A Preliminary Water Quality Assessment of Lower Kenai Peninsula Salmon-bearing Streams

A REPORT PREPARED BY
COOK INLET KEEPER

FOR THE
HOMER SOIL AND WATER CONSERVATION DISTRICT

October 2003

Prepared by Sue Mauger
Stream Ecologist

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October 2003

INTRODUCTION

Background

Through the Lower Kenai Peninsula Watershed Health Project, Cook Inlet Keeper (Keeper) and the Homer Soil and Water Conservation District (HSWCD) are jointly collecting reliable baseline water quality data on the Ninilchik River, Deep Creek, Stariski Creek, and Anchor River and educating local citizens about water quality issues. This report is the fifth published by the two partners, and presents water quality data collected from August 1998 through June 2003. The report offers a preliminary water quality assessment of the four rivers and is produced to partially fulfill the requirements of a Section 319 Clean Water Act Grant from the Alaska Department of Environmental Conservation.

The streams of the lower Kenai Peninsula support healthy sport and commercial fisheries, and provide important subsistence resources for Alaska Natives and other groups. However, current and potential changes in land use and natural resource management within the watersheds may degrade water quality. In the Pacific Northwest, many wild salmon runs have vanished because of habitat degradation or loss from dam construction, timber harvesting, mining, and urbanization. State and federal agencies lack the resources to conduct thorough water quality investigations on these rivers. Nonetheless, citizens, industry, and resource managers need a comprehensive and ongoing inventory of water quality in order to track changes and understand impacts. Only with this kind of information can we make economically and environmentally sound decisions.

The Lower Kenai Peninsula Watershed Health Project

Cook Inlet Keeper began professional-level water quality monitoring in 1998 on four salmon-bearing streams: Ninilchik River, Deep Creek, Stariski Creek, and Anchor River. Using EPA-approved or Standard Methods, Keeper monitors twelve sites for discharge, temperature, dissolved oxygen, pH, conductivity, nitrate-nitrogen, ammonia-nitrogen, orthophosphate, total phosphorus, apparent color, turbidity, settleable solids, total suspended solids and bacteria. Keeper monitors four sites on the Anchor River, three on both Ninilchik River and Deep Creek, and two on Stariski Creek (Figure 1). Monitoring goals are to 1) collect baseline data and determine natural variability over time for each parameter, 2) compare data with state water quality standards and federal recommendations, 3) identify water quality patterns within and between watersheds, and 4) educate local citizens about water quality issues. This report summarizes data collected from August 1998 through June 2003.

Previous Water Quality Research

Many organizations, the USGS in particular, have collected water quality and habitat data on the Ninilchik River, Deep Creek, Stariski Creek, and Anchor River watersheds (Figure 2). The Environment and Natural Resources Institute (ENRI) at the University of Alaska Anchorage monitors macroinvertebrates at sites in the four watersheds. Keeper's Citizens' Environmental Monitoring Program (CEMP) has several sites in the Anchor River watershed. Klukwan, Inc., has measured gravel embeddedness and other habitat characteristics in the Deep Creek watershed. The USGS collected water quality data from sites throughout the four watersheds at various times over the last 50 years. The information ranges from single measurements of discharge or pH at a site to extremely complex and detailed information. These data are listed in the project's Quality Assurance Project Plan (Cook Inlet Keeper, 2000).

As part of its National Water Quality Assessment Program (NAWQA), the USGS released a publication titled *Water Quality Assessment of the Cook Inlet Basin, Alaska: Summary of Data Through 1997* (Glass, 1999). This report summarizes and discusses water quality data for surface and groundwater sites throughout the Cook Inlet Watershed, including two sites monitored by Cook Inlet Keeper as part of the Lower Kenai Peninsula Watershed Health Project. As part of NAWQA, the USGS has established a gage on the lower Ninilchik River that continuously monitors streamflow and water temperature. Water quality, biological, and stream channel data are collected periodically as well.

Although much data have been collected by USGS in the four watersheds, little information has been collected recently or consistently over time. Through the Lower Kenai Peninsula Watershed Health Project, Cook Inlet Keeper and the Homer Soil and Water Conservation District are collecting water quality information at multiple sites over several years thus providing a reliable assessment of current water quality conditions in the four watersheds.

Report Contents

This report consists of the following components:
- study area description including GIS maps;
- discussion of study design and quality assurance protocols;
- explanation of the water quality parameters monitored;
- summary of data by watershed reporting natural variability over time for each site;
- comparison of data with state water quality standards and federal recommendations;
- comparison of water quality parameters to discharge and between watersheds;
- conclusions and recommendations for further monitoring.

Appendices to the report contain the following:
- results from Keeper's quality assurance checks (Appendix I);
- all water quality data collected from 8/98 to 6/03 in tabular form (Appendix II);
- list of Technical Advisory Committee Members (Appendix III).

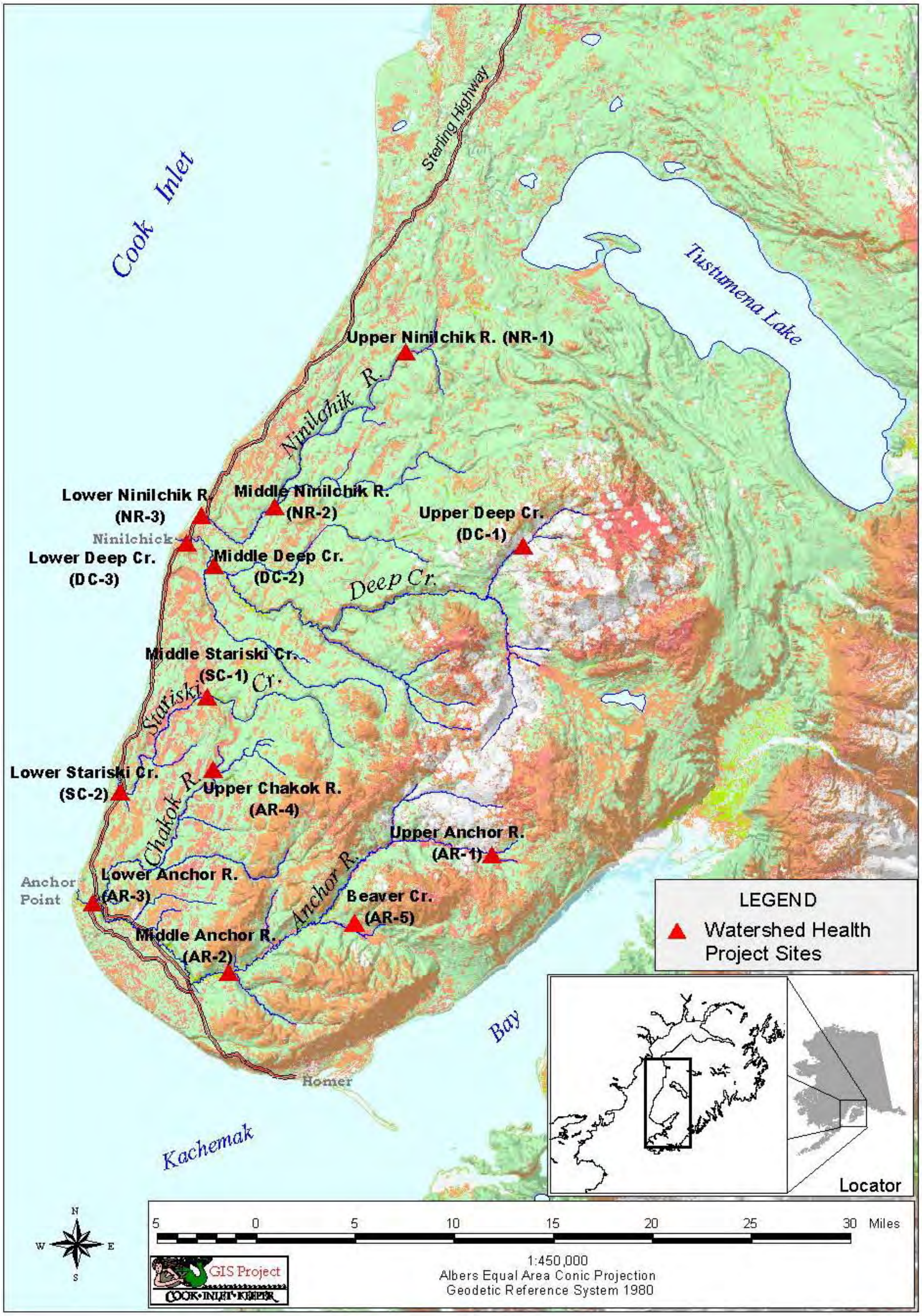


Figure 1. Lower Kenai Peninsula Watershed Health Project monitoring sites.

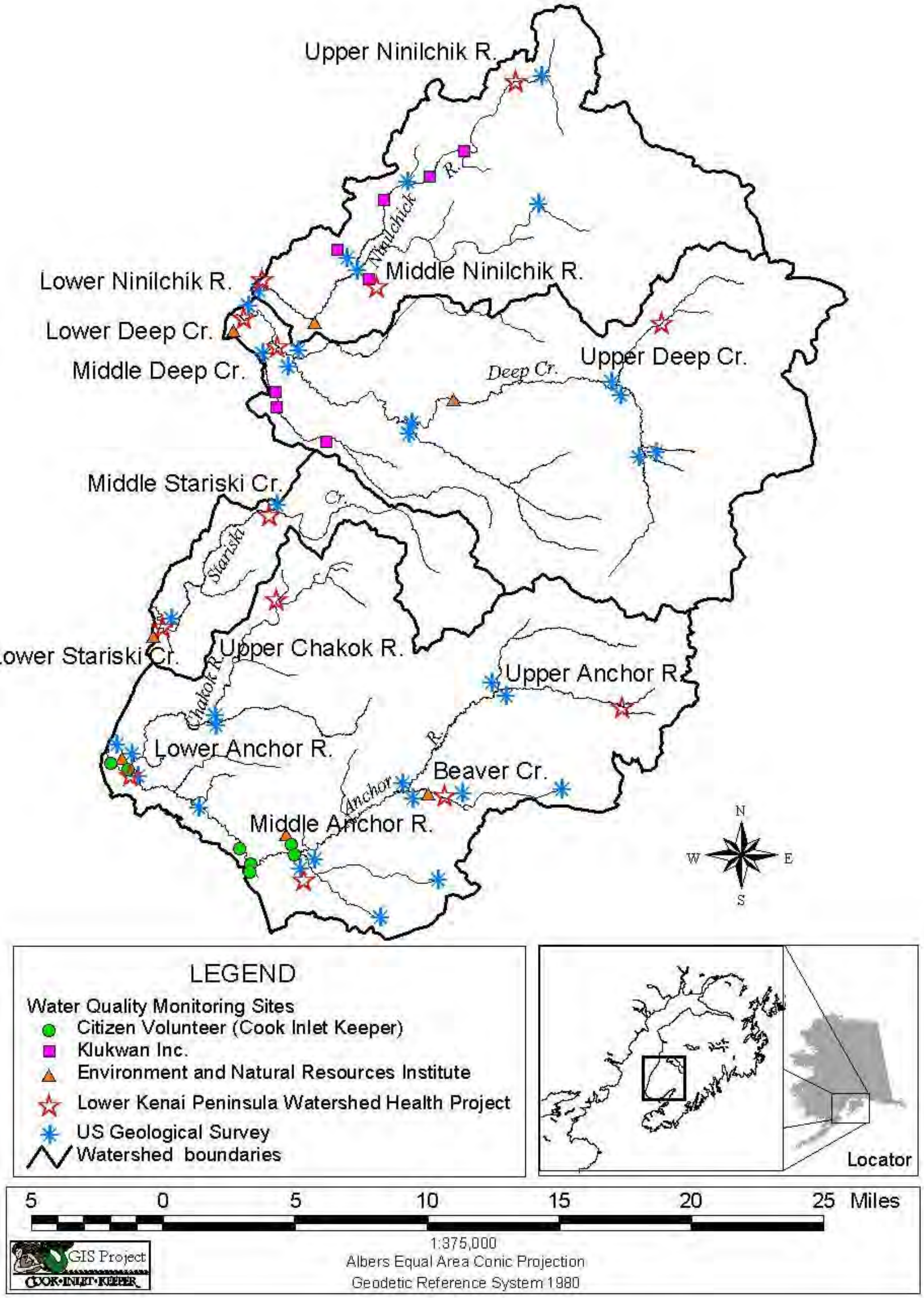


Figure 2. Location of Lower Kenai Peninsula Watershed Health Project sites in relation to monitoring sites used by other groups. Where sites overlap, symbols have been shifted for the sake of clarity.

STUDY AREA

The Ninilchik River, Deep Creek, Stariski Creek, and Anchor River watersheds lie in the southern part of the Kenai Peninsula. The region is bounded on the west by Cook Inlet and on the east by the Caribou Hills. The topography is gently rolling, with wide river valleys and extensive wetlands. Elevations range from sea level to around 2800 feet.

The climate of the study area is considered to be transitional between continental and maritime (Brabets et al, 1999). Temperatures in Homer, just south of the study area, range from an average temperature of -5.2 °C/22.7 °F in January to 11.9 °C/53.4 °F in July. Temperatures are generally colder in the central and northern parts of the study area than in the southern portion. Average annual precipitation is 24.84 inches in Homer. Most of the rain falls during August, September, October, and November (National Weather Service, 2003). High stream flows also occur in April and May when air temperatures increase, resulting in snowmelt and ice breakup.

The four watersheds are home to many species of wildlife. A wide variety of seabirds, shorebirds, raptors, waterfowl, and songbirds live in the watersheds. Moose, black and brown bear, fox, lynx, coyote, and many small mammals are found here. Finally, the streams host a variety of fish, including chinook salmon *Oncorhynchus tshawytscha*, coho salmon *O. kisutch*, pink salmon *O. gorbuscha*, Dolly Varden char *Salvelinus malma*, and steelhead (anadromous) and rainbow (resident) trout *O. mykiss*.

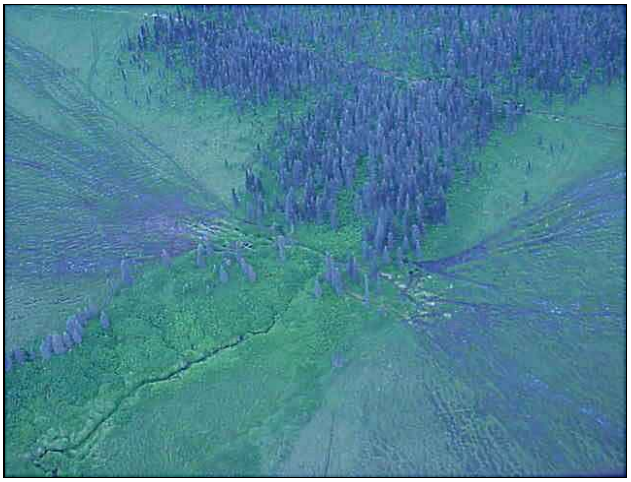
The towns of Anchor Point and Ninilchik, as well as the smaller communities of Happy Valley and Nikolaevsk, are located in the study area. The economic base of Anchor Point and Ninilchik is commercial fishing, sport fishing, and tourism. The recreational fishery for Dolly Varden in Anchor River is one of the largest in Alaska (Larson, 1995).

Land ownership within the four watersheds is complex, with varying proportions of Federal, Native Corporation, State, Borough, and private ownership (Figures 3-6; Table 1). Anchor River watershed has the highest proportion of privately owned land (28%) while Deep Creek has the lowest proportion (5%).

Land use has changed dramatically over the last ten years in the study area as logging has increased. Prior to 1990, much of the study area was relatively remote wilderness. Access was provided only by trails along seismic lines (Figures 3-6). In 1990, logging began in the four watersheds, and accelerated rapidly (Table 1). In the Ninilchik River watershed, for example, less than one percent of the watershed was slated for timber sales in 1990. By 1999, 44% of the watershed had been included in timber sales.

The increase in logging activity relates to concerns about fire danger due to large fuel loads from downed or standing beetle killed trees. Spruce beetle (*Dendroctonus rufipennis*) infestations during the 1990’s have resulted in extensive areas of dead spruce trees in Alaska. On the Kenai Peninsula approximately 1.1 million acres of forested land have been infested by the bark beetle. Increased water yields may result because of reduced transpiration from dead and dying trees (Holsten, 1999). Transport of sediment into stream channels may also increase with extensive logging.

In 1999, the Alaska Department of Fish and Game, Habitat and Restoration Division, looked at ORV (off road vehicle) trail stream crossings in the upper Anchor River and Deep Creek drainages. ORV use appears to be increasing in the study area with the increase in backcountry and logging roads. In this preliminary survey, ATV stream crossings exhibited exposed soils, bank alterations, riparian zone degradation, and increased bank widths (Weidmer, 2002).



ORV trail stream crossings in the Anchor River watershed.

In October and November 2002, the lower Kenai Peninsula experienced flood events not seen in the last 50-100 years. Channel scour, bank erosion and major habitat alteration reshaped salmon stream channels and riparian habitat. Poorly-placed and inadequately-sized culverts on private, Borough and State roads failed resulting in pulses of debris torrents, which caused extensive damage to roads, bridges and property downstream.

Sediment-laden flood waters of Deep Creek in October 2002.

Culvert damage at Stariski Creek on the Sterling Highway, Oct. 2002. (Photo courtesy of J. Clutts)

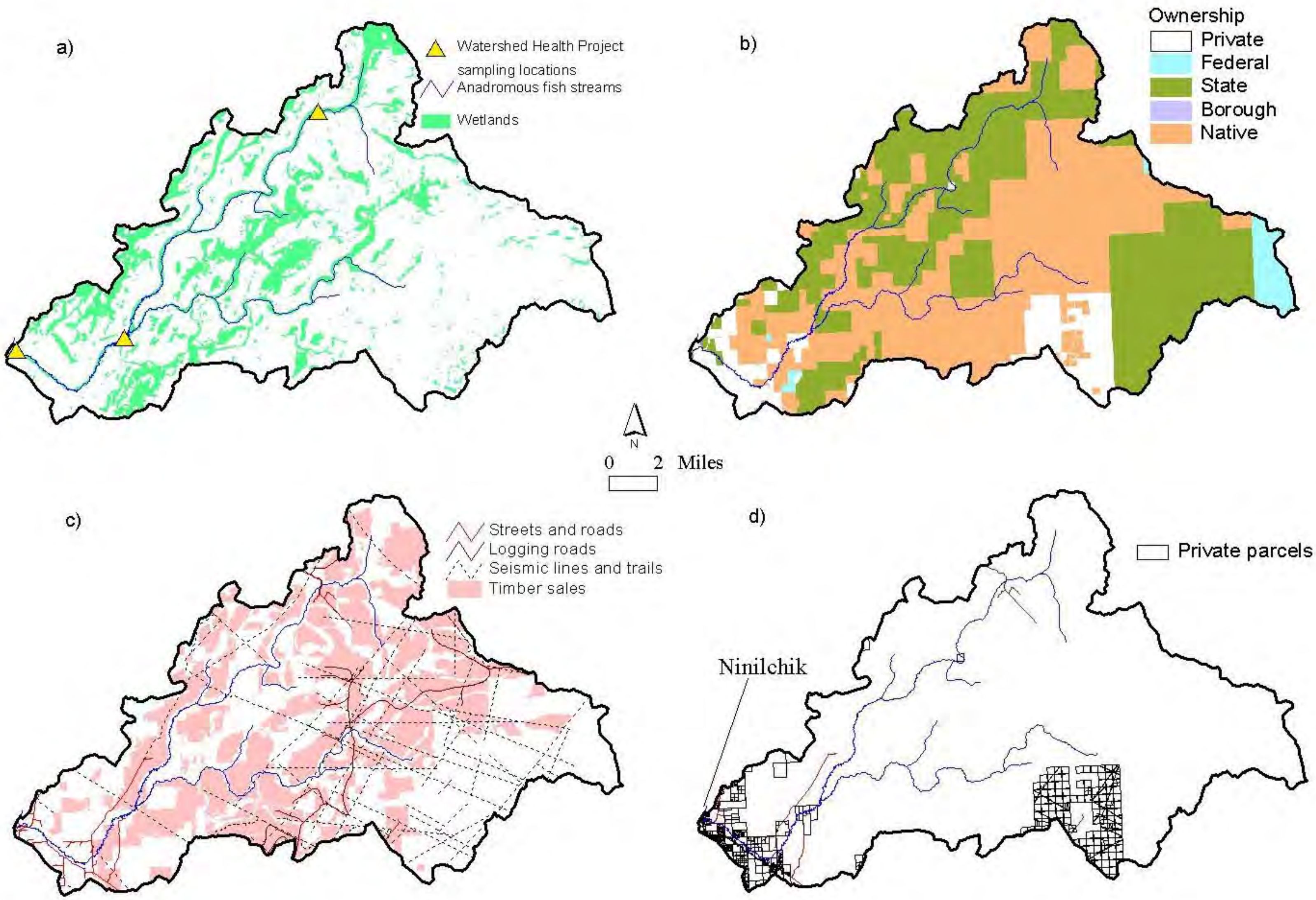


Figure 3. Ninilchik River watershed: a) wetlands and anadromous fish streams; b) land ownership; c) roads, trails, and timber sales; and d) communities and private parcels. Anadromous streams mapped by Alaska Department of Fish & Game; wetlands mapped by US Fish and Wildlife Service National Wetlands Inventory; and ownership, timber sales, trails and roads from Kenai Peninsula Borough data.

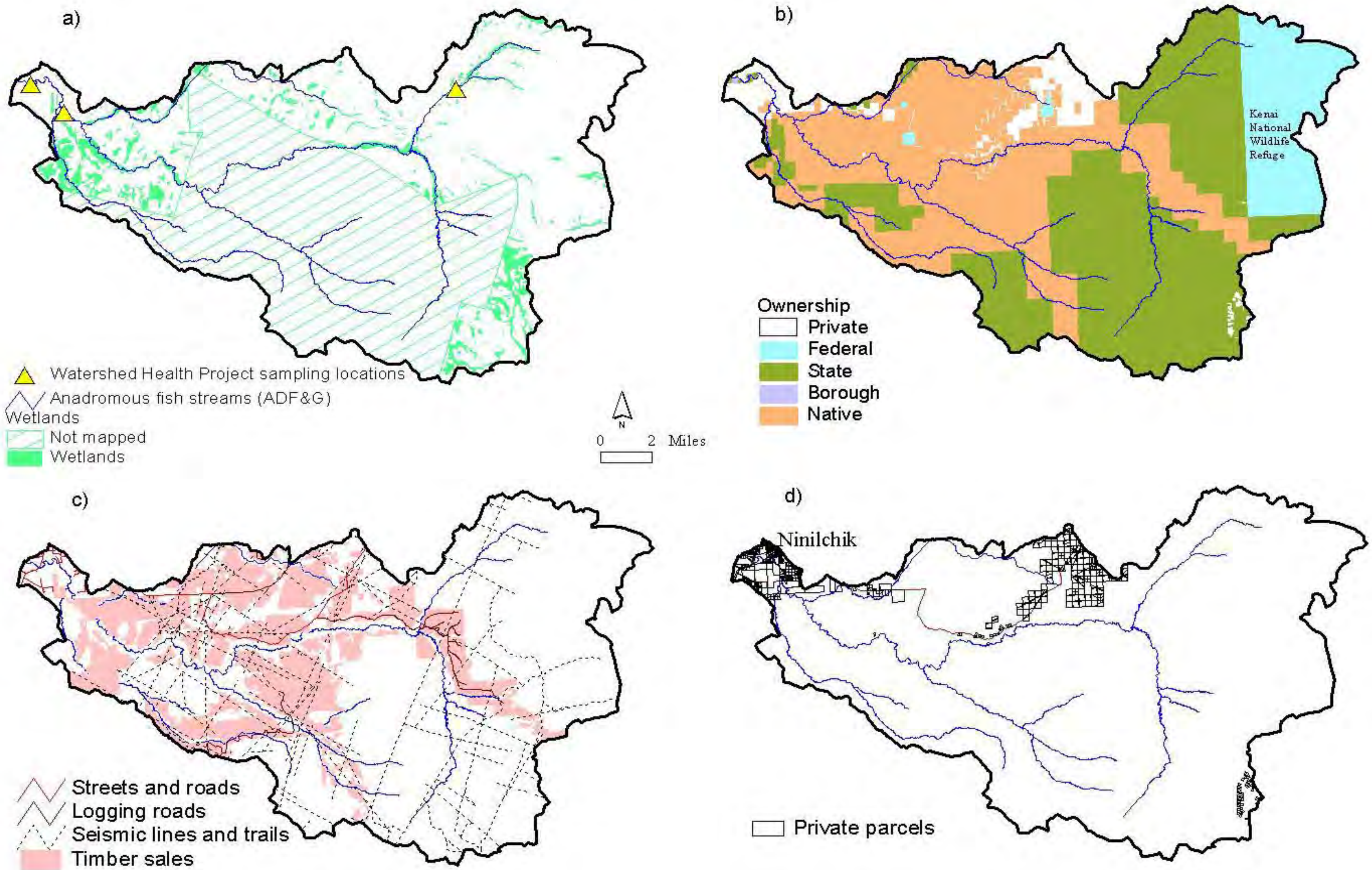


Figure 4. Deep Creek watershed: a) wetlands and anadromous fish streams; b) land ownership; c) roads, trails, and timber sales; and d) communities and private parcels. Anadromous streams mapped by Alaska Department of Fish & Game; wetlands mapped by US Fish and Wildlife Service National Wetlands Inventory; and ownership, timber sales, trails and roads from Kenai Peninsula Borough data.

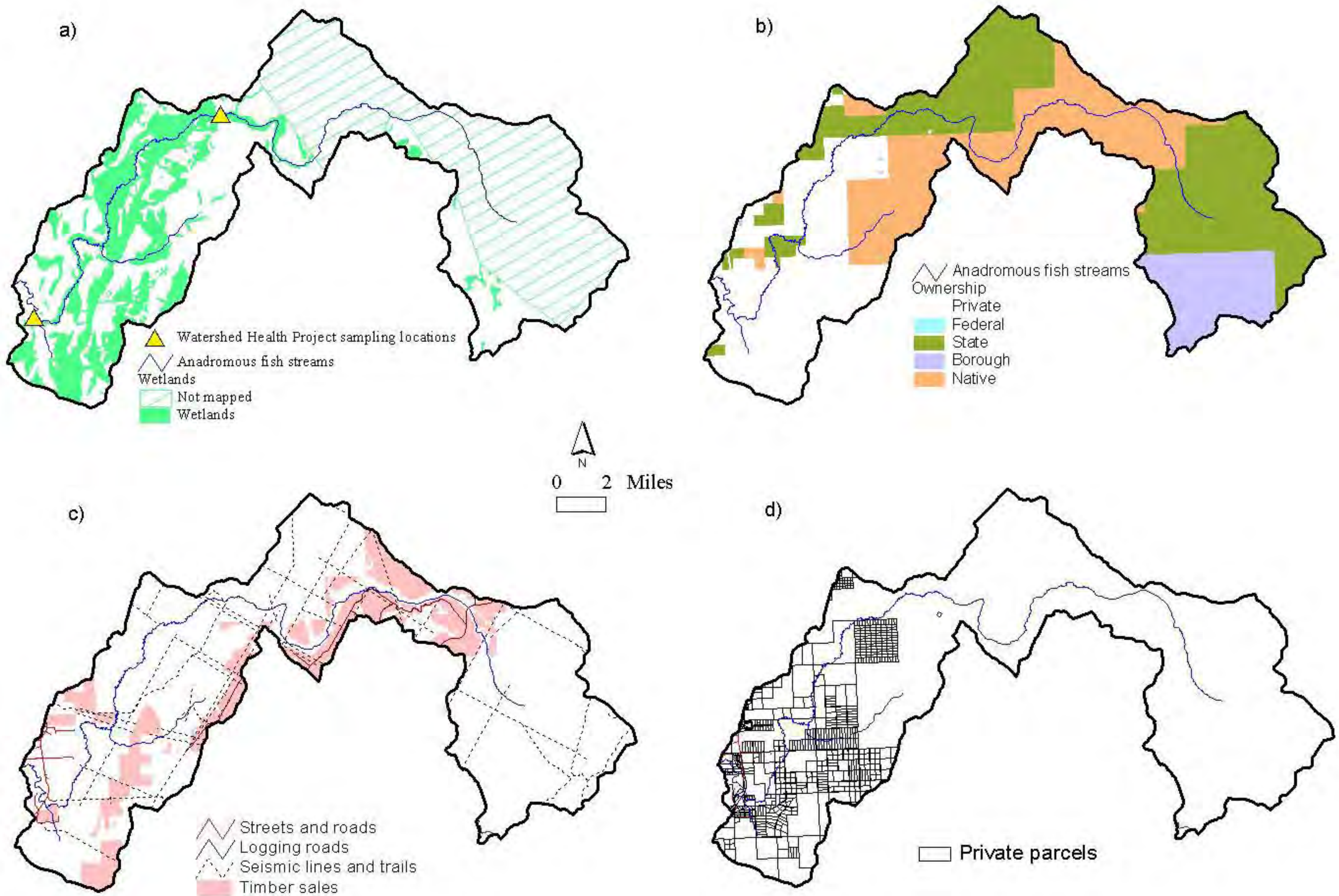


Figure 5. Stariski Creek watershed: a) wetlands and anadromous fish streams; b) land ownership; c) roads, trails, and timber sales; and d) communities and private parcels. Anadromous streams mapped by Alaska Department of Fish & Game; wetlands mapped by US Fish and Wildlife Service National Wetlands Inventory; and ownership, timber sales, trails and roads from Kenai Peninsula Borough data.

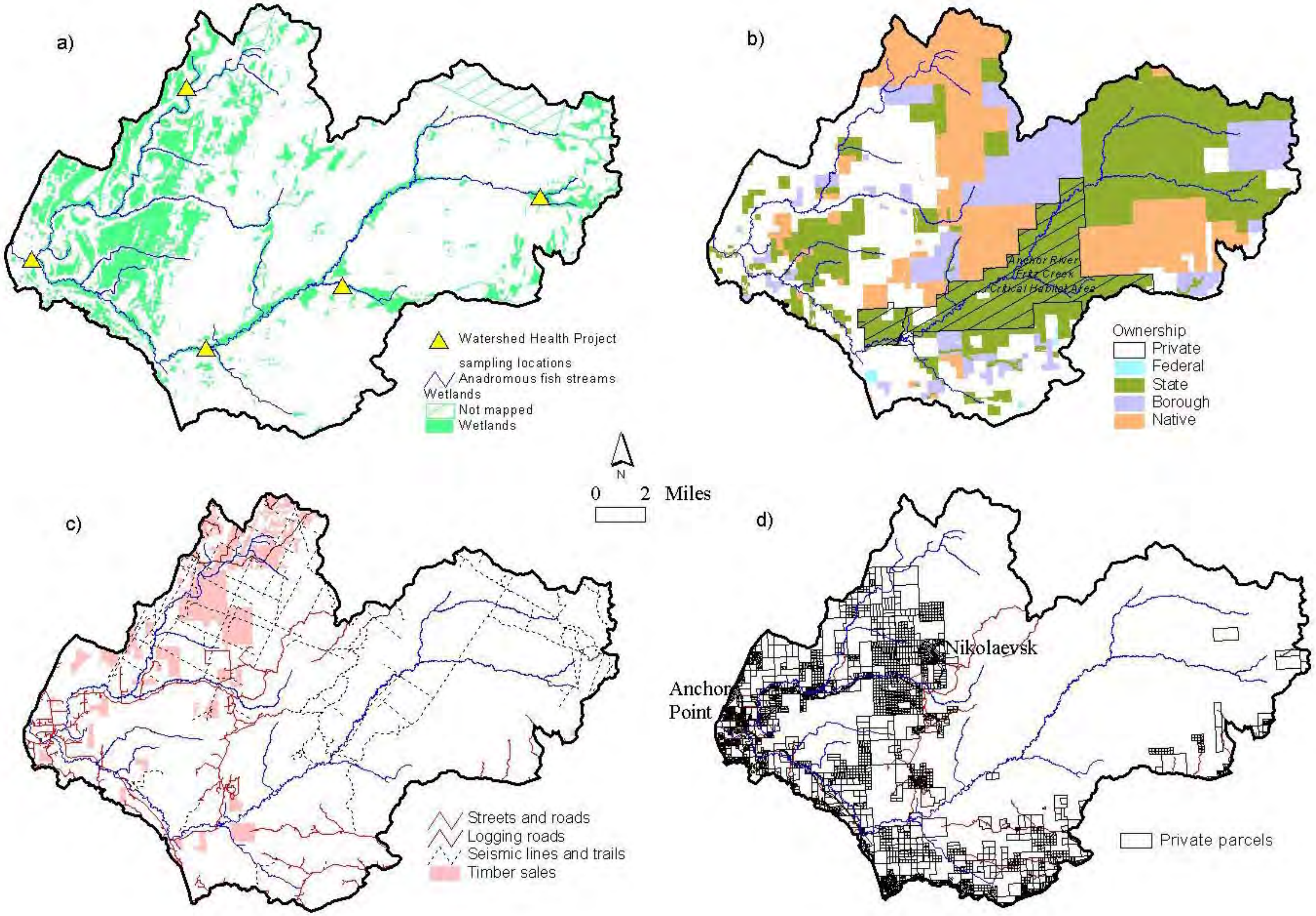


Figure 6. Anchor River watershed: a) wetlands and anadromous fish streams; b) land ownership; c) roads, trails, and timber sales; and d) communities and private parcels. Anadromous streams mapped by Alaska Department of Fish & Game; wetlands mapped by US Fish and Wildlife Service National Wetlands Inventory; and ownership, timber sales, trails and roads from Kenai Peninsula Borough data.

Table 1. Physical and political characteristics of the Ninilchik River, Deep Creek, Stariski Creek, and Anchor River watersheds.

Characteristic	Ninilchik River Watershed	Deep Creek Watershed	Stariski Creek Watershed	Anchor River Watershed
Drainage area	135 miles^2	211 miles^2	49 miles^2	225 miles^2
Miles of anadromous fish streams	52 miles	106 miles	28 miles	114 miles
Miles of Road	59 miles	52 miles	19 miles	146 miles
Wetlands:				
Percentage of area mapped for wetlands	~100%	54%	58%	97%
Wetlands, percentage of mapped area	20%	12%	22%	19%
Land ownership:				
Native Corporation	46 %	38%	25%	21%
Federal	3 %	12%	0%	< 1%
State	42 %	44%	37%	36%
Borough	< 1%	< 1%	10%	13%
Private	8%	5%	27%	28%
Other	<1%	<1%	1%	1%
Timber Sales, Cumulative area:				
Pre-1990	< 1%	3%	<1%	<1%
1990-1993	6%	4%	4%	<1%
1994-2000	44%	25%	15%	11%

METHODS

Study Design

The Lower Kenai Peninsula Watershed Health Project was developed with an objective of inventorying water quality and characterizing the health of the Ninilchik River, Deep Creek, Stariski Creek, and Anchor River watersheds. The study was designed under the direction of a Technical Advisory Committee of scientists from federal, state and local agencies as well as Tribal associations, community groups, and the University of Alaska (Appendix III).

Sample Site Selection

A total of twelve sampling sites were chosen to represent water quality conditions throughout each watershed. Sites were chosen on the upper reaches of the watershed, middle portion of the watershed, and near the mouth of the river, where the cumulative impacts of human use are expected to be the strongest. Three sites were chosen on Ninilchik River and Deep Creek, two on Stariski Creek, and four were located in the Anchor River watershed. When determining the exact location of each monitoring station, the following criteria were used: private property access, historical data available from the site, parameters previously measured, representative-ness, and logistical access (Keeper, 2000). One sampling location on the upper Anchor River (AR-1) was changed after access was deemed too difficult. The Technical Advisory Committee approved a new location on Beaver Creek (AR-5) in March 2000 (see Figure 1). In August 2002, access to the middle Deep Creek site (DC-2) was denied by the landowners as they embarked on a tree replanting project.

