large run of pink salmon during the winter of 2000–2001. *Reimeria sinuata* and *Achnanthes pusilla*, the dominant diatoms in 1999 and 2000, respectively, prefer oligotrophic water and have much higher oxygen-concentration requirements than does the dominant diatom in 2001, *Encyonema silesiacum*, which is cosmopolitan and has a broad trophic tolerance (Van Dam and others, 1994). All of these taxa are resilient to high water velocities (Stevenson and others, 1996; Hieber and others, 2001).

Blue-green algae were the only soft algae present in the DTH sample from both years at the Soldotna site. Differences from the RTH samples reflect potential microhabitat variation between depositional and riffle areas. The dominant diatom in 2000 was the same as in the RTH sample, and *Encyonema silesiacum* was again particularly abundant in the 2001 sample, along with *Achnanthidium minutissium*, a taxon also resilient to hydrologic disturbance (Barbour and others, 1999). The presence of *Encyonema silesiacum* does not necessarily imply elevated organic enrichment, but its broad tolerance enables it to persist under those conditions.

RTH and QMH samples for macroinvertebrates were collected at the same time as algae samples in 1999 at all four sites and in 2000 and 2001 at the Kenai River sites (tables 18-19). Similar to algae, the lowest number of taxa were found at the Johnson River (14). Nearly 95 percent of the individuals belonged to the order Diptera, and about 4 percent belonged to Ephemeroptera. One dipteran, *Diamesa sp.*, accounted for 60 percent of all individuals in the sample. *Diamesa sp.* belongs to a chironomid subfamily (Diamesinae) that dominates the macroinvertebrate community in other alpine streams, including glacier-fed systems (Slack and others, 1979; Margreiter-Kownacka, 1985). At Moose Creek, 31 taxa were identified in the RTH sample. The orders Diptera and Ephemeroptera accounted for about 39 percent and 38 percent of the sample, respectively. Nearly 30 percent of all taxa belonged to one chironomid genus, *Micropsectra*. Although chironomids generally are considered tolerant, *Micropsectra* is more sensitive to certain perturbations than are other members of that family (Wallace and others, 1991).

At the Kenai River below Skilak Lake, an average of 19 taxa were identified in the macroinvertebrate RTH samples. Plecoptera accounted for one-half of the sample in 1999, nearly 45 percent of the sample composed of one genus, *Capnia*. Taxa in this genus have been observed to increase in abundance after periods of increased flow, and they may prefer high-gradient streams (Fjellhiem and others, 1993; Jacobi and Cary, 1996). Diptera was the dominant order in 2000 and 2001, making up more than 90 percent of the 2000 sample and more than one-half of the 2001 sample. The 2000 sample was heavily represented by Diptera, largely because of the very high abundance of the Chironomid subfamily Diamesinae, which accounted for more than 85 percent of the sample that year. Similarly to *Capnia*, taxa belonging to Diamesinae are tolerant of high water velocity and are often abundant in high-gradient headwater streams (Slack and others, 1979; Margreiter-Kownacka, 1985).

At the Kenai River at Soldotna, the average number of taxa identified in RTH samples was 25. The order Diptera accounted for more than 75 percent of the taxa in the samples, and *Cricotopus/Orthocladius sp*. consistently was the most abundant. Even among other chironomids, *Cricotopus/ Orthocladius* taxa are especially resilient to pollution (Yasuno and others, 1985). In 1999 and 2001, Tubificida (sludge worms) were the second most abundant order. These oligochaetes are considered especially tolerant of frequently disturbed substrate, a wide range of flows, and poor water quality (Pedersen and Perkins, 1986; Winter and Duthie, 1998). A possible reason for the presence of Tubificida in 2001 could be due to the large run of pink salmon in the Kenai River in 2000 and the subsequent carcass decay during the winter of 2000–2001. The community consisted of 10 percent or fewer EPT taxa for all years.

The composition of the functional feeding groups found in RTH samples from the four sites were primarily collector-gatherers, generalist feeders that adapt more easily to environmental changes (Barbour and others, 1999). Shredders were the most abundant group in 1999 at the Kenai River below Skilak Lake. Shredders are particularly sensitive to both perturbations and riparian structure because of their feeding requirements (Rosenberg and Resh, 1993).

Fish samples were collected at the Kenai River below Skilak Lake and at Soldotna in October 1999, and at the Johnson River in August 1998 (table 20). Three juvenile Pacific salmon species were present at the Skilak Lake site and salmonids dominated the community. No external deformities were observed on these fish, indicating a healthy fish community. The only anomaly noted was an eroded fin on a slimy sculpin. At Soldotna, salmonids, including three juvenile Pacific salmon species, were the dominant family. Juvenile chinook salmon (*Oncorhynchus tshawytscha*) were by far the most abundant species. Less than 1 percent of salmonids and less than 2 percent of sculpins had signs of fin erosion, and no other anomalies were observed.

At the Johnson River, juvenile Dolly Varden char (Salvelinus malma, less than 70 mm) were the only fish that were captured, and none had external anomalies. The presence of this sole salmonid has been observed in other streams in the Cook Inlet basin with a similar alpine setting (Frenzel and Dorava, 1999), although slimy sculpin also have been present at some of these similar sites. Deposition of fine-grained sediment from a nearby glacier upstream probably contributes to poor fish habitat at this location.

Physical habitat surveys were conducted at the two sites on the Kenai River in May 1999 and at the Johnson River in August 1998. At the Kenai River below Skilak Lake, flow at the time of the survey was 1,500 ft^3/s. Mean depth was 4.3 ft and mean width was 525 ft. Average velocity through the reach ranged from 0.7 to 3.1 ft/s. The longitudinal profile was relatively flat, with a gradient of 0.012 percent, and the sinuosity of the reach was 1.62, indicating some meandering of the river. Because the channel is relatively wide, the open canopy angle is large, averaging 152 degrees. Vegetation on both banks consisted of shrubs and woodlands (fig. 14). Both left and right bank angles were consistent, ranging from 5 to 10 degrees along the reach, indicating stable banks. The bank and bed substrate consisted primarily of very coarse gravel with little or no sand embedded in the gravel (fig. 15).

At the Kenai River at Soldotna, discharge at the time of the survey was 1,890 ft^3/s. Wetted channel width was 490 ft and mean measured depth was 2.4 ft. Mean velocity was 3.1 ft/s and ranged from 1.8 to 5.0 ft/s. The reach surveyed was relatively straight, as evidenced by a sinuosity of 1.08 (fig. 16). The slope of the water surface was relatively flat (0.14 percent). Because the channel was wide, the open-canopy angle was large, averaging 126 degrees. The left bank consisted predominately of shrubs or woodlands, whereas land use on the right bank consisted of urban and residential development (fig. 16). Left-bank angles ranged between 5 and 90 degrees and right-bank angles between 10 and 90 degrees. The bank substrate consisted primarily of small cobbles with some silt and clay, and the bed substrate consisted of small and large cobbles (fig. 17). Embeddedness of the substrate was zero at all 33 sample points.

At the Johnson River, flow at the time of the survey was 502 ft^3/s. Average depth was 1.7 ft, and the mean width was 129 ft. Gradient of the stream was 1.4 percent and the reach was relatively straight (sinuosity equal to 1.02). Because the channel is relatively wide, the open canopy angle is large, averaging 151 degrees (fig. 18). Along most of the left bank, a point bar had formed that had no vegetation. Only at the downstream end of the reach did vegetation overhang the channel. Shrub and woodland vegetation was present all along the right-bank flood plain. The nearly vertical upper parts of the right bank were bare and eroding. Bank angles averaged about 39 degrees; however, the right bank generally was much steeper than the left bank because it is the outer bank of a meander bend. Bank substrate generally was very coarse gravel, tightly embedded with sand. The left-bank point bar was a sand substrate. Habitat suitable for fish was sparse and consisted of an occasional fallen willow or boulder in the channel in addition to surface turbulence that helps obscure fish.

A.

B.

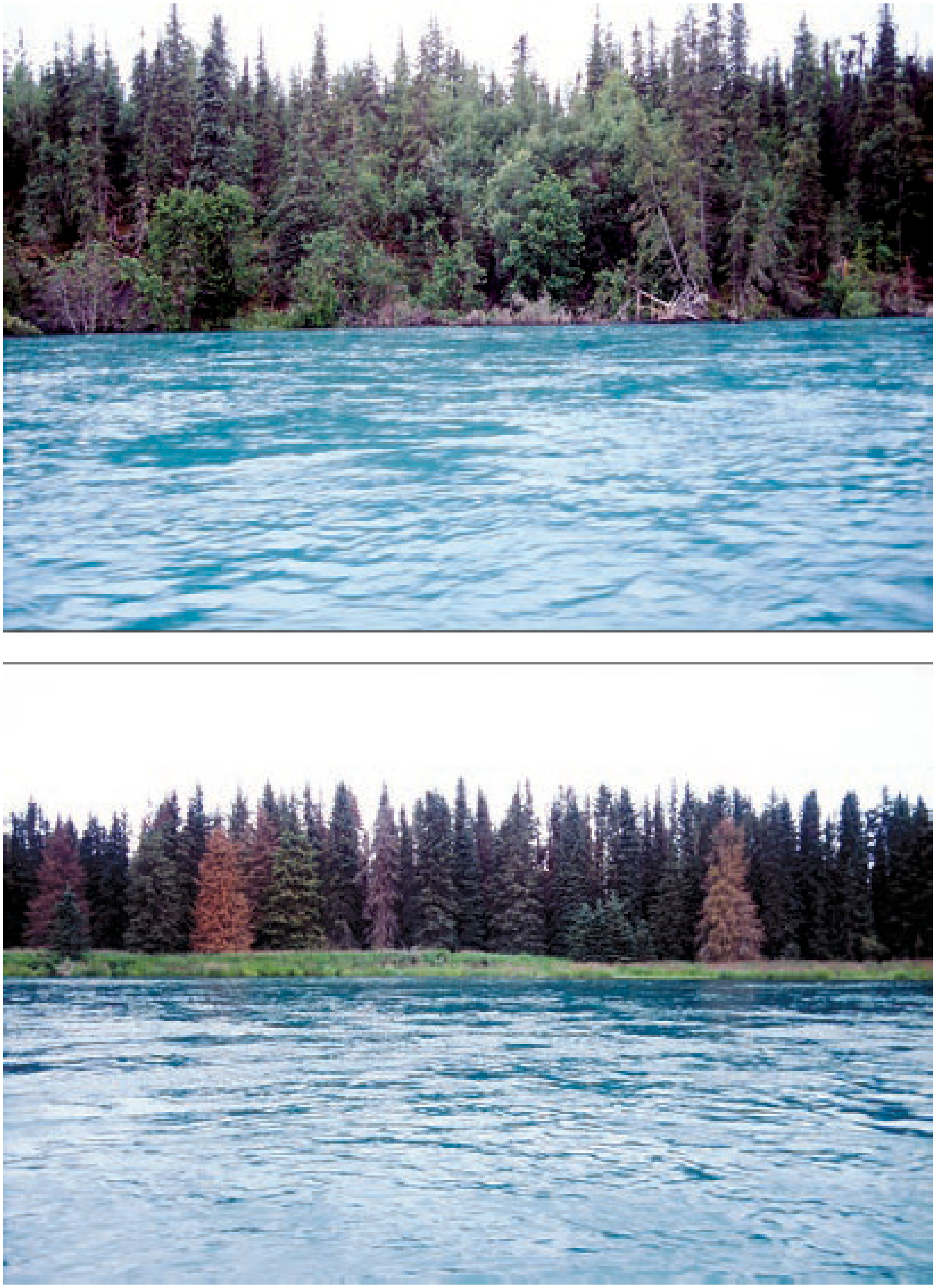

Figure 14. A. Streambank characteristics of the left and B. right banks in the study reach for the physical-habitat survey of the Kenai River below Skilak Lake, near Sterling (site 55), Cook Inlet Basin study unit, Alaska.

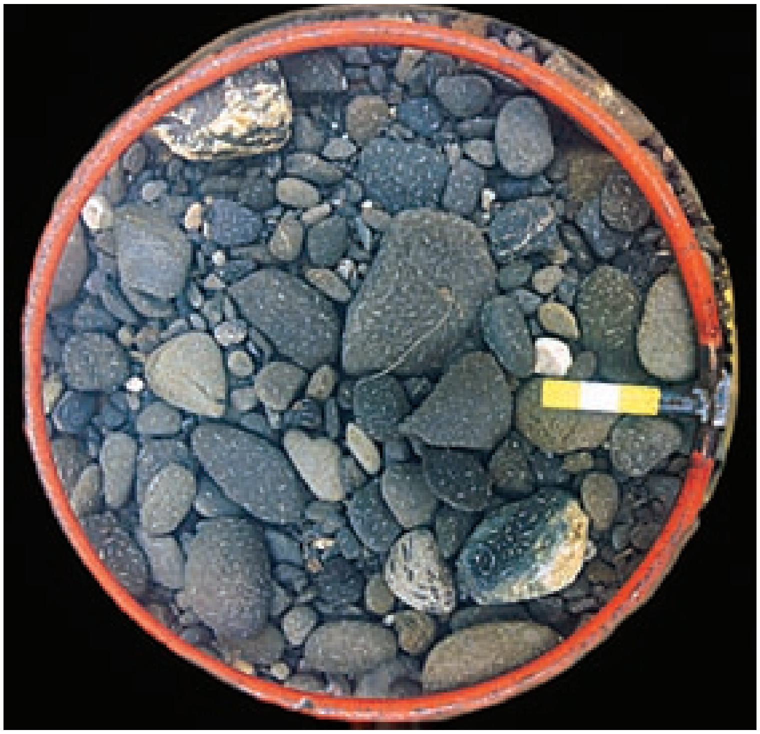

Figure 15. Bed substrate of the Kenai River below Skilak Lake, near Sterling (site 55), Cook Inlet Basin study unit, Alaska.

Figure 16. Study reach for the physical-habitat survey of the Kenai River at Soldotna (site 16), Cook Inlet Basin study unit, Alaska.
Arrows indicate direction of flow. Red lines indicate beginning and end of reaches.

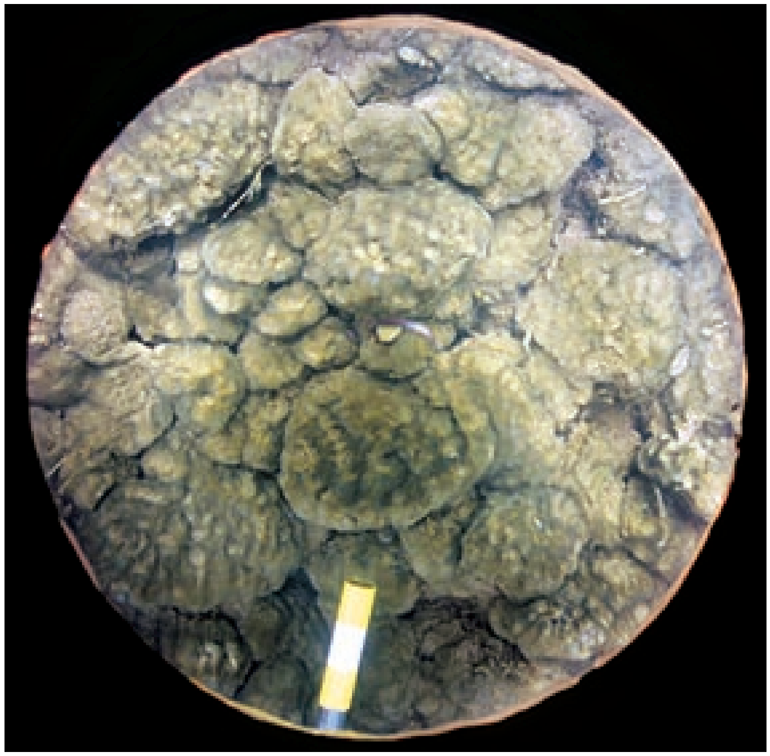

Figure 17. Bed substrate of the Kenai River at Soldotna (site 16), Cook Inlet Basin study unit, Alaska.

Figure 18. Streambank characteristics of the study reach, looking upstream from Johnson River above Lateral Glacier, near Tuxedni Bay (site 52), Cook Inlet Basin study unit, Alaska.

Lowland Basins

Two of the eight fixed sites were classified as lowland basin sites. The Ninilchik River is in the southern part of the Kenai Peninsula (site 7, fig. 1) and the Deshka River (site 44, fig. 1) is in the Susitna River basin in the central part of the Cook Inlet Basin. The Deshka River basin is undeveloped while the primary human activity in the Ninilchik River basin is logging. Brief descriptions of these two basins are as follows (basin characteristics are listed in table 1).

Ninilchik River at Ninilchik, Alaska, Station 15241600

The fixed site Ninilchik River at Ninilchik is 131 mi^2 and ranges in altitude from 20 to 2,050 ft above NGVD 29. The primary land cover is closed spruce forest. Physiographically, the basin is composed of plains and lowlands (69 percent) and plateaus and highlands (31 percent). Logging has occurred in the basin since about 1990, and as of 2000, 43 percent of the basin had been logged (fig. 19). The streamflow-gaging station was operated at this site from 1964 to 1985 and from 1999 to the present.

Deshka River near Willow, Alaska, Station 15294100

The Deshka River is in the Susitna River basin in the central part of the Cook Inlet Basin (fig. 1, site 44), drains an area of 591 mi^2, and has a 1 percent mean slope. Lakes (14.4 mi^2) and wetlands (234 mi^2) are common throughout the basin. Because 40 percent of the basin consists of wetlands and more than 2,700 lakes, the watershed is considered an ideal habitat for fish spawning. This site was chosen for study to gain a better understanding of the water quality of the Susitna River basin, which contributes about one-half the runoff to Cook Inlet. A streamflow-gaging station was operated at this site from 1978 to 1986 and from 1999 to 2001.

Flow characteristics for the Ninilchik and Deshka Rivers were near normal for water years 1999–2001, despite the above normal air temperatures in 2001 (figs. 20-21). For the Ninilchik River, the average annual discharge for 1999–2001 was 107 ft^3/s, the same as the long-term average. For the Deshka River, the average annual discharge for 1999–2001 was 823 ft^3/s, slightly below the long-term average of 870 ft^3/s. Most runoff from the Ninilchik and Deshka Rivers occurred from late April to mid-October (figs. 20-21). Sustained high flows from snowmelt occurred in late April or early May. Through the remainder of the runoff season, sharp and distinct hydrograph peaks resulted from rainstorms. Notable features in the runoff patterns for this period were the below-normal base flow for the winter of 1998–99, the above-normal base flow in the winter of 1999–2000, and the below-normal summer flow in 2000. Thirty-seven and 34 water samples were collected at the Ninilchik and Deshka Rivers, respectively, during water years 1999–2001 (figs. 20-21). These samples covered a range of flows with the exceedance probabilities ranging from less than 1 to greater than 95 percent.

Water temperatures for the Ninilchik and Deshka Rivers showed similar patterns (fig. 22). For about 6 months of the water year—during November through April—water temperature remains at 0 °C. For the remainder of the water year, variations in water temperature occur due to fluctuations in flow and in air temperature. Mean annual water temperature in the Deshka River averaged 5.5, 4.9, and 5.6 °C for water years 1999–2001 while the water temperature in the Ninilchik River was slightly cooler and averaged 4.4, 4.2, and 4.7 °C for the same period. Highest average daily water temperatures measured during water years 1999–2001 were 21.5, 20.5, and 20.5 °C for the Deshka River and 17.5, 16.0, and 17.0 °C for the Ninilchik River. Higher water temperatures noted at the Deshka River probably were due to the relatively warmer air temperatures in this part of the Cook Inlet Basin.

Specific conductance, an indicator of the quantity of dissolved ions in the water, ranged from 22 to 115 µS/cm at 25 °C at these two sampling sites (table 6). Concentrations of the dissolved elements at either site did not exceed recommended levels for drinking water and aquatic life. The Ninilchik River was classified as a calcium-magnesium bicarbonate water (fig. 23) and contained slightly higher concentrations of magnesium, sodium, and silica than the Deshka River water, which was classified as a calcium bicarbonate water. Based on Spearman's rank correlation coefficient (*rho*) and probability values less than 0.005, all ions indicated a significant correlation with specific conductance at both sites with the exception of chloride and sulfate at the Ninilchik River (table 7).

Suspended-sediment concentrations from the two sites ranged from 1 to 164 mg/L (table 6) and showed a significant correlation with discharge (rho = 0.87 and 0.92, $p < 0.0001$) (table 7). The regression equations computed by LOADEST indicated coefficients of determinations of 0.90 and 0.97, respectively (appendix C). The computed average annual suspended-sediment load was 3,700 tons for the Ninilchik River and 22,300 tons for the Deshka River (table 8). Most of the suspended-sediment load—73 and 75 percent—was transported during spring (March-May), and only 1 to 2 percent was transported during the winter low-flow months.

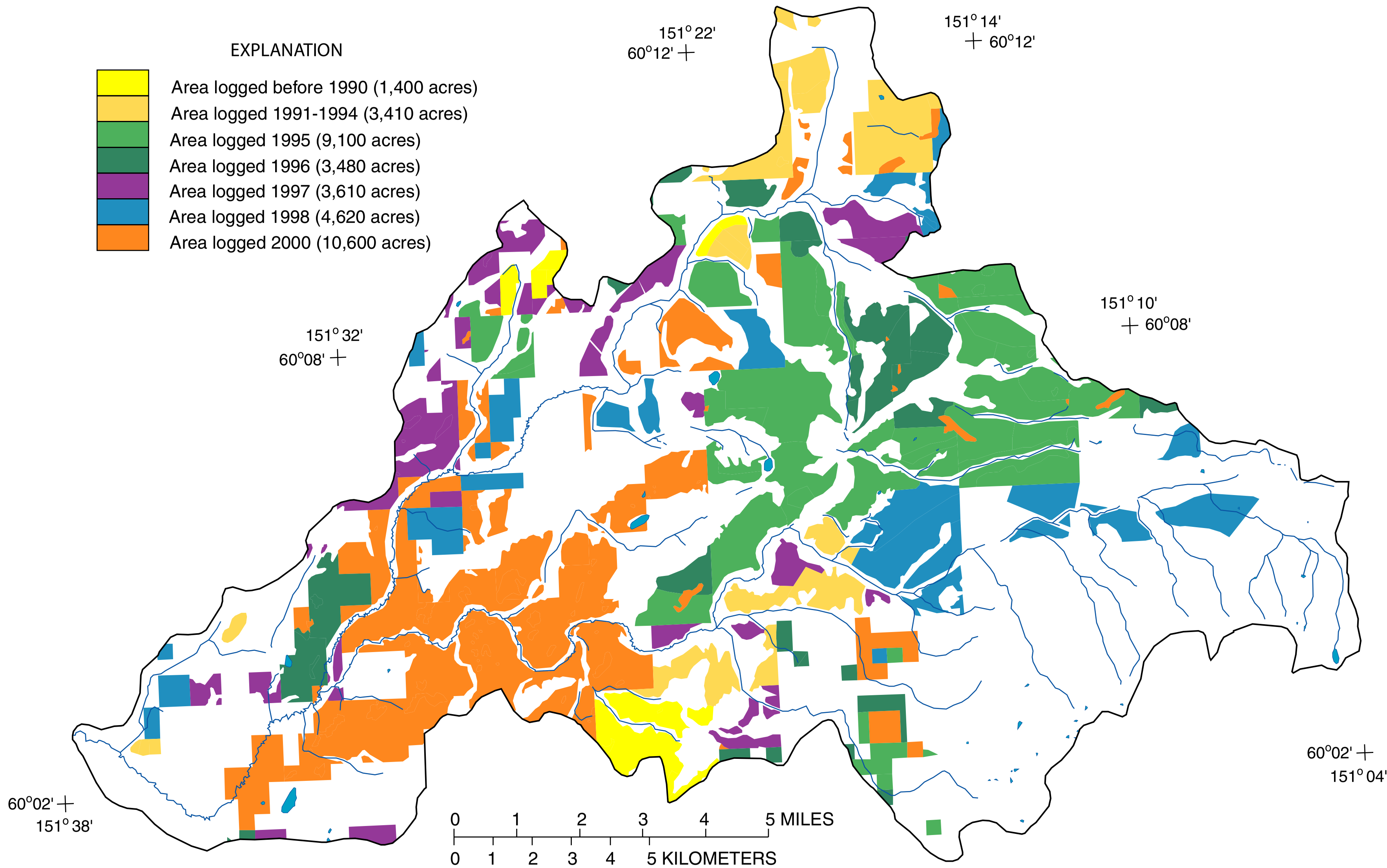

Figure 19. Logged areas of the Ninilchik River basin, Cook Inlet Basin study unit, Alaska.

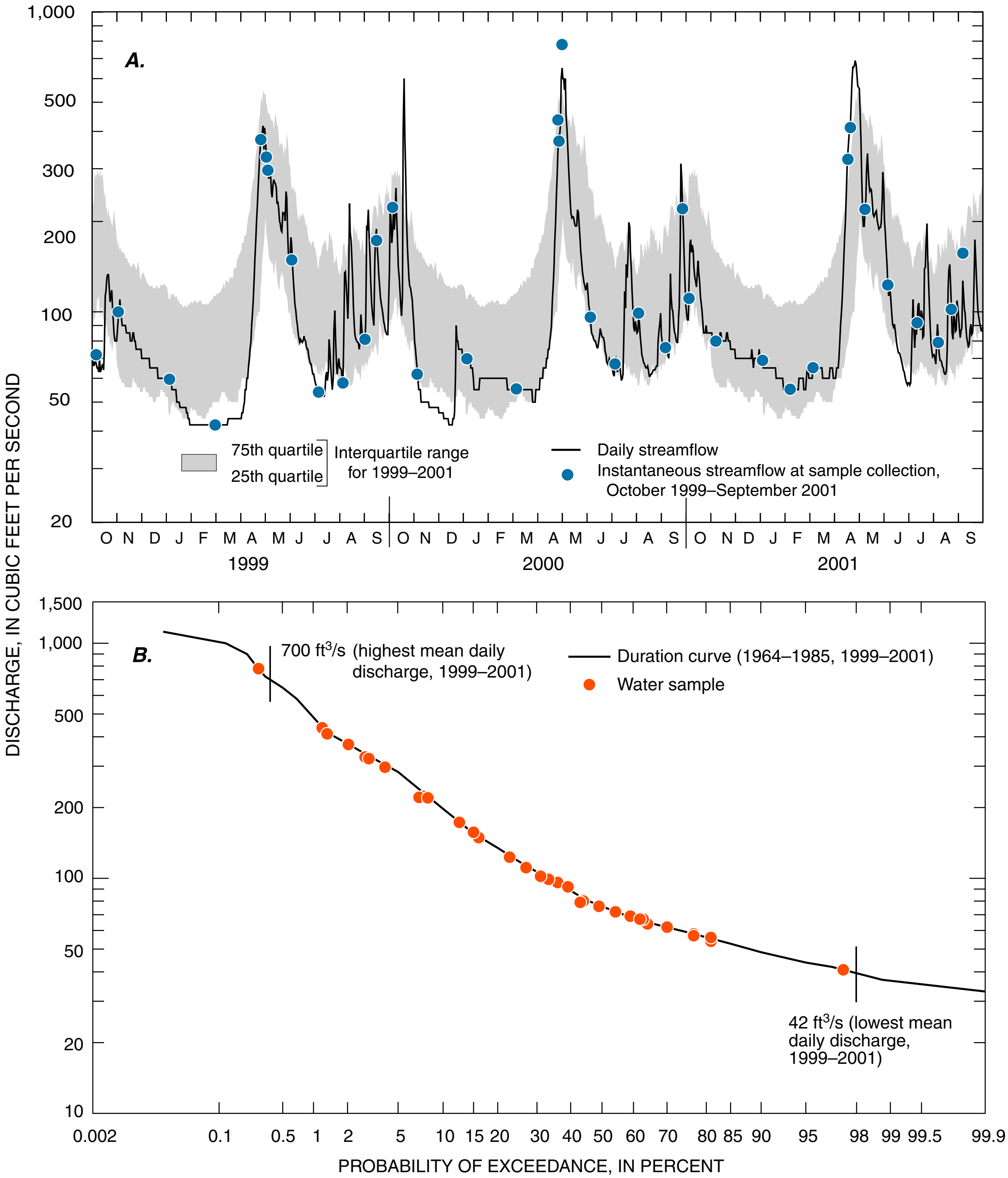

Figure 20. A. Daily and instantaneous streamflow at the time of sample collection, interquartile range of mean daily streamflows for the period of recod, and B. Percentage of time indicated discharge was equaled or exceeded at the Ninilchik River at Ninilchik (site 7), Cook Inlet Basin study unit, Alaska, water years 1999–2001.

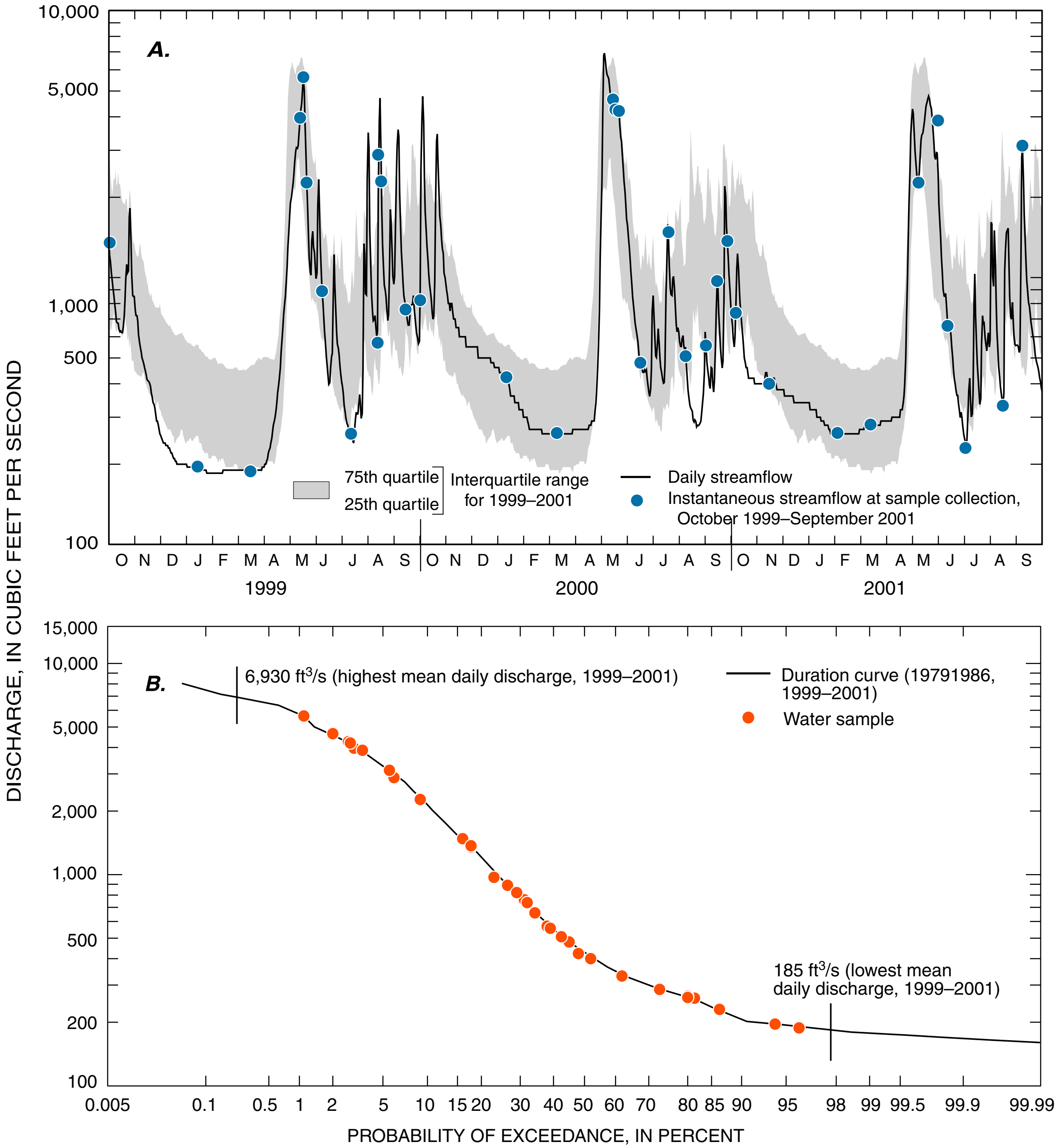

Figure 21. A. Daily and instantaneous streamflow at the time of sample collection, interquartile range of mean daily streamflows for the period of record, and B. Percentage of time indicated discharge was equaled or exceeded at the Deshka River near Willow (site 44), Cook Inlet Basin study unit, Alaska, water years 1999–2001.

