FRPA Effectiveness Monitoring within the Willer-Kash State Forest Harvest Area

Prepared for the

ALASKA
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Conservation

By

ARRI
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Summary

Monitoring methods were developed and implemented to evaluate the effectiveness of the Forest Resources and Practices Act and Regulations at protecting fish habitat and water quality in the Matanuska-Susitna Borough. Monitoring is being conducted at this time due to increase in timber harvest activities and the lack of previous studies. Monitoring methods included measures of physical, chemical and biotic stream characteristics and were implemented on four similar streams within the Willer-Kash Timber Harvest Area. Data were collected in the summer of 2006 prior to any timber harvest within the drainages upstream of the sampling locations. Sampling locations were selected on four streams. The single channels flow from east to west through a mixed birch spruce forest. Stream widths are near 4 m and stream slopes from 0.5 to 5 percent. Substratum is coarse gravel to cobble with few fines. Base flow discharge was between 5 and 10 cfs and increased to measured values of over 35 cfs and estimated peak flows of over 100 cfs on August 19. Maximum stream temperatures were 12°C and were well buffered. The intact riparian vegetation allows 35 to 75 percent transmission of light and contributes large woody debris in the range of near 10 pieces per 100 m. The streams were clear to slightly stained with low conductivity. Nutrient concentrations were similar to other regional streams and did not show consistent phosphorus or nitrogen limitation based upon molar ratios of these two elements. Stream water pH was above neutral prior to and below neutral following high flows. Turbidity increases up to 5 NTU were measured during increasing discharge. The streams supported diverse macroinvertebrate communities dominated by Baetid Mayflies. Water quality was ranked “Good” to “Excellent” based upon Alaska Stream Condition Index metric scores. All four streams supported adult spawning coho salmon and juveniles that had spent one winter in fresh water

Introduction

Alaska Department of Environmental Conservation support was provided under notice-to-proceed 18-9001-11-2B to develop and implement methodology to evaluate the effectiveness of the Alaska Forest and Resources Practices Act (FRPA) at protecting water quality and fish habitat. Forest resources within the Matanuska-Susitna Borough are dominated by a mixed forest of birch and spruce. Previous timber harvest activities have generally been limited and restricted to the removal of large diameter spruce for lumber and house logs. Timber harvest has been increasing recently with the developing market for birch chips. Additionally, the FRPA and accompanying regulations were modified during the 2005 to 2006 legislative session. Recent modifications defined how harvest activities were to be conducted adjacent to water bodies in order to protect both water quality and fish habitat. The FRPA requires the state to evaluate both the implementation and effectiveness of the act and regulations at achieving desired objectives.

The Aquatic Restoration and Research Institute (ARRI) has developed a sampling plan to monitor the effectiveness of the FRPA under direction of the Alaska Departments of Environmental Conservation, Natural Resources, and Fish and Game. The sampling plan was developed for implementation within the Willer-Kash Forest Harvest area near Willow, Alaska, but was designed for general application. The sampling plan (Appendix A) describes the project objectives, statistical approach, sampling locations, frequency, sample parameters, and field methods. In addition, a Quality Assurance Project Plan was developed providing additional detail on data collection, handling, analyses, and evaluation.

Only minor timber harvest activities have occurred within the region, approximately 20 years ago. Data collection conducted during 2006 and reported within this study reflects reference conditions which will be used to compare conditions following future timber harvests.

The objectives of this study were designed to begin to achieve the goal of evaluating the FRPA effectiveness within the Matanuska-Susitna Borough. Specific project objectives included the development of a sampling and the collection of pre-harvest reference data. This report is a description of pre-harvest data and a discussion of sampling methods and results.

Methods

Study Area and Sampling Locations

The Willer-Kash harvest area is bounded roughly by the Kashwitna River to the north and Willow Creek to the south (Figure 1). The Willow Mountain Critical Habitat Area lies to the east and the western boundary generally is the Range line between 3 and 4 West.

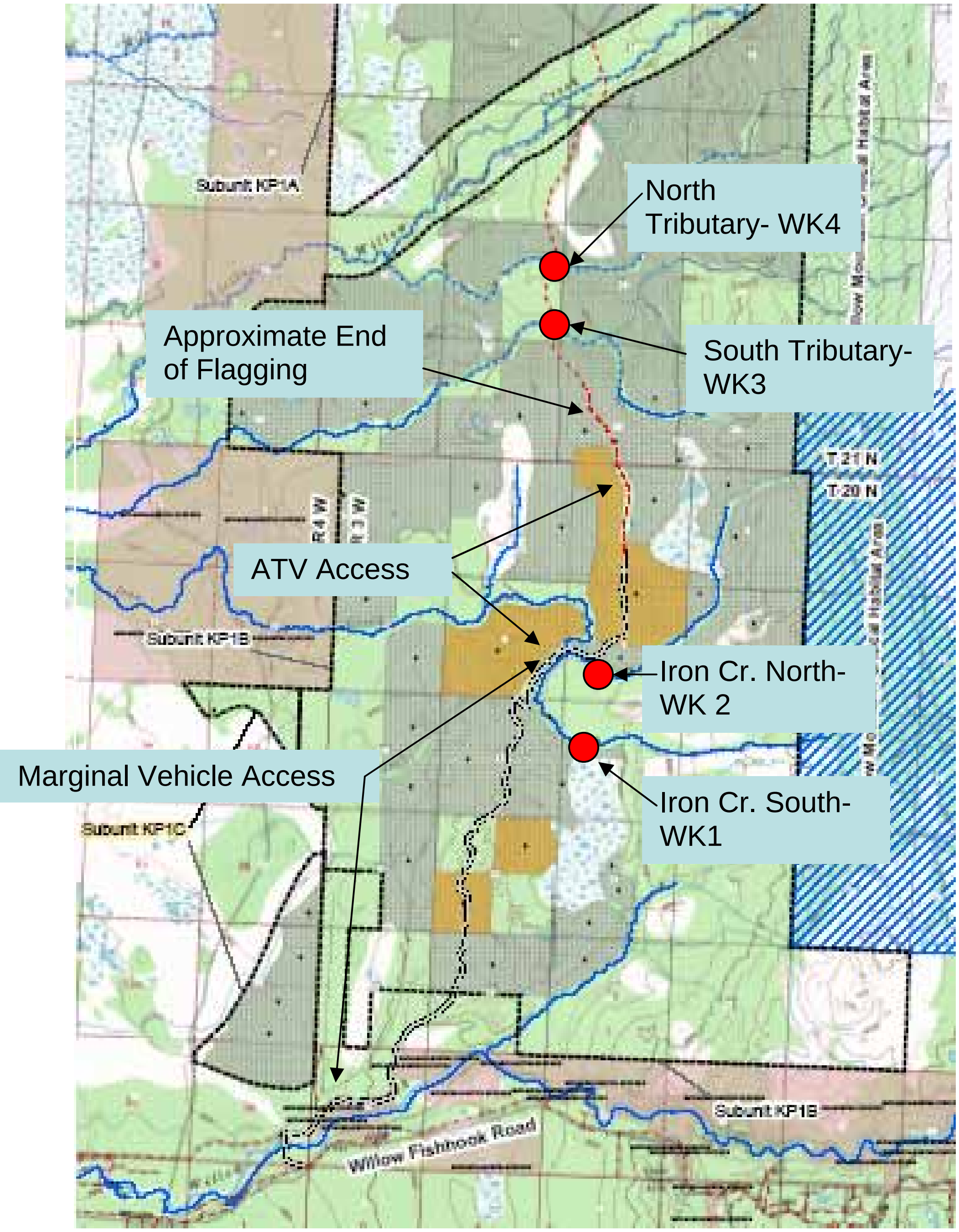


Figure 1. Map showing the access and location of sampling sites. Shaded areas represent proposed timber harvest areas.

Stream sampling locations were selected on four streams based upon similar physical characteristics, classified as Type IIC (stable streams and glacial water less than 50 feet wide) under the FRPA and proposed harvest within the drainage.

WK1 (61.8264 N x 149.8364 W) is located on the southern channel and main fork of Iron Creek, within Sections 15 and 16 (Anadromous Stream No. 247-41-10200-2130-3030 and is a second-order stream that drains into Little Willow Creek. Site WK2 (61.8350 N x 149.8329 W), located on the north fork of Iron Creek (Anadromous Stream No. 247-41-10200-2130-3030-4025) is within Sections 3, 9, and 10, and is a first order stream. Timber harvest is proposed along most of the upper reaches of the north fork, but only along the lower portions of the main fork. Therefore, these two tributaries provide both reference and potentially impacted sites.

WK3 and WK4 are two unnamed tributaries to Little Willow Creek. WK3 (61.8770 N x 149.8306 W) is located on the southern tributary, which flows through Sections 27 and 28 before crossing the proposed Willer-Kash road extension within Section 29 (T. 21 N., R. 3 W.) (Anadromous Stream No. 247-41-10200-2130-3036). WK 4 (61.8844 N x 149.8493 W) is on the northern tributary, which drains off of Willow Mountain and through Sections 21, 22, and 28 before crossing the proposed road extension in the northern half of Section 29. Significant timber harvest is proposed within both of these drainages allowing for evaluation of potential harvest-related impacts.

The sampling sites are labeled from south to north WK1 through WK4. Sites WK1 and WK2 are accessed from the Willow-Fishook Road to Shirleytown Road to the Willer-Kash Road then by all-terrain-vehicle and by foot (see Figure 1). Sites WK3 and WK3 were accessed by helicopter.

Physical Characteristics

Channel cross-sections were measured at three locations, separated by 20 m intervals, within each sampling reach. Cross-sections were measured using a meter tape, leveling rod, and hand level (Davis et al. 2001). The meter tape was secured across the stream bed above the level of maximum slope break. Height to the tape and water depth were measured using the leveling rod. The location of the wetted channel and ordinary high water mark were noted. Bank undercut was measured on both banks. Channel slope was calculated from U.S.G.S. 1:6300 scale topographic maps and water surface slope was measured on site using a hand level and leveling rod.

Discharge was measured using a Price pygmy meter, following equations for the sum of individual component flows as described by Rantz et al. 1982. Water pressure gauges (Hobo water level loggers) were placed within sand-point well tips driven into the stream bed and secured to the bank with plastic coated cable to continuously monitor changes in water depth corrected by atmospheric pressure data recorded at the Talkeetna Airport. Water level loggers also recorded temperatures on hourly intervals.

Substrate size distribution was obtained through Wolman pebble counts of 100 stones as modified by Bevenger and King (1995). Median diameter of all stones was determined using an aluminum hand held size analyzer. The percent of the stone volume embedded below the stream surface was estimated to the nearest 10 percent and recorded.

All large woody debris (LWD) and debris dams were counted within a 100-m sampling section and ranked based upon size and relative stream location to determine a large woody debris index (LWDI) score (Davis et al. 2001). Riparian downed coarse wood was counted along the right bank of each 100-m sampling reach and extending 20 m lateral to the stream channel. Coarse wood was identified by species and categorized by largest diameter (10 to 19 cm, 20 to 29 cm, or >30cm), and length (1 to 4 m, 5 to 9 m, or > 10 m).

Chemical Characteristics

Water samples for chemical and physical analyses were collected on 5 sampling dates at sites WK1 and WK2 and on three dates at WK3 and WK4. Analytical and quality assurance methods are described in the Quality Assurance Project Plan (Appendix A). Dissolved oxygen and temperature were measured in the field. Water samples were collected and returned to the ARRI laboratory for pH, specific conductance, and turbidity measurements. Unfiltered and filtered (0.45 μm pore size) water samples were collected from mid channel using a 60-ml syringe and acidified with sulphuric acid and shipped by Federal Express to AM Test, Inc. in Redmond, Washington for total phosphorus, total dissolved phosphorus, alkalinity, nitrate and nitrite nitrogen and ammonia nitrogen. On one sampling date samples from WK1 and WK2 were also analyzed for dissolved organic carbon.

Biotic Characteristics

Macroinvertebrates and juvenile fish were sampled at all sites on July 12 and 13, 2006. Replicate fish samples were collected at sites WK1 and WK2 on September 16, 2006. Macroinvertebrates were collected and analyzed using the Alaska Stream Condition Index (ASCI) methodology (Major and Barbour 2001). The invertebrate sample is a composite of 20 samples collected within a "D-Frame" net. Juvenile fish were captured within 4 minnow traps baited with commercial salmon roe. Traps were fished for 2 hours. Captured fish were identified to species, measured for fork length, and observed for any anomalies (deformities, eroded fins, lesions, or tumors) (Moulton II et al. 2002).

Benthic organic matter and periphytic algae were collected at sites WK1 and WK2. Benthic organic matter (BOM) was sampled by dislodging material from the stream bed to a depth of 10 cm, and sieving the suspended material from the flowing water in nested nets secured to a Surber-sampler frame (0.09 m^2) held on the stream bottom. The pore size of the inner net was 1 mm and the outer net 0.125 mm. Therefore, the organic matter was divided into coarse particulate organic matter (CPOM) and fine particulate organic matter (FPOM) size fractions. The organic material within the nets was transferred to whirl-pak bags and preserved with 95% ethanol. The ash free dry mass (AFDM) of the organic matter was determined gravimetrically.