Parameter Selection

Keeper chose monitoring parameters that are part of Alaska's water quality standards and federal water quality criteria and that provide useful indicators of watershed health. Keeper has refined its list of monitoring parameters over time. In August 1998, Keeper began monitoring the following parameters: water temperature, streamflow, pH, oxidation-reduction potential, conductivity, salinity, total dissolved solids, dissolved oxygen, nitrite-nitrogen, nitrate-nitrogen, ammonia-nitrogen, orthophosphate, total phosphorus, color, turbidity, suspended solids, and bacteria. After the first year of the project, under direction of the TAC, Keeper eliminated oxidation-reduction potential, which is more appropriate for groundwater than for surface water. Keeper also eliminated nitrite-nitrogen and salinity because the values for these parameters were too low to measure accurately. Keeper incorporated an additional parameter, settleable solids.

Monitoring Frequency

From August 1998 to May 2000, Keeper monitored all twelve sites monthly during the summer months of May through October. During the winter months of November through April, at least six sites were visited each month. Sites were visited in order of priority, with the lower, most accessible sites first, the middle sites second, and the least accessible upper sites last.

Starting in May 2000, the monitoring schedule has targeted high flow events such as spring break-up and the annual fall storms. With this approach, all sites are visited every six weeks during the summer months. And, each site is visited at least one additional time during snowmelt or storms. This schedule results in the same number of site visits during the summer months as the previous schedule, but the time of each visit is chosen so that each site is visited over a range of flow conditions.

Middle Anchor River during summer low flow.

Middle Anchor River during spring break-up.

Stream systems are dynamic, and a year's worth of field visits may capture only some of the natural variability. Water chemistry may be expected to vary from day to day, times of high flow to low flow, from season to season, and from year to year. Results indicate the water quality at the moment of that particular sample. Therefore, it is important to continue monitoring to develop a complete picture of variability for each water quality parameter. The more samples that are collected, the more this variability will be revealed.

<u>Measurement and Analysis Techniques</u>

Sampling and analysis methods were chosen so that data could be compared with data from other studies both in Alaska and around the United States. For most parameters, Keeper selected sampling methods from *Standard Methods for the Examination of Water and Wastewater, 19th Edition* (American Public Health Association, 1995), and/or methods that have been approved or accepted by the United States Environmental Protection Agency (EPA). Standard methods (accepted methods used by chemists around the country) and EPA-approved tests were used wherever possible so that results could be compared with other studies and accepted by other scientists. A more detailed discussion of both the project design and the sampling and analysis methods can be found in the Quality Assurance Project Plan (Cook Inlet Keeper, 2000).

It is important to remember when comparing Keeper's data with data collected by other groups that different methods may yield different results. For example, Keeper measured total dissolved solids using an electronic probe. The probe runs an electrical current through the water, and uses the conductance to calculate the level of total dissolved solids based on a conversion factor. The USGS, on the other hand, analyzed the amounts of the individual components that make up the dissolved solids in the water. USGS measured these components and then added the amounts together. What appear to be differences in past and present levels may be due to different methods rather than to actual changes in water quality.

Data Management

All water quality data are recorded in notebooks and on field data sheets and are entered into Keeper's Microsoft Access database. Data are screened for data entry errors; data that are suspected to be inaccurate due to instrument calibration concerns or that fall outside of the normal expected range for each parameter are not included in data analysis and presentation.

Data Presentation

The data are summarized using box plots, which illustrate mean (average), median, and other percentiles (Figure 7), to document natural variability over time for each site. For certain parameters, longitudinal trends and relationships to stream discharge have been highlighted. Differences between watersheds are explored using analysis of variance.

Keeper also compares data to state water quality standards and/or federal water quality criteria, and historical water quality data. State water quality standards were taken from *Water Quality Standards as Amended Through May 27, 1999* (ADEC, 1999). Federal water quality criteria were taken from *Quality Criteria for Water 1986* (EPA, 1986) and *1998 Update of Ambient Water Quality Criteria for Ammonia* (EPA, 1998).

Keeper compared data collected during 1998-2001 with historical data collected by the USGS from 1950 through 1970. Historical water quality data were obtained directly from the USGS in Anchorage, but are also available in published tables and through the World Wide Web (http://water.usgs.gov/ak/nwis). Keeper compared water quality data (i.e. stream temperature, conductivity, total dissolved solids, nitrate-nitrogen, total suspended solids, and apparent color) from the lowest sites on the four rivers with data collected by the USGS.

Quality Assurance

Keeper has quality checks on all aspects of the Lower Kenai Peninsula Watershed Health Project (Figure 8). First, the monitoring plan was developed under the direction of a Technical Advisory Committee (TAC) of scientists from federal and state agencies as well as industry (Appendix III). The TAC chose sampling sites, determined the sampling frequency, and reviewed the chosen methods. Next, Keeper and the TAC chose standard field and lab methods that are used throughout the state and the country so that data collected by Keeper could be easily compared with data from other studies. Third, Keeper incorporates quality assurance steps into the data collection process. For example, Keeper splits samples with a professional lab annually to compare results. Keeper also uses a standard solution of known concentration with each laboratory analysis to estimate precision and accuracy. The results of the sample splits are found in Appendix I. Finally, all quality assurance methods are described in detail in Keeper's Lower Kenai Peninsula Watershed Health Project Quality Assurance Project Plan (QAPP). The QAPP in turn was reviewed by the TAC and approved by both Alaska Department of Environmental Conservation and the U.S. Environmental Protection Agency.

The QAPP is available upon request from Cook Inlet Keeper.

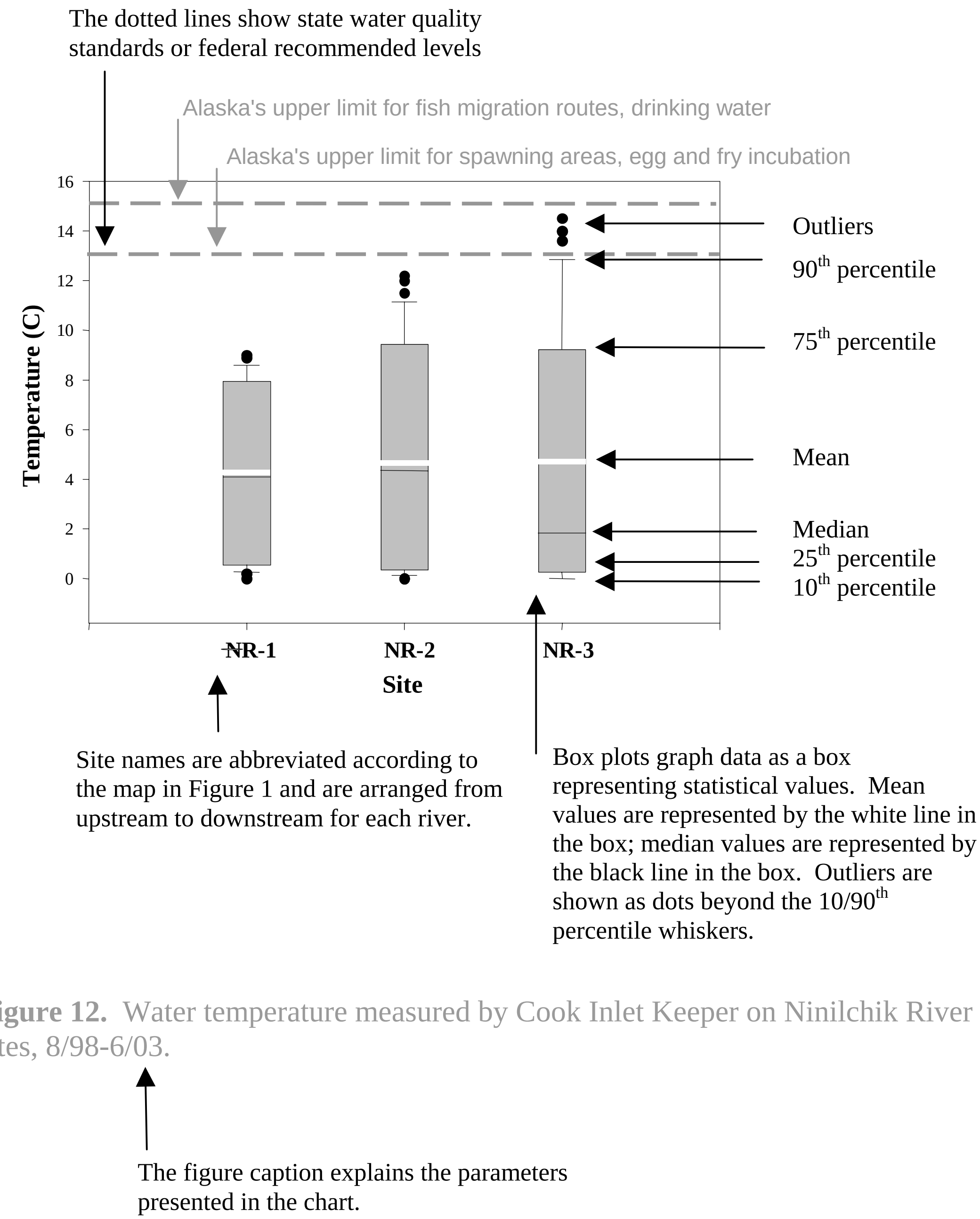


Figure 7. Data presentation method used in this report.

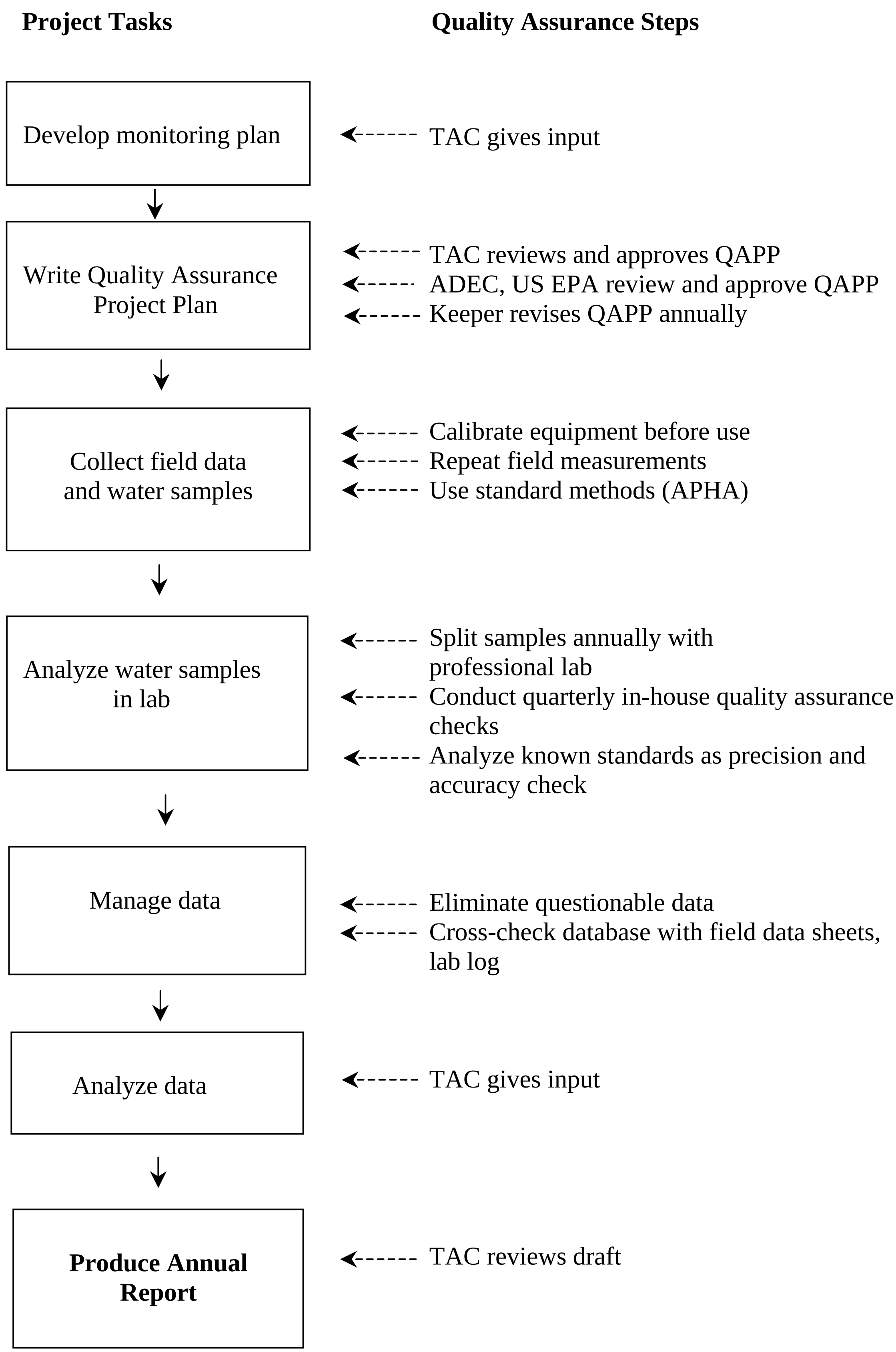


Figure 8. Lower Kenai Peninsula Watershed Health Project tasks and associated quality assurance steps.

WATER QUALITY PARAMETERS

Parameters

Streamflow (discharge) is the volume of water moving through a stream at any given point in time. Streamflow is often expressed in cubic feet per second (cfs). The discharge of a stream can vary on a daily basis in response to precipitation, snowmelt, dry periods, and withdrawals of water by people. Streamflow affects water chemistry; thus, water quality measurements should always be looked at in relation to streamflow.

Water Temperature is a crucial aspect of aquatic habitat. Aquatic organisms are adapted to live within a certain temperature range. As the upper and lower limits of the range are approached, organisms become more susceptible to disease. Also, fish that spend extra energy searching for cool areas may be at a disadvantage when competing for food. Stream temperature results from inputs of solar radiation as well as air temperature (EPA, 1991).

Dissolved Oxygen is needed by fish and other stream organisms to live. In natural small streams, dissolved oxygen levels are usually 100% of the holding capacity of the water. As plant and animal material decays, it consumes dissolved oxygen, particularly in slow-moving areas of the stream. Turbulence, interaction with the air, and photosynthesis replenish oxygen to the water (Table 2). Colder water can hold more dissolved oxygen than warmer water. Dissolved oxygen measurements can be expressed as a concentration in milligrams per liter (mg/L), or as percent saturation: the amount of oxygen the water holds compared to what it could absorb at that temperature.

pH is a measure of the level of activity of hydrogen ions in a solution, resulting in the acidic or basic quality of the solution. The pH range is from 0 (acidic) to 14 (basic), with 7 being neutral (Figure 9). Stream organisms are adapted to certain pH ranges. Humans can impact pH through mining activities (which make water more acidic) and by increasing nutrients, which increase plant growth and pH (Table 2). Most natural rivers range from 6.5 pH units to 8 pH units.

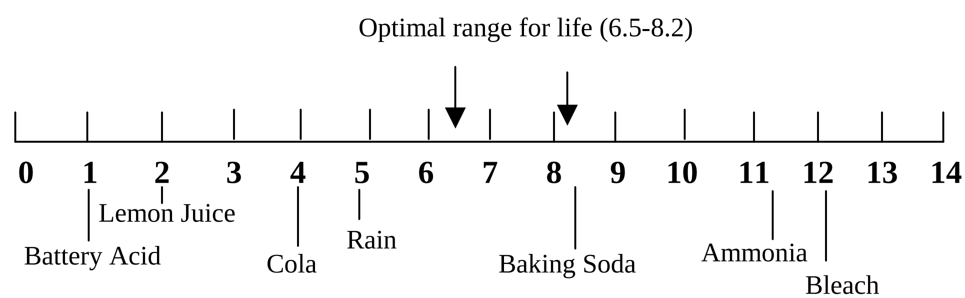


Figure 9. pH levels of some common substances.

Total Dissolved Solids is a measure, in milligrams per liter (mg/L), of the amount of dissolved materials in the stream. Ions such as potassium, sodium, and chloride all contribute to a dissolved solids measurement. Measuring total dissolved solids is a way of estimating the suitability of water for irrigation and drinking water. Groundwater has higher levels of dissolved solids from increased contact with rock and more time to dissolve rock and mineral materials. Thus, when stream flows are high from rain or snow melt, dissolved solids measurements are expected to be low. When stream flow is low, most of the source water is from groundwater and dissolved solids levels are higher (Hem, 1992).

Conductivity is the ability of a substance to conduct an electrical current, measured in microsiemens per centimeter (μS/cm). The presence of ions in a sample of water gives it its ability to conduct electricity; thus conductivity is an indicator of the amount of dissolved solids in the stream. Conductivity is often used to estimate the amounts of dissolved solids rather than measuring each dissolved constituent individually.

Nutrients are chemical elements that are essential to plant and animal life and growth. Nitrogen and phosphorus are nutrients that are important to aquatic life, but at high levels they are considered contaminants. Keeper measures nitrate-nitrogen, ammonia-nitrogen, orthophosphate, and total phosphorus. Both nitrogen and phosphorus are affected by chemical and biological processes that change their form and transfer them to or from water, soil, biological organisms, and the atmosphere (Mueller et al., 1999). High levels of nutrients can cause increased growth of algae beyond what is normal and impact the quality of the water. Decaying algae mats can cause foul odors and tastes and remove dissolved oxygen from the water. In nature, both nitrogen and phosphorus come from the soil and decaying plants and animals (Table 2).

Turbidity is an optical property of water that refers to the amount of light scattered or absorbed by the water (American Public Health Association, 1995). In this project, turbidity is measured in nephelometric turbidity units (NTUs). Increasing turbidity is described visually as increasing cloudiness. Silt, clay, organic material, and colored organic compounds can all contribute to turbidity. Although turbidity may be a sign of suspended sediment, it cannot be correlated with a weight concentration of suspended material. Turbidity is an important parameter of drinking water for both aesthetic and practical reasons (EPA, 1991).

Suspended Solids can cause problems both as it travels through the water and after it is deposited on the stream bed. Suspended sediment can reduce visibility, making it hard for fish to find prey. It can clog the gills of fish and suffocate macroinvertebrates. Once suspended sediment is deposited, it can fill the spaces between gravel pieces in the bed of the stream. This reduces the permeability of the bed material, meaning that water cannot filter through, bringing dissolved oxygen and nutrients to stream insects, fish eggs and fry. High levels of suspended solids make treatment of water for drinking difficult.

Settleable Solids are the volume of solids that settles out of a sample of water compared to the total volume of the sample. This is another way of measuring the amount of sediment in a water sample. The State of Alaska uses the amount of settleable solids as the parameter of importance for meeting the state water quality standard for sediment to protect swimming.

Apparent Color The color of water comes from the leaching of organic debris (dead plants) in wetlands. The color of water is not directly related to any chemical properties of the water. However, it is an important aesthetic quality of drinking water.

Table 2. Water quality parameters and common natural and human impact sources.

Parameter	**Common Natural Contributions**	**Common Human Impact Sources**
Discharge	Precipitation, snowmelt, groundwater	Withdrawals of stream or groundwater, dams, impermeable surfaces
Temperature	Solar radiation, shade, groundwater contributions	Removal of riparian vegetation, inputs from treatment plants
Dissolved Oxygen	Turbulence, interaction with air	Decaying plant and animal material, sewage, effluent
pH	Decaying wetland plants, geology	Mine tailings leaching, agricultural runoff, algae blooms
Total Dissolved Solids	Geology, discharge	Road and fertilizer runoff
Conductivity	Geology, discharge	Pollution, road and fertilizer runoff
Nitrogen: Ammonia and Nitrate	Decaying plant and animal material	Sewage, wastewater treatment plant effluent, fertilizers, logging and lawn debris, deposition from the atmosphere
Phosphorus: Orthophosphate and Total Phosphorus	Decaying plant material, soils, underlying geology	Detergents, fertilizers, sediment
Turbidity	Discharge, natural erosion	Road building and erosion, forest harvest, mining, grazing, wastewater discharges
Suspended Solids	Discharge, natural erosion	Road building and erosion, forest harvest, mining, grazing, wastewater discharges
Settleable Solids	Discharge, natural erosion	Road building and erosion, forest harvest, mining, grazing, wastewater discharges
Color	Chemical compounds from decaying plants	Chemical contaminants

WATER QUALITY DATA

Ninilchik River Watershed

Upper Ninilchik River site: **NR-1**

Lower Ninilchik River site: **NR-3**

Middle Ninilchik River site: **NR-2**

Streamflow (discharge)

Collecting stream flow data during ice cover, snow melt periods, and high flow events (>300 cfs) has proven to be a challenge using methods for wadeable streams. In April and August 2001, U.S. Geological Survey (USGS) personnel worked with Keeper staff to collect high flow data using a variety of methods. Keeper's measurements on the middle and lower Ninilchik River sites (NR-2, NR-3) are comparable to continuous data collected from the USGS gauge on the lower Ninilchik River (Figure 10). Peak flows (>1,000 cfs) from the USGS gauge (station # 15241600) for the Fall floods of 2002 were:

October 24, 2002	5,800 cfs	November 24, 2002	1,610 cfs
October 25, 2002	2,000 cfs	November 25, 2002	1,190 cfs
October 26, 2002	1,050 cfs		

USGS measurements are provisional and subject to change.

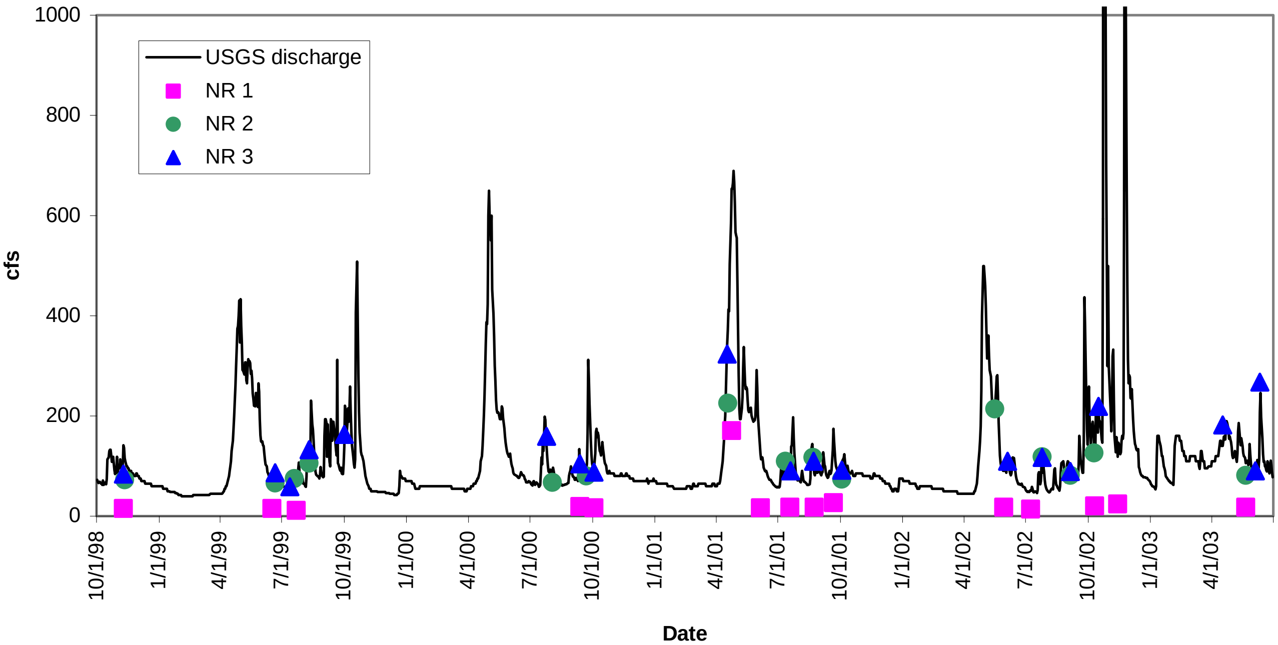


Figure 10. Discharge data for sites measured by Cook Inlet Keeper on the Ninilchik River and discharge measurements from USGS stream gauge (station number 15241600).

<u>Water Temperature</u>

Water temperature is one of the most significant factors in the health of stream ecosystems. Temperature affects salmon egg and fry incubation, fish metabolism, organisms' resistance to disease, the availability of oxygen and nutrients to fish and wildlife, and other factors. Researchers have determined that adult cold-water fish species may cease to migrate or die unspawned if exposed to long periods of warmer than usual temperatures (Bell, 1973). Water temperature measurements exceeded 13^{o}C, Alaska's water quality standards to protect cold-water fish habitat, in June, July, and August 1999, July 2000, and July 2002 at the lower Ninilchik River site (Figure 11). Because these streams support runs of salmon and other fish which are extremely important to the economic and ecologic health of the region, Keeper deployed continuous temperature loggers in the summer of 2002 to thoroughly assess stream temperature variation and how it might affect habitat and water quality.

Data from a continuous temperature logger showed the frequency and extent of elevated temperatures at the lower Ninilchik River in the summer of 2002 (Figure 12). Temperatures exceeded 13^{o}C on 56 days with an average of 13.6 hours/day above 13^{o}C. Temperatures exceeded 15^{o}C on 35 days with an average of 9.7 hours/day above 15^{o}C. Data provided by the Alaska Department of Fish and Game showed temperatures exceeded 13^{o}C on 53 days and 15^{o}C on 32 days at the Ninilchik River weir on Brody Road.

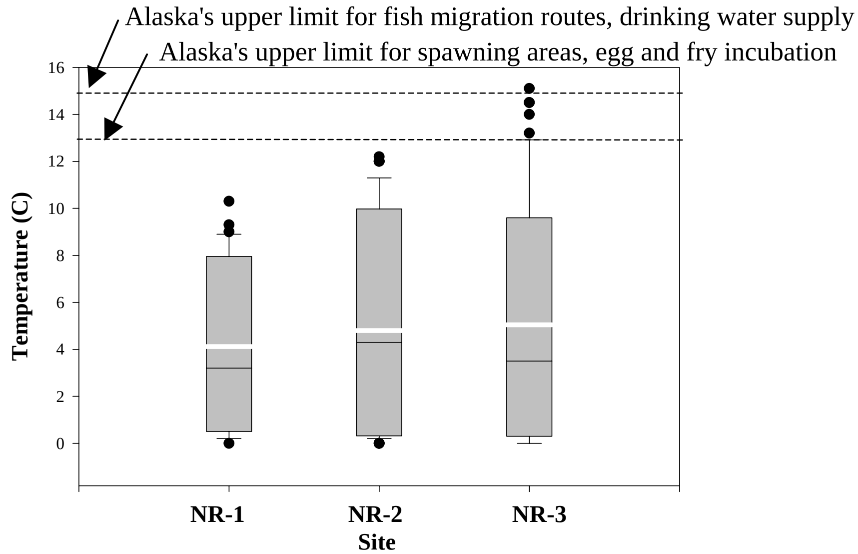


Figure 11. Water temperature measured by Cook Inlet Keeper on Ninilchik River sites, 8/98-6/03.

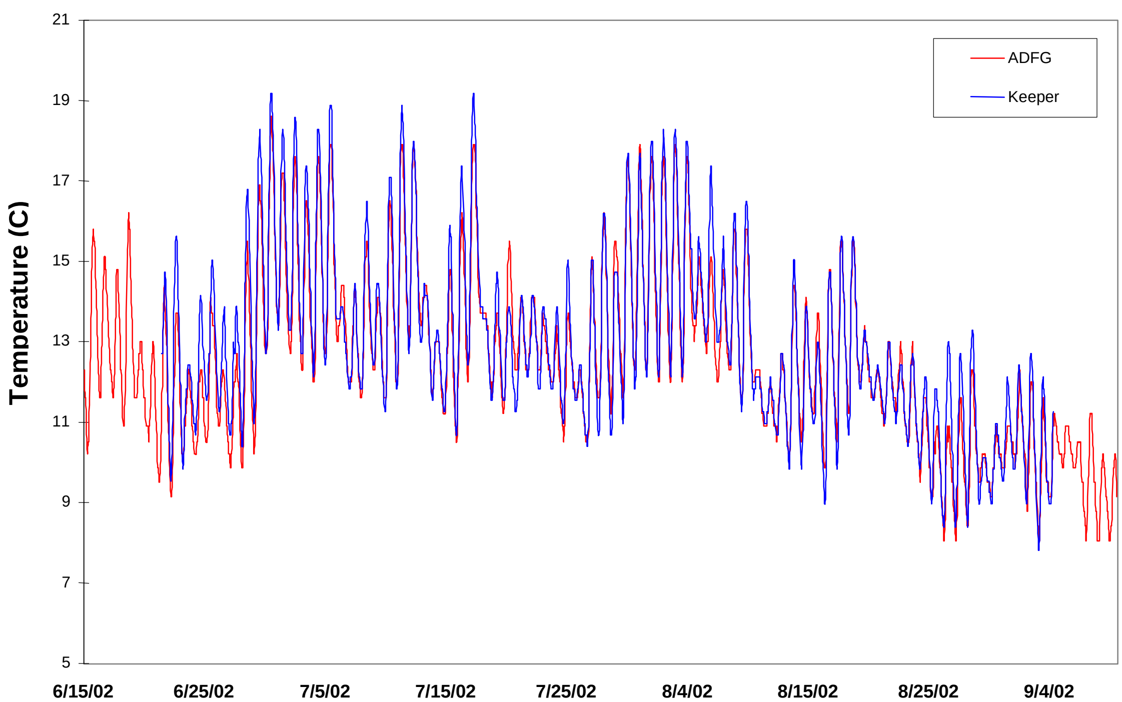


Figure 12. Continuous temperature logger data collected from 6/02 – 9/02 at the lower Ninilchik River site by Cook Inlet Keeper (blue) and upstream at the weir site on Brody Road by the Alaska Department of Fish and Game (red).

Dissolved Oxygen

Dissolved oxygen concentrations at all sites were within the State of Alaska's range of 7 to 17 mg/L to protect aquatic life (Figure 13). The wide range of dissolved oxygen measurements at each site is due to seasonal changes in water temperature; colder water holds more dissolved oxygen than warmer water. All sites were at or below Alaska's limit for percent saturation of dissolved oxygen (Figure 14).

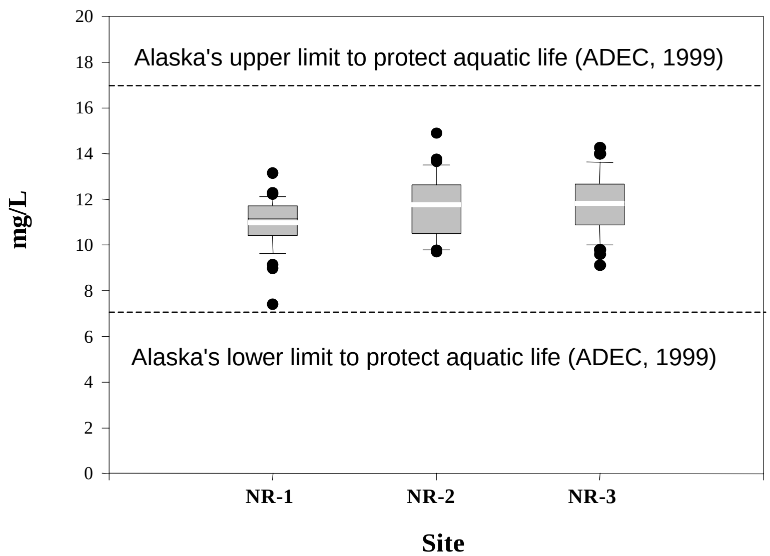


Figure 13. Dissolved oxygen concentrations measured by Cook Inlet Keeper on Ninilchik River sites, 8/98-6/03.

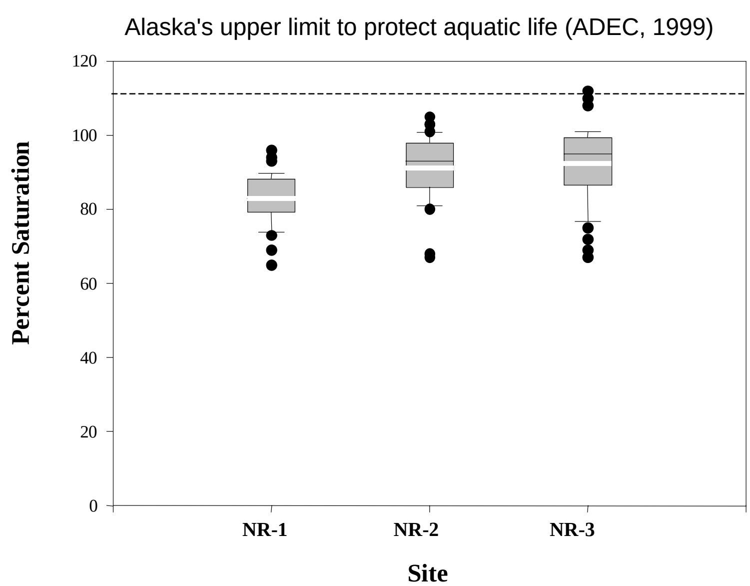


Figure 14. Percent saturation of dissolved oxygen measured by Cook Inlet Keeper on Ninilchik River sites, 8/98-6/03.

pH

Most pH measurements were within Alaska's water quality standards (Figure 15). Five measurements were below the state standard to protect fish and wildlife.

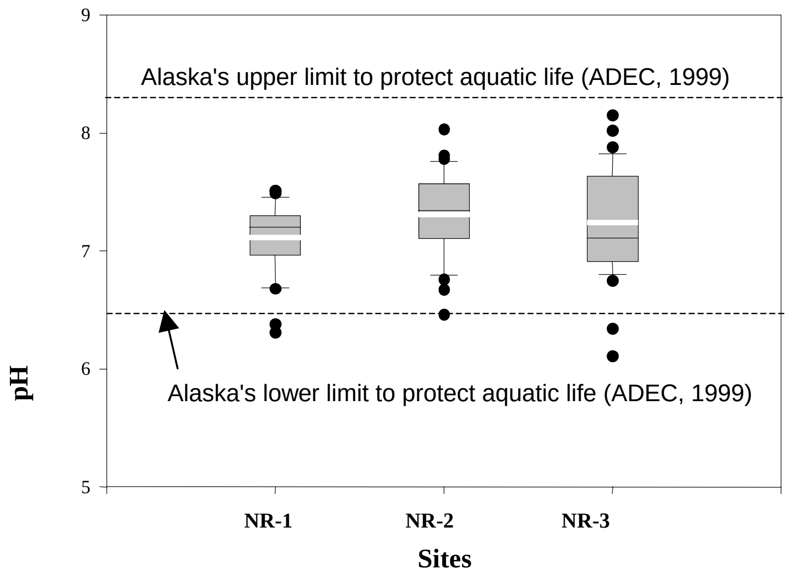


Figure 15. pH measured by Cook Inlet Keeper on Ninilchik River sites, 8/98-6/03.

Total Dissolved Solids

All TDS measurements were within the state water quality standard of 500 mg/L for drinking water supply or 1000 mg/L to protect aquatic life (Figure 16).

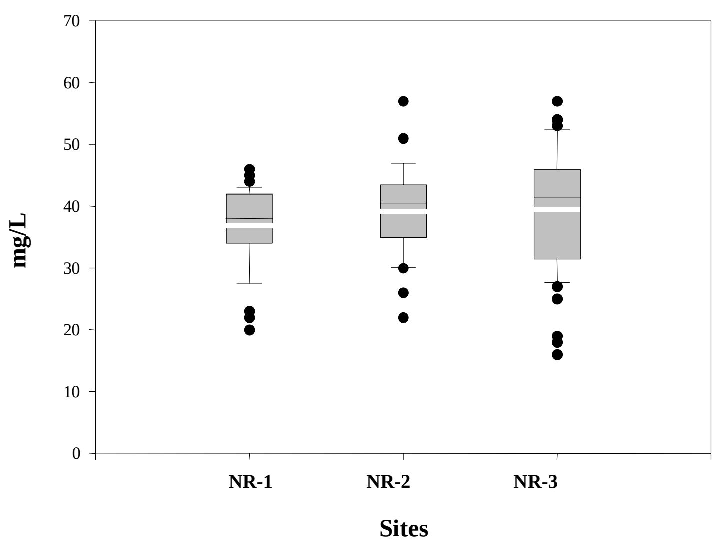


Figure 16. Total dissolved solids measured by Cook Inlet Keeper on Ninilchik River sites, 8/98-6/03.

Conductivity

Conductivity measurements range from 36 μS/cm to 120 μS/cm at Ninilchik River sites (Figure 17). The variability in conductivity measurements at each site is related to changes in stream flow and associated changes in levels of dissolved solids. During periods of low flow, or in the winter, much of the stream water comes from groundwater rather than surface runoff. Groundwater has higher levels of dissolved solids than surface water, and thus higher conductivity measurements (Hem, 1992).