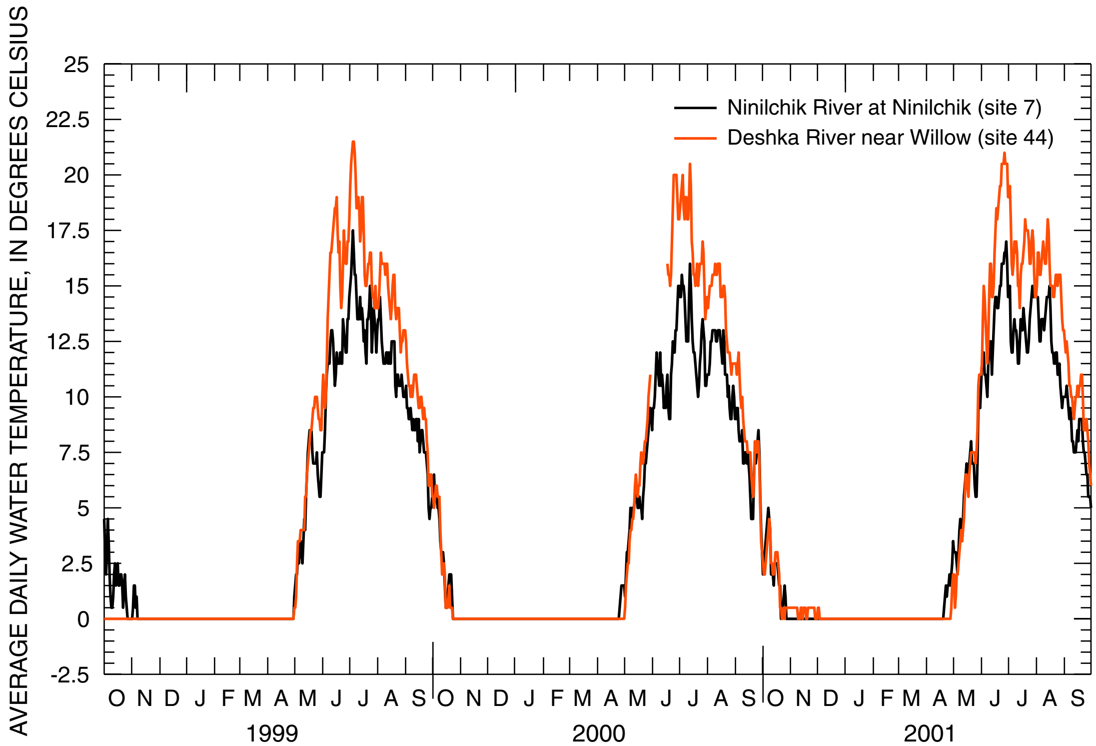

Figure 22. Average water temperature for fixed sites in lowland basins, Cook Inlet Basin study unit, Alaska, water years 1999–2001.

Table 6. Summary of values of field measurements and concentrations of nutrients, major ions, organic carbon, and suspended sediment in water samples from fixed sites in lowland basins, Cook Inlet Basin study basin, Alaska, water years 1999–2001

[Locations of sites are shown in figure 1. Values are given in milligrams per liter unless otherwise noted. °C, degree Celsius; µS/cm, microsiemen per centimeter at 25 degrees Celsius; µg/L, microgram per liter; <, actual value is less than value shown]

Constituent	Minimum	Maximum	Mean	Median
Ninilchik River at Ninilchik (site 7; 37 samples)				
Water temperature (°C)	0	17	5.7	3.0
Specific conductance (µS/cm at 25 °C)	38	115	82	88
pH	6.8	8.0	7.4	7.5
Dissolved oxygen	9.7	14.4	11.9	11.8
Ammonia nitrogen, dissolved	.002	.216	.0375	.024
Ammonia-plus-organic nitrogen, dissolved	.158	.386	.246	.245
Ammonia-plus-organic nitrogen, total	.183	1.032	.385	.374
Nitrite nitrogen, dissolved	.001	.011	.003	.002
Nitrite-plus-nitrate nitrogen, dissolved	.005	.153	.068	.053
Total nitrogen	.188	1.183	.453	.427
Phosphorus, total	.066	.309	.131	.118
Phosphorus, dissolved	.044	.102	.064	.057
Orthophosphate phosphorus, dissolved	.001	.093	.053	.051
Alkalinity (as $CaCO_3$)	14	52	37	40
Bicarbonate (as $CaCO_3$)	18	63	45	48
Calcium	3.1	9.4	6.6	6.8
Magnesium	1.5	4.5	3.1	3.2
Sodium	2.3	8.1	5.9	6.7
Potassium	1.3	2.6	1.8	1.8
Sulfate	.1	.7	.4	.4
Chloride	1.5	4.3	2.5	2.4
Fluoride	.08	.13	.1	.1
Silica	12	35	25	28
Iron (µg/L)	380	1,250	692	690
Manganese (µg/L)	42	172	97	101
Dissolved solids, residue at 180 °C	48	113	83	88
Organic carbon, dissolved	3.5	9.9	6.2	5.8
Organic carbon, suspended	.2	2.0	.6	.4
Suspended sediment	1	164	29	18

Table 6. Summary of values of field measurements and concentrations of nutrients, major ions, organic carbon, and suspended sediment in water samples from fixed sites in lowland basins, Cook Inlet Basin study basin, Alaska, water years 1999–2001—*Continued)*

[Locations of sites are shown in figure 1. Values are given in milligrams per liter unless otherwise noted. ºC, degree Celsius; µS/cm, microsiemen per centimeter at 25 degrees Celsius; µg/L, microgram per liter; <, actual value is less than value shown]

Constituent	Minimum	Maximum	Mean	Median
Deshka River near Willow (site 44; 34 samples)				
Water temperature (ºC)	0	20	8.7	7.8
Specific conductance (µS/cm at 25 ºC)	22	94	53	54
pH	6.5	7.6	7.1	7.1
Dissolved oxygen	8.0	13.2	10.3	10.4
Ammonia nitrogen, dissolved	.002	.247	.019	.008
Ammonia-plus-organic nitrogen, dissolved	.094	.528	.233	.226
Ammonia-plus-organic nitrogen, total	.134	.633	.332	.307
Nitrite nitrogen, dissolved	.001	.008	.002	.001
Nitrite-plus-nitrate nitrogen, dissolved	.005	.764	.110	.068
Total nitrogen	.139	1.397	.442	.817
Phosphorus, total	.012	.113	.045	.034
Phosphorus, dissolved	.004	.042	.013	.012
Orthophosphate phosphorus, dissolved	.001	.092	.010	.005
Alkalinity (as $CaCO_3$)	8	46	23	23
Bicarbonate (as $CaCO_3$)	9.5	56	27	27
Calcium	2.1	10.2	6.2	6.2
Magnesium	.6	2.5	1.4	1.4
Sodium	.8	5.6	1.7	1.7
Potassium	.1	1.1	.7	.7
Sulfate	.1	.8	.4	.3
Chloride	.1	1.1	.4	.4
Fluoride	<.1	<.1	<.1	<.1
Silica	2.0	20.3	12.0	11.9
Iron (µg/L)	50	820	550	540
Manganese (µg/L)	14.3	115	48	36
Dissolved solids, residue at 180 ºC	10	85	52	53
Organic carbon, dissolved	2.3	13.7	6.6	6.5
Organic carbon, suspended	.1	1.0	.4	.3
Suspended sediment	2	99	19	6

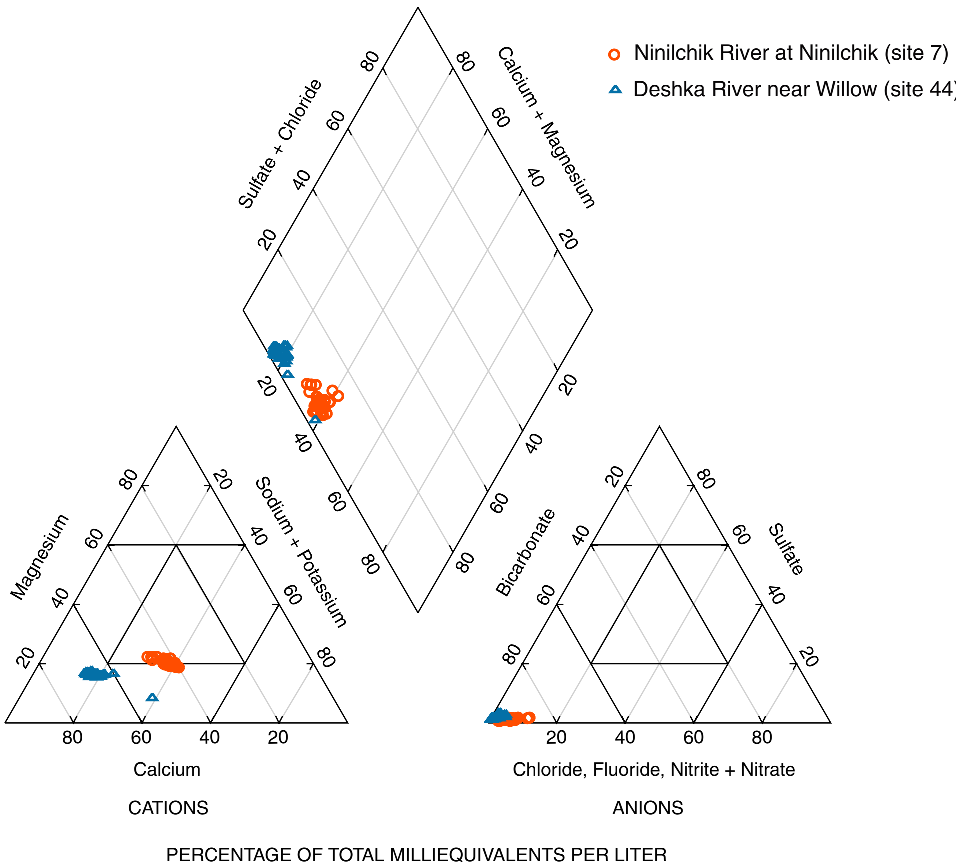

Figure 23. Concentrations of major ions in water samples from fixed sites in lowland basins, Cook Inlet Basin study unit, Alaska, water years 1999–2001.

Table 7. Relations between dissolved solids and major ions to specific conductance, and suspended-sediment concentration to discharge in water samples from fixed sites in lowland basins, Cook Inlet Basin study unit, Alaska, October 1998 through September 2001

[**Site:** Site locations are shown in figure 1. Specific conductance in microsiemens per centimeter at 25 °C. Discharge in cubic feet per second. Spearman's rank correlation coefficients (*rho*) and probability values (*p*-values) are significant (in **bold**) when *rho* is greater than 0.5, and *p*-values are less than 0.005; <, actual value is less than value shown]

Water-quality constituent	*rho*	*p*-value
Ninilchik River at Ninilchik (site 7; 37 samples)		
Calcium	**0.96**	**<0.0001**
Magnesium	**.96**	**<.0001**
Sodium	**.93**	**<.0001**
Bicarbonate	**.96**	**<.0001**
Silica	**.87**	**<.0001**
Potassium	**.63**	**<.0001**
Chloride	.42	.010
Sulfate	.44	.007
Dissolved solids	**.95**	**<.0001**
Suspended sediment	**.87**	**<.0001**
Deshka River near Willow (site 44; 34 samples)		
Calcium	**0.96**	**<0.0001**
Magnesium	**.92**	**<.0001**
Sodium	**.98**	**<.0001**
Bicarbonate	**.98**	**<.0001**
Silica	**.79**	**<.0001**
Potassium	**.65**	**<.0001**
Chloride	**.52**	**.0015**
Sulfate	**.73**	**<.0001**
Dissolved solids	**.93**	**<.0001**
Suspended sediment	**.92**	**<.0001**

Table 8. Load estimates of suspended sediment, total nitrogen, total phosphorus, and dissolved organic carbon for fixed sites in lowland basins, Cook Inlet Basin study unit, Alaska, water years 1999–2001

[Locations of sites are shown in figure 1]

Constituent and season	Load (tons per day)	Total load (year or season) (tons)	Upper 95th percent confidence limit (tons per day)	Lower 95th percent confidence limit (tons per day)	Standard error of prediction (tons per day)
Ninilchik River at Ninilchik (site 7)					
Suspended sediment					
Average annual	10.1	3,690	14.0	7.0	1.8
Spring	29.2	2,690	43.8	18.6	6.5
Summer	5.6	520	7.9	3.8	1.0
Autumn	4.5	410	6.8	2.8	1.0
Winter	.74	70	1.14	.46	.17
Total Nitrogen					
Average annual	0.11	40	0.13	0.10	0.01
Spring	.22	20.2	.26	.19	.02
Summer	.10	9.2	.11	.08	.01
Autumn	.10	9.0	.12	.08	.01
Winter	.04	3.6	.05	.03	.004
Total phosphorus					
Average annual	0.04	15	0.043	0.038	0.02
Spring	.07	6.4	.08	.06	.006
Summer	.033	3.0	.038	.028	.003
Autmn	.035	3.2	.042	.030	.003
Winter	.014	1.3	.016	.013	.001
Dissolved organic carbon					
Average annual	1.83	668	1.91	1.74	0.04
Spring	3.60	331	3.87	3.35	.13
Summer	1.41	130	1.51	1.31	.05
Autumn	1.67	152	1.80	1.54	.07
Winter	.60	54	.66	.55	.03

Table 8. Load estimates of suspended sediment, total nitrogen, total phosphorus, and dissolved organic carbon for fixed sites in lowland basins, Cook Inlet Basin study unit, Alaska, water years 1999–2001—*Continued)*

[Locations of sites are shown in figure 1]

Constituent and season	Load (tons per day)	Total load (year or season) (tons)	Upper 95th percent confidence limit (tons per day)	Lower 95th percent confidence limit (tons per day)	Standard error of prediction (tons per day)
Deshka River near Willow (site 44)					
Suspended sediment					
Average annual	61	22,300	80	46	8
Spring	181	16,700	248	128	30
Summer	24	2,210	30	19	3
Autumn	34	3,100	43	27	4
Winter	2.8	252	3.5	2.3	.3
Total nitrogen					
Average annual	0.83	303	0.94	0.73	0.05
Spring	1.45	133	1.75	1.19	.14
Summer	.71	65	.82	.61	.05
Autumn	.98	89	1.19	.80	.10
Winter	.17	15	.21	.13	.02
Total phosphorus					
Average annual	0.12	43.8	0.15	0.10	0.01
Spring	.26	23.9	.35	.20	.04
Summer	.09	8.3	.11	.07	.01
Autumn	.11	10.0	.14	.09	.01
Winter	.023	2.1	.029	.018	.003
Dissolved organic carbon					
Average annual	16.1	5,880	17.2	15.1	0.53
Spring	29.3	2,700	32.3	26.4	1.51
Summer	13.6	1,250	14.7	12.6	.52
Autumn	18.2	1,660	20.2	16.4	.96
Winter	3.1	279	3.4	2.7	.19

Concentrations of total nitrogen and DOC were similar at both sites (table 6). Phosphorus concentrations at the Ninilchik River were significantly different and are thought to be due to the geology of the Ninilchik River basin. The concentrations of these constituents varied with flow—concentrations were highest at high discharges during snowmelt and rainfall events (figs. 24-25). Concentrations of DOC at the Ninilchik River ranged from 3.5 to 9.9 mg/L and at certain times were a magnitude higher than nitrogen and phosphorus concentrations (figs. 24-25). Concentrations of DOC followed the same trend as nitrogen and phosphorus.

Seasonal variation in the loads of total nitrogen, total phosphorus, and dissolved organic carbon calculated by LOADEST are similar to suspended sediment. Most of the total load—about 50 percent—of these constituents was transported during the spring (table 8). Approximately equal amounts (about 20 percent) were transported during the summer and autumn months. Ten percent or less of the total load of these constituents was transported during the winter.

RTH, DTH, and QMH samples of periphytic algae were collected once per year (usually in August) from 1999 to 2001 at the Ninilchik and Deshka Rivers during low-flow conditions (tables16-18). At the Ninilchik River, an average of 61 taxa were identified in RTH samples, with a high of 91 species in 2001. For the DTH samples, an average of 72 species were identified, with a high of 89 species in the 2001 sample (note: the 2000 DTH sample was not included in the analysis because of analytical problems at the laboratory). The high numbers of species in the 2001 samples possibly were due to the above normal air temperatures. *Amphithrix janthina*, a nitrogen-fixing blue-green alga, was the most abundant of the soft algae (non-diatom) in both the RTH and DTH samples for all years, accounting for 95 to 100 percent of the soft algae. Nitrogen-fixing blue-green algae typically dominate in oligotrophic waters where bioavailable nitrogen (nitrate and ammonia) concentrations are low or phosphorous concentrations are high (Bahls, 1993). The diatom community consisted of more than 10-percent *Achnanthes lanceolata* each year. The genus *Achnanthes* has the capacity to pioneer frequently disturbed substrate (Hieber and others, 2001), and *Achnanthes lanceolata*, in particular, has been frequently observed as a colonizing species (Lowe, 1974).

At the Deshka River, an average of 39 taxa were identified in RTH samples, with a high of 63 taxa in 2001, more than twice that was found in previous years. DTH samples contained an average of 65 taxa, with a high of 87 taxa, also in 2001. Similar to the Ninilchik River, the high number of species found in 2001 possibly was due to the above normal air temperatures. The relative composition of soft algae in RTH samples, by major algal division, indicated that green algae were the most abundant soft algae from 1999 and 2000, whereas blue-green algae were the most abundant in 2001. Green algae typically favor relatively high nitrogen concentrations and blue-green algae typically favor lower nitrogen concentrations (Bahls, 1993), indicating that the stream site may have been more organically enriched during the first two sampling periods. The diatom community in RTH samples generally was similar among the 3 years sampled, dominated by the genus *Fragilaria* each year. This genus is moderately tolerant to organic enrichment, but also is found in oligotrophic waters (Palmer, 1969; Lowe, 1974; Van Dam and others, 1994), potentially explaining its high abundance when either green or blue-green algae are the dominant soft algal division. It also is a pioneering genus, similar to other abundant genera *Achnanthes* and *Synedra* (Stevenson and others, 1996; Hieber and others, 2001).

In DTH samples from the Deshka River, soft algae was dominated by a single red alga in 1999 (*Audouinella violacea*) and by blue-green algae in 2000 and 2001, all of which may be common in pristine environments (Bahls, 1993). The dominant diatom in 1999 and 2000 was *Tabellaria flocculosa*, a taxon preferring relatively high oxygen concentrations and low biochemical-oxygen demand (Van Dam and others, 1994). It also is considered to be a good indicator of consistent pH levels less than 7 (Lowe, 1974; Pan and others, 1996). *Achnanthidium minutissium* dominated the diatom community in 2001, a taxon tolerant of a broad range of water-quality conditions and resilient to scour episodes (Barbour and others, 1999).

At both sites, RTH and QMH samples of macroinvertebrates also were collected once per year (tables 18-19) from 1999 to 2001 at the same time algae samples were collected. For the Ninilchik River, an average of 32 taxa were identified in the RTH samples with Diptera being the dominant order each year, accounting for more than 30 percent of the community. The most common Dipterans were *Pericoma/Telmatoscopus sp*. (family Psychodidae), which are highly tolerant to a wide range of conditions (Wagner and Masteller, 1992). Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies), together referred to as EPT, represented more than 45 percent of the community. *Rhithrogena sp*. (Ephemeroptera) was the most prevalent EPT taxa. *Rhithrogena* species are more tolerant than many mayflies and are able to strongly grasp substrate during high flows or seek refuge in shoreline areas (Hynes, 1970; Rempel and others, 1999; Courtney and Clements, 2000).

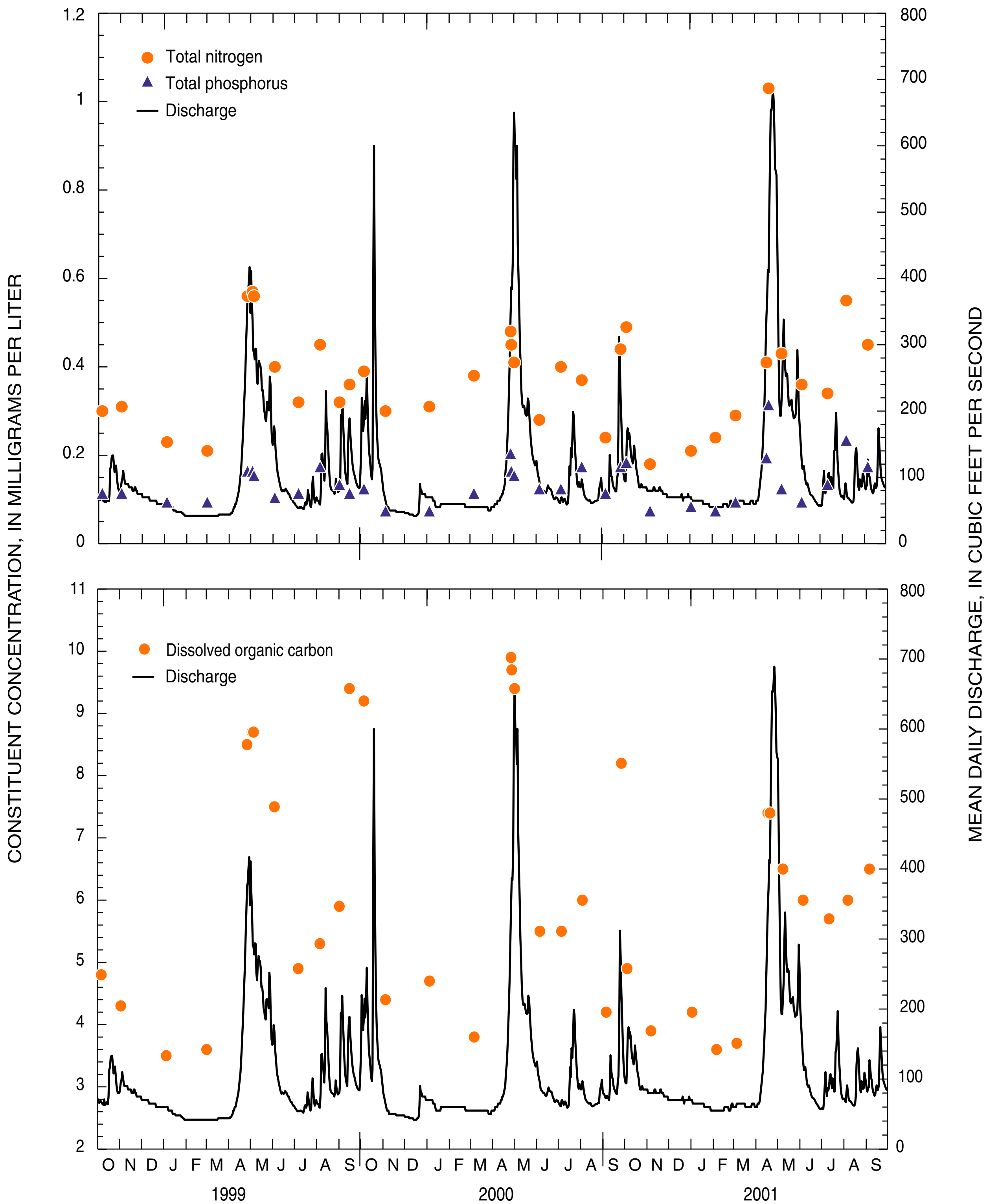

Figure 24. Variation in concentrations of total nitrogen, total phosphorus, and dissolved organic carbon with discharge for the Ninilchik River at Ninilchik (site 7), Cook Inlet Basin study unit, Alaska, water years 1999–2001.

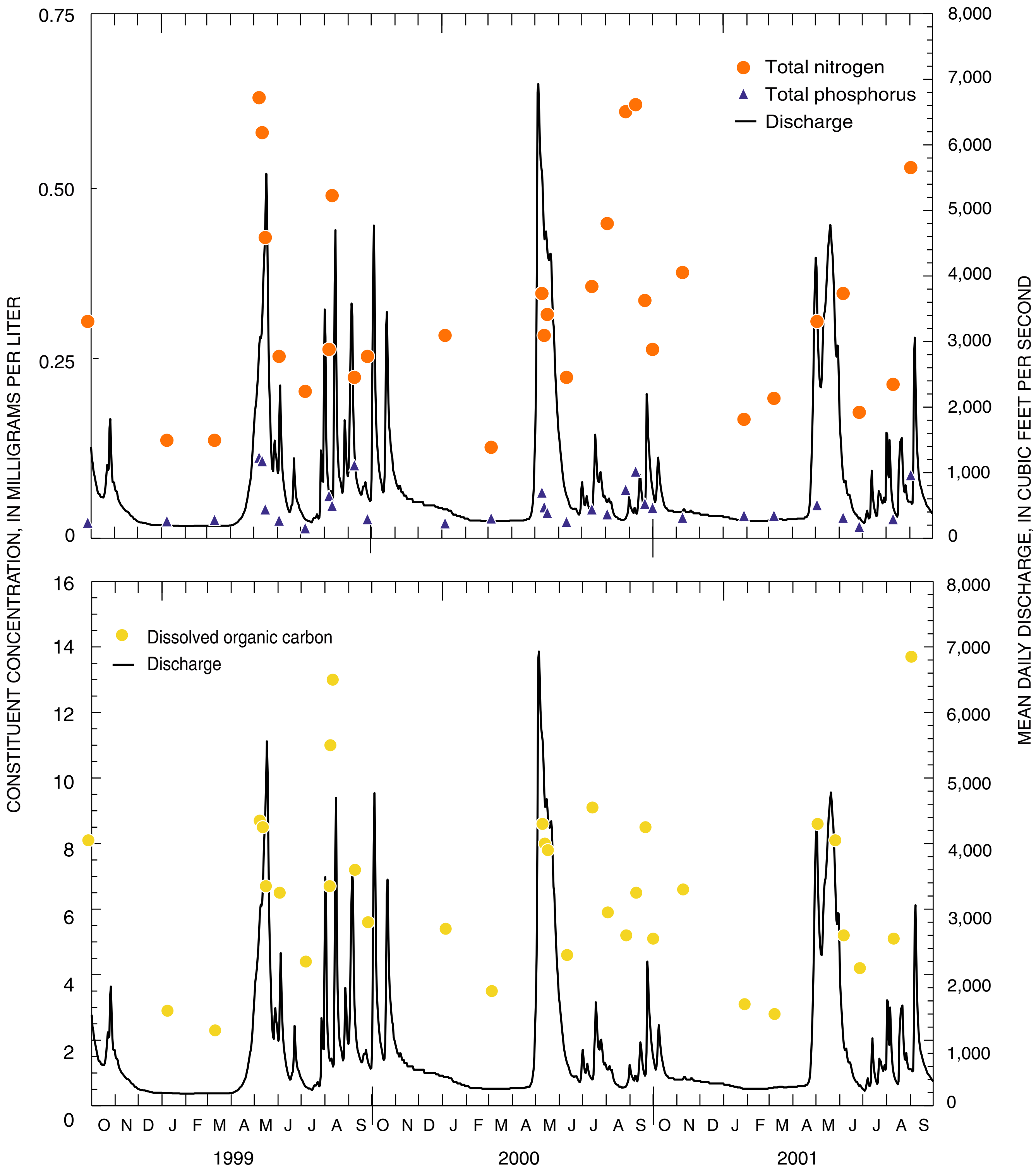

Figure 25. Variation in concentrations of total nitrogen, total phosphorus, and dissolved organic carbon with discharge for the Deshka River at Willow (site 44), Cook Inlet Basin study unit, Alaska, water years 1999–2001.

At the Deshka River, an average of 29 unambiguous taxa were identified in the RTH samples. Diptera was consistently the dominant order, representing more than 45 percent of the community each year. In particular, *Cricotopus/Orthocladius sp*. was highly abundant, a group of taxa that are particularly resilient to pollution (Yasuno and others, 1985). Trichoptera and Ephemeroptera each accounted for more than 10 percent of the community in two of the three samples. The relative abundance of Acari (water mites), a taxon determined to be highly sensitive to sedimentation in interior Alaska (Wagener and LaPerriere, 1985), was substantial in 1999, constituting more than 20 percent of the community.

Scrapers, specialist feeders that are commonly indicative of healthy water-quality conditions, dominated the community in the Ninilchik River at Ninilchik in 1999 and 2001. Collector-gatherers, generalist feeders that are more tolerant of changing conditions, dominated in 2000. These differences are attributed to the different flow conditions that occurred prior to the time of sampling. In 2000, flow conditions were approximately 80 ft^3/s the entire month. In 1999 and 2001, however, flow conditions 5 to 10 days before sample collection were relatively high (150 to 200 ft^3/s) At the Deshka River, predators, believed to respond to the quantity and diversity of prey and therefore to be a potential indicator of community condition (Kearns and Karr, 1994), were most abundant in 1999. Generalist feeders (collector-gatherers and filtering-collectors) were most abundant in 2000 and 2001.

Fish were collected from the Ninilchik River at Ninilchik in September 1999 (table 20). Salmonids were the most abundant family, and coho salmon (*Oncorhynchus kisutch*) were the only juvenile Pacific salmon species present. Spawning adult chinook (*Oncorhynchus tshawytscha*) and pink (*Oncorhynchus gorbuscha*) salmon were observed but not collected during the study. Less than 2 percent of salmonids examined had eroded fins, including only one individual from each of the three species. Most likely, the eroded fins are due to the hydraulics of the Ninilchik River (relatively high velocities at high flows) and not due to degradation.

The fish community in the Deshka River near Willow was sampled in August and October 1999 (table 20). Only two salmonid taxa were captured, although juvenile coho salmon far outnumbered other fish. For example, adult Chinook and pink salmon also were observed on numerous visits to the Deshka River. Two species, northern pike (*Esox lucius*) and burbot (*Lota lota*), were collected from the Deshka River but were not found at any of the other sites sampled in Cook Inlet Basin. Burbot is a bottom species native to rivers throughout Alaska, but sampling gear used in this study unit were not very efficient for their capture. Northern pike, native to interior and western regions of Alaska, have been illegally introduced in southcentral Alaska (Alaska Department of Fish and Game, 2003).