The abundance of attached algae was determined by collecting periphyton growing naturally on stones and determining the concentration of chlorophyll-*a*. Periphyton was sampled from 5 randomly selected stones within each sampling reach at WK1 and WK2 in September. The periphyton enclosed within the diameter of 30-cc syringe was dislodged with a small brush, removed by suction, and collected on a Whatman GF/C filter. Labeled samples were kept in the dark, frozen, and stored in the laboratory until analyses. The filtered samples were analyzed for chlorophyll-*a* by acetone extraction and flourometery correcting for pheophytin through acidification.

Results

Physical Characteristics

The physical channel characteristics were similar among all four sample streams. Channel characteristics are shown in Table 1. Channel width to depth ratios were below 20 for all sites except WK3. WK3 also differed from the other sites due to higher banks and steeper channel and water surface slopes.

Table 1. Stream channel and substratum characteristics for the four sampling locations.

	WK1	WK2	WK3	WK4
Channel Width (m)	4.80	3.73	4.43	4.8
Area (m2)	1.46	1.01	0.96	1.29
Mean depth (m)	0.31	0.26	0.23	0.27
Width to Depth ratio	17.00	15.90	22.02	17.9
Minimum Bank Height (m)	0.12	0.12	0.46	0.22
Maximum Bank Height (m)	1.17	1.10	0.85	1.27
Minimum Bank Slope (degrees)	3.30	7.40	7.60	12.9
Maximum Bank Slope (degrees)	42.50	66.00	59.90	13.9
Bank Undercut (m)	0.15	0.22	0.27	0.10
Water Surface Slope	0.009	0.012	0.035	0.004
Channel Slope	0.014	0.015	0.024	0.022
D20 (mm)	5.6	8.0	18.0	20.0
D50 (mm)	32.0	30.0	33.0	50.0
D70 (mm)	50.0	60.0	55.0	70.0
Embedded >30%	32.0	40.0	22.4	13.5

Substratum size distribution also was similar among the four reference sites. The cumulative percent less than D20, D50, and D70 are shown in Table 1. The distribution is shown in Figure 2. The size distribution was slightly larger for sites WK3 and WK4. Sites WK1 and WK2 had more fine to medium sized gravel and sites WK3 and WK4 had slightly more coarse gravel to cobble material. The percent of material less than 2 mm was below 20% for all sites. None of the sites showed a high percentage of the substrate embedded more than 30%. Embeddedness was greatest at site WK2 with 40% of the substrate embedded more than 30% (Figure 3).

Pieces of large woody debris ranged from 8 to 15 for each 100-m sampling reach (Table 2). The largest number of debris dams (six) were found at site WK1, compared to one or two for the remainder of the sites. The LWDI was near 300 for most of the sites but doubled at WK1 because of the large number of debris dams. The amount of coarse wood within the riparian area ranged from 23 to 57. On an aerial basis the range of coarse wood is from 0.01 to 0.03 pieces/m2.

The percent of total available photosynthetically active radiation passing through the canopy ranged from 34 to 76%. Highest percent transmission was at WK3 and WK4 and the lowest at WK 1 and WK2 (Figure 4).

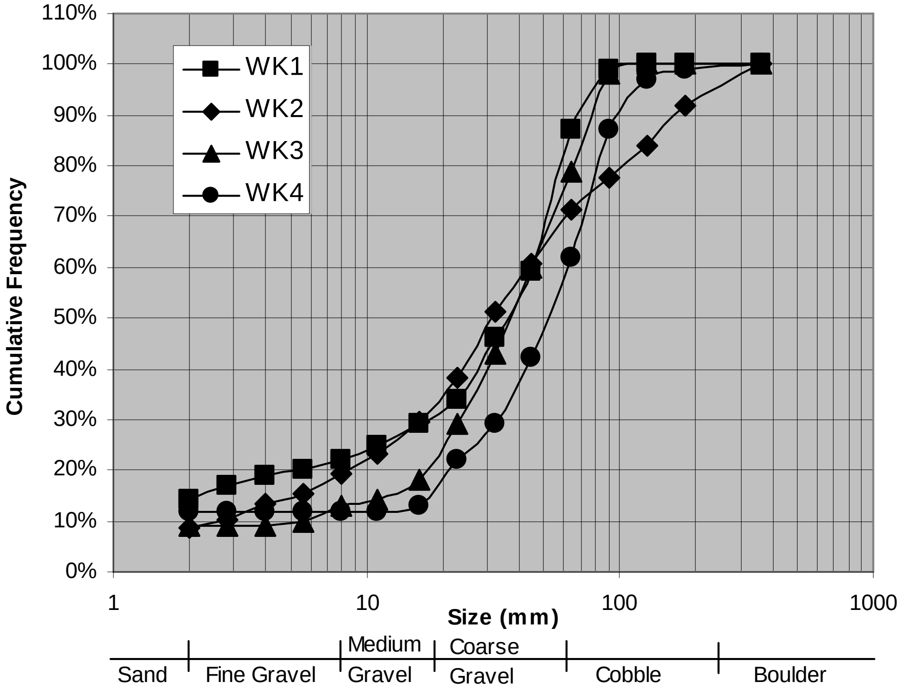


Figure 2. Cumulative particle size distribution for the four Willer-Kash sampling locations.

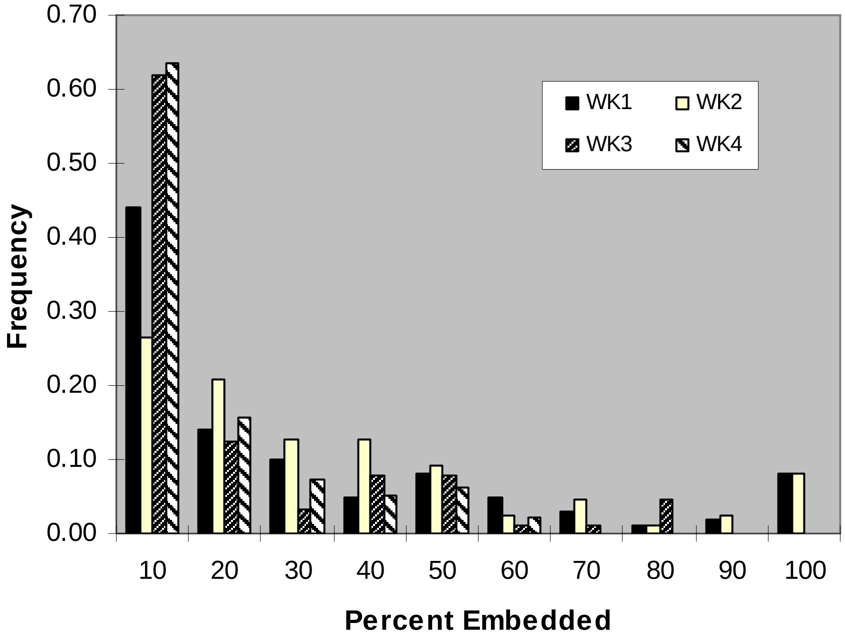


Figure 3. Frequency distribution of particle embeddedness.

Table 2. Stream large woody debris and riparian coarse wood.

Large Woody Debris					Riparian Coarse Wood				
	Pieces	Dams	LWDI	Pieces/m^2	Spruce	Birch	Alder	Total	Pieces/m^2
WK1	15	6	810	0.07	11	18	0	29	0.01
WK2	13	1	320	0.04	11	8	4	23	0.01
WK3	8	2	299	0.03	23	8	2	33	0.02
WK4	10	2	276	0.03	11	35	11	57	0.03

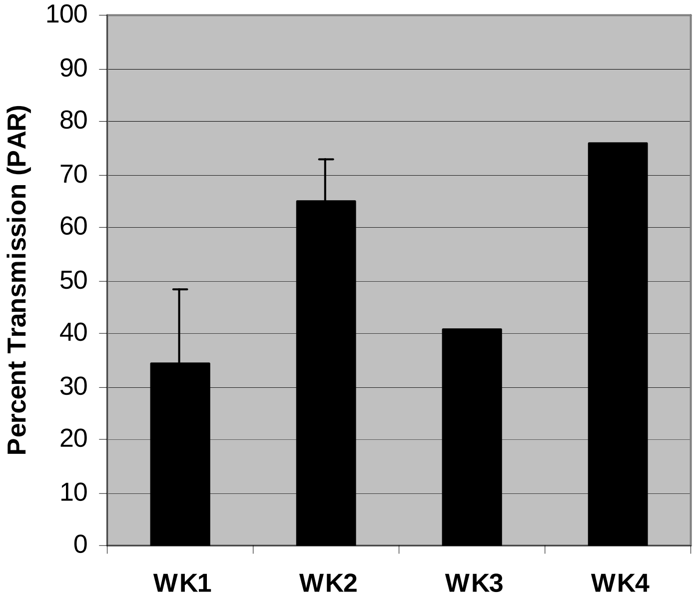


Figure 4. Percent of total available photosynthetically active radiation passing through the riparian canopy.

Due to the loss of data loggers from high flows and animals, we have only partial temperature data for WK1, WK3, and WK4, and continuous discharge data only at WK1. The data logger at WK1 was lost during high flows on July 14 and replaced on July 27. The data logger at WK2 was washed from the stream during high flows of July 14 and August 14 to 16 and between these dates removed from the stream either by people or animals. Reliable temperature and flow data are not available for WK2. At WK3, the combined pressure and temperature logger also was washed from the stream on July 14, and restored on August 30. The WK4 pressure and temperature logger was washed out of the stream near July 14, but washed back into the channel a few days latter. The logger was found on the stream bed approximately 40 m downstream from its original placement location. Temperature data are reported; however, we were unable to reconcile differences in pressure with the limited number of discharge measurements.

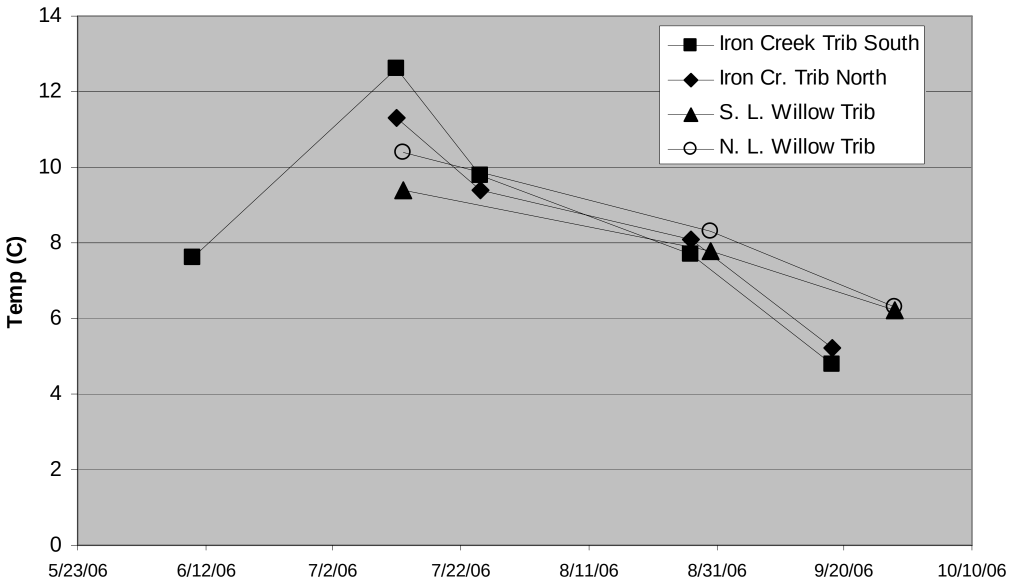
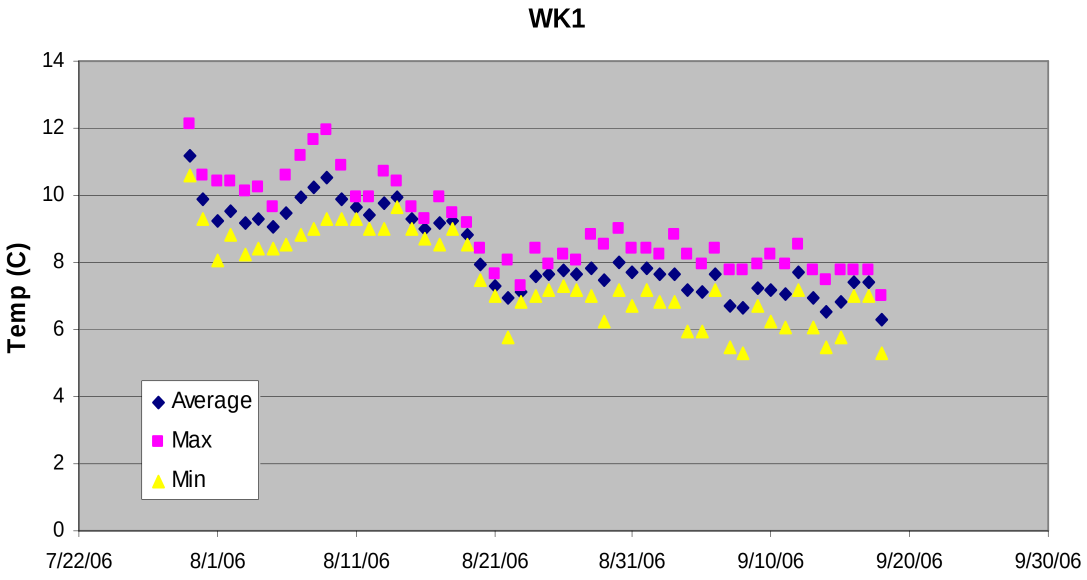


Figure 5. Stream water temperatures measured on water quality sampling dates.