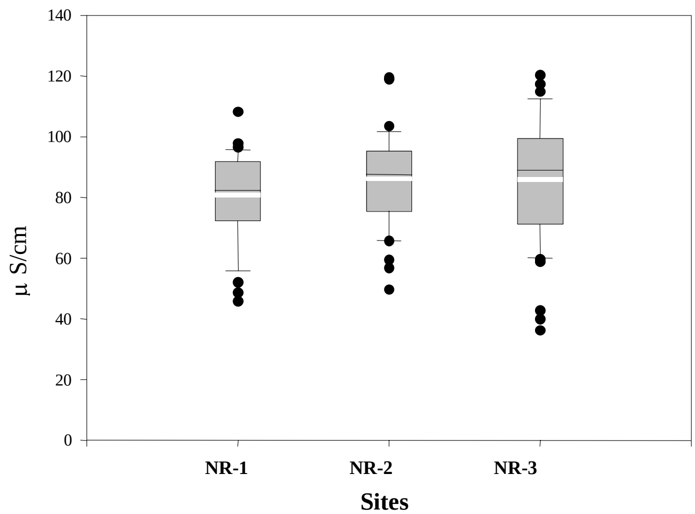


Figure 17. Conductivity measured by Cook Inlet Keeper on Ninilchik River sites, 8/98 – 6/03.

Nitrate-nitrogen

Nitrate-nitrogen levels were far below 10.0 mg/L, Alaska's maximum contaminant level for drinking water (Figure 18).

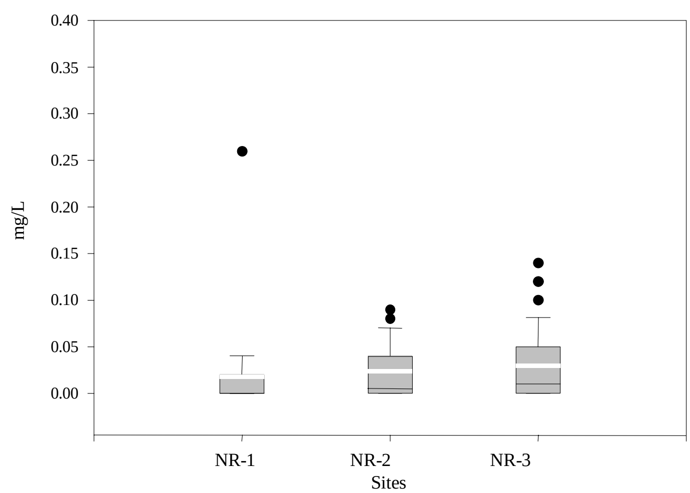


Figure 18. Nitrate-nitrogen concentrations measured by Cook Inlet Keeper on Ninilchik River sites, 8/98-6/03.

Ammonia-nitrogen

Ammonia-nitrogen levels at all sites were well below EPA's criteria to protect aquatic life (Figure 19).

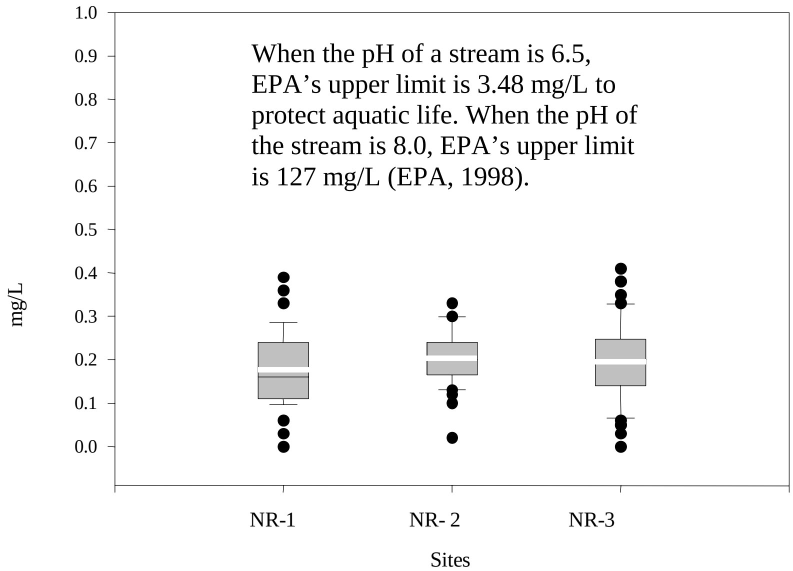


Figure 19. Ammonia-nitrogen values measured by Cook Inlet Keeper on Ninilchik River sites, 8/98-6/02.

Orthophosphate-phosphorus

Orthophosphate-phosphorus concentrations range from 0.04 mg/L to 0.16 mg/L (Figure 20).

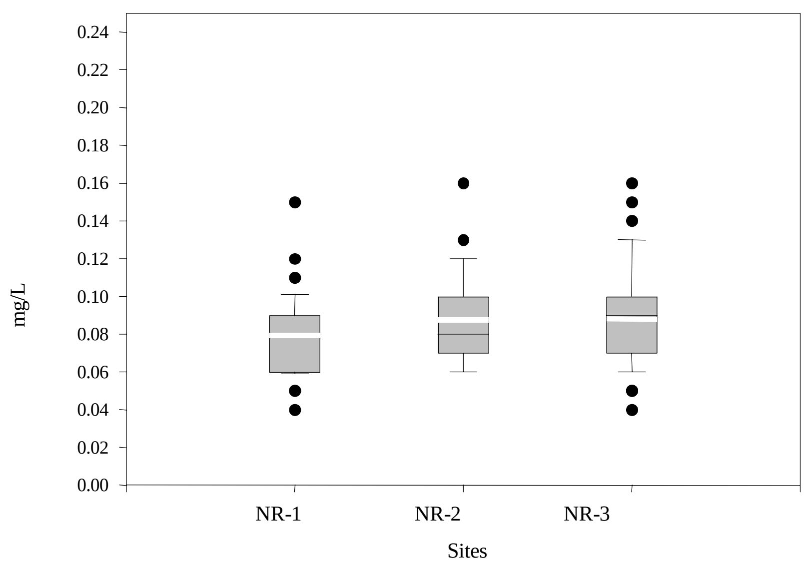


Figure 20. Orthophosphate-phosphorus concentrations measured by Cook Inlet Keeper on Ninilchik River sites, 8/98-6/03.

Total Phosphorus

Thirty-five percent (NR-1), fifty-eight percent (NR-2), and forty-seven percent (NR-3) of total phosphorus measurements were above EPA's recommended level of 0.10 mg/L as phosphorus (Figure 21).

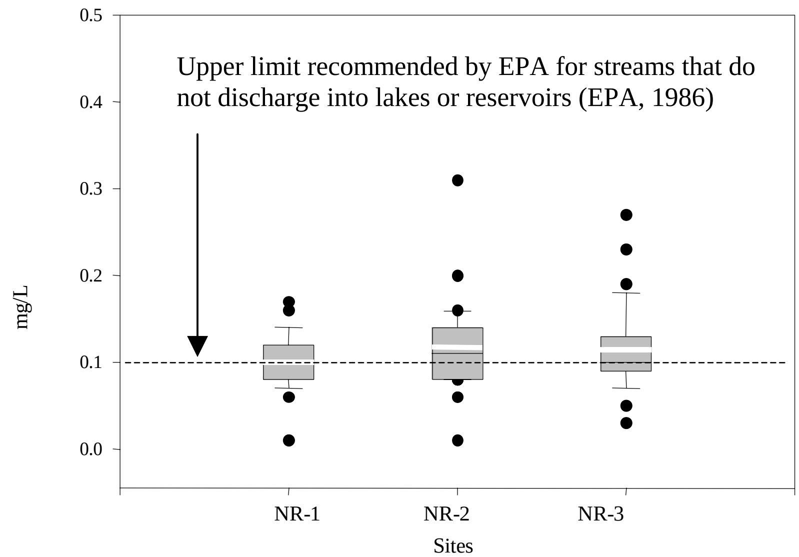


Figure 21. Total phosphorus measured by Cook Inlet Keeper on Ninilchik River sites, 8/98-6/03.

Turbidity

The relationship of Keeper's turbidity data to state standards is difficult to determine because standards are described in relation to natural conditions rather than as specific values (Figure 22).

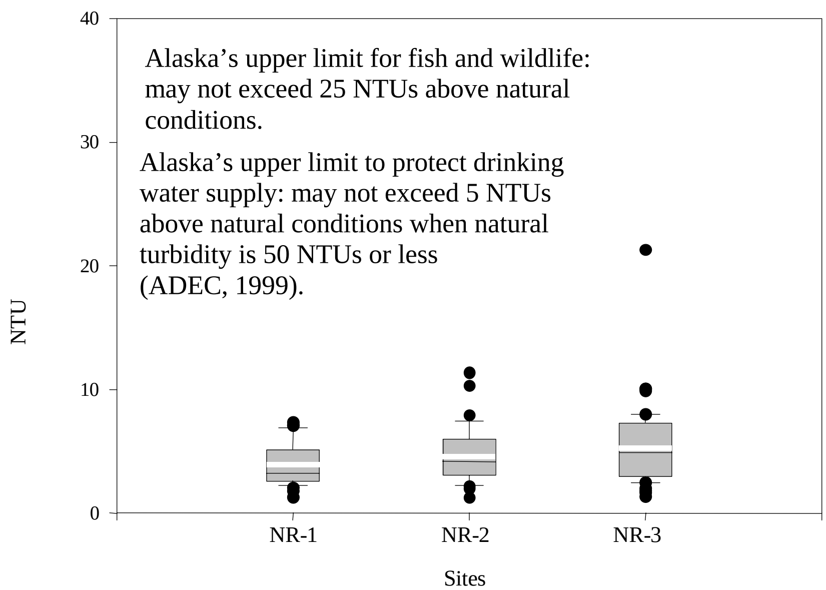


Figure 22. Turbidity measured by Cook Inlet Keeper on Ninilchik River sites, 8/98-6/03.

Total Suspended Solids

Alaska's standard for sediment is defined in terms of habitat impairment rather than a concentration of suspended solids, so Keeper's suspended solids data cannot be compared with a standard (Figure 23).

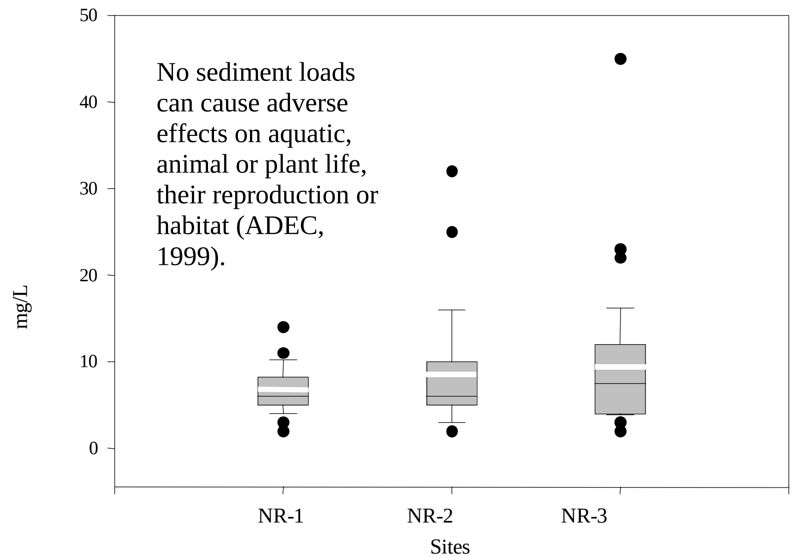


Figure 23. Total suspended solids measured by Cook Inlet Keeper on Ninilchik River sites, 8/98-6/03.

Settleable Solids

Settleable solids were measured in increments of 0.1 mg/L. Most values were between 0.0 and 0.1 mg/L that were recorded as 0.1 mg/l. All values at the upper Ninilchik River (NR-1) were ≤0.1 mg/L (Figure 24).

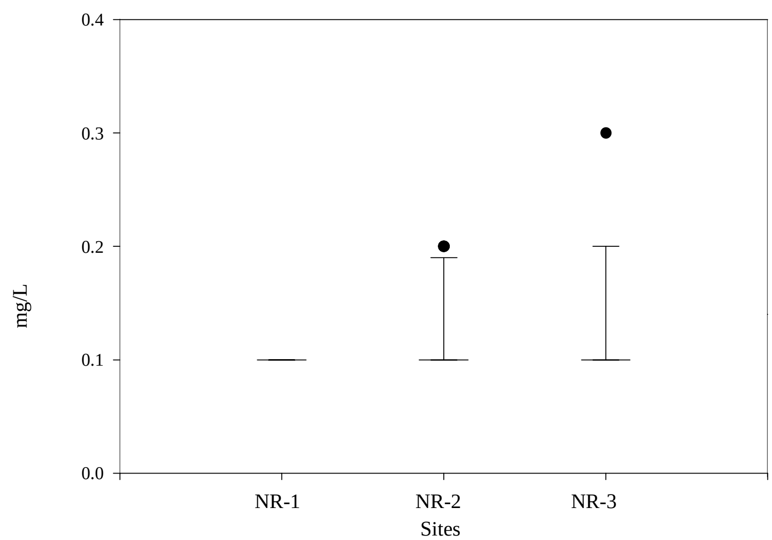


Figure 24. Settleable solids measured by Cook Inlet Keeper on Ninilchik River sites, 8/99-6/03.

Apparent Color

The relationship of Keeper's color data to state standards is difficult to determine because the standards are described in relation to natural conditions rather than as a specific value (Figure 25).

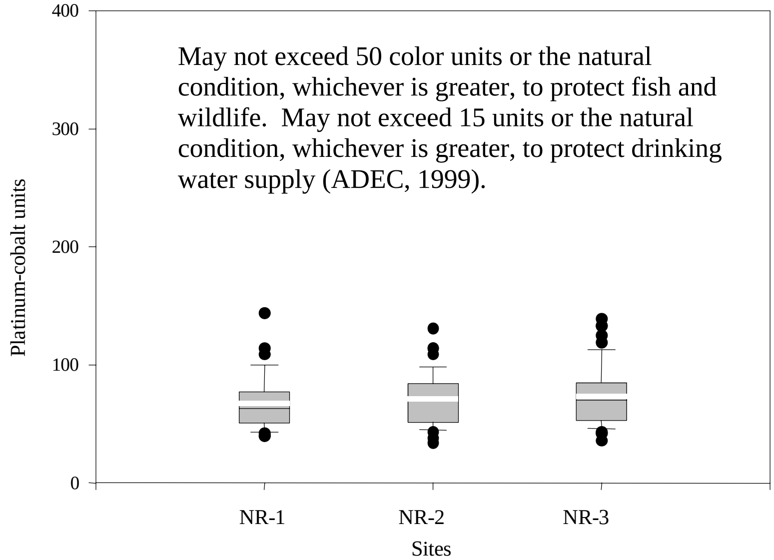
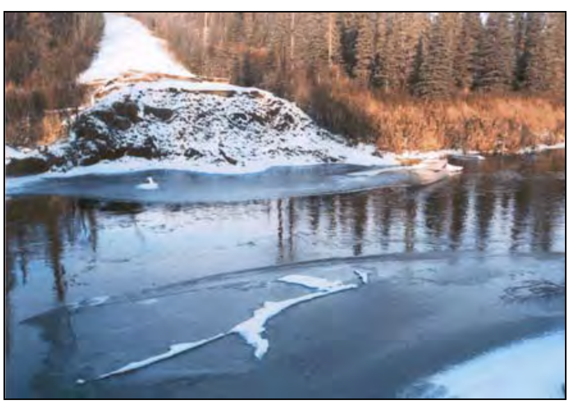


Figure 25. Apparent color measured by Cook Inlet Keeper on Ninilchik River sites, 8/98-6/03.



Brody Road bridge crosses the Ninilchik River and was washed out in October 2002.

Repairs to Mission Avenue bridge in Ninilchik were needed after the Fall floods of 2002.

Comparison of Water Quality Parameters to Discharge

Discharge is an important stream variable because of its impact on water quality and on the living organisms and habitats in the stream. Discharge, or stream flow, is a function of water volume and velocity. Water volume is affected by weather, snow melt, evapotranspiration, topography, geology, and human withdrawals. Velocity changes with channel width and depth and can affect the organisms living in the water, rate of sediment delivery, and dissolved oxygen concentrations. Changes in climate, impervious surfaces, vegetation composition and abundance can alter discharge patterns in a watershed.

Having water quality data collected alongside a stream gauging station makes the discharge and water quality data much more valuable than if these data are collected separately. Understanding the relationship between discharge and water quality will allow us to quantify natural variability and how our activities in the watershed might be changing the quality and quantity of water in our salmon-bearing streams.

With data from the Ninilchik River stream gauge, the following patterns are apparent: 1) low stream flows deliver higher conductivity (Figure 26) and total dissolved solids (Figure 27), and 2) high stream flows deliver higher concentrations of ammonia-nitrogen (Figure 28), total phosphorus (Figure 29), turbidity (Figure 30), suspended solids (Figure 31), and color (Figure 32).

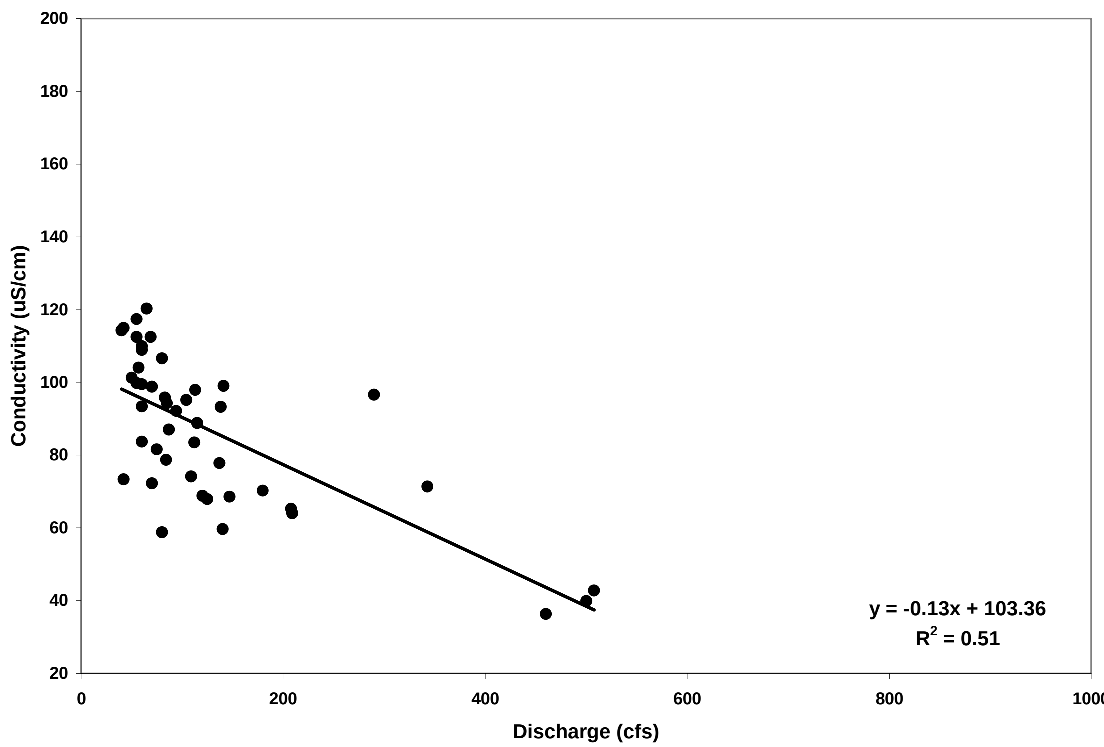


Figure 26. Relationship between discharge and conductivity at the lower Ninilchik River site.

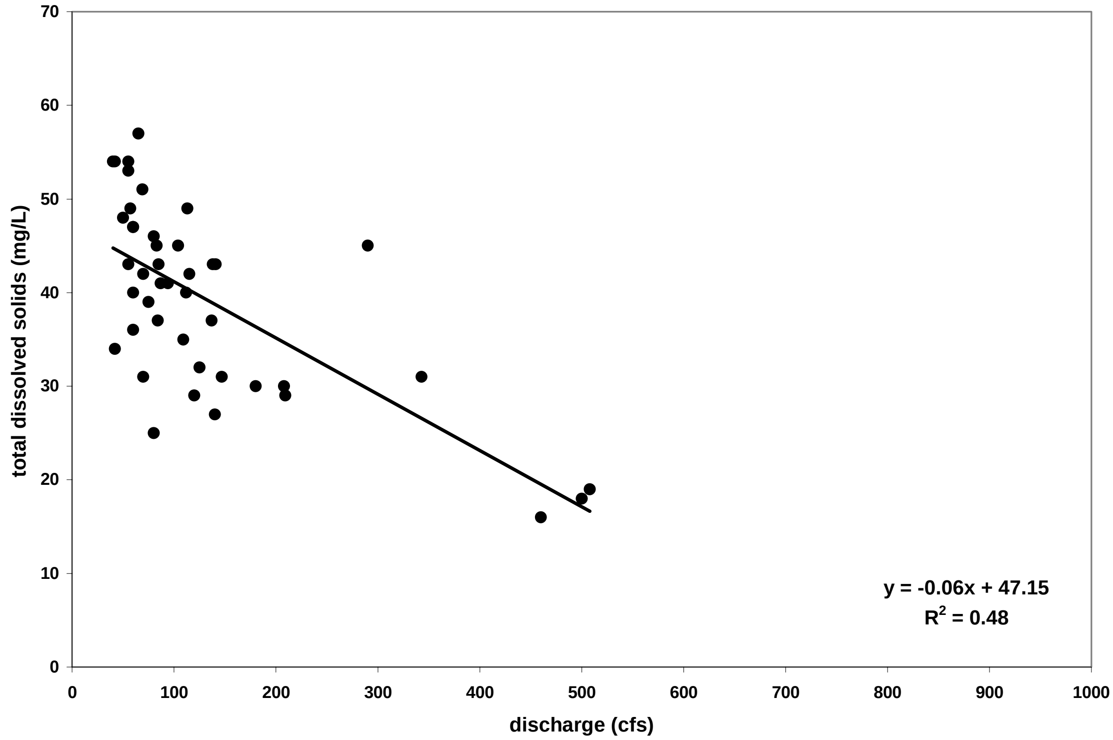


Figure 27. Relationship between discharge and total dissolved solids at the lower Ninilchik River site.

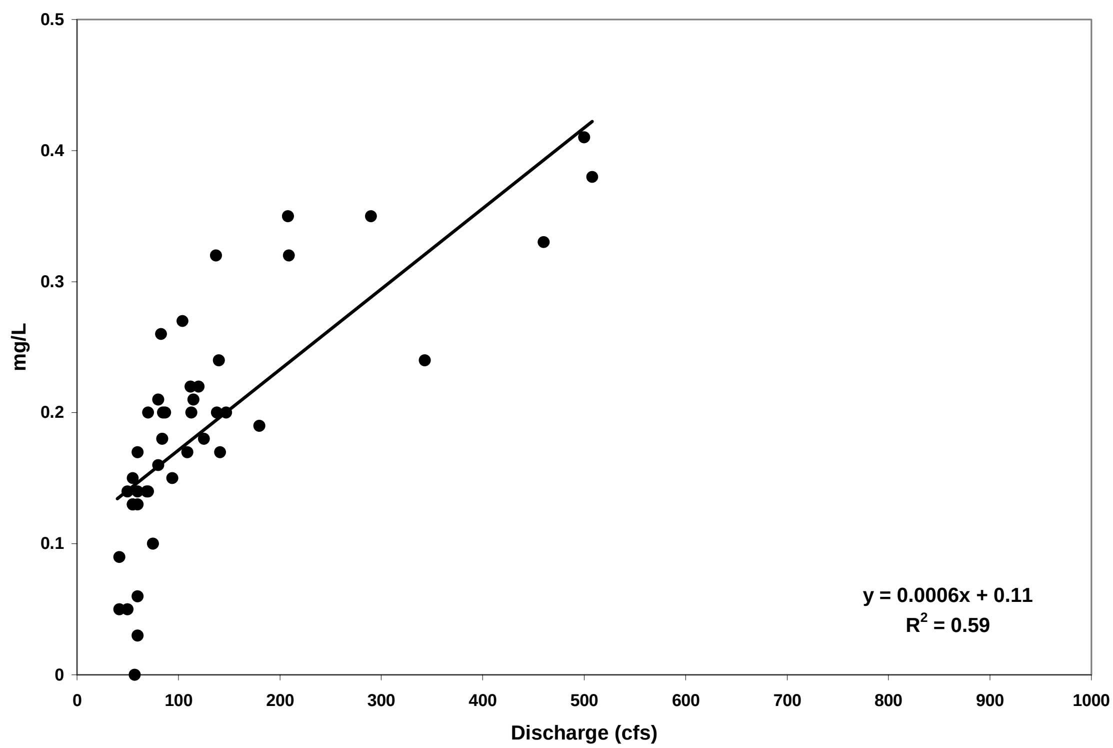


Figure 28. Relationship between discharge and ammonia-nitrogen at the lower Ninilchik River site.

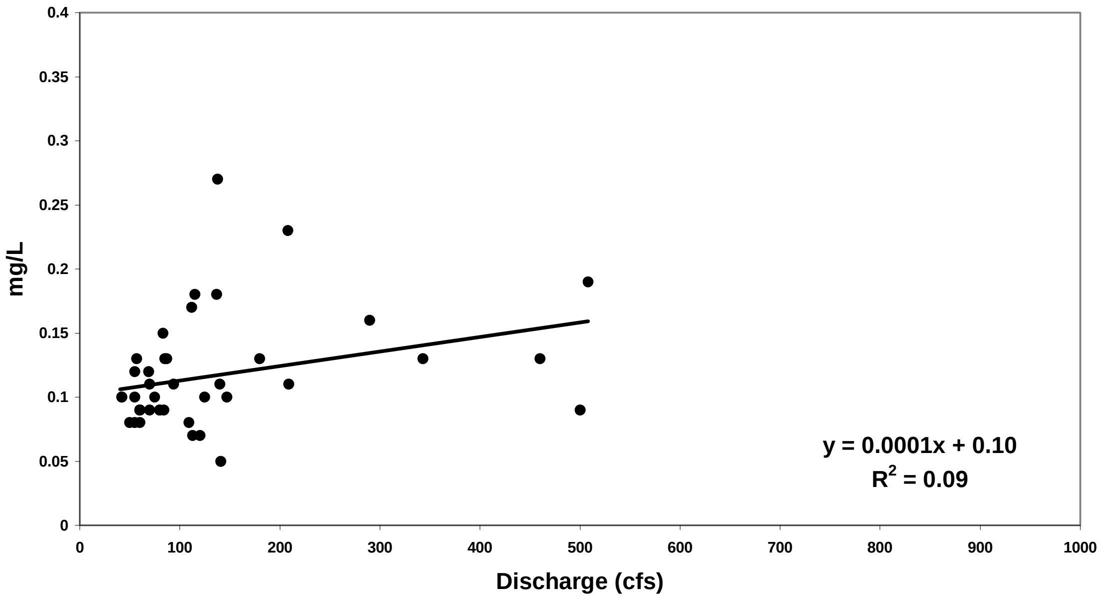


Figure 29. Relationship between discharge and total phosphorus at the lower Ninilchik River site.

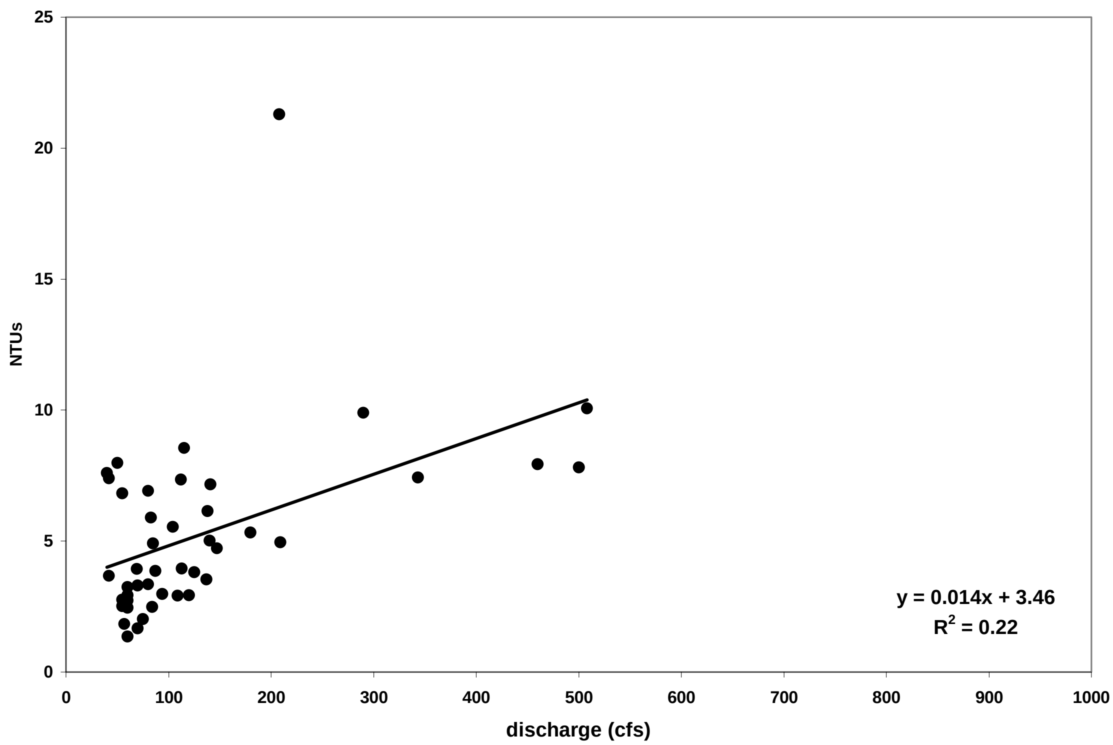


Figure 30. Relationship between discharge and turbidity at the lower Ninilchik River site.

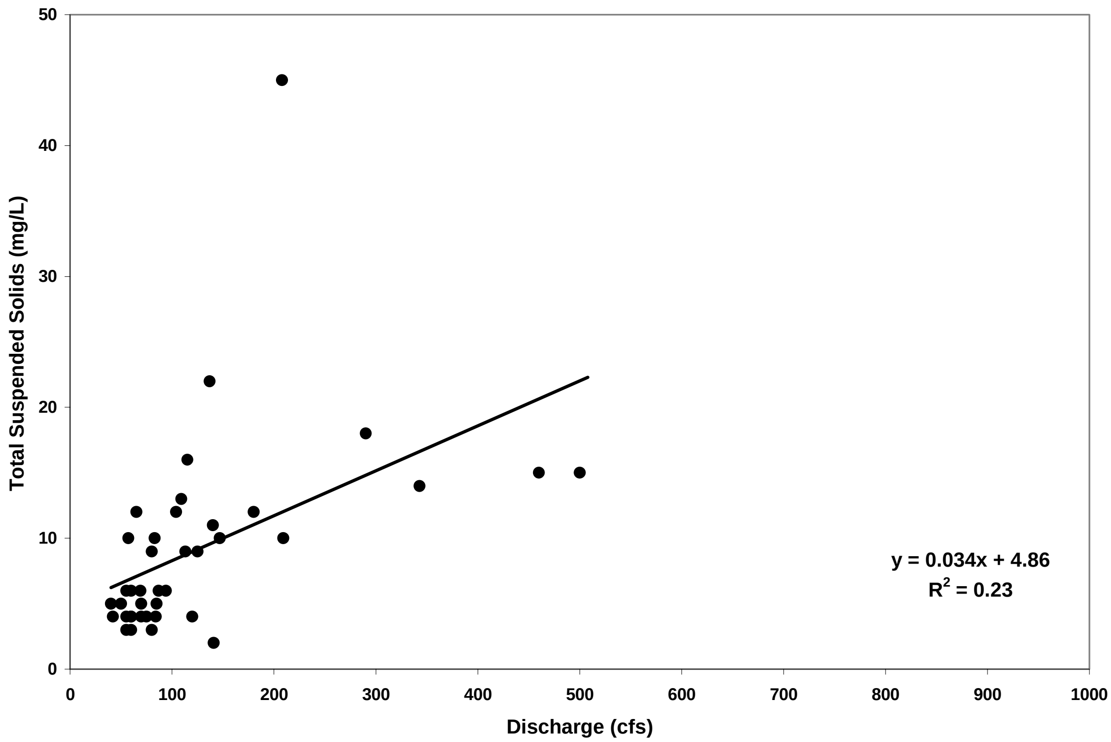


Figure 31. Relationship between discharge and total suspended solids at the lower Ninilchik River site.

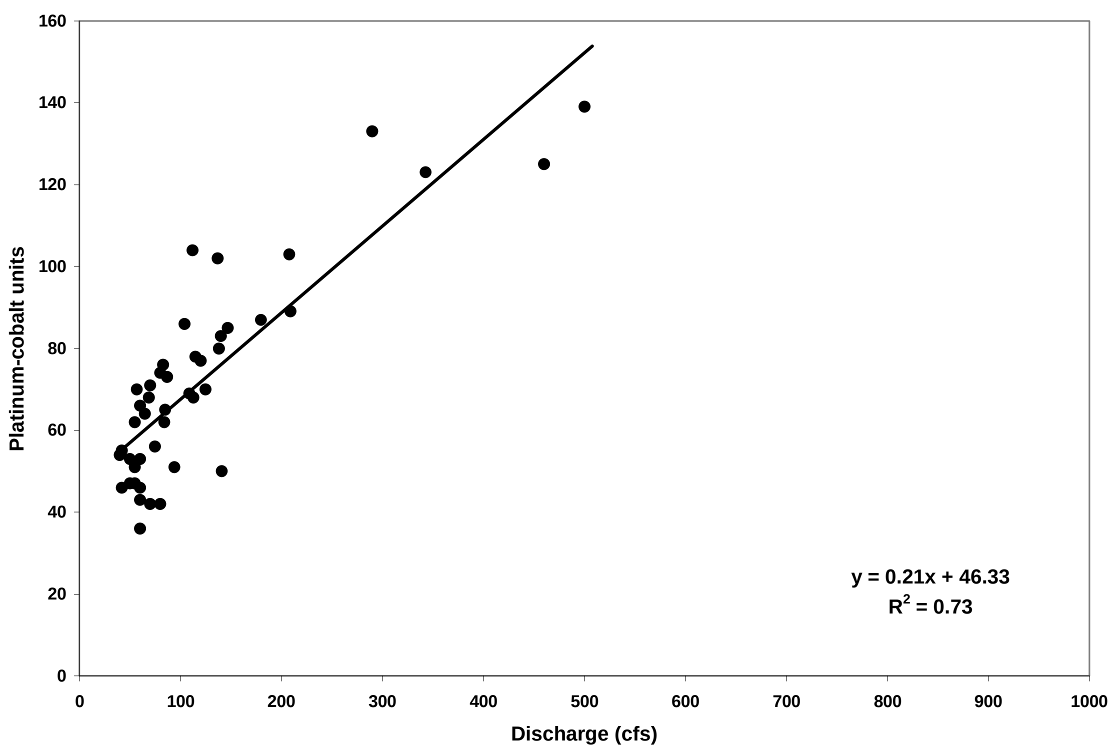
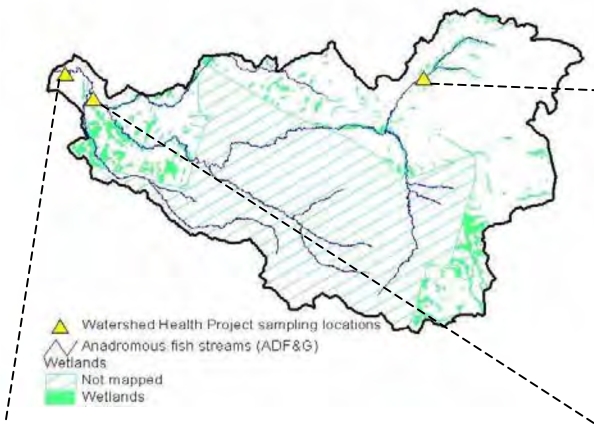
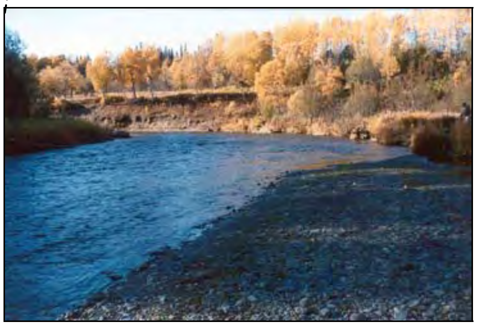


Figure 32. Relationship between discharge and color at the lower Ninilchik River site.