The physical habitat of the Ninilchik River was surveyed in August 1999. Flow at the time of the survey was 79 ft^3/s. Mean depth was 1.6 ft and the mean width was 43 ft. The gradient of the reach was 0.29 percent, relatively flat, and the sinuosity of the reach was 1.16, although parts of the Ninilchik River are somewhat meandering (fig. 26). Vegetation on both banks consisted of shrubs and woodlands. Due to the height of the trees, the canopy angle was only 81 degrees, moderately open (fig. 26). Both left and right bank angles varied greatly, ranging from 15 to 70 degrees along the reach. The bank substrate consisted primarily of silt and clay and the bed substrate consisted of coarse gravel and large boulders. The embeddedness of the substrate varied considerably, from 0 to 100 percent. Habitat for fish consisted of overhanging vegetation along the banks and several pools within the reach.

The physical habitat of the Deshka River was surveyed in August 1999 (fig. 27). Discharge at the time of the survey was 597 ft^3/s. The reach was relatively straight, with a sinuosity of 1.04, and the slope relatively flat at 0.15 percent. Vegetation on both banks consisted of shrubs and woodlands. Both left and right bank angles varied somewhat. Along the left bank, angles ranged between 0 and 20 degrees for the first eight transects and about 0 and 50 degrees for the last three transects. Along the right bank, angles were 10 degrees or less for the first five transects, but the remaining transects were characterized by overhanging vegetation. The bank substrate along the left bank consisted primarily of silt and clay, with some small cobbles noted in the last three transects. Along the right bank, the substrate consisted of coarse gravel and small cobbles for the first four transects and primarily silt and clay for the remaining seven transects. Habitat for fish consisted of overhanging vegetation along banks and a number of pools and woody debris piles along the reach.

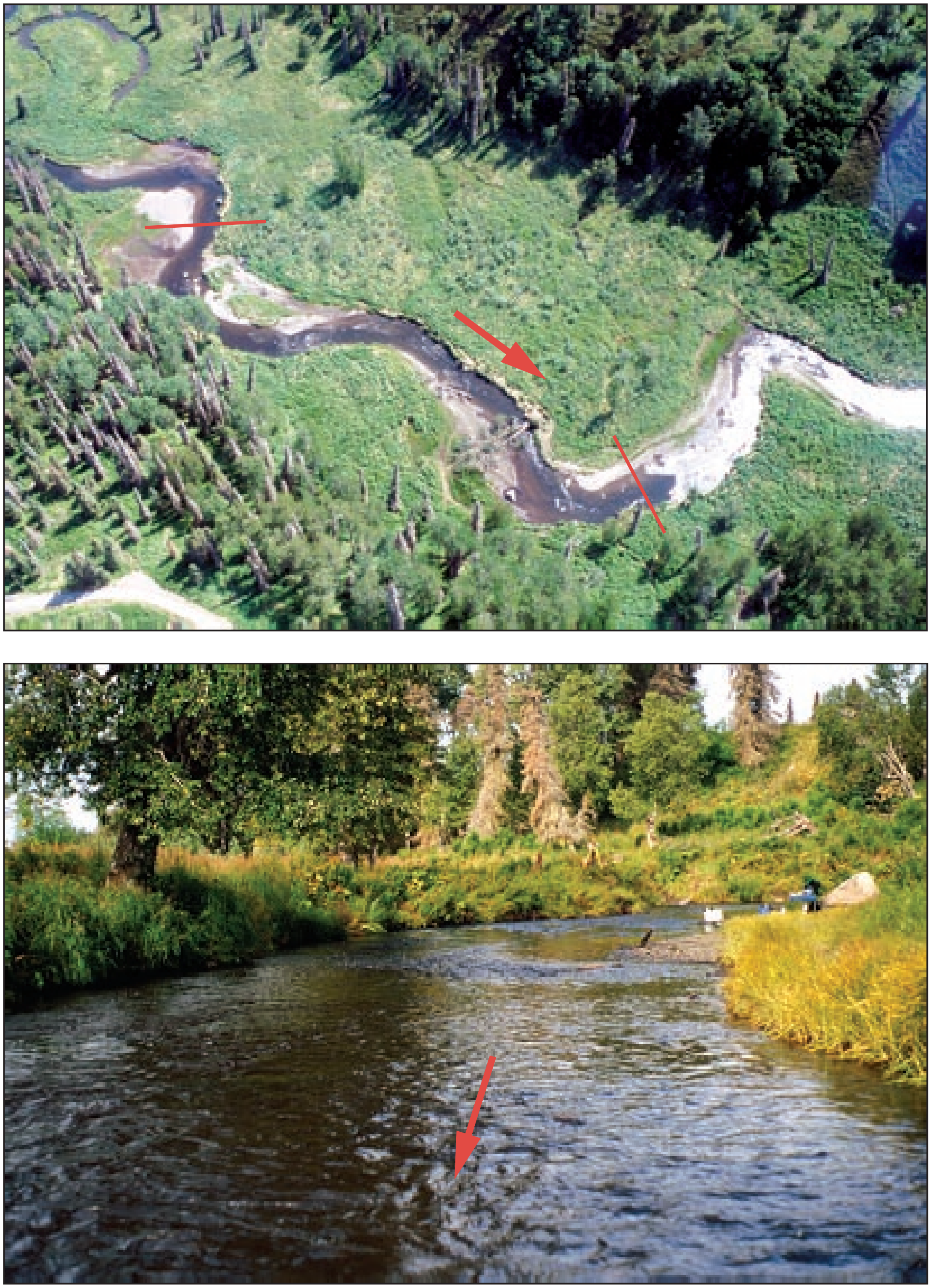

Figure 26. Sinuosity and streambank characteristics in the study reach for the physical-habitat survey of the Ninilchik River, Cook Inlet Basin study unit, Alaska.
Arrows indicate direction of flow. Red lines indicate beginning and end of reaches.

Figure 27. Sinuosity and streambank characteristics of the Deshka River near Willow (site 44), Cook Inlet Basin study unit, Alaska. Arrows indicate direction of flow. Red lines indicate beginning and end of reaches.

Urban Basins

About one-half the population of Alaska resides in the Cook Inlet Basin. Anchorage is the principal place of residence for about 260,000 people but communities such as Palmer and Wasilla in the Matanuska Valley and Kenai and Soldotna on the Kenai Peninsula showed the highest recent increase in population based on the 2000 census. To study the effects of urbanization in the Cook Inlet Basin, two sites were chosen in the Municipality of Anchorage: South Fork Campbell Creek, an undeveloped basin, and Chester Creek, a developed basin. Brief descriptions of the basins follow (basin characteristics are listed in table 1).

South Fork Campbell Creek near Anchorage, Alaska, Station 15274000

South Fork Campbell Creek near Anchorage is within the Municipality of Anchorage (fig. 1, site 23). The watershed drains 29.4 mi^2, is relatively pristine, and served as the reference site for comparison with urbanized watersheds. The upper part of the basin originates in the Chugach Mountains and is steep and the lower part is flat. Most of the watershed lies in a State and municipality owned park. The streamflow-gaging station was operated from 1948 to 1971 and from 1999 to 2001.

Chester Creek at Arctic Boulevard, at Anchorage, Alaska, Station 15275100

Chester Creek drains an area of 27.3 mi^2. Most of the upper part of the Chester Creek watershed is moderately rugged mountains and the lower part of the basin is relatively flat. About one-half the watershed has been urbanized (fig. 28). Located in the Municipality of Anchorage, Chester Creek flows through much of the urbanized area of the Municipality. The site at Arctic Boulevard was operated as a NAWQA intensive fixed site in 1999, during which time additional water-quality samples were collected and analyzed for pesticides and volatile organic compounds. The streamflow-gaging station was operated from 1966 to 1986, 1987 to 1993, and from 1999 to present.

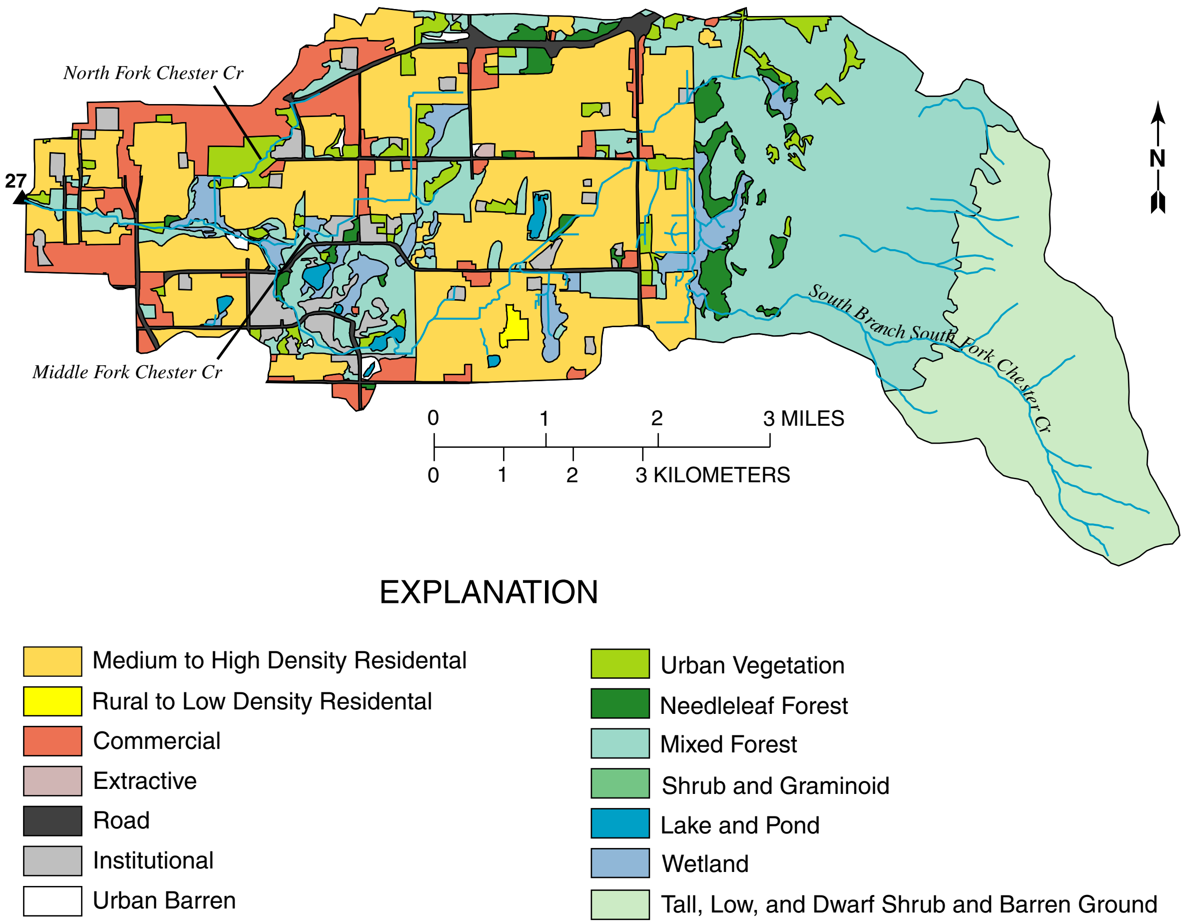

Figure 28. Land use in the Chester Creek basin, Cook Inlet Basin study unit, Alaska.

Streamflows at South Fork Campbell Creek and Chester Creek were near the long-term averages during water years 1999–2001 (table 1, figs. 29-30). At South Fork Campbell Creek, the three-year average for 1999–2001 was 37.1 ft^3/s, slightly lower than the long-term average of 38.1 ft^3/s. At Chester Creek, the three-year average for 1999–2001 was 22.1 ft^3/s, slightly higher than the long-term average of 20.0 ft^3/s. Most runoff from South Fork Campbell Creek occurred from late April to mid-October (fig. 29*A*). Sustained high flows from snowmelt occurred in mid to late June. Through the remainder of the runoff season, high flows were due to rainfall. These flows are usually sharp and of a short duration and the peak discharge for each water year occurred during these storms. At Chester Creek, rainfall runoff is distinguished by the sharp discharge peaks commonly associated with urban streams (fig. 30*A*). Notable runoff features of Chester Creek from 1999 to 2001 were the below-normal base flow during the winter of 1998–99, above-average flow for the winter of 1999–2000, and below-normal flow for August and September 2001.

Forty-one water samples were collected over a range of flows from October 1998 to September 2001 at South Fork Campbell Creek (fig. 29*A*). Sampling occurred over a wide range of flows with exceedance probabilities ranging from 1 to 96 percent (fig. 29*B*). At Chester Creek, 49 environmental samples were collected from 1999 to 2001 (fig. 30*A*). Samples were distributed over a range of flows with exceedance probabilities ranging from less than 0.1 to 96 percent (fig. 30*B*). At both sites, samples from water year 1999 were analyzed for 88 VOCs and about100 pesticide compounds.

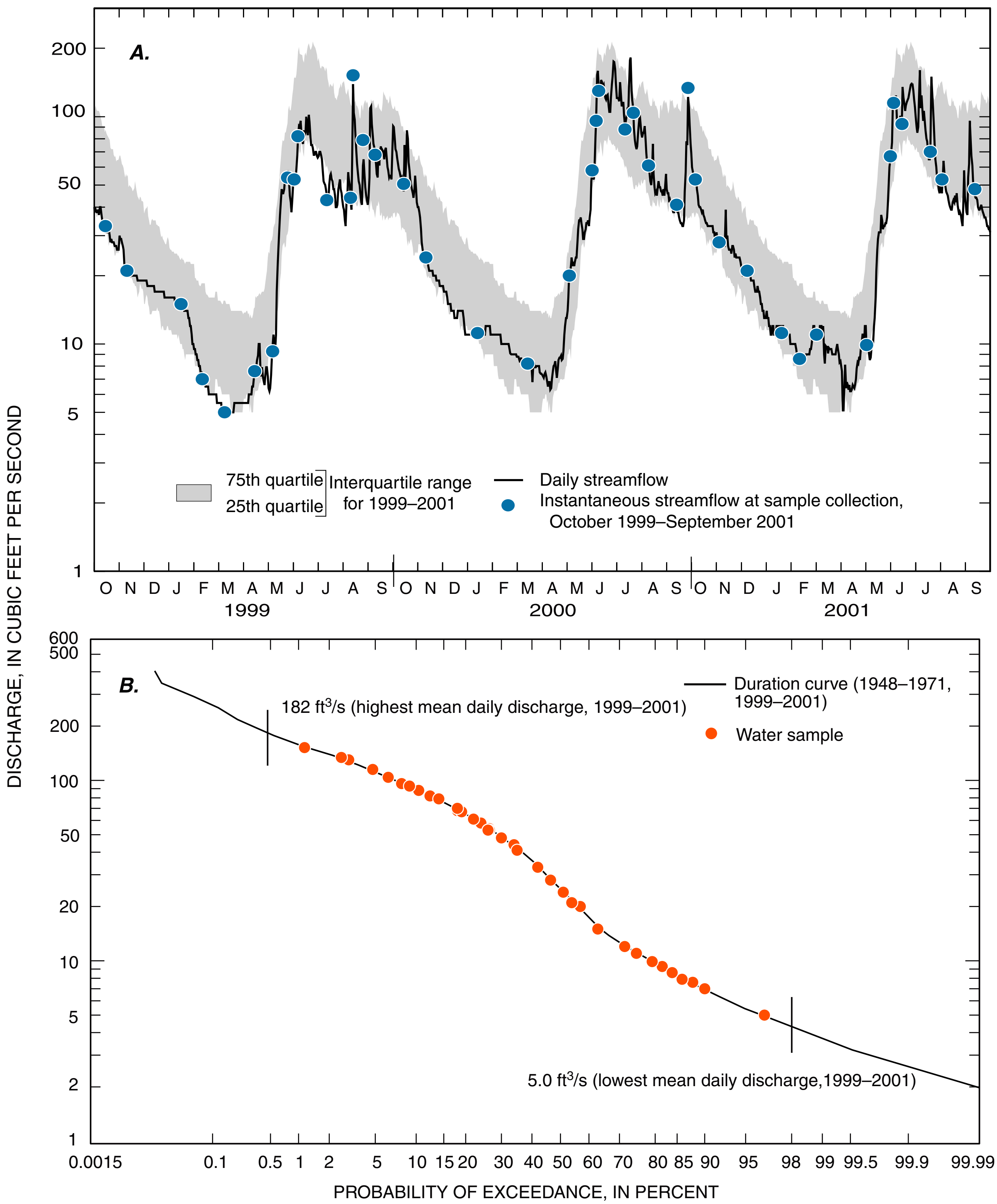

Figure 29. A. Daily and instantaneous streamflow at the time of sample collection, interquartile range of mean daily streamflows for the period of record, and B. Percentage of time indicated discharge was equaled or exceeded for South Fork Campbell Creek near Anchorage (site 23), Cook Inlet Basin study unit, Alaska, water years 1999–2001.

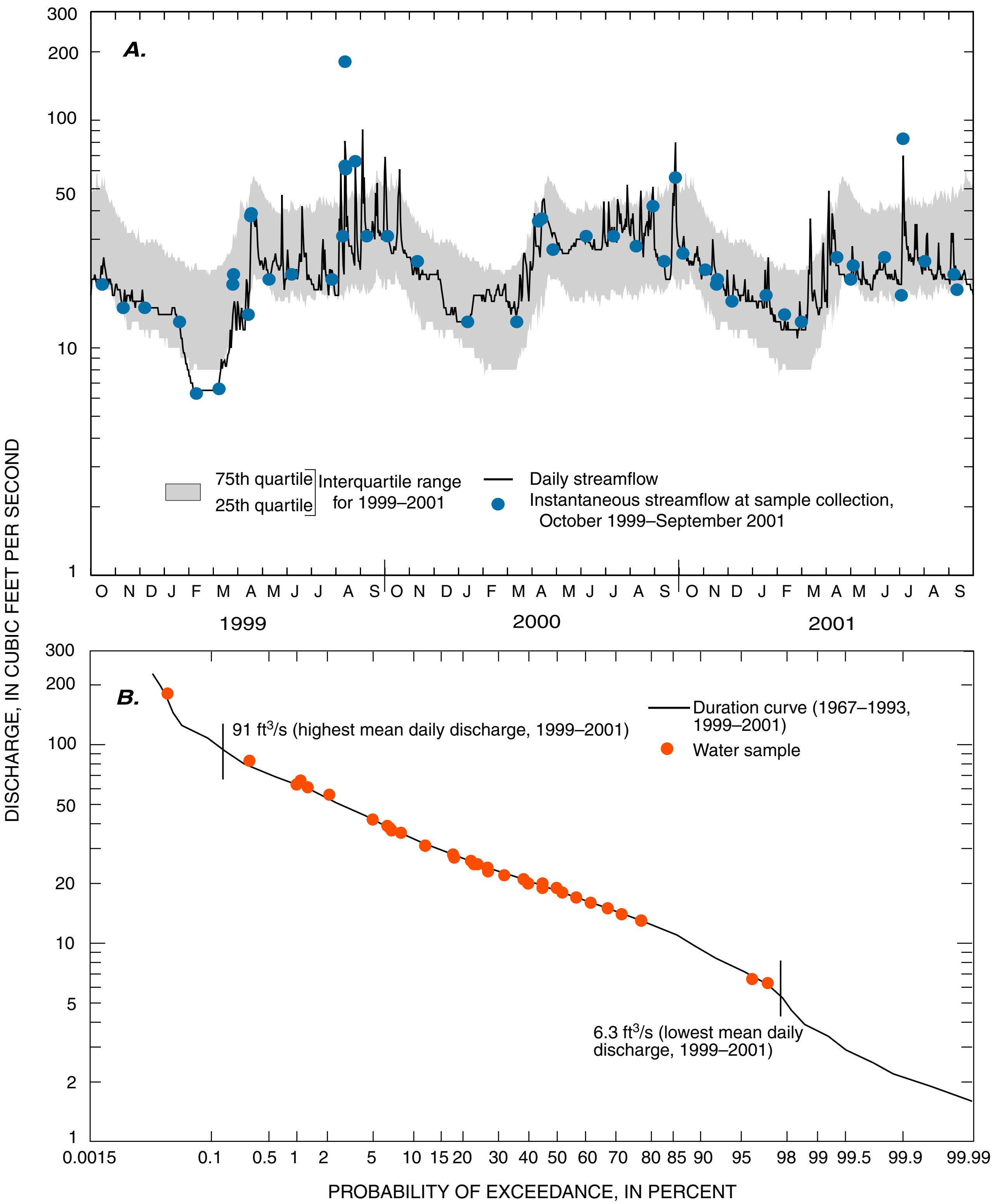

Figure 30. A. Daily and instantaneous streamflow at the time of sample collection, interquartile range of mean daily streamflows for the period of record, and B. Percentage of time indicated discharge was equaled or exceeded at Chester Creek at Arctic Boulevard, at Anchorage (site 27), Cook Inlet Basin study unit, Alaska, water years 1999–2001.

Comparison of water temperatures of the South Fork Campbell Creek and Chester Creek indicated similar patterns (fig. 31), with Chester Creek having consistently higher water temperatures than South Fork Campbell Creek during the open-water periods. From approximately November through March, water temperature was 0 °C at both sites. Water temperature during the summer may have varied because of fluctuations in streamflow and air temperature. Annual water temperature for South Fork Campbell Creek averaged 3.3 °C for water years 1999–2001 while water temperatures for Chester Creek averaged 5.2, 5.3, and 5.9 °C for the same three years. Highest average daily water temperatures measured during water years 1999–2001 at South Fork Campbell Creek were 12.0, 10.5, and 11.5 °C and at Chester Creek were 15.0, 13.5, and 15.0 °C.

Of the 88 VOCs for which samples were analyzed, 10 compounds were detected in Chester Creek and none in South Fork Campbell Creek (table 9). Most of the detections were less than the nondetection value (NDV), with the exception of MTBE, chloroform, and methyethylketone. Most of the detections greater than the laboratory reporting level (LRL) were found in samples collected in winter and may be attributable to the lower volatility and the greater partitioning of these compounds from air to water at cooler temperatures. For example, in most winters, air temperatures in Anchorage average about 15 °F (–9.4 °C). During the winter of 1998–99, however, several cold events occurred, the most pronounced from January 26 to February 11 (fig. 32). During this period, maximum air temperatures for the day were only as high as 12 °F (–11 °C) and minimum air temperatures were as low as 25 °F (–32 °C). Also, VOCs may be found in the shallow aquifer that provides most of the flow in Chester Creek during the winter.

Potential sources of VOCs detected in Chester Creek include by-products of compounds used in gasoline, commercial and industrial processes, and the chlorination of drinking water. MTBE is a fuel oxygenate added to gasoline to enhance combustion, reduce carbon-monoxide emissions, and reduce concentrations of the byproduct ozone in the atmosphere. MTBE was used as an additive to gasoline in Anchorage during winters of 1992–93. Chloroform and bromodichloromethane are trihalomethanes produced as by-products of the chlorination of water. Tetrachloroethylene (TCE) is used for dry cleaning, in the production of chloroflourocarbons, and in spot removers, degreasers, paint strippers, and rug cleaners. Methylethylketone is used in solvents in the surface-coating industry and in the manufacturing of colorless synthetic resins.

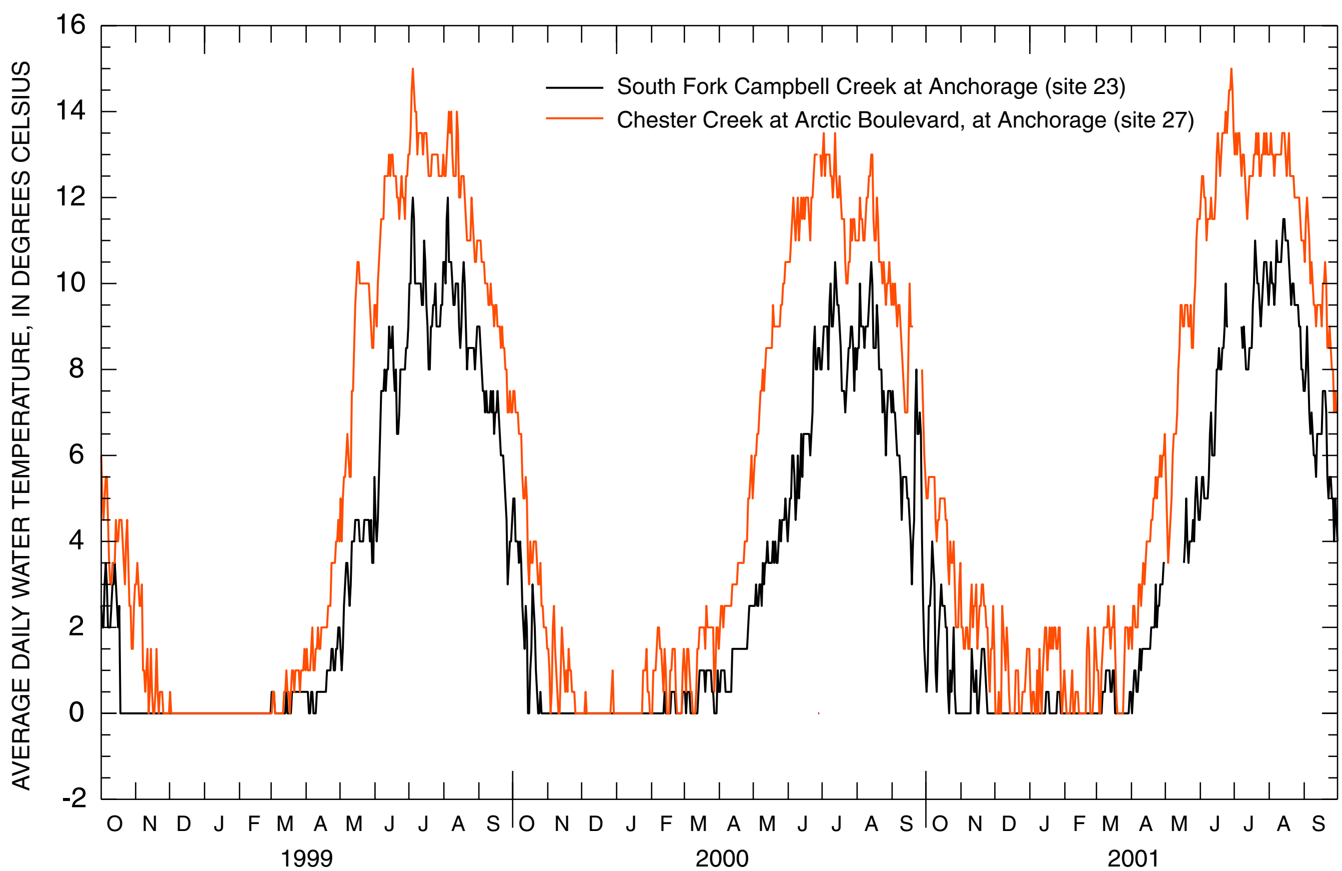

Figure 31. Average water temperature for fixed sites in urban basins, Cook Inlet Basin study unit, Alaska, water years 1999–2001.

Table 9. Volatile organic compounds detected in water samples from a fixed site in urban basins, Cook Inlet Basin study unit, Alaska, 1999

[All values are given in micrograms per liter. E, estimated; <, actual value is less than value shown]

Date	Methyl-benzene (toulene)	Metapar-xylene	1,2,4 - Trimethyl-benzene	Benzene	Ethyl-benzene	Methyl *tert*-butyl ether (MTBE)	Trichloro-methane (chloroform)	Tetrachloro-ethylene	Bromodi-chloro-methane	Methyl-ethyketone
Chester Creek at Arctic Boulevard, at Anchorage (site 27)										
Winter										
01-19-99	E0.07	E0.03	<0.06	E0.03	E0.01	0.4	E0.08	E0.01	<0.05	<1.6
02-09-99	.12	E.06	E.02	E.06	E.02	.8	.18	E.02	E.02	<1.6
03-09-99	.17	E.10	E.06	E.08	E.03	.4	E.10	E.01	<.05	<1.6
Summer										
06-07-99	E0.03	E.02	E0.01	E0.02	E0.01	0.2	E0.02	E0.01	<.05	<1.6
07-27-99	E.02	<.06	<.06	<.10	<.03	E.1	E.04	E.01	<.05	<1.6
08-09-99	E.05	<.06	<.06	E.01	<.03	E.1	E.05	E.01	<.05	<1.6
09-08-99	E.06	<.12	<.11	E.03	<.06	<.3	E.05	<.20	<.10	<3.2
Rainfall										
08-12-99	E0.11	<0.12	<0.11	E.03	<0.06	<0.3	E0.06	E0.05	<.10	<3.2
08-12-99	E.22	E.09	<.11	E.05	E.03	<.3	E.03	E.02	<.10	5.7
08-13-99	E.06	<.12	<.11	E.02	<.06	<.3	E.07	<.20	<.10	<3.2
08-25-99	.23	<.12	<.11	E.05	<.06	<.3	E.06	E.03	<.10	<3.2

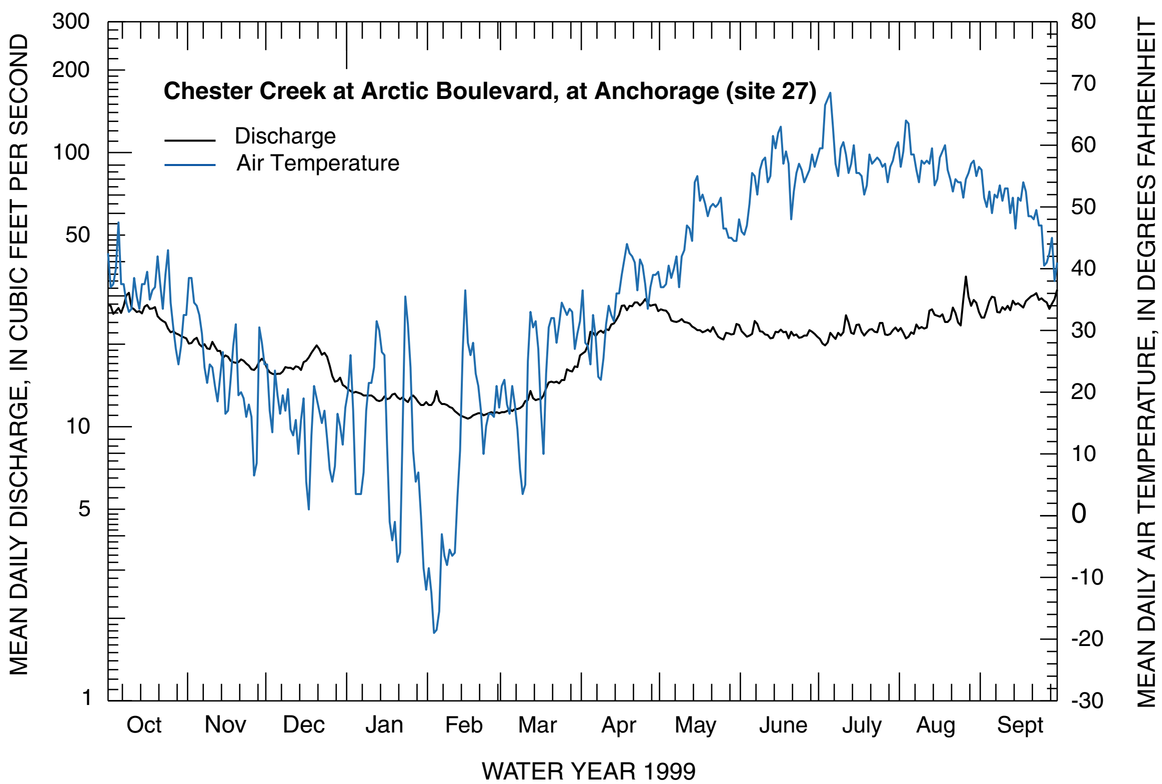

Figure 32. Average air temperature and daily mean discharge for a fixed site in urban basins, Cook Inlet Basin study unit, Alaska, water year 1999.