Stream water temperatures measured in conjunction with stream sampling were highest on July 12 at 12.6°C and a low at WK3 of 9.4°C (Figure 5). Stream water temperatures were very similar between WK1 and WK2 on July 25 and September 18 and among all sites on August 25. Water temperatures at WK3 and WK4 were less than 1°C different on all sampling dates.

Maximum stream water temperature was recorded in early August at WK1 near 12°C and decreased continuously after this date (Figure 6). The maximum daily change in temperature was 4.5°C. There was only a poor relationship between maximum stream and air temperature recorded at the Talkeetna Airport. The available data show average temperatures at all sites generally below 10°C. The maximum daily change in water temperature was 3.6 at WK4 and 2.0 at WK3 (primarily Sept. data). There was a weak relationship between maximum air and water temperature at WK4 (Figure 8).

Stream discharge was less than 10 cfs at all sites when measured in July prior to any large precipitation event (Figure 9). On August 24, following extreme high flows, discharge was measured at near 40 cfs for WK1 and WK2. Estimated discharge at WK1 increased to over 80 cfs on July 14 and over 100 cfs on August 19 (Figure 10). These flows followed cumulative previous storm accumulations of 1.9 and 7.8 inches of rain, respectively (Figure 11).



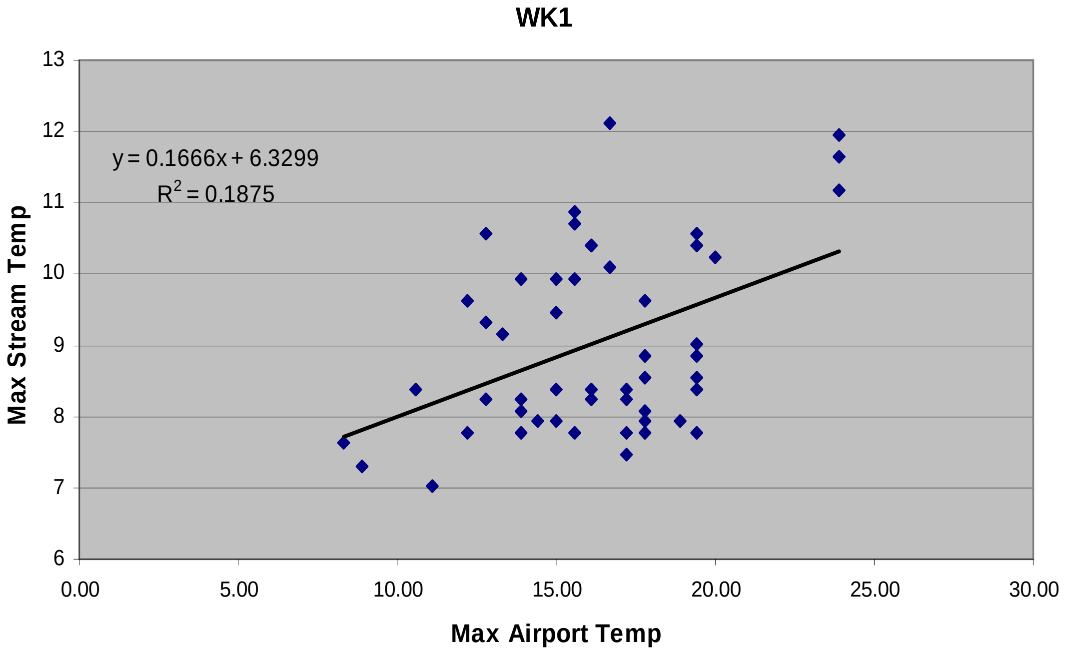
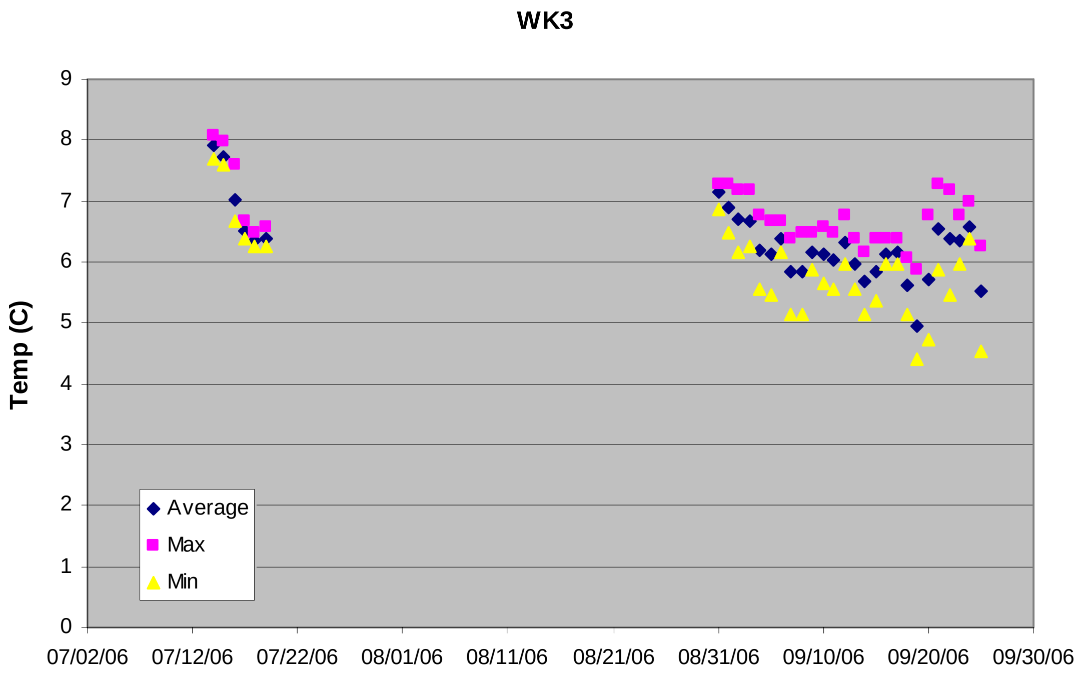


Figure 6. Stream water temperature data for WK1 and the relationship between maximum air and stream temperatures.



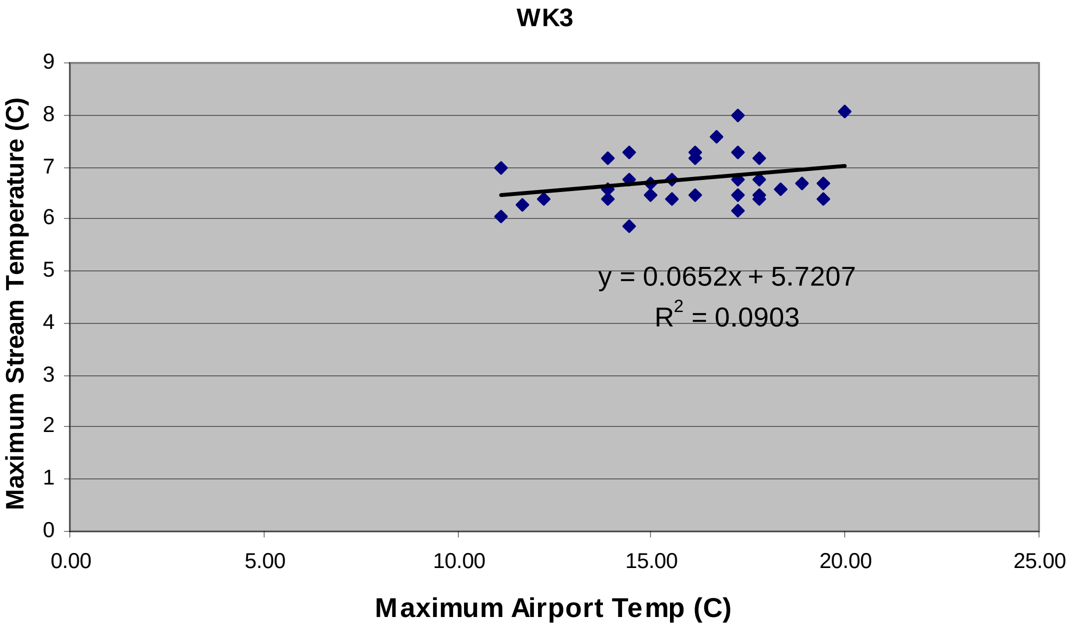
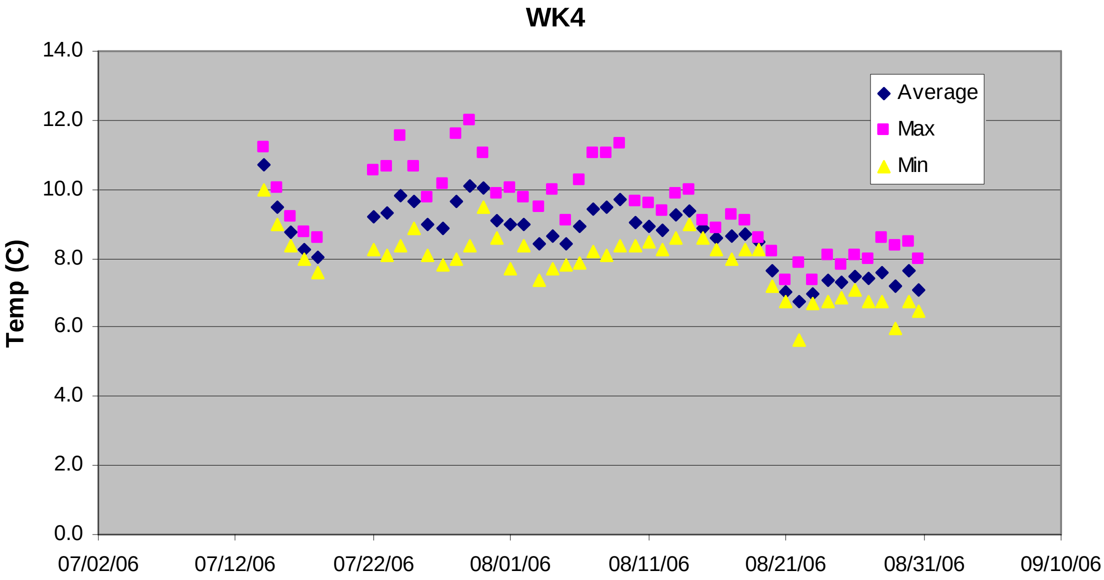


Figure 7. WK3 stream water temperatures and the relationship between maximum stream and air temperature.



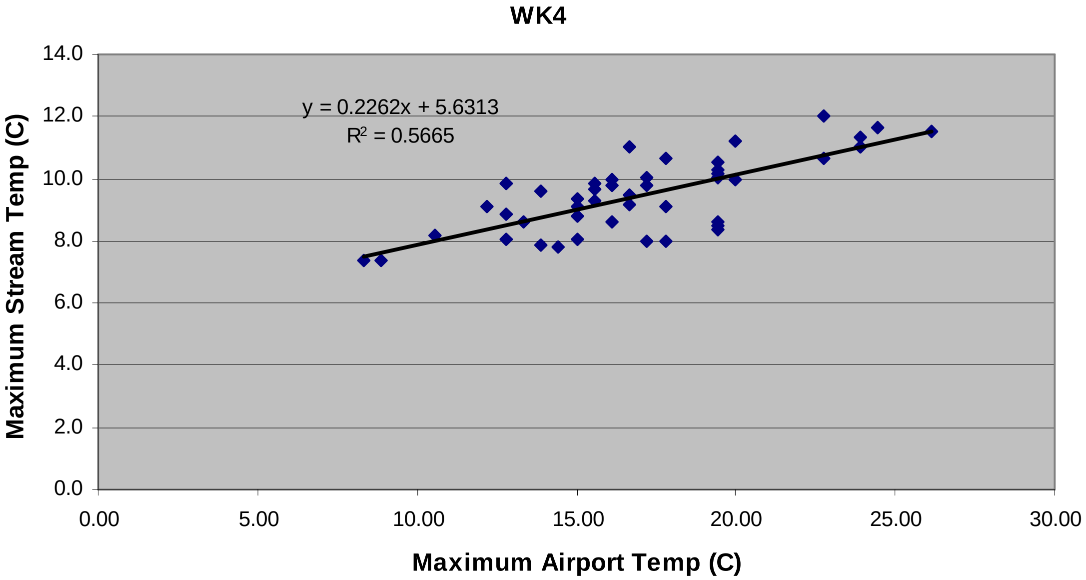


Figure 8. Stream water temperatures recorded at WK4, and the relationship with maximum air temperatures.

