FRED Reports

Kenai River Water Quality Investigation
Completion Report

by

V. P. Litchfield and G. B. Kyle

Number 123

Alaska Department of Fish & Game
Division of Fisheries Rehabilitation,
Enhancement and Development

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Commissioner

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ABSTRACT

A two-year water quality investigation was initiated on the Kenai River in the fall of 1989 to assess current water quality and to establish a baseline for evaluating future impacts from recreation and development. The investigation was conducted as a multiagency project with cooperation from the Alaska Department of Natural Resources (ADNR), Alaska Department of Fish and Game (ADF&G), the U. S. Fish and Wildlife Service (USF&WS), and the Kenai River Advisory Board (KRAB). Results from sampling in 1989-1990 indicated that overall the water quality of the Kenai River was unimpaired; however, there were elevated concentrations of some water quality parameters in the lower river. In 1991, sampling focused on the lower river, and as found in 1990, water quality parameters and nutrient concentrations were normal relative to other Alaskan waters. In addition, metal concentrations were well within federal and state criteria for freshwater aquatic life, as were hydrocarbon compounds found in the lower river with the exception of the occasional presence of oil sheens below outfalls of two storm drains. In 1990 and 1991, fecal coliform bacteria counts below the Soldotna Bridge were elevated compared to the upper river, and some individual samples were found approaching State of Alaska criteria for secondary water recreation use. Benthic invertebrate populations differed between the upper and lower river, indicating differential impacts or habitats; however, there is no evidence of a residual toxic effect from any contaminants. Finally, as the potential for impairment of water quality in the Kenai River is a serious concern relative to preserving the ecosystem of this highly valued resource producer, annual monitoring of critical parameters should be conducted.

INTRODUCTION

The Kenai River has long been the subject of numerous biological, economic and political discussions pertaining to sustaining the viability of recreational use and aquatic habitat. Although various fishery research projects have been conducted on the Kenai River, water quality investigations have been lacking. In 1989, a multiagency project was launched to assess the current status of water quality and to establish a baseline for physical, chemical, and biological data to use as a reference for monitoring future impacts. In general, information collected in 1989 and 1990 (Litchfield and Kyle 1991) indicated that water quality parameters were within concentrations found to be non-harmful to aquatic life. However, there were elevated concentrations of some water quality parameters during intense use in the lower portion of the river. In 1991, water quality sampling was continued in the upper river and intensified in the lower river. This report provides results of the 1991 sampling, includes pertinent 1990 data, and offers recommendations for future monitoring of water quality in the Kenai River.

Study Site Description-- The Kenai River begins at the outlet of Kenai Lake in Copper Landing and flows 132 km (82 mi) through state, federal and private lands before emptying into Cook Inlet near the city of Kenai. In addition to the nine major tributaries, the lower Kenai River has several storm drains and several treated waste-water discharges (e.g. salmon processing plants and the Soldotna Sewer Treatment Plant) emptying into the mainstem. The flow discharge of the Kenai River at the Soldotna gaging station ranged from a minimum of 27 m^3/s (950 cfs) to a maximum of 453 m^3/s (16,000 cfs) during 1990 and 1991 (Figure 1). The highest flows occurred during July-September and the lowest flows occur during the late-winter months (January-March). The mean monthly flow for 1991 was substantially lower than in 1990, and lower than the 25 year average (Figure 1) (Lamke *et. al.* 1991).

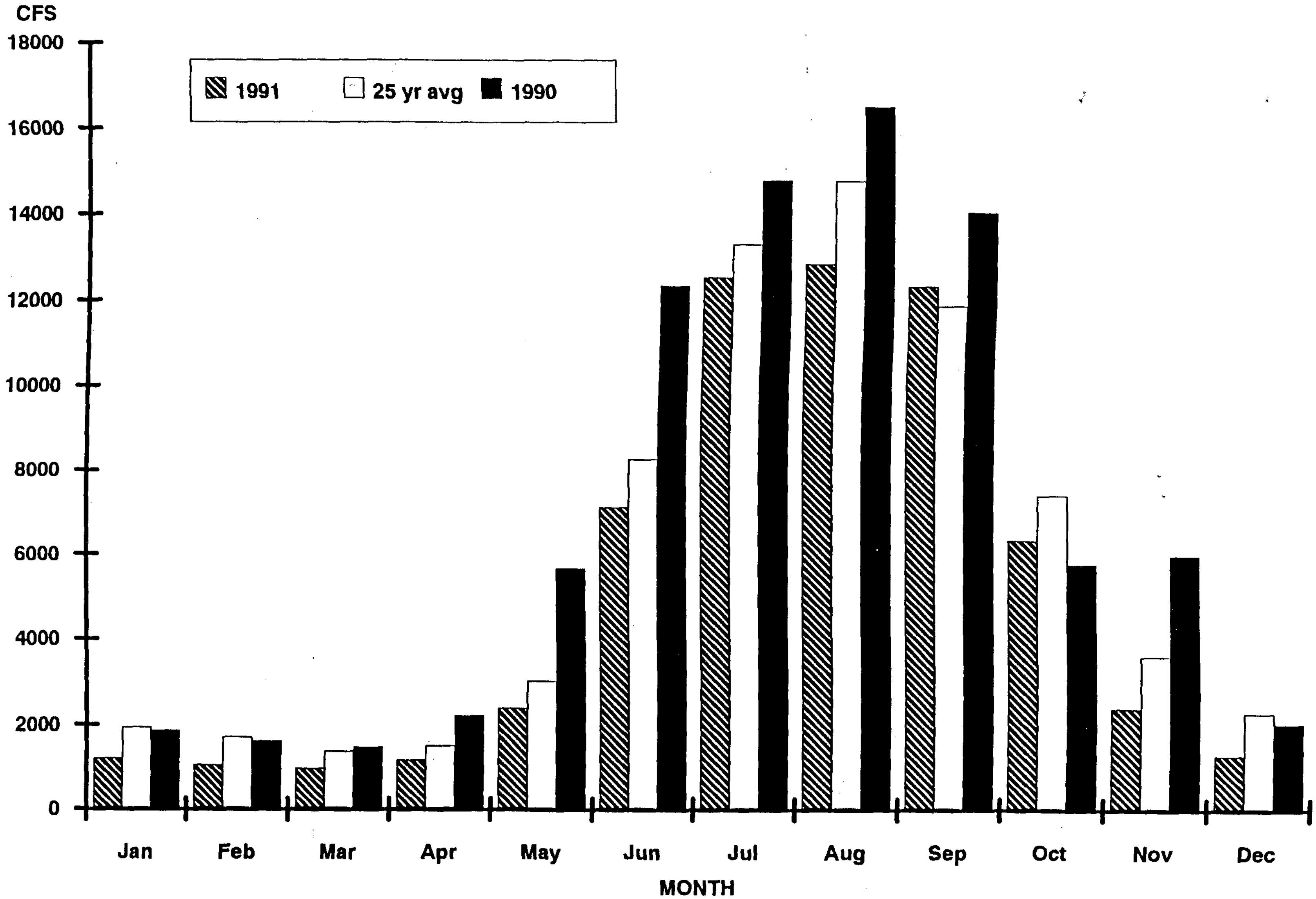
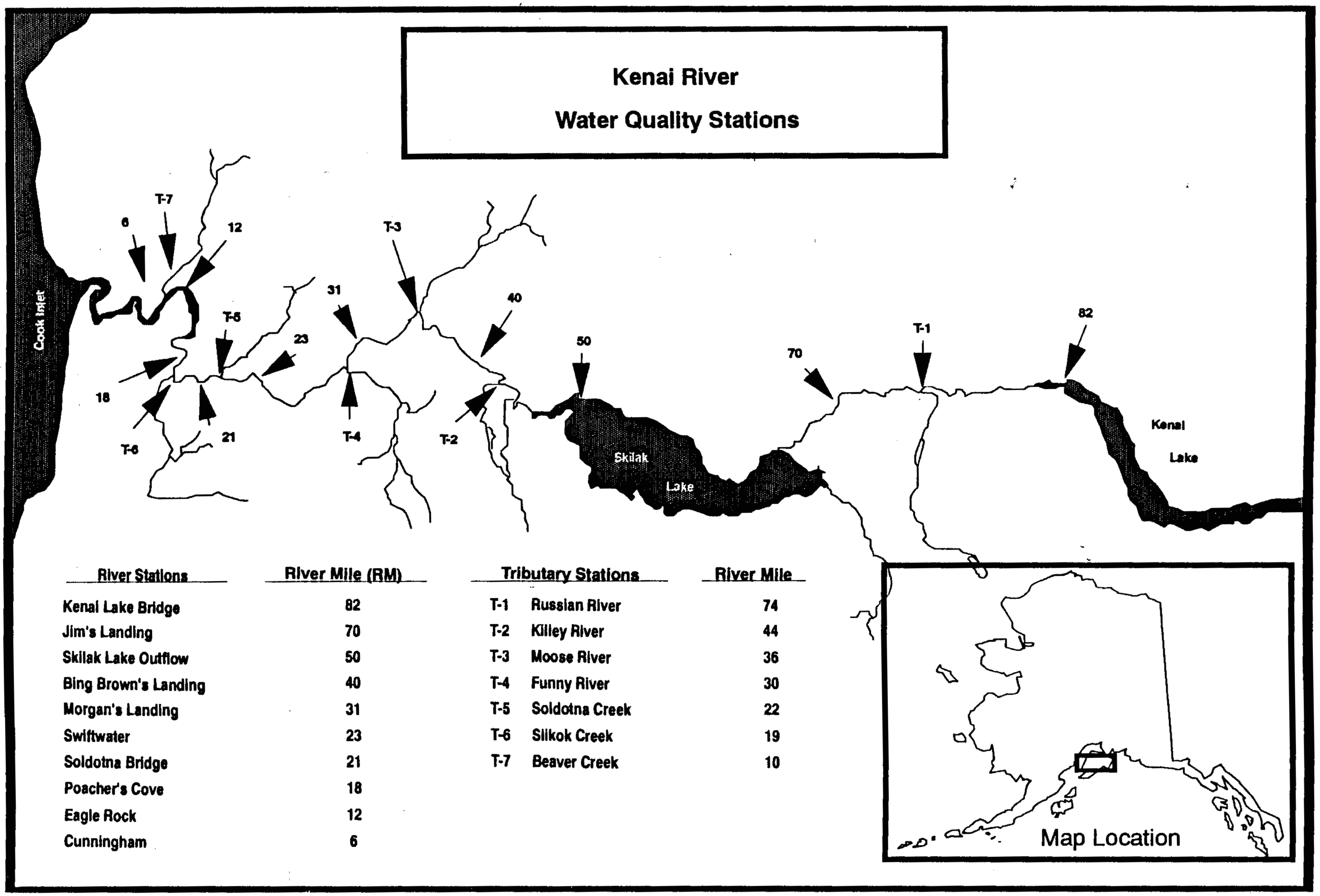


Figure 1. Kenai River discharge (CFS) at the Soldotna Bridge for 1990, 1991, and the 25-year average.

METHODS

Data collected in 1989 and 1990 revealed differences in some water quality parameters between the largely undeveloped upper river and the more urbanized lower river (Litchfield and Kyle 1991). In general, in 1990 the majority of parameters were below threshold concentrations relative to effects on aquatic life; however, some parameters were detected at elevated concentrations in the lower river. Due to saltwater influence on most of the analytical tests, the limnological station at river mile (RM) 0 was moved upriver to RM 6 in 1991; however, fecal coliform and hydrocarbons were examined at both sites. With the exception of the station nearest to Cook Inlet, the same ten stations used in 1990 were used again in 1991 (Figure 2). Three stations were located between Skilak and Kenai lakes, six were between the Soldotna Bridge and Skilak Lake, and four were located below the Soldotna Bridge. In addition to these sample stations, four other lower river sites were sampled (Figure 3) and the same seven tributaries of the Kenai River sampled in 1990 were sampled in 1991 (Figure 2).

Sampling was conducted on a monthly basis during the ice-free period (April-November) for the mainstem stations and once in the spring and fall for the tributaries. Physical data collected included temperature and Secchi disk depth. Mid-river surface and subsurface water was collected and examined for chemical and biological water quality parameters (Litchfield and Kyle 1991). In addition, benthic invertebrate samples were collected in the spring. Certain parameters that were not detected in the upper river stations in 1990 were examined only in the lower portions of the river in 1991. As in 1990, the tributaries were sampled near the confluence with the Kenai River but far enough upstream to eliminate mainstem influence. A motorized boat was used to collect samples in the spring and summer, and in the late fall when the river was too low for navigation, shore samples were collected.



River Stations	River Mile (RM)
Kenai Lake Bridge	82
Jim's Landing	70
Skilak Lake Outflow	50
Bing Brown's Landing	40
Morgan's Landing	31
Swiftwater	23
Soldotna Bridge	21
Poacher's Cove	18
Eagle Rock	12
Cunningham	6

Tributary Stations		River Mile
T-1	Russian River	74
T-2	Killey River	44
T-3	Moose River	36
T-4	Funny River	30
T-5	Soldotna Creek	22
T-6	Slikok Creek	19
T-7	Beaver Creek	10

Figure 2. Location of water quality sample stations in the mainstem (River Mile 6-82) and in seven tributaries (T1-7) of the Kenai River.