Deep Creek Watershed



Upper Deep Creek site: **DC-1**



Lower Deep Creek site: **DC-3**

Middle Deep Creek site: **DC-2**

<u>Streamflow (discharge)</u>

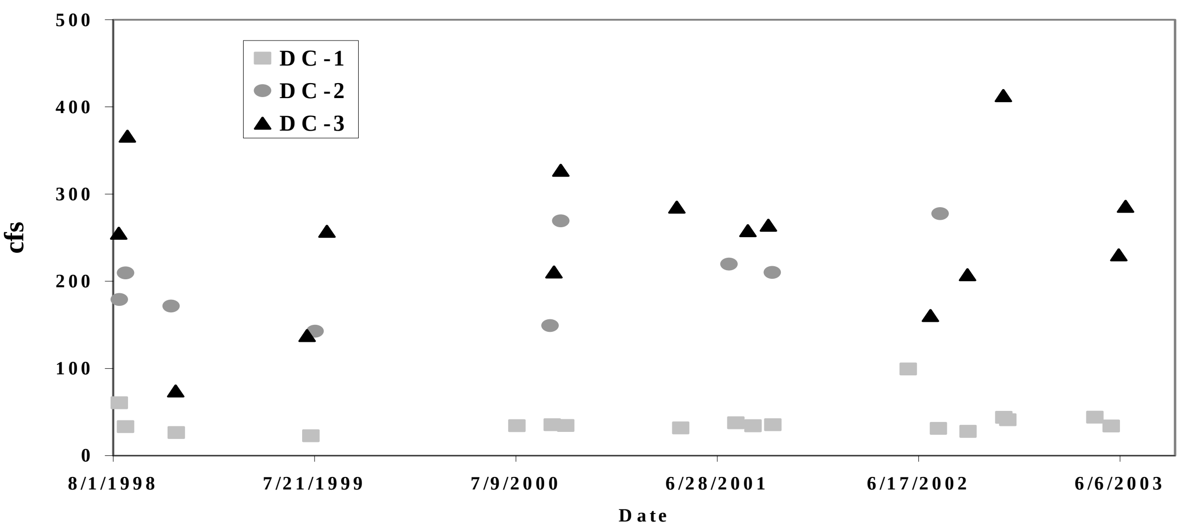


Figure 33. Discharge measurements for sites measured by Cook Inlet Keeper on Deep Creek.

Water Temperature

Water temperature measurements exceeded Alaska's water quality standards to protect cold-water fish habitat at middle and lower sites in July, 1999 and 2002 (Figure 34). Data from a continuous temperature logger showed the frequency and extent of elevated temperatures at the lower Deep Creek site (Figure 35). Temperature exceeded 13^{o}C on 50 days with an average of 11.4 hours/day above 13^{o}C. Temperatures exceeded 15^{o}C on 28 days with an average of 7.7 hours/day above 15^{o}C.

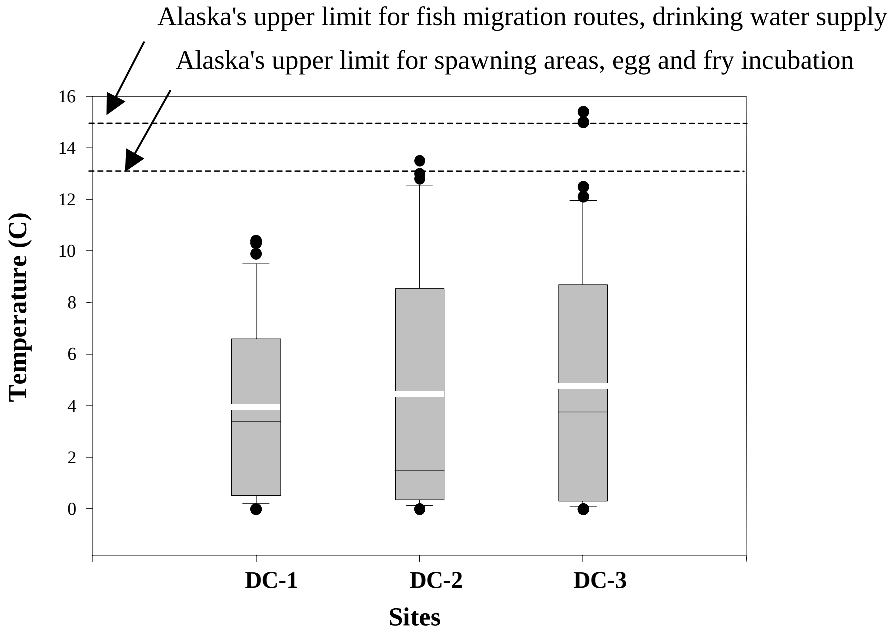


Figure 34. Water temperature measured by Cook Inlet Keeper on Deep Creek sites, 8/98-6/03.

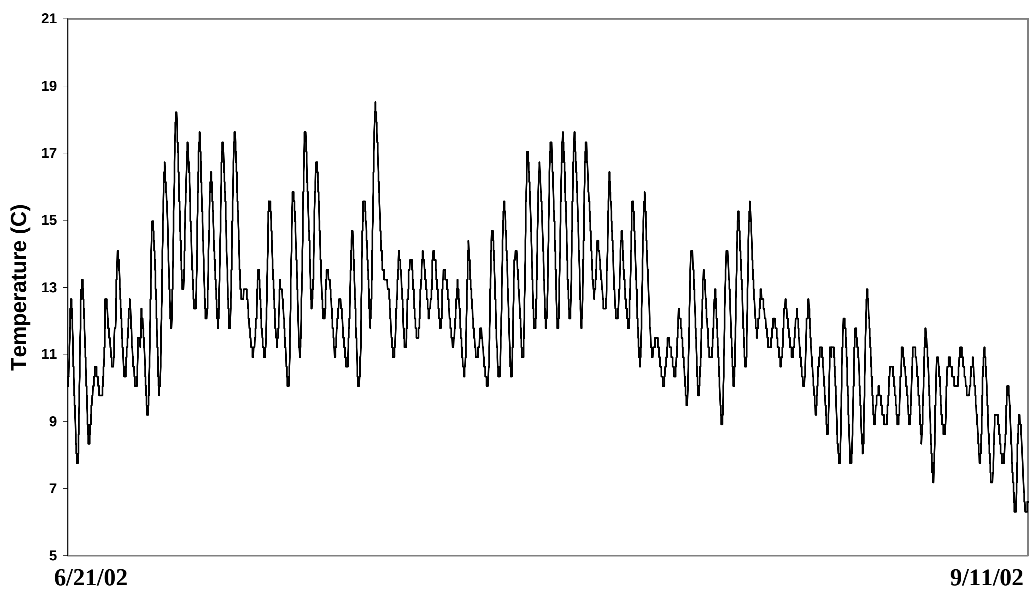


Figure 35. Continuous temperature logger data collected from 6/02-9/02 at the lower Deep Creek site.

Dissolved Oxygen

Dissolved oxygen concentrations at all sites were within the State of Alaska's range of 7 to 17 mg/L to protect aquatic life (Figure 36). All sites were at or below Alaska's limit for percent saturation of dissolved oxygen (Figure 37).

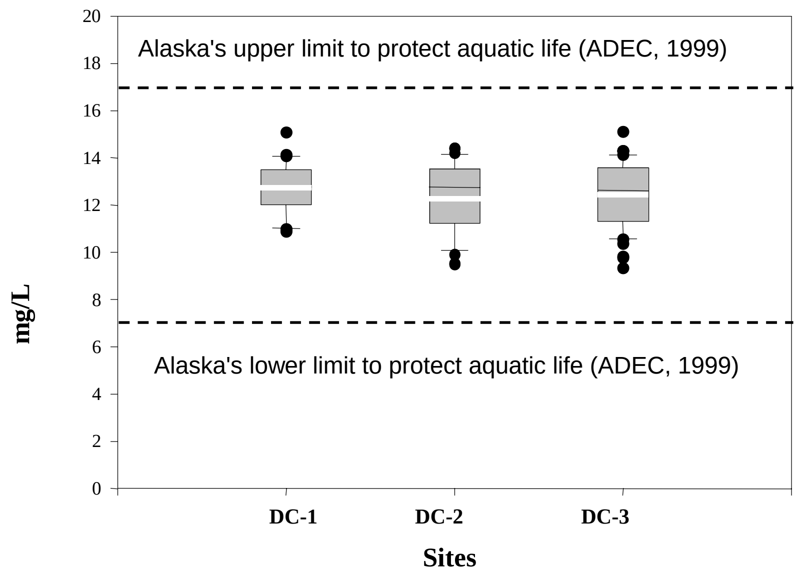


Figure 36. Dissolved oxygen concentrations measured by Cook Inlet Keeper on Deep Creek sites, 8/98-6/03.

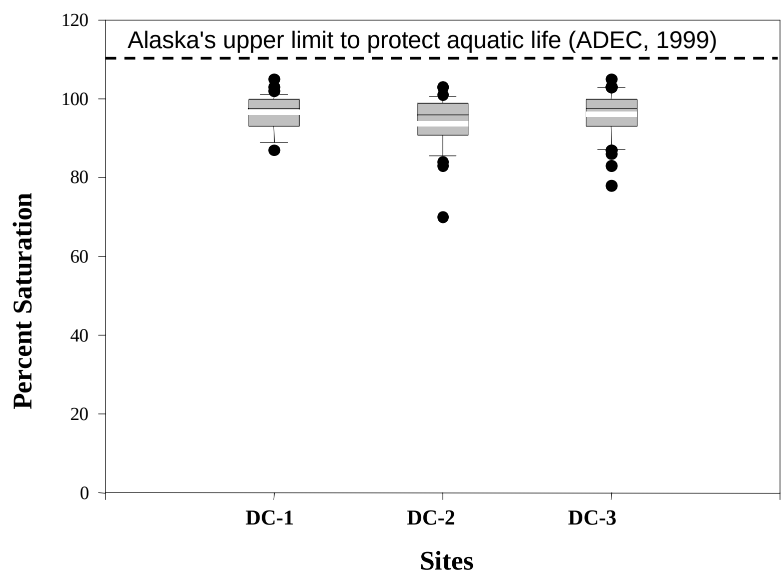


Figure 37. Percent saturation of dissolved oxygen measured by Cook Inlet Keeper on Deep Creek sites, 8/98-6/03.

pH

Most pH measurements were within Alaska's water quality standards (Figure 38). One measurement on the middle Deep Creek site fell below the standard to protect fish and wildlife at 6.46.

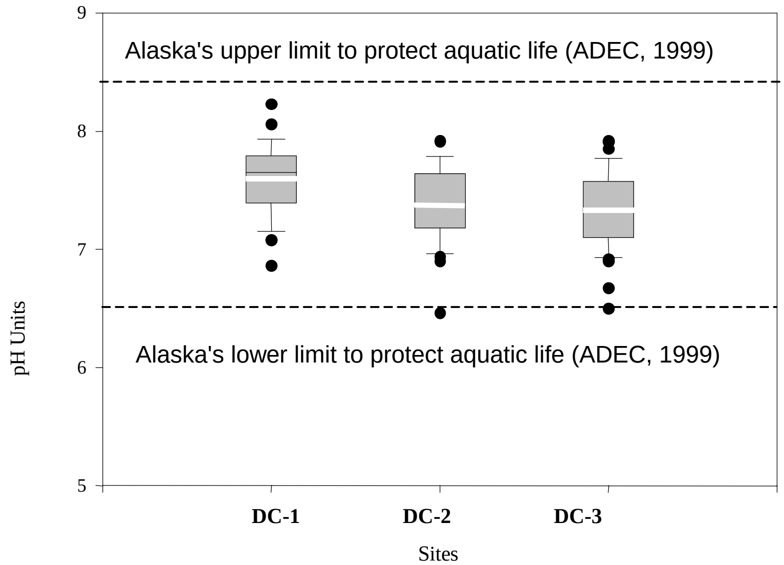


Figure 38. pH measured by Cook Inlet Keeper on Deep Creek sites, 8/98-6/03.

Total Dissolved Solids

All TDS measurements were within the state water quality standard of 500 mg/L for drinking water supply or 1000 mg/L to protect aquatic life (Figure 39).

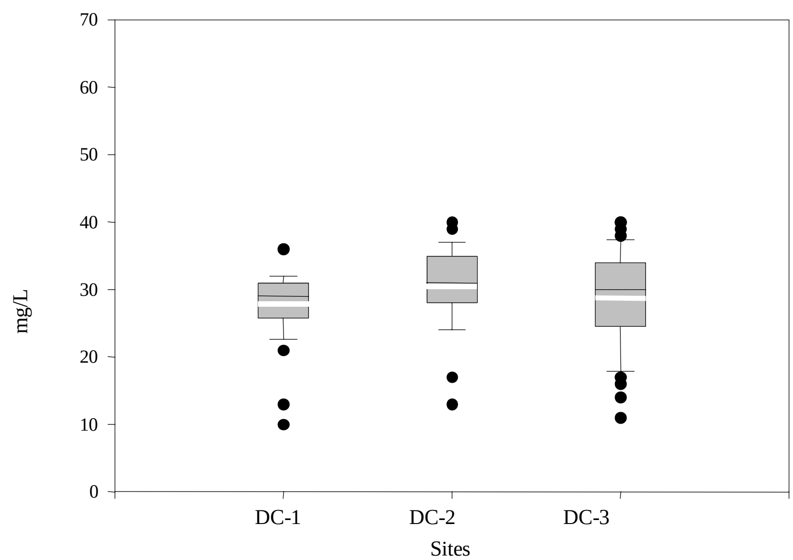


Figure 39. Total dissolved solids measured by Cook Inlet Keeper on Deep Creek sites, 8/98-6/03.

Conductivity

Conductivity measurements range from 22 μS/cm at the upper Deep Creek site to 84.7 μS/cm at middle Deep Creek sites (Figure 40).

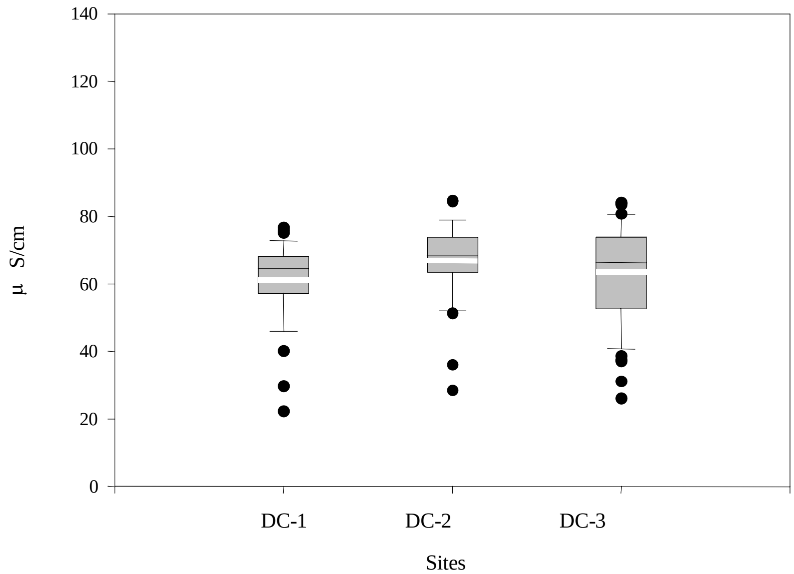


Figure 40. Conductivity measured by Cook Inlet Keeper on Deep Creek sites, 8/98 – 6/03.

Nitrate-nitrogen

Nitrate-nitrogen levels were far below 10.0 mg/L, Alaska's maximum contaminant level for drinking water (Figure 41).

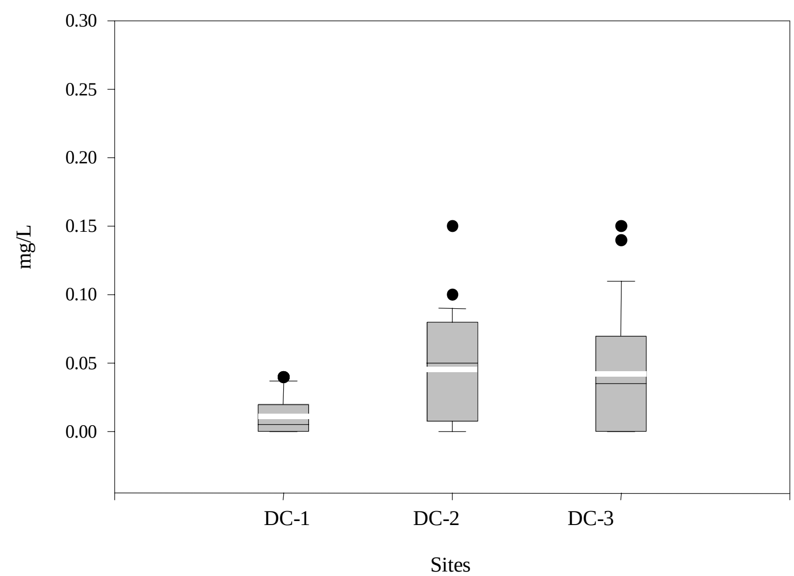
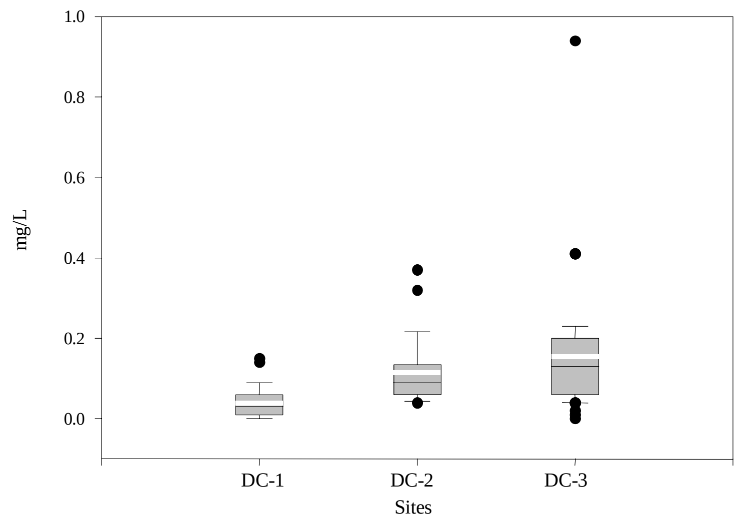


Figure 41. Nitrate-nitrogen concentrations measured by Cook Inlet Keeper on Deep Creek sites, 8/98 – 6/03.

Ammonia-nitrogen

Ammonia-nitrogen levels at all sites were within EPA's criteria to protect aquatic life (Figure 42). The measurement from lower Deep Creek was over range (>2.5 mg/L) on October 30, 2002. The highest value (0.94 mg/L) was measured on June 11, 2003.



Criteria: When the pH of a stream is 6.5, EPA's upper limit is 3.48 mg/L to protect aquatic life. When the pH of the stream is 8.0, EPA's upper limit is 127 mg/L (EPA, 1998).

Figure 42. Ammonia-nitrogen values measured by Cook Inlet Keeper on Deep Creek sites, 8/98-6/03.

Orthophosphate-phosphorus

The highest measurements for orthophosphate-phosphorus concentrations were taken at the lower Deep Creek site (DC-3) on October 30, 2002 (0.32 mg/L) and June 11, 2003 (0.19 mg/L) (Figure 43).

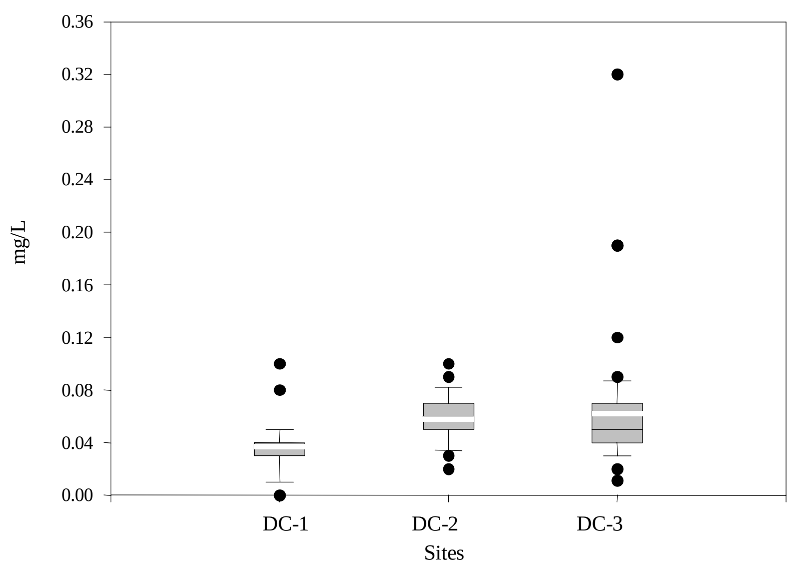


Figure 43. Orthophosphate-phosphorus concentrations measured by Cook Inlet Keeper on Deep Creek sites, 8/98-6/03.

Total Phosphorus

Zero percent (DC-1), fourteen percent (DC-2), and thirty-one percent (DC-3) of the total phosphorus measurements were above EPA's recommended level of 0.10 mg/L as phosphorus (Figure 44). The highest measurements were taken at the lower Deep Creek site on October 30, 2002 (0.72 mg/L) and June 11, 2003 (0.69 mg/L).

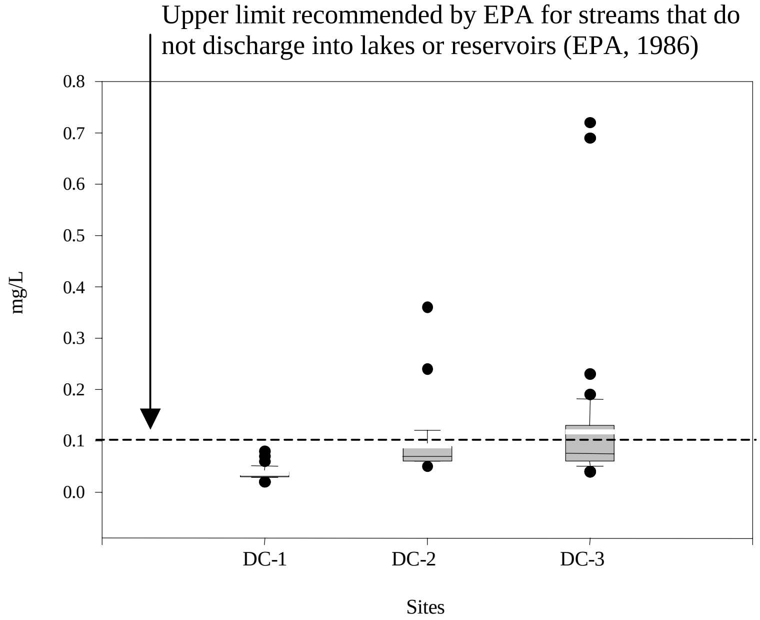


Figure 44. Total phosphorus measured by Cook Inlet Keeper on Deep Creek, 8/98-6/03.

Turbidity

The relationship of Keeper's turbidity data to state standards is difficult to determine because standards are described in relation to natural conditions rather than as specific values (Figure 45). The highest values were measured at lower Deep Creek on October 30, 2002 (915 NTUs) and June 11, 2003 (230 NTUs).

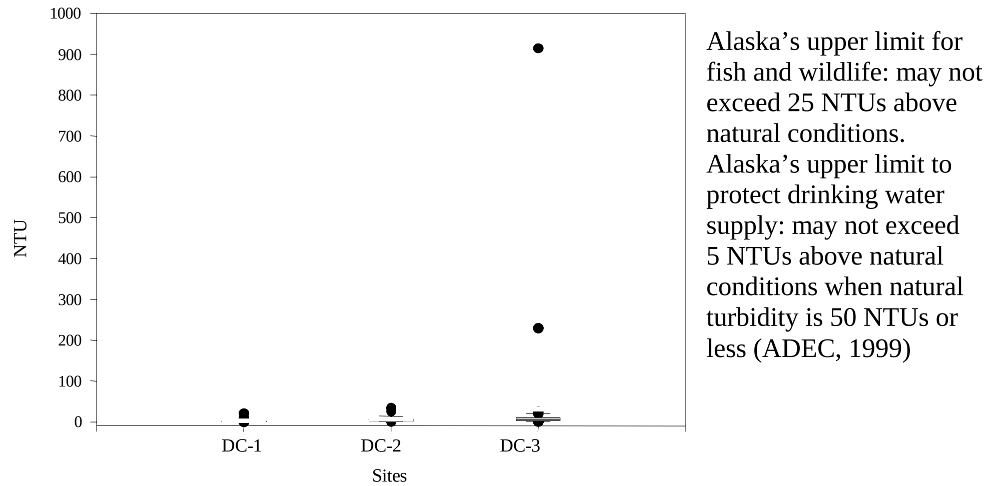
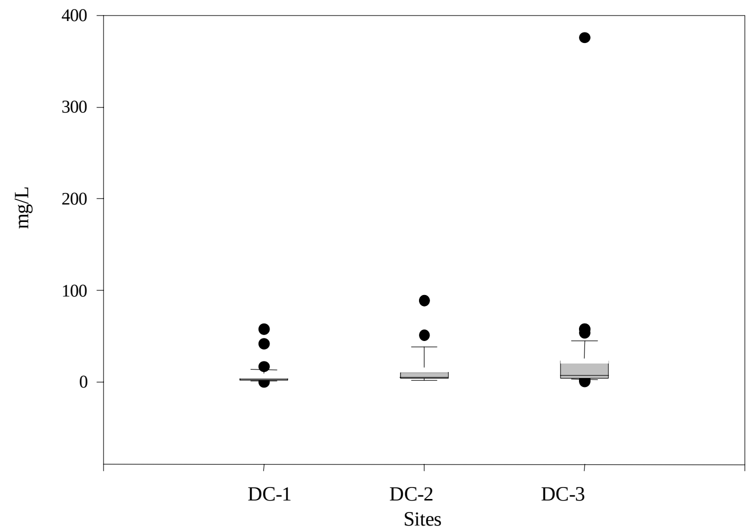


Figure 45. Turbidity measured by Cook Inlet Keeper on Deep Creek sites, 8/98-6/03.

Total Suspended Solids

Alaska's standard for sediment is defined in terms of habitat impairment rather than a concentration of suspended solids, so these data cannot be compared with a standard (Figure 46). The measurement from lower Deep Creek on October 30, 2002 was over-range (>750 mg/L). The highest recorded value (376 mg/L) was taken on June 11, 2003.



Standard: No sediment loads can cause adverse effects on aquatic, animal or plant life, their reproduction or habitat (ADEC, 1999).

Figure 46. Total suspended solids measured by Cook Inlet Keeper on Deep Creek sites, 8/98-6/03.

Settleable Solids

Settleable solids were measured in increments of 0.1 mg/L. Most values were between 0.0 and 0.1 mg/L which were recorded as 0.1 mg/L. All values at upper Deep Creek (DC-1) were ≤0.1 mg/L (Figure 47). The highest measurements were recorded on October 30, 2002 (2.1 mg/L) and June 11, 2003 (0.9 mg/L) at the lower site (DC-3).

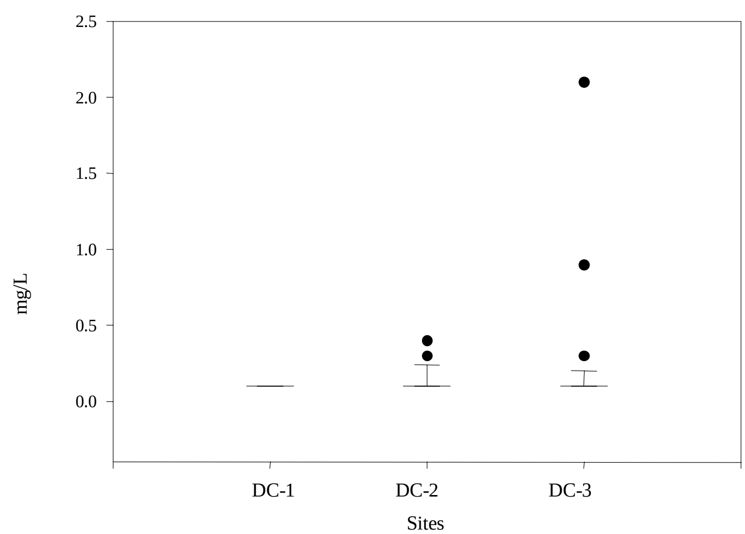


Figure 47. Settleable solids measured by Cook Inlet Keeper on Deep Creek, 8/99-6/03.

Apparent Color

The relationship of Keeper's color data to state standards is difficult to determine because the standards are described in relation to natural conditions rather than as a specific value (Figure 48). The measurements from lower Deep Creek were over range (>500) on October 30, 2002 and June 11, 2003.

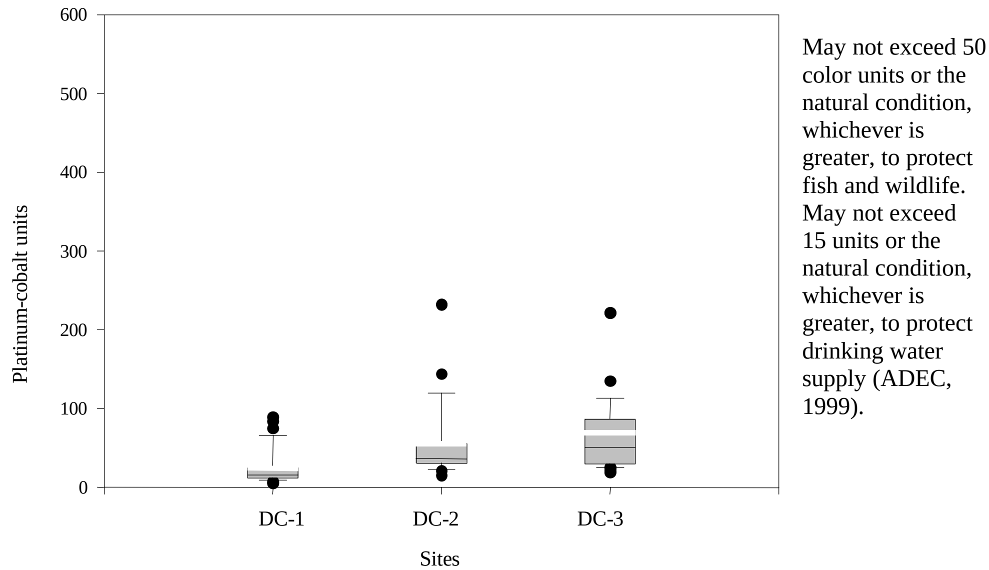
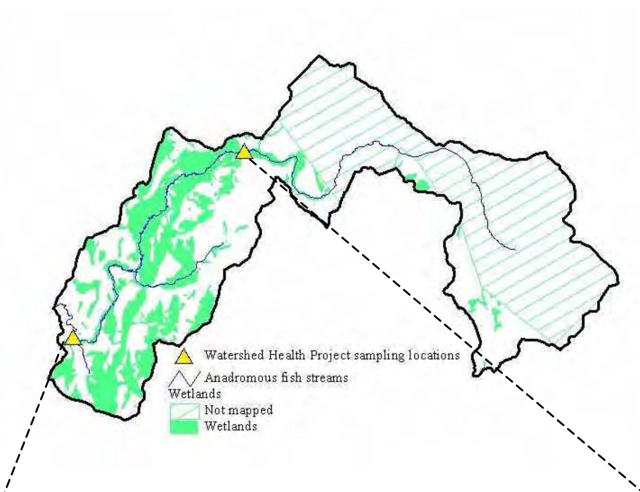


Figure 48. Apparent color measured by Cook Inlet Keeper on Deep Creek sites, 8/98-6/03.

Bark on upstream side of willows scoured off along the banks of upper Deep Creek following the October 2002 flood.

Stariski Creek Watershed



Lower Stariski Creek site: **SC-2**

Middle Stariski Creek site: **SC-1**

<u>Streamflow (discharge)</u>

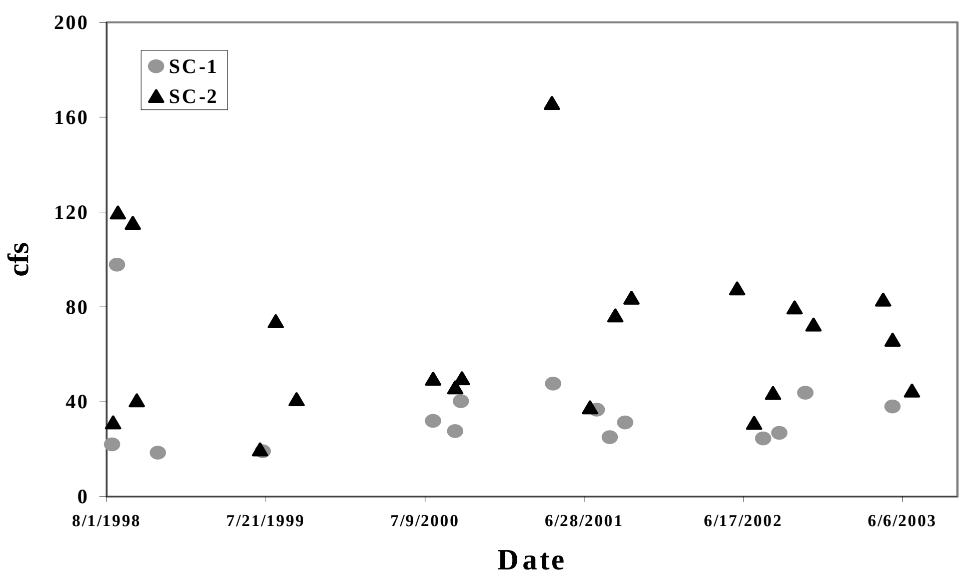


Figure 49. Discharge measurements for sites measured by Cook Inlet Keeper on Stariski Creek.

Water Temperature

Water temperature measurements in June 1999, and July 1999, 2000, and 2002 exceeded Alaska's water quality standards to protect cold-water fish habitat and drinking water supply at the lower Stariski Creek site (Figure 50).

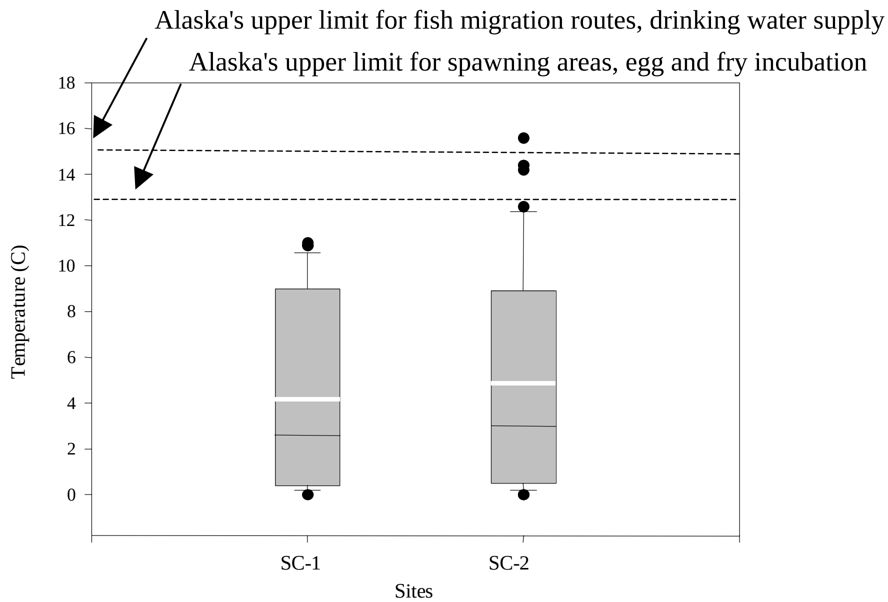


Figure 50. Water temperature measured by Cook Inlet Keeper on Stariski Creek sites, 8/98-6/03.

Dissolved Oxygen

Dissolved oxygen concentrations at all sites were within the State of Alaska's range of 7 to 17 mg/L to protect aquatic life (Figure 51). All sites were at or below Alaska's limit for percent saturation of dissolved oxygen (Figure 52).