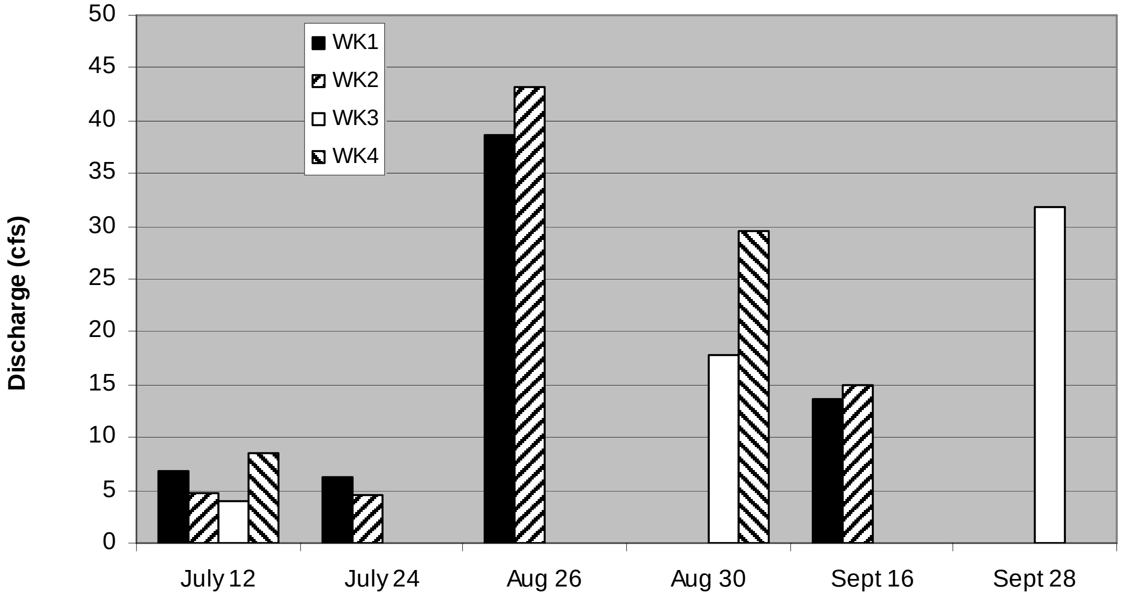


Figure 9. Stream discharge measured on water quality sampling dates.

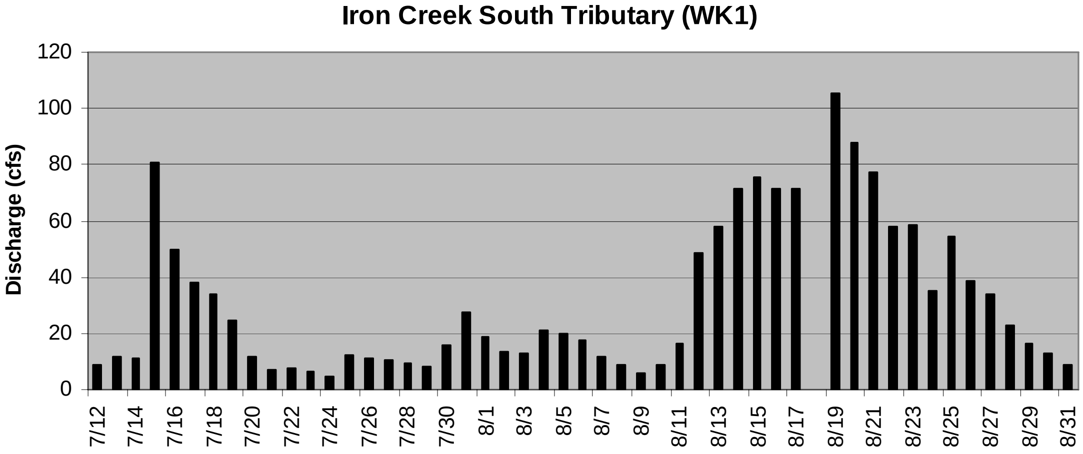


Figure 10. Estimated discharge from rating curve for WK1 showing peak flows on July 15 and August 19, 2006.

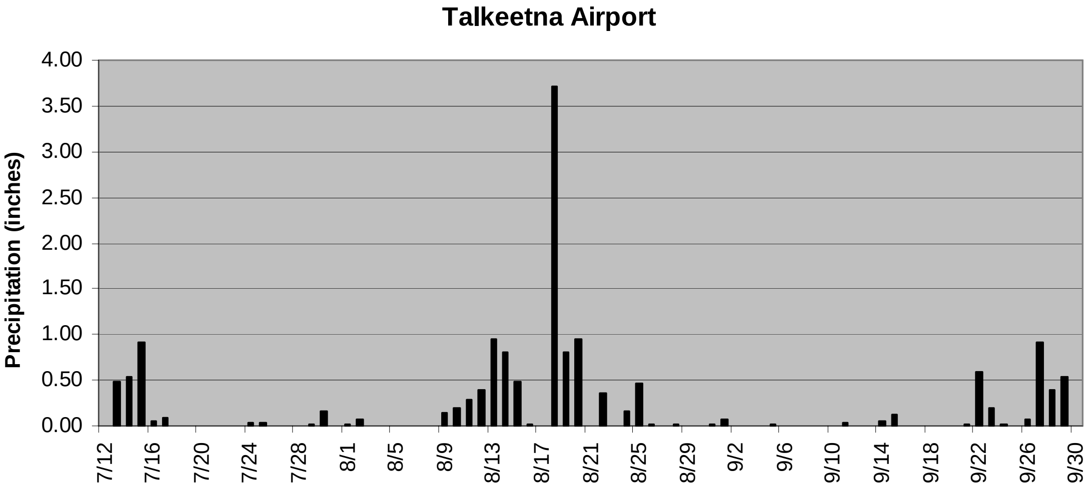
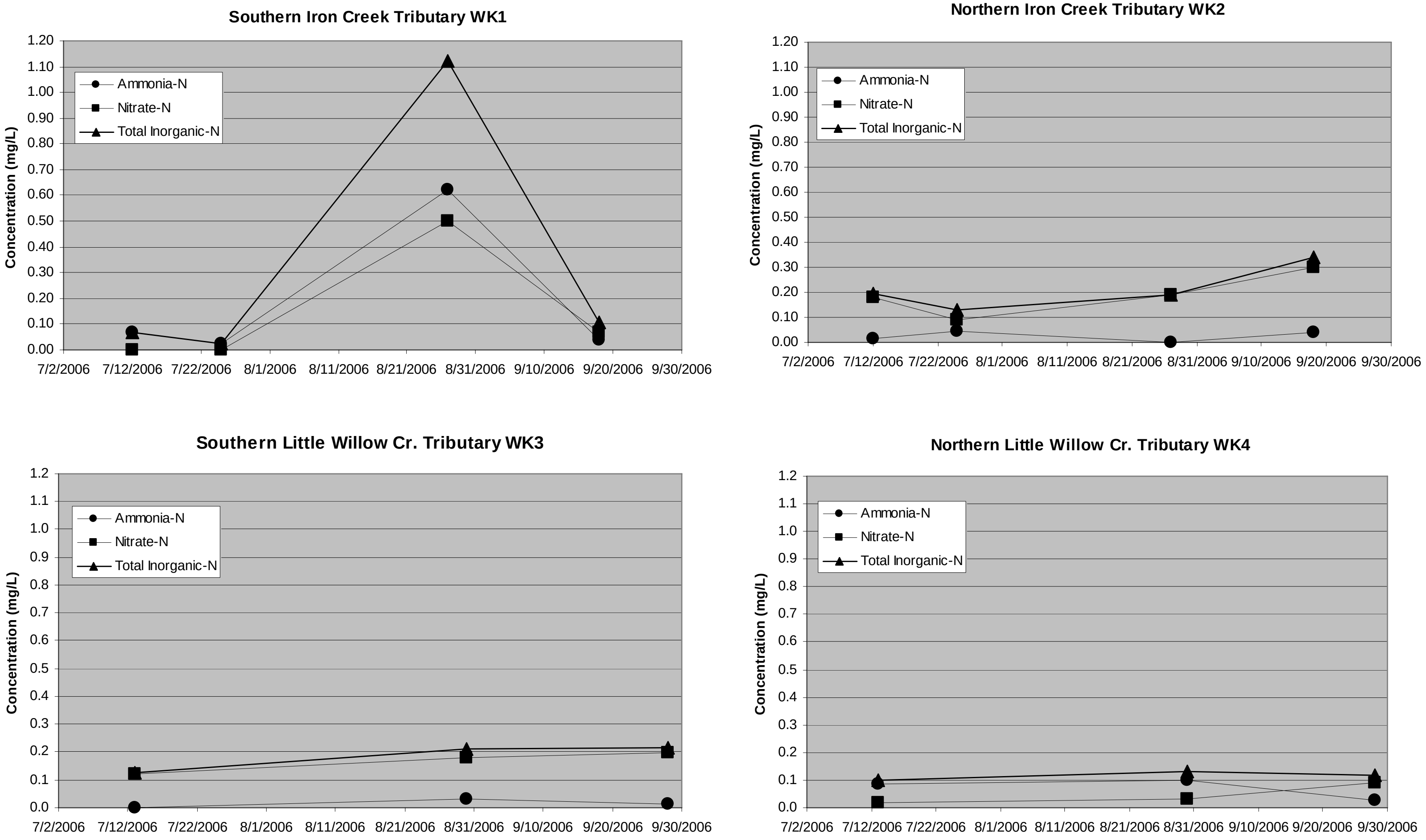


Figure 11. Daily cumulative precipitation at the Talkeetna Airport in 2006.

The concentration of macronutrients are shown in Figures 12 and 13. At WK1 there was a large increase in both ammonia and nitrate +nitrite-N following the high flow events on August 19. These large changes were not observed at the other sites. Total dissolved phosphorus was highest during high flows at WK1 and WK2 but did not respond the same at WK3 and increased only slightly at WK4. Although neither total nor dissolved phosphorus concentration responded consistently among locations following storms, the ratio of total to total dissolved phosphorus decreased to near 1. That is, dissolved phosphorus dominated the phosphorus pool during high flow. Molar ratios of total inorganic nitrogen to total dissolved phosphorus were highly variable. At WK1 and WK3 ratios were below 18 suggesting possible nitrogen limitation of primary production in July but increased well above this value in August and September. Ratios at WK4 were the opposite with phosphorus potentially limiting in July and nitrogen in August and September. There was no apparent pattern at WK2.

Stream water pH and specific conductance decreased following storms, while turbidity increased (Figures 14 through 16). There were only minor increases in turbidity in samples collected on August 27 and August 30, 17 to 20 days following peak flows. Prior to storms, stream water at all sites appeared clear to slightly stained. Following storms, the stained stream water appeared to increase from leached organic material rather than a brown color from suspended sediment.

Dissolved oxygen was at or near saturation on all sampling dates. Saturation concentrations varied with temperature, but ranged from 11.1 to 12.2 mg/L. Concentrations of dissolved organic carbon were 6.4 and 10.0 mg/L at WK1 and WK2, respectively, on August 27 following peak flows.



Southern Iron Creek Tributary WK1

Northern Iron Creek Tributary WK2

Southern Little Willow Cr. Tributary WK3

Northern Little Willow Cr. Tributary WK4

Figure 12. Ammonia, nitrate +nitrite, and total inorganic nitrogen for the four sampling locations.