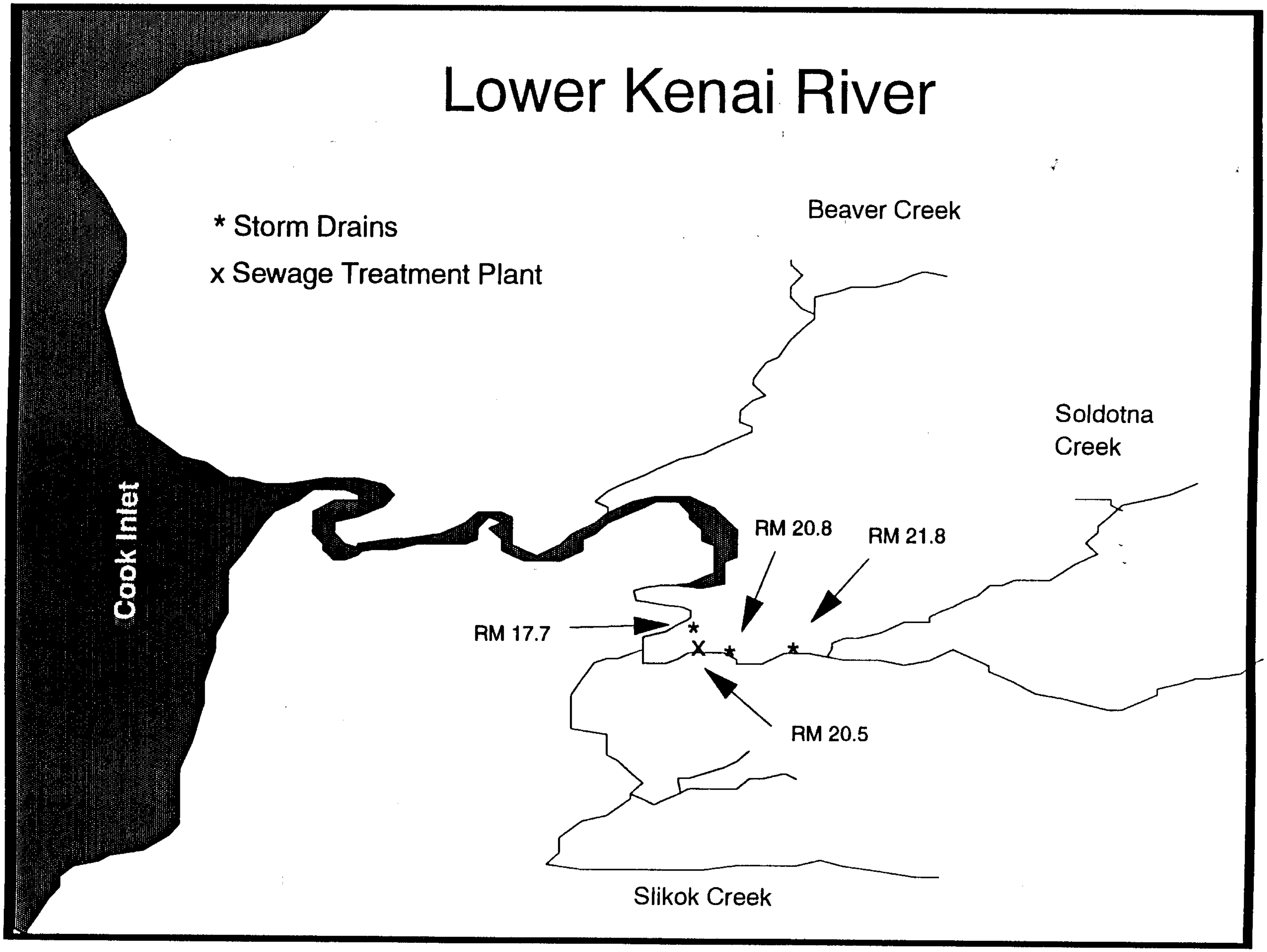


Figure 3. Location of additional 1991 sampling locations in the lower Kenai River.

Nutrients and general water quality parameters were analyzed by the ADF&G Limnology Laboratory in Soldotna using methods detailed by Koenings *et al.* (1987). Sampling procedures and contractual analysis was identical to 1990 as described by Litchfield and Kyle (1991), with the following exceptions or additions. Metal analysis was conducted on water samples from five stations in the mainstem and seven tributaries. In addition, a total of 28 juvenile fish representing six different species were collected throughout the river with baited minnow traps (eggs in a perforated canister) and analyzed for metals. The water samples and 14 whole fish and 15 liver tissue samples were analyzed for a "full element" scan utilizing inductively coupled plasma mass spectrometry (ICP-MS) by Elemental Research Inc. of Vancouver B.C. Canada.

Water samples for analysis of hydrocarbons were sent to Analytical Resources Incorporated of Seattle, Washington. Both total petroleum hydrocarbon (TPH) and volatile organics analysis (VOA) were determined using the United States Environmental Protection Agency (EPA) infra-red method number 418.1 (EMSL 1983) and GC-MS 624 (Federal Register 1984), respectively. In 1991, water sampling to determine hydrocarbon content was limited to the lower section of the Kenai River, as in 1990 detectable levels were found only in this area. Additional locations in the lower river were sampled for hydrocarbons in 1991 to monitor influence from several storm drains entering the Kenai River (Figure 3). In 1991, in order to lower the TPH detection limit (from 1000 to 500 μg/L), a greater volume of sample was collected than in 1990. Surface water was collected in pre-cleaned 1000-ml amber glass containers for TPH analysis, and three 40-ml viles for VOA. The VOA samples were preserved with 0.05 ml 1:1 HCL, and two blanks were included in every shipment.

In addition to the above analysis of hydrocarbons on water samples, as part of a Masters thesis to determine the suitability of sculpin as a model for pollution, Cheryl

Paige of the University of Alaska-Anchorage conducted assays (Paige 1992) on livers from two species of sculpin, *Cottus aleuticus* and *Cottus cognatus* in the Kenai River. Sculpins were selected for this investigation because hydrocarbon compounds tend to settle in the substrate, and as sculpins are bottom-feeders they would naturally have a high potential for ingesting these compounds. Sculpins (n = 8-24 per site) were collected in 1990 from six sites in the river (near Russian River, Moose River, Funny River, Soldotna Creek, Slikok Creek, and Beaver Creek), and in 1991 from Slikok and Beaver creeks. The livers were immediately removed upon capture and preserved in a microsome homogenization buffer until further processing in the laboratory. In general, this technique uses an enzyme which responds to exposure to xenobiotics such as polynuclear aromatic hydrocarbons and polychlorinated biphenols. The activity of this enzyme increases with ingestion of xenobiotics and results in aiding an organism to excrete the contaminant. Analysis consisted of measuring specific activity rates (nmoles resorufin/min/mg protein) of ethoxyresorufin-o-dealkylase (EROD) through fluorescence detection (Andersson *et al.* 1985).

Benthic invertebrate samples were collected during the month of May, when the gravel substrate (benthic habitat) was accessible. Due to the results found in 1990, benthic investigations in 1991 were intensified such that a total of thirteen locations from RM 17-79 were sampled, and the number of randomly selected samples per location was increased from three to five. All benthic samples were sent to the Environmental and Natural Resource Institute of the University of Alaska-Anchorage for analysis. The samples were sorted and identified to the family level, and to genera for Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies), the EPT genera. Sample locations were compared using four biotic metrics: 1) the number of EPT genera, 2) the EPT to total individuals ratio, 3) the Baetids (mayflies) to total EPT ratio, and 4) the percent dominant taxa which reveals the presence or absence of invertebrate families according to a tolerance rating (Hilsenoff 1988).

The number of EPT genera increases as water quality becomes higher providing habitat conditions are comparable. A pristine site rarely supports higher than 10 EPT genera. Percent dominant taxa reflects loss of sensitive groups and as the higher one tolerant taxa dominates (notably Chironomids or Oligochaeta worms), the greater chance that water quality is impacting aquatic habitat. The EPT to total individuals ratio reflects a higher water quality as the ratio approaches a maximum of one; however, in reality the ratio never attains one as there are still Chironomids and other Dipterans in the most pristine of waters. The Baetids to total EPT individuals ratio indicates less water quality degradation as the ratio approaches zero. Baetid mayflies are one of the most tolerant genera of pollution and generally water quality is high when this group is less dominant.

Finally, coliform bacterial analysis (fecal coliform) was conducted on surface water from samples in the lower river. Throughout 1990, total, fecal, and fecal streptococcus coliform colonies were detected at low counts, but elevated counts of fecal coliform (FC) were observed in the lower river and one tributary. These findings plus the fact that only FC is regulated (for water recreation use), prompt the sampling for FC (and limited FS) only in the lower river and the tributaries during 1991.

RESULTS AND DISCUSSION

Physical Parameters-- The influence of saltwater at river mile (RM) 6 is minimal; however, certain parameters (physical as well as chemical and biological) are biased by this effect. Thus, the mainstem stations are reported (unless noted) without including results from the station at RM 6.

Seasonal temperatures among the nine mainstem stations (RM 12-82) ranged from 2-12°C and averaged 7.5°C which was approximately 1.0°C warmer than in 1990. In 1991, oxygen analysis consisted of the determination of biochemical oxygen demand (BOD) which is the measurement of oxygen required for the decomposition of organic material commonly found in waste waters, effluent, and polluted waters. In 1991, BOD ranged from 0 to 2.6 mg/L, and averaged 0.8 mg/L compared to an average of 0.1 mg/L in 1990 (Litchfield and Kyle 1991). Although the BOD values were slightly higher in 1991, the average concentration is still considered low with no excessive demands by organisms associated with polluted waters.

Secchi disk readings in the mainstem of the Kenai River ranged from 0.5-1.5 m and averaged 0.9 m over the 1991 season. The seasonal variation of turbidity ranged from 0.3 to 9 NTU for RM 12-82 which was considerably lower than in 1990, except for the month of August. The higher turbidity in 1990 was associated with higher flows (Figure 4) and in the fall by the glacial outburst of Snow Lake. In addition to an increased glacial influence, the scouring effect of high river levels result in elevated sediment loading. Turbidity in the tributaries ranged from a low of 0.4 NTU in the Russian River to a high of 42 NTU in the Killey River. Throughout the sampling period of 1991, the one-percent light level (depth range at which photosynthesis occurs) extended to the mean depth which indicates that turbidity did not limit the vertical extent of photosynthesis.

General Water Quality-- General water quality parameters for stations in the mainstem of the Kenai River are summarized in Tables 1 and 2 and for the tributaries in Table 3. Conductivity ranged from 56 to 81 μmhos/cm during the season and averaged 65 μmhos/cm in the mainstem, and in the tributaries ranged from 27 μmhos/cm in the Killey River to 164 μmhos/cm in Soldotna Creek. These concentrations are typical for a

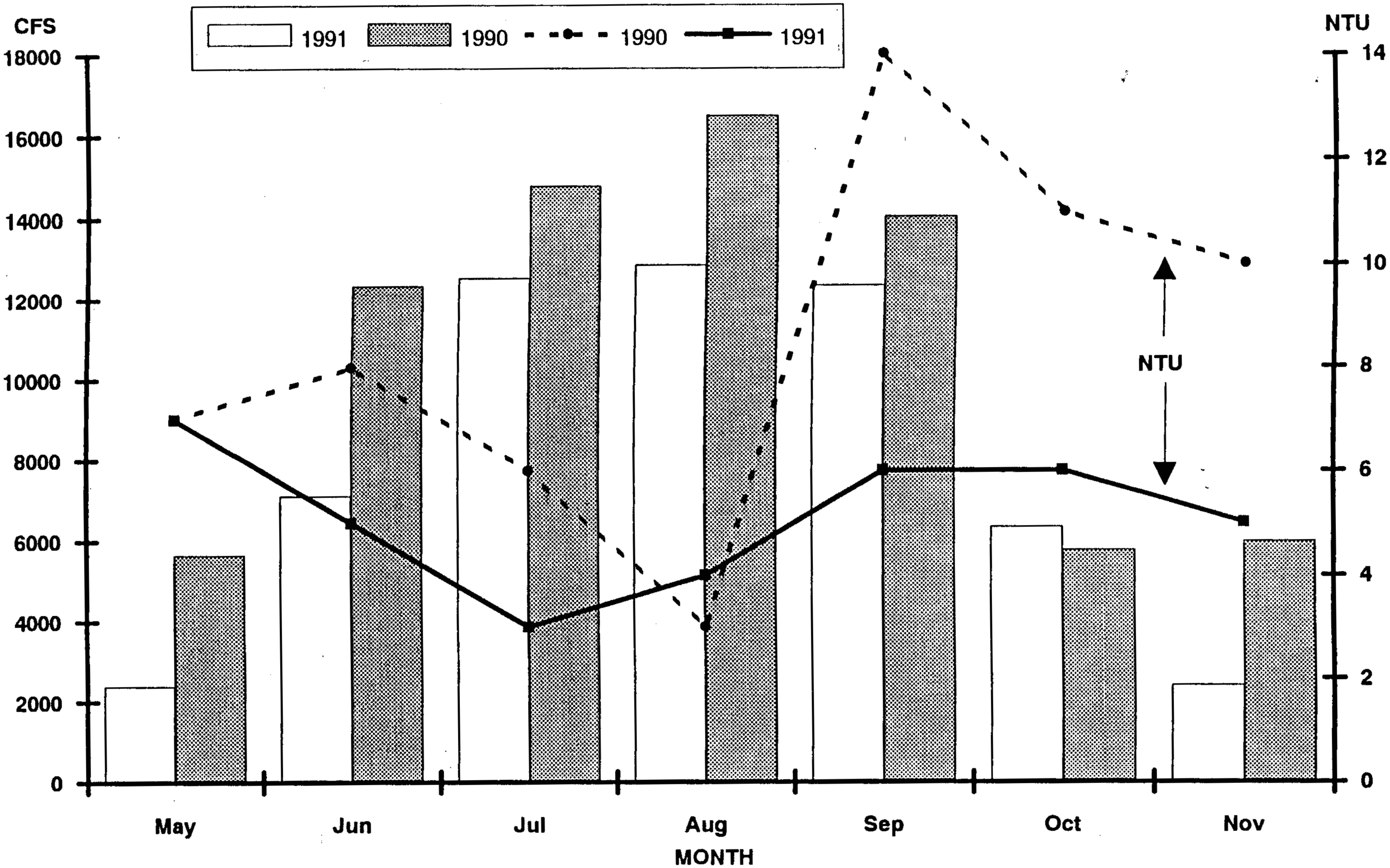


Figure 4. Relationship between turbidity (NTU) and discharge (CFS) in the Kenai River at the Soldotna Bridge for 1990 and 1991.