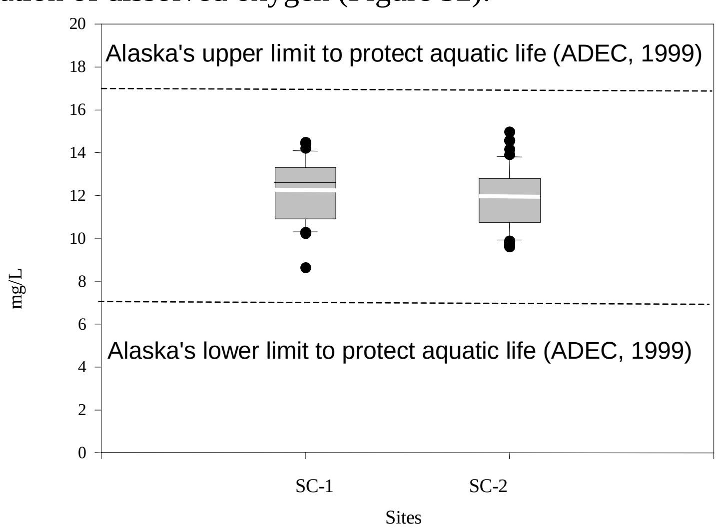


Figure 51. Dissolved oxygen concentrations measured by Cook Inlet Keeper on Stariski Creek sites, 8/98-6/03.

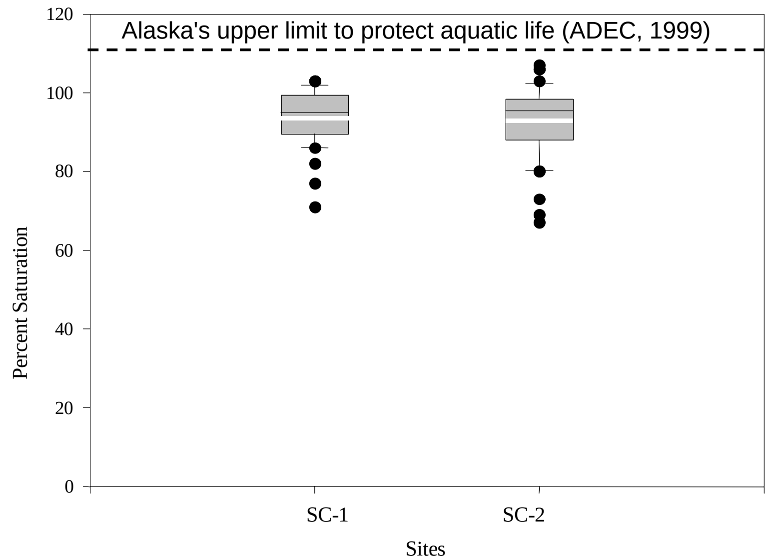


Figure 52. Percent saturation of dissolved oxygen measured by Cook Inlet Keeper on Stariski Creek sites, 8/98-6/03.

pH

Most pH measurements were within Alaska's water quality standards (Figure 53). Two measurements on the lower Stariski Creek site fell below the standard to protect fish and wildlife at 6.60 (12/99) and 6.19 (2/00).

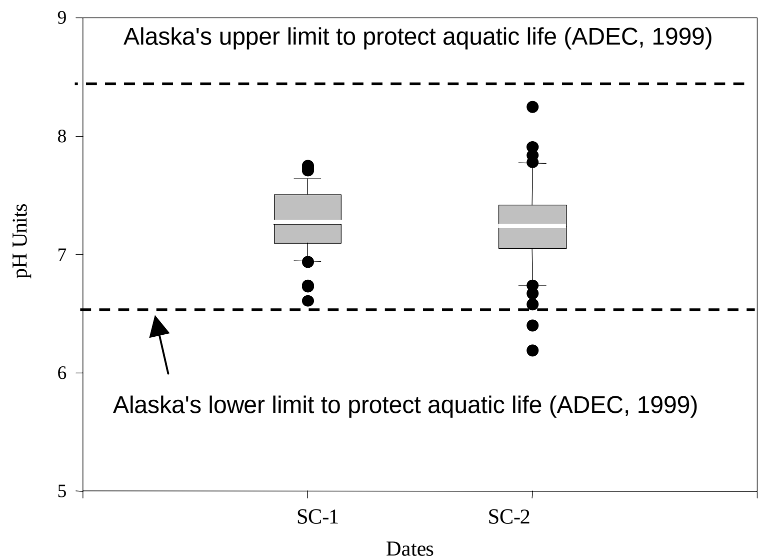


Figure 53. pH measured by Cook Inlet Keeper on Stariski Creek, 8/98-6/03.

Total Dissolved Solids

All TDS measurements were within the state water quality standard of 500 mg/L for drinking water supply or 1000 mg/L to protect aquatic life (Figure 54).

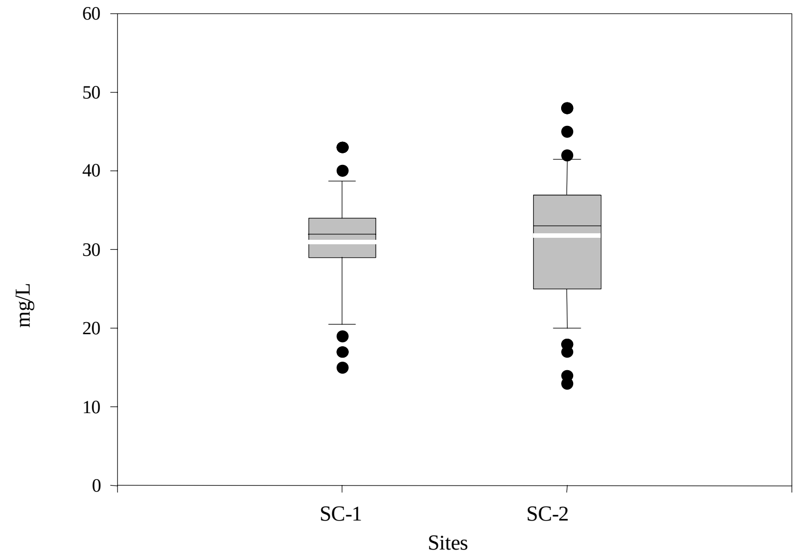


Figure 54. Total dissolved solids measured by Cook Inlet Keeper on Stariski Creek sites, 8/98-6/03.

Conductivity

Conductivity measurements range from 30.3 µS/cm at the lower Stariski Creek site to 115.4 µS/cm at middle Stariski Creek site (Figure 55).

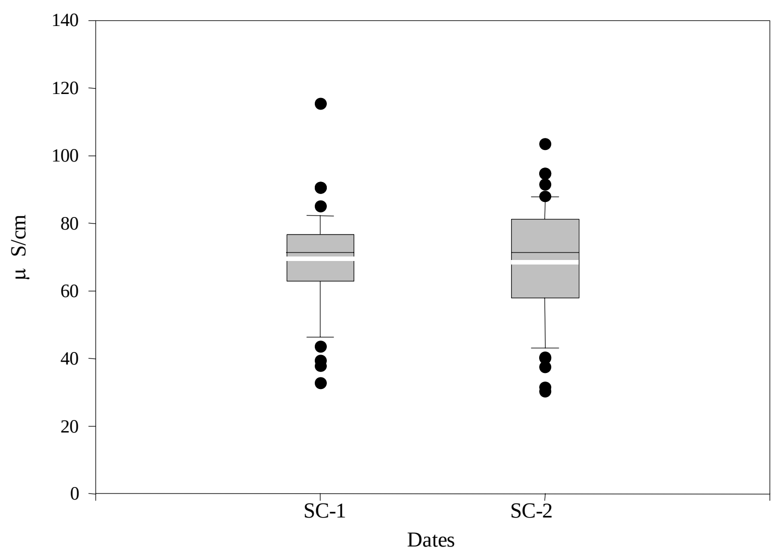


Figure 55. Conductivity measured by Cook Inlet Keeper on Stariski Creek sites, 8/98 – 6/03.

Nitrate-nitrogen

Nitrate-nitrogen levels were far below 10.0 mg/L, Alaska's maximum contaminant level for drinking water (Figure 56).

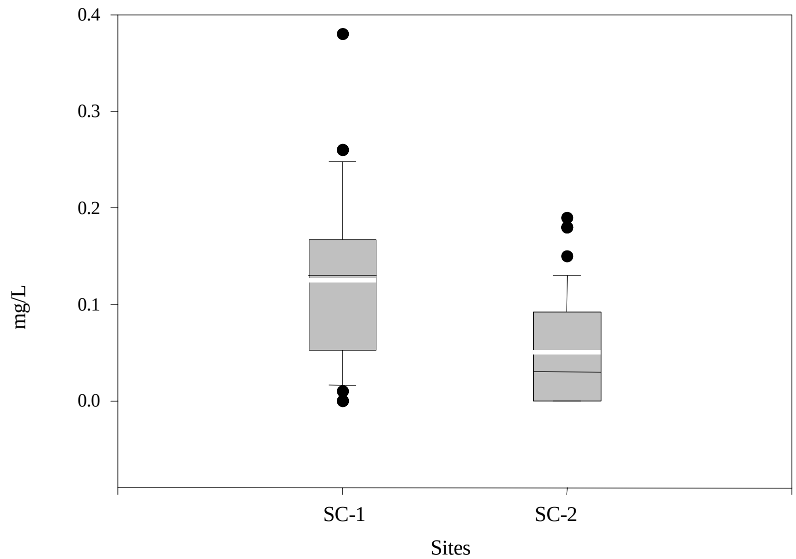
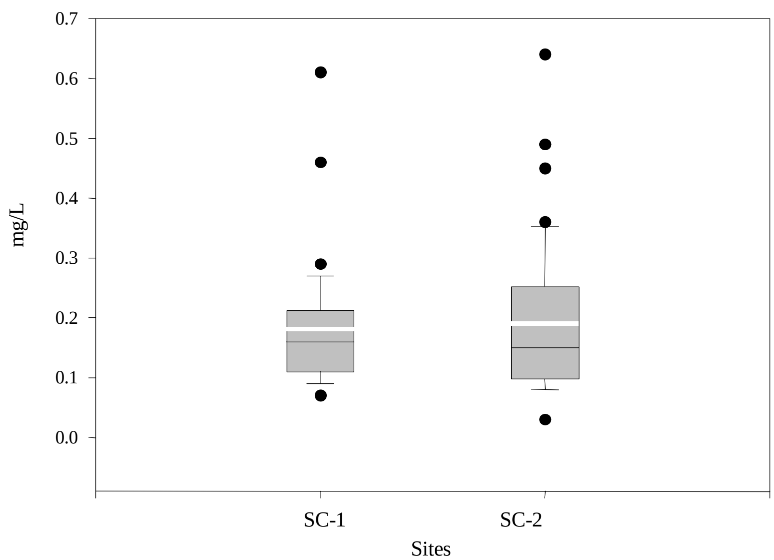


Figure 56. Nitrate-nitrogen concentrations measured by Cook Inlet Keeper on Stariski Creek sites, 8/98 – 6/03.

Ammonia-nitrogen

Ammonia-nitrogen levels at all sites were within EPA's criteria to protect aquatic life (Figure 57).



Criteria: When the pH of a stream is 6.5, EPA's upper limit is 3.48 mg/L to protect aquatic life. When the pH of the stream is 8.0, EPA's upper limit is 127 mg/L (EPA, 1998).

Figure 57. Ammonia-nitrogen values measured by Cook Inlet Keeper on Stariski Creek sites, 8/98-6/03.

Orthophosphate-phosphorus

Orthophosphate-phosphorus concentrations range from 0.02 mg/L to 0.17 mg/L at the middle Stariski Creek site (SC-1) (Figure 58).

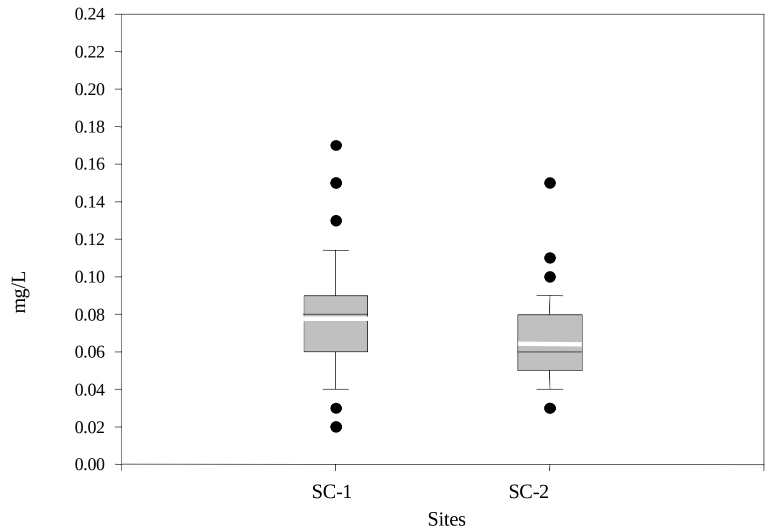


Figure 58. Orthophosphate-phosphorus concentrations measured by Cook Inlet Keeper on Stariski Creek sites, 8/98-6/03.

Total Phosphorus

Forty-four percent (SC-1) and thirty-nine percent (SC-2) of the total phosphorus measurements were above EPA's recommended level of 0.10 mg/L as phosphorus (Figure 59).

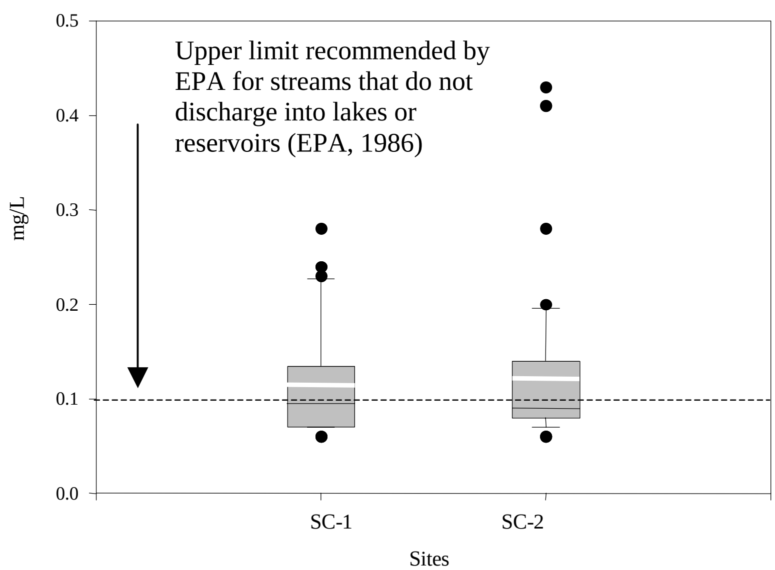
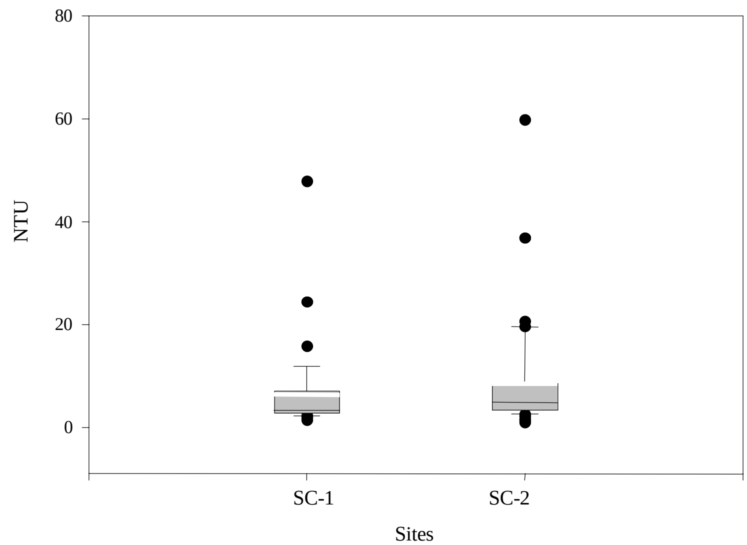


Figure 59. Total phosphorus measured by Cook Inlet Keeper on Stariski Creek sites, 8/98-6/03.

Turbidity

The relationship of Keeper's turbidity data to state standards is difficult to determine because the standards are described in relation to natural conditions rather than as a specific value (Figure 60).

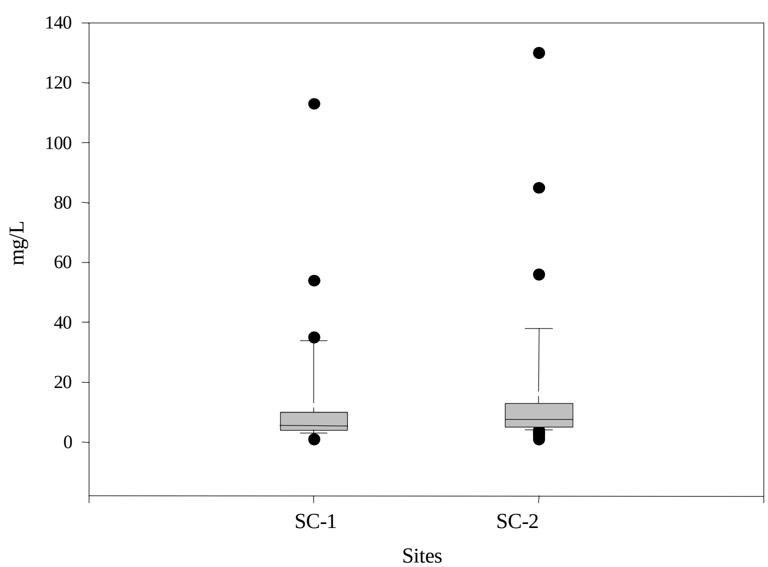


Alaska's upper limit for fish and wildlife: may not exceed 25 NTUs above natural conditions.
Alaska's upper limit to protect drinking water supply: may not exceed 5 NTUs above natural conditions when natural turbidity is 50 NTUs or less (ADEC, 1999)

Figure 60. Turbidity measured by Cook Inlet Keeper on Stariski Creek sites, 8/98-6/03.

Total Suspended Solids

Alaska's standard for sediment is defined in terms of habitat impairment rather than a concentration of suspended solids, so Keeper's suspended solids data cannot be compared with a standard (Figure 61).



Standard: No sediment loads can cause adverse effects on aquatic, animal or plant life, their reproduction or habitat (ADEC, 1999).

Figure 61. Total suspended solids measured by Cook Inlet Keeper on Stariski Creek sites, 8/98-6/03.

Settleable Solids

Settleable solids were measured in increments of 0.1 mg/L. Most values were between 0.0 and 0.1 mg/L which were recorded as 0.1 mg/L (Figure 62).

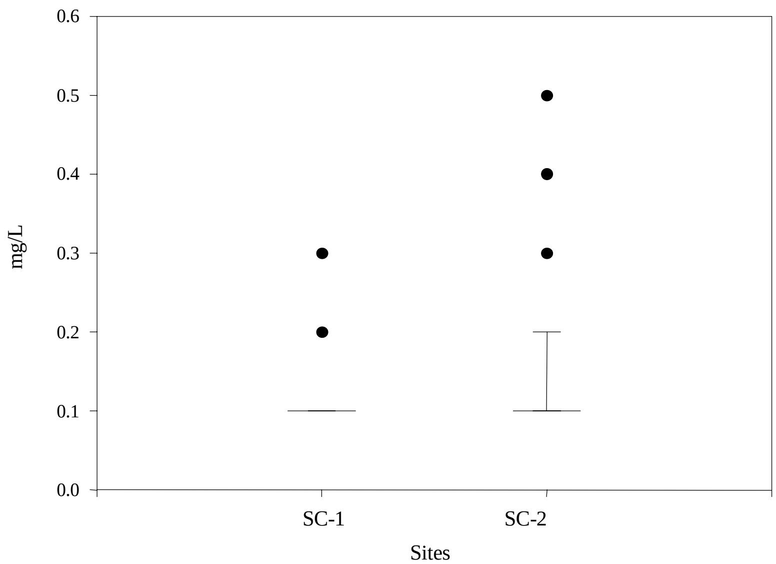
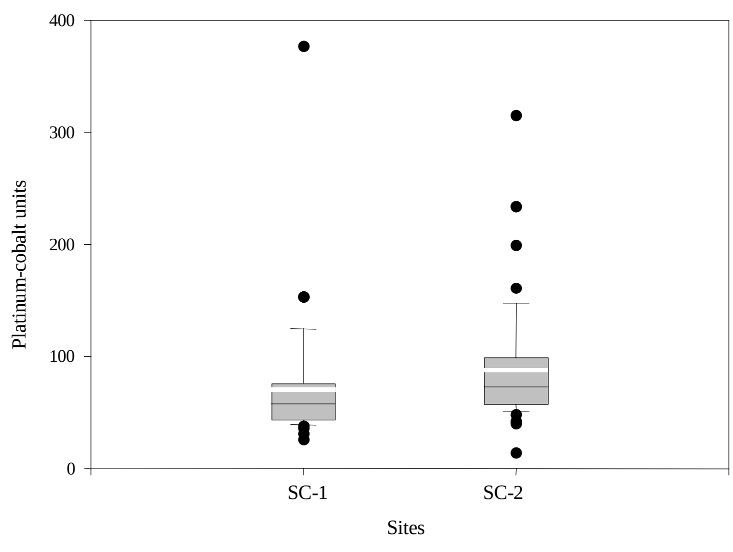


Figure 62. Settleable solids measured by Cook Inlet Keeper on Stariski Creek sites, 8/99-6/03.

Apparent Color

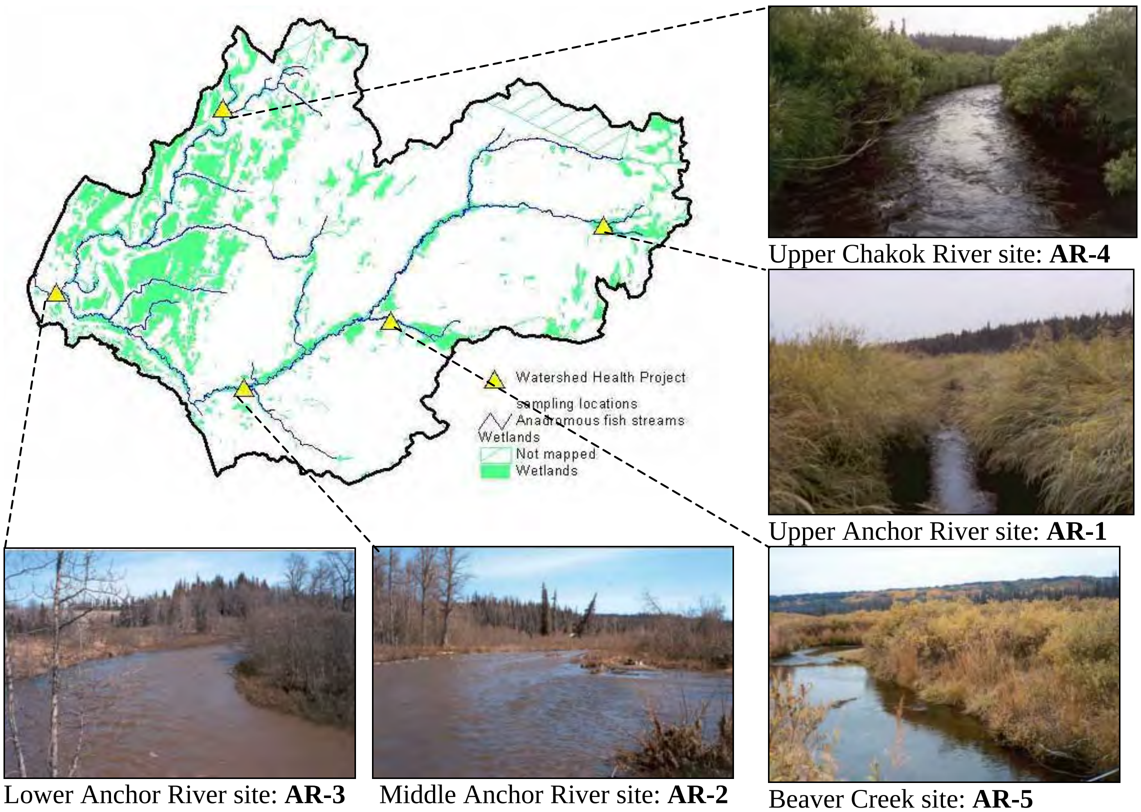
The relationship of Keeper's color data to state standards is difficult to determine because the standards are described in relation to natural conditions rather than as a specific value (Figure 63).



May not exceed 50 color units or the natural condition, whichever is greater, to protect fish and wildlife. May not exceed 15 units or the natural condition, whichever is greater, to protect drinking water supply (ADEC, 1999).

Figure 63. Apparent color measured by Cook Inlet Keeper on Stariski Creek sites, 8/98-6/03.

Anchor River Watershed



Streamflow (discharge)

Discharge data during high flow events (>300 cfs) has proven to be difficult to collect using methods for wadeable streams. In April and August 2001, USGS personnel worked with Keeper staff to collect high flow data using non-wadeable methods (Figure 64).

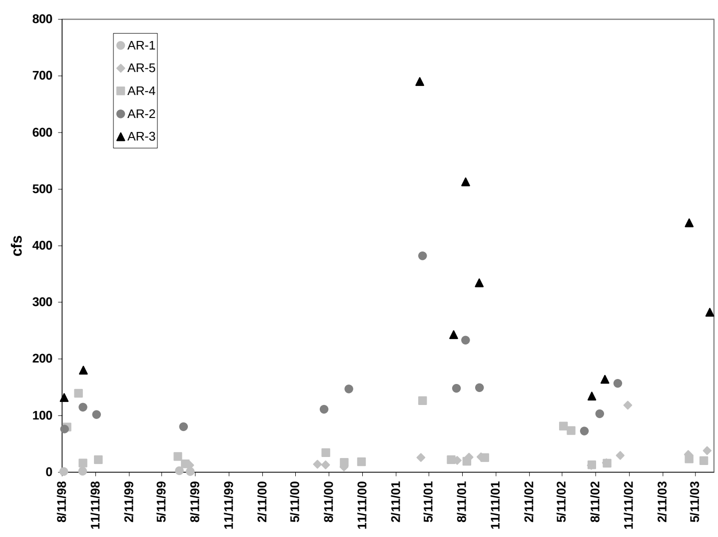


Figure 64. Discharge measurements taken by Cook Inlet Keeper on Anchor River sites.

Water Temperature

Water temperature measurements in August 1998, July 1999, July 2002, and June 2003 exceeded Alaska's water quality standards to protect cold-water fish habitat and drinking water supply at the lower Anchor River site (Figure 65). Data from a continuous temperature logger showed the frequency and extent of elevated temperatures at the lower Anchor River site. Temperatures exceeded 13^{o}C on 54 days with an average of 11.0 hours/day above 13^{o}C. Temperatures exceeded 15^{o}C on 32 days with an average of 8.4 hours/day above 15^{o}C (Figure 66).

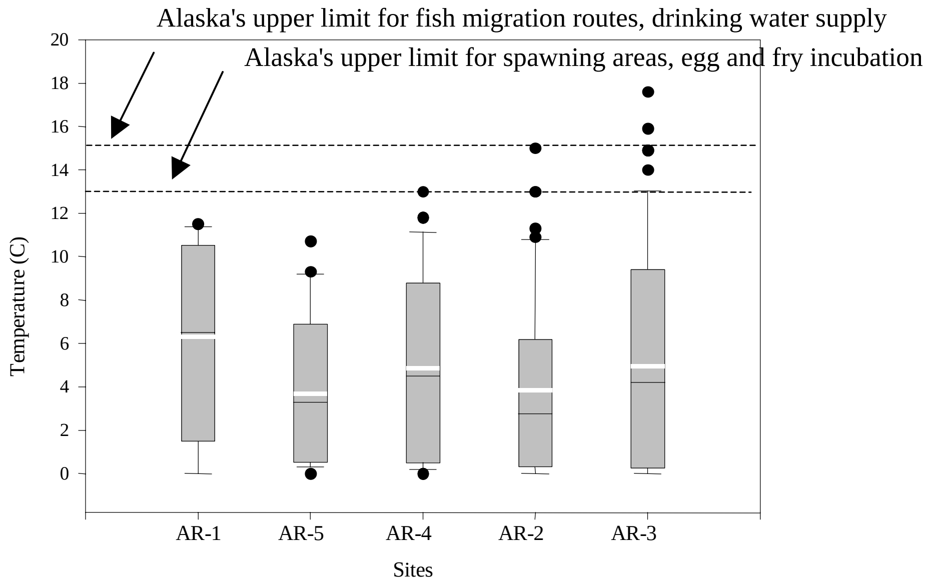


Figure 65. Water temperature measured by Cook Inlet Keeper on Anchor River sites, 8/98-6/03.

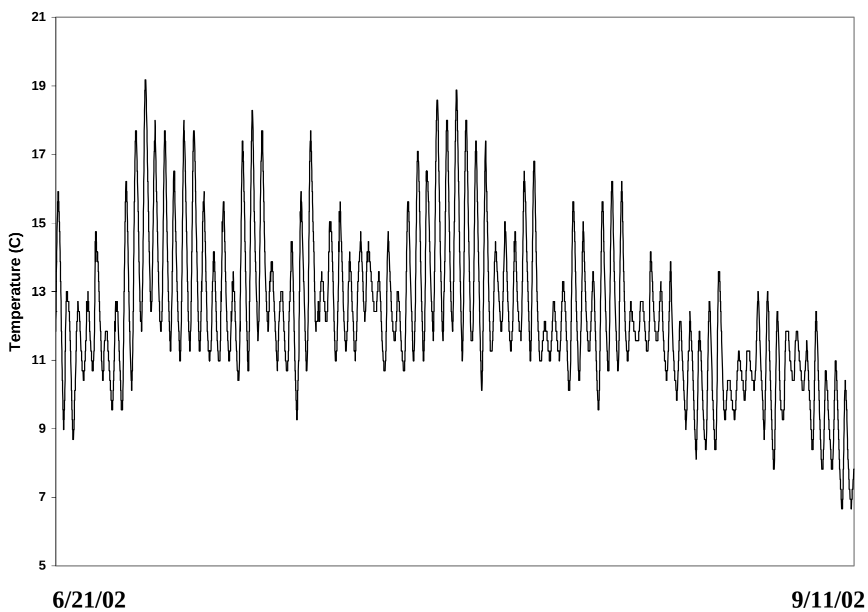


Figure 66. Continuous temperature logger data collected from 6/02 – 9/02 at the lower Anchor River site.

Dissolved Oxygen

Dissolved oxygen concentrations at all sites were within the State of Alaska's range of 7 to 17 mg/L to protect aquatic life (Figure 67). All sites were at or below Alaska's limit for percent saturation of dissolved oxygen (Figure 68).

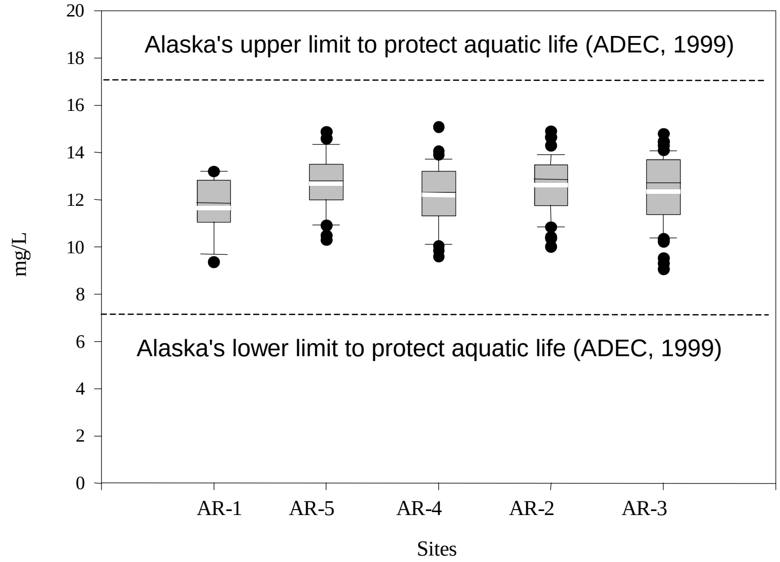


Figure 67. Dissolved oxygen concentrations measured by Cook Inlet Keeper on Anchor River sites, 8/98-6/03.

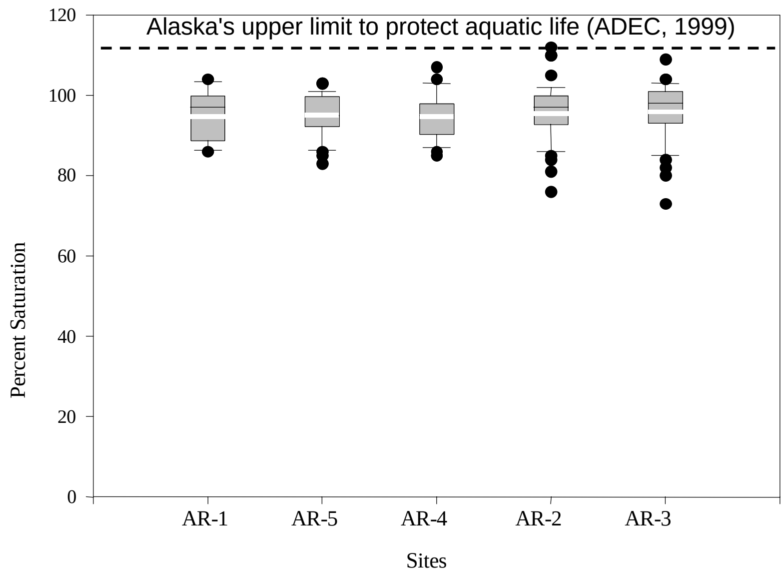


Figure 68. Percent saturation of dissolved oxygen measured by Cook Inlet Keeper on Anchor River sites, 8/98-6/03.

pH

Most pH measurements were within Alaska's water quality standards (Figure 69). Five measurements fell below the standard to protect fish and wildlife with a low reading of 6.20 at the lower Anchor River site.

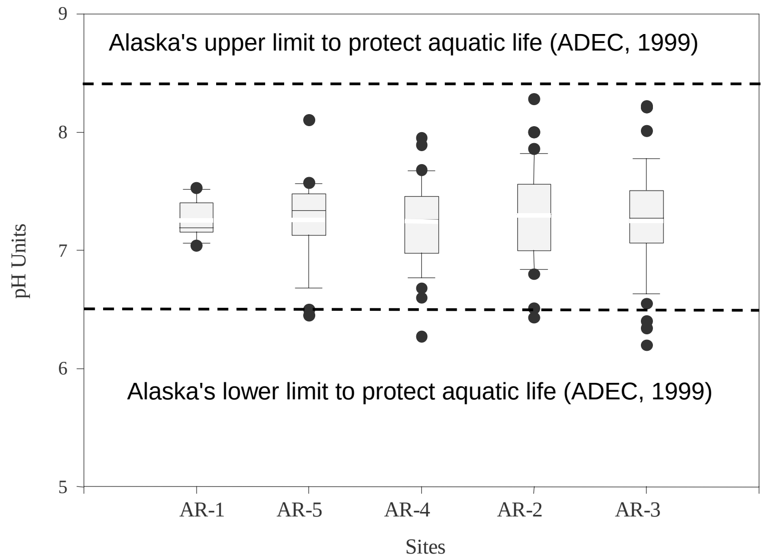


Figure 69. pH measured by Cook Inlet Keeper on Anchor River sites, 8/98-6/03.

Total Dissolved Solids

All TDS measurements were within the state water quality standard of 500 mg/L for drinking water supply or 1000 mg/L to protect aquatic life (Figure 70).