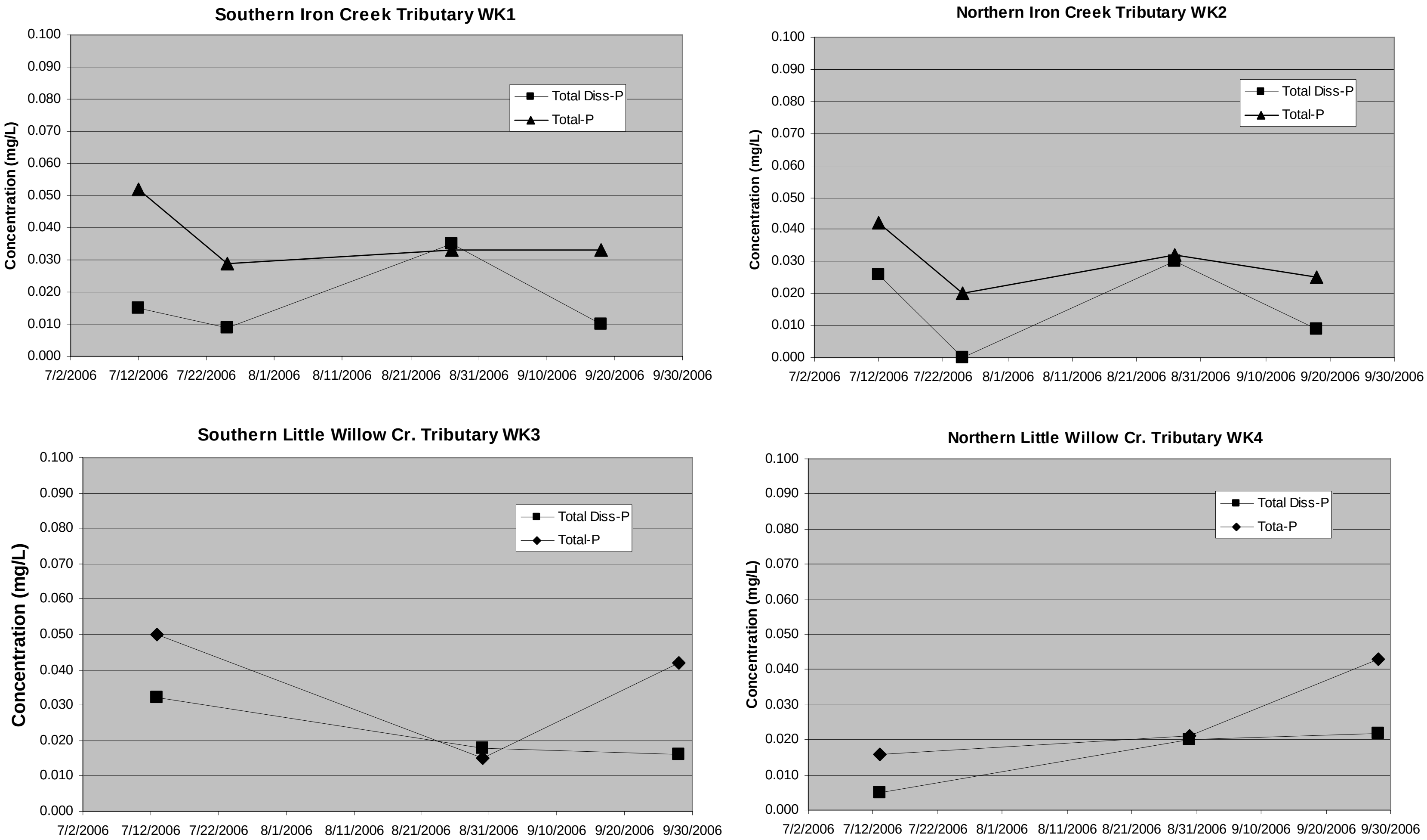


Figure 13. Total and total dissolved phosphorus concentrations from sampling conducted during 2006.

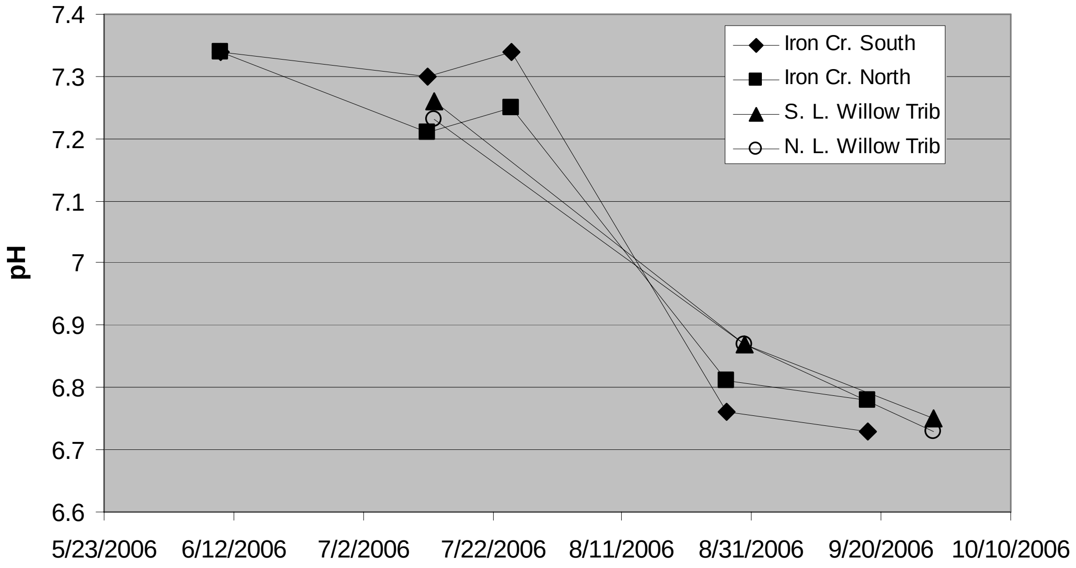


Figure 14. Stream water pH showing a decrease following August 19 peak flows.

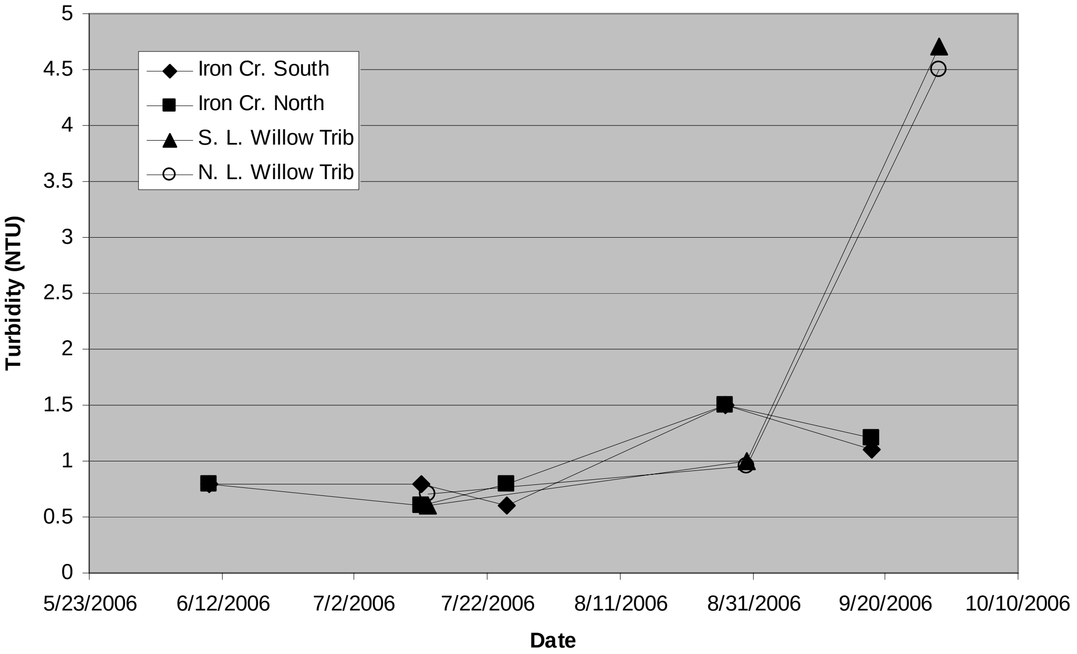


Figure 15. Stream water turbidity showing mild increase with increasing flows.

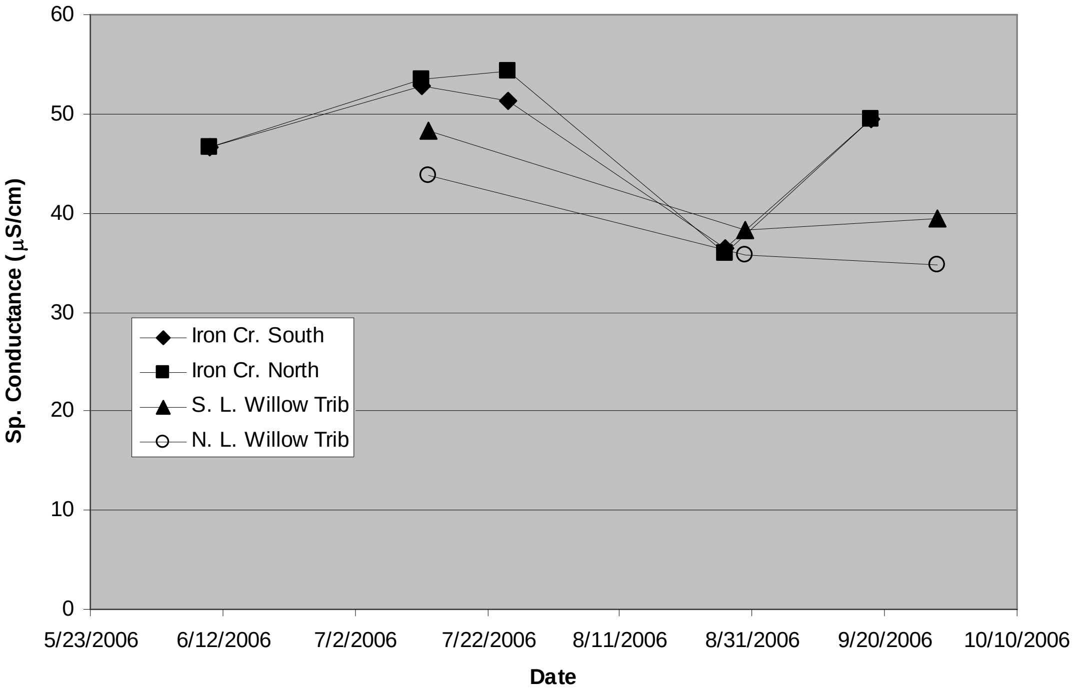


Figure16. Specific conductance showing decrease at all sites from samples collected during high flows.

Biotic Characteristics

The macroinvertebrate metric scores, ASCI metrics, and ASCI rankings are shown in Table 1. The water quality at all of the sites was ranked “Good” to “Excellent” using the ASCI metric and scoring criteria. WK1 received the highest “Excellent” ranking. The Ephemeroptera order contained the most taxa and were dominated by the Baetidae family. The relative number of Baetidae taxa resulted in the lower rankings for sites WK2 through WK4. For example, the percent of the Ephemeroptera that were not within the Baetidae family was 15 at WK1 but only 6 to 8 at WK2 through WK4. This resulted in low ASCI scores for this metric. One additional ASCI metric reflects the relative abundance of Baetidae to total Ephemeroptera, which was also low for all sites but particularly for sites WK2 through WK4. WK2 received the lowest total score. WK2 had the most number of Baetidae and also very few Plecoptera.

Coho salmon juveniles (*Oncorhynchus kisutch*) were captured in July at all sites except for site WK4 (Table 2). Although no juveniles were captured at WK4, numerous young of the year were observed along the steam margins in low velocity areas. Similar observations were made at the other sites; however, these small juveniles were not retained within the fish traps. The greatest number of fish were captured at site WK1. The size distribution of juvenile salmon is shown in Figure 1. The unimodal size distribution suggests a single age class, probably represented by one year old fish.

Fall fish sampling was conducted at WK1, WK2, and WK3 in September. Sampling followed extreme high flow events that occurred in late August. Adult coho salmon were seen at all sampling locations, WK1 through WK4. Juvenile catch rates at WK1 were much lower. The sample included 85 to 90-mm fish and a 48-mm fish likely representing fish from both 2004 and 2005 spawning. Small (less than 50 mm) fish were also captured at site WK2, along with 2 juvenile rainbow trout (*Oncorhynchus mykiss*). Numerous small fish were captured at WK3; however sampling did not include fish of a length representative of 1 year old fish.

Table 3. Macroinvertebrate metric scores and ASCI rankings.

	WK1	**WK2**	**WK3**	**WK4**
Ephemeroptera	86	159	65	85
Plecoptera	19	8	37	34
Trichoptera	12	18	54	21
Diptera	63	45	45	66
Richness	12	13	12	12
Ephemeroptera Taxa	4	3	4	4
Trichoptera Taxa	3	4	3	3
% Plectopera	10.50	3.43	17.37	16.19
% Ephemptera (no Baetidae)	14.92	6.01	7.51	8.10
% Diptera	34.81	19.31	21.13	31.43
Baetidae/Ephemeroptera	0.69	0.91	0.75	0.80
% Non-insects	0.55	1.29	5.63	1.90
HBI	4.21	3.96	3.48	4.02
%Scrapers	12.71	3.86	4.23	7.62
% Collectors	58.56	74.68	31.92	59.05
% EPT no Baetids or Zapada	23.76	15.02	33.80	20.00
ASCI Scores-Low /Gradient Coarse Substrate				
Ephemeroptera taxa 100 * X / 5.5	72.73	54.55	72.73	72.73
% Ephemeroptera (no Baetidae) 100 * X / 20	74.59	30.04	37.56	40.48
% Plecoptera 100 * X / 14	74.98	24.52	100.00	100.00
Baetidae / Ephemeroptera 100 * (100 - X) / 100	31.40	8.81	24.62	20.00
% non-insects 100 * (30 - X) / 30	98.16	95.71	81.22	93.65
O/E (family 75%) 2 100 * X	80	90	80	80
% scrapers 100 * X / 15	84.71	25.75	28.17	50.79
HBI 100 * (6.5 - X) / 2	100.00	100.00	100.00	100.00
Average	**77.07**	**53.67**	**65.54**	**69.71**
Ranking	**Excellent**	**Good**	**Good**	**Good**

Table 4. Numbers of juvenile fish captured at the sampling sites in July and September. Fall sampling was not conducted at WK3 and WK4.