Table 1. General water quality parameters and nutrient concentrations (ug/L) for Kenai River stations (River Mile 31-82) sampled during 1991. Values are seasonal means with ranges in parentheses.

	River Mile				
Parameter	82	70	50	40	31
Conductivity (umhos/ cm)	67 (64-69)	72 (69-78)	61 (59-66)	59 (56-63)	65 (58-79)
pH (units)	7.4 (7.3-7.6)	7.5 (7.4-7.6)	7.4 (7.3-7.6)	7.4 (7.3-7.4)	7.3 (6.8-7.5)
Alkalinity (mg/L)	24.6 (23-31)	26.4 (23-36)	22.5 (21-26)	22.3 (20-27)	25.1 (18-40)
Turbidity (NTU)	6.1 (3.3-9.0)	4 (0.5-6.0)	3.7 (1.6-6.8)	5.5 (3.6-7.2)	5.7 (4.6-6.8)
Color (Pt. units)	7 (5-9)	7 (4-11)	8 (6-10)	7 (4-9)	8 (5-15)
Calcium (mg/L)	10.7 (9.6-12.4)	11.4 (10.5-12.4)	9.5 (8.5-10.4)	9 (7.7-10.0)	9.9 (9.3-11.0)
Magnesium (mg/L)	0.7 (<0.2-1.4)	0.7 (<0.2-1.4)	0.4 (<0.2-0.8)	0.4 (<0.2-0.8)	0.9 (<0.2-2.2)
Iron (ug/L)	370 (186-658)	275 (158-278)	193 (60-375)	355 (201-639)	340 (254-465)
Total-P (ug/L)	12.0 (10.0-11.5)	12.2 (8.5-19.2)	8.9 (5.6-11.6)	14.7 (10.2-16.7)	18.0 (12.9-29.9)
TFP (ug/L)	1.9 (1.4-2.4)	1.9 (1.2-3.2)	1.6 (1.2-2.1)	2.1 (1.5-2.9)	4.2 (1.8-9.9)
FRP (ug/L)	1.5 (1.0-1.9)	1.8 (1.1-3.3)	1.3 (0.8-1.7)	1.7 (1.1-2.2)	3.5 (1.4-7.7)
TKN (ug/L)	33.6 (20-54)	38.9 (6-106)	24 (12-33)	34.7 (19-72)	53.2 (13-172)
Ammonia (ug/L)	5.7 (4.2-9.3)	5.1 (4.2-7.3)	4.4 (3.2-5.2)	6 (4.7-9.3)	6.3 (3.2-11.3)
Nirate + Nitrite (ug/L)	209 (182-240)	245.2 (197-439)	179.6 (162-203)	171.9 (158-188)	158.5 (135-175)
Reactive silicon (ug/L)	1529 (1270-1770)	1579 (1331-1797)	1278 (1087-1478)	1437 (1230-1753)	1840 (1284-2930)

Table 2. General water quality parameters and nutrient concentrations (ug/L) for Kenai River stations (River Mile 6-23) sampled during 1991. Values are seasonal means with ranges in parentheses.

Parameter	River Mile 23	21	18	12	6
Conductivity (umhos/cm)	62 (56-79)	64 (60-73)	66 (59-81)	66 (60-78)	88 (60-167)
pH (units)	7.5 (7.2-7.8)	7.5 (7.3-7.7)	7.4 (7.3-7.7)	7.4 (7.2-7.6)	7.4 (7.2-7.5)
Alkalinity (mg/L)	25.1 (21-35)	26.1 (22-34)	26.3 (23-34)	26.3 (22-36)	26.7 (22-37)
Turbidity (NTU)	4.8 (2.3-7.4)	4.4 (0.3-6.8)	4.7 (2.4-6.2)	4.3 (1.9-6.3)	23.3 (3.0-120.0)
Color (Pt. units)	10 (4-14)	9 (6-15)	8 (5-21)	7 (5-14)	8 (5-15)
Calcium (mg/L)	9.4 (7.7-11.0)	9.5 (8.5-11.0)	9.8 (8.5-11.0)	10.6 (9.6-12.5)	10 (7.7-11.4)
Magnesium (mg/L)	0.9 (<0.2-1.5)	0.6 (<0.2-1.5)	0.7 (0.2-1.4)	0.8 (0.2-1.5)	1.3 (<0.2-4.5)
Iron (ug/L)	347 (99-538)	365 (126-566)	337 (134-558)	326 (136-562)	1203 (214-4963)
Total-P (ug/L)	14.7 (8.0-27.9)	15.1 (8.8-25.7)	21 (10.2-45.2)	15.8 (11.4-24.4)	72 (15.2-330.0)
TFP (ug/L)	3.6 (1.8-8.5)	3.7 (1.7-8.4)	8.4 (2.3-22.3)	5.6 (2.0-13.0)	8.5 (2.3-19.6)
FRP (ug/L)	2.7 (1.0-6.5)	2.8 (1.0-6.9)	7.2 (1.4-22.4)	5 (1.7-12.9)	7.8 (1.9-19.0)
TKN (ug/L)	46 (24-137)	46.3 (21-124)	86.2 (29-253)	59.7 (23-160)	109.4 (34-283)
Ammonia (ug/L)	5.2 (1.2-11.3)	5.8 (3.2-8.3)	6.6 (<1.1-13.0)	4.4 (<1.1-13.0)	9.1 (1.4-37.6)
Nirate + Nitrite (ug/L)	156.3 (137-167)	158.8 (137-171)	159.4 (104-292)	148.3 (110-173)	148.5 (115-187)
Reactive silicon (ug/L)	1755 (1261-2581)	1766 (1227-2702)	1828 (1227-2894)	1956 (1216-3786)	2166 (1227-4716)

Table 3. General water quality parameters and nutrient concentrations (ug/L) for seven Kenai River tributaries sampled during 1991. Values are seasonal means with ranges in parentheses.

	Tributary						
Parameter	Russian R	Killey R	Moose R	Funny R	Soldotna C	Slikok C	Beaver C
Conductivity (umhos/cm)	85 (78-95)	42 (27-68)	137 (115-151)	81 (76-90)	129 (89-164)	100 (68-131)	86 (78-94)
pH (units)	7.6 (7.5-7.7)	7.0 (6.8-7.2)	7.9 (7.5-8.3)	7.6 (7.4-7.7)	7.6 (7.3-7.8)	7.4 (7.1-7.6)	7.3 (7.2-7.6)
Alkalinity (mg/L)	34 (31-36)	16 (9-29)	73 (68-78)	40 (36-43)	63 (47-79)	47 (34-62)	40 (32-46)
Turbidity (NTU)	1 (0-1)	25 (3-42)	2 (0-6)	4 (2-7)	2 (0-4)	2 (1-3)	7 (6-7)
Color (Pt. units)	6 (5-8)	9 (6-12)	25 (22-29)	25 (15-39)	26 (22-33)	31 (26-35)	28 (13-55)
Calcium (mg/L)	13.5 (12-16)	4.6 (3-7)	21.1 (17-25)	10.2 (10-11)	16.2 (11-21)	11.9 (7-16)	11.1 (9-14)
Magnesium (mg/L)	1.1 (0.3-1.5)	0.8 (0.2-1.4)	3 (2.2-3.8)	3.5 (3.0-3.8)	3.2 (0.5-6.0)	4.3 (3.0-6.0)	2.7 (1.4-3.7)
Iron (ug/L)	46 (29-62)	2334 (436-3310)	828 (326-1157)	907 (358-1226)	649 (175-961)	965 730-1319)	1739 920-2182)
Total-P (ug/L)	10.2 (7-16)	52.1 (11-73)	38.8 (24-61)	44.3 (30-63)	87.9 (67-117)	31.2 (28-35)	50.8 (35-81)
TFP (ug/L)	4.3 (2-7)	4.9 (5-5)	21.1 (14-29)	20.8 (16-27)	59 (49-69)	17.2 (16-18)	21.2 (10-39)
FRP (ug/L)	3.3 (1-6)	4.1 (4-4)	18.6 (13-24)	18.4 (15-20)	56.6 (49-62)	14.5 (11-17)	19.2 (10-34)
TKN (ug/L)	110.9 (78-150)	79.8 (62-109)	246.7 (198-317)	194.2 (151-266)	257.2 (192-359)	272.2 (220-302)	200.5 (121-343)
Ammonia (ug/L)	18.9 (2-45)	5.2 (<1-9)	5 (<1-13)	2.1 (<1-3)	5 (<1-13)	3.2 (<1-7)	4.9 (3-9)
Nirate + Nitrite (ug/L)	505 (4-749)	99 (23-238)	4 (<3-6)	21 (9-40)	23 (23-57)	79 (35-101)	58 (6-94)
Reactive silicon (ug/L)	1842 (1663-2110)	2799 (1994-4099)	6047 (5925-6281)	6873 (5925-8099)	8988 (6586-11058)	8118 (5934-9850)	5345 (4030-6616)

glacial river with fluctuating flows, and sampling throughout the river did not indicate any obvious influx of inorganic pollutants. The station at RM 6 had slightly higher conductivity levels (60-167 μmhos/cm), presumably due to the influence of saltwater. In the mainstem of the Kenai River, pH varied from 6.8 to 7.8, and averaged 7.4. In the tributaries, pH ranged from 6.8 in the Killey River to 8.3 in Moose River. The pH values are almost identical to 1990 and were within the State of Alaska Water Quality Standard Regulations (ADEC 1991) for the propagation of fish and aquatic life.

Alkalinity in natural waters is a gage of its pH buffering capability and is largely due to the presence of carbonate and bicarbonate ions. Alkalinity ranged from 18 to 40 mg/L and averaged 25 mg/L over the season in the mainstem, while in the tributaries alkalinity ranged from 9 mg/L in the Killey River to 79 mg/L in Soldotna Creek. Alkalinity values both within the mainstem and in the tributaries were similar to 1990 and were within the normal range for Alaskan waters. Total iron concentrations in the mainstem ranged from 60 to 658 μg/L and averaged 323 μg/L. The 1991 iron concentrations were considerably lower than in 1990 (seasonal average = 560 μg/L), and can be attributed to lesser amounts of suspended material in the water column in 1991 which is associated with turbidity levels (Figure 5). Total iron in the tributaries ranged from 29 μg/L in the Russian River to 3,310 μg/l in the Killey River (Table 3). Greater variability of iron levels were noticed in the tributaries during both 1990 and 1991; but this is expected due to smaller drainage areas being strongly influenced by localized environmental events.