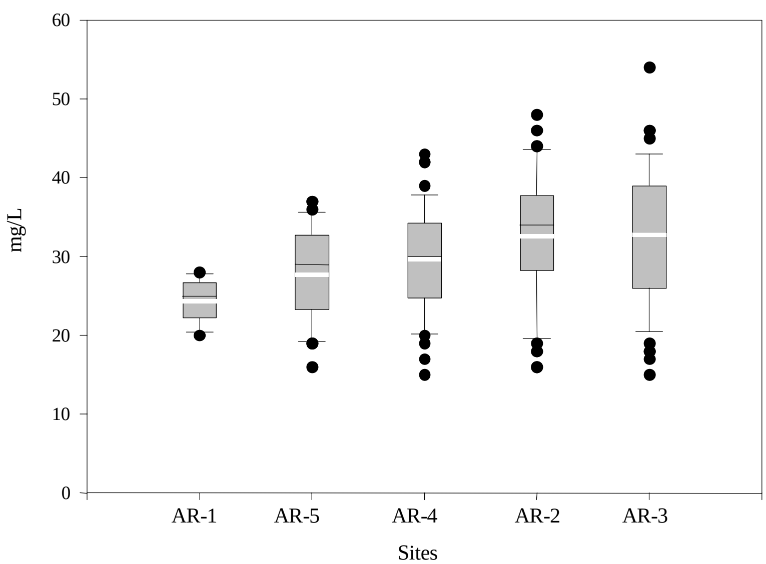


Figure 70. Total dissolved solids measured by Cook Inlet Keeper on Anchor River sites, 8/98-6/03.

Conductivity

Conductivity measurements range from 32.8 µS/cm at the upper Anchor River site to 118.5 µS/cm at the lower Anchor River site (Figure 71).

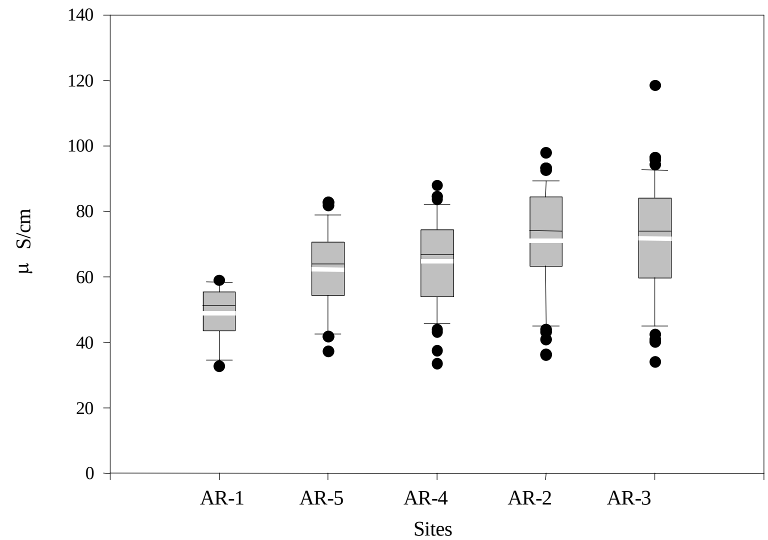


Figure 71. Conductivity measured by Cook Inlet Keeper on Anchor River sites, 8/98 – 6/03.

Nitrate-nitrogen

Nitrate-nitrogen levels were far below 10.0 mg/L, Alaska's maximum contaminant level for drinking water (Figure 72).

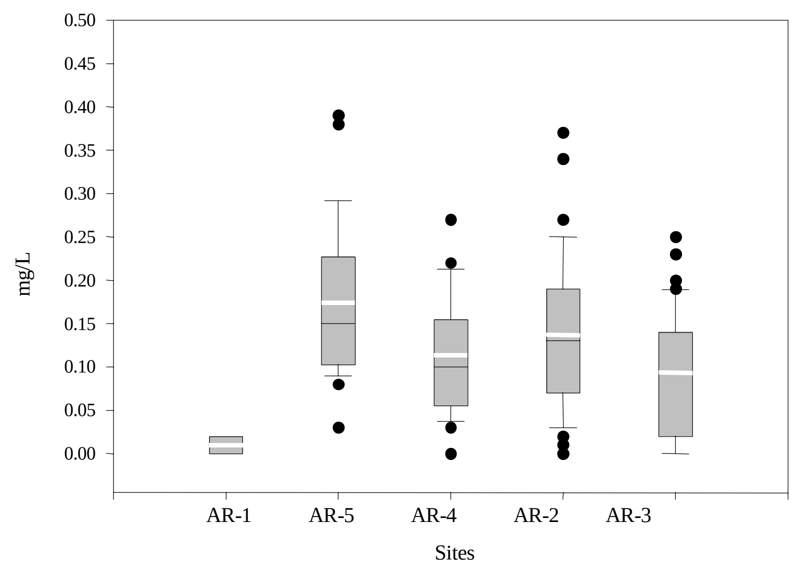
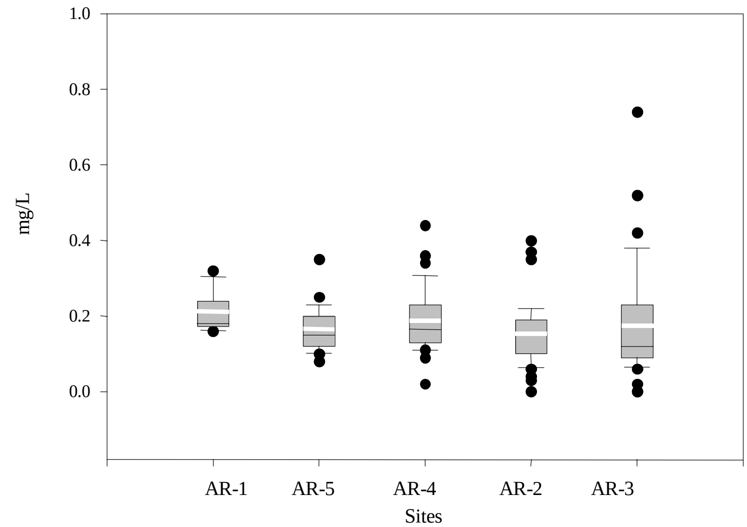


Figure 72. Nitrate-nitrogen concentrations measured by Cook Inlet Keeper on Anchor River sites, 8/98 – 6/03.

Ammonia-nitrogen

Ammonia-nitrogen levels at all sites were within EPA's criteria to protect aquatic life (Figure 73).



Criteria: When the pH of a stream is 6.5, EPA's upper limit is 3.48 mg/L to protect aquatic life. When the pH of the stream is 8.0, EPA's upper limit is 127 mg/L (EPA, 1998).

Figure 73. Ammonia-nitrogen values measured by Cook Inlet Keeper on Anchor River sites, 8/98-6/03.

Orthophosphate-phosphorus

Orthophosphate-phosphorus concentrations range from 0.00 mg/L at the lower Anchor River site (AR-3) to 0.19 mg/L at the middle Anchor River site (AR-2) (Figure 74).

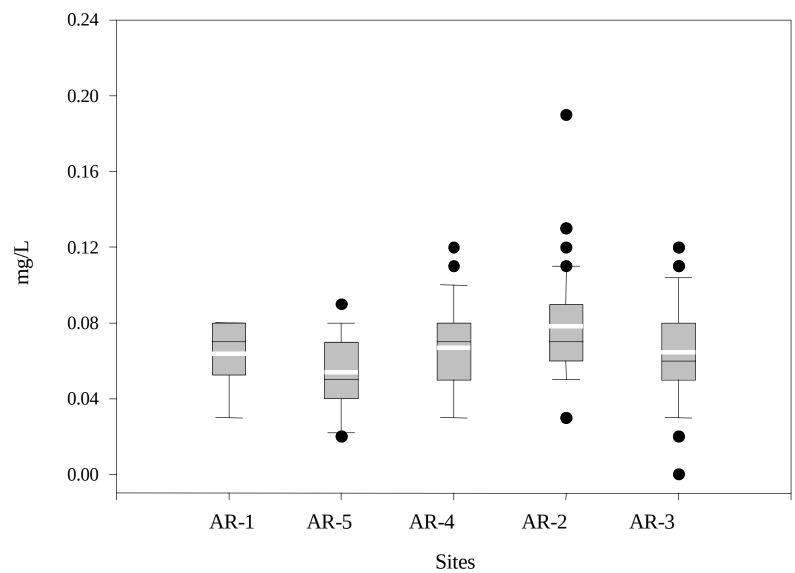


Figure 74. Orthophosphate-phosphorus concentrations measured by Cook Inlet Keeper on Anchor River sites, 8/98-6/03.

Total Phosphorus

Seventeen percent (AR-1), seven percent (AR-5), fourteen percent (AR-4), thirty-four percent (AR-2), and twenty-seven percent (AR-3) of the total phosphorus measurements were above EPA's recommended level of 0.10 mg/L as phosphorus (Figure 75).

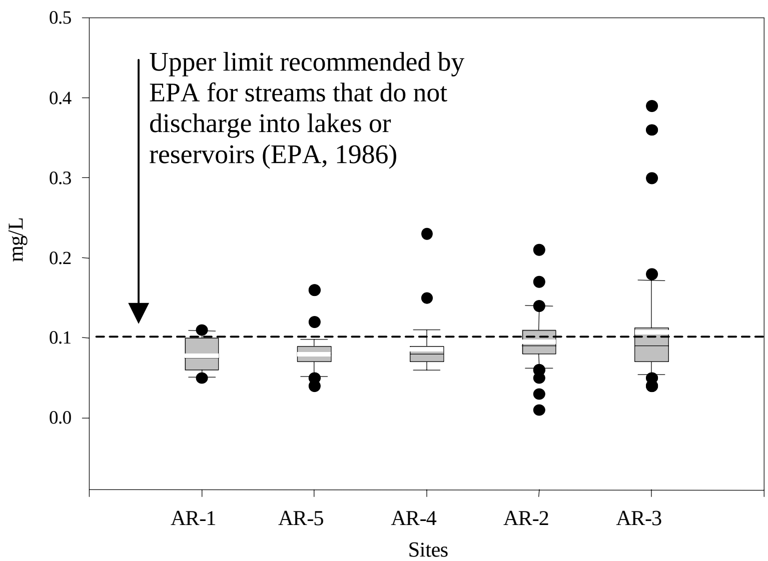


Figure 75. Total phosphorus measured by Cook Inlet Keeper on Anchor River sites, 8/98-6/03.

Turbidity

The relationship of Keeper's turbidity data to state standards is difficult to determine because the standards are described in relation to natural conditions rather than as a specific value (Figure 76).

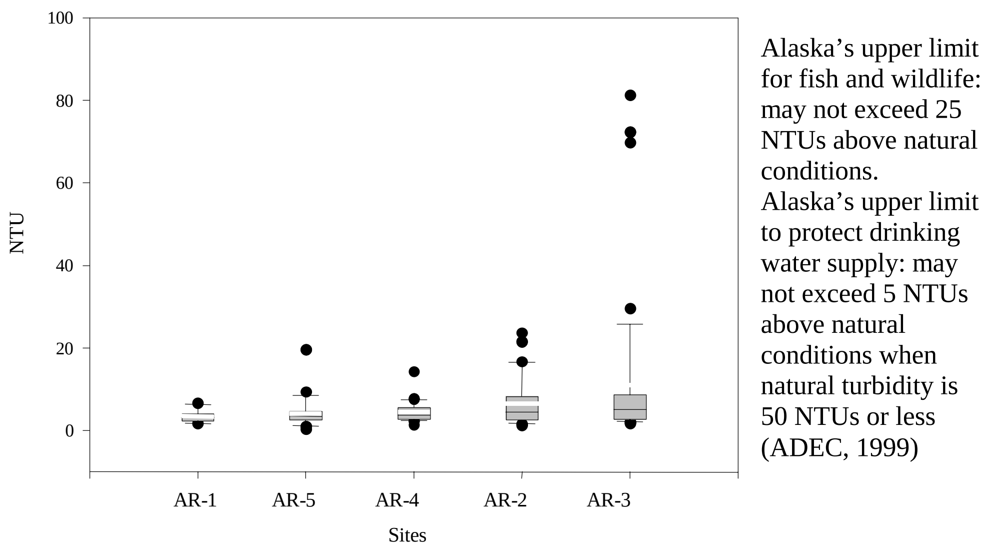
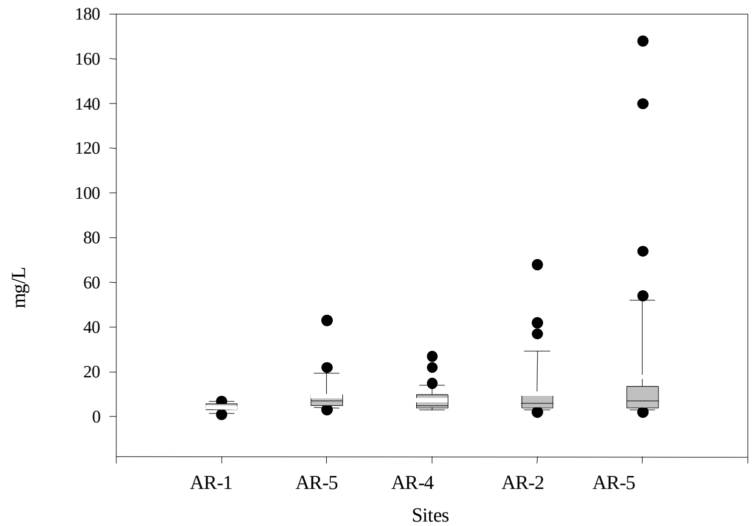


Figure 76. Turbidity measured by Cook Inlet Keeper on Anchor River sites, 8/98-6/03.

Total Suspended Solids

Alaska's standard for sediment is defined in terms of habitat impairment rather than a concentration of suspended solids, so Keeper's suspended solids data cannot be compared with a standard (Figure 77).



Standard: No sediment loads can cause adverse effects on aquatic, animal or plant life, their reproduction or habitat (ADEC, 1999).

Figure 77. Total suspended solids measured by Cook Inlet Keeper on Anchor River sites, 8/98-6/03.

Settleable Solids

Settleable solids were measured in increments of 0.1 mg/L. Most values were between 0.0 and 0.1 mg/L which were recorded as 0.1 mg/L. All values at Beaver Creek (AR-5) and upper Chakok River (AR-4) were ≤0.1 mg/L (Figure 78). No settleable solids data were collected on the upper Anchor River site (AR-1).

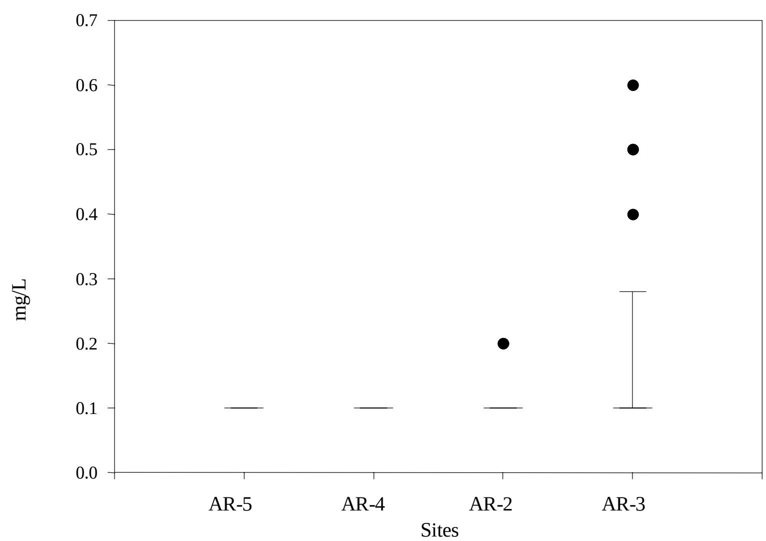


Figure 78. Settleable solids measured by Cook Inlet Keeper on Anchor River sites, 8/99-6/03.

Apparent Color

The relationship of Keeper's color data to state standards is difficult to determine because the standards are described in relation to natural conditions rather than as a specific value (Figure 79).

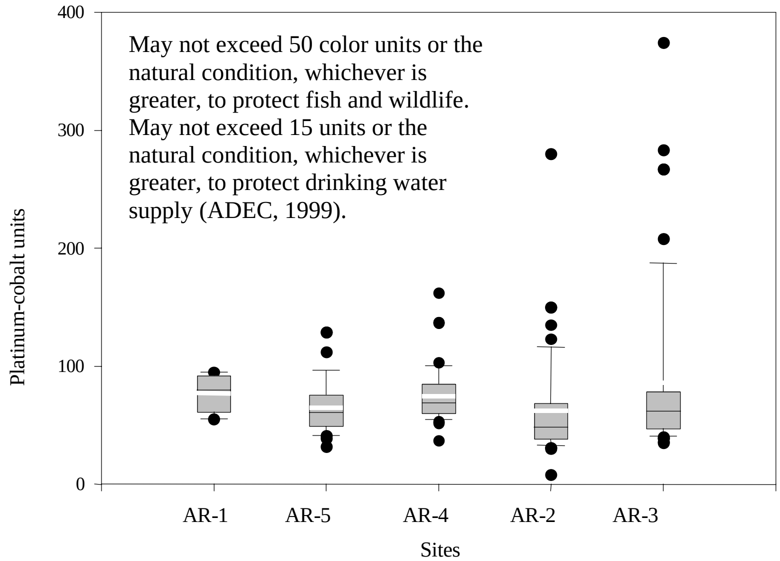


Figure 79. Apparent color measured by Cook Inlet Keeper on Anchor River sites, 8/98-6/03.

The left photo, taken on August 22, 2002, and right photo, taken on July 17, 2003, show a shift in the stream channel caused by a fallen cottonwood tree at the middle Anchor River site. King salmon were seen spawning in 2002 at a spot now six feet under newly deposited gravels from the 2002 Fall floods.

WATER QUALITY DATA SUMMARY
AUGUST 1998-JUNE 2003

Summary

Cook Inlet Keeper and the Homer Soil and Water Conservation District have been monitoring water quality on Ninilchik River, Deep Creek, Stariski Creek, and Anchor River since August 1998 to document current water quality conditions and compare current conditions with the water quality standards that the State of Alaska has developed. Based on these data the water quality of the four rivers is high in general. However, some measurements for temperature and pH fall outside the ranges set by the State of Alaska to protect its waters. Thirty percent of the total phosphorus measurements are above the level suggested by EPA for streams and rivers.

On Ninilchik River:

- USGS stream gauge recorded high flows from the Fall 2002 floods as 5,800 cfs on October 24 and 1,600 cfs on November 24.
- Water temperatures in June, July, and August 1999 and July 2000 at the lower site were above 13^{o}C, Alaska's upper limit for spawning areas, egg and fry incubation. Temperatures exceeded 13^{o}C on 56 days and 15^{o}C on 35 days in summer 2002.
- Five pH measurements were below Alaska's lower limit to protect aquatic life.
- 47% of the total phosphorus measurements were above EPA's suggested level.

On Deep Creek:

- Water temperatures in July 1999 at the middle and lower sites were above 13^{o}C, Alaska's upper limit for spawning areas, egg and fry incubation. Temperatures exceeded 13^{o}C on 50 days and 15^{o}C on 28 days in summer 2002.
- One pH measurement was below Alaska's lower limit to protect aquatic life.
- 17% of the total phosphorus measurements were above EPA's suggested level.
- Highest recorded values for ammonia, orthophosphate, total phosphorus, turbidity, total suspended solids, seattleable solids and color occurred on October 30, 2002 and June 11, 2003.

On Stariski Creek:

- Water temperatures in June 1999, and July 1999, 2000, 2002 were above 13^{o}C, Alaska's upper limit for spawning areas, egg and fry incubation at the lower site.
- Two pH measurements were below Alaska's lower limit to protect aquatic life.
- 41% of the total phosphorus measurements were above EPA's suggested level.

On Anchor River:

- Water temperatures in August 1998, July 1999, June 2003 at the lower site were above 13^{o}C, Alaska's upper limit for spawning areas, egg and fry incubation. Temperatures exceeded 13^{o}C on 54 days and 15^{o}C on 32 days in summer 2002.
- Five pH measurements were below Alaska's lower limit to protect aquatic life.
- 22% of the total phosphorus measurements were above EPA's suggested level.

Data for turbidity, total suspended solids, and apparent color are difficult to relate to state standards because they are described in relation to natural conditions rather than as a specific value. Keeper's data should be valuable in determining what the natural conditions are for these streams, although some land-use changes may have already occurred that affect these water quality parameters.

With data from the Ninilchik River stream gauge, the following patterns are apparent:
- high stream flows deliver higher concentrations of ammonia-nitrogen, total phosphorus, turbidity, suspended solids, and color.
- low stream flows deliver higher conductivity and total dissolved solids.

Differences in water quality parameters between watershed were apparent (See Cook Inlet Keeper, 2001 for analysis):
- significant differences were found between the watersheds for conductivity, total dissolved solids, nitrate-nitrogen, and orthophosphate.

COMPARISONS WITH HISTORICAL DATA

Keeper compared current water quality data from the Lower Kenai Peninsula Watershed Health Project with historical data collected by the USGS between 1950 and 1970 (See Cook Inlet Keeper, 2001 for analysis). Keeper compared temperature, conductivity, total dissolved solids, nitrate-nitrogen, total suspended solids, and apparent color data collected by the two organizations at four sites.

Differences between past and present data can best be explained by differences in methods rather than by changes in water quality. Keeper and USGS used different methods for total dissolved solids, nitrate-nitrogen, suspended solids, and apparent color. USGS's methods for total dissolved solids and nitrate-nitrogen may be incorporated into Keeper's protocols in the future when funds for new laboratory equipment become available. Differences in sampling time and frequency may also account for different results. In particular, the USGS captured a greater range of total suspended solids concentrations then Keeper by sampling a greater range of flow conditions.

Comparisons between USGS data from 1950 - 1970 and Lower Kenai Peninsula Watershed Health Project data from August 1998 - June 2001 showed the following:
- temperature measurements were similar between the two time periods;
- conductivity measurements were similar between the two time periods;
- total dissolved solids measured by the USGS were higher than values measured by Keeper;
- nitrate-nitrogen concentrations measured by the USGS were higher than measured by Keeper;
- total suspended solids concentrations measured by the USGS showed greater variability than Keeper data; and
- apparent color levels measured by the USGS were generally lower than those measured by Keeper.

DIRECTIONS FOR FUTURE MONITORING

Monitoring needs to continue on the lower Kenai Peninsula's salmon streams to investigate concerns about high water temperatures, elevated phosphorus levels, increasing sedimentation, and post-flood habitat recovery. Monitoring is imperative to provide adequate baseline information to track changes in these watersheds, which are experiencing dramatic increases in land-use activity, to ensure they do not become impaired waterbodies.

Although data collected by Cook Inlet Keeper show that water quality in Ninilchik River, Deep Creek, Stariski Creek, and Anchor River is usually within Alaska's water quality standards, elevated temperature levels may pose risks to these important salmon streams. Keeper's monitoring has revealed that summer temperature levels consistently exceed Alaska's standards. Water temperature is one of the most significant factors in the health of stream ecosystems. Temperature affects salmon egg and fry incubation, fish metabolism, organisms' resistance to disease, and availability of oxygen and nutrients to fish and wildlife. To determine the frequency and duration of elevated temperatures, Keeper deployed temperature loggers in the lower reaches of the Ninilchik River, Deep Creek, and Anchor River in June 2002. Data from these loggers suggest that water temperatures exceeded state standards more than 50 days during summer months.

Extensive historical temperature data are not available so there is no way to be certain if these elevated temperatures are typical of these systems. However, a recent USGS report suggests that streams within the Cook Inlet Basin may experience a water temperature change of 3^{o}C in the coming years. This is based on a model that uses air temperature to predict water temperature and simulates future trends in water temperature based on increased air temperature due to climate warming. Ninilchik River was one of the 15 sites predicted to see a 3^{o}C change, a magnitude of change that is considered significant for the incidence of disease in fish populations (Kyle and Brabets, 2001). Keeper deployed temperature loggers again in June 2003 to continue to track the extent of elevated summer temperatures in all four streams. These data will be presented in future monitoring reports.

Throughout the past four years of the salmon stream monitoring program, thirty percent of the total phosphorus measurements exceeded 0.1 mg/L (100 µg/L), the level recommended by EPA for streams and rivers that do not drain into lakes and reservoirs (EPA, 1986). This level is only recommended, however, and EPA is currently developing better ways to estimate appropriate levels of phosphorus. A more recent report developed for the Western Forested Mountains (Nutrient Ecoregion II) cites 0.01 mg/L (10 µg/L) as the recommended level for streams and rivers (EPA, 2000). Nutrient Ecoregion II includes all or parts of the States of Washington, Oregon, California, Idaho, Montana, Wyoming, Utah, South Dakota, New Mexico, and Arizona. EPA has not yet developed nutrient criteria for Alaska.

The elevated phosphorus levels on the lower Kenai Peninsula streams may be due, in part, to the volcanic origin and sedimentary geology of the region; however, phosphorus levels often increase with sediment inputs into streams. Sediment levels rise with increased stream discharge and land-use activity. It is likely that urban development, logging, mining, road construction, all-terrain vehicle use, and wetlands development play a role in increasing sediment input and thus increasing phosphorus levels in these salmon streams. And while phosphorus is a nutrient crucial to aquatic life, it is considered a contaminant at high levels. At high concentrations, phosphorus can cause algal blooms resulting in dramatic decreases in dissolved oxygen concentrations.

Many measurements of orthophosphate, which is an inorganic dissolved form of phosphorus and is biologically available, were also above the EPA recommended level for total phosphorus. There are no federal or state standards for orthophosphate levels. More information is needed to determine whether the observed phosphorus levels are naturally occurring and whether increased sedimentation is exacerbating the problem and threatening to degrade the water quality in these watersheds. To address these sediment concerns, Cook Inlet Keeper and the Homer Soil and Water Conservation District, in collaboration with Community Rivers Planning Coalition, have secured an EPA Wetlands Development Grant to examine turbidity patterns in the Anchor River. Turbidity is an indicator of suspended sediments in the water column. This grant will increase our understanding of sediments levels and its relationship to streams discharge. By establishing a number of turbidity stations, we will learn which land-use activities are contributing a disproportionate amount of sediment into stream channels.

Alaska’s standards for turbidity and total suspended solids are difficult to use as they require an understanding of natural conditions which is generally lacking in the State. The data included in this report should be valuable in determining what the natural conditions are for these streams; however, these may be the parameters that change most rapidly as land-use activities increase and that may have the greatest affect on lower Kenai Peninsula communities and economies. A 2001 report from the Alaska Department of Fish and Game states “Deep Creek was not fishable for the first three weekends it was open to fishing because the water was high and muddy” and “Anchor River anglers also suffered from high muddy water during the first three weekends the fishery was open” (ADF&G, 2001). Monitoring turbidity in these rivers and educating citizens about activities that contribute to muddy waters is critical.

Keeper has relied on a stream gauge on the Ninilchik River, which was established and is maintained by USGS, to understand the relationship between water quality and water quantity. Having water quality and discharge data collected concurrently makes these two types of data much more valuable than if they are collected separately. Much of the variability in conductivity, total dissolved solids, ammonia-nitrogen, total phosphorus, turbidity, suspended and settleable solids, and apparent color appear to be related to stream flow levels. High stream flows deliver higher concentrations of ammonia-nitrogen, total phosphorus, turbidity, suspended and settleable solids, and color, while low stream flows deliver higher levels of conductivity and total dissolved solids.

Unfortunately, funding for maintenance of the Ninilchik River gauge is lacking starting in October 2003. Loss of this dataset means we loose a valuable tool to detect changes in the relationship between water quality and water quantity. And this relationship is likely to change in the coming years as global climate change alters Kenai Peninsula watersheds by affecting flooding frequencies, stream temperature, precipitation levels, surface and ground water volumes, soil nutrient dynamics, and other hydrologic characteristics. In addition, climate change may impact geographic distribution of wetlands. The U.S. Fish and Wildlife Service's National Wetlands Inventory program has mapped more than 220 square miles of wetlands on the lower Kenai Peninsula. Wetlands regulate climate and hydrologic regimes and act as sources and sinks of greenhouse gases. Wetlands also provide specific functional roles, like extensive water storage and sediment retention.

In Fall 2002, the lower Kenai Peninsula experienced flood events not seen in the last 50-100 years. Major habitat alteration reshaped salmon stream channels and riparian habitat especially in the lower reaches of the Anchor River and Deep Creek. Keeper's five years of baseline habitat and water quality data are invaluable in assessing conditions before the flooding. The most significant change in water quality appears to be in Deep Creek. In October 2002 and again, after steady rainfall, in June 2003, Deep Creek samples showed elevated levels of ammonia, orthophosphate, total phosphorus, turbidity, total suspended solids, seattleable solids and color. The minimal snow pack of the 2002-2003 winter (Natural Resources Conservation Service, 2003) and the less-than-average rainfall of summer 2003 (National Weather Service, 2003) has meant low water levels and flows for lower Kenai Peninsula streams. Future Fall rains or Spring melt periods may release additional nutrients and sediments trapped in floodplains. Continued monitoring is needed to understand the impacts of these flooding events on habitat and water quality.

The University of Alaska Anchorage Environment and Natural Resources Institute (ENRI) initiated macroinvertebrate assessments of Kenai Peninsula salmon streams in 1997. These rivers ranked only "fair" by ENRI's assessment process. Because sediment can clog invertebrate gills, increase phosphorous levels, and affect algal productivity, changes in macroinvertebrate communities may be an early warning signal that these high priority watersheds are being degraded. The "fair" rating suggests this may already be happening. In order to track the biological communities in these streams and to understand flood affects on stream productivity, Keeper expanded its bioassessment program in the summer of 2003 to include sampling on all four salmon streams using ENRI's technical-level methods. These data will be made available when sample processing and identification is completed.

This monitoring project addresses habitat and water quality issues of concern on waters identified by the State of Alaska as at risk; Anchor River, Deep Creek, and Ninilchik River are listed as high priority and Stariski Creek as medium priority on the State's Alaska Clean Water Actions Priority List. Monitoring is an essential component of a comprehensive and effective strategy to maintain stream health and protect watersheds that support important public resources, as well as local economic and social opportunities. The time, effort, and money spent to monitor a health waterbody is significantly less than what is spent to restore an impaired water body.

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APPENDIX I.

Results of Quality Assurance Checks

Keeper estimates the precision and accuracy of its laboratory analysis in three ways:

- Splitting samples annually with a professional lab, using the same procedures.
- Splitting samples quarterly with the Project's QA Officer during Keeper's laboratory analysis.
- Analyzing a known standard solution for each parameter during each laboratory analysis session.

In August 1998, Keeper split ten samples with a professional lab: CTE, Inc., in Anchorage, Alaska. CTE analyzed samples for ammonia-nitrogen, orthophosphate-phosphorus, total phosphorus, apparent color, and total suspended solids. CTE used different methods for apparent color so these results are not included in Table 3. The greatest difference between the split samples was for ammonia-nitrogen concentrations: CTE's measurements were an average of 0.11 mg/L lower than Keeper's measurements.

In May 2000, Keeper split six samples with another professional lab: Northern Testing Laboratories, Inc. (NTL), in Anchorage, Alaska. NTL analyzed samples for nitrate-nitrogen, ammonia-nitrogen, orthophosphate-phosphorus, total phosphorus, total suspended solids, conductance, and turbidity. NTL's minimum method reporting level for ammonia-nitrogen was 1.00 mg/L, which was above Keeper's ammonia-nitrogen values so no comparison could be made. Keeper's nitrate-nitrogen values for four of the six samples were below NTL's minimum method reporting level of 0.10 mg/L.

In May/June 2001, Keeper split ten samples with NTL. Samples were analyzed for nitrate-nitrogen, orthophosphate-phosphorus, total phosphorus, total suspended solids, conductance, and turbidity. NTL's minimum method reporting limit for orthophosphate–phosphorus was 0.04 mg/L, which was above Keeper's orthophosphate values for eight samples. Keeper's nitrate-nitrogen values for five samples were below NTL's minimum method reporting level of 0.10 mg/L. The nitrate-nitrogen value for one sample was above Keeper's detection limit of 0.40 mg/L. The greatest difference between the split samples was for total suspended solids; NTL's measurements were an average of 42.3 mg/L higher than Keeper's measurements.

In both June 2002 and June 2003, Keeper split six samples with NTL. Samples were analyzed for nitrate-nitrogen, orthophosphate-phosphorus, total phosphorus, total suspended solids, conductance, and turbidity. Keeper's nitrate-nitrogen values for three samples in 2002 and five samples in 2003 were below NTL's minimum method reporting level of 0.10 mg/L. In 2002, the greatest difference between the split samples was for total suspended solids; NTL's measurements were an average of 14.2 mg/L higher than Keeper's measurements. This difference in suspended solids data was not seen in 2003.

Keeper also split samples during laboratory quality assurance sessions to test how results can differ between two people using the same methods at the Keeper lab. The results of the sample split showed negligible differences between people using the same method.

Table 3. Results of Keeper's quality assurance checks. The table shows the average difference between the sample splits and Keeper's data. The number of samples analyzed are identified in parentheses.

	Nitrate-Nitrogen	**Ammonia-Nitrogen**	**Orthophosphate-Phosphorus**	**Total Phosphorus**	**Color**	**Suspended Solids**	**Conductivity**	**Turbidity**
1998 professional sample split (CTE)		-0.11 mg/L (5)	0.02 mg/L (5)	-0.02 mg/L (10)		-7 mg/L (10)		
2000 professional sample split (NTL)	0.06 mg/L (2)		-0.01 mg/L (6)	-0.01 mg/L (6)		4 mg/L (6)	-7.4 µS/cm (6)	-5.1 NTU (6)
2001 professional sample split (NTL)	0.09 mg/L (4)		-0.02 mg/L (2)	0.03 mg/L (10)		42.3 mg/L (10)	-0.3 µS/cm (10)	-12.4 NTU (10)
2002 professional sample split (NTL)	0.06 mg/L (3)		-0.02 mg/L (6)	0.00 mg/L (6)		14.2 mg/L (6)	7.7 µS/cm (6)	-3.2 NTU (6)
2003 professional sample split (NTL)	0.02 mg/L (1)		0.01 mg/L (6)	-0.01 mg/L (6)		0 mg/L (6)	-1.3 µS/cm (6)	-1.8 NTU (6)
1998-2003 split with QA Officer	0.01 mg/L (4)	0.01 mg/L (5)	-0.01 mg/L (4)	0.01 mg/L (4)	0.7 Unit (7)	0.3 mg/L (6)		

APPENDIX II.

All Water Quality Data Collected by Cook Inlet Keeper, 8/98-6/03.
Values that exceed federal recommendations or state standards are in **bold**.