Five pesticide compounds were detected at concentrations greater than the LRL in the Chester Creek water samples: the insecticides carbaryl and diazinon and the herbicides prometon, 2,4-D, and dichlorprop (table 10). Most of the detections were in samples collected during the open-water season-spring breakup through October. The detection of these compounds in Chester Creek is consistent with their use. Carbaryl is widely used in the Anchorage area to control spruce bark beetles and 2,4-D is a common ingredient in several "weed and feed" products. Diazinon is used to control ants and other insects in gardens and homes and prometon is used along roadways and other rights of way to control weed growth.

Specific conductance at South Fork Campbell Creek ranged from 53 to 110 µS/cm at 25 ^{o}C and from 120 to 480 µS/cm at 25 ^{o}C for Chester Creek (table 11). Concentrations of dissolved solids and dissolved elements were below drinking-water standards and aquatic-life standards. Both waters were classified as a calcium bicarbonate water (fig. 33), although during snowmelt periods, higher values of chloride, sodium, and magnesium were found at Chester Creek. Based on Spearman's *rho* and the probability values, all major ions with the exception of potassium at both sites and silica at Chester Creek were significantly correlated with specific conductance (table 12).

Table 10. Pesticides detected in water samples from a fixed site in urban basins, Cook Inlet Basin study unit, Alaska, 1999

[All values are given in micrograms per liter. M, presence verified, not quantified; E, estimated; <, actual value is less than value shown]

Chester Creek at Arctic Boulevard, at Anchorage (site 27)							
Date	**Carbaryl**	**Diazinon**	**Prometon**	**2,4,D**	**2,4,D methyl ester**	**Clopyralid**	**Dichlorprop**
Winter							
10-15-98	E0.007	<0.002	<0.02	<0.15	–	<0.23	<0.03
11-10-98	<.003	<.002	M	<.15	–	<.23	<.03
12-07-98	<.003	<.002	<.02	<.15	–	<.23	.03
01-19-99	<.003	<.002	<.02	<.15	–	<.23	<.03
02-09-99	<.003	<.002	<.02	<.15	–	<.23	<.03
03-09-99	<.003	<.002	<.02	<.15	–	<.23	<.03
Snowmelt							
03-26-99	E0.247	<0.010	0.02	<0.15	–	<0.23	<1.01
03-27-99	E.269	<.010	E.02	<.15	–	<.23	<.92
04-14-99	E.016	<.002	E.02	<.08	<0.09	<.04	<.05
04-17-99	E.068	.006	.07	.08	<0.09	E.06	<.05
04-18-99	E.043	.008	.06	E.07	<0.09	<.04	<.05
Summer Baseflow							
05-10-99	E0.013	0.010	E0.01	<0.08	<0.09	<0.04	<0.05
06-07-99	E.043	<.002	M	.11	E0.02	<.04	<.05
07-27-99	E.059	.043	<.02	E.04	<0.09	<.04	<.05
08-09-99	E.021	.011	.02	.10	<0.09	<.04	<.05
09-08-99	E.010	<.002	E.01	E.02	<0.09	<.04	<.05
Rainfall							
08-12-99	E0.167	<0.040	0.06	0.41	<0.09	<0.04	0.13
08-12-99	E.332	<.010	.04	<.08	<0.09	<.04	<.05
08-13-99	E.023	<.002	.02	<.08	<0.09	<.04	<.05
08-25-99	E.189	<.002	.04	.13	<0.09	<.04	<.05

Table 11. Summary of values of field measurements and concentrations of nutrients, major ions, organic carbon, and suspended sediment in water samples from fixed sites in urban basins, Cook Inlet Basin study unit, Alaska, 1999–2001

[Locations of sites are shown in figure 1. Values are given in milligrams per liter unless otherwise noted. °C, degree Celsius; µS/cm, microsiemen per centimeter at 25 degrees Celsius; µg/L, microgram per liter. E, estimated; –, not determined; <, actual value is less than value shown]

Constituent	Minimum	Maximum	Mean	Median
South Fork Campbell Creek near Anchorage (site 23; 41 samples)				
Water temperature (°C)	0	11.9	4.5	4.5
Specific conductance (µS/cm at 25 °C)	53	110	81	79
pH	7.1	8.2	7.7	7.7
Dissolved oxygen	8.2	15.4	12.6	12.4
Ammonia nitrogen, dissolved	.002	.178	.008	.003
Ammonia-plus-organic nitrogen, dissolved	.05	.136	.09	.10
Ammonia-plus-organic nitrogen, total	.04	.224	.098	.096
Nitrite nitrogen, dissolved	.001	.002	.001	.001
Nitrite-plus-nitrate nitrogen, dissolved	.057	1.32	.282	.224
Total nitrogen	.097	1.54	.38	.32
Phosphorus, total	.001	.022	.007	.005
Phosphorus, dissolved	.001	.006	.005	.006
Orthophosphate phosphorus, dissolved	.001	.04	.004	.002
Alkalinity (as $CaCO_3$)	17	38	25	24
Bicarbonate (as $CaCO_3$)	20	45	31	30
Calcium	8.1	16.0	11.9	12.2
Magnesium	1.1	2.6	1.8	1.7
Sodium	.3	1.9	1.1	1.1
Potassium	.1	1.8	.2	.2
Sulfate	6.5	13.6	10.9	11.7
Chloride	.2	.7	.4	.4
Fluoride	<.1	<.1	<.1	<.1
Silica	.04	8.3	6.2	6.2
Iron (µg/L)	<10	<10	<10	<10
Manganese (µg/L)	1.1	4.0	2.8	3.0
Dissolved solids, residue at 180 °C	39	75	57	56
Organic carbon, dissolved	.3	2.4	1.0	.8
Organic carbon, suspended	.1	1.1	.2	.2
Suspended sediment	1	39	5	2

Table 11. Summary of values of field measurements and concentrations of nutrients, major ions, organic carbon, and suspended sediment in water samples from fixed sites in urban basins, Cook Inlet Basin study unit, Alaska, 1999–2001—*Continued*

[Locations of sites are shown in figure 1. Values are given in milligrams per liter unless otherwise noted. °C, degree Celsius; µS/cm, microsiemen per centimeter at 25 degrees Celsius; µg/L, microgram per liter. E, estimated; –, not determined; <, actual value is less than value shown]

Constituent	Minimum	Maximum	Mean	Median
Chester Creek at Arctic Boulevard, at Anchorage (site 27; 49 samples)				
Water temperature (degrees Celsius)	0	15.4	5.2	3.5
Specific conductance (µS/cm at 25 °C)	120	480	260	261
pH	7.1	8.6	7.8	7.8
Dissolved oxygen	9.2	14.6	12.0	12.0
Ammonia nitrogen, dissolved	.002	.48	.068	.024
Ammonia-plus-organic nitrogen, dissolved	.068	1.26	.26	.17
Ammonia-plus-organic nitrogen, total	.08	2.40	.48	.24
Nitrite nitrogen, dissolved	.001	.069	.009	.006
Nitrite-plus-nitrate nitrogen, dissolved	.005	.91	.58	.62
Total nitrogen	.085	3.31	.96	.86
Phosphorus, total	.004	.590	.08	.02
Phosphorus, dissolved	.002	.210	.021	.006
Orthophosphate phosphorus, dissolved	.001	.094	.010	.004
Alkalinity (as $CaCO_3$)	21	100	71	77
Bicarbonate (as $CaCO_3$)	43	122	88	94
Calcium	14	37	30	32
Magnesium	3.1	14.7	7.4	7.5
Sodium	3.9	35	9.2	8.0
Potassium	.8	5.0	1.6	1.1
Sulfate	8.7	27	20	21
Chloride	6.6	94	20	16
Fluoride	<.10	<.10	<.10	<.10
Silica	5.4	13.5	10.3	10.6
Iron (µg/L)	30	520	123	100
Manganese (µg/L)	32	215	80	75
Dissolved solids, residue at 180 °C	72	279	159	160
Organic carbon, dissolved	1.5	7.9	3.1	2.5
Organic carbon, suspended	.2	5.0	1.0	.6
Suspended sediment	1	322	33	9

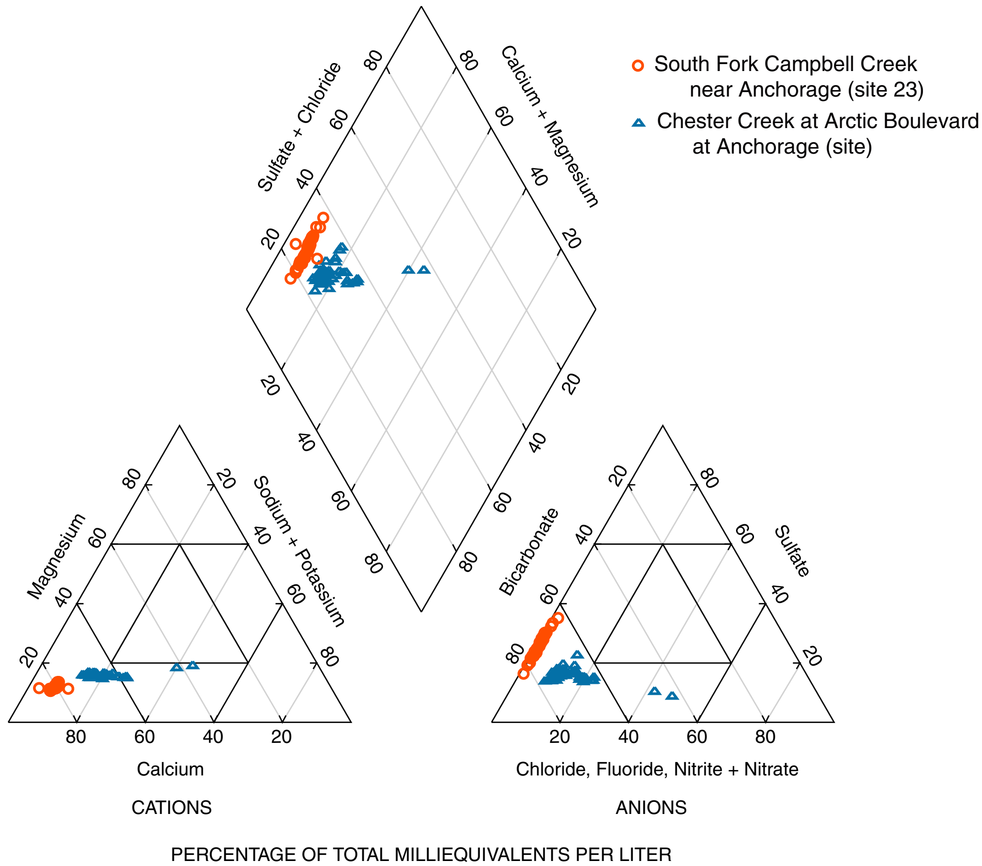

Figure 33. Concentrations of major ions in 49 water samples from fixed sites in urban basins, Cook Inlet Basin study unit, Alaska, water years 1999–2001.

Table 12. Relations between dissolved solids and major ions to specific conductance, and suspended-sediment concentration to discharge in water samples from fixed sites in urban basins, Cook Inlet Basin study unit, Alaska, October 1998 through September 2001

[**Site:** Site locations are shown in figure 1. Specific conductance in microsiemens per centimeter at 25 °C. Discharge in cubic feet per second. Spearman's rank correlation coefficients (*rho*) and probability values (*p*-values) are significant (in **bold**) when *rho* is greater than 0.5, and *p*-values are less than 0.005; <, actual value is less than value shown]

Water-quality constituent	*rho*	*p*-value
South Fork Campbell Creek near Anchorage (site 23; 41 samples)		
Calcium	**0.92**	**<0.0001**
Magnesium	**.92**	**<.0001**
Sodium	**.88**	**<.0001**
Bicarbonate	**.82**	**<.0001**
Silica	**.85**	**<.0001**
Potassium	.05	.7610
Chloride	**.52**	**.0006**
Sulfate	**.66**	**<.0001**
Dissolved solids	**.62**	**<.0001**
Suspended sediment	**.62**	**<.0001**
Chester Creek at Arctic Boulevard, at Anchorage (site 27; 49 samples)		
Calcium	**0.56**	**<0.0001**
Magnesium	**.83**	**<.0001**
Sodium	**.66**	**<.0001**
Bicarbonate	**.56**	**<.0001**
Silica	.40	.007
Potassium	.05	.7561
Chloride	**.66**	**<.0001**
Sulfate	**.62**	**<.0001**
Dissolved solids	**.89**	**<.0001**
Suspended sediment	.48	.0006

Specific conductance was recorded continuously at Chester Creek during water year 2001. Normally, specific conductance is inversely related to discharge due to the dilution of stream water by low specific conductance runoff. However, during the winter months from November to March (and part of April), specific conductance was directly related to discharge (fig. 34). This corresponds to the 'wash off' of deicing compounds from streets during snowmelt periods. After winter, the relation reversed and specific conductance decreased as discharge increased. This 'change of relation' occurred only at Chester Creek, the urbanized site, of the eight basic fixed sites studied.

Average annual concentrations of suspended sediment at the two sites ranged from 1 to 39 mg/L at South Fork Campbell Creek and from 1 to 322 mg/L at Chester Creek (table 11). These concentrations were statistically correlated with discharge at South Fork Campbell Creek but not at Chester Creek. One possible reason for the lack of correlation at Chester Creek is that during snowmelt runoff, sand and fine sediment that washed off roadways and streets caused higher concentrations of suspended sediment to occur than would be expected based on discharge alone. Regression models developed by LOADEST (appendix C) estimated an annual suspended-sediment load of 215 ton/yr for South Fork Campbell Creek and 420 ton/yr for Chester Creek (table 13). At South Fork Campbell Creek, 79 percent of the load was transported during the summer season, and 12 percent during autumn. Minor amounts of suspended sediment—2 and 7 percent—were transported in the winter and spring seasons. At Chester Creek, 43 percent of the load was transported during the spring, during snowmelt, whereas summer and autumn flows transported 24 and 20 percent of the load, respectively, with 12 percent transported in the winter.

Concentrations of nutrients and DOC at South Fork Campbell Creek were low, with a median concentration of 0.320 mg/L of total nitrogen and median concentration of 0.005 mg/L of total phosphorus (table 11). Median concentration of DOC was 0.8 mg/L. Concentrations of the nutrients usually were highest during snowmelt or storm runoff (fig. 35). The highest concentrations of DOC were noted during snowmelt in all 3 years and during a storm in August 1999 (fig. 35). At Chester Creek, nutrients and DOC showed distinct seasonal patterns/peaks (fig. 36). Peak concentrations were evident in snowmelt and during rainstorms, reflecting the washoff of materials from impervious surfaces. Concentrations of total nitrogen were as high as 2.4 mg/L and concentrations of total phosphorus were as high as 0.59 mg/L. Concentrations of DOC followed the same pattern as the nutrients, and concentrations were as high as 7.9 mg/L during snowmelt of 1999. LOADEST calculated the annual loads of total nitrogen, total phosphorus, and DOC transported past the South Fork Campbell Creek gage to be 3.6, 0.4, and 40 tons, respectively for water years 1999–2001 (table 13). Sixty to 80 percent of these loads were transported in the summer months. Between 14 and 25 percent of these loads were transported in the autumn. For Chester Creek, LOADEST calculated total loads of total nitrogen to be 7.3 ton/yr, total phosphorus to be 1.5 ton/yr, and DOC to be 66 ton/yr (table 13). From 63 to 74 percent of the total loads of these constituents were transported during the spring and summer months. Eighteen to 23 percent of the loads were transported in the autumn.

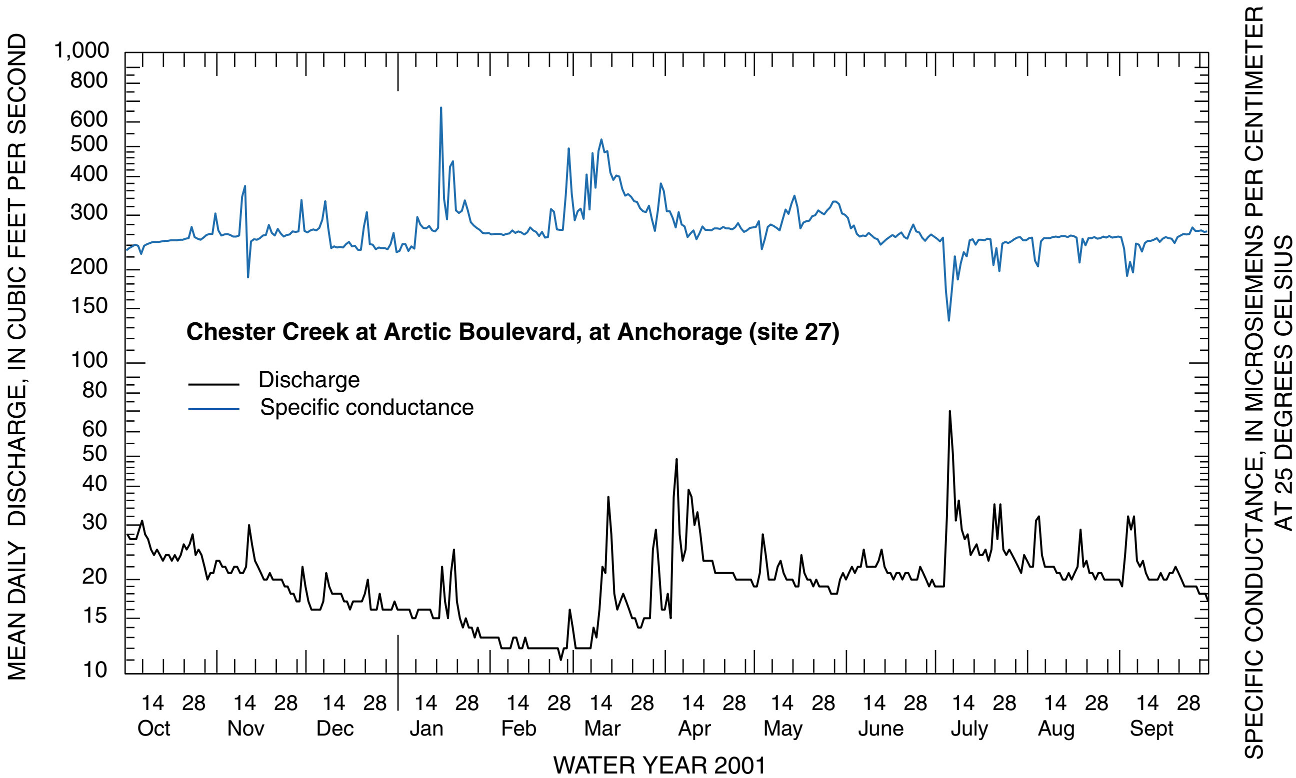

Figure 34. Relation between specific conductance and mean daily discharge for a fixed site in urban basins, Cook Inlet Basin study unit, Alaska, water year 2001.

Table 13. Load estimates of suspended sediment, total nitrogen, total phosphorus, and dissolved organic carbon in water samples from fixed sites in urban basins, Cook Inlet Basin study unit, Alaska, water years 1999–2001

[Locations of sites are shown in figure 1]

Constituent and season	Load (tons per day)	Total load (year or season) (tons)	Upper 95th percent confidence limit (tons per day)	Lower 95th percent confidence limit (tons per day)	Standard error of prediction (tons per day)
South Fork Campbell Creek near Anchorage (site 23)					
Suspended sediment					
Average annual	0.59	215	0.81	0.42	0.10
Spring	.17	15.6	0.24	0.11	0.03
Summer	1.84	169	2.65	1.23	0.36
Autumn	.27	24.6	0.39	0.18	0.05
Winter	.06	5.4	0.09	0.04	0.01
Total nitrogen					
Average annual	0.01	3.6	0.01	0.01	0.0006
Spring	.004	.4	.005	.004	.0004
Summer	.024	2.2	.03	.02	.002
Autumn	.009	.8	.01	.008	.0008
Winter	.003	.2	.004	.002	.0003
Total phosphorus					
Average annual	0.001	0.4	0.0013	0.0007	0.0001
Spring	.0002	.02	.0003	.0002	.00004
Summer	.003	.28	.004	.002	.0006
Autumn	.0005	.04	.0007	.0004	.00008
Winter	.0002	.02	.0002	.0001	.00003
Dissolved organic carbon					
Average annual	0.11	40.2	0.13	0.09	0.01
Spring	.03	2.8	.04	.03	.003
Summer	.26	23.9	.32	.22	.03
Autumn	.11	10.0	.13	.10	.01
Winter	.02	1.8	.03	.02	.002

Table 13. Load estimates of suspended sediment, total nitrogen, total phosphorus, and dissolved organic carbon in water samples from fixed sites in urban basins, Cook Inlet Basin study unit, Alaska, water years 1999–2001—*Continued*

[Locations of sites are shown in figure 1]

Constituent and season	Load (tons per day)	Total load (year or season) (tons)	Upper 95th percent confidence limit (tons per day)	Lower 95th percent confidence limit (tons per day)	Standard error of prediction (tons per day)
Chester Creek at Arctic Boulevard, at Anchorage (site 27)					
Suspended sediment					
Average annual	1.15	418	1.79	0.70	0.28
Spring	1.98	182	3.59	.98	.67
Summer	1.13	104	2.03	.57	.38
Autumn	.93	85	1.79	.43	.35
Winter	.54	49	1.05	.24	.21
Total nitrogen					
Average annual	0.02	7.3	0.026	0.019	0.002
Spring	.04	3.7	.046	.028	.0046
Summer	.028	2.6	.035	.022	.003
Autumn	.017	1.5	.022	.013	.0024
Winter	.008	.7	.011	.006	.0013
Total phosphorus					
Average annual	0.004	1.5	0.0048	0.0026	0.00055
Spring	.006	.6	.009	0.003	.0014
Summer	.004	.4	.006	0.002	.0009
Autumn	.003	.3	.004	0.002	.0007
Winter	.0015	.2	.0018	0.0007	.00029
Dissolved organic carbon					
Average annual	0.18	65.7	0.22	0.14	0.06
Spring	.22	20.2	.27	.17	.07
Summer	.24	22.1	.28	.20	.08
Autumn	.17	15.5	.22	.12	.05
Winter	.084	7.6	.12	.04	.02

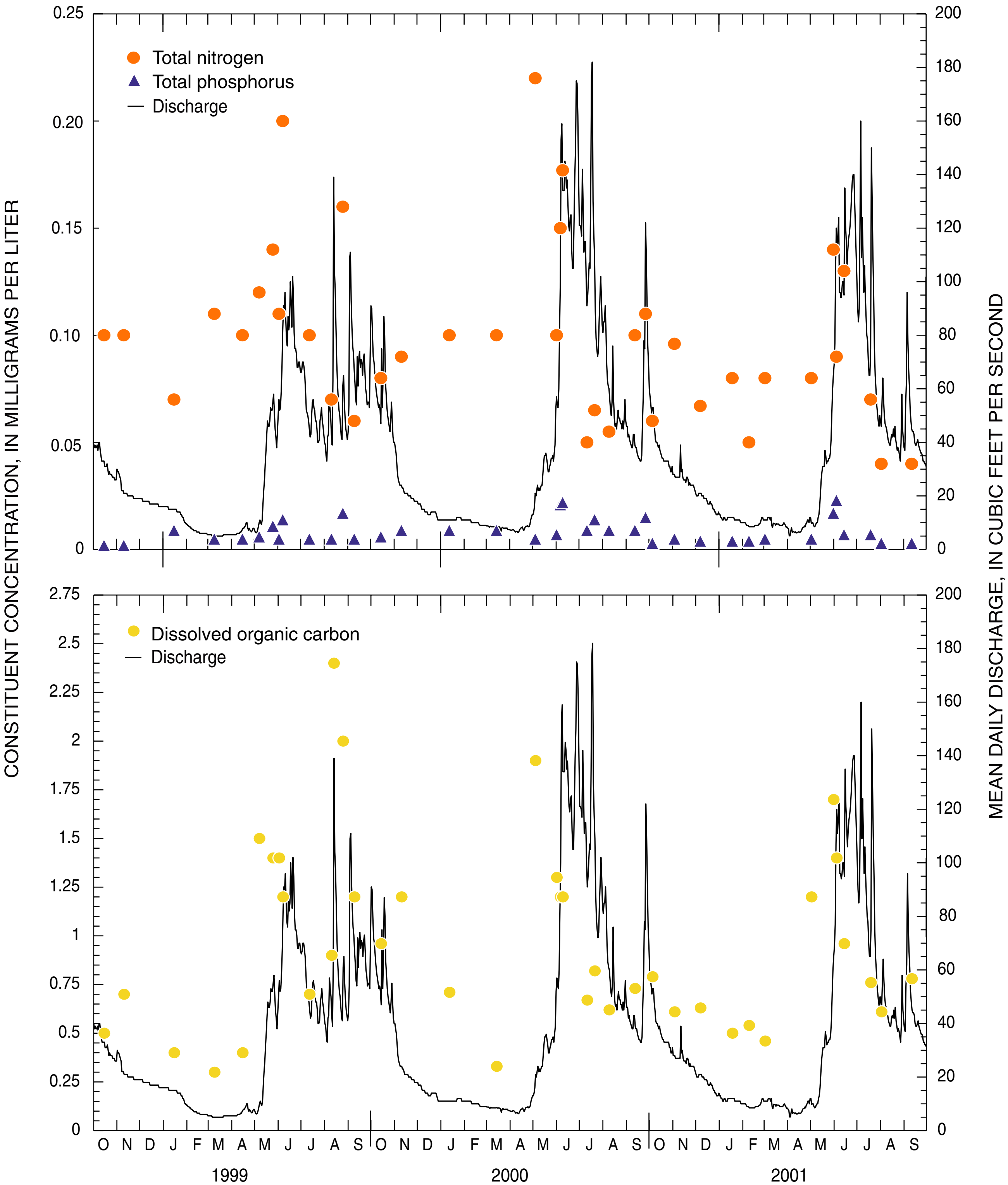

Figure 35. Variation in concentrations of total nitrogen, total phosphorus, and dissolved organic carbon with discharge for South Fork Campbell Creek near Anchorage (site 23), Cook Inlet Basin study unit, Alaska, water years 1999–2001.

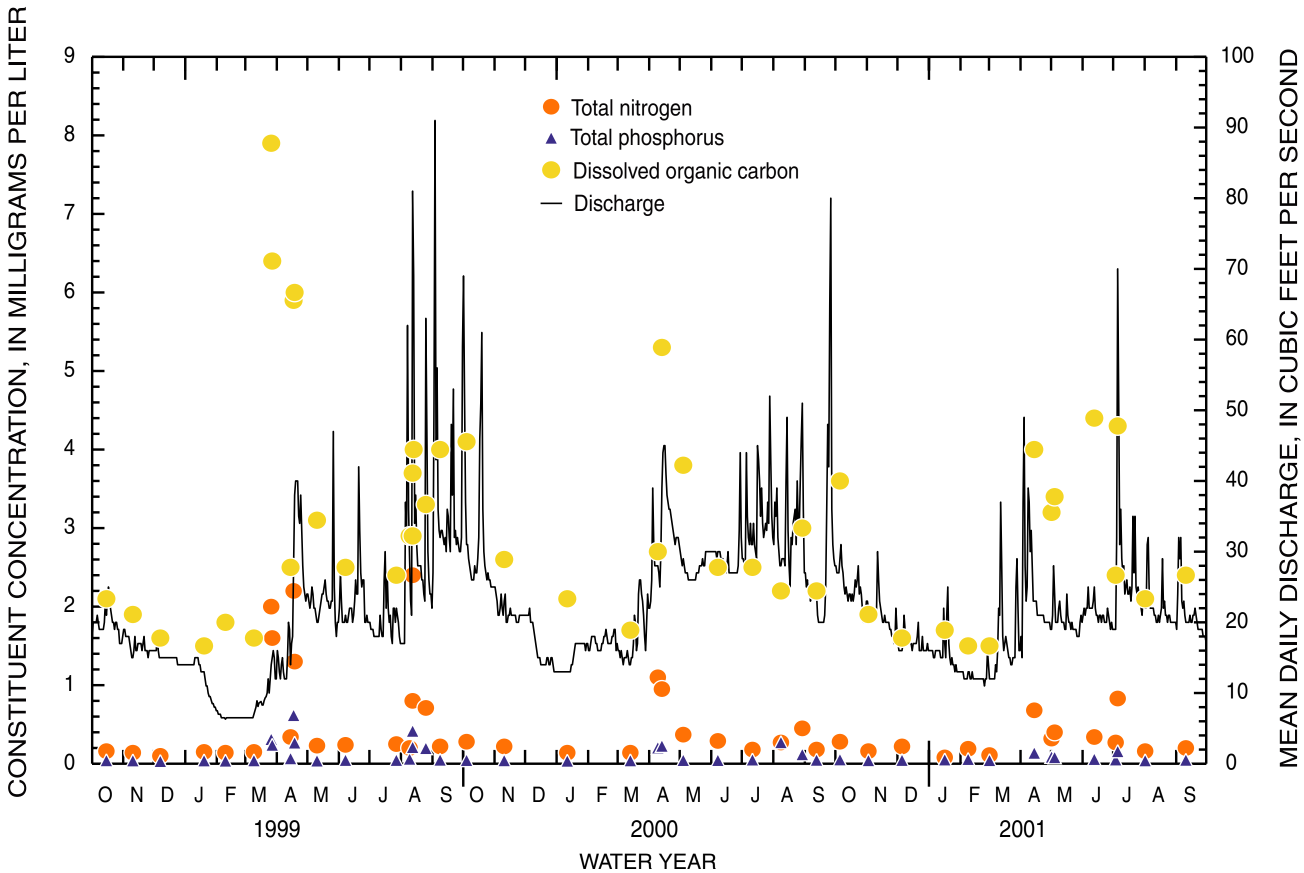

Figure 36. Variation in concentrations of total nitrogen, total phosphorus, and dissolved organic carbon with discharge for Chester Creek at Arctic Boulevard, at Anchorage (site 27), Cook Inlet Basin study unit, Alaska, water years 1999–2001.

RTH, DTH, and QMH samples of periphytic algae were collected from South Fork Campbell Creek and Chester Creek in September 1999, in June 2000, and in September 2001 from primary reach C of both sites (figs. 37-38, tables 15-17). At South Fork Campbell Creek, an average of 16 taxa were identified in RTH samples and 24 taxa in DTH samples. At Chester Creek, an average of 18 taxa were identified in RTH samples and 24 taxa in DTH samples. The relative composition of soft algae in the RTH samples from South Fork Campbell Creek by major algal division indicated green algae dominated in this reach. However, the DTH samples indicated that the soft-algae composition was dominated by blue-green algae. Blue-green algae typically dominates at lower nitrogen levels rather than green algae (Bahls, 1993). Because nitrogen concentrations were low at South Fork Campbell Creek, it is unknown why green algae dominated in the RTH sample. At Chester Creek, RTH and DTH samples were dominated by blue-green algae every year. Dominance at this site is most likely because of elevated phosphorous concentrations.

The dominant diatom taxa in RTH samples from South Fork Campbell Creek for all years (*Achnanthes pusilla, Diatoma mesodon*, and *Reimeria sinuata*) are considered sensitive to pollution and require continuously high oxygen concentrations (near 100 percent saturation) (Bahls, 1993; Van Dam and others, 1994). The dominant taxa in 1999 and 2000 are both from early successional genera (*Achnanthes, Diatoma*) often found in frequently disturbed locations (Stevenson and others, 1996; Hieber and others, 2001). In the DTH samples, *Achnanthes pusilla* was the dominant diatom in each reach. This taxon requires continuously high oxygen concentrations, prefers oligotrophic water, and is resilient to scour events (Van Dam and others, 1994; Hieber and others, 2001). The dominant diatom in 2001, *Achnanthidium minutissium*, also can survive scour events (Barbour and others, 1999).