Nutrients-- Three important nutrients governing productivity are phosphorus, nitrogen and silicon. Data from 1990 found that the Kenai River was not nutrient limited (Litchfield and Kyle 1991), and 1991 data further supports this conclusion. That is, mean total phosphorus (TP), total filterable phosphorus (TFP), and filterable reactive

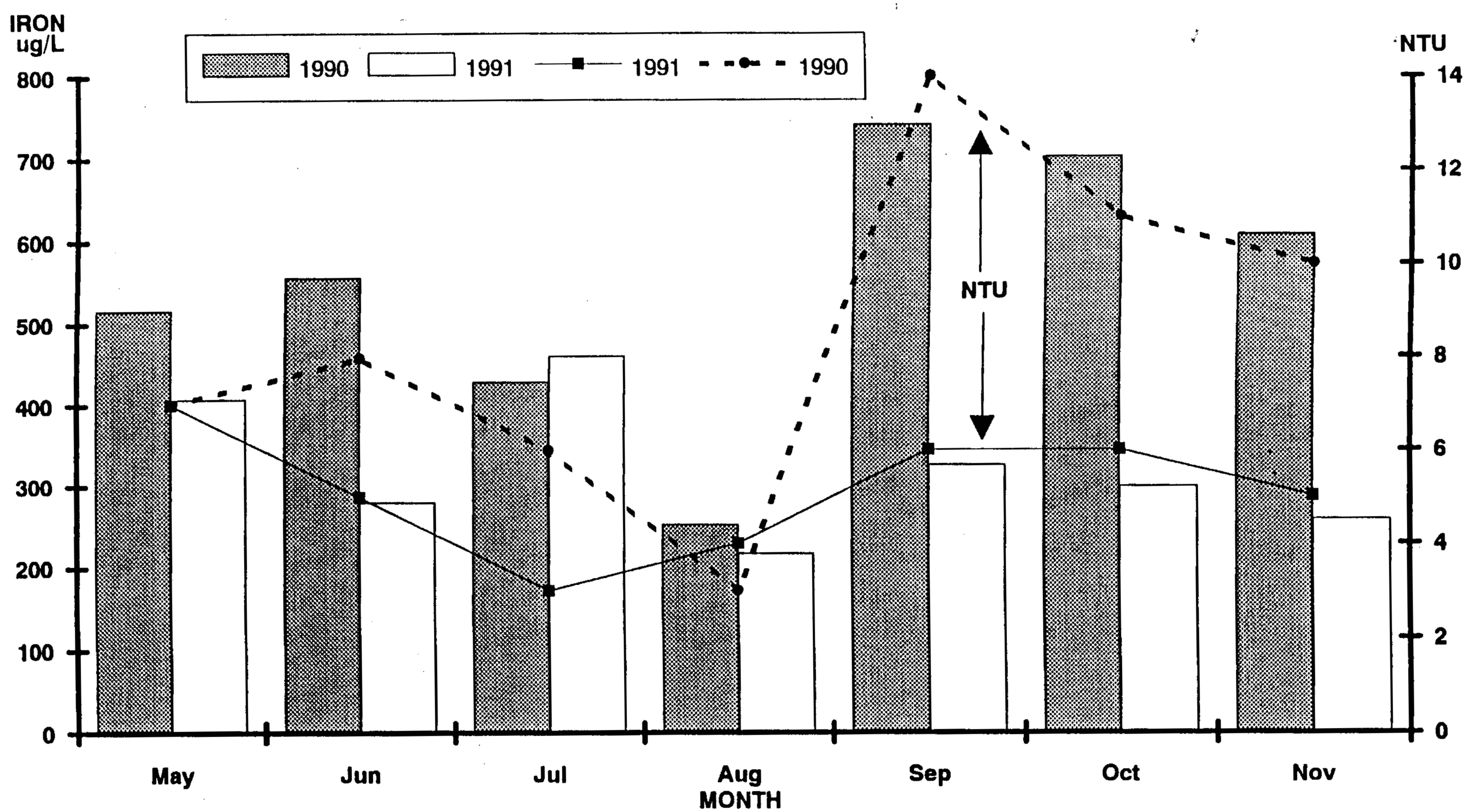


Figure 5. Relationship between total iron concentration (ug/L) and turbidity (NTU) for the mainstem Kenai River stations for 1990 and 1991.

phosphorus (FRP) concentrations in the mainstem were 15, 4 and 3 μg/L, respectively (Figure 6), and were similar to 1990 concentrations. Because colorimetric measurements of TP in turbid solutions cause elevated readings due to the backscattering of light, TP concentrations of water samples are artificially high and need to be corrected. Applying a 40% correction factor (Koenings *et al.* 1987) to glacial water samples results in an average TP of 6.0 μg/L in the mainstem of the Kenai River during 1991, which is not considered high for Alaska waters. Phosphorus concentrations in the tributaries were also similar to 1990, with the highest TP concentrations found in Soldotna Creek and Killey River. Elevated TP levels in the Killey River are associated with increased turbidity, while the higher values found in Soldotna Creek reflect organically-stained water.

Total Kjeldahl nitrogen, a measure of organic nitrogen and total ammonia, ranged from 6 to 253 μg/L and averaged 47 μg/L in the mainstem (Tables 1 and 2), and ranged from 62 to 343 μg/L in the tributaries (Table 3). Reactive silicon ranged from 1,087 to 3,786 μg/L and averaged 1,663 μg/L for the nine mainstem stations, and in the tributaries ranged from a seasonal mean low of 1,933 μg/L in the Russian River to a high of 8,677 μg/L in Soldotna Creek. The variability of reactive silicon among the tributaries is due largely to the watershed soil type. For example, Soldotna Creek drains an area comprising of clay which aluminum silicate is a large component. In addition, high silicon concentrations were observed in the tributaries during late fall when flow rates were high. In summary, 1991 nutrient levels in the Kenai River and its tributaries are within normal ranges relative to other natural waters, and as in 1990 show neither nutrient deficiency or excessive unnatural organic enrichment. The Appendix contains a detailed listing of all nutrient and general water quality parameters by location and date.

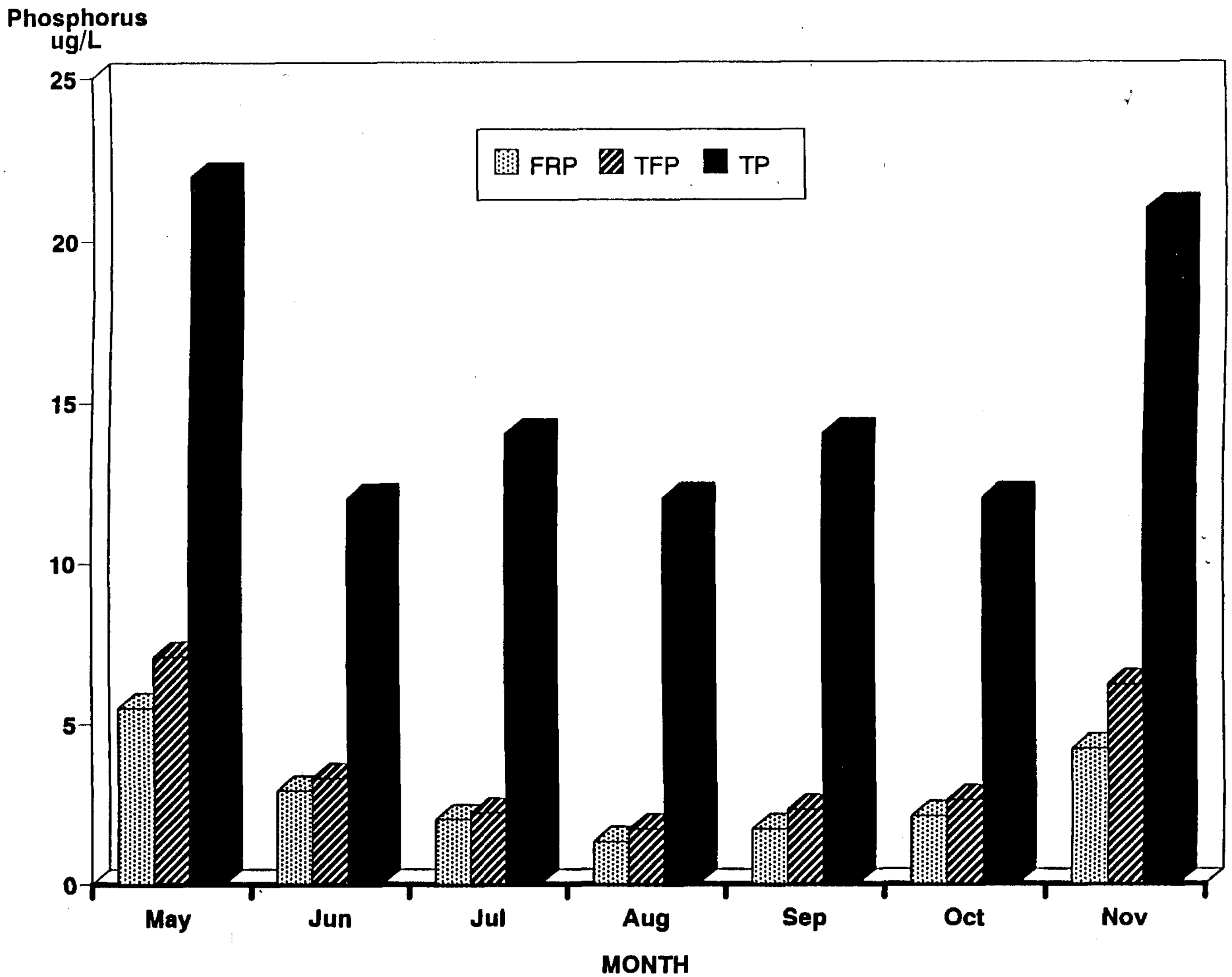


Figure 6. Monthly concentrations (ug/L) of total phosphorus (TP), total filterable phosphorous (TFP), and filterable reactive phosphorous (FRP) for the mainstem Kenai River stations in 1991.

Metals-- Seasonal mean metal concentrations for 1991 samples are presented in Table 4 for five mainstem stations and in Table 5 for seven tributaries. Similar to 1990, metal analysis of water samples collected throughout 1991 revealed concentrations (for regulated dissolved metals) below aquatic toxicity levels (ATL) as defined by the United States Environmental Protection Agency (EPA 1986). All samples were analyzed for both total and dissolved (filtered) metal concentrations to determine the relative percentage of metal concentrations in suspended solids (total minus dissolved metals). The percentage of the total metal concentration found in suspended solids varied from a mean of 4 to 89% for 14 elements sampled from five stations in the mainstem of the Kenai River (Table 6). In addition, some elements fluctuated in percentage of metals in the suspended and dissolved state by sample location. The EPA regulated metals are measured on dissolved samples; however, the majority of metals in Table 6 had a high percentage of total concentrations in the suspended state, which warrants further investigation relative to impacts on aquatic life.

Results of metal analysis of 29 juvenile fish (14 whole specimens and 15 liver samples) representing six different species that were captured from the upper and lower river are presented in Tables 7 and 8. The EPA does not provide acute toxicity levels of metals for fish; however, metal content of fish collected from the Kenai River can be relatively compared and used for future reference. In addition, extreme care was taken to conduct contamination-free sample collection and extraction, as it has been reported by Ahlers *et al.* (1990) that even the slightest interference from a laboratory that is not dust and metal free can be detected in trace amounts. However, all samples were handled equally and thus results obtained from the different specimens and river stations are useful for comparison. The most significant difference appeared to be among the different specimens/species sampled rather than between the upper and lower river. For example, tissue of sculpins revealed aluminum concentrations ranging from 29-

Table 4. Seasonal mean concentrations (ug/L) of dissolved metals found in samples collected from the mainstem of the Kenai River in 1991.

	River Mile				
Element (ug/L)	82	40	21	18	12
Aluminum	38	43	32	30	31
Calcium	9475	7900	7950	8475	8100
Titanium	1.1	1.7	2.5	2.3	2.1
Chromium	0.32	0.38	<dl \a	<dl	<dl
Iron	45	50	88	110	85
Nickel	<dl	<dl	<dl	<dl	<dl
Zinc	14	18	10	11	13
Cadmium	<dl	0.07	0.08	0.09	0.08
Lead	0.08	0.09	0.11	0.08	0.2
Magnesium	603	593	780	890	903
Silicon	1328	1375	1675	1825	1900
Manganese	1.6	1.7	5.9	12	8.4
Cobalt	0.07	0.05	0.05	0.07	0.06
Copper	0.83	0.8	1.3	1.6	1.2
Arsenic	0.68	0.97	1.1	1.6	1.5
Selenium	0.4	1.2	0.8	1.4	0.7
Strontium	53	43	42	46	44
Barium	28	69	25	29	41
Potassium	580	737	850	933	833

\a Less than detection limits.

Table 5. Seasonal mean concentrations (ug/L) of dissolved metals found in samples collected from seven Kenai River tributaries in 1991.

	Tributary						
	Russian R	Killey R	Moose R	Funny R	Soldotna C	Slikok C	Beaver C
Element (ug/L)	T-1	T-2	T-3	T-4	T-5	T-6	T-7
Aluminum	9	82	14	19	18	24	25
Calcium	7800	2700	10350	5150	7250	5350	5950
Titanium	4.4	<dl \a	25.3	2.0	<dl	<dl	<dl
Chromium	0.27	0.32	<dl	<dl	<dl	<dl	<dl
Iron	20	210	610	705	585	500	1050
Nickel	<dl	<dl	<dl	<dl	<dl	<dl	<dl
Zinc	21	39	14	14	14	17	23
Cadmium	<dl	<dl	<dl	<dl	<dl	0.11	<dl
Lead	0.1	0.11	<dl	0.23	<dl	0.1	<dl
Magnesium	495	460	1700	1700	2050	1550	1230
Silicon	995	1650	3250	4100	4800	4400	3250
Manganese	2	8	86	32	52	25	73
Cobalt	<dl	<dl	<dl	<dl	<dl	<dl	0.1
Copper	1.4	1.7	1.0	1.9	1.5	1.3	1.9
Arsenic	0.8	0.9	5.1	2.3	7.6	1.6	3.3
Selenium	<dl	<dl	<dl	0.47	0.57	<dl	0.86
Strontium	99	26	93	52	81	54	60
Barium	88	141	51	34	45	33	46
Potassium	190	375	830	675	1250	955	895

\a Less than detection limits.

Table 6. Comparison of the percent total metals in the dissolved and suspended state for five stations located throughout the Kenai River in 1991.