Site ID	Date	Water Temp.°C	Dslvd. O_2, mg/L	Dsvld.O_2, % Sat.	pH	Cond., µS,cm	TDS, mg/L	Turb., NTUs	App. Color	Orthophos., mg/L	Total Phos., mg/L	Ammonia-N, mg/L	Nitrate-N, mg/L	TSS mg/L	Settle-able mg/L
AR-1	8/15/98	11.5	9.37	86	7.46	59.0	28	4.09	94	0.07	**0.11**	0.18		4	
AR-1	8/31/98	6.5	11.86	97	7.04	47.4	23	3.62	87	0.03	0.09	0.32		4	
AR-1	9/23/98	6.0	11.00	88	7.23	53.8	25	2.41	80		0.05	0.24		3	
AR-1	10/6/98	0.0	13.20	97	7.15	32.8	27		57	0.08	0.06	0.17		7	
AR-1	11/12/98	0.0	13.15	91	7.19	51.3	22	6.61	55			0.16	0.00	1	
AR-1	6/28/99	9.4	11.86	104	7.53	42.2	20	1.69	74	0.06	0.06	0.18		5	
AR-1	7/28/99	10.9	11.21	101	7.18	56.0	26	2.77	95	0.08	0.10	0.24	0.02	6	
AR-2	8/18/98	8.2	10.84	92	7.57	89.3	42		56	0.12	**0.14**	0.18		2	
AR-2	8/25/98	8.7	11.60	100	7.44			4.92	75	0.10	0.08	0.18		8	
AR-2	9/4/98					66.3	31	2.64	61	0.11	0.10	0.26		6	
AR-2	9/24/98	4.6	13.90	110	7.43	74.1	34	3.84	72	0.08	0.10	0.21		9	
AR-2	10/7/98	3.1	12.92	96	7.52	58.5	48		41	0.11	0.08	0.12	0.13	6	
AR-2	11/13/98	0.4	13.49	93	7.00	79.1	34	6.49	42		0.01	0.13	0.16	2	
AR-2	12/3/98	0.3	12.71	88	7.00	78.3	34	6.36	31	0.08	0.08	0.14	0.17	2	
AR-2	1/14/99	0.0	12.20	84	7.17	86.5	40	8.36	8	0.13	**0.11**	0.10	0.24	7	
AR-2	2/24/99	1.0			6.89	93.3	44		37		0.08	0.12	0.26	3	
AR-2	3/8/99	0.0	14.10	97	7.16	92.6	44	7.82	41	0.08	0.09	0.10	0.25	5	
AR-2	4/12/99	0.5	13.70	97	8.00	98.0	46	9.10	50	0.11	**0.11**	0.11	0.24	6	
AR-2	5/18/99	3.0	13.92	102	6.80	83.1	37	21.50	280	0.03	**0.21**	0.40	0.19	68	
AR-2	6/24/99	10.9	11.12	101	7.65	63.2	30	1.34	46	0.13	0.08	0.18	0.11	4	
AR-2	7/9/99	11.0	11.38	105		77.5	36	1.76	41	0.09	0.08	0.00	0.00	4	
AR-2	8/13/99	10.2	10.42	93	7.39	54.2	25	12.70	135	0.09	**0.17**	0.37	0.02		0.2
AR-2	10/4/99	4.7	12.86	100	6.98	64.6	29	4.25	65	0.07	0.08	0.19	0.06		0.1
AR-2	10/19/99	2.7	13.31	98	6.51	44.0	19	16.70		0.05	**0.14**	0.35	0.03		0.2

Site ID	Date	Water Temp.°C	Dslvd. O_2, mg/L	Dsvld.O_2, % Sat.	pH	Cond., µS,cm	TDS, mg/L	Turb., NTUs	App. Color	Orthophos., mg/L	Total Phos., mg/L	Ammonia-N, mg/L	Nitrate-N, mg/L	TSS mg/L	Settle-able mg/L
AR-2	11/17/99	0.0	14.30	98	7.11			2.07	33	0.06	0.07	0.09	0.19		0.1
AR-2	12/15/99	0.0	13.60	93	6.84	75.8	35	3.14	35	0.07	0.09	0.14	0.16		
AR-2	1/24/00	0.0	13.20	90		83.3	39		36	0.06	0.08	0.04	0.16	5	0.1
AR-2	2/1/00	0.0				88.4	42	10.80	39	0.07	0.03	0.10	0.27	4	0.1
AR-2	3/21/00	0.0	13.70	94		89.3	42	4.51	46	0.09	**0.13**	0.11	0.18	9	0.1
AR-2	4/10/00	0.0	14.90	102		92.1	44	4.74	48	0.08			0.16	14	0.1
AR-2	5/24/00	2.2	13.04	95	7.06	49.6	22	7.19	96	0.05	**0.11**	0.17	0.07	20	0.1
AR-2	7/28/00	10.5	11.30	100	**6.43**	79.0	34	2.73	62	0.19	**0.12**	0.19	0.05	7	0.1
AR-2	9/13/00	6.3	12.28	99	7.80	86.6	40	1.97	55	0.10	**0.11**	0.15	0.05	6	0.1
AR-2	10/4/00	3.7	12.87	97	7.55	85.2	38	6.37	60	0.09	**0.13**	0.15	0.08	10	0.1
AR-2	12/13/00	1.0	13.30	94	7.23	73.3	31	1.94	38	0.05	0.06	0.13	0.16	4	0.1
AR-2	1/19/01	1.0	13.50	95	7.41	43.1	18	16.60	125	0.06	**0.13**	0.22	0.08	32	0.1
AR-2	2/22/01	0.5	13.30	92	6.93	80.5	34	1.43	33	0.06	0.06	0.09	0.17	3	0.1
AR-2	4/24/01	3.2			7.84	59.4	26	14.85	101	0.06	**0.14**	0.21	0.09	29	0.1
AR-2	6/6/01	5.0	12.77	100	7.32	36.4	16	13.80	91	0.03	0.08	0.15	0.11	25	0.1
AR-2	7/26/01	13.0	10.37	98	7.70	68.9	32	4.58	63	0.07	0.09	0.19	0.03	7	0.1
AR-2	8/20/01	9.8	11.25	98	7.61	64.6	30	8.37	83	0.07		0.19	0.01	10	0.1
AR-2	9/27/01	4.9	13.00	101	7.69	72.5	33	3.04	62	0.08	0.10	0.18	0.07	6	0.1
AR-2	12/5/01	0.2	11.00	76	7.32	75.5	32	3.93	35	0.08	0.08	0.15	0.25	4	0.1
AR-2	1/3/02	0.4	12.40	86	7.29	55.8	24	1.54	56	0.07	0.07	0.20	0.08	3	0.1
AR-2	3/6/02	0.3	12.30	85	7.21	84.9	36	2.65	30	0.05	0.08	0.08	0.21	5	0.1
AR-2	4/18/02	0.3	12.60	87	7.40	86.3	37	4.59	44	0.10	0.09	0.07	0.18	5	0.1
AR-2	5/24/02	3.2	13.92	103	6.84	36.2	16	23.70	150	0.05	**0.14**	0.21	0.07	42	0.1
AR-2	6/3/02	6.1	12.08	96		48.8	22	5.89	77	0.06	0.08	0.12	0.08	12	0.1
AR-2	7/11/02	**15.0**	10.02	98	7.86	74.3	35	1.66	40	0.09	0.08	0.06	0.00	5	0.1
AR-2	8/22/02	11.3	10.85	98		78.1	37	3.33	52	0.10	**0.12**	0.17	0.09	4	0.1
AR-2	10/10/02	2.8	12.91	95	7.16	66.4	29	2.47	49	0.07	0.09	0.16	0.15	6	0.1
AR-2	10/31/02	3.9	12.79	96	7.22	40.9	18	16.70	123	0.06	**0.11**	0.22	0.12	37	0.1

Site ID	Date	Water Temp.°C	Dslvd. O_2, mg/L	Dsvld.O_2, % Sat.	pH	Cond., µS,cm	TDS, mg/L	Turb., NTUs	App. Color	Orthophos., mg/L	Total Phos., mg/L	Ammonia-N, mg/L	Nitrate-N, mg/L	TSS mg/L	Settle-able mg/L
AR-2	1/9/03	0.3	11.80	81	6.96	64.6	28	2.35	31	0.05	0.05	0.03	0.24	3	0.1
AR-2	2/20/03	0.3	12.70	88	7.42	63.6	27	2.00	36	0.08	0.07	0.18	0.37	4	0.1
AR-2	3/26/03	0.4	14.64	101		73.7	32	4.43	38	0.06	0.09	0.06	0.34	10	0.1
AR-2	6/3/03	9.6	12.98	112	8.28	65.5	30	2.80	44	0.05	0.08	0.09	0.05	4	0.1
AR-3	8/16/98	**14.0**	9.07	87	7.09			4.36	53	0.12	**0.13**	0.18		5	
AR-3	8/25/98	9.7	11.23	99	7.38	57.4	27	8.74	120	0.07	**0.14**	0.35		15	
AR-3	9/4/98	8.0	11.46	98	7.58	63.8	30	3.63	72	0.08	0.09	0.28		7	
AR-3	9/30/98	6.7	11.36	92	7.27	84.4	40	7.13	57	0.06	0.07	0.17		4	
AR-3	10/8/98	2.5	13.47	99	7.12	95.8	43	7.06	55	0.09	0.09	0.06	0.14	8	
AR-3	11/19/98	0.4	13.70	95		83.3	36	7.02	46	0.07	0.07	0.09	0.12	3	
AR-3	12/15/98	0.2	11.79	82	7.19	76.3	36		40	0.06		0.12	0.17	9	
AR-3	1/11/99	0.5	13.20	93	7.30	84.2	40	8.50	56	0.11	0.08	0.06	0.17	6	
AR-3	2/24/99	0.0			7.27	94.4	44		44	0.09	0.07	0.08	0.19	3	
AR-3	3/8/99	1.0	13.90	98	6.74	96.5	46	8.11	59	0.10	0.07	0.08	0.17	4	
AR-3	4/12/99	0.0	13.90	95	7.37	118.5	54	9.30	71	0.08	0.09	0.08	0.20	7	
AR-3	5/18/99	3.5	14.46	109	6.55	70.2	31	15.10	267	0.04	**0.16**	0.38	0.08	57	
AR-3	6/15/99	8.6	11.64	99	7.51	68.4	32	2.52	62	0.07	0.09		0.10	5	
AR-3	7/12/99	**15.9**	10.22	103		82.1	39	4.01	47	0.07	0.08	0.08		5	
AR-3	8/13/99	10.4	10.34	93		47.6	22	17.20	177	0.06	**0.19**	0.39	0.00		0.3
AR-3	9/27/99	4.7	12.81	100	7.48	74.0	33	2.53	64	0.08	0.09	0.11	0.05		0.1
AR-3	10/18/99	2.0	14.05	101	**6.40**	40.3	18	69.80		0.08	**0.30**	0.74	0.02		0.6
AR-3	11/17/99	0.0	14.10	97	6.67			2.70	46	0.06	0.07	0.07	0.20		0.1
AR-3	12/15/99	0.0	13.80	95	**6.34**	71.5	34	3.99	45	0.06	0.07	0.10	0.18		
AR-3	1/24/00	0.0	13.20	90		86.3	40		39	0.04	0.07	0.00	0.13	4	0.1
AR-3	2/1/00				7.17	90.2	42	3.62	47	0.05	0.07	0.08	0.17	5	0.1
AR-3	3/21/00	0.0	14.30	98		91.0	43	5.13	73	0.07	0.08	0.10	0.09	10	0.1
AR-3	4/10/00	0.0	14.80	101		94.5	45	5.12	72	0.07			0.04	13	0.1
AR-3	5/24/00	4.4	12.80	99	6.98	57.9	26	8.88	102	0.04	0.10	0.17	0.08	16	0.1

Site ID	Date	Water Temp.°C	Dslvd. O_2, mg/L	Dsvld.O_2, % Sat.	pH	Cond., µS,cm	TDS, mg/L	Turb., NTUs	App. Color	Orthophos., mg/L	Total Phos., mg/L	Ammonia-N, mg/L	Nitrate-N, mg/L	TSS mg/L	Settle-able mg/L
AR-3	7/6/00	11.8	10.41	95	6.90	81.8	39	2.32	58	0.07	0.10	0.00	0.00	10	
AR-3	7/24/00	12.4	10.50	98		65.3	31	5.54	97	0.07	**0.13**	0.30	0.00	13	0.1
AR-3	9/13/00	7.5	12.45	103	8.01	90.9	42	2.77	62	0.10	0.10	0.12	0.01	5	0.1
AR-3	10/4/00	4.2	12.77	98	7.63	86.9	39	7.22	68	0.07	**0.12**	0.11	0.06	14	0.1
AR-3	12/13/00	0.5	13.70	95	7.27	74.4	32	1.73	41	0.05	0.05	0.12	0.14	3	0.1
AR-3	1/12/01	1.0	12.80	90	7.51	80.8	34	1.85	36	0.06	0.05	0.08	0.16	2	0.1
AR-3	2/9/01	0.5	13.70	95	7.06	81.5	35	2.03	35	0.05	0.04	0.09	0.14	2	0.1
AR-3	4/16/01	1.9	14.09	101		59.7	26	8.71	115	0.03	0.09	0.23	0.00	17	0.1
AR-3	5/24/01	4.3	13.27	102	7.35	40.2	18	29.60	156	0.03	**0.14**	0.19	0.14	54	0.1
AR-3	7/18/01	**14.0**	10.74	104	8.21	74.1	35	2.98	65	0.06	0.08	0.16	0.00	4	0.1
AR-3	8/20/01	9.7	11.21	98	7.46	67.3	31	13.50	109	0.06		0.23	0.00	20	0.1
AR-3	9/26/01	7.0	12.71	104	7.69	68.9	32	5.60	75	0.10	0.10	0.22	0.03	7	0.1
AR-3	12/12/01	0.2	10.60	73	7.09	88.9	38	6.15	47	0.11	0.09	0.11	0.23	9	0.1
AR-3	1/9/02	0.2	12.40	85	7.21	54.1	23	2.10	52	0.03	0.04	0.13	0.02	3	0.1
AR-3	3/6/02	0.2	12.90	89	7.05	83.2	36	2.69	44	0.05	0.07	0.10	0.13	4	0.1
AR-3	4/24/02	0.4	12.10	84	7.21	56.9	24	5.11	72	0.02	0.08	0.16	0.00	10	0.1
AR-3	4/29/02	0.4	12.20	85	7.43	41.0	17	72.40	283	0.00	**0.39**	0.52	0.00	168	0.5
AR-3	5/20/02	5.0	13.39	103	7.13	34.1	15	81.30	374	0.00	**0.36**	0.42	0.04	140	0.4
AR-3	6/5/02	10.3	11.78	103		50.7	24	6.54	74	0.06	0.08	0.15		15	0.1
AR-3	7/31/02	**17.6**	9.30	97	**6.20**	81.9	39	2.86	48	0.12	0.10	0.12	0.13	4	0.1
AR-3	9/5/02	11.6	11.33	103		80.4	38	2.88	52	0.11	**0.11**	0.12	0.07	3	0.1
AR-3	10/16/02	5.3	11.84	98	7.39	59.8	27	5.63	80	0.05	0.09	0.25	0.09	10	0.1
AR-3	10/31/02	4.4	13.27	101	7.09	42.4	19	34.30	208	0.05	**0.18**	0.38	0.11	74	0.1
AR-3	1/3/03	0.2	11.60	80	6.86	74.4	32	2.14	39	0.04	0.05	0.02	0.25	2	0.1
AR-3	3/6/03	0.2	14.04	96	7.56	61.4	26	4.99	73	0.06	0.08	0.16	0.14	10	0.1
AR-3	4/24/03	4.6	12.71	97	7.98	50.8	23	20.20	203	0.06	**0.16**	0.28	0.11	45	0.1
AR-3	6/3/03	10.5	11.40	101	8.22	69.6	33	2.40	49	0.03	0.06	0.17	0.00	5	0.1
AR-3	6/19/03	**14.9**	9.53	99	7.56	62.6	29	2.28	67	0.02	0.07	0.09	0.01	6	0.1

Site ID	Date	Water Temp.°C	Dslvd. O_2, mg/L	Dsvld.O_2, % Sat.	pH	Cond., µS,cm	TDS, mg/L	Turb., NTUs	App. Color	Orthophos., mg/L	Total Phos., mg/L	Ammonia-N, mg/L	Nitrate-N, mg/L	TSS mg/L	Settle-able mg/L
AR-4	8/13/98	11.8	10.44	96	7.46	71.1	33	3.88	74	0.12	**0.23**	0.22		5	
AR-4	8/24/98	9.7	9.85	87	7.45	52.7	25	14.30	162	0.07	**0.15**	0.44		27	
AR-4	9/4/98	7.0				58.4	28	2.79	68	0.08	0.06	0.30		7	
AR-4	9/25/98	6.7	10.53	88	7.21	64.9	30	7.55	89	0.06	0.10	0.34		13	
AR-4	10/7/98	2.0	12.54	91	7.25	50.1	43	6.99	53	0.09	0.07	0.13	0.10	3	
AR-4	11/18/98	0.4	12.25	85	6.88	70.4	30	6.85	52	0.07	0.06	0.09	0.17	3	
AR-4	12/9/98	0.5	12.50	86	7.25	68.8	32	7.69	59	0.07	0.08	0.17	0.16	6	
AR-4	1/21/99				6.83	79.9	38		37	0.08	0.08	0.14	0.19	4	
AR-4	2/25/99	0.0	13.60	93	7.39	88.0	42	7.69	60	0.11	0.08	0.13	0.22	3	
AR-4	4/22/99	1.0	13.50	95	7.17	64.8	31	7.42	103	0.07	0.09	0.25	0.05	5	
AR-4	5/27/99	4.0	13.72	104	6.91	37.5	17		83	0.03			0.14	15	
AR-4	6/24/99	10.1	11.27	100	7.42	57.4	27	1.46	62	0.06	0.07	0.18	0.05	3	
AR-4	7/14/99	11.4	10.87	102		77.4	36	2.77	64	0.07	0.08	0.14	0.04	3	
AR-4	10/4/99	5.0	12.22	95	6.68	53.9	24	5.15	87	0.03	0.07	0.23	0.03		0.1
AR-4	2/15/00	0.0				82.9	38	3.57	60	0.08	0.08	0.13	0.09		
AR-4	5/31/00	5.8	12.23	98	6.87	64.8	30	2.31	66	0.05	0.07	0.12	0.18	5	0.1
AR-4	7/6/00	10.5	11.62	103	6.92	78.6	37	2.43	66	0.08	0.10	0.02	0.07	10	
AR-4	8/2/00	10.1	10.06	89	7.28			5.64	102	0.08	**0.15**	0.30	0.06	22	0.1
AR-4	9/21/00	7.6	11.44	95	7.68	83.8	39	3.47	69	0.09	0.09	0.13	0.04	6	0.1
AR-4	11/8/00	0.5	13.90	97	7.26	72.7	31	2.59	55	0.05	0.06	0.11	0.15	3	0.1
AR-4	1/18/01	1.0	12.40	87	7.32	50.7	21	2.55	72	0.04	0.06	0.16	0.09	6	0.1
AR-4	3/2/01	0.4	13.52	93	7.17	84.6	36	4.06	66	0.06	0.07	0.15		5	0.1
AR-4	4/24/01	1.1			7.42	50.4	22	6.69	98	0.03	0.09	0.26	0.00	14	0.1
AR-4	5/29/01	5.4	12.78	100	7.67	50.5	23	4.34	67	0.03	0.08	0.14		10	0.1
AR-4	7/11/01	10.3	10.66	95	7.89	74.6	35	3.17	74	0.11	0.08	0.12	0.07	5	0.1
AR-4	8/23/01	11.8	10.12	93	7.62	73.2	34	3.34	86	0.07		0.23	0.05	4	0.1
AR-4	10/11/01	2.3	13.14	96		60.1	26	2.72	69	0.06	0.07	0.21	0.07	5	0.1
AR-4	12/13/01	0.2	12.30	85	7.24	74.4	32	4.89	59	0.09	0.08	0.11	0.21	5	0.1

Site ID	Date	Water Temp.°C	Dslvd. O_2, mg/L	Dsvld.O_2, % Sat.	pH	Cond., µS,cm	TDS, mg/L	Turb., NTUs	App. Color	Orthophos., mg/L	Total Phos., mg/L	Ammonia-N, mg/L	Nitrate-N, mg/L	TSS mg/L	Settle-able mg/L
AR-4	2/20/02	0.2	13.60	94	7.15	73.8	32	2.87	60	0.04	0.07	0.09	0.12	6	0.1
AR-4	3/13/02	0.3	13.10	90	7.57	80.3	34	3.71	56	0.07	0.07	0.13	0.14	4	0.1
AR-4	5/15/02	3.4	13.23	99	7.28	43.1	19	5.83	77	0.05	0.08	0.18	0.27	14	0.1
AR-4	6/5/02	8.8	11.51	97		43.9	20	4.85	94	0.05	0.08	0.31		13	0.1
AR-4	7/31/02	**13.0**	9.59	90	6.60	77.2	36	4.22	72	0.10	0.10	0.21	0.15	7	0.1
AR-4	9/11/02	6.9	11.67	95		71.1	33	3.37	79	0.08	0.09	0.15	0.08	5	0.1
AR-4	11/6/02	5.3	11.86	92		33.5	15	5.19	137	0.03	**0.11**	0.36	0.00	14	0.1
AR-4	1/30/03	0.3	14.05	97	**6.27**	70.8	30	3.36	55	0.07	0.08	0.19	0.27	3	0.1
AR-4	3/5/03	0.2	15.07	104		56.2	24	2.50	80	0.05	0.06	0.20	0.10	3	0.1
AR-4	4/24/03	3.7	13.14	98	7.61	58.9	26	2.94	87	0.10	0.08	0.22	0.15	5	0.1
AR-4	6/3/03	7.3	13.11	107	7.95	61.7	28	2.29	59	0.04	0.06	0.15	0.14	5	0.1
AR-5	11/9/99	0.3	14.88	103	6.50	59.1	25	1.55	32	0.04	0.06	0.23	0.21		0.1
AR-5	2/16/00	0.0	14.60	100	7.53	77.2	36	3.72	41	0.09	0.08	0.11	0.12	7	
AR-5	6/1/00	4.7	12.84	100		48.2	22	6.01	60	0.04	0.09	0.13	0.15	9	0.1
AR-5	7/10/00	9.2	11.23	98	8.10	70.8	33	0.28	61	0.08	0.08	0.15	0.08	10	0.1
AR-5	8/1/00	8.2	10.30	88	**6.45**	70.8	33	2.96	77	0.08	0.08	0.23	0.09	7	0.1
AR-5	9/20/00	4.4	12.65	98		81.9	37	2.02	55	0.08	0.09	0.12	0.10	5	0.1
AR-5	11/9/00	1.0	13.20	93	7.35	72.4	31	4.52	57	0.07	**0.12**	0.13	0.19	13	0.1
AR-5	1/11/01	1.0	12.80	90	7.13	60.1	26	0.96	44	0.03	0.05	0.12	0.21	3	0.1
AR-5	2/21/01	0.5	13.40	94	6.76	70.8	30	2.56	42	0.04	0.09	0.12	0.23	5	0.1
AR-5	4/19/01	1.6	13.87	99		68.3	30	4.00	77	0.05	0.07	0.20	0.10	8	0.1
AR-5	6/7/01	4.8	13.07	101	7.49	41.9	19	9.41	75	0.02	0.08	0.11	0.26	22	0.1
AR-5	7/27/01	9.2	10.92	94	7.48	63.4	30	3.02	65	0.06	0.07	0.20	0.11	6	0.1
AR-5	8/29/01	7.8	11.33	95	7.38	66.3	31	5.32	112	0.04	0.09	0.35	0.03	8	0.1
AR-5	10/10/01	3.9	12.62	96	7.26	64.6	29	4.11	84	0.05	0.08	0.20	0.09	9	0.1
AR-5	11/8/01	0.3	12.30	85	6.99	77.8	33	3.39	50	0.06	0.08	0.15	0.25	4	0.1
AR-5	1/16/02	0.3	12.50	86		54.2	23	1.04	62	0.04	0.04	0.15	0.14	3	0.1
AR-5	2/27/02	0.5	13.10	91	7.38	79.3	34	3.59	49	0.09	0.07	0.11	0.30	5	0.1

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AR-5	3/21/02	0.6	13.70	95		82.8	36	4.04	49	0.02	0.08	0.08	0.26	5	0.1
AR-5	5/23/02	4.4	12.29	93	6.93	41.8	19	19.60	129	0.02	**0.16**	0.23	0.22	43	0.1
AR-5	7/30/02	10.7	10.49	92	7.39	68.3	32	4.77	75	0.06	0.10	0.19	0.13	9	0.1
AR-5	9/9/02	7.6	12.32	101	7.30	63.9	29	2.74	72	0.07	0.08	0.10	0.10	5	0.1
AR-5	10/17/02	3.4	13.02	97	7.31	54.7	24	2.79	57	0.07	0.06	0.17	0.15	4	0.1
AR-5	11/7/02	3.3	13.54	101	7.13	37.3	16	9.17	100	0.05	0.09	0.23	0.15	20	0.1
AR-5	1/28/03	0.7	11.90	83	7.56	61.0	26	3.32	39	0.05	0.07	0.10	0.38	6	0.1
AR-5	2/19/03	0.4	14.27	98	7.41	56.0	24	1.56	47	0.05	0.05	0.15	0.39	4	0.1
AR-5	4/21/03	1.9	14.35	103	7.32	45.3	20	4.79	71	0.07	0.08	0.19	0.14	11	0.1
AR-5	6/12/03	9.3	10.99	94	7.57	46.0	21	3.52	76	0.04	0.08	0.25	0.13	10	0.1
DC-1	8/12/98	9.0	11.00	97	7.69	66.2	31	1.20	16	0.03	0.08	0.07		2	
DC-1	8/23/98	7.0	11.08	91	7.79	65.3	31	1.89	24	0.04	0.03	0.05		5	
DC-1	9/6/98	6.0	11.37	93	7.48	62.6	30	1.19	11	0.10	0.05	0.09		2	
DC-1	9/27/98	5.5	12.45	97	7.70	40.2	31	1.21	17	0.04	0.03	0.05		3	
DC-1	11/20/98	0.4	15.08	105	7.08	62.7	27	5.26	5	0.05	0.04	0.00	0.02	1	
DC-1	3/22/99	1.0	13.90	98	7.80	76.8	36	5.28	9		0.03	0.00	0.01	2	
DC-1	5/24/99	3.4	13.40	102		52.4	23		84	0.01				58	
DC-1	7/15/99	9.5	11.42	100		67.3	31	0.14	12	0.05	0.03	0.02		1	
DC-1	11/11/99	0.0	14.00	96					38	0.04	0.04	0.06	0.02		0.1
DC-1	3/7/00	0.0	13.90	95	7.40	75.9	36	0.63	9	0.05	0.05	0.01	0.02	5	0.1
DC-1	5/8/00	2.7	13.40	99	6.86	59.6	26	0.68	33	0.03	0.07	0.07	0.00	4	0.1
DC-1	7/11/00	10.3	11.07	99		63.1	30	0.26	26	0.03	0.03	0.06	0.00	8	0.1
DC-1	9/11/00	6.6	12.29	100	7.55	66.1	30	0.35	24	0.04	0.04	0.09	0.00	2	0.1
DC-1	10/5/00	3.7	13.19	100	7.62	67.0	30	0.46	19	0.02	0.03	0.04	0.00	3	0.1
DC-1	12/1/00	0.5			7.08			0.28	14	0.04	0.03	0.04	0.01	2	0.1
DC-1	1/24/01	1.0	12.70	89		69.7	30	0.48	13	0.04	0.04	0.02	0.02	3	0.1
DC-1	3/8/01	0.6	14.08	98	7.89	75.2	32	0.98	7	0.02	0.04	0.01		2	0.1
DC-1	4/25/01	3.0	12.40	92	7.88	72.2	32	0.66	13	0.03	0.03	0.04	0.01	3	0.1

Site ID	Date	Water Temp.°C	Dslvd. O_2, mg/L	Dsvld.O_2, % Sat.	pH	Cond., µS,cm	TDS, mg/L	Turb., NTUs	App. Color	Orthophos., mg/L	Total Phos., mg/L	Ammonia-N, mg/L	Nitrate-N, mg/L	TSS mg/L	Settle-able mg/L
DC-1	6/4/01	4.3	12.66	97		22.3	10	5.06	66	0.01	0.05	0.15	0.02	13	0.1
DC-1	7/31/01	9.9	11.02	97	7.73	59.4	28	0.24	18	0.02	0.02	0.05	0.00	2	0.1
DC-1	8/30/01	7.7	12.02	100	7.69	68.1	31	0.13	17	0.05	0.02	0.07	0.00	2	0.1
DC-1	10/4/01	6.0	12.55	100	7.65	64.5	29	0.37	13	0.04	0.03	0.02	0.00	0	0.1
DC-1	11/14/01	0.2	12.60	87	7.36	67.5	29	0.44	14	0.02	0.03	0.01	0.02	2	0.1
DC-1	1/30/02	0.4	13.50	94	7.30	69.4	30	0.67	10	0.03	0.03	0.01	0.03	3	0.1
DC-1	3/14/02	0.3	13.50	93	7.50	68.9	29	0.22	11	0.03	0.04	0.02	0.01	2	0.1
DC-1	4/5/02	0.4	12.90	89	7.26	68.7	29		13	0.04	0.05	0.02	0.00	4	0.1
DC-1	5/30/02	5.4	12.56	98	7.96	29.8	13		43	0.01	0.02	0.05	0.00	5	0.1
DC-1	7/22/02	10.4	10.88	96	8.23	64.5	30	0.32	17	0.04	0.03	0.00	0.00	2	0.1
DC-1	9/12/02	6.6	12.83	103	7.84	63.8	29	0.43	10	0.04	0.03	0.00	0.00	1	0.1
DC-1	11/14/02	1.6	13.97	98	7.66	47.4	21	1.42	23	0.05	0.03	0.01	0.04	4	0.1
DC-1	11/21/02	0.7	14.07	98	7.54	53.9	23	0.94	13	0.08	0.03	0.01	0.04	2	0.1
DC-1	1/8/03	0.2	12.90	89	7.36	58.1	25	2.31	14	0.04	0.03	0.02	0.04	6	0.1
DC-1	2/27/03	1.5	14.14	100	7.76	61.1	27	9.74	75	0.03	0.05	0.04	0.00	17	0.1
DC-1	4/23/03	4.0	13.38	101	7.60	54.7	24	21.40	89	0.00	0.06	0.14	0.00	42	0.1
DC-1	5/22/03	9.2	10.96	93	8.06	53.2	25	4.35	29	0.01	0.03	0.01	0.00	8	0.1
DC-2	8/12/98	13.0	9.54	91	7.59	68.0	32	3.07		0.06	0.09	0.15		4	
DC-2	8/23/98	9.0	10.36	90	7.91	72.1	34	3.78	41	0.06	0.08	0.13		4	
DC-2	9/1/98	8.0	11.99	101	7.40	52.7	25	16.50	232	0.07	**0.24**	0.37		51	
DC-2	9/22/98	7.5	11.45	95	7.63	70.3	33	2.21	37	0.07	0.09	0.13		3	
DC-2	11/11/98	0.5	13.47	93	7.22	71.5	30	6.79	34			0.06	0.06	3	
DC-2	12/16/98	0.5	14.00	99	7.00	74.0	35	5.84	15		0.05	0.09	0.08	5	
DC-2	1/25/99	0.5	13.00	92	6.94	74.0	34	6.57	24	0.05	0.06	0.06	0.10	4	
DC-2	2/25/99	0.5	9.90	70	7.12	77.7	36	6.19	21	0.09	0.07	0.04	0.08	2	
DC-2	3/17/99	0.5	13.80	97	7.08	84.7	40	7.48	35	0.07	0.07	0.06	0.09	5	
DC-2	4/8/99	0.0	14.40	99	7.33	84.5	39	6.59	39		0.08	0.04	0.15	6	
DC-2	5/5/99	2.8			6.90	66.5	30	8.52	80	0.10	0.10	0.21	0.01	10	

Site ID	Date	Water Temp. °C	Dslvd. O_2, mg/L	Dsvld. O_2, % Sat.	pH	Cond., µS,cm	TDS, mg/L	Turb., NTUs	App. Color	Orthophos., mg/L	Total Phos., mg/L	Ammonia-N, mg/L	Nitrate-N, mg/L	TSS mg/L	Settle-able mg/L
DC-2	6/17/99	10.0			7.57	51.3	24	2.65	46	0.03	0.09		0.01	11	
DC-2	7/22/99	**13.5**	10.64	103	7.70	74.1	35	1.08	31		0.06	0.04		5	
DC-2	2/23/00	0.0	14.20	97	7.20	78.7	37	2.81	32	0.07	0.06	0.06	0.07		0.1
DC-2	4/18/00	0.0	14.10	97	**6.46**	72.2	35		103	0.06			0.06	30	0.3
DC-2	9/7/00	8.8	11.33	97		79.2	37	1.27	27	0.06	0.07	0.06	0.00	4	0.1
DC-2	9/26/00	8.6	10.94	93	7.61	67.3	31	1.85	53	0.05	0.07	0.13	0.01	9	0.1
DC-2	11/30/00	0.5	14.20	99	7.21	59.9	26	1.48	35	0.05	0.06	0.10	0.05	5	0.1
DC-2	1/4/01	0.5	13.10	91	7.53	68.6	29	0.89	23	0.06	0.06	0.07	0.07	4	0.1
DC-2	3/1/01	0.3	13.89	96	7.28	76.5	33	1.50	26	0.04	0.06	0.05		3	0.1
DC-2	4/26/01	1.5	12.90	92	7.38	56.5	24	11.90	92	0.04	**0.12**	0.22	0.01	25	0.1
DC-2	6/6/01	5.0	12.75	99	7.69	28.5	13	25.90	136	0.02	**0.12**	0.19	0.00	47	0.1
DC-2	7/19/01	12.4	10.56	98	7.73	63.5	30	1.96	36	0.03	0.06	0.13	0.00	2	0.1
DC-2	9/5/01	8.1	12.00	101	7.75	63.4	29	5.25	56	0.04	0.08	0.16	0.00	10	0.1
DC-2	10/3/01	4.6	13.02	100	7.92	67.7	31	1.69	33	0.05	0.06	0.09	0.01	2	0.1
DC-2	12/12/01	0.3	12.20	84	7.22	72.6	31	2.46	23	0.05	0.06	0.07	0.08	5	0.1
DC-2	1/17/02	0.2	12.77	88	7.00	66.0	28	0.99	32	0.05	0.06	0.06	0.05	2	0.1
DC-2	2/28/02	0.2	12.80	88	7.36	66.7	28	5.41	47	0.07	0.07	0.06	0.06	8	0.1
DC-2	4/29/02	0.3	12.00	83	6.93	49.5	21	34.50	144	0.04	**0.36**	0.32	0.08	89	0.4
DC-2	5/29/02	8.4	11.46	96	7.26	36.1	17	10.60	76	0.02	0.09	0.12	0.00	23	0.1
DC-2	7/25/02	12.8	9.49	89	7.81	61.7	29	4.75	56	0.05	0.08	0.08	0.00	11	0.1
DC-3	8/11/98	12.5	9.33	87	7.71	63.8	30	2.90	119	0.12	**0.13**	0.23		7	
DC-3	8/26/98	8.0	12.06	103	7.47	65.7	31	8.03	54		0.06	0.21		7	
DC-3	9/1/98	8.0	12.00	102	7.33	52.0	25	11.30	135	0.08	**0.23**	0.30		54	
DC-3	9/22/98	7.5	11.06	92	7.60	69.3	32	2.24	50	0.07	0.09	0.22		2	
DC-3	10/5/98	6.0	12.18	96		84.1	38	2.55	38		0.06	0.04		3	
DC-3	11/19/98	0.3	13.88	96	7.02	79.6	34	6.18	25	0.07	0.06	0.06	0.07	2	
DC-3	12/3/98	0.5	13.44	93	7.09	83.9	36	5.99	21	0.06	0.04	0.15	0.14	1	
DC-3	1/14/99	0.5	13.30	94	7.06	76.1	40	6.48	28	0.09	0.06	0.04	0.11	5	

Site ID	Date	Water Temp.°C	Dslvd. O_2, mg/L	Dsvld.O_2, % Sat.	pH	Cond., µS,cm	TDS, mg/L	Turb., NTUs	App. Color	Orthophos., mg/L	Total Phos., mg/L	Ammonia-N, mg/L	Nitrate-N, mg/L	TSS mg/L	Settle-able mg/L
DC-3	2/11/99	0.5													
DC-3	3/10/99	1.0			7.14	82.7	39	7.08	28	0.06	0.07	0.18	0.10	5	
DC-3	5/27/99	4.0	14.02	103	6.90	31.1	14		222	0.03	**0.15**	0.41		58	
DC-3	6/17/99	10.0			7.59	51.8	24	1.92	46	0.04	0.08		0.01	8	
DC-3	7/8/99	**15.0**	10.36	101		72.6	34	3.29	32	0.06	**0.19**			6	
DC-3	8/12/99	10.7	11.01	100		75.0	35	3.37	51	0.08	0.09	0.04	0.01		0.0
DC-3	10/1/99	6.2	12.61	102	7.02	67.9	31	7.00	61	0.06	**0.12**	0.15	0.00		0.2
DC-3	10/19/99	2.5	12.74	93	6.67	37.5	16	25.80		0.05	**0.16**	0.41	0.02		0.3
DC-3	11/10/99				6.95				25	0.06	0.05	0.06	0.07		
DC-3	12/13/99	0.0	14.30	98	6.50	74.2	35	1.98	25	0.04	0.06	0.08	0.09		0.1
DC-3	1/20/00	0.0	13.60	93		73.9	34	2.23	29	0.04	0.06	0.00	0.15	4	0.1
DC-3	2/15/00	0.0			6.92	78.4	36	2.72	29	0.07	0.06	0.06	0.03		
DC-3	3/8/00	0.0	14.10	97	7.14	80.8	39	3.52	32	0.06	0.10	0.04	0.06	8	0.1
DC-3	4/11/00	0.0	15.10	103	7.23	83.5	40		38	0.06			0.02	16	0.1
DC-3	5/25/00	3.6	13.30	100	7.12	46.4	21	8.25	93	0.02	0.07	0.15	0.00	19	0.1
DC-3	7/25/00	11.8	9.77	90	7.26	56.9	27	2.69	67	0.07	0.08	0.18	0.00	10	0.1
DC-3	9/14/00	6.9	12.21	100	7.33	75.9	35	1.50	38	0.08	0.07	0.09	0.00	5	0.1
DC-3	9/26/00	9.2	11.26	97	7.51	66.9	31	2.54	62	0.06	**0.13**	0.13	0.00	7	0.1
DC-3	11/14/00	1.0	14.10	100	7.37	50.5	22	12.70	88	0.04	**0.16**	0.23	0.04	22	0.2
DC-3	1/3/01	0.5	12.90	90	7.29	64.1	27	1.04	29	0.04	0.05	0.08	0.07	3	0.1
DC-3	3/7/01	0.3	14.29	99	7.54	80.4	35	3.16	28	0.04	0.07	0.05		6	0.1
DC-3	4/18/01	2.6	14.11	103	7.71	68.2	30	18.65	101	0.05	**0.22**	0.21	0.00	44	0.2
DC-3	5/23/01	3.9	13.08	99	7.45	38.6	17	21.10	106	0.03	**0.13**	0.20	0.06	43	0.1
DC-3	7/12/01	10.6	11.06	99	7.80	59.7	28	2.41	43	0.06	0.05	0.06	0.00	3	0.1
DC-3	8/21/01	12.1	10.78	100	7.85	64.6	30	2.94	52	0.05		0.14	0.00	3	0.1
DC-3	9/26/01	5.2	12.75	100	7.45	64.3	29	7.20	73	0.04	0.07	0.15	0.00	15	0.1
DC-3	12/6/01	0.2	11.30	78	7.33	52.2	22	1.38	19	0.03	0.04	0.08	0.05	2	0.1
DC-3	1/9/02	0.2	12.00	83	7.07	60.7	26	1.36	32	0.04	0.05	0.09	0.04	3	0.1