At Chester Creek, *Achnanthes pusilla* was the most abundant taxa in the RTH samples. This was unexpected at this urban location, but is consistent with the prevalence of blue-green algae. The genus *Achnanthes* also is known as a pioneer taxon found on substrate where other taxa are unable to remain attached during high-velocity flows, similar to *Achnanthidium minutissium* (Barbour and others, 1999; Hieber and others, 2001), which accounted for one-half of all diatoms in the 2001 sample. *Navicula viridula* was the most abundant diatom in 1999. This taxon is particularly tolerant to pollution (Palmer, 1969), can survive heavy siltation by being motile (Barbour and others, 1999), and is normally found in eutrophic waters (Lowe, 1974; Pan and others, 1996). Because blue-green and red algae also were common in the riffle habitat, the motile ability of *Navicula viridula* may explain its dominance in Chester Creek at Arctic Boulevard.

Much like the RTH samples, the dominant diatoms in the 2000 and 2001 DTH samples from Chester Creek are characterized by being sensitive to pollution or having the ability to survive scour events. The 1999 sample was dominated by *Stephanodiscus hantzschii* and two taxa in the genera *Nitzschia. Stephanodiscus hantzschii* is a tolerant taxon primarily found in eutrophic water (Lowe, 1974; Rott and others, 1998), and the genus Nitzschia is one of the most pollution-tolerant genera (Palmer, 1969), and also is motile and able to survive heavy siltation (Barbour and others, 1999). This suggests that depositional microhabitat may have been organically enriched around the time of sampling in 1999.

RTH and QMH samples of microinvertebrates were collected at the same time as algae samples between 1999 and 2001 (tables 18 and 19). On average, 32 unambiguous taxa were identified in the RTH samples from South Fork Campbell Creek. The dominant orders were Ephemeroptera and Diptera in 1999 and 2000 and Tubificida in 2001, respectively. The relatively high presence of Tubificida in 2001 is thought to be due to the fact that this sample was collected in early September, and the entire month of August was characterized by low flow and above normal air temperatures. Two of the most prevalent taxa were *Microspectra* (Diptera) and *Baetis bicaudatus* (Ephemeroptera). *Microspectra* are sometimes found in headwater streams, and are especially sensitive to certain perturbations than are other chironomids (Wallace and others, 1991). Baetids have a similar capacity to exist in fast water and are relatively resilient to high flow events (Merrit and Cummins, 1978; Rempel and others, 1999). At Chester Creek, an average of 21 taxa were identified in the RTH samples. Oligochaetes consistently dominated the community, with sludge worms (Tubificida) constituting nearly 50 percent or more of the sample each year. These worms are considered to be highly tolerant of poor water quality, substrate disturbance, and flow conditions (Pedersen and Perkins, 1986; Winter and Duthie, 1998). Diptera was the second most abundant order each year, and there were sparse EPT taxa.

Regarding functional feeding groups, collector-gatherers, which are generalists (Barbour and others, 1999), dominated in all years and in all reaches at South Fork Campbell Creek except for the 1999 sample from reach C. That sample was dominated by scrapers, which are more specialized feeders and more sensitive to environmental disturbances. At Chester Creek, principally because of the extremely high counts of Tubificida, which are classified as collector-gatherer feeders (Barbour and others, 1999), this functional feeding group of generalists heavily outnumbered other feeding groups.

Figure 37. Location of primary reach C and adjacent reaches B and D for the physical-habitat survey of South Fork Campbell Creek near Anchorage (site 23), Cook Inlet Basin study unit, Alaska.

Figure 38. Location of primary reach C and adjacent reaches B and D for the physical-habitat survey of Chester Creek at Arctic Boulevard, at Anchorage (site 27), Cook Inlet Basin study unit, Alaska.

Fish were sampled in South Fork Campbell Creek in October 1999 and July 2000 (table 20). During the 2000 sampling, salmonids dominated the community in all reaches, particularly juvenile Chinook salmon. Stocking programs to greatly increase the abundance of both coho salmon (*Oncorhynchus kisutch*) and rainbow trout (*Oncorhynchus mykiss*) in Campbell Creek (Stratton and Cyr, 1997) complicate the assessment of fish-community composition as a response to habitat or water quality. For all samples, five of seven rainbow trout had eroded fins, a common occurrence for fish raised in a hatchery (Meador and others, 1993). Less than 1 percent of sculpins had eroded fins, which are considered to be due to the hydraulics of South Fork Campbell Creek.

Fish were sampled in Chester Creek at Arctic Boulevard in October 1999 and June 2000 (table 20). Data from the 2000 sampling period, when all three reaches were sampled, indicated that salmonidae was the dominant family, although slimy sculpin also were particularly abundant. Rainbow trout, stocked in the stream since 1971 (Stratton and Cyr, 1997), were the most abundant salmonid in all years. The large abundance of this stocked species makes interpretations about habitat or water quality based on the fish community difficult. The capture of juvenile coho salmon in 2000 but not in 1999 is most likely due to the time of sampling. The smolt outmigration occurs primarily in the late spring and early summer, and sampling in 1999 took place in October. For all samples, more than 5 percent of rainbow trout had eroded fins, possibly because of crowded hatchery conditions (Meador and others, 1993), especially since fin erosion was observed only on about 1 percent of the other salmonids at this site. Anomalies observed on a few other rainbow trout, including lesions, a missing eye, and fungi, also may be due to hatchery crowding or hatchery water-quality conditions.

Physical-habitat characteristics of South Fork Campbell Creek were surveyed at three different reaches in 1999 and 2000. The characteristics at Reach C were similar to those at the other two reaches (fig. 37) and is the only reach discussed further. Discharge for this survey was 100 ft^3/s. The reach is meandering and has a sinuosity of 1.99 and a gradient of the 0.98 percent. The mean width was 27 ft with a mean depth of 1.6 ft. Stream velocities ranged from 0.72 to 5.8 ft/s with an average of 3.6 ft/s. Because the channel was relatively narrow with many large cottonwood trees along the banks (fig. 39), the open canopy angle was small, averaging 38 degrees. Riparian vegetation consists of spruce trees, cottonwood trees, and shrubs covering 100 percent of the banks, and vegetation overhung the reach along both banks (fig. 39). Bank substrate consisted of sand, and the bed substrate ranged from fine/medium gravel to very coarse gravel to small cobbles with no embeddedness (fig. 40). Habitat suitable for fish cover, consisting of woody debris and deep pools, was prevalent along the entire reach.

Figure 39. Streambank characteristics in the study reach C for the physical-habitat survey of South Fork Campbell Creek near Anchorage (site 23), Cook Inlet Basin study unit, Alaska.

Figure 40. Bed substrate of the South Fork Campbell Creek near Anchorage (site 23), Cook Inlet Basin study unit, Alaska.

Three reaches—A, B, and C—were surveyed at Chester Creek in May and July 2000 (fig. 38). Characteristics of all three reaches were similar. Discharges at the time of the surveys ranged from 26 to 34 ft^3/s. The water-surface gradient was relatively flat, with a slope of 0.42 percent. The surveyed reaches had been channelized and were relatively straight, with a sinuosity of 1.02. Channel width was about 25 ft and the average depth was 1.2 ft. Velocities ranged from 0 to 2.84 ft/s. Because the channel was narrow, the open canopy angle averaged only 21 degrees and ranged from 0 to 56 degrees (fig. 41). Vegetation on both banks consisted of shrubs and woodlands. This section of Chester Creek flows through a narrow greenbelt with residential housing beyond the greenbelt on both banks. Both left and right bank angles varied greatly, ranging from 0 to 70 degrees. The bank substrate was consistent along the reaches and consisted of very fine sand. The bed substrate consisted of fine to medium gravel (fig. 42), and the embeddedness of the substrate ranged from 0 to 100 percent. Habitat for fish consisted of overhanging vegetation along the banks and a number of woody debris accumulation piles.

Figure 41. Streambank characteristics of primary reach C, looking downstream, in Chester Creek at Arctic Boulevard, at Anchorage (site 27), Cook Inlet Basin study unit, Alaska.

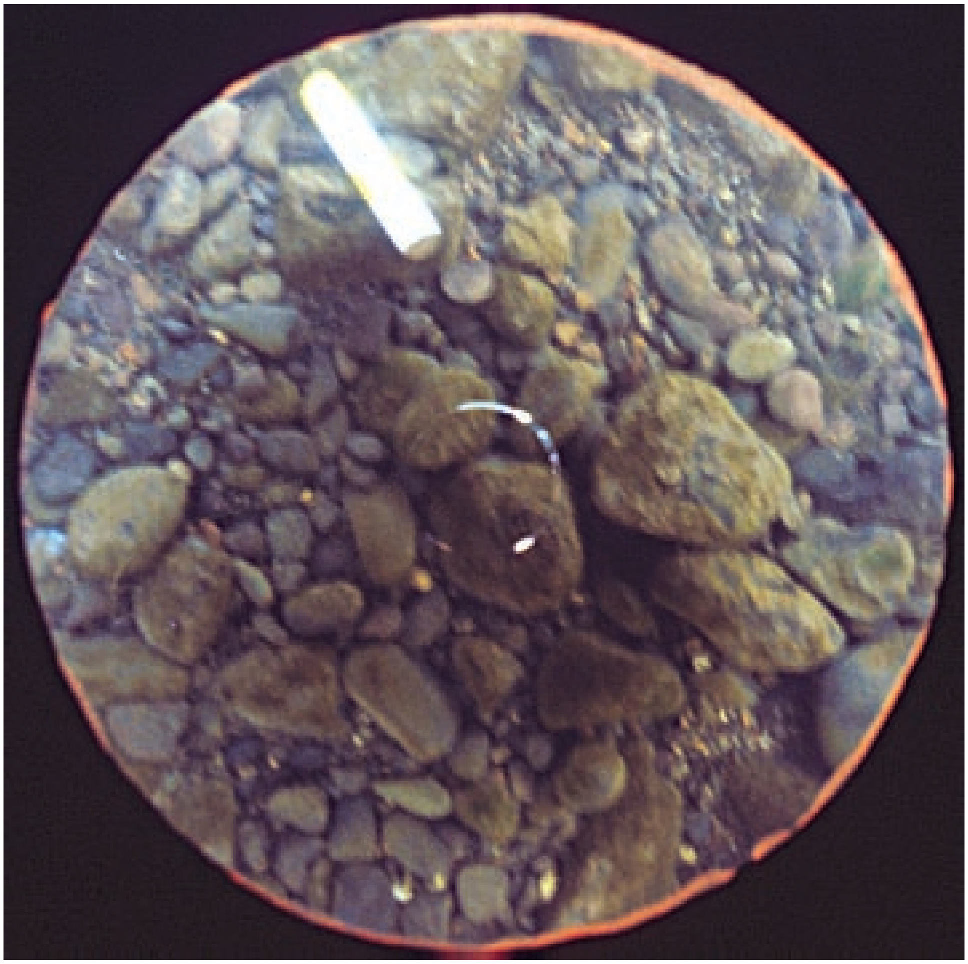

Figure 42. Bed substrate of Chester Creek at Arctic Boulevard, at Anchorage (site 27), Cook Inlet Basin study unit, Alaska.

Comparisons Among All Fixed Sites

Each of the sites monitored in the Cook Inlet Basin represents a different set of basin characteristics. These basin characteristics ranged from the urban setting at Chester Creek to the lowlands and wetlands that dominate the Deshka River to the glaciers and lakes in the Kenai River watershed. These characteristics influence the amount and timing of the loads of chemical constituents and compounds transported by streams.

Water-quality constituents of particular interest in the Cook Inlet Basin are suspended sediment, the nutrients nitrogen and phosphorus, and DOC. Suspended sediment is a concern because deposition of fine sediment in fish-spawning areas can smother fish eggs. The differences and similarities of the water-quality and biological data among the fixed sites are presented in this section. These comparisons show that differences and similarities in water quality and biological conditions are related to the basin characteristics of each site. Some comparisons could not be made for Moose Creek or the Johnson River because of the lack of specific data for these two sites.

Water Temperature

Stream temperature is an important physical factor for the five species of Pacific salmon that use many of the streams and rivers in the Cook Inlet Basin for spawning and rearing. To maximize survival, each of the five species has adapted to specific spawning times and water temperatures in order that incubation and emergence occur at the most favorable time of the year. The optimum water temperature for salmon depends on the species, the life stage, and the season. However, continued global warming may alter spawning and rearing habitat for Pacific salmon in the Cook Inlet Basin. Temperature increases may affect the process of transition from freshwater to saltwater (smolting) in juvenile salmonids, as well. Adult coldwater fish may cease to migrate or die unspawned if exposed to long periods of warmer-than-usual temperatures (Bell, 1973).

In a study of 584 streams and rivers in the contiguous United States, Mohseni and others (1998) determined the annual mean water temperature to be 12.0 °C. In contrast, the annual mean water temperatures for six fixed sites in the Cook Inlet Basin ranged from 3.3 to 6.2 °C during 1999–2001 (fig. 43). Water temperatures of these streams generally were at 0 °C for about one-half the year. During summer months, water temperature depended on the basin's physical characteristics. For example, the fixed sites on the Ninilchik and Deshka Rivers drain lowland, forested settings. Waters at these sites warm rapidly after snowmelt and were at their highest (17.5 to 21.5 °C) around July 1. The Kenai River Basin contains large areas of glaciers in its headwaters and has two large mainstem lakes upstream from the monitoring sites. The effects of these lakes and glaciers moderate the temperature of the Kenai River. Waters of the Kenai River gradually warmed in spring and cooled in autumn and the maximum water temperature approached about 14 °C. In the Municipality of Anchorage, data from South Fork Campbell Creek and Chester Creek afforded comparison between a virtually undeveloped basin and a highly urbanized basin, respectively. The effect of urbanization may be the cause for higher summer maximum temperatures, generally about 15 °C for Chester Creek, than for South Fork Campbell Creek, about 12 °C.

Major Ions

As previously noted, the waters at each of the fixed sites, with the exception of the Ninilchik River, were classified as calcium bicarbonate. However, there were differences in concentrations of the major ions. Median values and ranges in calcium, bicarbonate, and chloride concentrations were highest at Chester Creek, the urban site, which reflected the effects of de-icing materials applied on roads during the winter months. Concentrations of sodium exhibited the same trend. Silica and sulfate concentrations, however, were more dependent on the geology of the particular basin. For example, concentrations and ranges in silica were highest at Ninilchik and Deshka Rivers. Ranges in concentrations of sulfate were similar at South Fork Campbell Creek, Chester Creek, Moose Creek, and Johnson River.

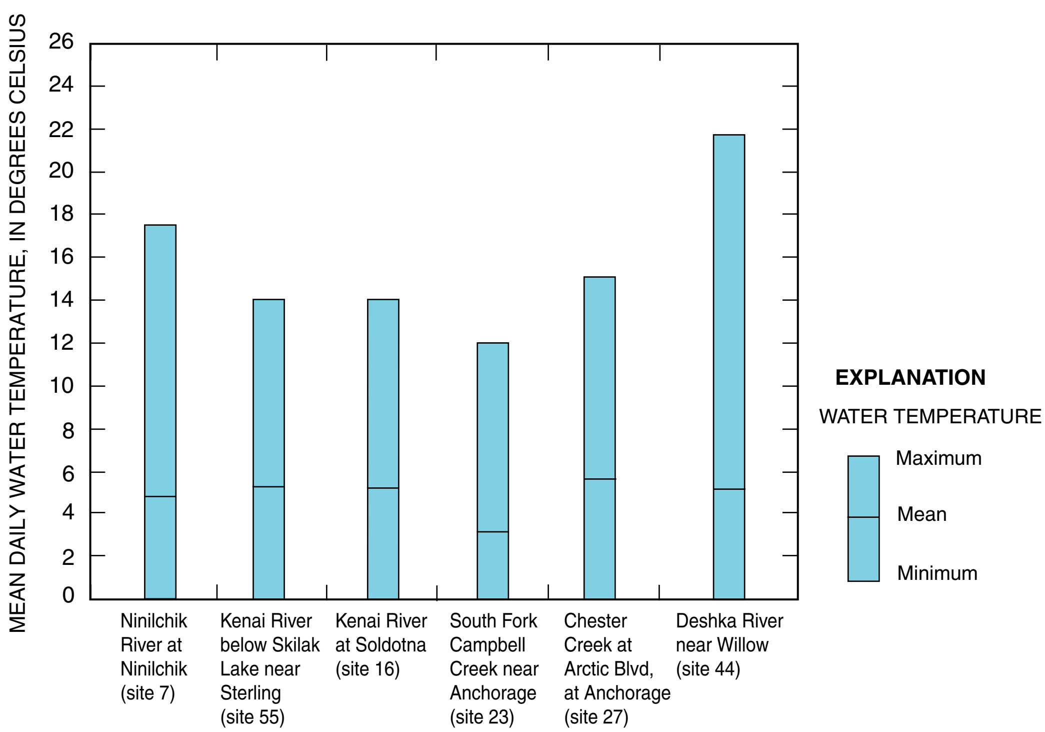

Figure 43. Comparison of ranges in mean daily water temperature for six fixed sites, Cook Inlet Basin study unit, Alaska, 1999–2001.

Nitrogen, Phosphorus, and Dissolved Organic Carbon

Nitrogen and phosphorus are essential for healthy plant and animal populations; however, elevated concentrations of these nutrients can degrade water quality. For example, elevated nitrogen and phosphorus concentrations in surface water can trigger eutrophication, resulting in excessive, often unsightly growth of algae and other nuisance aquatic plants. These plants can interfere with recreational activities, such as fishing, swimming, and boating; cause taste and odor problems; and can depress dissolved-oxygen concentrations to levels that are hazardous for aquatic life. DOC provides the major source of energy for non-photosynthetic biological activity, but also is a major control on the mobility of metals in streams and lakes affected by point source contaminants.

In the Cook Inlet Basin, the watersheds of five of the fixed sites, Kenai River below Skilak Lake, Kenai River at Soldotna, South Fork Campbell Creek, Johnson River, and Moose Creek, consist of some combination of glaciers, rough mountainous land, and poorly developed soils. Median concentrations of nitrogen, phosphorus, and DOC were lowest at these sites (fig. 44). In contrast, the Ninilchik and Deshka River Basins have well-developed soils and wetlands that are sources of nutrients and carbon. Chester Creek, the urban basin, also had higher concentrations of nutrients and DOC, which may be caused by both urbanization (use of fertilizers and increased sediment- bound phosphorus from disturbed soils) and land characteristics (wetlands and lowland soils).

Loads of Selected Constituents

During the winter, most streams and rivers in the Cook Inlet Basin were at low flow and ice covered. Because flow was low, loads of suspended sediment, nutrients, and DOC also were low. In the spring and summer, due to high flows from snowmelt or rainfall, most of the load of a given constituent was transported. A basin's particular characteristics (altitude, percentage of lakes and glaciers), however, determined the timing and magnitude of the load transported.

Among the fixed sites monitored in the Cook Inlet Basin, three sites draining relatively low-lying areas—the Ninilchik River, Chester Creek, and the Deshka River—transported most of their suspended sediment, nutrients, and DOC loads in the spring runoff that results from the melting snowpack (fig. 45). For the two sites on the Kenai River, Skilak Lake caused a delay in runoff of melting snow and ice and most of the loads were transported during the summer months. At South Fork Campbell Creek, which drains a higher altitude watershed than does Chester Creek, most of the load also was transported during the summer months.

On an annual basis, the yield of a particular constituent that was transported by each stream also depended on its basin characteristics (fig. 46). For example, the Kenai River at Soldotna had the largest average yield of suspended sediment of the fixed sites. Contributing to the Kenai River is the inflow of glacier-fed Killey River, downstream of Skilak Lake, which transports additional suspended sediment into the Kenai. The Deshka River transported the largest amount of DOC and total nitrogen because of the abundance of wetlands within the basin.

Algae

There was no apparent pattern for the dominant soft algae in RTH or DTH samples from most sites. The only site with consistent results was the Ninilchik River at Ninilchik, where both quantitative samples were composed entirely of blue-green algae almost every year. Blue-green algae also dominated the quantitative samples from the Kenai River below Skilak Lake, except in 2000, when a red algae was the only non-diatom present. The consistent presence of blue-green algae indicates oligotrophic conditions at these sites around the time of sampling.

Algal samples from the fixed sites suggest that hydrologic factors, such as frequent high flows, are strongly influencing the diatom assemblage. However, care must be taken in making assumptions about water-quality conditions if algal samples are collected very soon following high flows such as those caused by snowmelt. The autecology of dominant diatoms provides additional information on possible implications for environmental conditions in the 2 or 3 weeks prior to sampling (Pan and others, 1996). The most evident shared characteristic among many of the dominant diatoms was their resilience to high water velocities and scour episodes. This includes the genera *Achnanthes, Synedra*, and *Cymbella* and the taxon *Achnanthidium minutissium* (Stevenson and others, 1996; Hieber and others, 2001).

The genus *Achnanthes*, in particular, was commonly abundant at all fixed sites, averaging 20 percent of the diatoms per site in RTH samples and 17 percent in DTH samples. This may be expected, as it is one of the richest genera in Alaska (Foged, 1981) and has been observed as the most abundant taxon during all seasons elsewhere in the State (Anderson, 1984). Increased relative abundance of *Achnanthes* also can result from increasing light availability (Kutka and Richards, 1996), which may help explain its summer abundance in Alaska, where day lengths are long.

Community metrics that can provide information on water quality and the physiochemical environment in streams were compared among the fixed sites that were sampled over a 3-year period. For sites where multiple reaches were sampled, only results from the primary reach C were included in the analysis. At Johnson River and Moose Creek, algae samples were collected only one time and only from the RTH samples. Results from this limited sampling are included in the algae metrics (table 15).

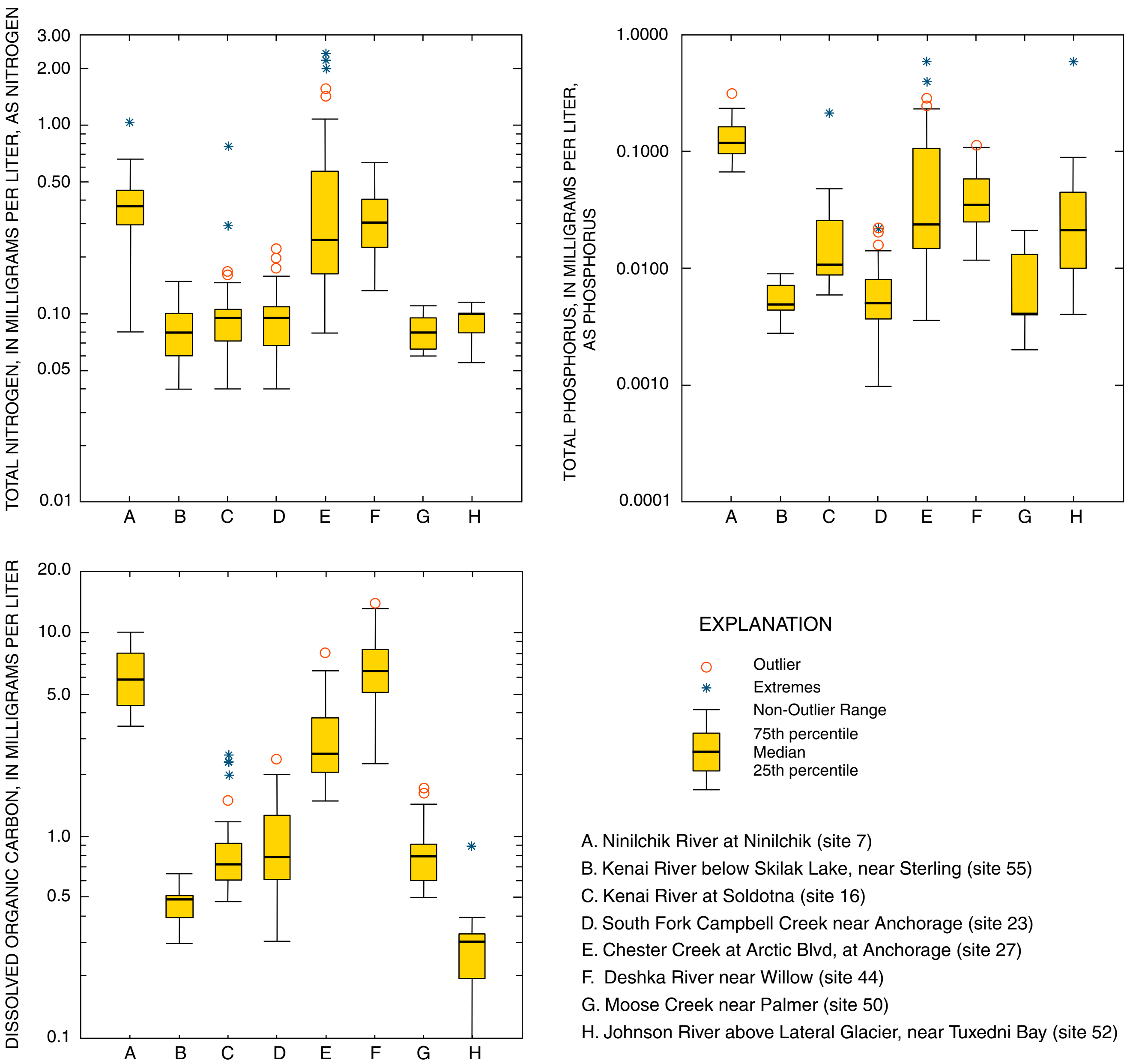

Figure 44. Concentrations of total nitrogen, total phosphorus, and dissolved organic carbon in water samples collected at fixed sites, Cook Inlet Basin study unit, Alaska, water years 1999–2001.

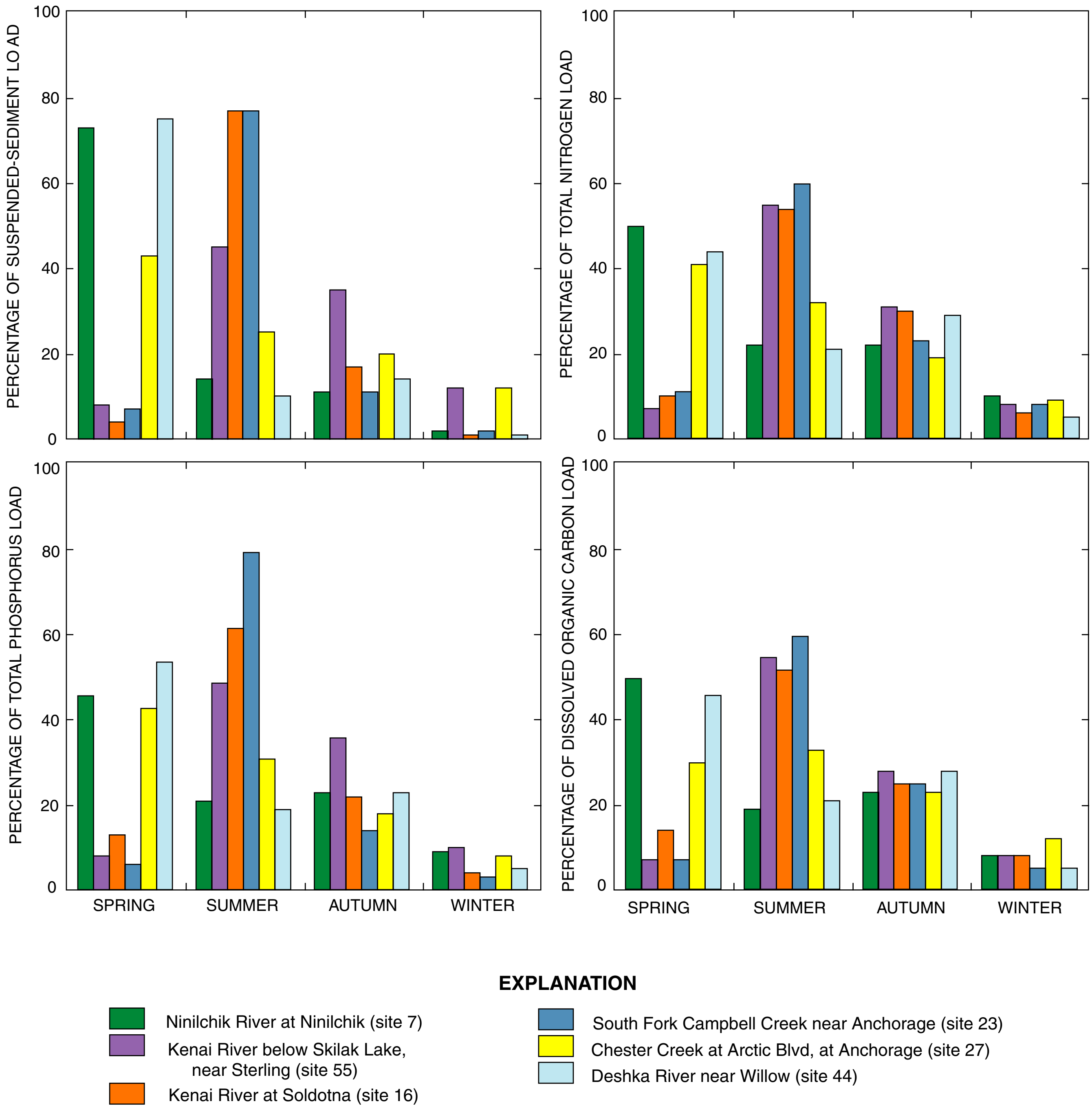

Figure 45. Seasonal percentage of suspended sediment, total nitrogen, total phosphorus, and dissolved organic carbon loads for six fixed sites, Cook Inlet Basin study unit, Alaska, water years 1999–2001.