	River Mile										Mean of all stations	
	82		40		21		18		12			
Element	\a D	S	D	S	D	S	D	S	D	S	D	S
Aluminum	12	88	10	90	10	90	9	91	10	90	11	89
Titanium	13	87	8	92	96	4	12	88	13	87	27	73
Chromium	38	63	33	67	14	86	40	60	N/A	N/A	32	68
Iron	11	89	7	93	38	62	20	80	21	79	24	76
Nickel	33	67	50	50	N/A	N/A	69	31	N/A	100	51	49
Lead	24	76	36	64	46	54	31	69	77	23	46	54
Magnesium	77	23	85	15	83	17	96	4	98	2	88	12
Silicon	67	33	74	26	80	20	84	16	92	8	81	19
Manganese	20	80	17	83	24	76	60	40	44	56	43	57
Cobalt	28	72	19	81	21	79	29	71	29	71	34	66
Copper	49	51	57	43	35	65	84	16	71	29	59	41
Arsenic	77	23	65	35	65	35	94	6	83	17	94	6
Strontium	90	10	100	0	95	5	100	0	100	0	96	4
Potassium	81	81	72	28	79	21	90	10	85	15	81	19

\a D indicates percentage of metal concentration in the dissolved state and S indicates percentage of metal concentration in the suspended state.

Table 7. Metal concentrations (ug/L) of tissue samples from individual fingerlings collected in the Kenai River from River Mile 50-80 and River Mile 15-23 in 1991.

	River Mile 50-80						
Element (ug/L) \a	SCP	SCP	KS	KS	KS	RB	SCP
Aluminum	29	1,991	277	282	132	1,513	1,283
Manganese	17	24	27	16	6	236	18
Cobalt	0.3	1.2	1.0	0.4	0.3	0.5	0.6
Copper	4.7	3.8	7.9	8.7	6.0	17.1	6.4
Arsenic	0.5	0.4	1.2	0.6	0.5	0.8	0.6
Selenium	2.5	2.2	2.8	1.1	1.0	0.7	0.8
Strontium	56	66	63	48	53	31	47
Barium	4.7	16.4	7.1	3.1	2.8	<dl \ b	5.1
Magnesium	1,480	1,749	3,211	1,702	2,024	1,976	2,206
Calcium	56,536	47,293	74,861	43,335	45,064	32,472	41,519
Titanium	2.2	18.8	4.6	8.3	5.7	11.8	8.7
Chromium	1.1	2.2	1.5	1.2	1.3	0.8	1.7
Iron	372	722	1,073	420	327	1,524	1,743
Nickle	2.0	3.1	2.6	2.4	2.0	2.2	2.6
Zinc	120	120	258	249	209	172	191
Bromine	255	67	19	29	41	14	11
Rubidium	3.9	7.3	8.8	7.1	6.2	4.8	5.4
Lead	0.198	0.201	0.319	0.249	<dl	<dl	0.335

	River Mile 15-23						
Element (ug/L) \a	CS	SCP	STL	CS	KS	DV	SCP
Aluminum	296	1,785	3,509	93	71	7,879	124
Manganese	27	38	139	18	32	1,399	65
Cobalt	0.3	0.5	0.9	0.2	0.1	3.3	0.4
Copper	3.7	6.9	10.0	4.3	3.6	11.9	3.2
Arsenic	2.3	0.6	2.1	0.7	0.5	2.5	0.6
Selenium	1.6	2.3	0.4	1.3	2.3	1.6	3.3
Strontium	41	34	43	32	43	18	111
Barium	4.0	6.5	15.8	3.0	4.3	42.9	16.1
Magnesium	1,813	2,175	2,677	1,530	1,540	4,784	2,854
Calcium	44,930	21,170	59,519	29,828	31,960	11,206	89,253
Titanium	7.9	24.5	41.9	3.1	3.3	84.0	4.0
Chromium	2.4	2.6	3.1	1.4	1.5	7.8	2.0
Iron	886	1,121	2,875	245	257	10,766	616
Nickle	1.7	2.1	5.0	1.1	1.4	6.5	3.4
Zinc	120	118	212	171	203	166	170
Bromine	38	16	8	26	17	28	22
Rubidium	6.0	8.9	8.2	5.9	5.5	5.4	3.7
Lead	0.6	0.3	0.4	<dl	<dl	0.4	0.4

\a CS = Coho Salmon SCP = Sculpin DV = Dolly Varden
KS = King Salmon STL = Stickleback RB = Rainbow Trout

\b Less than detection limits.

Table 8. Metal concentrations (ug/L) of liver samples from individual fingerlings collected in the Kenai River from RM 50-82 and RM 19-23 in 1991.

	River Mile 50-82							
Element (ug/L) \a	DV	KS	SCP	RB	SCP	SCP	SCP	SCP
Aluminum	2	5	17	25	46	6	13	8
Manganese	0.7	1.3	2.4	30.2	41.0	0.6	1.9	0.9
Cobalt	0.2	0.2	<dl \b	0.1	1.1	<dl	0.1	0.2
Copper	16.0	8.3	10.0	16.9	7.5	6.3	47.8	5.1
Arsenic	0.3	<dl	<dl	1.4	0.1	1.8	0.5	0.1
Selenium	1.7	0.9	1.0	1.6	1.5	4.8	1.8	1.4
Strontium	0.3	0.4	0.6	0.4	1.3	0.1	0.3	0.4
Magnesium	261	387	512	333	860	202	387	342
Calcium	137	185	273	403	503	125	346	277
Titanium	<dl	0.3	1.2	10.4	1.0	0.3	0.4	0.4
Iron	87	129	56	126	753	23	42	53
Nickle	<dl	<dl	<dl	<dl	0.3	0.1	0.2	0.1
Zinc	44	53	79	94	84	27	73	46
Bromine	46	53	66	274	91	813	93	31
Cadmium	<dl	<dl	<dl	<dl	0.2	<dl	0.2	1.2
Mercury	<dl	<dl	<dl	<dl	0.1	<dl	<dl	<dl
Lead	<dl	0.1	0.1	0.4	<dl	<dl	1.0	0.1

	River Mile 19-23						
Element (ug/L) \a	CS	SCP	CS	CS	KS	DV	DV
Aluminum	10	33	8	9	12	4	5
Manganese	1.2	1.9	1.1	2.4	1.7	3.0	5.9
Cobalt	0.2	0.1	<dl	0.2	<dl	0.1	<dl
Copper	3.9	12.5	4.2	7.8	4.4	6.8	6.6
Arsenic	0.2	0.5	0.1	<dl	<dl	0.1	0.1
Selenium	3.2	1.6	0.6	1.4	0.8	1.2	1.1
Strontium	<dl	0.2	0.1	0.2	0.2	0.1	0.1
Magnesium	238	333	229	332	308	168	201
Calcium	84	117	93	104	91	144	92
Titanium	0.4	1.4	0.3	0.5	<dl	<dl	<dl
Iron	48	219	75	118	48	105	143
Nickle	<dl	<dl	<dl	<dl	0.5	<dl	<dl
Zinc	45	51	34	45	30	45	73
Bromine	139	91	31	15	66	18	20
Cadmium	0.2	<dl	<dl	<dl	<dl	<dl	<dl
Mercury	<dl	<dl	<dl	<dl	<dl	<dl	<dl
Lead	<dl	0.6	0.1	0.1	<dl	<dl	<dl

\a CS = Coho Salmon SCP = Sculpin DV = Dolly Varden
KS = King Salmon STL = Stickleback RB = Rainbow Trout

\b Less than detection limits.

1,991 μg/L in RM 50-80, and 124-1,785 μg/L in RM 15-23 (Table 7). In comparison, aluminum found in the tissue of juvenile king salmon (*Onchorhynchus tshawytscha*) in RM 50-80 ranged from 132-282 μg/L, and for coho salmon (*Oncorhynchus kisutch*) in RM 15-23 ranged from 93-296 μg/L. Finally, the limited sampling for trace metals in rearing fish does not provide conclusive information on metal contamination; however the data is useful for relative comparisons in the future.

Hydrocarbons-- In 1991, an attempt was made to systematically collect samples of spring meltwater runoff from storm drains for analysis of total petroleum hydrocarbons (TPH); however, because of a dry spring, gradually melting snow, and access problems (bank snow) this was not accomplished. Of the thirteen TPH samples analyzed from nine stations in the lower river, only two samples (stations) were above the detection limit of 500 μg/L. Water samples from these two stations (RM 17.7 and RM 21.8), which are located at storm drains (Figure 3), were taken immediately after a rainfall. The TPH concentrations at RM 17.7 and RM 21.8 were 1,300 and 2,600 μg/L, respectively. The storm drain at RM 21.8 enters the river behind the State of Alaska Department of Transportation vehicle maintenance shop, and drains sections of the Sterling Highway and portions of several side streets. The storm drain at RM 17.7 enters the river at the west end of Marydale Drive, and drains several side streets. In addition to concentrations above detection limits at these two stations, a surface sheen was quite visible. The State of Alaska Water Quality Standard Regulations (ADEC 1991) stipulate concentrations of TPH above 15 μg/L as unacceptable for aquatic life, and that surface water shall be virtually free from floating oil, a sheen, or discoloration. This was the only rainfall event monitored in 1990 and 1991, but since urban runoff has been identified as a principle source of toxic pollutants (Field and Turkeltaub 1981), further monitoring of storm drains entering the Kenai River is warranted. Although new EPA regulations regarding storm water management for cities with populations greater than 100,000 are not applicable to the Kenai-Soldotna area; State of Alaska permitting procedures require the criteria of no surface sheen be met (ADEC 1991). At the present time, there is no effective treatment at storm water outfalls in the Kenai-Soldotna area that enter the Kenai River. However, the City of Soldotna is installing an outfall sedimentation chamber and oil/grease separator system at a storm drain located near Knight Drive that will be functional in the summer of 1992 (Steve Bonebrake[1] pers. comm.). Monitoring this system should be conducted to address treatment on other effluent outfalls draining into the Kenai River and it's tributaries.

The number of mainstem and tributary water samples tested for volatile organics analysis (VOA) that exceeded the detection limit was greater in 1991 than in 1990, and in part, reflects the more concentrated effort in the lower river and intensified sampling during times of peak boat traffic in July. In 1990, 22 of the 58 VOA samples (38%) exhibited values higher than detection limits, while in 1991, 45 of the 53 samples (85%) were above the detection limit (Table 9). In addition, components of gasoline namely benzene, toluene, ethylbenzene, and total xylenes (BTEX) were found at higher concentrations in 1991 than in 1990 (Figure 7). Benzene, one of the most toxic compounds, has an acute toxicity concentration of 5,300 μg/L for freshwater aquatic organisms, although toxicity may be much lower for more sensitive organisms than those tested by the United States Environmental Protection Agency (EPA 1986). The highest concentration for benzene found in the 1991 samples was 4.7 μg/L compared to 1.7 μg/L in 1990. Although VOA levels found in the mainstem of the Kenai River were considerably lower than the acute toxicity level, concentrations near the source(s) of contamination could be much higher. In the tributaries, VOA levels were also below ATL but elevated levels were found in tributaries near greater motorized activity

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Table 9. Summary of hydrocarbon compounds found in concentrations (ug/L) at or above detection limits for water samples collected from the mainstem and tributaries of the Kenai River in 1991.

		Hydrocarbon compound					
River mile/tributary	Sample date	Acetone	Trichlorofluoro-methane	Benzene	Toluene	Ethyl-benzene	Total xylenes
6	5-6	<dl \a	<dl	<dl	<dl	<dl	<dl
12	5-6	<dl	<dl	<dl	<dl	<dl	<dl
18	5-6	<dl	<dl	0.10	<dl	<dl	<dl
20.8	5-6	<dl	0.30	<dl	<dl	<dl	<dl
21	5-6	<dl	<dl	0.20	0.20	<dl	0.20
21.8	5-6	<dl	<dl	0.20	0.70	0.10	1.20
23	5-6	<dl	<dl	<dl	<dl	<dl	<dl
0	6-5	<dl	<dl	0.30	0.70	<dl	1.10
6	6-5	<dl	0.30	<dl	<dl	<dl	<dl
12	6-5	0.90	0.50	2.50	7.10	0.70	8.00
20.8	6-5	<dl	0.30	<dl	0.20	<dl	0.30
21	6-5	<dl	<dl	0.10	0.10	<dl	0.30
21.8	6-5	<dl	0.60	0.20	0.50	<dl	0.60
23	6-5	<dl	0.10	<dl	0.20	<dl	<dl
17.7	7-1	4.90	<dl	0.06	0.20	<dl	0.10
20.8	7-1	4.00	0.09	0.05	0.20	<dl	0.10
21.8	7-1	2.80	<dl	<dl	<dl	<dl	<dl
22	7-1	1.90	<dl	<dl	0.20	<dl	0.30
6	7-9	0.92	<dl	<dl	7.20	0.68	8.70
12	7-9	1.50	<dl	2.00	5.20	0.46	6.40
17.7	7-9	<dl	<dl	0.10	0.24	<dl	0.23
18	7-9	0.98	<dl	0.23	0.56	<dl	0.60
20.8	7-9	2.00	<dl	0.08	0.17	<dl	<dl
21	7-9	1.00	<dl	0.07	0.19	<dl	0.19
21.8	7-9	1.10	<dl	0.07	0.14	<dl	0.13
22	7-9	1.20	<dl	0.13	0.29	<dl	0.30
0	7-30	1.20	<dl	0.20	0.40	0.07	0.40
6	7-30	1.30	<dl	4.70	11.00	2.20	11.00
12	7-30	0.50	0.20	2.40	6.00	1.00	5.00
17.7	7-30	0.80	<dl	0.40	1.00	0.20	1.00
18	7-30	1.00	<dl	0.60	1.50	0.30	1.60
20.8	7-30	<dl	<dl	0.30	0.70	0.10	0.60
21	7-30	1.40	<dl	0.30	0.60	0.10	0.60
21.8	7-30	<dl	<dl	0.30	0.60	<dl	0.50
23	7-30	<dl	<dl	0.20	0.40	0.07	0.30

-continued-

Table 9 continued. Summary of hydrocarbon compounds found in concentrations (ug/L) at or above detection limits for water samples collected from the mainstem and tributaries of the Kenai River in 1991.