Site ID	Date	Water Temp.°C	Dslvd. O_2, mg/L	Dsvld.O_2, % Sat.	pH	Cond., µS,cm	TDS, mg/L	Turb., NTUs	App. Color	Orthophos., mg/L	Total Phos., mg/L	Ammonia-N, mg/L	Nitrate-N, mg/L	TSS mg/L	Settle-able mg/L
DC-3	2/21/02	0.2	13.30	92	7.33	72.9	31	2.35	31	0.05	0.06	0.02	0.07	5	0.1
DC-3	4/25/02	0.3	12.50	86	7.37	69.1	30	10.14	71	0.09	**0.14**	0.13	0.05	27	0.1
DC-3	5/16/02	5.8	12.72	100		37.1	17	17.60	106	0.03	**0.14**	0.19	0.04	48	0.1
DC-3	6/4/02	8.7	11.31	95		44.0	20	6.05	60	0.05	0.07	0.15	0.00	14	0.1
DC-3	7/8/02	**15.4**	10.56	105	7.92	70.2	33	1.48	37	0.11	0.07	0.04	0.00	4	0.1
DC-3	9/11/02	7.0	12.62	102	7.52	66.3	30	1.86	41	0.05	0.07	0.06	0.00	4	0.1
DC-3	10/16/02	4.5	12.68	98		55.1	25	4.63	63	0.05	0.08	0.23	0.01	10	0.1
DC-3	10/30/02	3.5	11.86	88		26.2	11	915.00	>500	0.32	**0.72**	>2.50	0.00	>750	2.1
DC-3	11/13/02	0.2	14.21	98		52.9	22	19.95	113	0.04	**0.14**	0.21	0.04	39	0.1
DC-3	1/3/03	0.3	12.60	87	7.18	65.0	28	1.94	27	0.05	0.04	0.01	0.11	3	0.1
DC-3	3/6/03	0.3	14.13	97	7.63	67.1	29	8.28	73	0.05	0.06	0.13	0.10	14	0.1
DC-3	3/27/03	0.3	13.61	94		72.7	31	16.20	90	0.07	0.10	0.12	0.11	31	0.1
DC-3	6/4/03	9.3	11.39	98	7.91	66.4	31	11.50	113	0.05	0.09	0.18	0.00	26	0.1
DC-3	6/11/03	9.0	11.11	95		49.7	23	230.00	>500	0.19	**0.69**	0.94	0.07	376	0.9
DC-3	6/16/03	12.2	9.82	96	7.73	64.3	30	11.50	86	0.03	0.08	0.11	0.02	24	0.1
NR-1	8/10/98	8.0			6.97	69.1	36	2.70	96	0.08	0.10	0.33		106	
NR-1	8/27/98	6.0	11.54	93	7.25	86.5	41	3.21	114	0.08	0.08	0.24		4	
NR-1	9/6/98	5.5	11.02	89	7.17	78.8	38	3.30	63	0.09	0.10	0.22		8	
NR-1	9/28/98	4.1	11.59	87	7.25	55.8	45	7.15	72	0.09	0.08	0.22		7	
NR-1	11/9/98	0.0	11.96	83	7.12	93.8	40	7.34	40		0.01	0.10	0.04	3	
NR-1	12/2/98	0.5	11.75	82	6.68	97.9	42	6.92	42	0.08	0.09	0.12	0.26	2	
NR-1	4/28/99	1.0	11.00	69	6.70	71.8	34	7.09	92	0.09	**0.12**	0.28		4	
NR-1	5/17/99	9.0	9.16	77	6.99	87.8		6.77	144	0.06	0.08	0.39	0.01	6	
NR-1	6/16/99	8.6	10.42	89	7.46	82.4	38	2.42	66	0.11	0.09		0.01	8	
NR-1	7/22/99	8.0	11.37	96	7.20	95.7	44	4.79	61	0.12	**0.12**	0.10	0.00	9	
NR-1	10/21/99	1.3	13.15	94	**6.38**	52.1	23	2.71	75	0.06	0.07	0.24	0.02		0.1
NR-1	5/9/00	3.2	11.72	87	**6.31**	48.7	22	2.25	80	0.08	0.10	0.22	0.03	6	0.1
NR-1	7/7/00	8.6	10.43	89		90.6	42	2.58	60	0.10	**0.13**	0.00	0.00	11	

Site ID	Date	Water Temp.°C	Dslvd. O_2, mg/L	Dsvld.O_2, % Sat.	pH	Cond., µS,cm	TDS, mg/L	Turb., NTUs	App. Color	Orthophos., mg/L	Total Phos., mg/L	Ammonia-N, mg/L	Nitrate-N, mg/L	TSS mg/L	Settle-able mg/L
NR-1	9/12/00	5.7	11.13	88	7.33	91.0	42	2.23	59	0.08	**0.16**	0.20	0.00	6	0.1
NR-1	10/3/00	2.4	12.24	89	7.43	85.5	38	2.08	50	0.07	0.09	0.14	0.01	6	0.1
NR-1	11/30/00	0.5	12.00	83		72.1	31	1.29	40	0.04	0.06	0.13	0.02	4	0.1
NR-1	1/3/01	0.5	11.50	80	6.84	94.3	40	2.41	44	0.05	0.08	0.11	0.04	5	0.1
NR-1	2/8/01	1.0	11.60	82	6.95	108.3	46	3.89	53	0.06	0.08	0.11	0.01	6	0.1
NR-1	4/23/01	0.5	11.14	77	7.27	45.9	20	3.80	109	0.08	0.10	0.28	0.00	7	0.1
NR-1	6/5/01	7.7	9.75	81		80.2	37	4.73	67	0.08	**0.12**	0.17	0.00	11	0.1
NR-1	7/18/01	8.9	10.26	88	7.41	91.5	43	4.87	73	0.08	**0.12**	0.21	0.00	7	0.1
NR-1	8/23/01	7.8	9.95	83	7.45	92.0	43	5.27	81	0.10		0.27	0.00	10	0.1
NR-1	9/20/01	7.5	8.98	75	7.21	87.8	41	3.37	78	0.08	**0.12**	0.28	0.00	9	0.1
NR-1	1/21/02	0.2			6.87	82.4	35	2.56	47	0.05	0.07	0.15	0.01	4	0.1
NR-1	3/7/02	0.2	12.30	85	7.18	95.0	41	4.62	66	0.15	**0.11**	0.10	0.00	9	0.1
NR-1	3/27/02	0.7	12.10	85	7.23	96.6	42	5.41	67	0.08	**0.11**	0.03	0.00	8	0.1
NR-1	5/29/02	8.5	10.14	85		74.1	34	5.72	69	0.09	**0.14**	0.17	0.00	14	0.1
NR-1	7/8/02	9.3	10.45	89	7.49	77.9	36	3.07	53	0.07	**0.14**	0.06	0.00	6	0.1
NR-1	8/22/02	10.3	7.42	65		79.2	37	5.25	100	0.09	**0.17**	0.36	0.00	9	0.1
NR-1	10/10/02	1.5	11.27	80	7.19	71.3	31	1.80	58	0.07	0.10	0.16	0.00	5	0.1
NR-1	11/13/02	0.4	11.78	81	7.01	64.6	28	2.78	59	0.06	0.09	0.14	0.00	7	0.1
NR-1	1/29/03	0.5	11.17	77	7.29	84.4	36	3.09	45	0.09	0.08	0.11	0.02	5	0.1
NR-1	2/26/03	0.5	10.76	74	7.22	81.7	35	3.06	53	0.06	0.10	0.16	0.02	7	0.1
NR-1	3/27/03	0.2	10.65	73		92.3	39	3.21	43	0.07	0.08	0.11	0.04	5	0.1
NR-1	5/21/03	5.7	10.39	81	7.51	73.0	33	3.18	45	0.06	0.10	0.10	0.00	6	0.1
NR-2	8/10/98	12.0	9.77	89	7.37	65.7	35	7.91	114	0.09	**0.15**	0.33		32	
NR-2	8/27/98	9.0	11.59	98	7.49	87.3	41	4.14	85	0.11	**0.11**	0.30		5	
NR-2	9/3/98	8.0	11.54	98	7.34	90.2	43	4.50	84	0.08	**0.14**	0.29		6	
NR-2	9/22/98	7.5	10.27	84	7.46	92.1	44	3.71	81	0.10	0.10	0.27		8	
NR-2	11/11/98	0.4	13.40	93	7.08	99.8	43	7.39	34		0.01	0.17	0.08	3	
NR-2	12/7/98	0.0	11.76	82	7.11	101.9	45		52	0.09	0.10	0.22	0.09	3	

Site ID	Date	Water Temp.°C	Dslvd. O_2, mg/L	Dsvld.O_2, % Sat.	pH	Cond., µS,cm	TDS, mg/L	Turb., NTUs	App. Color	Orthophos., mg/L	Total Phos., mg/L	Ammonia-N, mg/L	Nitrate-N, mg/L	TSS mg/L	Settle-able mg/L
NR-2	1/18/99	0.5	14.90	105	6.67	77.5	38	7.11	45	0.07	0.10	0.17	0.07	5	
NR-2	3/3/99	1.0													
NR-2	4/7/99	0.0													
NR-2	5/5/99	2.0	13.76	101	6.76			10.30	109	0.11	**0.16**	0.30		15	
NR-2	6/21/99	9.9	11.22	99	7.81	84.6	40	3.10	65	0.08	**0.14**		0.01	7	
NR-2	7/19/99	11.5	10.55	95		97.6	46	4.79	82		**0.14**	0.18		10	
NR-2	8/10/99	10.8	10.55	95		83.1	39	5.19	96	0.12	**0.16**	0.21	0.00		0.2
NR-2	10/6/99	4.3	12.43	96	6.86	66.6	30		99	0.06	**0.12**	0.30	0.00		0.2
NR-2	3/28/00	0.0	12.60	86		119.6	57		69	0.08	**0.11**	0.21	0.05	6	0.1
NR-2	5/25/00	4.6	12.59	98	6.81	69.2	31	3.69	81	0.07	**0.11**	0.20	0.00	16	0.1
NR-2	7/7/00	12.2	10.36	96		100.0	47	3.30	61	0.11	**0.15**	0.02	0.00	9	
NR-2	8/2/00	11.0	10.10	92	7.10	100.5	47	4.28	83	0.12	**0.15**	0.24	0.00	9	0.1
NR-2	9/21/00	5.7	12.09	96	7.75	103.6	47	2.48	59	0.13	**0.12**	0.17	0.00	6	0.1
NR-2	11/8/00	0.5	12.80	89	7.30	93.2	40	2.00	45	0.07	0.08	0.14	0.03	5	0.1
NR-2	1/4/01	0.5	11.70	81	7.21	95.0	45	2.18	45	0.07	0.08	0.17	0.06	10	0.1
NR-2	3/7/01	0.3	12.73	88	7.58	119.0	51	4.20	48	0.07	0.08	0.15		3	0.1
NR-2	4/18/01	0.7	13.09	91	7.47	74.2	32	11.35	131	0.08	**0.20**	0.28	0.00	25	0.2
NR-2	5/23/01	5.9	12.36	99	7.49	56.8	26	4.58	70	0.06	0.08	0.19	0.03	8	0.1
NR-2	7/12/01	10.5	10.37	93	7.78	90.4	42	5.99	72	0.16	**0.14**	0.16	0.00	8	0.1
NR-2	8/21/01	10.1	9.72	86	7.63	87.9	41	6.28	88	0.10		0.22	0.00	11	0.1
NR-2	10/3/01	4.4	12.39	95	7.68	95.3	43	4.72	66	0.08	**0.13**	0.20	0.00	6	0.1
NR-2	12/6/01	0.2	9.90	68	7.12	95.5	41	3.06	38	0.08	0.08	0.15	0.04	2	0.1
NR-2	1/17/02	0.3	9.77	67	6.95	82.9	35	1.26	47	0.08	0.06	0.13	0.04	2	0.1
NR-2	2/21/02	0.2	11.80	81	7.21	94.8	41	3.12	55	0.07	0.08	0.10	0.04	6	0.1
NR-2	4/25/02	0.2	11.70	80	7.21	73.6	31	3.96	85	0.09	**0.12**	0.20	0.00	6	0.1
NR-2	5/16/02	5.6	12.08	94		49.7	22	6.58	93	0.06	**0.11**	0.22	0.02	15	0.1
NR-2	7/25/02	12.0	9.75	89	7.31	85.5	41	6.10	78	0.10	**0.31**	0.20	0.00	16	0.1
NR-2	9/4/02	10.0	11.65	101	7.68	84.8	40	3.37	67	0.10	**0.12**	0.24	0.00	6	0.1

Site ID	Date	Water Temp.°C	Dslvd. O_2, mg/L	Dsvld.O_2, % Sat.	pH	Cond., µS,cm	TDS, mg/L	Turb., NTUs	App. Color	Orthophos., mg/L	Total Phos., mg/L	Ammonia-N, mg/L	Nitrate-N, mg/L	TSS mg/L	Settle-able mg/L
NR-2	10/9/02	2.8	13.67	100	7.34	71.9	32	3.00	76	0.08	0.10	0.26	0.00	8	0.1
NR-2	1/29/03	0.2	11.88	82	**6.46**	89.0	38	2.69	43	0.08	0.08	0.19	0.07	4	0.1
NR-2	2/26/03	0.3	13.53	93	7.57	84.4	36	2.83	50	0.08	0.06	0.15	0.06	4	0.1
NR-2	4/17/03	2.0	12.96	93	7.34	59.5	26	4.75	84	0.07	**0.14**	0.24	0.00	11	0.1
NR-2	5/21/03	10.3	11.74	103	8.03	76.7	36	2.25	52	0.06	0.10	0.12	0.01	3	0.1
NR-3	8/11/98	12.0			7.67	76.7	36		119					23	
NR-3	8/26/98	9.0	11.62	100	7.53	89.0	42	4.94	91	0.08	**0.15**	0.30		8	
NR-3	9/3/98	8.0	11.65	101	7.45	91.3	43	5.33	78		0.03	0.25		7	
NR-3	9/28/98	7.0	11.86	95	7.20	60.6	46	7.36	76	0.10	0.07	0.28		10	
NR-3	10/5/98	5.0	12.46	95	7.45	112.5	51	3.93	68	0.13	**0.12**	0.14	0.03	6	
NR-3	11/9/98	0.4	12.93	89	7.20	99.1	43	7.17	50		0.05	0.17	0.06	2	
NR-3	12/2/98	0.5	11.17	77	7.30	106.6	46	6.92	42	0.08	0.09	0.16	0.06	3	
NR-3	1/13/99	0.5	11.60	82	7.41	101.3	48	7.99	53			0.14	0.10	5	
NR-3	2/11/99	0.0			7.10	114.3	54	7.59	54	0.13			0.12	5	
NR-3	3/10/99	1.0	11.80		7.01	114.9	54	7.39	55		0.10	0.05		4	
NR-3	4/7/99	1.0			7.87	117.4	54	6.82	62	0.15	**0.12**	0.13	0.14	4	
NR-3	5/17/99	9.5	12.39	108	7.75	96.6	45	9.90	133	0.08	**0.16**	0.35	0.04	18	
NR-3	6/21/99	**14.5**	11.40	110	8.02	81.6	39	2.02	56	0.08	0.10	0.10	0.01	4	
NR-3	7/12/99	**14.0**	10.30	100		104.1	49	1.84	70	0.11	**0.13**		0.02	10	
NR-3	8/10/99	**13.6**	9.59	93		83.5	40	7.35	104	0.11	**0.17**	0.22	0.00		0.2
NR-3	10/1/99	5.8	12.16	97	7.09	93.3	43	6.14	80	0.09	**0.27**	0.20	0.00		0.2
NR-3	10/19/99	2.1	13.76	100	**6.34**	42.8	19	10.07		0.09	**0.19**	0.38	0.02		0.2
NR-3	11/10/99	0.0	14.00	96	6.80				47	0.08	0.08	0.05	0.04		
NR-3	12/13/99	0.0	12.30	87	6.94	73.4	34	3.67	46	0.08	0.10	0.09	0.09		0.1
NR-3	1/20/00	0.0	12.10	86		99.5	47	2.46	43	0.07	0.09	0.06	0.08	4	0.1
NR-3	2/15/00				6.81	108.9	51	2.73	46	0.09	0.09	0.17	0.02		
NR-3	3/8/00	0.0	13.10	89	6.85	112.5	53	2.77	51	0.11	0.10	0.15	0.08	6	0.1
NR-3	4/11/00	0.0	14.00	96	6.93	120.3	57		64	0.09			0.04	12	0.1

Site ID	Date	Water Temp.°C	Dslvd. O_2, mg/L	Dsvld.O_2, % Sat.	pH	Cond., µS,cm	TDS, mg/L	Turb., NTUs	App. Color	Orthophos., mg/L	Total Phos., mg/L	Ammonia-N, mg/L	Nitrate-N, mg/L	TSS mg/L	Settle-able mg/L
NR-3	5/25/00	5.2	12.66	100	7.08	68.6	31	4.72	85	0.07	0.10	0.20	0.00	10	0.1
NR-3	7/25/00	**13.2**	9.80	94	6.87	77.8	37	3.53	102	0.10	**0.18**	0.32	0.00	22	0.1
NR-3	9/12/00	8.3	11.66	99	8.15	97.9	49	3.95	68	0.11	0.07	0.20	0.00	9	0.1
NR-3	10/3/00	3.5	12.93	97	7.76	92.2	41	2.98	51	0.09	**0.11**	0.15	0.01	6	0.1
NR-3	11/14/00	1.0			7.09	58.8	25	3.35	74	0.06	0.09	0.21	0.01	9	0.1
NR-3	1/19/01	1.0	12.20	86	7.32	93.4	40	3.24	66	0.11	0.08	0.13	0.04	4	0.1
NR-3	3/1/01	0.3	11.40	79	6.90	109.9	47	2.94	53	0.07	0.09	0.14		6	0.1
NR-3	4/17/01	0.6	14.27	99	7.47	71.4	31	7.42	123	0.07	**0.13**	0.24	0.00	14	0.1
NR-3	6/5/01	11.3	10.77	98	7.76	67.9	32	3.82	70	0.06	0.10	0.18	0.00	9	0.1
NR-3	7/19/01	12.5	10.07	94	7.71	95.8	45	5.90	76	0.14	**0.15**	0.26	0.01	10	0.1
NR-3	8/22/01	10.7	10.58	95	7.69	95.2	45	5.55	86	0.09		0.27	0.00	12	0.1
NR-3	10/3/01	5.6	12.62	99	7.81	94.3	43	4.91	65	0.09	**0.13**	0.20	0.00	5	0.1
NR-3	12/5/01	0.2	9.80	67	7.10	98.8	42	3.30	42	0.05	0.09	0.14	0.08	5	0.1
NR-3	1/3/02	0.2	10.90	75	7.04	72.3	31	1.66	71	0.09	**0.11**	0.20	0.01	4	0.1
NR-3	2/28/02	0.2	10.50	72	6.86	99.8	43	2.52	47	0.09	0.08	0.13	0.06	3	0.1
NR-3	4/25/02	0.2	11.70	81	7.09	70.3	30	5.32	87	0.10	**0.13**	0.19	0.00	12	0.1
NR-3	5/2/02	1.6	11.80	85	7.11	36.3	16	7.93	125	0.05	**0.13**	0.33	0.00	15	0.1
NR-3	6/4/02	9.9	12.94	112		74.2	35	2.92	69	0.07	0.08	0.17	0.00	13	0.1
NR-3	7/25/02	**15.1**	9.12	90	**6.11**	88.8	42	8.55	78	0.16	**0.18**	0.21	0.00	16	0.1
NR-3	9/4/02	11.3	11.20	101		87.0	41	3.86	73	0.08	**0.13**	0.20	0.00	6	0.1
NR-3	10/16/02	4.6	12.75	97	7.35	64.0	29	4.96	89	0.08	**0.11**	0.32	0.00	10	0.1
NR-3	10/30/02	3.3	11.98	89	6.90	39.9	18	7.81	139	0.04	0.09	0.41	0.00	15	0.1
NR-3	1/3/03	0.3	10.00	69	6.80	83.7	36	1.36	36	0.05	0.09	0.03	0.07	3	0.1
NR-3	3/6/03	0.2	13.62	94	6.75	68.8	29	2.94	77	0.06	0.07	0.22	0.03	4	0.1
NR-3	4/17/03	3.5	13.58	101		59.7	27	5.02	83	0.07	**0.11**	0.24	0.00	11	0.1
NR-3	6/4/03	10.1	11.48	100	7.88	78.7	37	2.49	62	0.07	0.09	0.18	0.01	4	0.1
NR-3	6/11/03	9.2	10.75	93		65.2	30	21.30	103	0.09	**0.23**	0.35	0.02	45	0.3
SC-1	8/13/98	10.5	8.64	77	7.49	82.2	34	3.37	63	0.12	**0.20**	0.27		6	

Site ID	Date	Water Temp.°C	Dslvd. O_2, mg/L	Dsvld.O_2, % Sat.	pH	Cond., µS,cm	TDS, mg/L	Turb., NTUs	App. Color	Orthophos., mg/L	Total Phos., mg/L	Ammonia-N, mg/L	Nitrate-N, mg/L	TSS mg/L	Settle-able mg/L
SC-1	8/24/98	9.0	10.79	94	7.45	59.5	29	11.20	153	0.10	**0.23**			35	
SC-1	9/2/98	6.5	12.42	103	7.38	60.5	28	4.66	79	0.06	**0.12**	0.26		11	
SC-1	9/25/98	5.9	10.80	88	7.26	69.8	32	7.64	84	0.15	**0.15**	0.29		16	
SC-1	11/23/98	0.5			7.23	74.4	32	6.92	41	0.17		0.09	0.15	5	
SC-1	12/10/98	0.5			7.23	72.0	34	7.71	42	0.09	**0.23**	0.16	0.14	9	
SC-1	1/20/99				7.17	79.8	38	7.84	45	0.08	0.07	0.11	0.20	4	
SC-1	3/4/99	1.0	13.50	95		115.4	43		44	0.09	0.09	0.09	0.20	1	
SC-1	4/15/99	1.0	14.20	100	7.02	90.5	43	7.90	55	0.09	**0.11**	0.14	0.26	6	
SC-1	5/13/99	2.6	14.09	103	7.21	43.5	19	15.80	153	0.06	**0.18**	0.46		35	
SC-1	6/23/99	10.3	10.98	98	7.71	59.9	28	1.45	58	0.08	0.09	0.12	0.06	5	
SC-1	7/14/99	10.6	10.82	97		82.3	39	2.77	51	0.08					
SC-1	11/18/99	0.0	13.60	93	6.74			3.80	58	0.08	0.07	0.10	0.11		
SC-1	2/22/00	0.0	14.50	100	7.07	85.1	40	3.25	43	0.08	0.09	0.11	0.15		0.1
SC-1	6/5/00	9.3	11.59	101	6.73	64.4	30				0.08	0.13		5	0.1
SC-1	7/27/00	10.9	10.27	93	6.99	70.7	33	2.46	78	0.09	**0.11**	0.25	0.04	8	0.1
SC-1	9/14/00	7.5	12.25	102	7.53	77.9	36	2.04	57	0.10	0.10	0.14	0.01	7	0.1
SC-1	9/27/00	4.9	12.20	95	7.43	71.2	32	3.33	67	0.10	0.08	0.19	0.03	8	0.1
SC-1	12/14/00	0.5	13.00	90	7.11	67.7	29	2.30	38	0.04	0.06	0.09	0.14	5	0.1
SC-1	1/12/01	1.0	12.20	86	7.25	73.9	32	1.81	31	0.05	0.07	0.09	0.15	3	0.1
SC-1	3/2/01	0.4	12.87	89	6.94	79.3	34	2.87	43	0.08	0.08	0.12		3	0.1
SC-1	4/20/01	1.6	13.96	100	7.51	71.3	31	6.54	81	0.05	**0.11**	0.20	0.02	14	0.1
SC-1	5/24/01	2.6	13.13	96	7.65	39.4	17	12.10	86	0.04	**0.12**	0.20	0.09	24	0.1
SC-1	7/26/01	11.0	10.23	93	7.52	62.9	29	5.41	76	0.08	0.10	0.26	0.07	8	0.1
SC-1	8/24/01	9.7	10.82	95	7.51	76.8	36	3.69	61	0.05		0.17	0.05	3	0.1
SC-1	9/27/01	3.7	12.97	98	7.42	71.7	32	2.86	60	0.08	**0.14**	0.20	0.05	5	0.1
SC-1	12/13/01	0.2	10.30	71	6.61	76.3	33	2.99	43	0.08	0.07	0.12	0.17	4	0.1
SC-1	1/31/02	0.2	12.60	87	7.08	75.6	32	3.22	48	0.13	0.08	0.11	0.12	6	0.1
SC-1	3/13/02	0.2	13.00	90	7.15	80.8	35	3.35	46	0.08	0.08	0.10	0.18	4	0.1

Site ID	Date	Water Temp.°C	Dslvd. O_2, mg/L	Dsvld.O_2, % Sat.	pH	Cond., µS,cm	TDS, mg/L	Turb., NTUs	App. Color	Orthophos., mg/L	Total Phos., mg/L	Ammonia-N, mg/L	Nitrate-N, mg/L	TSS mg/L	Settle-able mg/L
SC-1	4/24/02	0.3	11.80	82	7.16	71.5	31	6.94	62	0.05	**0.14**	0.16	0.07	15	0.1
SC-1	5/20/02	4.0	13.72	103	7.02	37.8	17	24.40	141	0.02	**0.24**	0.27	0.13	54	0.2
SC-1	7/31/02	10.9	10.38	93	7.75	74.9	35	3.67	51	0.10	**0.12**	0.20	0.14	5	0.1
SC-1	9/5/02	9.5	11.04	95	7.54	71.0	33	2.80	60	0.09	**0.11**	0.17	0.11	3	0.1
SC-1	11/6/02	5.0	12.68	98	7.19	32.8	15	47.90	377	0.02	**0.28**	0.61	0.00	113	0.3
SC-1	11/20/02	0.6	14.43	100	7.42	56.3	24	2.62	52	0.06	0.07	0.14	0.16	4	0.1
SC-1	1/30/03	0.3	13.86	95	7.51	69.5	30	2.26	36	0.06	0.07	0.17	0.26	3	0.1
SC-1	2/20/03	0.2	12.70	88		66.5	28	2.25	42	0.07	0.07	0.27	0.24	4	0.1
SC-1	3/26/03	0.3	12.72	87	7.30	75.8	32	2.53	26	0.08	0.06	0.07	0.38	4	0.1
SC-1	5/15/03	5.7	12.60	99	7.73	52.9	24	2.95	61	0.03	0.07	0.10	0.00	6	0.1
SC-2	8/15/98	12.0	9.60	89	7.40	70.3	33	5.95	91	0.15	**0.13**	0.24		11	
SC-2	8/26/98	8.0	11.75	100	7.40	89.0	29	3.10	14	0.07	**0.14**	0.34		20	
SC-2	9/2/98	9.0	11.54	104	7.32	60.1	28	6.74	103	0.05	**0.12**	0.31		13	
SC-2	9/28/98	7.0	11.42	92	7.30	45.8	35		76	0.08	0.08	0.26		10	
SC-2	10/7/98	3.0	12.81	95	7.42	58.2	48	7.35	72		**0.11**	0.12		6	
SC-2	11/23/98				7.25	103.5	48	7.40	52	0.07	0.07	0.08	0.09	3	
SC-2	12/15/98	0.5	11.59	80	7.05	77.6	37		57	0.08	0.08	0.15	0.12	10	
SC-2	1/11/99	0.5	11.30	80	7.20	82.9	39	8.64	62		0.08	0.08	0.14	7	
SC-2	2/24/99	1.0			6.84	91.5	43		51	0.09	0.08	0.08	0.15	3	
SC-2	3/4/99	1.0	11.70	82		94.7	45		56		0.09	0.09	0.13	1	
SC-2	4/20/99	0.5	13.40	94	7.78	73.6	35	8.19	99	0.08	0.10	0.14		9	
SC-2	5/13/99	5.0	12.80	100	6.98	40.1	18	19.60	199	0.09	**0.28**	0.49		56	
SC-2	6/23/99	**14.2**	10.36	101	7.81	64.7	31	3.26	71	0.08	**0.11**	0.15	0.01	10	
SC-2	7/8/99	**15.6**	9.87	99		80.1	38	1.01	63	0.09				6	
SC-2	8/12/99	10.8	10.51	98	7.33	77.6	36	14.30	134	0.11	**0.22**	0.17	0.02		0.4
SC-2	9/27/99	3.8	13.51	103	7.17	71.4	32	3.37	75	0.08	0.10	0.13	0.05		0.1
SC-2	10/8/99	1.7	14.97	107	6.58	40.4	18	20.60		0.05	**0.20**	0.45	0.02		0.3
SC-2	11/18/99	0.0	12.90	88	6.67			1.58	40	0.08	0.08	0.08	0.18		0.1

Site ID	Date	Water Temp.^{o}C	Dslvd. O_2, mg/L	Dsvld.O_2, % Sat.	pH	Cond., µS,cm	TDS, mg/L	Turb., NTUs	App. Color	Orthophos., mg/L	Total Phos., mg/L	Ammonia-N, mg/L	Nitrate-N, mg/L	TSS mg/L	Settle-able mg/L
SC-2	12/15/99	0.0	12.70	87	**6.40**	69.2	33	4.88	54	0.06	0.10	0.10	0.13		
SC-2	2/1/00				**6.19**	86.1	41	3.80	57	0.06	0.07	0.09	0.12	6	0.1
SC-2	3/8/00	0.0	13.90	95	7.15	87.9	41	5.22	56	0.07	0.09	0.10	0.10	6	0.1
SC-2	4/11/00	0.0	14.10	97	7.21	88.0	42		81	0.08			0.02	14	0.1
SC-2	5/24/00	5.2	12.64	100	6.74	58.9	27	12.20	117	0.06	**0.16**	0.23	0.03	34	0.2
SC-2	7/27/00	**14.4**	9.74	95	7.39	75.3	36	3.78	103	0.10	**0.13**	0.27	0.00	13	0.1
SC-2	9/14/00	8.9	11.22	99	7.84	83.3	39	3.24	70	0.08	0.09	0.14	0.00	6	0.1
SC-2	9/29/00	2.6	13.32	98	7.39	78.8	35	3.58	76	0.06	**0.11**	0.18	0.00	8	0.1
SC-2	12/14/00	0.5	12.70	88	7.20	74.2	32	2.22	42	0.04	0.06	0.09	0.09	4	0.1
SC-2	1/18/01	1.0	12.50	88	6.93	57.9	25	3.11	67	0.03	0.07	0.15	0.03	7	0.1
SC-2	2/22/01	0.5	11.70	81	6.88	86.3	37	3.95	51	0.05	0.07	0.11	0.04	5	0.1
SC-2	2/22/01	0.5	11.70	81	6.95	86.0	37	3.87	51	0.05	0.08	0.11	0.04	6	0.1
SC-2	2/22/01	0.5	12.30	85	6.96	86.1	37	3.66	49	0.06	0.07	0.12	0.04	5	0.1
SC-2	4/17/01	2.0	12.39	89	7.50	54.0	24	11.45	132	0.04	**0.17**	0.26	0.00	30	0.1
SC-2	5/29/01	6.3	12.18	98	7.25	37.5	17	59.80	234	0.09	**0.43**	0.38	0.00	130	0.5
SC-2	7/11/01	11.6	10.66	97	7.91	78.7	37	3.45	76	0.04	0.09	0.08	0.00	6	0.1
SC-2	9/5/01	9.9	11.14	98	7.69	72.0	34	11.90	102	0.05	**0.18**	0.26	0.00	22	0.1
SC-2	10/11/01	1.9	13.60	98	7.17	59.7	26	5.67	87	0.04	0.09	0.24	0.00	12	0.1
SC-2	12/5/01	0.2	9.70	67	7.05	87.1	37	4.81	61	0.04	0.07	0.08	0.12	5	0.1
SC-2	1/3/02	0.2	10.00	69	7.21	52.4	22	1.38	72	0.06	0.06	0.21	0.00	2	0.1
SC-2	2/28/02	0.2	12.30	85	7.19	81.3	35	4.08	53	0.06	0.08	0.10	0.08	5	0.1
SC-2	4/18/02	0.2	12.80	88	7.04	83.9	36	5.53	66	0.05	0.10	0.08	0.07	6	0.1
SC-2	5/2/02	1.3	11.70	83	7.53	30.3	13	19.10	181	0.03	**0.15**	0.36	0.00	38	0.1
SC-2	6/3/02	8.6	11.33	96	7.08	54.7	25	20.50	133	0.05	**0.19**	0.16	0.04	42	0.2
SC-2	7/11/02	**14.0**	10.20	98	7.68	74.0	35	2.88	61	0.06	0.09	0.08	0.00	5	0.1
SC-2	8/22/02	12.6	10.46	97		78.2	37	4.78	78	0.09	**0.14**	0.25	0.04	5	0.1
SC-2	10/9/02	3.7	14.15	106	7.27	61.2	27	4.86	88	0.05	0.09	0.25	0.01	9	0.1
SC-2	10/30/02	3.6	12.65	94		31.5	14	36.80	315	0.06	**0.41**	0.64	0.00	85	0.1

Site ID	Date	Water Temp.°C	Dslvd. O_2, mg/L	Dsvld.O_2, % Sat.	pH	Cond., µS,cm	TDS, mg/L	Turb., NTUs	App. Color	Orthophos., mg/L	Total Phos., mg/L	Ammonia-N, mg/L	Nitrate-N, mg/L	TSS mg/L	Settle-able mg/L
SC-2	11/20/02	0.7	13.56	95		58.3	25	4.67	67	0.04	0.08	0.15	0.10	8	0.1
SC-2	1/9/03	0.3	10.60	73	6.76	71.3	30	3.54	48	0.07	0.08	0.03	0.19	5	0.1
SC-2	3/5/03	0.2	14.56	100	7.22	50.9	22	3.72	83	0.03	0.06	0.20	0.03	7	0.1
SC-2	4/24/03	4.4	12.79	97	7.42	56.8	25	17.30	161	0.07	**0.16**	0.26	0.06	38	0.1
SC-2	5/15/03	8.7	12.57	106	7.71	54.3	25	4.95	74	0.05	0.08	0.17	0.00	10	0.1
SC-2	6/4/03	10.9	10.84	96	8.25	66.5	31	2.56	65	0.04	0.08	0.16	0.00	6	0.1
SC-2	6/27/03	11.2	9.85	94	7.46	66.2	31	3.18	80	0.04	0.08	0.11	0.00	5	0.1

APPENDIX III.

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