	7/12/2006	9/16/2006
Site	No.	No.
WK1	29	3
WK2	4	4
WK3	6	15
WK4	0	n/a

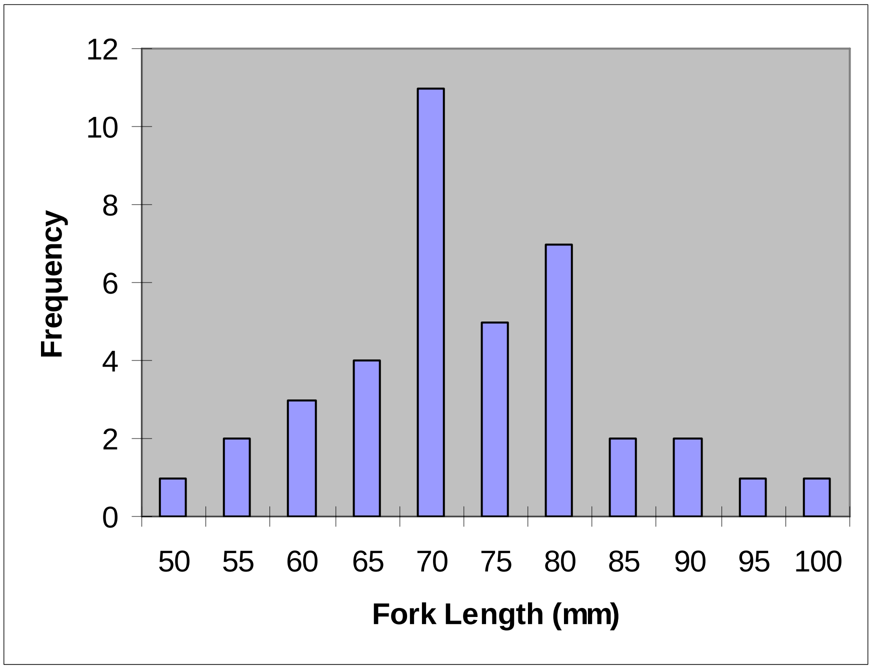


Figure 17. Size distribution of juvenile coho salmon captured in July 2006.

Average periphyton biomass, as indicated by chlorophyll-a concentrations, was greater at WK1 than at WK2 (Figure 18). Variability within each site was high, however, and differences were not significant (p = 0.17, T-test). Total, coarse, and fine benthic organic matter are shown in Figure 19. There was a high amount of variability in coarse material within each site, but average coarse organic matter exceeded the amount of fines.

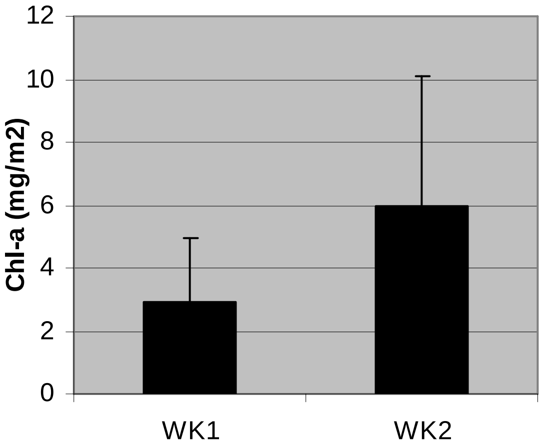


Figure 18. Periphyton chlorophyll-a for two sampling locations. Error bars are one standard deviation.

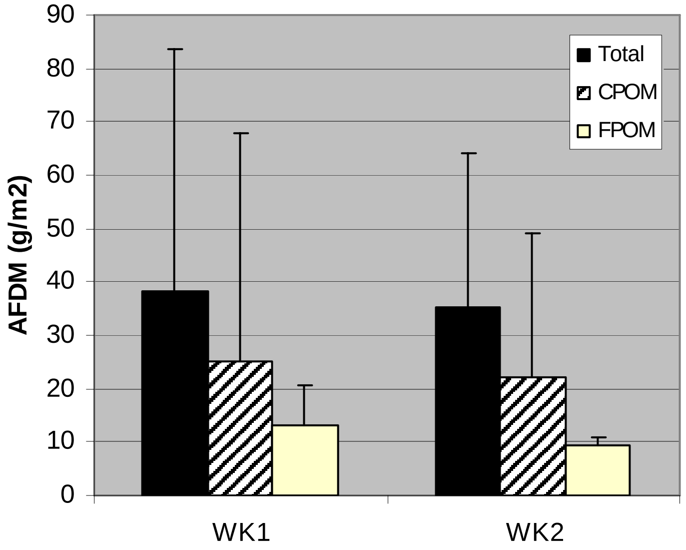


Figure 19. Benthic organic matter as Ash-Free-Dry-Mass in coarse and fine fractions. Error bars are one standard deviation.

Discussion

These data provide a baseline against which potential changes due to timber harvest and other land use practices within the respective drainages can be evaluated. The streams flow from east to west, out of the Talkeetna Mountains toward the Susitna River and are typical of streams within this region. They flow through a mixed spruce and birch forest with a narrow riparian zone of tall alder and willow scrub. The stream banks are vegetated and range in height from 0.1 to over 1.0 meter high. The streams form a single stable channel although discrete locations of high (>1.5 m) eroding banks were observed on all of the streams. There were no signs of extensive bank erosion even though these streams likely experienced flows that exceeded the 100 year occurrence interval (Conway and Meyer 2006). The stream substrate is composed of medium to coarse gravel, the portion of fines and embeddedness are low. Previous studies have shown that the percentage of fines often exceeds 20 percent at impacted locations (Davis and Muhlberg 2001, Davis and Muhlberg 2002). Although we did not obtain samples during peak flows, there was not a large difference in turbidity between low and high flows. Stream water turbidity in Wasilla Creek increased from near 5 to 62 NTU with a discharge change from 21 to 56 cfs (Davis and Muhlberg 2002). Turbidity in these streams was measured at flows below 10 cfs and above 30 cfs; however, turbidity increased only to a maximum of 4.5 NTU. Although turbidity was not measured in the sample streams during peak flows, water samples were collected from a number of streams crossing the Park’s Highway on August 20, less than 24 hours after recorded peaks. Turbidity increased to over 60 NTU in Willow Creek, Montana Creek, and the Kashwitna River, but much less for Little Willow (16 NTU), Grey’s (4.5 NTU), and Goose Creeks (11 NTU).

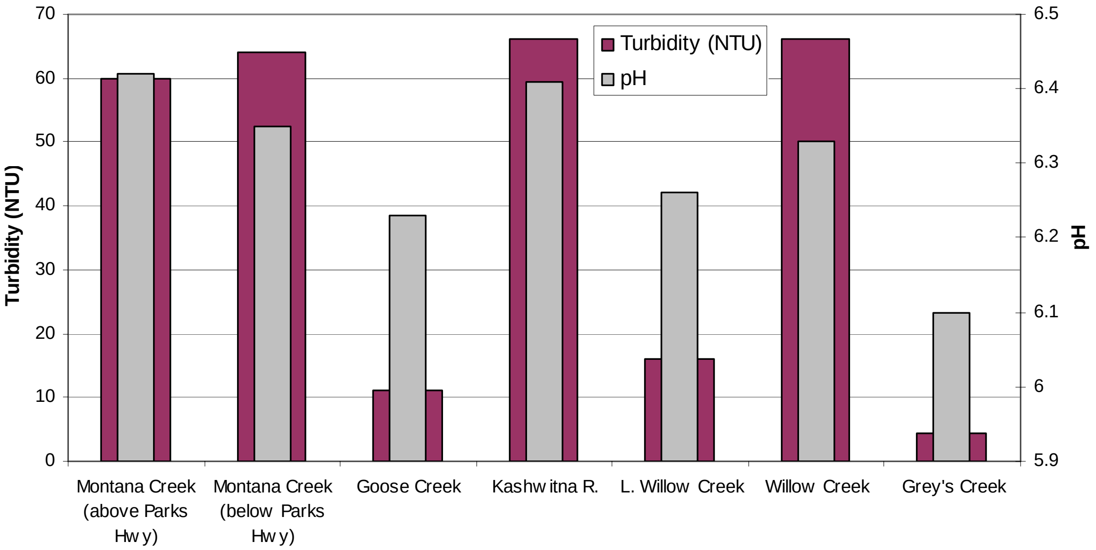


Figure 20. August 20, 2006 turbidity and pH during 50 to 100 year flood event.

In comparison to storm events, turbidity in excess of 100 NTU were recorded in Cottonwood Creek (Wasilla, AK) during the Park’s Highway Road construction (Davis and Davis 2005).

The streams contained cool water, small daily changes and weak correlations with air temperatures. These characteristics suggest that water temperatures within these streams are well buffered. The temperature of stream water is a function of energy inputs from solar radiation, conduction from the surrounding air influenced by convection and advection, and convection through tributary and ground water sources. Changes in stream water temperatures can be buffered by hyporheic and ground water exchange (Poole and Berman 2001). Removal of the riparian vegetation can increase solar input and allow for the convection of warm air across the water surface (Johnson 2004). Increases in channel width also can increase the available surface water for energy exchange through solar radiation and conduction between the air and water surface. Decreases in stream discharge reduce the heat dissipative capacity of the receiving water. Stream water temperatures can be reduced by the inflow or convection of relatively cooler water through tributaries or groundwater inputs. The evaporation of surface water also reduces stream temperatures by releasing water with a high temperature load (Poole and Berman 2001).

The maximum daily change was 3.6 C among these streams. Johnson (2004), measured daily temperature differences of over 10°C in a poorly buffered bedrock reach of a second order stream in the Oregon Cascades. A 6°C daily change was recorded in Montana Creek and 5.6°C for the Little Susitna River within Hatcher Pass, both of which are much wider streams with less riparian shading (Davis et al. 2006a, Davis et al. 2006b). Daily temperature changes of 4.6°C were recorded in Cottonwood Creek (Davis et al. 2006c). Similarly, the slope of the regression line between maximum regional air temperatures and stream temperature was low ranging from 0.06 to 0.22. As a comparison, the slope for similar regressions in Montana Creek were 0.29 to 0.45 and from 0.4 to 0.6 at most Cottonwood Creek sites. A poor correlation with regional air temperature and a low slope of 0.09was recorded for the upper portion of Cottonwood Creek. Temperature buffering is likely provided by groundwater and hyporheic flow and riparian vegetation cover.

The riparian vegetation allowed 30 to 75 percent of available light to the stream surface. The difference in light penetration between WK1 and WK2 (35 to 65 percent, respectively) may account for the differences in periphyton biomass. The chlorophyll-a values of 3 to 6 mg/m2 were consistent with previous measures in small regional streams but much less than recorded for the much wider sections of Montana Creek (Davis et al. 2006b). Therefore, increasing the amount of light reaching the stream channel will be expected to result in an increase in periphyton chlorophyll-a. The abundance of benthic organic matter recorded at WK1 and WK2 were similar to values obtained in Wasilla Creek (Davis and Muhlberg 2002) and coarse material exceeded fines. In contrast, the benthic organic matter in Montana Creek is dominated by the fine fraction. These differences are consistent with tenets of stream ecology (Vannote et al. 1980). Therefore, decreases in the riparian vegetation would likely result in a decrease in coarse benthic organic matter.

The amount of large woody debris pieces and the LWDI were within the range of values observed in similar sized streams. The number of pieces of wood ranged from 5 to 10 and the LWDI from 400 to 800 in Wasilla Creek (Davis and Muhlberg 2002). Fewer pieces, but more dams were recorded in forested reaches of Cottonwood Creek resulting in LWDI of 300 (Davis et al. 2006c). Although the streams within the Willer-Kash region experienced extremely high flows in 2006, we did not observe any obvious increase in LWD recruitment or transport.

The four sampling streams are well oxygenated, with clear to slightly organically stained water. Following the August storm, dissolved organic carbon (DOC) values at WK1 and WK2 were 6.4 and 10.0 mg/L, respectively. The highest values measured in Cottonwood Creek were 4.0 mg/L during the spring. DOC concentrations in streams where wetlands made up 1 percent of the drainage ranged from 3.5 to 7.2 mg/L (Eckhardt and Moore 1990). Stream water pH was above neutral prior to storms, but ranged from 6.75 to 6.85 following storm flows. A decrease in pH following storms is consistent with previously reported data from other locations (Davis and Davis 2005, Davis et al. 2006b) and is due to flushing of organic acids from upland soils (Boyer et al. 1997). Similar low pH values were recorded during high flows in other regional streams (see Figure 20). Average nitrate+nitrite-N concentrations were below 0.20 mg/L and ammonia-N below 0.1 mg/L. These findings are consistent with samples collected in the upper Little Susitna River and Montana Creek in 2005, except that nitrate +nitrite concentrations were generally below detection limits in those studies. In the upper Little Susitna River nitrate +nitraite-N concentrations were higher in 2006 compared to 2005 and it is hypothesized that the difference is the result of reduced terrestrial uptake as 2006 was a much cooler and cloudier year than 2005. Total phosphorus concentrations averaged below 0.03 mg/L and total dissolved phosphorus below 0.02 mg/L. These values are similar to those obtained in the Little Susitna River and Montana Creek where total and total dissolved phosphorus were below 0.03 mg/L (Davis et al. 2006a, Davis et al. 2006b).