		Hydrocarbon compound					
River mile/tributary	Sample date	Acetone	Trichlorofluoro-methane	Benzene	Toluene	Ethyl-benzene	Total xylenes
0	9-9	<dl	0.14	0.10	0.25	<dl	0.19
6	9-11	2.70	0.09	0.22	0.53	0.11	0.38
12	9-11	2.70	0.19	0.59	1.50	0.26	1.20
17.7	9-9	5.90	0.25	0.06	0.15	<dl	<dl
18	9-11	1.70	0.25	0.12	0.69	<dl	0.20
21	9-11	6.70	0.53	<dl	0.17	<dl	<dl
21.8	9-9	6.10	0.20	0.08	0.19	<dl	0.39
22	9-9	1.4	0.15	0.06	0.19	<dl	0.18
Slikok C	5-8	<dl	<dl	<dl	<dl	<dl	<dl
Soldotna C	5-8	<dl	<dl	<dl	<dl	<dl	<dl
Funny R	5-8	<dl	<dl	<dl	<dl	<dl	<dl
Moose R	5-8	<dl	<dl	<dl	<dl	<dl	<dl
Slikok C	7-1	17	<dl	<dl	<dl	<dl	<dl
Slikok C	7-9	1.17	<dl	<dl	<dl	<dl	<dl
Moose R	7-9	2.8	<dl	<dl	<dl	<dl	0.16
Beaver C	7-30	1.8	<dl	0.7	1.5	0.3	1.6
Beaver C	9-10	3.8	<dl	<dl	0.09	<dl	<dl
Moose R	9-10	<dl	0.33	<dl	0.15	<dl	0.15

\a Less than detection limits.

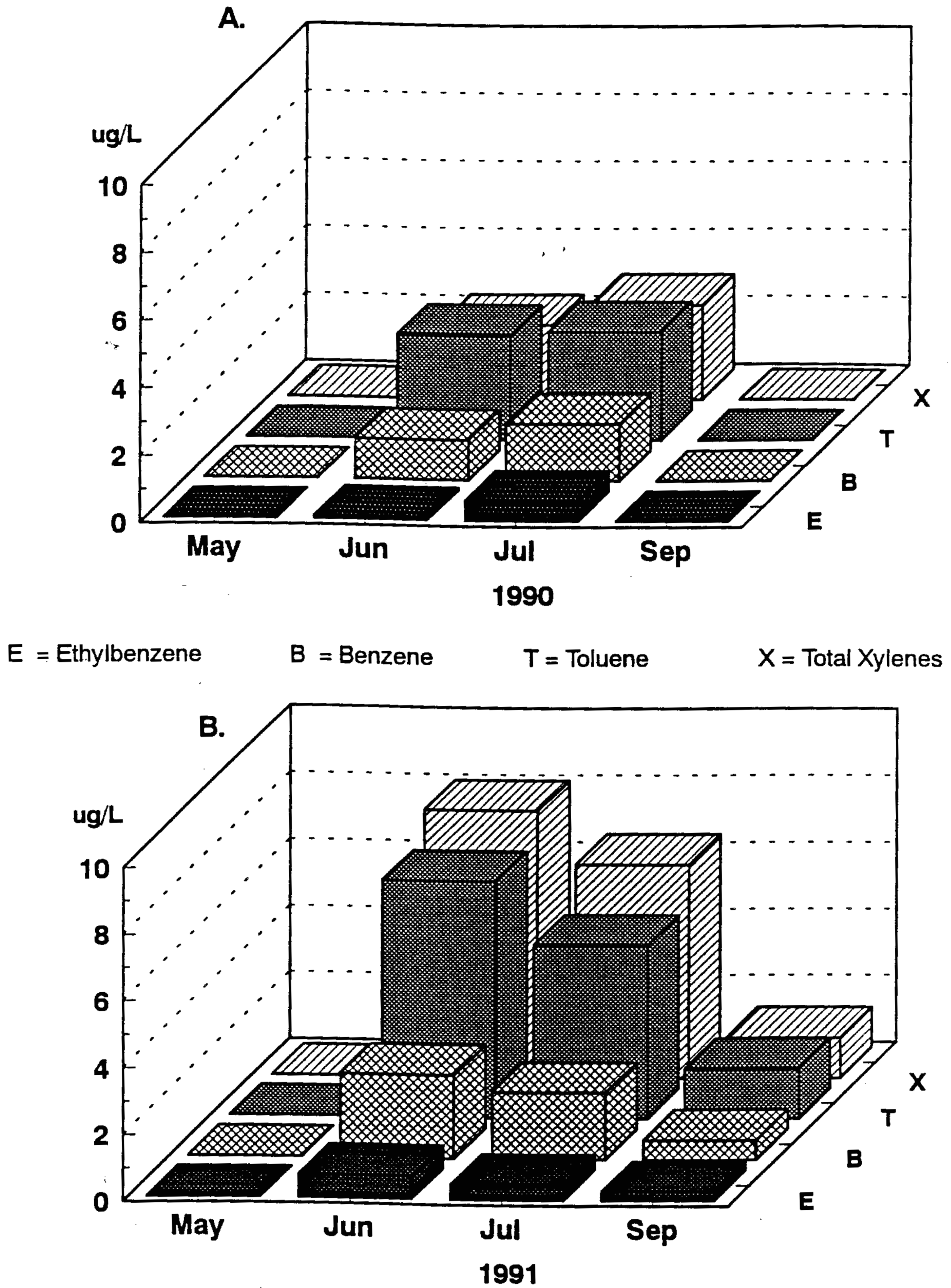

Figure 7. Monthly concentrations (µg/L) of total xylenes, toluene, benzene and ethybenzene at River Mile 12 in the Kenai River for 1990 (A) and 1991 (B).

(Table 9). In summary, increased sampling for hydrocarbons (VOA) in 1991 during peak outboard use revealed a more frequent incidence of BTEX compounds at higher concentrations, which suggests that motorized boats may be the primary source of contamination.

Hydrocarbon analysis of liver samples from sculpin collected throughout the river indicated that enzyme activity (EROD) was higher in and adjacent to areas of the river that receive motorized use (Figure 8). That is, samples from the Moose River, Soldotna Creek, Slikok Creek, and Beaver Creek revealed moderate to high relative levels of enzyme activity (Figure 8), and as compared to induced samples in the laboratory (Paige 1992). Conversely, samples from the Russian and Funny rivers, which are more remotely located from motorized activity, had the lowest enzyme activity. Although limited sampling was done, the results suggest that motorized activity may be associated with hydrocarbon content of sculpin and warrants further investigation.

Coliform Bacteria-- In 1991 fecal coliform (FC) was detected at higher concentrations than in 1990 at stations below the Soldotna Bridge. For example in 1990, FC counts averaged 2/100 ml over the season at and above RM 21 (Soldotna Bridge) compared to an average of 29/100 ml at RM 18 and below (Litchfield and Kyle 1991). In 1991, FC counts at RM 21 and RM 23 were comparable to 1990 with seasonal averages of 2/100 ml and 3/100 ml, respectively. However, stations located at RM 18 and below had FC counts ranging from 13-204/100 ml (Figure 9A), and averaged 74/100 ml over the sampling period in 1991 (Figure 9B). Samples taken above and below the Soldotna Sewer Treatment Plant in mid May on the north side of the river revealed FC counts of 4/100 ml and 142/100 ml, respectively.

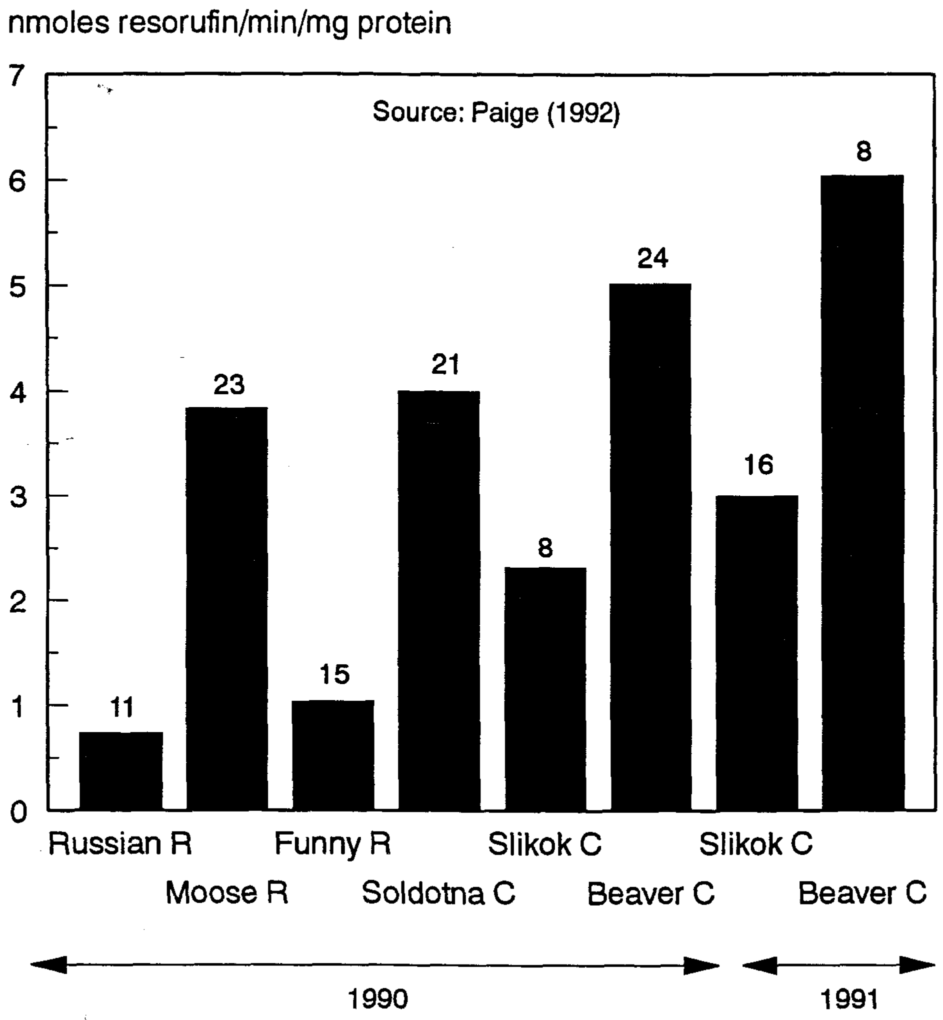

Figure 8. Mean rates of enzyme activity (nmoles resorufin/min/mg protein) for sampled sculpin in the Kenai River. Numbers above each histogram indicate sample size.

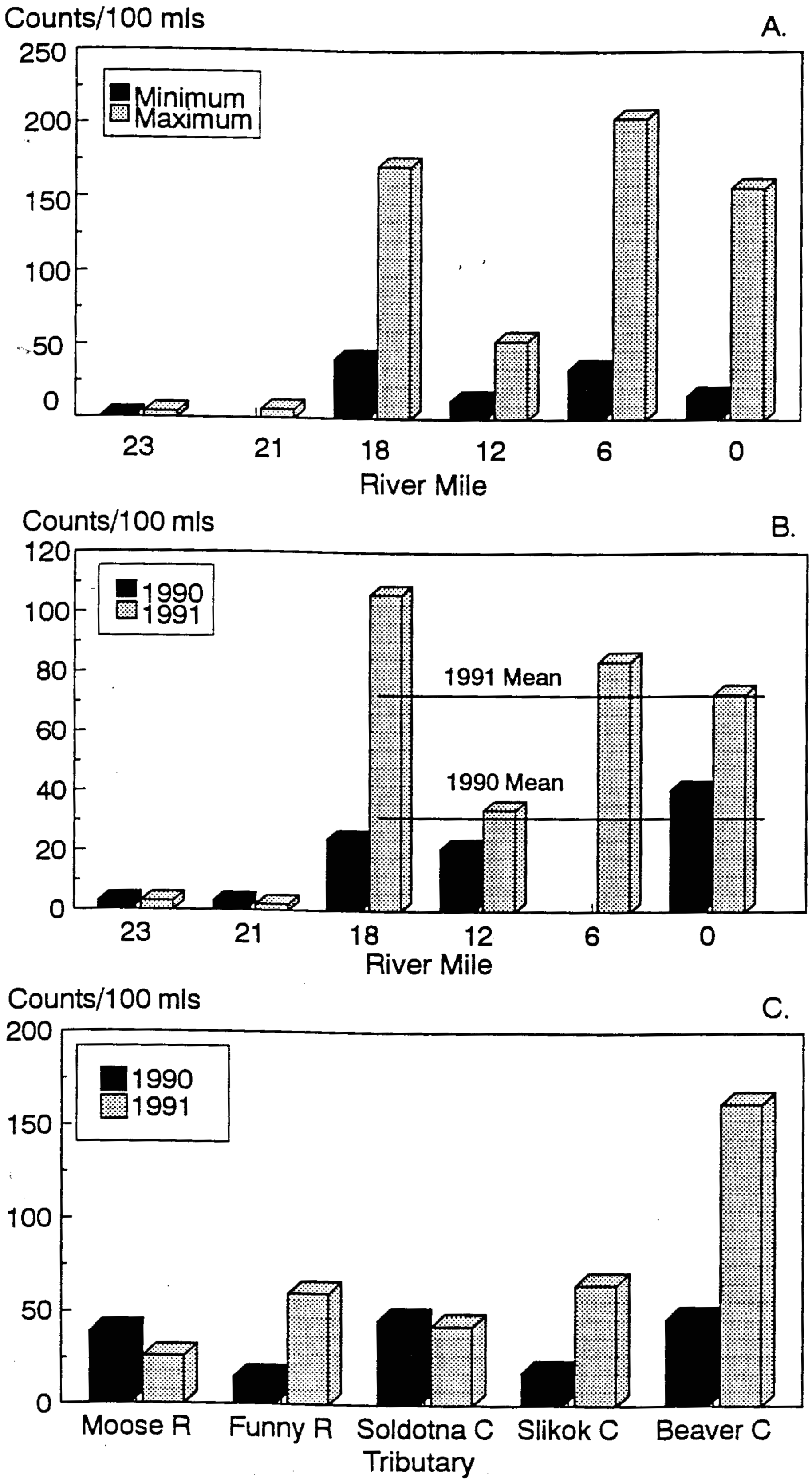

Figure 9. Ranges (A) and seasonal means (B) of fecal coliform counts for mainstem Kenai River stations (River Mile 0-23), and seasonal mean counts for five Kenai River tributaries (C) for 1990 and 1991.