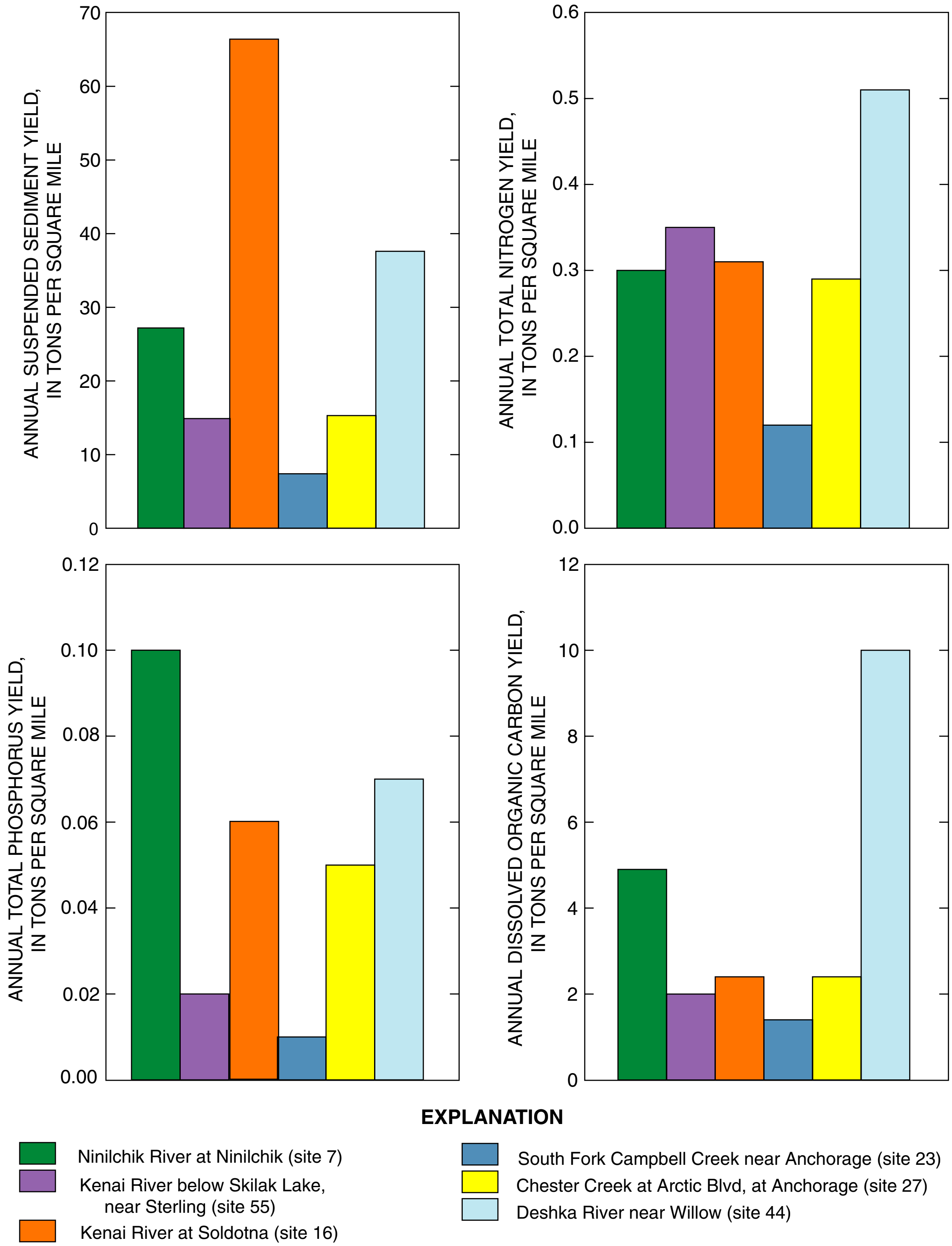

Figure 46. Annual yields of suspended sediment, total nitrogen, total phosphorus, and dissolved organic carbon for six fixed sites,Cook Inlet Basin study unit, Alaska, water years 1999–2001.

Taxa Richness

Algal taxa richness tends to increase slightly in streams with minor disturbances (sometimes referred to as the 'intermediate disturbance hypothesis') but decreases with the severity of disturbance, so that richness typically is lowest at the most highly impacted sites (Stephen Porter, U.S. Geological Survey, written commun., 2002). Site taxa richness ranged from 14 to 91 for RTH samples and from 36 to 89 for DTH samples (fig. 47). Richness for RTH and DTH samples from the Ninilchik River was highest every year, excluding the 2000 DTH sample. Possible reasons for the relatively high values in 2001 may be due to the relative mild winter, which reduced the natural stresses on the rivers such as ice cover or the fact that the Ninilchik is a relatively small basin that did not undergo any large floods from 1999 to 2001. The lowest richness for both sample types came from South Fork Campbell Creek every year except in 1999, when the RTH sample from Chester Creek had the lowest richness. At the Johnson River, taxa richness is most likely low because of natural stresses such as cold water and limited levels of nutrients and light (Bahls, 1993). Given the pristine alpine setting of the Johnson River and the turbid water because of glacial sediments (Frenzel and Dorava, 1999), this is a likely explanation for the low richness.

Total Algal Biovolume

Biovolume is largely dependent on taxa present, because the volume of a cell in some taxa may be orders of magnitude greater than that in another taxa. Total algal biovolume (TAB) is an indicator of standing crop, which can fluctuate according to available nutrients (Pringle, 1987), available light (Stevenson and others, 1996), and grazing pressure (Bergey, 1995). TAB for RTH samples varied greatly, ranging from about 3.0×10^6 to 8.5×10^9 m^3/cm^2 (fig. 48). The highest TAB in 1999 and the second highest in 2000 and 2001 was in the Deshka River. Possible reasons may be due to the relatively high amount of DOC found in this basin or the relatively warm water temperatures. The lowest values in 1999 and 2001 were from the Ninilchik River. TAB for DTH samples ranged from 2.8×10^8 to 1.2×10^{10} m^3/cm^2 (fig. 48), and no site consistently had the highest or lowest value.

Shannon Diversity for Diatoms

Shannon diversity index values for diatom assemblages have proven to be sensitive to changes in water quality (Barbour and others, 1999). Like measures of richness, diversity index values tend to be highest at slightly disturbed sites and lowest at highly impacted sites (Stephen Porter, written commun., 2002). For example, higher diversity has been observed in forested streams than in agricultural streams (Scudder and Stewart, 2001). Values for RTH samples from the sites with yearly samples ranged from 1.9 to 4.9 (fig. 49), similar to those found in the Rocky Mountains (Cox-Lillis, 2000). Values for the Johnson River and Moose Creek were 0.7 and 1.2, respectively. However, it was felt these relatively low values were due to natural stresses such as cold water and limiting levels of nutrients. Values for DTH samples ranged from 2.8 to 5.6 (fig. 49). For all years and both types of samples, values were highest in the Ninilchik River and the Deshka River, the two lowland basins. Diversity values were lowest in Chester Creek (an urban site) for all years and both types of samples.

Percentage of Motile Diatoms

The percentage of diatoms that are motile is used as an indicator of siltation, because such diatoms can move to avoid burial by deposited sediments. Therefore, sites with fewer motile taxa typically have lower rates of sedimentation. This metric has proven useful to identify streams with high amounts of erosion and siltation, particularly in agricultural areas, but natural sediment dynamics and watershed size also can influence this metric value (Potapova and others, 2002). For example, low-gradient streams will have naturally higher sedimentation rates than high-gradient streams. This metric is useful primarily for RTH samples, because DTH samples were collected from sediment deposits. The 1999 RTH sample for Chester Creek contained 40 percent motile diatoms, the largest value for all years (fig. 50), which is consistent with the high degree of embeddedness at that site. The Ninilchik River had the highest percentage of motile taxa in RTH samples collected in 2000 and 2001, with 27 and 9 percent, respectively. The high percentage of motile diatoms at the Ninilchik River may reflect upstream land uses, such as logging, that increase sedimentation of the streambed. South Fork Campbell Creek had the lowest percentage, with 0 percent for all years.

The percentage of motile diatoms has been a useful metric for evaluating sites nationally (Potapova and others, 2002). When compared with other sites across the country, the percentage of motile diatoms in RTH samples from Cook Inlet Basin fixed sites was in the top 25 percent of the national distribution for least disturbed streams based on this index (fig. 51). These Cook Inlet Basin sites also were in the lower range for streams classified as undeveloped (Groschen and others, 2000), including Chester Creek.

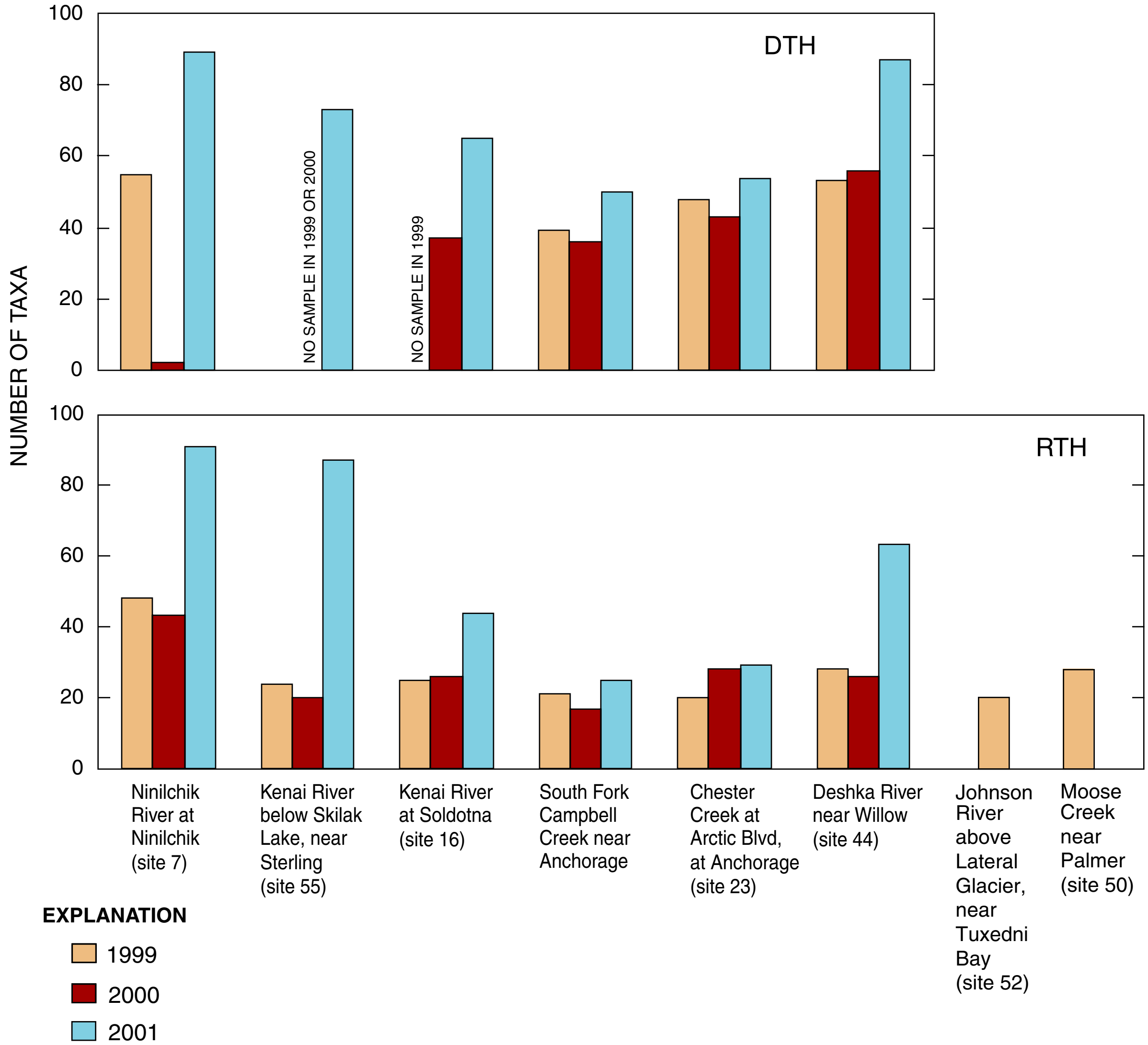

Figure 47. Taxa richness of algae RTH and DTH samples from fixed sites, Cook Inlet Basin study unit, Alaska.

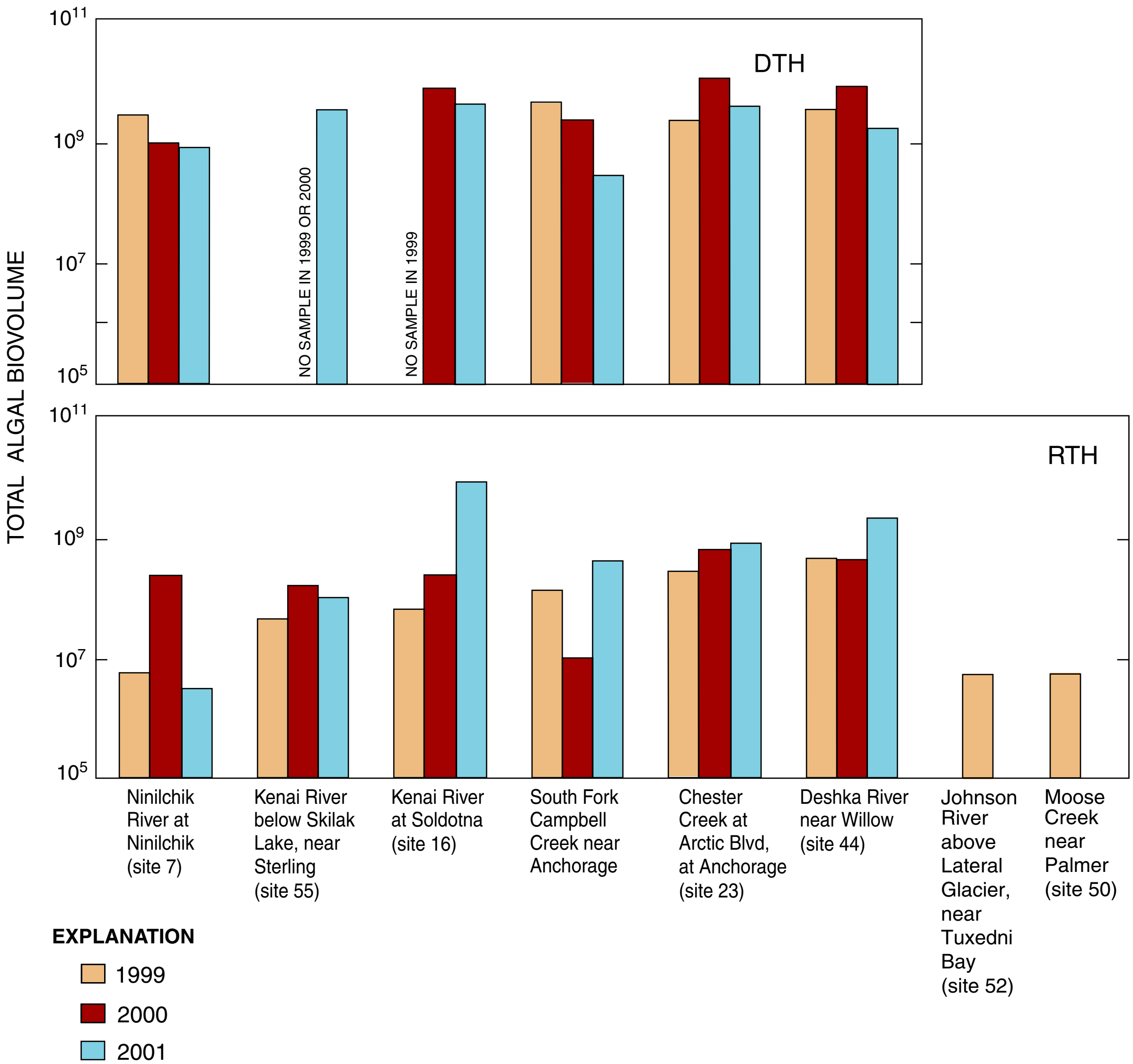

Figure 48. Total algal biovolume of RTH and DTH samples from fixed sites, Cook Inlet Basin study unit, Alaska.

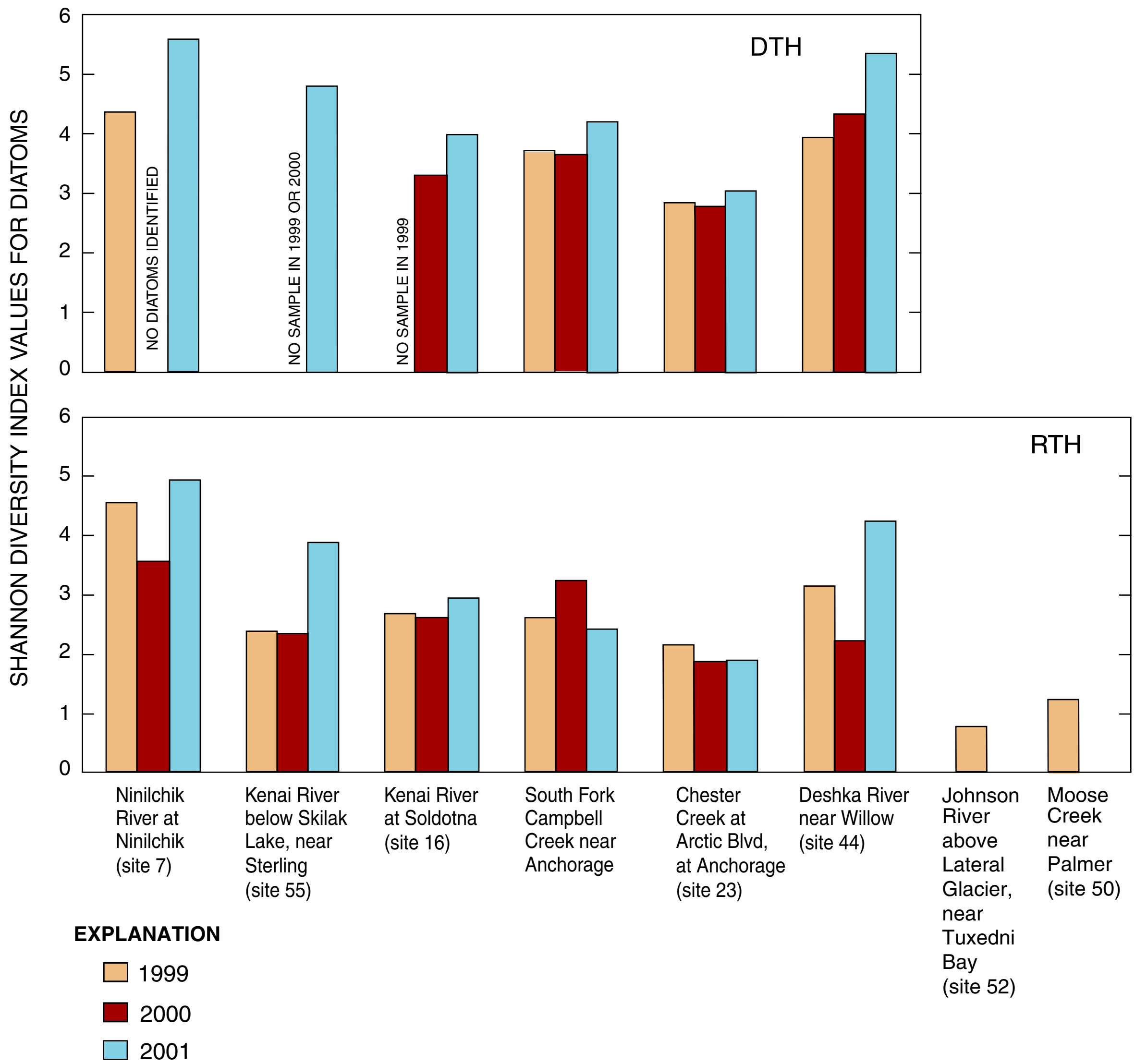

Figure 49. Shannon diversity index values for diatoms in algae RTH and DTH samples from fixed sites, Cook Inlet Basin study unit, Alaska.

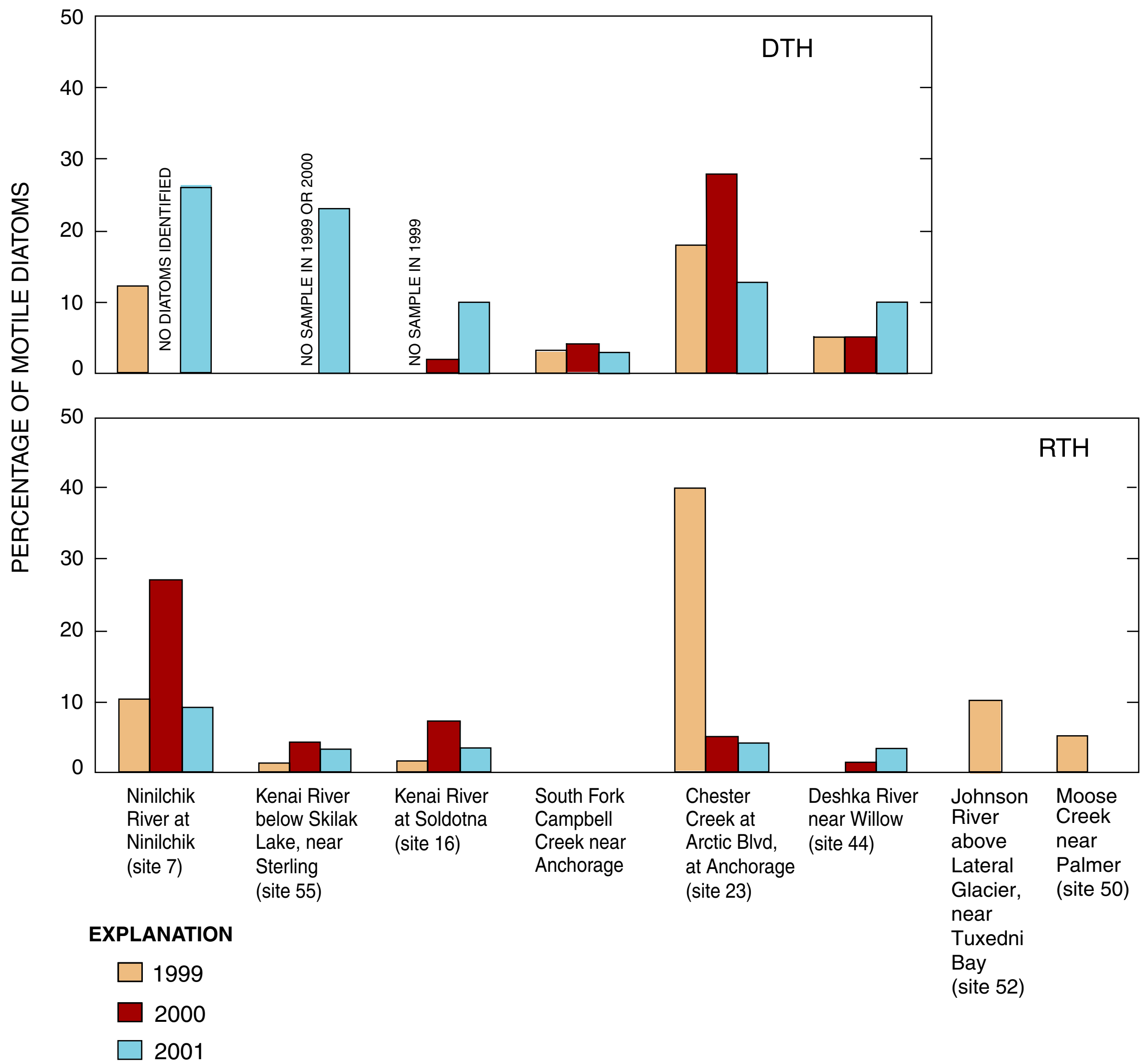

Figure 50. Percentage of motile diatoms in algae RTH and DTH samples from fixed sites, Cook Inlet Basin study unit, Alaska.

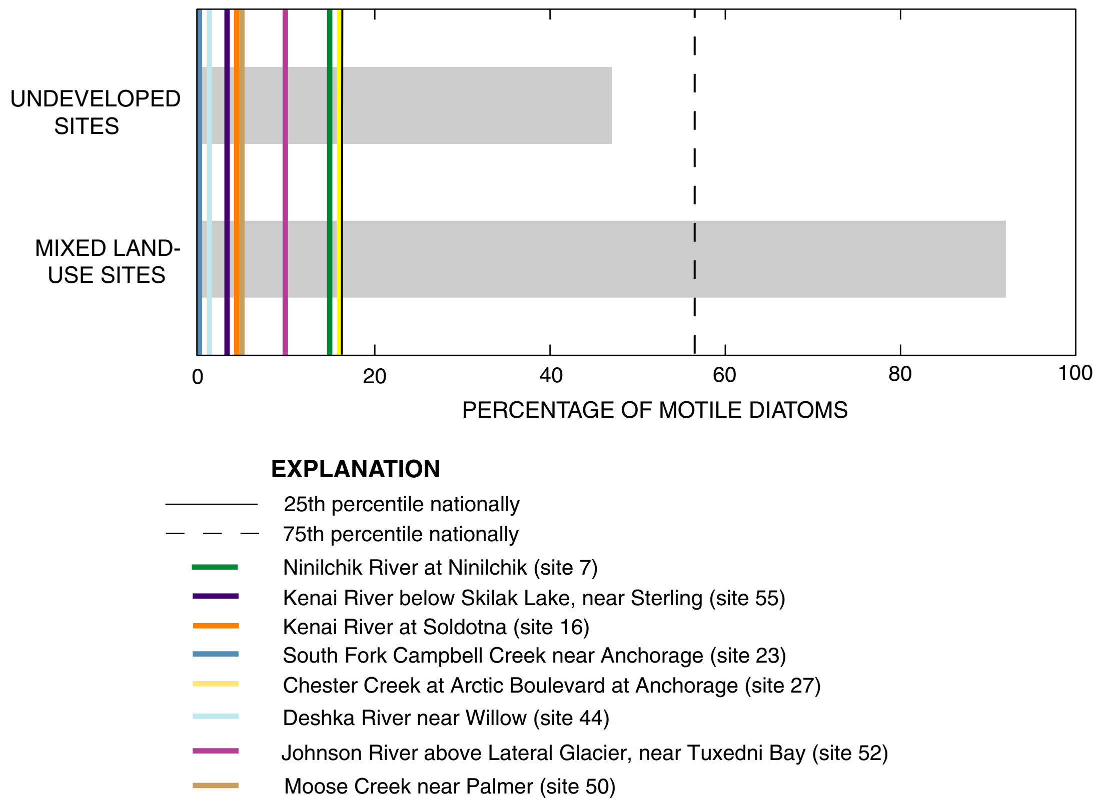

Figure 51. Comparison of average percentage of motile diatoms for fixed sites in the Cook Inlet Basin study unit, Alaska, with the distribution of national values for different land-use types.
(Modified from Groschen and others, 2000).

Macroinvertebrates

The macroinvertebrate community at most fixed sites was similar to that at many other Alaskan streams and rivers, where Diptera (true flies) are the dominant order, followed in relative abundance by Ephemeroptera (mayflies) and Plecoptera (stoneflies) (Oswood, 1989). A noticeable difference from this pattern was observed in a few samples collected from urban-influenced sites, where oligochaetes, a class of worms, were particularly abundant. These taxa include Tubificida (sludge worms), which are highly tolerant of poor water quality and physical disturbance (Pedersen and Perkins, 1986; Winter and Duthie, 1998). This indication of a stressed environment was apparent for Chester Creek but somewhat uncertain for the Kenai River at Soldotna. Oligochaetes dominated the macroinvertebrate assemblage at the Chester Creek site, making up more than 80 percent of the total invertebrate abundance in most samples. Although oligochaetes were the second most abundant taxa in the 1999 and 2001 samples from the Kenai River at Soldotna, it was felt their presence was due to enrichment of the river by dead salmon carcasses. Nearly one-third of the 2001 sample from South Fork Campbell Creek also consisted of oligochaetes, but they accounted for less than 2 percent in the other years sampled. Given the consistently good water quality and healthy conditions of the other biological communities found at this site during the 3-year sampling period, there may have been an uncommon stress at this site, or a more depositional microhabitat may have been sampled at this site before the macroinvertebrate sample was collected in 2001.

Although the dominant macroinvertebrate taxa varied at the different sites, overall, many of these taxa have the ability to live in high-gradient streams or survive high flow disturbance. For example, chironomids, by far the dominant family at most sites, can quickly colonize habitats that have been disturbed (Lehmkuhl, 1979). This is consistent with characteristics of the algal communities sampled at the same time, with a prevalence of colonizing algal taxa that can withstand high water velocities.

Macroinvertebrate data from RTH samples were used to calculate eight community metrics (table 14, fig. 52) that have demonstrated a predictable response to anthropogenic impacts (Gibson, 1996). These metrics are used to describe the relative health of macroinvertebrate communities in comparison to other sites. Although this is most useful for comparing the sites in Cook Inlet Basin, metric values also were qualitatively compared to those from a national data set (Cuffney, 2002) even though the unique conditions in northern latitudes, including extreme diurnal cycles and long periods of ice cover, may result in natural differences in aquatic communities between Alaskan streams and sreams in other parts of the Nation. For example, frozen sediments and extreme streambed-temperature ranges can strongly influence the composition of benthic macroinvertebrates (Olsson, 1981; Irons and others, 1989). Metrics were calculated for each of the sites that were sampled from 1998 to 2001.

Table 14. Summary of macroinvertebrate community metrics

[Data from Cuffney, 2002]

Metric	Description
CHRP	Percentage of taxa composed of Chironomidae (midges)
TOLA	Average of abundance-weighted U.S. EPA tolerance
TOLR	Average U.S. EPA tolerance based on richness
EPTR	Number of Ephemeroptera, Plecoptera, and Tricoptera taxa
EPTRP	Percentage of taxa composed of Ephemeroptera, Plecoptera, and Tricoptera
EVEN	Eveness (Shannon-Wiener diversity/maximum diversity)
RICH	Number of taxa
V2DOMP	Percentage of total abundance represented by the two most abundant taxa

Taxa Richness

Decreasing macroinvertebrate taxa richness (RICH) typically indicates stream degradation (Weber, 1973). Richness was lowest in the Johnson River and in the Kenai River below Skilak Lake, with an average of 14 and 19 taxa, respectively. Both sites represent undeveloped areas, and it is assumed that natural stresses such as cold water or winter ice cover result in these low values of taxa richness. The highest taxa richness was in the Ninilchik River and South Fork Campbell Creek, where an average of 32 taxa per site were identified. These two sites, along with the Deshka River, were the only sites with richness values that fell within the range (10th to 90th percentile) observed for undeveloped sites nationally.

Percentage of EPT and Abundance EPT

Because taxa from Ephemeroptera, Plecoptera, and Trichoptera, collectively referred to as EPT, are considered to be intolerant of pollution (Lenat, 1988), their relative contribution to invertebrate assemblages is considered to be a reliable indicator of water-quality conditions. The average number of EPT taxa (EPTR) in the Johnson River and Chester Creek were four and six, respectively, and the average relative abundance of EPT taxa (EPTRP) was 29 and 28 percent, respectively, the lowest for all Cook Inlet Basin BFS. These values probably reflect the impact of urbanization in the Chester Creek basin and the relatively harsh winter environment of the Johnson River basin. Values were highest in the Deshka River, with an average EPTR of 14 and an EPTRP of 49 percent of the community. Regarding the number of EPT taxa, values for all sites were in the lower 50th percentile for national observations at undeveloped sites. Regarding the percentage of EPT taxa, most sites were in the upper 50th percentile for undeveloped sites, with the exception of Chester Creek at Arctic Boulevard (an urban site) and the Kenai River at Soldotna, which were in the lower 50th percentile.

Percentage of Chironomidae

In contrast to EPT taxa, the percentage of chironomids (CHRP) often increases as the community health decreases (Barbour and others, 1999). The Kenai River at Soldotna had the greatest percentage of chironomids, averaging 44 percent per sample. The site with the lowest proportion of chironomids was Chester Creek, the urban site. Here, invertebrate assemblages were highly dominated by oligochaetes, which accounted for nearly 80 percent of invertebrate taxa in most samples. Comparisons of chironomid relative abundance between Alaskan sites and other national sites should be made with caution. There is a greater proportion of the order Diptera in Alaskan macroinvertebrate communities than in communities found in the contiguous United States, and a large number belong to the family Chironomidae (Oswood, 1989).

Taxa Dominance

Macroinvertebrate communities in impacted streams are often dominated by just a few, commonly tolerant, taxa (Cuffney, 2002). The combined relative abundance of the two most dominant taxa (V2DOMP) is often used to evaluate anthropogenic impacts. The average percentage of dominance by the top two taxa was highest at Chester Creek, the urban basin (74 percent) and the Johnson River, the high altitude alpine basin (78 percent) and lowest at the Ninilchik River (32 percent). The value for the Ninilchik River was the only value within the range observed for undeveloped sites nationally.