Macroinvertebrate and fish sampling demonstrated good water quality supporting spawning and rearing coho salmon and rearing rainbow trout. Macroinvertebrate ASCI scoring was developed based upon the distribution of metrics within reference and potentially impacted steams. Relative to this distribution, water quality within these four streams was ranked “Good” to “Excellent”. A ranking of less than excellent for these sites does not indicate a reduction of water quality but merely reflects their position in the distribution among all reference streams within the Matanuska-Susitna Borough. Reference streams included streams of many different sizes, physical, and chemical characteristics and so it is not unreasonable to expect variation among non-impacted sites. These data provide a baseline against which future changes can be evaluated.

Fish sampling documented the presence of adult coho salmon in all of the sample streams, rearing coho salmon of 2 age classes, and rearing rainbow trout within one of the 4 streams. Young of the year fish were able to find refuge from the large August flows as they were present in all of the streams sampled in September. Aerial observations of the channel upstream of WK3 suggest that anadromous fish habitat exceeds that specified by the Alaska Department of Fish and Game.

Data Review, Validation, and Verification

The completeness objective of 95% was not met for all of the sample parameters due to difficulties with site access and floods. Data collection problems with temperature and discharge were discussed within the results section. Water chemistry samples were collected on three, instead of four, occasions at WK3 and WK4. Juvenile fish were not sampled at WK4 in the fall, and periphyton algae and benthic organic matter were collected at WK1 and WK2 only. Project accuracy objectives determined from measurements of standards were met for all sample parameters. Precision objectives calculated from sample replicates were not met for ammonia nitrogen and total dissolved phosphorus on all sampling dates. For ammonia nitrogen, differences between replicates ranged from 0.01 to 0.15 mg/L. Erroneously high values due to atmospheric diffusion are the primary cause of precision problems in ammonia analyses. Therefore, the lower of the two values is reported. Differences between replicate total phosphorus and total dissolved phosphorus ranged from 0.003 to 0.004 mg/L. Due to the low concentration of total dissolved phosphorus these differences resulted in a maximum precision value of 50% which exceeded the objective of 75%.

Literature Cited

Bevenger, G. S., and R. M. King. 1995. A pebble count procedure for assessing watershed cumulative effects. USDA Forest Service. Rockey Mountain Forest and Range Experiment Station. Fort Collins, CO. Research Paper RM-RP-319.

Boyer, E.W., G.M. Hornberger, K.E. Bencala and D.M. McKnight. 1997. Response characteristics of DOC flushing in an alpine catchment. Hydrological Processes 11:1635-1647.

Conway, J.S., and D.F. Meyer. 2006. August 2006 flooding in the Matanuska-Susitna Borough, Alaska. U.S. Geological Survey. Poster downloaded from alaska.usgs.gov/water.html on December 14, 2006.

Davis, J. C., and G. A. Davis. 2005. Cottonwood Creek TMDL Development—Residue. Aquatic Restoration and Research Institute. Final Report for the Alaska Department of Environmental Conservation, ACWA 05-02. Talkeetna, Alaska.

Davis, J. C., and G. A. Muhlberg. 2002. Wasilla Creek Stream Condition Evaluation. Alaska Department of Fish and Game, Habitat and Restoration Division, Technical Report No. 02-05. Anchorage, Alaska. 20p.

Davis, J.C., and G.A. Muhlberg. 2001. Chester Creek stream condition evaluation. Alaska Department of Fish and Game, Habitat and Restoration Division, Technical Report No. 01-07. Anchorage.

Davis, J.C, G.A. Davis, and L. Eldred. 2006a. Montana Creek ecological and water quality assessment. Aquatic Restoration and Research Institute. Final Report for the Alaska Department of Environmental Conservation. ACWA 06-03. Talkeetna, Alaska.

Davis, J.C., G.A. Davis, and L. Eldred. 2006b. Little Susitna Water Quality Monitoring Report (March 2005-April 2006). Aquatic Restoration and Research Institute. Final Report for the Alaska Department of Environmental Conservation. Talkeetna, Alaska.

Davis, J.C., G.A. Davis, and L. Eldred. 2006c. Cottonwood Creek Ecological Assessment. Aquatic Restoration and Research Institute. Final Report for the Alaska Department of Environmental Conservation. ACWA 06-02. Talkeetna, Alaska.

Davis, J.C., G.W. Minshall, C.T. Robinson, and P. Landres. 2001. Monitoring wilderness stream ecosystems. Gen. Tech. Rep. RMRS-GTR-70. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 137p.

Johnson, S.L. 2004. Factors influencing stream temperatures in small streams: substrate effects and a shading experiment. Can. J. Fish. Aquat. Sci. 61: 913-923.

Major, E.B., and M.T. Barbour. 2001. Standard operating procedures for the Alaska Stream Condition Index: A modification of the U.S. EPA rapid bioassessment protocols, 5th edition. Prepared for the Alaska Department of Environmental Conservation, Anchorage, Alaska.

Moulton, S.R. II, J.G. Kennen, R.M. Goldstein, and J.A. Hambrook, 2002. Revised protocols for sampling algal, invertebrate, and fish communities as part of the national water-quality assessment program. U.S. Geological Survey, Open-File Report 02-150.

Poole, G.C. and C.H. Berman. 2001. An ecological perspective on in-stream temperature: Natural heat dynamics and mechanisms of human-caused thermal degradation. Environ. Manage. 27, 6: 787-802.

Rantz, S. E., and others. 1982. Measurement and computation of streamflow--Volume 1. Measurement of stage and discharge. U.S. Geological Survey Water-Supply Paper 2175, 284p.

Vannote, R. L., G. W. Minshall, K. W. Cummins, J. R. Sedell, and C. E. Cushing. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences 37:30-37.

Appendix A—Sampling Plan

MAT-SU FRPA EFFECTIVENESS MONITORING

WILLER-KASH STATE HARVEST AREA

Contract 18-9001-11

Version 3.0

Prepared For

The Alaska Department of Environmental Conservation

by

The Aquatic Restoration and Research Institute
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May 2006

Aquatic Restoration and Research Institute

Project Manager: ________________________________ **Date:** ______________

Alaska Department of Environmental Conservation

Project Manager: ________________________________ **Date:** ______________

Introduction

This document describes a monitoring plan to determine the effectiveness of forestry management practices in maintaining fish habitat and water quality. The Alaska Department of Environmental Conservation (ADEC) has established goals for FRPA effectiveness monitoring. These goals are to determine if there are significant changes in water quality following timber harvest and whether State water quality standards are maintained. Implementation of the management practices also must meet the statutory intent for riparian areas (AS 41.17.115) harvested under the guidelines of the proposed Region II riparian standards (AS 41.17.118) or best management practices (BMP). The proposed methods to develop an effectiveness monitoring plan are designed for stream types located within, and applied to, state-owned lands of the Willer-Kash timber harvest area. The monitoring plan must be cost-effective and address potential short- and long-term effects to fish habitat and water quality. Effectiveness monitoring is being designed and implemented due to a paucity of monitoring data, predicted increases in harvest activity, and the development of new riparian standards within Region II.

Forestry effectiveness monitoring involves determining if best management practices and riparian management guidelines avoid or limit changes to stream channel characteristics during and after timber harvest. Most monitoring approaches are “reference based” in that stream conditions following timber harvest are compared to conditions within the same system prior to harvest or to similar unharvested stream systems (McDonald et al. 1991, Davis et al. 2001, Martin 1995). Natural variability in dynamic stream systems can be addressed by obtaining data from both harvested and unharvested stream systems over time. As characteristics vary among streams that differ physically and chemically, it is important that comparisons are made among similar stream classification types (i.e. Rosgen 1994). This sampling plan also is reference based, with reference data collected from stream systems prior to the initiation of harvest activities. The selection of stream characteristics has been chosen based upon water quality standards, and the riparian management intent of the Forest Resources and Practices Act (FRPA). Relevant literature will be reviewed to select standard and established measurement methods and dependent variables that are independent of annual variability.

Methods

Study Area and Sampling Locations

The Willer-Kash harvest area is bounded roughly by the Kashwitna River to the north and Willow Creek to the south (Figure 1). The Willow Mountain Critical Habitat Area lies to the east and the western boundary generally is the Range line between 3 and 4 West. Although Forest Land Use Plans (FLUPs) have not been developed under the proposed stream classification system, the Kashwitna River, Little Willow Creek, and Willow Creek likely will be classified as Type IIA streams (large dynamic non-glacial rivers) although the Kashwitna may be considered glacial and Willow Creek at this elevation is largely contained. Proposed timber harvest along Willow Creek and the Kashwitna River will not likely be sufficient to evaluate BMP effectiveness. Based upon

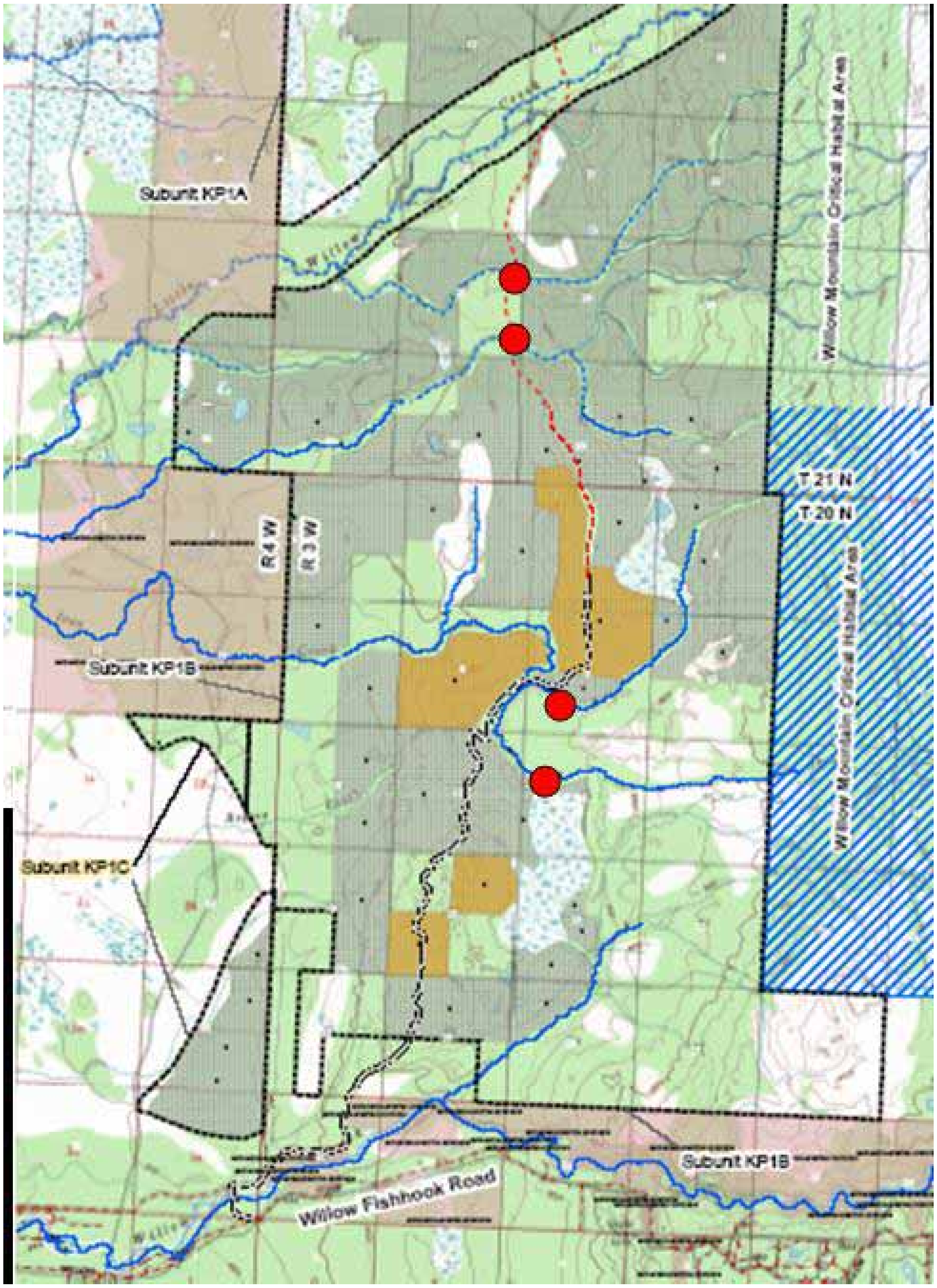

Figure 21. Map of the Willer-Kash Harvest Area showing proposed sampling locations (red dots).

the Five-Year Harvest Schedule maps, the majority of proposed timber harvest will occur along tributaries to Little Willow and Willow Creeks. Stream sampling locations are proposed for the following streams based upon similar physical characteristics, classification as Type IIC under the FRPA, and proposed harvest within the drainage. The characteristics of which are summarized as follows:

Iron Creek and its two tributaries above the road crossing occur within the harvest area. Both of these tributary streams are likely Type IIC. The southern channel, within Sections 15 and 16 is the main fork of Iron Creek (Anadromous Stream No. 247-41-10200-2130-3030) and is a second-order stream flowing into Little Willow Creek. The north fork of Iron Creek (Anadromous Stream No. 247-41-10200-2130-3030-4025) is within Sections 3, 9, and 10, and is a first order stream. Timber harvest is proposed along most of the upper reaches of the north fork, but only along the lower portions of the main fork. Therefore, these two tributaries provide both reference and potentially impacted sites.