In the tributaries, FC counts ranged from 2-300/100 ml in 1991, with the highest counts from samples collected in Beaver and Slikok creeks. In 1991, Beaver Creek showed the only substantial increase in seasonal mean FC counts compared to 1990 (Figure 9C). Fecal streptococcus (FS) analysis in 1991 was conducted on a limited basis to determine FC/FS ratios. Although sources of contamination can potentially be determined by examining FC /FS ratios, the majority of the levels found in the Kenai River were too low for statistical analysis. However, there were two samples taken from Beaver Creek that revealed FC/FS ratios of 3.26 and 2.89, which indicate a predominance of human waste in mixed pollution. In addition, there was one sample from Funny River that had a FC/FS ratio of 4.12, indicating the presence of human waste. Although coliform counts in these two tributaries at the sites sampled were sufficient to obtain statistically valid FC /FS ratios, other criteria such as closeness to the source were not determined.

The State of Alaska does not have regulation standards for coliform bacteria for the propagation of fish or aquatic life; however, regulations for FC exist for secondary water recreation use, which applies to the Kenai River. These regulations state that the mean of 5 samples taken in a 30-day period shall not exceed 200/100 ml, and no more than 10% of the total samples shall exceed 400/100 ml (ADEC 1991). Although the two highest individual FC counts (300/100 ml at Beaver Creek and 204/100 ml at RM 6) exceeded the 200/100 ml limit, the mean of all samples were within the limit for secondary recreation use. Whereas the impact of current FC levels in the Kenai River appears minimal, continued monitoring of this water quality indicator is suggested due to the fact that the highest levels found were in areas of urbanization, and were in sharp contrast to the levels found in the more rural stretches located in the upper river. It is important to note that although intensified sampling may be one reason for the detection of elevated FC levels in 1991 compared to 1990; river discharge may also be a contributing factor. That is, the substantially lower flows of 1991 reduces the dilution of organic input, and thus comparable organic input in a greater discharge (1990) would exhibit lower coliform counts.

Macroinvertebrates-- Similar to bacteria, benthic populations can be used to gage water quality since tolerances of macroinvertebrates to organic pollution differs (Table 10). It is important to note that although a benthic organism may have a high tolerance to pollution, it can be found in water of pristine quality; thus, the absence of low tolerance organisms is a better indicator of water degradation.

In 1991, as in 1990, higher densities of Chironomids (and other Diptera) that are more tolerant of pollution were found in the lower river. More importantly, Leutridae (stonefly family) and other invertebrate families sensitive to pollution were found throughout the river. Thus, these data in general indicate that water quality is not severely impacting macroinvertebrate habitat.

From the biotic measures, it appears that stations in the uppermost stretch of the Kenai River (RM 70-79) represent pristine water quality conditions. That is, numbers of EPT genera were 8 or higher, EPT/total ratios exceeded 0.60 (except at RM 70 = 0.42), the Baetids/EPT ratios were lower than 0.20, and the percent dominant taxa was less than 50% (Table 11). Below RM 70 there was a significant drop in the EPT/total individuals ratio to below 0.20 and an increase in the percent dominant taxa, which is maintained at the remainder of the sites below RM 70 except RM 32. This is due to increased numbers of Chironomids at these sites, particularly at RM 25 where numbers exceeded 10,000/m^2. The EPT/total ratio at RM 25 was 0.05 (lowest of all the sites) and the percent dominant taxa was 94% (highest of all sites). The site at RM 25, and others where large numbers of Chironomids were found, indicate the necessity of examining

Table 10. Tolerances of macroinvertebrate families to changes in water quality based on Hilsenoff (1988) where 0 indicates organisms least tolerant of pollution and 10 most tolerant.

Scale	Plecoptera (Stoneflies)	Ephemeroptera (Mayflies)	Tricoptera (Caddisflies)	Diptera (True flies)
0	Leuctridae Pteronarcyidae		Glossosomatidae Rhyacophilidae	
1	Chloroperlidae Perlidae Capniidae	Ephemerellidae	Brachycentridae	
2	Nemouridae Perlodidae Taeniopterygidae			
3				Tipulidae
4		Baetidae Heptageniidae	Limnephilidae	
5				
6				Chironomidae Simuliidae Empididae Ceratopogonidae
7				
8				Oligochaeta (not Diptera)
9				
10				Psychodidae

Table 11. Summary of the number of insect families, number of EPT genera, the EPT/total ratio, and the Baetids/EPT ratio for Kenai River mainstem stations sampled for macroinvertebrates in 1991.

River mile	Percent dominant taxa	No. of EPT genera	EPT/total ratio	Baetids/EPT ratio
79	30	9	0.63	0.16
73	27	10	0.65	0.04
70	44	8	0.42	0.09
40	81	6	0.14	0.12
37	79	9	0.15	0.10
32	64	9	0.37	0.05
25	94	9	0.05	0.08
24	82	9	0.16	0.11
22	80	9	0.17	0.14
21	68	6	0.19	0.13
19	88	4	0.08	0.14
18	73	9	0.18	0.05
17	81	10	0.13	0.08

more than one biometric measure to evaluate water quality. For example, at RM 25 nine EPT genera were found in high densities for families (e.g. Leuctridae, Chloroperlidae, Glossomatidae, and Brachycentridae) with low tolerances (0 or 1 rating) to water quality degradation (Hilsenoff 1988). High numbers of EPT genera were also found at RM 18 and RM 17 both located below the Soldotna Bridge. At RM 17 a high number (10) of EPT genera was observed; however, the Baetids/EPT ratio was below 0.20. The one site where the number of EPT genera was significantly lower was RM 19; four EPT genera were found and very sensitive families such as Leuctridae and Glossomatidae were absent. However, high numbers of Chloroperlidae stoneflies and a low Baetids/EPT ratio indicate that water quality is still good at this site. These findings suggests that there is no residual toxic effect from any contaminants, but that there may be some form of organic enrichment occurring which is supporting high numbers of Chironomids.

In summary, the macroinvertebrate data indicates that water quality is good to excellent at all sites as pollution-sensitive macroinvertebrates were found throughout the river. The major concern is the large number of Chironomids at a number of sites which appears to indicate some form of organic enrichment; however, no obvious effects on macroinvertebrate habitat were evident.

CONCLUSION

Overall, the two-year investigation of water quality in the Kenai River and its seven major tributaries indicate that although differences were observed between the more rural upper river and the more urbanized lower river, this watershed as a whole is not suffering any major impacts from present usage. General water quality parameters and nutrients were found in concentrations that were normal relative to other Alaskan waters, and metal concentrations were well within federal and state criteria for freshwater aquatic life. Hydrocarbon compounds were present in the lower river and at concentrations within EPA standards; however, the presence of oil sheens at the two storm drain outfalls warrant further investigation. Fecal coliform bacteria counts below the Soldotna Bridge were elevated compared to upper river locations, and some individual samples were found approaching State of Alaska criteria for secondary water recreation use. Finally, benthic invertebrate populations differed between the upper and lower river, indicating differential impacts or habitats; however, there is no evidence of a residual toxic effect from any contaminants.

Although in general, water quality parameters were within compliance with state and federal standards, sampling in 1991 which focused on the more urbanized lower river, revealed elevated levels of certain parameters. The two-year water quality investigation of the Kenai River and its seven major tributaries supports the findings of the State of Alaska Water Quality Assessment (ADEC 1990) which lists the Kenai River as a suspected water body for pollution from recreation, septic tanks, sewage treatment plants, and urban run-off. The potential for major impacts on water quality of the Kenai River is evident; however, the ability exists for effectively monitoring and treating pollutants before entering the river. Although impacts from these sources may at present be minimal, the water quality of the Kenai River relative to preserving its sensitive and valued ecosystem demands attention today and in the future.

RECOMMENDATIONS

Conduct intermittent sampling of critical parameters such as fecal coliform, hydrocarbon, metals, and nutrients for the purpose of monitoring future impacts on the water quality of the Kenai River. Three stations representing the upper, middle and lower portions of the Kenai River should be surveyed at least twice each year to monitor critical water quality parameters. Monitoring of hydrocarbon and fecal coliform parameters especially after snowmelt and urban runoff should be conducted. Finally, detailed correlative analysis should be conducted for areas of the river receiving motorized activity and the occurrence of hydrocarbons, especially compounds of gasoline (BTEX).

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APPENDIX

WATER QUALITY SUMMARY
General Tests and Metals

Kenai River Mainstem Stations

DATE	River Mile	Sp.Cond. (umhos/cm)	pH (Units)	Alk (mg/l)	Turb (NTU)	Color (Pt)	Calc (mg/l)	Mg (mg/l)	Iron (ug/l)
05/06/91	23	114	7.8	35	7.4	14.0	11.0	1.4	518
05/06/91	21	73	7.7	34	6.8	15.0	9.6	1.4	550
05/06/91	18	73	7.4	34	6.2	21.0	8.7	1.4	480
05/08/91	82	68	7.4	31	9.0	6.0	9.6	1.4	390
05/08/91	70	78	7.5	36	4.8	4.0	10.5	1.4	198
05/08/91	31	79	7.5	39	6.2	15.0	9.6	2.2	465
05/08/91	12	73	7.5	36	5.8	14.0	9.6	1.4	376
05/08/91	6	167	7.5	36	12.0	15.0	9.6	4.5	823
05/10/91	50	59	7.3	26	6.8	6.0	8.7	0.6	375
05/10/91	40	62	7.4	26	6.2	8.0	7.8	0.6	310
06/03/91	82	68	7.4	24	8.0	6.0	11.0	0.9	362
06/03/91	70	72	7.5	26	4.8	11.0	12.0	0.9	268
06/03/91	50	59	7.5	23	3.4	8.0	10.0	0.2	255
06/03/91	40	58	7.4	22	5.6	4.0	10.0	0.2	290
06/03/91	31	59	7.5	23	5.6	8.0	10.0	0.9	254
06/05/91	23	64	7.6	24	4.4	14.0	8.8	1.5	280
06/05/91	21	64	7.6	24	5.4	9.0	8.8	1.5	258
06/05/91	18	64	7.6	25	4.0	6.0	9.8	0.8	227
06/05/91	12	64	7.6	25	4.6	8.0	9.8	1.5	317
06/05/91	6	68	7.4	26	7.8	8.0	9.8	0.8	214
07/09/91	23	59	7.6	22	2.3	8.0	7.7	0.7	538
07/09/91	21	60	7.6	23	0.3	8.0	8.5	0.2	566
07/09/91	18	59	7.5	24	3.8	8.0	8.5	0.2	558
07/09/91	12	60	7.4	23	1.9	5.0	12.5	0.2	562
07/09/91	6	61	7.4	22	3.0	6.0	7.7	0.2	978
07/10/91	82	69	7.6	25	3.5	5.0	10.7	0.3	658
07/10/91	70	69	7.5	25	0.5	6.0	11.6	0.3	498
07/11/91	50	61	7.3	22	1.6	6.0	8.5	0.2	90
07/11/91	40	56	7.4	22	5.1	6.0	7.7	0.2	404
07/11/91	31	60	7.4	22	5.0	5.0	9.3	0.2	260
07/30/91	23	64	7.2	22	2.8	4.0	10.4	0.2	99
07/30/91	21	62	7.3	25	2.3	6.0	10.4	0.2	126
07/30/91	18	65	7.3	24	2.4	5.0	10.4	0.2	134
07/30/91	12	65	7.2	23	2.5	5.0	10.4	0.2	136
07/30/91	6	66	7.2	23	7.5	6.0	11.4	0.2	574
08/01/91	82	66	7.3	24	3.3	5.0	12.4	0.2	186
08/01/91	70	74	7.4	23	2.6	9.0	12.4	0.2	158
08/01/91	50	66	7.5	21	2.4	10.0	10.4	0.2	90
08/01/91	40	63	7.3	23	6.5	9.0	9.5	0.2	639
08/01/91	31	65	6.8	18	6.0	5.0	9.5	0.2	374
09/09/91	82	67	7.6	23	6.4	9.0	9.8	0.8	302
09/09/91	70	69	7.6	23	5.4	6.0	10.8	0.8	274
09/09/91	50	61	7.6	21	2.0	6.0	9.8	0.8	60
09/09/91	40	57	7.4	20	7.2	6.0	8.9	0.8	431
09/09/91	31	58	7.4	21	6.8	8.0	9.8	0.8	412
09/11/91	23	57	7.4	21	5.8	9.0	7.8	0.2	422