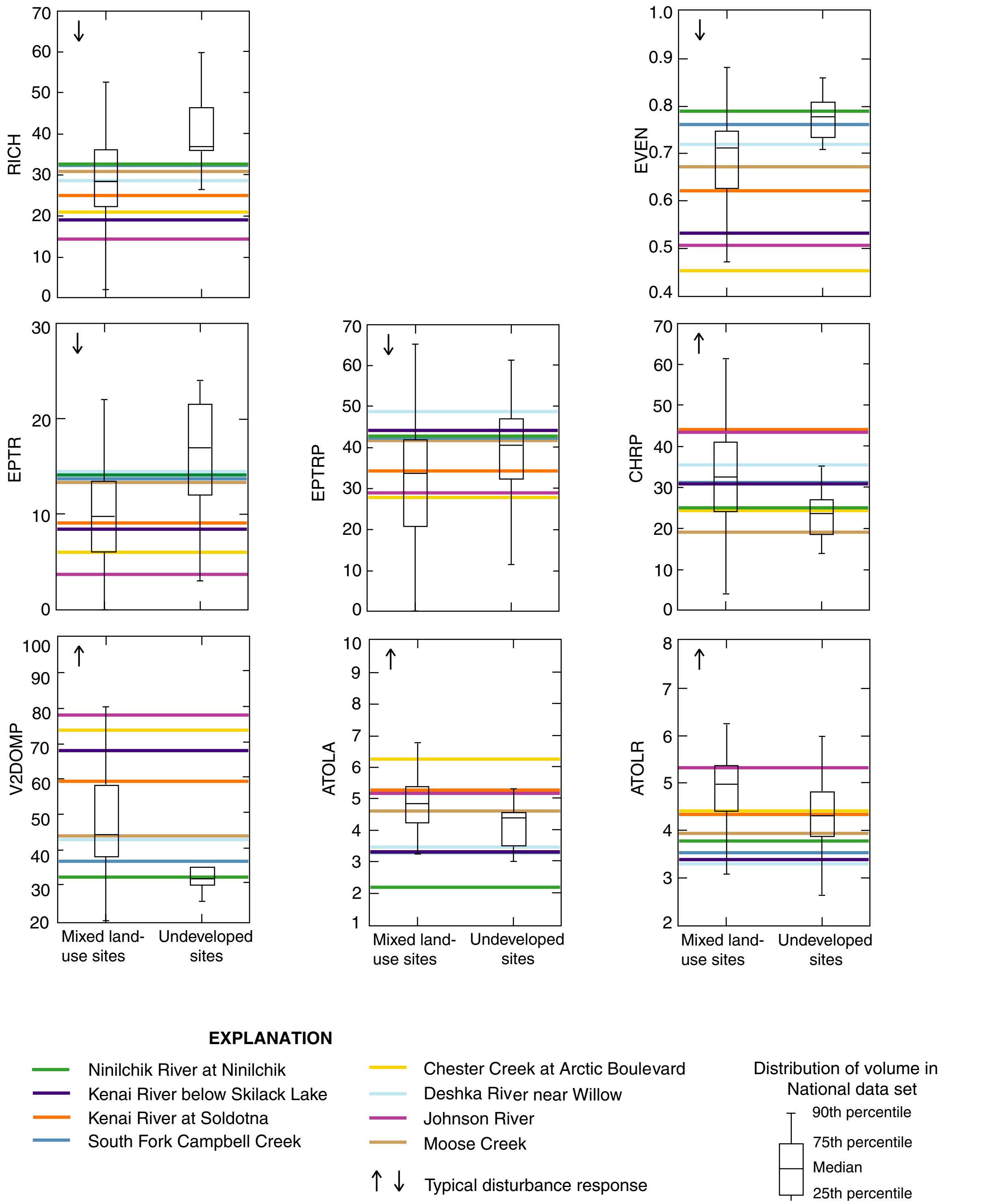

Figure 52. Comparison of average values for invertebrate community metrics from sites in the Cook Inlet Basin study unit, Alaska, with national values for different land-use types.
(See table 14, p. 82, for definitions of metrics.)

Pollution Tolerance Indices

Two metrics, TOLR (the average tolerance based on the taxa richness) and TOLA (tolerance based on the abundance-weighted mean), were calculated (Cuffney, 2002). USEPA tolerance values range from 0 for taxa very intolerant to pollution to 10 for taxa very tolerant to pollution, so higher metric values reflect more tolerant assemblages. On average, macroinvertebrate communities from Chester Creek had the highest tolerance values of all sites, based on both metrics. Communities from the Deshka River were most sensitive according to the TOLR metric and the Ninilchik River communities were most sensitive according to the TOLA metric. All sites fell within the range of TOLR index scores observed for undeveloped sites nationally. The Ninilchik River had an average TOLA index score lower than any observed for other undeveloped sites.

Fish

The fish communities generally were similar among all sites (table 20), consisting of one or more salmonid species and slimy sculpins (*Cottus cognatus*). This is typical of the cold water lotic systems found in southcentral Alaska. Threespine sticklebacks (*Gasterosteus aculeatus*) also were present at all sites except for South Fork Campbell Creek and Johnson River. The remainder of the assemblages at each site consisted of a few less-abundant species.

Very few external anomalies were observed on fish at any of the sites and all sites had values that were indicative of clean water-quality conditions. Nearly all anomalies observed were eroded fins, which can result from physical abrasion due to spawning or hatchery crowding in addition to poor water quality (Meador and others, 1993). Given the generally high-quality water in most of the Cook Inlet Basin rivers and streams sampled, the noted instances of fin erosion are most likely due to physical abrasion. Although the highest incidence of external anomalies was observed at Chester Creek, where poor water quality also was documented, nearly all anomalies were found on rainbow trout that were stocked in the stream.

The use of fish communities to evaluate general water-quality conditions is most often based on a regionally adapted multimetric Index of Biotic Integrity (Karr; 1981). Because species richness is extremely low in the waters of south-central Alaska, a multimetric community analysis of this type is less useful. There are far fewer species in Cook Inlet Basin systems than in even some of the cold water, low richness streams in the contiguous U.S. where some metrics have been developed (Lyons and others, 1996; Niemela and others, 1998). Except in extreme cases where only highly tolerant species may be found to the exclusion of other species, fish-community composition is not a particularly useful indicator of ecological health in the Cook Inlet Basin. However, data provide a record of not only taxa presence, but also the absence of taxa that may show up in the future as introduced fish.

Summary and Conclusions

As part of the U.S. Geological Survey's National Water-Quality Assessment (NAWQA) program, the water-quality, biological, physical-habitat condition of eight fixed sites in the Cook Inlet Basin of Alaska were studied from October 1998 to September 2001. Major findings are:

Climate: From a global context, the study period was characterized by La Nina-like and negative-PDO conditions. The study period years may be categorized as slightly cool-wet (water year 1999), slightly warm-wet (2000), and significantly warm-dry (2001). Air temperatures ranged from modestly cool in water year 1999 to near normal in 2000, and to notably warm in 2001. Air temperatures are highly correlated with glacier runoff, and thus higher-than-normal runoff occurred from these basins in water year 2001. Precipitation was near normal during the study period.

Water Quality: Water temperature of all streams studied in the Cook Inlet Basin remains at 0 °C for about 6 months each year. Average yearly water temperatures for six sites ranged from 3.3 to 6.2 °C. At basins with lowland, forested settings, such at the Ninilchik and Deshka Rivers, water temperatures warmed rapidly after snowmelt and were at their highest around July 1, whereas glacier melt and large lakes in the Kenai River basin moderate the water temperature of the Kenai River. Urbanization may have affected the water temperature of Chester Creek, causing higher summer temperatures than an adjacent, relatively undisturbed watershed, the South Fork Campbell Creek basin.

Concentrations of all water-quality constituents sampled were less than drinking-water standards. With the exception of the pesticide carbaryl, all concentrations were below aquatic-life standards. The waters of the Cook Inlet Basin are classified as calcium bicarbonate or calcium-magnesium bicarbonate. However, concentrations of the major ions differ among the sites studied. The urban stream, Chester Creek, had the highest concentrations of calcium, magnesium, chloride, and sodium, most likely caused by runoff following the application of de-icing materials during the winter. However, the lowland streams, Ninilchik River and Deshka River, had the highest concentrations of silica, due to the local geology.

Fixed sites in the Cook Inlet Basin that have glaciers within their watersheds, rough mountainous terrain, and poorly developed soils have low concentrations of nitrogen, phosphorus, and dissolved organic carbon. In contrast, the Ninilchik and Deshka River Basins have well-developed soils and wetlands that are sources of nutrients and dissolved organic carbon. Chester Creek, the urban basin, also has higher concentrations of nutrients and organic carbon, which may be due to effects of development, wetlands, and lowland soils.

For the three sites draining relatively low-lying areas—the Ninilchik River, Chester Creek, and the Deshka River—most of the loads of suspended sediment, nutrients, and dissolved organic carbon were transported in the spring from the melting snowpack. For the two sites on the Kenai River, Skilak Lake has a delay effect and most of the loads are transported during summer months. South Fork Campbell Creek, which drains higher altitude land than does Chester Creek, also transports most of its load during summer months.

On an annual basis, the amount of a particular constituent that is transported by a particular stream also depends on its basin characteristics. For example, the Kenai River at Soldotna transports the largest amount of suspended sediment of the fixed sites. Contributing to this sediment load is the inflow of glacier-fed Killey River, downstream of Skilak Lake, which transports additional suspended sediment into the Kenai River. However, the Deshka River transports the largest amount of dissolved organic carbon because of the high percentage of wetlands within the basin.

Biology: Aquatic communities in the Cook Inlet Basin are naturally different than similar sites in the contiguous United States because of the unique conditions of northern latitudes, such as extreme diurnal cycles and long periods of ice cover. Frozen sediments and extreme streambed temperature ranges strongly influence the composition of algae and benthic macroinvertebrates. In addition, hydrologic factors such as frequent high flows strongly influence diatom assemblages. Blue-green algae was the dominant algae found at all sites, although in some years green algae was the most dominant algae at some sites. The genus *Achnanthes*, which is small and typically resistant to scour, was the most abundant diatom found at the Cook Inlet Basin fixed sites. Macroinvertebrate communities consist primarily of Diptera (true flies), Ephemeroptera (mayflies), and Plecoptera (stoneflies). Lowland basins such as the Ninilchik River and the Deshka River had higher abundance of biological communities than glacier-fed basins such as the Kenai River and Johnson River. However, samples from Chester Creek, an urban stream, were dominated by oligochaetes, a class of worms that typically are tolerant of poor water quality and degraded habitat. Most of the functional feeding groups were collector-gathers. The number of taxa for both algae and macroinvertebrates were highest in water year 2001 and may be due to the relative mild winter of 2000–2001 and above average air temperatures for this water year.

Physical habitat: The fixed sites studied in the Cook Inlet Basin study unit were low gradient. Bank substrate consisted of silt clay, or sand, and the bed substrate consists of coarse gravel or cobbles with little or no embeddedness. Vegetation is primarily shrubs and woodlands with spruce or cottonwood trees. Suitable fish habitat, such as woody debris, pools, cobble substrate, and overhanging vegetation was found at most sites.

On the basis of multiple lines of evidence, of the three human activities occurring in some of the fixed site basins—high recreational use, logging, and urbanization—only urbanization has affected the water quality. Urbanization of Chester Creek basin has led to increased dissolved material during snowmelt periods, detection of a number of volatile organic compounds and pesticides, an increase in the number of tolerant species, and a change in the physical habitat of the stream. High recreational use and logging may be affecting site-specific areas within the Kenai River and Ninilchik River Basins, respectively, but these effects, if any, were not detected at the respective sampling sites.

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Appendix A. National Water-Quality Laboratory Analytical Schedules

Table A1. Minimum reporting levels for major ions and trace metals analyzed in filtered surface-water samples by inductively coupled plasma, laboratory schedule 2750

[Concentrations are given in milligrams per liter (mg/L) unless otherwise noted. **USGS NWIS code**: U.S. Geological Survey National Water Information System No. **CAS No.**: Chemical Abstracts Service No. **MRL**, minimum reporting level; **LRL**, laboratory reporting level; **IRL**, Instrument reporting level. µg/L, microgram per liter; °C, degree Celsius; –, no value]

Constituent	USGS NWIS code	CAS No.	MRL/LRL/IRL (mg/L)
Bromide	71870	24959-67-9	0.016
Calcium	00915	7440-70-2	.011
Magnesium	00925	7439-95-4	.008
Sodium	00930	7440-23-5	.1
Potassium	00935	7440-09-7	.16
Iron (µg/L)	01046	7439-89-6	8
Manganese (µg/L)	01056	7439-96-5	.4
Chloride	00940	16887-00-6	.2
Sulfate	00945	14808-79-8	.18
Fluoride	00950	16984-48-8	.17
Silica	00955	7631-86-9	.02
Residue on evaporation at 180 °C	70300	–	10

Table A2. Minimum reporting levels for nutrients analyzed in filtered and whole surface-water samples, laboratory schedule 1119

[**USGS NWIS code**: U.S. Geological Survey National Water Information System No. **CAS No.**: Chemical Abstracts Service No. **MRL**, minimum reporting level; **LRL**, laboratory reporting level. mg/L, milligram per liter; N, nitrogen; P, phosphorus; –, no value]

Constituent	USGS NWIS code	CAS No.	MRL/LRL (mg/L)
Nitrogen, ammonia, dissolved, as N	00608	7664-41-7	0.015
Nitrogen, nitrite, dissolved, as N	00613	14797-65-0	.0023
Nitrogen, ammonia + organic, dissolved, as N	00623	17778-88-0	.1
Nitrogen, ammonia + organic, total, as N	00625	17778-88-0	·1
Nitrogen, nitrite + nitrate, dissolved, as N	00631	–	.022
Phosphorus, total, as P	00665	7723-14-0	.0037
Phosphorus, dissolved, as P	00666	7723-14-0	.0044
Phosphorus, dissolved, orthophosphate, as P	00671	14265-44-2	.007

Table A3. Minimum reporting levels for organic carbon analyzed in surface-water samples, laboratory schedule 2075

[**USGS NWIS code**: U.S. Geological Survey National Water Information System No.. **CAS No**.: Chemical Abstracts Service No. **MRL**, minimum reporting level; **LRL**, laboratory reporting level. mg/L, milligram per liter; –, no value]

Constituent	USGS NWIS code	CAS No.	MRL/LRL (mg/L)
Organic carbon, suspended	00689	_	0.2
Organic carbon, dissolved	00681	_	.33

Table A4. Minimum reporting levels for pesticides and transformation products analyzed in filtered surface-water samples by gas chromatography/mass spectrometry, laboratory schedule 2001

[**USGS NWIS code**: U.S. Geological Survey National Water Information System No. **CAS No.**: Chemical Abstracts Service No. **MRL**, minimum reporting level; **LRL**, laboratory reporting level. µg/L, microgram per liter; DDE, dichlorodiphenyldichloroethylene; DCPA, dimethyltetrachloroterephthalate; EPTC, S-ethyl dipropylthiocarbamate; HCH, hexachlorocyclohexane; –, no value]

Pesticide or degradation product	Type	USGS NWIS code	CAS No.	MRL/LRL (µg/L)
2,6-Diethylaniline	Transformation product	82660	579-66-8	0.006
Acetochlor	Herbicide	49260	34256-82-1	.006
Alachlor	Herbicide	46342	15972-60-8	.0045
Atrazine	Herbicide	39632	1912-24-9	.007
Azinphos-methyl	Insecticide	82686	86-50-0	.05
Benfluralin	Herbicide	82673	1861-40-1	.01
Butylate	Herbicide	04028	2008-41-5	.002

Table A4. Minimum reporting levels for pesticides and transformation products analyzed in filtered surface-water samples by gas chromatography/mass spectrometry, laboratory schedule 2001—*Continued*

[**USGS NWIS code**: U.S. Geological Survey National Water Information System No. **CAS No.**: Chemical Abstracts Service No. **MRL**, minimum reporting level; **LRL**, laboratory reporting level. μg/L, microgram per liter; DDE, dichlorodiphenyldichloroethylene; DCPA, dimethyltetrachloroterephthalate; EPTC, S-ethyl dipropylthiocarbamate; HCH, hexachlorocyclohexane; –, no value]

Pesticide or degradation product	Type	USGS NWIS code	CAS No.	MRL/LRL (μg/L)
Carbaryl	Insecticide	82680	63-25-2	0.041
Carbofuran	Insecticide	82674	1563-66-2	.02
Chlorpyrifos	Insecticide	38933	2921-88-2	.005
Cyanazine	Herbicide	04041	21725-46-2	.018
p,p'-DDE	Transformation product	34653	72-55-9	.0025
DCPA	Herbicide	82682	1861-32-1	.003
Deethylatrazine	Transformation product	04040	6190-65-4	.006
Diazinon	Insecticide	39572	333-41-5	.005
Dieldrin	Insecticide	39381	60-57-1	.0048
Disulfoton	Insecticide	82677	298-04-4	.021
EPTC	Herbicide	82668	759-94-4	.002
Ethalfluralin	Herbicide	82663	55283-68-6	.009
Ethoprophos	Insecticide	82672	13194-48-4	.005
Desulfinylfipronil amide	Insecticide	62169		.009
Fipronil sulfide	Insecticide	62167	120067-83-6	.005
Fipronil sulfone	Insecticide	62168	120068-36-2	.005
Desulfinylfipronil	Insecticide	62170		.004
Fipronil	Insecticide	62166	120068-37-3	.007
Fonofos	Insecticide	04095	944-22-9	.0027
alpha-HCH	Insecticide[1]	34253	319-84-6	.0046
Lindane (*gamma*-HCH)	Insecticide	39341	58-89-9	.004
Linuron	Herbicide	82666	330-55-2	.035
Malathion	Insecticide	39532	121-75-5	.027
Metolachlor	Herbicide	39415	51218-45-2	.013
Metribuzin	Herbicide	82630	21087-64-9	.006
Molinate	Herbicide	82671	2212-67-1	.0016
Napropamide	Herbicide	82684	15299-99-7	.007
Parathion	Insecticide	39542	56-38-2	.01
Parathion-methyl	Insecticide	82667	298-00-0	.006
Pebulate	Herbicide	82669	1114-71-2	.0041
Pendimethalin	Herbicide	82683	40487-42-1	.022
cis-Permethrin	Insecticide	82687	54774-45-7	.006
Phorate	Insecticide	82664	298-02-2	.011
Prometon	Herbicide	04037	1610-18-0	.015
Propachlor	Herbicide	04024	1918-16-7	.01
Propanil	Herbicide	82679	709-98-8	.011
Propargite	Insecticide	82685	2312-35-8	.023
Propyzamide	Herbicide	82676	23950-58-5	.0041
Simazine	Herbicide	04035	122-34-9	.005
Tebuthiuron	Herbicide	82670	34014-18-1	.016
Terbacil	Herbicide	82665	5902-51-2	.034
Terbufos	Insecticide	82675	13071-79-9	.017
Thiobencarb	Herbicide	82681	28249-77-6	.0048
Triallate	Herbicide	82678	2303-17-5	.0023
Trifluralin	Herbicide	82661	1582-09-8	.009
Surrogate recoveries				MRL (percent)
Diazinon-d_{10} (surrogate)		91063	100155-47-3	.1
alpha-HCH-d_6 (surrogate)		91065	–	.1

[1]Pesticide can be a component of the technical mixture of lindane as well as a transformation product of lindane (Larson and others, 1997).

Table A5. Minimum reporting levels for pesticides and transformation products analyzed in filtered surface-water samples by high-performance liquid chromatography/photodiode-array detection, laboratory schedule 2050

[**USGS NWIS code**: U.S. Geological Survey National Water Information System No. **CAS No.**: Chemical Abstracts Service No. **MRL**, minimum reporting level; **LRL**, laboratory reporting level. μg/L, microgram per liter; 2,4-5-T, (2,4-5-trichlorophenoxy) acetic acid; 2,4-D, (2,4-dichlorophenoxy) acetic acid; 2,4-DB, 4-(2,4-dichlorophenoxy) butyric acid; MCPA, (4-chloro- 2-methylphenoxy) acetic acid; MCPB, 4-(4-chloro-o-tolyloxy)butyric acid; BDMC, 4-bromo-3,5-dimethyl phenyl-n-methylcarbamate; –, no value]

Pesticide or degradation product	Type	USGS NWIS code	CAS No.	MRL/LRL (μg/L)
2,4,5-T	Herbicide	39742	93-76-5	0.07
2,4-D	Herbicide	39732	94-75-7	.16
2,4-DB	Herbicide	38746	94-82-6	.25
2-(2,4,5-Trichlorophenoxy) propionic acid	Herbicide	39762	93-72-1	.025
3-Hydroxycarbofuran	Transformation product	49308	16655-82-6	.11
4,6-Dinitro-2-methylphenol	Herbicide	49299	534-52-1	.25
Acifluorfen	Herbicide	49315	50594-66-6	.05
Aldicarb	Insecticide	49312	116-06-3	.21
Aldicarb sulfone	Transformation product	49313	1646-88-4	.2
Aldicarb sulfoxide	Transformation product	49314	1646-87-3	.27
Bentazon	Herbicide	38711	25057-89-0	.05
Bromacil	Herbicide	04029	314-40-9	.09
Bromoxynil	Herbicide	49311	1689-84-5	.07
Carbaryl	Insecticide	49310	63-25-2	.08
Carbofuran	Insecticide	49309	1563-66-2	.15
Chloramben	Herbicide	49307	133-90-4	.21
Chlorothalonil	Insecticide	49306	1897-45-6	.25
Clopyralid	Herbicide	49305	1702-17-6	.42
Dacthal monoacid	Degradation product	49304	887-54-7	.07
Dicamba	Herbicide	38442	1918-00-9	.11
Dichlobenil	Herbicide	49303	1194-65-6	.09
Dichlorprop	Herbicide	49302	120-36-5	.12
Dinoseb	Herbicide	49301	88-85-7	.09
Diuron	Herbicide	49300	330-54-1	.12
Fenuron	Herbicide	49297	101-42-8	.07
Fluometuron	Herbicide	38811	2164-17-2	.06
Linuron	Herbicide	38478	330-55-2	.06
MCPA	Herbicide	38482	94-74-6	.2
MCPB	Herbicide	38487	94-81-5	.26
Methiocarb	Insecticide	38501	2032-65-7	.07
Methomyl	Insecticide	49296	16752-77-5	.47
Neburon	Herbicide	49294	555-37-3	.07
Norflurazon	Herbicide	49293	27314-13-2	.042
Oryzalin	Herbicide	49292	19044-88-3	.28
Oxamyl	Insecticide	38866	23135-22-0	.16
Picloram	Herbicide	49291	1918-02-1	.09
Propham	Herbicide	49236	122-42-9	.22
Propoxur	Insecticide	38538	114-26-1	.12
Triclopyr	Herbicide	49235	55335-06-3	.07
Surrogate recoveries				MRL (percent)
BDMC (surrogate)		99835	–	.1

Table A6. Minimum reporting levels for volatile organic compounds analyzed in whole surface-water samples by purge and trap chromatography/mass spectrometry, laboratory schedule 2020

[**USGS NWIS code:** U.S. Geological Survey National Water Information System No. **CAS No.**, Chemical Abstracts Service No. **MRL**, Minimum reporting level; **LRL**, 1999 laboratory minimum reporting level. µg/L, microgram per liter; –, no value]

Compound (Common name)	USGS NWIS code	CAS No.	MRL/LRL (µg/L)	Compound	USGS NWIS code	CAS No.	MRL/LRL (µg/L)
1,1,1,2-Tetrachloroethane	77562	630-20-6	0.03	Benzene	34030	71-43-2	0.021
1,1,1-Trichloroethane	34506	71-55-6	.032	Bromobenzene	81555	108-86-1	.036
1,1,2,2-Tetrachloroethane	34516	79-34-5	.09	Bromochloromethane	77297	74-97-5	.12
1,1,2-Trichloroethane	34511	79-00-5	.064	Bromodichloromethane	32101	75-27-4	.048
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)	77652	76-13-1	.06	Bromoethene	50002	593-60-2	.1
1,1-Dichloroethane	34496	75-34-3	.035	Tribromomethane (Bromoform)	32104	75-25-2	.1
1,1-Dichloroethene	34501	75-35-4	.044	Bromomethane (Methyl bromide)	34413	74-83-9	.26
1,1-Dichloropropene	77168	563-58-6	.05	*n*-Butylbenzene	77342	104-51-8	.19
1,2,3,4-Tetramethylbenzene (Prehnitene)	49999	488-23-3	.23	Carbon disulfide	77041	75-15-0	.07
1,2,3,5-Tetramethylbenzene (Isodurene)	50000	527-53-7	.2	Chlorobenzene	34301	108-90-7	.028
1,2,3-Trichlorobenzene	77613	87-61-6	.27	Chloroethane	34311	75-00-3	.12
1,2,3-Trichloropropane	77443	96-18-4	.16	Trichloromethane (Chloroform)	32106	67-66-3	.024
1,2,3-Trimethylbenzene	77221	526-73-8	.12	Chloromethane (Methyl chloride)	34418	74-87-3	.17
1,2,4-Trichlorobenzene	34551	120-82-1	.12	Dibromochloromethane	32105	124-48-1	.18
1,2,4-Trimethylbenzene	77222	95-63-6	.056	Dibromomethane	30217	74-95-3	.05
1,2-Dibromo-3-chloropropane	82625	96-12-8	.5	Dichlorodifluoromethane	34668	75-71-8	.18
1,2-Dibromoethane	77651	106-93-4	.036	Dichloromethane (Methylene chloride)	34423	75-09-2	.16
1,2-Dichlorobenzene	34536	95-50-1	.048	Diethyl ether (Ethyl ether)	81576	60-29-7	.17
1,2-Dichloroethane	32103	107-06-2	.13	Diisopropyl ether	81577	108-20-3	.1
1,2-Dichloropropane	34541	78-87-5	.029	Ethyl methacrylate	73570	97-63-2	.18
1,3,5-Trimethylbenzene	77226	108-67-8	.044	Ethyl *tert*-butyl ether	50004	637-92-3	.05
1,3-Dichlorobenzene	34566	541-73-1	.03	Ethylbenzene	34371	100-41-4	.03
1,3-Dichloropropane	77173	142-28-9	.12	Hexachlorobutadiene	39702	87-68-3	.14
1,4-Dichlorobenzene	34571	106-46-7	.05	1,1,1,2,2,2-Hexachloroethane (Hexachloroethane)	34396	67-72-1	.19
2,2-Dichloropropane	77170	594-20-7	.05	(1-Methylethyl)benzene (Isopropylbenzene)	77223	98-82-8	.06
2-Butanone (Methyl ethyl ketone)	81595	78-93-3	5	Methyl acrylate	49991	96-33-3	2
1-Chloro-2-methylbenzene (*o*-Chlorotoluene)	77275	95-49-8	.04	Methyl acrylonitrile	81593	126-98-7	.57
2-Hexanone	77103	591-78-6	.7	Iodomethane (Methyl iodide)	77424	74-88-4	.35
3-Chloro-1-propene	78109	107-05-1	.12	Methyl methacrylate	81597	80-62-6	.35
1-Chloro-4-methylbenzene (p-Chlorotoluene)	77277	106-43-4	.05	Naphthalene	34696	91-20-3	.05
1-Isopropyl-4-methylbenzene (p-Isopropyltoluene)	77356	99-87-6	.12	Ethenylbenzene (Styrene)	77128	100-42-5	.042
4-Methyl-2-pentanone (Methyl isobutyl ketone)	78133	108-10-1	0.37	Tetrachloroethene	34475	127-18-4	.027
Acetone	81552	67-64-1	7	Tetrachloromethane	32102	56-23-5	.06
2-Propenenitrile (Acrylonitrile)	34215	107-13-1	1.2	Tetrahydrofuran	81607	109-99-9	2.2

Table A6. Minimum reporting levels for volatile organic compounds analyzed in whole surface-water samples by purge and trap chromatography/mass spectrometry, laboratory schedule 2020—*Continued*

[**USGS NWIS code:** U.S. Geological Survey National Water Information System No. **CAS No.**, Chemical Abstracts Service No. **MRL**, Minimum reporting level; **LRL**, 1999 laboratory minimum reporting level. µg/L, microgram per liter; –, no value]

Compound (Common name)	USGS NWIS code	CAS No.	MRL/LRL (µg/L)	Compound	USGS NWIS code	CAS No.	MRL/LRL (µg/L)
Methylbenzene (Toluene)	34010	108-88-3	.05	Methyl tert-butyl ether (MTBE)	78032	1634-04-4	.17
Trichloroethene	39180	79-01-6	.038	(1,1-Dimethylethyl)benzene	77353	98-06-6	.1
Trichlorofluoromethane	34488	75-69-4	.09	tert-Amyl methyl ether	50005	994-05-8	.08
Chloroethene (Vinyl chloride)	39175	75-01-4	.11	*trans*-1,2-Dichloroethene	34546	156-60-5	.032
cis-1,2-Dichloroethene	77093	156-59-2	.038	*trans*-1,3-Dichloropropene	34699	10061-02-6	.09
cis-1,3-Dichloropropene	34704	10061-01-5	.09	*trans*-1,4-Dichloro-2-butene	73547	110-57-6	.7
1,3-plus-1,4-Dimethylbenzene (m,p-Xylene)	85795	–	.06				
n-Propylbenzene	77224	103-65-1	.042	Surrogate recoveries			MRL
2-Ethyltoluene (*o*-Ethyltoluene)	77220	611-14-3	.06	1,2-Dichloroethane-*d4* (surrogate)	99832	17060-07-0	.1
1,2-Dimethylbenzene (*o*-Xylene)	77135	95-47-6	.07	1,4-Bromofluorobenzene (surrogate)	99834	460-00-4	.1
(1-Methylpropyl)benzene	77350	135-98-8	.06	Toluene-*d8* (surrogate)	99833	2037-26-5	.1

Appendix B. Quality Assurance/ Quality Control—Methods, Results, and Discussion

Ten field blank-water samples and one laboratory blank-water sample prepared with organic water were submitted for major-ion analysis between the dates of October 1998 and September 2001. Five constituents were detected in these samples (table B1). Calcium was the most frequently detected constituent in 5 of the 11 samples (including the laboratory blank). Of the field blank-water samples, most constituents were detected in samples prepared for the Ninilchik River at Ninilchik (fig.1, site 7). Concentrations of all detected constituents were well below the minimum concentrations detected in stream water from the sites where the blanks were prepared. The 'closest' concentration of a major ion compound in a field blank-water sample to a concentration in an environmental sample was for magnesium detected in a sample prepared at the Ninilchik River at Ninilchik, but the concentration of the environmental sample detected at this site (1.54 mg/L) was five times the concentration as detected in the blank sample (0.3 mg/L). There was no concern of problematic contamination of samples in the field or laboratory with major ions and thus no adjustments were made to the database.

Between May 1998 and September 2001, 12 blank-water samples were prepared for nutrient analyses (table B2). Five nutrient compounds were detected in the 12 samples. There were no detections of total phosphorus or dissolved ammonia-plus-organic nitrogen. Dissolved ammonia nitrogen was detected in 7 of the 12 samples and dissolved orthophosphate was detected in 5 of the 12 samples. Dissolved nitrate-plus-nitrite concentrations in the blanks were usually 4 times or more lower than the concentrations of the environmental samples at the sites where the blanks were prepared. There were 21 total nutrient compound detections. Five of the detections were in concentrations equal to or more than the concentration of the same compound detected in the environmental sample. This might suggest some contamination; however, these concentrations are at very low levels (less than 0.014 mg/L). For reference, the value of the environmental sample on the day of blank preparation is listed in parenthesis alongside the value of the blank.

Twelve blank-water samples were prepared for organic carbon analyses between October 1998 and September 2001 (table B3). Dissolved organic carbon was detected in 4 of the 12 samples, with the highest concentration of 0.25 mg/L. Suspended organic carbon was not detected. Because the detected concentration of the dissolved organic carbon was close to the detection limit it was felt that there was no contamination and the datasets were not altered.

Table B1. Concentrations of major ions in field-blank water samples for the Cook Inlet study unit, Alaska

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

Station No.	Site No.	Sample date	Sample time	Sample type	Constituent (USGS NWIS code)									
					Calcium (00915)	Silica (00955)	Iron (01046) (µg/L)	Chloride (00940)	Magnesium (00925)	Fluoride (00950)	Sodium (00930)	Manganese (01056) (µg/L)	Potassium (00935)	Sulfate (00945)
15241600	7	01-09-99	1045	field	0.54	0.131	<10	<0.1	0.303	<0.1	0.079	<3	<0.1	–
15241600	7	01-05-00	1355	field	–	–	–	–	–	–	–	<1	–	–
15241600	7	05-09-01	1540	field	.0161	–	<10	<.08	–	<.2	–	<3	<.09	–
15266110	55	13-06-01	1515	field	–	–	<10	<.08	–	<.2	–	<3	<.09	–
15266300	16	07-03-00	1450	field	–	–	–	–	–	–	–	<1	–	–
15266300	16	13-07-01	1230	field	–	–	<10	<.08	–	<.2	–	<3	<.09	–
15274000	6	12-07-99	1804	field	–	E.044	<10	<.1	–	<.1	–	<3	<.1	–
15274000	6	14-03-00	1250	field	–	–	–	–	–	–	–	<1	–	–
15274000	6	02-03-01	1045	field	E.008	–	<10	<.08	–	<.16	–	<3.2	<.09	–
15275100	27	15-10-98	0929	field	E.017	–	<10	–	E.002	–	E.034	<3	<.1	–
15275100	27	05-12-00	1330	lab	.0131	–	<10	<.08	E.005	<.16	–	<3.2	<.09	E0.07

Table B2. Concentrations of nutrients in field-blank water samples for the Cook Inlet Basin study unit, Alaska

[Values in parentheses are for environmental samples collected from the same site on the same date. **USGS NWIS code:** U.S. Geological Survey National Water Information System. N, nitrogen; <, less than; –, no data; E, estimated]

Station No.	Site No	Sample date	Time	Constituent (USGS NWIS code), in milligrams per liter						
				Phosphorus, total (00665)	Dissolved phosphorus (00666)	Dissolved ortho-phosphate phosphorus (00671)	Dissolved nitrite, as N (00613)	Dissolved nitrite-plus-nitrate, as N (00631)	Dissolved ammonia, as N (00608)	Dissolved ammonia-plus-organic, as N (00623)
15241600	7	01-09-99	1045	<0.004	–	–	–	–	0.005 (0.053)	<0.1
15241600	7	01-05-00	1355	<.008	–	–	–	–	.01 (.216)	<.1
15241600	7	05-09-01	1540	<.004	–	–	–	0.006 (0.054)	.006 (.022)	<.1
15266110	55	13-06-01	1515	<.004	–	–	–	–	.002 (.002)	<.1
15266300	16	07-03-00	1450	<.008	–	–	–	–	–	<.1
15266300	16	13-07-01	1230	<.004	–	–	–	.007 (.139)	–	<.1
15274000	23	12-07-99	1804	<.004	–	0.002 (0.002)	0.001 (0.002)	.014 (.057)	–	<.1
15274000	23	14-03-00	1250	<.008	–	.001 (.002)	–	–	–	<.1
15274000	23	02-03-01	1045	<.004	–	–	–	–	.007 (.009)	<.1
15275100	27	15-10-98	0929	<.001	0.003 (0.005)	.001 (.002)	NULL	.006 (.7)	–	<.1
15275100	27	05-12-00	1330	<.004	E.003 (.007)	–	.001 (.007)	–	.011 (.045)	<.1
15294100	44	12-08-99	1400	<.004	–	.001 (.002)	–	–	.009 (.008)	<.1

Table B3. Concentrations of dissolved and suspended organic carbon in field-blank water samples for the Cook Inlet Basin study unit, Alaska

[Concentrations are in milligrams per liter. **USGS NWIS code:** U.S. Geological Survey National Water Information System. <, less than; na, not analyzed; E, estimated; –, no data]

Station No.	Site No.	Sample date	Sample time	Blank type (99102)	Compound (USGS NWIS code)	
					Carbon, dissolved (00681)	Carbon, suspended (00689)
15241600	7	01-09-99	1055	Field	<0.1	<0.2
		01-05-00	1350	Field	<.33	<.2
		05-09-01	1541	Field	<.3	–
15266110	55	06-13-01	1510	Field	E.1747	–
15266300	16	07-03-00	1455	Field	<.33	<.2
		07-13-01	1231	Field	E.246	–
15274000	23	12-07-99	1806	Field	<.1	<.2
		03-14-00	1255	Field	<.33	<.2
		02-03-01	1045	Field	<.15	<.12
15275100	27	10-15-98	1029	Field	.2	<.2
		05-12-00	1335	Lab	<.15	<.12
15294100	44	12-08-99	1430	Field	.2	<.2

On September 8, 1999, at Chester Creek at Arctic Boulevard, at Anchorage (fig. 1, site 27), two blank-water samples for volatile organic compounds (VOCs) and pesticides were prepared with nitrogen-gas-purged volatile grade water. No compounds were detected in these blank samples and thus, the datasets were not altered.

Replicate sample pairs were used to evaluate consistency and precision of concentration values. Ten pairs of split replicate samples for major ions (table B4), 11 pairs for nutrients (table B5), 11 pairs for carbon analyses (table B6), 2 pairs for pesticides (table B7), and 1 pair for VOCs were submitted between May 1998 and August 2001. The relative percentage of difference in concentrations was used to express variability in each pair of samples. Percentage of differences were not calculated in circumstances in which one or both concentrations of compounds in replicate pairs were not detected or reported at or above the MRL or LRL. Most ion concentrations had relative percentage of differences less than 3 percent (table B4) and the median difference for all major ions was 1.2 percent.Variability between results was lowest for calcium, which ranged from 0.2 to 2.7 percent, and highest for potassium which ranged from 0 to 34 percent. Variability in percentage of differences tended to be higher for the nutrient analyses, ranging from 0 to 120 percent (table B5).

Table B4. Concentrations of major ions in replicate environmental water samples for the Cook Inlet Basin study unit, Alaska

[**Replicate types**: 10-concurrent, 20-sequential, 30-split, 40-split-concurrent; compound detection values are in milligrams per liter except for iron and manganese, which are in micrograms per liter. **USGS NWIS code**: U.S. Geological Survey National Water Information System. <, less than; nc, not calculated; relative percentage of difference = $\frac{|R1 - R2|}{\left(\frac{R1 + R2}{2}\right)} \times 100$, where $R1$ = sample 1 result and $R2$ = sample 2 result]

Station No.	Sample date	Site No.	Replicate type	Constituent (USGS NWIS code)									
				Calcium (00915)	Silica (00955)	Iron (01046)	Chloride (00940)	Magnesium (00925)	Fluoride (00950)	Sodium (00930)	Manganese (01056)	Potassium (00935)	Sulfate (00945)
15241600	27-04-00	7	20	4.2595	14.009	822.91	1.72	2.009	<0.1	2.9462	116.65	1.51	E 0.17
			20	4.2218	14.049	940.07	1.79	2.0374	<.1	2.9952	121.42	1.51	E.19
Relative percentage of difference				.9	.3	13.3	4.0	1.4	nc	1.6	4.0	.0	11.1
15241600	05-06-01	7	10	5.3038	20.489	500.94	1.83	2.3811	<.2	4.6328	70.03	1.77	.51
			10	5.4128	21.109	507.89	1.88	2.4801	<.2	4.7829	70.349	1.77	.48
Relative percentage of difference				2.0	3.0	1.4	2.7	4.1	nc	3.2	.5	.0	6.1
15241600	06-08-01	7	10	8.5639	30.021	852.8	2.08	3.8397	<.2	7.1568	81.139	1.85	.4
			10	8.5838	30.017	765.2	2.15	3.8605	<.2	7.1952	81.134	1.92	.49
Relative percentage of difference				.2	.0	10.8	3.3	.5	nc	.5	.0	3.7	20.2
15266110	29-06-00	55	10	9.8292	2.8178	<10	.77	.7189	<.1	1.0528	<2.2	.75	5.55
			10	9.7991	2.7835	<10	.74	.7105	<.1	1.0441	<2.2	.76	5.5
Relative percentage of difference				.3	1.2	nc	4.0	1.2	nc	.8	nc	1.3	.9
15266110	06-03-01	55	20	9.6094	2.589	<10	.82	.6958	<.16	1.0031	<3.2	1.1	6.6
			20	9.357	2.5688	24.233	.83	.6829	<.16	.993	<3.2	.78	6.65
Relative percentage of difference				2.7	.8	nc	1.2	1.9	nc	1.0	nc	34.0	.8
15274000	07-12-00	23	20	13.066	7.2364	<10	.46	1.9928	<.16	1.2492	<3.2	.2	12.44
			20	13.019	7.2628	<10	.46	1.9903	<.16	1.261	<3.2	.2	12.46
Relative percentage of difference				.4	.4	nc	.0	.1	nc	.9	nc	.0	.2
15275100	18-04-99	27	20	24.251	8.014	199.21	25.277	6.145	<.1	11.327	102.6	4.51	15.74
			20	24.014	7.994	213.17	25.247	6.107	<.1	11.427	103	4.56	15.848
Relative percentage of difference				1.0	.2	6.8	.1	.6	nc	.9	.4	1.1	.7
15275100	13-04-00	27	20	25.715	7.9493	159.48	22.85	6.7676	<.1	9.3551	130.35	2.97	16.78
			20	25.198	7.7168	162.17	21.42	6.5	<.1	9.0826	131.71	3.21	16.15
Relative percentage of difference				2.0	3.0	1.7	6.5	4.0	nc	3.0	1.0	7.8	3.8
15294100	26-09-00	44	30	5.3257	11.007	454.86	1.13	1.257	<.1	1.4537	60.868	.81	.4
			30	5.3477	11.064	481	1.1	1.2692	<.1	1.4565	59.778	.78	.38
Relative percentage of difference				.4	.5	5.6	2.7	1.0	nc	.2	1.8	3.8	5.1
15294100	11-06-01	44	10	6.7479	12.684	517.08	.21	1.5912	<.2	1.7697	44.846	.74	.39
			10	6.8221	12.677	513.82	.22	1.5858	<.2	1.798	44.722	.75	.5
Relative percentage of difference				1.1	.1	.6	4.7	.3	nc	1.6	.3	1.3	24.7
Summary:													
Minimum percentage of difference				.2	.0	.6	.0	.1	.0	.2	.0	.0	.2
Maximum percentage of difference				2.7	3.0	13.3	6.5	4.1	.0	3.2	4.0	34.0	24.7
Median percentage of difference				.95	.45	5.6	3	1.1	0	.95	.5	1.3	3.8

Table B5. Concentrations of nutrients in replicate environmental water samples for the Cook Inlet Basin study unit, Alaska

[Replicate types: 10-concurrent, 20-sequential, 30-split, 40-split-concurrent; compound values are in milligrams per liter and dissolved unless otherwise noted; USGS NWIS, U.S. Geological Survey National Water Information System; <, less than; nc, not calculated; relative percentage of difference = $\frac{|R1 - R2|}{\left(\frac{R1 + R2}{2}\right)} \times 100$, where R1 = sample 1 result and R2 = sample 2 result]

Station No.	Sample date	Site No.	Replicate type	Constituent (USGS NWIS code)							
				Phosphorus, total (00665)	Phosphorus (00666)	Orthophosphate phosphorus (00671)	Nitrite, as N (00613)	Nitrite-plus-nitrate, as N (00631)	Ammonia, as N (00608)	Ammonia-plus-organic, as N, total (00625)	Ammonia-plus-organic, as N (00623)
15241600	27-04-00	7	20	0.156	0.043	0.034	0.002	0.042	<0.002	0.447	0.298
			20	.153	.047	.037	.004	.042	.023	.413	.319
Relative percentage of difference				1.9	8.9	8.5	66.7	.0	nc	7.9	6.8
15241600	05-06-01	7	10	.0845	.0556	.042	0.002	.029	.017	.284	.203
			10	.0924	.0578	.047	.002	.026	.022	.365	.186
Relative percentage of difference				8.9	3.9	11.2	.0	10.9	25.6	25.0	8.7
15241600	06-08-01	7	10	.227	.0942	.085	.006	.089	.044	.546	.306
			10	.23	.0946	.086	.007	.092	.042	.655	.269
Relative percentage of difference				1.3	.4	1.2	15.4	3.3	4.7	18.2	12.9
15266110	29-06-00	55	10	0.008	<.006	<.001	.004	.16	.132	<.1	<.1
			10	E.004	<.006	<.001	.001	.157	<.002	E.053	<.1
Relative percentage of difference				nc	nc	nc	120.0	1.9	nc	nc	nc
15266110	06-03-01	55	20	.005	<.006	<.007	<.001	.165	.003	E.072	E.059
			20	.005	<.006	<.007	<.001	.168	.004	E.057	E.062
Relative percentage of difference				.0	nc	nc	nc	1.8	28.6	23.3	5.0
15274000	07-12-00	23	20	E.003	<.006	<.007	<.001	.302	<.002	E.067	<.1
			20	E.003	E.003	.007	<.001	.314	<.002	E.057	<.1
Relative percentage of difference				.0	nc	nc	nc	3.9	nc	16.1	nc
15275100	18-04-99	27	20	.239	.091	.07	.019	.611	.397	1.331	.817
			20	.289	.09	.07	.019	.598	.385	1.411	.779
Relative percentage of difference				18.9	1.1	.0	.0	2.2	3.1	5.8	4.8
15275100	13-04-00	27	20	.199	.09	.071	.014	.651	.276	.947	.659
			20	.228	.096	.073	.014	.626	.3	1.076	.717
Relative percentage of difference				13.6	6.5	2.8	.0	3.9	8.3	12.8	8.4
15294100	17-05-99	44	30	.108	.017	.006	.002	.069	.005	.581	.297
			30	.106	.016	.005	.002	.072	.005	.567	.322
Relative percentage of difference				1.9	6.1	18.2	.0	4.3	.0	2.4	8.1
15294100	26-09-00	44	30	.047	.015	.008	.004	.078	.031	.337	.282
			30	.047	.015	.007	.004	.083	.031	.349	.289
Relative percentage of difference				.0	.0	13.3	.0	6.2	.0	3.5	2.5
15294100	11-06-01	44	10	.0304	.0135	E.005	.001	.017	.007	.356	.226
			10	.0276	.0128	E.004	.001	.005	.005	.263	.184
Relative percentage of difference				9.7	5.3	22.2	.0	109.1	33.3	30.0	20.5
Summary:											
Minimum percentage of difference				.0	.0	.0	.0	0.0	.0	.0	2.4
Maximum percentage of difference				10.0	18.9	8.9	22.2	120.0	109.1	33.3	30.0
Median percentage of difference					1.9	3.9	2.8	0	3.6	4.7	12.8

Table B6. Concentrations of organic carbon in replicate environmental water samples, Cook Inlet Basin, Alaska

[**Replicate types:** 10-concurrent, 20-sequential, 30-split, 40-split-concurrent; compound detection values are in milligrams per liter except for iron and manganese, which are in micrograms per liter. **USGS NWIS code**: U.S. Geological Survey National Water Information System. <, less than; –, not analyzed; nc, not calculated; relative percentage of difference = $\frac{|R1 - R2|}{\left(\frac{R1 + R2}{2}\right)} \times 100$, where $R1$ = sample 1 result and $R2$ = sample 2 result]

Station No.	Sample date	Site No.	Constituent (USGS NWIS code)	
			Carbon, dissolved (00681)	Carbon, suspended (00689)
15241600	04-27-00	7	9.678	1.336
			9.928	1.013
Relative percentage of difference			2.6	27.5
15241600	05-06-01	7	5.9822	–
			5.7178	–
Relative percentage of difference			4.5	nc
15241600	06-08-01	7	5.9527	–
			5.6842	–
Relative percentage of difference			4.6	nc
15266110	06-29-00	55	0.455	<.2
			0.517	<.2
Relative percentage of difference			12.8	nc
15266110	06-03-01	55	.469	<.12
			.453	<.12
Relative percentage of difference			3.5	nc
15274000	07-12-00	23	.631	<.12
			.612	<.12
Relative percentage of difference			3.1	nc
15275100	12-08-99	27	3.7	1.5
			3.6	4.5
Relative percentage of difference			2.7	100.0
15275100	04-13-00	27	5.322	1.509
			5.208	1.456
Relative percentage of difference			2.2	3.6
15294100	05-17-99	44	8.5	1
			8.2	.4
Relative percentage of difference			3.6	85.7
15275100	09-26-00	44	8.468	.488
			8.281	.487
Relative percentage of difference			2.2	.2
15275100	11-06-01	44	5.2119	–
			5.4805	–
Relative percentage of difference			5.0	nc
Summary:				
	Minimum percentage		2.2	.2
	Maximum		12.8	100
	Median percentage of		3.5	27.5

Samples with low concentrations of constituents of compounds near the analytical reporting limits tended to have the highest percentage of difference.The variability in these low concentrations data must be considered in subsequent analysis. Relative percentage of difference between pairs of organic carbon ranged from 2.2 to 12.8 percent for dissolved organic carbon and from 0.2 to 100 percent for suspended organic carbon (table B6). As with nutrients, large percentage of differences between concentrations of dissolved and suspended organic carbon were by and large between replicate pairs with low concentrations. Differences ranged from 3.9 to 32.1 percent for the pesticides (table B7). The replicate VOC samples processed in August 1999 had detections of trichloromethane, toluene, benzene, ethybenzene, dichloromethane, and tetrachloroethane. All concentrations were lower than the LRLs. The highest relative percentage of difference was for trichloromethane at 11 percent and the lowest was for tetrachloroethene at 2.3 percent.

Ten field blank-water samples and 1 laboratory blank-water sample prepared with organic water were submitted for major ion analysis between the dates of October 1998 and September 2001. Five constituents were detected in these samples (table B1). Calcium was the most frequently detected constituent in 5 of the 11 samples (including the laboratory blank). Of the field blank-water samples, most compounds were detected in samples prepared for the Ninilchik River at Ninilchik (fig.1, site 7). Concentrations of all detected compounds were well below the minimum concentrations detected in stream water from the sites where the blanks were prepared. The ‘closest’ concentration of a major ion compound in a field blank-water sample to a concentration in an environmental sample was for magnesium, detected in a sample prepared at the Ninilchik River at Ninilchik, but the concentration of the environmental sample detected at this site (1.54 mg/L) was five times the concentration detected in the blank sample (0.3 mg/L). There was no concern of problematic contamination of samples in the field or laboratory with major ions and thus no adjustments were made to the database.

Between May 1998 and September 2001, 12 blank-water samples were prepared for nutrient analyses (table B2). Five nutrient compounds were detected in the 12 samples. There were no detections of total phosphorus or dissolved ammonia-plus organic nitrogen. Dissolved ammonia nitrogen was detected in 7 of the 12 samples and dissolved orthophosphate was detected in 5 of the 12 samples. Dissolved nitrate-plus-nitrite concentrations in the blanks were usually 4 times or more lower than the concentrations of the environmental samples at the sites where the blanks were prepared. There were 21 total nutrient compound detections. Five of the detections were in concentrations equal to or more than the concentration of the same compound detected in the environmental sample. This might suggest some contamination; however, these concentrations are at very low levels (less than 0.014 mg/L). For reference, the value of the environmental sample on the day of blank preparation is listed in parenthesis alongside the value of the blank.

Twelve blank-water samples were prepared for organic carbon analyses between October 1998 and September 2001 (table B3). Dissolved organic carbon was detected in 4 of the 12 samples, with the highest concentration of 0.25 mg/L. No suspended organic carbon was detected. Because the detected concentration of the dissolved organic carbon was close to the detection limit, it was felt that there was no contamination and the datasets were not altered.

On September 8, 1999, at Chester Creek at Arctic Boulevard at Anchorage (fig. 1, site 27), two blank-water samples for volatile organic compounds (VOCs) and pesticides were prepared with nitrogen-gas-purged volatile grade water. No compounds were detected in these blank samples and thus the datasets were not altered.

Replicate sample pairs were used to evaluate consistency and precision of concentration values. Ten pairs of split replicate samples for major ions (table B4), 11 pairs for nutrients (table B5), 11 pairs for carbon analyses (table B6), 2 pairs for pesticides (table B7), and 1 pair for VOCs were submitted between May 1998 and August 2001. The relative percentage of difference in concentrations was used to express variability in each pair of samples. Percentage of differences were not calculated in circumstances in which one or both concentrations of compounds in replicate pairs were not detected or reported at or above the MRL or LRL. Most ion concentrations had relative percentage of differences less than 3 percent (table B4) and the median difference for all major ions was 1.2 percent.Variability between results was lowest for calcium, which ranged from 0.2 to 2.7 percent, and highest for potassium which ranged from 0 to 34 percent. Variability in percentage of differences tended to be higher for the nutrient analyses, ranging from 0 to 120 percent (table B5). Samples with low concentrations near the analytical reporting limits tended to have the highest percentage of difference.The variability in these low concentrations data must be considered in subsequent analysis. Relative percentage of difference between pairs of organic carbon ranged form 2.2 to 12.8 percent for dissolved organic carbon and from 0.2 to 100 percent for suspended organic carbon (table B6). As with nutrients, large percentage of differences between concentrations of dissolved and suspended organic carbon were by and large between replicate pairs with low concentrations. Differences ranged from 3.9 to 32.1 percent for the pesticides (table B7). The replicate VOC samples processed in August 1999 had detections of trichloromethane, toluene, benzene, ethybenzene, dichloromethane, and tetrachloroethane. All concentrations were lower than the LRLs. The highest relative percentage of difference was for trichloromethane at 11 percent and the lowest was for tetrachloroethene at 2.3 percent.

Similar to the nutrient and pesticides replicate results, concentrations were low which resulted in large percentage of differencees. Based on these replicate data, no changes were made to any data sets for any compound class.

Mean recoveries for pesticides in one pair of field-matrix spiked water samples analyzed under schedule 2001 ranged from 50 to 151 percent. Standard deviation of percentage of recoveries ranged from 0.6 to 9.8 percent. Recoveries were good and consistent for these two samples. The highest percentage of recoveries were made for the compounds simazine (151), propargite (147), and linuron (144). Lowest percentage of recoveries were for compounds *cis*-permethrin (50), p,p DDE (72), and benfluralin (81). Compounds with the most variation in percentage of recovery included disulfoton, propargite, and terbufos. Compounds with the most consistency in percentage of recovery include dieldrin, triallate, and EPTC.

For one pair of VOC field-matrix spiked water samples prepared at Chester Creek at Arctic Boulevard at Anchorage, mean recoveries for VOCs ranged from 26 to 115 percent and standard deviations ranged from 17 to 74 percent. Recoveries and precision for VOCs in field-spiked samples was poor due to inexperience with field methods (table B8).Compounds with the lowest mean recovery included 2,2-dichloropropane (26 percent mean recovery), and hexachloroethane (40 percent mean recovery). Compounds with the highest mean recovery include 1,2,3-trichlorobenzene (115 percent recovery) and acetone (111 percent mean recovery). The compound with the lowest standard deviation in percent recovery was benzene and the highest standard deviation in pecent recovery was 1,2,3-trichlorobenzene. Of the compounds in the field-matrix spike, none were detected in environmental water samples greater than the LRL. No changes were made to field matrix samples.

Pesticide samples contained surrogate analytes to monitor the precision and accuracy of analytical procedures. Mean recoveries for diazinon-*d*10 and *alpha*-HCH-*d*6 in samples from sites 23 and 27 ranged from 89 to 126 percent (table B9). Terbuthylazine was detected in only 5 of the total 19 samples analyzed for pesticides and ranged from 106 to 111 percent recovery. Data for BDMC recoveries was unavailable. Recoveries of VOC surrogate analytes were good with a mean recovery of 103 percent for 1,2-dichloroethane-*d*4, 99 percent for toluene-*d*8, and 94 percent for 1,4-bromofluorobenzene (table B10). No alterations were made to the data sets based on surrogate recoveries.

Table B7. Concentrations of pesticide compounds detected in replicate environmental water samples for the Cook Inlet Basin study unit, Alaska

[Compound detection values are in micrograms per liter. **USGS NWIS code**: U.S. Geological Survey National Water Information System. <, less than; E, estimated; nc, not calculated; relative percentage of difference = $\frac{|R1 - R2|}{\left(\frac{R1 + R2}{2}\right)} \times 100$, where R1 = sample 1 result and R2 = sample 2 result]

Station No.	Sample date	Site No.	Compound (USGS NWIS code)					
			Atrazine (39632)	Diazinon (39572)	Prometon (04037)	CAAT (04039)	2,4-Dichlorophen oxyacetic acid (39732)	Dichlorprop (49302)
15275100	04-18-99	27	<0.001	0.0	0.1	E0.0039	E0.0708	<0.05
			<.001	.0	.1	E.0053	–	–
Relative percentage of difference			nc	32.1	3.9	30.4	nc	nc
15275100	12-08-99	27	<.001	<.04	.1	<.0599	.4	.1
			<.001	<.04	.1	<.0599	.4	.1
Relative percentage of difference			nc	nc	5.9	nc	2.6	.2

Table B8. Summary of percentage of mean recoveries from field-matrix-spike volatile organic compound analyses for the Cook Inlet Basin study unit, Alaska

Volatile organic constituent	Number of samples	Mean (percent)	Standard deviation (percent)
1,1,1-Trichloroethane	2	25	6
1,1-Dichloroethene	2	31	9
1,2-Dichloroethane	2	43	14
1,4-Dichlorobenzene	2	42	17
Bromoform	2	42	16
Bromodichloromethane	2	38	13
Dibromochloromethane	2	38	15
Ethylbenzene	2	38	12
Methyl *tert*-butyl ether	2	50	15
Tetrachloroethene	2	36	11
Tetrachloromethane	2	27	11
Trichloroethene	2	35	10

Table B9. Summary of surrogate compound recoveries in filtered water samples for pesticide analyses for the Cook Inlet Basin study unit, Alaska

[Values are percentages. **USGS NWIS code**: U.S. Geological Survey National Water Information System. nc, not calculated; –, not determined]

Station No. (Site No.)	Number of samples		Compound (USGS NWIS code)		
			Diazinon-*d*10 (91063)	Terbuthylazine (91064)	Alpha-HCH-*d*6 (91065)
15274000 (23)	1	Mean	100.06	–	92.75
		Standard deviation	0	0	0
15275100 (27)	18	Mean	107.05	108.29	97.9
		Standard deviation	10.11	2.33	6.31

Table B10. Summary of surrogate compound recoveries in whole water samples for volatile organic compound analyses for the Cook Inlet Basin study unit, Alaska

[Values are percentages. **USGS NWIS code**: U.S. Geological Survey National Water Information System. nc, not calculated]

Station No (Site No.)	Number of samples		Compound (USGS NWIS code)		
			1,2-dichloroethane-*d*4 (99832)	Toluene-*d*8 (99833)	1,4-bromofluorobenzene (99834)
15274000 (23)	22	Mean	105.22	97.16	91.63
		Standard deviation	1.18	3.30	3.51
15275100 (27)	32	Mean	102.09	98.84	94.49
		Standard deviation	4.58	5.06	7.07

Appendix C. Regression equations for estimates of the load of suspended sediment, total nitrogen, total phosphorus, and dissolved organic carbon for fixed sites in the Cook Inlet Basin study unit.

[**Regression equation**: ln, natural logarithm; Q, streamflow in cubic feet per second; sin, sine; cos, cosine; dtime is decimal time]

Constituent (kilograms per day)	Regression Equation	Coefficient of determination (R^2)
	Ninilchik River at Ninilchik (site 7, figure 1)	
Suspended sediment	7.9 + 1.96 Ln(Q) + 0.11 Sin(dtime) – 0.67 Cos(dtime)	0.90
Total nitrogen	4.3 + 1.20 Ln(Q) + 0.01 Sin(dtime) – 0.20 Cos(dtime)	.93
Total phosphorus	3.3 + 1.21 Ln(Q) – 0.05 Sin(dtime) – 0.22 Cos(dtime)	.93
Dissolved organic carbon	7.2 + 1.34 Ln(Q) – 0.04 Sin(dtime) – 0.16 Cos(dtime) – 0.05 (dtime)	.98
	Kenai River below Skilak Lake, near Sterling (site 55, figure 1)	
Suspended sediment	10.8 + 0.89 Ln(Q) – 0.09 Sin(dtime) + 0.25 Cos(dtime)	0.75
Total nitrogen	7.6 + 1.05 Ln(Q) – 0.21 (dtime)	.93
Total phosphorus	4.4 + 0.61 Ln(Q) – 0.12 Ln(Q)^2 – 0.25 Sin(dtime) – 0.12 Cos(dtime)	.92
Dissolved organic carbon	8.5 + 1.03 Ln(Q) + 0.07 Ln(Q)^2 + 0.11 (dtime)	.98
	Kenai River at Soldotna (site 16, figure 1)	
Suspended sediment	12.1 + 1.45 Ln(Q) + 0.08 Sin(dtime) – 0.81 Cos(dtime)	0.90
Total nitrogen	7.4 + 0.33 Ln(Q) – 0.57 Sin(dtime) – 0.80 Cos(dtime) – 0.16 (dtime)	.81
Total phosphorus	5.5 + 0.38 Ln(Q) – 0.31 Ln(Q)^2 – 0.08 Sin(dtime) – 0.84 Cos(dtime)	.78
Dissolved organic carbon	8.8 + 0.31 Ln(Q) – 0.28 Sin(dtime) – 0.63 Cos(dtime) + 0.18 (dtime)	.88
	South Fork Campbell Creek near Anchorage (site 23, figure 1)	
Suspended sediment	6.8 + 2.18 Ln(Q) + 0.93 Sin(dtime) + 0.24 Cos(dtime) – 0.27 (dtime)	0.88
Total nitrogen	3.0 + 1.32 Ln(Q) – 0.39 Sin(dtime) – 0.14 Cos(dtime) – 0.23 (dtime)	.91
Total phosphorus	–0.4 + 2.06 Ln(Q) + 0.38 Ln(Q)^2 – 0.50 Sin(dtime) – 0.25 Cos(dtime)	.88
Dissolved organic carbon	4.7 + 1.3 Ln(Q)	.90
	Chester Creek at Arctic Boulevard. at Anchorage (site 27, figure 1)	
Suspended sediment	7.6 + 2.38 Ln(Q) + 0.74 Sin(dtime) + 0.25 Cos(dtime) – 0.52 (dtime)	0.63
Total nitrogen	3.3 + 2.18 Ln(Q) + 0.63 Sin(dtime) – 0.03 Cos(dtime) – 0.20 (dtime)	.88
Total phosphorus	0.8 + 2.70 Ln(Q) – 0.73 Sin(dtime) – 0.13 Cos(dtime)	.80
Dissolved organic carbon	5.4 + 1.52 Ln(Q) – 0.22 Ln(Q)^2 + 0.23 Sin(dtime) – 0.08 Cos(dtime) – 0.11(dtime)	.91
	Deshka River near Willow (site 44, figure 1)	
Suspended sediment	9.4 + 2.0 Ln(Q) + 0.18 Ln(Q)^2	0.97
Total nitrogen	6.3 + 1.3 Ln(Q) – 0.25 Sin(dtime) – 0.04 Cos(dtime)	.96
Total phosphorus	4.3 + 1.40 Ln(Q)	.91
Dissolved organic carbon	9.3 + 1.33 Ln(Q) – 0.23 Sin(dtime) – 0.07 Cos(dtime)	.99

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