continued

WATER QUALITY SUMMARY
General Tests and Metals

Kenai River Mainstem Stations

DATE	River Mile	Sp.Cond. (umhos/cm)	pH (Units)	Alk (mg/l)	Turb (NTU)	Color (Pt)	Calc (mg/l)	Mg (mg/l)	Iron (ug/l)
09/11/91	21	60	7.4	22	5.0	8.0	8.9	0.2	345
09/11/91	18	60	7.4	22	5.5	6.0	9.9	0.2	354
09/11/91	12	61	7.3	22	4.4	5.0	10.3	0.6	319
09/11/91	6	60	7.3	22	7.0	5.0	9.9	0.2	514
10/07/91	23	62	7.5	23	6.4	9.0	10.3	0.6	330
10/07/91	21	62	7.5	23	6.4	9.0	10.3	0.6	345
10/07/91	18	61	7.5	23	5.8	5.0	10.3	0.6	318
10/07/91	12	62	7.5	24	6.3	5.0	10.3	0.6	319
10/07/91	6	61	7.5	23	5.8	6.0	10.3	0.6	354
10/09/91	82	66	7.3	22	6.8	8.0	10.7	0.8	316
10/09/91	70	70	7.4	24	6.0	8.0	10.7	0.8	278
10/09/91	50	59	7.4	21	6.2	9.0	9.8	0.2	289
10/09/91	40	59	7.3	20	4.0	8.0	9.8	0.2	209
10/09/91	31	61	7.4	22	5.8	8.0	9.8	0.8	270
11/05/91	23	69	7.4	28	4.4	11.0	10.0	1.4	240
11/05/91	21	66	7.4	31	4.6	10.0	10.0	0.2	368
11/05/91	18	81	7.2	31	5.2	8.0	11.0	1.4	286
11/05/91	12	78	7.3	31	4.6	6.0	11.0	1.4	252
11/05/91	6	132	7.4	34	120.0	10.0	11.0	2.8	4963
11/07/91	82	64	7.4	23	6.0	9.0	11.0	0.7	376
11/07/91	70	73	7.4	27	3.8	6.0	12.0	0.7	254
11/07/91	40	60	7.4	22	3.6	6.0	9.0	0.7	201
11/07/91	31	72	7.3	30	4.6	9.0	11.0	1.4	344

WATER QUALITY SUMMARY
Nutrients and Primary Production

Kenai River Mainstem Stations

DATE	River Mile	TP (ug/l)	TFP (ug/l)	FRP (ug/l)	TKN (ug/l)	NH3+NH4 (ug/l)	NO3+NO2 (ug/l)	RSi (ug/l)
05/06/91	23	27.9	8.5	6.5	137.2	5.2	136.7	2581
05/06/91	21	25.7	8.4	6.9	124.2	6.3	136.7	2702
05/06/91	18	28.1	18.6	13.5	150.1	1.4	133.6	2894
05/08/91	82	13.2	2.4	1.8	51.7	4.2	239.7	1568
05/08/91	70	19.2	1.7	1.1	106.1	4.2	439.1	1773
05/08/91	31	29.9	9.9	7.7	171.7	6.3	134.6	2846
05/08/91	12	24.4	10.7	8.6	159.6	1.1	122.2	2653
05/08/91	6	37.3	12.4	10.4	148.4	4.1	119.4	2955
05/10/91	50	11.5	1.7	1.6	33.2	4.7	203.2	1314
05/10/91	40	13.7	2.4	1.8	71.5	4.7	188.2	1568
06/03/91	82	12.9	1.9	1.9	54.2	6.3	237.5	1270
06/03/91	70	9.6	1.9	2.2	63.0	7.3	267.6	1331
06/03/91	50	9.8	2.1	1.7	12.0	5.2	181.8	1087
06/03/91	40	10.8	2.9	2.2	18.9	6.3	171.0	1244
06/03/91	31	12.9	4.5	3.9	16.3	3.2	166.7	1358
06/05/91	23	12.5	3.1	3.2	24.1	3.2	160.2	1341
06/05/91	21	13.4	4.5	3.9	30.1	3.2	153.9	1428
06/05/91	18	14.6	4.1	3.4	29.2	1.1	147.7	1341
06/05/91	12	13.9	4.7	3.5	38.8	1.1	150.5	1358
06/05/91	6	20.4	4.3	3.5	43.1	1.4	150.5	1445
07/09/91	23	17.2	2.1	2.2	30.1	1.2	149.6	1570
07/09/91	21	17.7	2.4	2.1	33.6	4.2	166.7	1570
07/09/91	18	19.4	4.0	3.2	44.8	3.0	159.0	1570
07/09/91	12	17.5	2.5	2.2	40.5	3.0	147.7	1616
07/09/91	6	55.4	19.6	19.0	170.0	6.1	160.5	1638
07/10/91	82	11.5	1.5	1.5	30.2	4.2	194.6	1730
07/10/91	70	11.1	1.7	1.7	19.8	4.2	196.7	1730
07/11/91	50	5.6	1.2	1.1	23.2	3.2	162.4	1478
07/11/91	40	10.2	1.8	1.8	34.5	4.2	162.4	1524
07/11/91	31	15.5	2.8	2.6	43.1	4.2	166.7	1570
07/30/91	23	9.2	1.8	1.1	36.2	4.2	149.6	1261
07/30/91	21	8.8	1.7	1.0	35.3	4.7	149.6	1227
07/30/91	18	10.2	2.3	1.4	36.2	4.5	108.1	1227
07/30/91	12	11.4	2.0	1.7	31.8	4.1	109.5	1216
07/30/91	6	24.7	2.3	1.9	45.7	3.0	115.2	1227
08/01/91	82	10.0	1.5	1.0	24.1	9.3	196.7	1502
08/01/91	70	9.2	1.7	1.2	20.7	6.3	201.0	1389
08/01/91	50	7.1	1.3	0.8	26.7	4.7	175.3	1214
08/01/91	40	26.8	1.5	1.6	42.2	5.2	158.1	1230
08/01/91	31	18.6	1.8	1.9	35.3	5.2	153.9	1284
09/09/91	82	12.9	1.9	1.4	21.5	4.2	181.8	1517
09/09/91	70	15.7	3.2	3.3	47.4	4.4	192.5	1517
09/09/91	50	8.0	1.6	1.2	24.9	4.2	171.0	1334
09/09/91	40	16.7	1.9	1.1	49.1	9.3	158.1	1375
09/09/91	31	17.8	1.9	1.4	44.8	7.3	158.1	1428
09/11/91	23	14.1	2.3	1.5	37.9	6.3	158.1	1412

continued

WATER QUALITY SUMMARY
Nutrients and Primary Production

Kenai River Mainstem Stations

DATE	River Mile	TP (ug/l)	TFP (ug/l)	FRP (ug/l)	TKN (ug/l)	NH3+NH4 (ug/l)	NO3+NO2 (ug/l)	RSi (ug/l)
09/11/91	21	13.8	2.3	1.2	48.2	5.8	158.1	1429
09/11/91	18	14.8	3.2	2.6	45.7	8.8	103.9	1435
09/11/91	12	14.7	2.6	2.0	47.4	5.6	167.6	1452
09/11/91	6	20.9	2.9	2.4	42.2	6.7	144.9	1476
10/07/91	23	14.1	2.9	1.0	31.0	5.2	173.2	1635
10/07/91	21	13.5	2.8	2.4	20.6	8.3	175.3	1586
10/07/91	18	14.5	4.3	4.1	44.5	4.0	171.8	1598
10/07/91	12	14.0	4.0	3.9	23.2	3.5	167.6	1610
10/07/91	6	15.2	4.2	3.9	33.5	4.6	187.3	1708
10/09/91	82	13.4	2.4	1.3	111.2	5.2	216.1	1464
10/09/91	70	12.0	1.2	1.3	6.0	4.2	196.7	1513
10/09/91	50	11.6	1.5	1.4	20.6	4.2	183.9	1244
10/09/91	40	13.7	1.9	1.4	112.4	6.3	179.6	1366
10/09/91	31	14.0	2.3	1.7	12.9	6.3	175.3	1464
11/05/91	23	8.0	4.6	3.5	25.8	11.3	166.7	2486
11/05/91	21	12.5	3.7	2.4	31.9	8.3	171.0	2419
11/05/91	18	45.2	22.3	22.4	252.8	23.3	292.0	2730
11/05/91	12	14.8	13.0	12.9	76.7	13.0	173.2	3786
11/05/91	6	330.0	13.7	13.8	282.8	37.6	161.8	4716
11/07/91	82	10.0	1.4	1.4	19.8	6.3	196.7	1653
11/07/91	70	8.5	1.9	1.8	9.4	5.2	222.5	1797
11/07/91	40	11.2	2.3	1.8	24.1	6.3	186.1	1753
11/07/91	31	17.4	6.3	5.6	48.2	11.3	153.9	2930

WATER QUALITY SUMMARY
General Tests and Metals

Kenai River Tributaries

DATE	Trib. #	Sp.Cond. (umhos/cm)	pH (Units)	Alk (mg/l)	Turb (NTU)	Color (Pt)	Calc (mg/l)	Mg (mg/l)	Iron (ug/l)
05/06/91	5	89	7.3	47	4.2	33.0	10.0	3.0	961
05/06/91	6	68	7.1	34	1.6	35.0	6.9	3.0	730
05/07/91	3	115	7.5	68	6.2	29.0	17.0	2.2	1157
05/07/91	4	77	7.4	43	7.6	39.0	10.0	3.0	1136
05/08/91	1	83	7.6	36	1.0	8.0	12.2	1.4	62
05/08/91	7	86	7.2	46	7.4	55.0	8.7	3.7	2182
05/10/91	2	68	7.2	29	3.2	12.0	6.9	1.4	436
07/08/91	3	151	8.3	78	0.0	22.0	24.7	3.0	1000
07/08/91	4	76	7.7	36	4.6	15.0	9.8	3.7	1226
07/08/91	5	164	7.8	79	0.0	22.0	20.7	6.0	810
07/08/91	6	131	7.6	61	3.4	26.0	15.8	6.0	1319
07/08/91	7	94	7.6	41	7.6	13.0	13.8	3.0	2116
07/10/91	1	78	7.5	31	0.4	5.0	12.6	0.3	46
07/11/91	2	30	6.8	10	31.0	8.0	3.0	0.2	3255
09/09/91	1	95	7.7	36	1.4	5.0	15.8	1.5	29
09/09/91	2	27	6.9	9	42.0	6.0	3.9	0.8	3310
09/09/91	3	145	7.8	73	1.5	24.0	21.7	3.8	326
09/09/91	4	90	7.6	42	2.0	22.0	10.8	3.8	358
09/11/91	5	135	7.6	63	2.2	23.0	18.0	0.5	175
09/11/91	6	101	7.4	44	3.2	33.0	12.9	4.0	845
09/11/91	7	78	7.2	31	6.4	17.0	10.9	1.4	920

WATER QUALITY SUMMARY
Nutrients and Primary Production

Kenai River Tributaries

DATE	Trib. #	TP (ug/l)	TFP (ug/l)	FRP (ug/l)	TKN (ug/l)	NH3+NH4 (ug/l)	NO3+NO2 (ug/l)	RSi (ug/l)
05/06/91	5	116.5	69.2	62.2	358.8	12.5	11.9	6586
05/06/91	6	27.8	17.2	11.3	294.2	6.7	34.6	5934
05/07/91	3	61.0	28.5	24.3	317.3	13.0	6.3	5934
05/07/91	4	63.1	26.8	20.3	266.4	3.0	40.2	6320
05/08/91	1	8.2	2.4	1.4	104.9	2.0	749.3	2110
05/08/91	7	81.1	39.1	34.0	342.7	8.8	6.3	6616
05/10/91	2	10.6	4.6	4.0	108.7	5.6	238.2	4099
07/08/91	3	31.1	20.7	18.6	197.8	0.9	2.4	6281
07/08/91	4	40.0	15.8	15.0	151.0	3.0	14.7	6596
07/08/91	5	80.2	58.8	58.9	192.4	1.4	57.2	11058
07/08/91	6	30.9	18.1	17.3	220.4	0.4	101.0	9850
07/08/91	7	35.9	14.1	13.8	120.8	3.0	94.0	5388
07/10/91	1	6.5	4.0	2.8	77.7	9.8	351.5	1753
07/11/91	2	72.9	5.4	4.4	68.7	8.8	36.0	2304
09/09/91	1	15.8	6.5	5.7	150.2	44.9	413.7	1663
09/09/91	2	72.8	4.7	4.0	61.9	1.1	23.2	1994
09/09/91	3	24.2	14.0	12.8	225.0	1.1	2.4	5925
09/09/91	4	29.9	19.7	19.8	165.3	0.4	9.1	8099
09/11/91	5	67.0	49.0	48.6	220.4	1.1	2.4	9320
09/11/91	6	34.9	16.4	14.8	301.9	1.9	101.0	8571
09/11/91	7	35.4	10.3	9.8	138.1	3.0	74.2	4030