The two tributaries to Little Willow Creek are unnamed; however, the first tributary flows through Sections 27 and 28 before crossing the proposed Willer-Kash road extension within Section 29 (T. 21 N., R. 3 W.) (Anadromous Stream No. 247-41-10200-2130-3036). The northern tributary drains off of Willow Mountain and through Sections 21, 22, and 28 before crossing the proposed road extension in the northern half of Section 29. Both of these are second order streams and appear to be Type IIC based upon aerial photography. Significant timber harvest is proposed within both of these drainages allowing for evaluation of potential harvest-related impacts.

Sample Measurements, Frequency, and Dependent Variables

The monitoring plan requires the description of the physical, chemical, and biological parameters to be measured, measurement frequency and duration, and methods of parameter measurement (qualitative or quantitative). Stream parameters were selected based upon applicable State Water Quality Standards (18 AAC 70) and the statutory regulatory intent for riparian areas. The management intent for riparian areas is the maintenance of large woody debris (LWD), bank stability and channel morphology, water temperature, water quality including nutrient cycling, food sources (for fish), clean (free of fine sediment and organics) spawning gravel, and sunlight (AS 41.17.115). Applicable water quality parameters include dissolved oxygen, pH, specific conductance (surrogate for total dissolved solids (TDS)), fine sediment, petroleum hydrocarbons, and debris. Proposed sample parameters and measurement methods are listed in Table 2.

Physical Characteristics

Substratum Size Distribution

The stream bed material provides the primary habitat for aquatic organisms. The size and stability of the channel material is a function of the sediment source and the stream transport capacity. The removal of upland vegetation through timber harvest operations can alter evapotranspiration processes leading to changes in the timing and amplitude of stream hydrographs and channel transport capacity. Mechanical disruption of soil layers and the exposure of mineral soil through yarding and road construction have the potential to increase sediment delivery rates to adjacent streams. Increases in fine sediment (< 2 mm) above transport capacity can have negative effects on aquatic biota through the restriction of water and dissolved oxygen movement through the stream bed material.

Stream substrate and the distribution of fines will be determined through Wolman pebble counts, estimates of percent embeddedness, core samples and measures of turbidity (see water chemistry section). Wolman pebble counts will measure the intermediate axis of 100 randomly selected stones within a 100-m long sampling section. Embeddedness is recorded concomitant with pebble counts, and is a semi-qualitative estimate of the portion of the selected stones that are embedded within fine material. Fines will be further evaluated by obtaining and sieving substrate core samples taken from ten randomly selected sites within the sampling section. As substratum is largely a function of peak flows, initial sampling frequency should be annual. Potential forestry effects should diminish with regeneration, so sampling frequency can decrease to every other year following the first 3 years.

Dependent variables will include D20, D50, and D70 (cumulative percent of bed material with diameters less than or equal to 20 mm, 50 mm, and 70 mm, respectively). For embeddedness, the relative percent of the particles embedded over 30% will be used as the dependent variable. The average mass of fine sediment will be used as the dependent variable from core samples.

Large Woody Debris

Woody debris provides a number of different functions within stream systems. Woody debris can reduce stream energy and contain sediments (Estep and Beschta 1985, Buffington and Montgomery 1999). Wood alters flow paths and creates diverse habitats. Large wood is a site of nutrient and organic matter storage and provides a substrate for aquatic invertebrates. The amount of large woody debris within a stream is a function of inputs and transport. Changes in the density of streamside woody vegetation and hydrologic changes can influence the amount and type of debris within a stream.

Large woody debris will be counted and measured (length and width) and identified by plant species within each stream system. An index of woody debris influence on the stream system will be calculated. Dependent variables will include total amount of woody debris per length of stream and the large woody debris index (Davis et al. 2001).

Water Temperature

Stream water temperatures affect most biochemical processes and further define the physical habitat of biotic organisms. Stream water temperatures are the result of a number of factors. Some of these include the surface area exposed to solar energy, which can be affected by the density of riparian vegetation as well as channel width, confinement and aspect (Johnson 2004, Poole and Berman 2001). Total stream volume and the portion of surface or subsurface recharge can influence stream water temperatures. Many of these factors are influenced by the community of riparian and upland vegetation.

Stream water temperatures will be measured using Onset Stowaway temperature loggers, Onset combined temperature and water level loggers, or Hach Hydrolab MS5 multi-sensor probe. Loggers will be placed within a well-mixed portion of each stream sampling site, above and immediately downstream and upstream from proposed harvest units and on the stream margin to record air temperature. Loggers will be set to record water temperature every hour. Dependent variables will be the daily maximum change in temperature, longitudinal temperature differences, and daily maximums as a function of air temperature recorded at the Talkeetna Airport and local air temperatures.

Turbidity

Turbidity is a measure of the reflective properties of water and is influenced by the amount of inorganic and organic sediment within the water column. High turbidity levels can affect the feeding and survival of fish and invertebrates. High turbidity is often associated with increased fines within the sediment which can alter the flow path and transport of nutrients and oxygen within and below the stream bed. This has a direct and negative effect on aquatic organisms and incubating fish eggs that are living within the substrate.

Stream water turbidity will be measured during the rising limb of the hydrograph during storm events using meters and automated samplers in the two Iron Creek tributaries and using the Hydrolab MS5 in the two tributaries to Little Willow Creek. Maximum turbidity and the change in turbidity following storms and spring runoff will be used as dependent variables.

Discharge

Stream flow or discharge provides the living space for stream organisms, affects substrate and channel form, water temperatures and sedimentation. Discharge can change with the removal of upland vegetation due to modified rates of snowmelt, interception of precipitation, evapotranspiration, and soil infiltration.

Discharge will be monitored continuously using pressure gauges and data recorders. A rating curve will be developed through the relationship between physical measures of discharge on multiple occasions (4 to 5) at flow extremes. Dependent variables will be timing and volume of peak and base flows relative to total yield, and discharge response to precipitation events.

Solar Radiation

For small streams, the density of riparian vegetation and surrounding forest absorbs solar radiation reducing the amount reaching the stream surface. The amount of solar radiation reaching a stream surface affects water temperature and primary productivity. Stream water temperatures can affect the distribution, development rates, and health of fish and invertebrates. Increasing the amount of solar radiation and instream production relative to external organic food sources can cause a change in the invertebrate community.

Solar radiation will be measured at a representative site within each stream and at an unshaded location using a meter that measures the photosynthetically active wavelengths. Radiation measurements will be continuous for a 24 to 48 hour period during the spring, summer, and fall. Dependent variables will be the portion of total daily solar radiation at stream sites relative to open locations.

Chemical Characteristics

Dissolved Oxygen

Oxygen affects the chemical state and physical properties of elements and is required for the respiration of aquatic organisms. The saturation point of oxygen in water varies with water temperature. Oxygen enters the water through diffusion and as a product of photosynthesis. Oxygen is consumed through chemical reactions and biotic respiration. Oxygen concentration should be near saturation in most turbulent streams; however, excessive organic matter, high temperatures, and low turbulence can result in concentrations well below saturation.

Dissolved oxygen concentrations will be measured in the field using oxygen probes and meters concomitant with water chemistry sampling during spring runoff, summer baseflow, and in the fall during plant senescence. Dissolved oxygen will be measured and recorded using the Hydrolab MS5 in the two northern tributaries to Little Willow Creek. Dissolved oxygen reading will be corrected for differences in water temperature and pressure.

Specific Conductance, pH, Hydrocarbons and Foam

Specific conductance is a measure of total ion concentrations and is used as a surrogate for total dissolved solids. Specific conductance is a gross indication of the availability of elements necessary for the growth and survival of biotic organisms. Ion concentrations within streams reflect the underlying geology as modified by terrestrial processes. Ion concentrations can change as the flow paths from the catchment change. Ion concentrations often decrease when streamflow is composed of surface runoff in greater proportion than groundwater. Similarly, pH is a measure of hydrogen ion concentrations and can be affected by geology, flow pathways, and biological processes. High and low concentrations of hydrogen ions can affect the survival of aquatic organisms.

Water sampling will be conducted to document water chemistry during snowmelt, base flow conditions, and fall precipitation. Weekly sampling will be conducted in May, bi-weekly for June, July and August, and weekly in September (May sampling will be excluded in 2006; however it should be conducted in 2007 prior to harvest if possible). Hydrolab multi-probe sensors will be placed within the two northern tributaries to Little Willow Creek and measure and record pH and specific conductance. May and September discrete sampling will be linked with the rising hydrograph when possible. Sampling should be conducted prior to forestry activities, annually following timber harvest for the first three to five years, and then every five years. Qualitative observations will be made looking for the presence of foam deposits and any oil sheen. Dependent variables will be mean concentrations and the difference in concentration between base flow and surface runoff.

Macronutrients

The macronutrients, nitrogen and phosphorus, along with solar radiation, often control the rates of autochthonus production. Nitrogen, while the dominant atmospheric gas, requires microbial fixation prior to use by biological organisms. Nitrogen is made available through the decomposition and release of nitrogen from organic material. Stream nitrogen concentrations often decrease during summer as biological uptake in terrestrial systems increases. Forest timber removal can increase nitrogen availability through increased decomposition while reducing terrestrial uptake resulting in increasing stream concentrations and total annual flux. Phosphorus is primarily from geological sources, but can increase as more mobile oxidized forms are flushed from storage within saturated riparian and wetland soils. Stream increases in nutrients can cause short-term increases in production followed by reduced productivity as soil storage is diminished and terrestrial uptake increases with forest regeneration.

Nitrogen (nitrate + nitrite, ammonium, and organic) and phosphorus (total and dissolved) will be measured at the same frequency as pH and conductivity described above with the following exception. For the two northern tributaries water samples will be collected in July and September and submitted for laboratory analyses. Nitrate and ammonia will be recorded in-situ using the Hydrolab multi-sensor and data logger.

Biological Characteristics

Periphyton Algae

Instream or autochthonus production in the form of algae or aquatic plants is one of the two major energetic pathways supporting stream organisms. The amount of algae within a stream can increase when productivity is greater than losses to grazing insects and sloughing. As mentioned previously, productivity can increase following forest harvest with increasing temperatures, solar radiation, and nutrients. Chlorophyll-a, a pigment used in photosynthesis, while not a true measure of algal biomass, can be used to indicate increases in stream periphyton.

Algae will be collected from accumulations on artificial substrates. Non-glazed ceramic tiles will be placed within the stream at 5 locations, 4 weeks prior to sampling. Sample will be conducted during mid summer when algal biomass should be near maximum seasonal high. Algae will be collected on filters, frozen, and transported to an analytical laboratory for chlorophyll-a analyses. Samples will be collected once a year for three to five years following harvest and then on five year intervals. Sampling will be conducted in late July during the peak growing season. Mean chlorophyll-a concentrations will be the dependent variable.

Benthic and Dissolved Organic Matter

Organic matter derived from terrestrial sources, or allochthonous organic matter, is the other major energy source for stream systems. Organic matter on the stream bed is the result of leaves and other terrestrial material deposited in the stream by wind or water. The amount of debris at a given location can be influenced by factors that retain organic material. These include large woody debris and debris dams, stable substrate, and diverse flow habitats (i.e. side channels and pools). The loss of terrestrial vegetation within a watershed can increase discharge during storm events and flush organic material from the stream channel. Dissolved organic matter is leached from terrestrial vegetation or is a product of decomposition and transported in water to streams. Dissolved organic matter; therefore, is also affected by processes which influence decomposition rates and hydrology.

Benthic organic matter will be collected on one occasion in mid-summer by dislodging the bed material at 5 randomly selected points within the sampling reach and collecting the resuspended material in mesh nets. The material will be divided into coarse and fine fractions. The amount of organic material will be based upon the mass lost upon ignition or the ash free dry mass. Dissolved organic matter will be collected concomitantly with water samples collected for chemical analyses.

Dependent variables will be the mean total, coarse, and fine benthic organic matter, the maximum dissolved organic matter and the increase in dissolved matter during storm events.

Macroinvertebrates

The larval stage of aquatic insects and other invertebrates are a diverse group of organisms. The abundance, diversity, feeding habits, and relative density of the many different aquatic organisms have been used to assess changes in water quality and habitat (Allen et al. 2003, Plafkin et al. 1989). Macroinvertebrates have been used because of their relative immobility, and differential responses to stream conditions.

Macroinvertebrates will be sampled using the technical level Alaska Stream Condition Index (ASCI) methodology. Sample collection will be conducted either in the spring, autumn, or both occasions. Dependent variables will include multiple different invertebrate metrics as well as the ASCI score.

Juvenile Fish

Similar to aquatic insects, egg incubation and juvenile salmon survival depends upon a consistent source of water. Changes in water temperature, dissolved oxygen concentration, volume, turbidity, pH, and food abundance can all affect the distribution and development of resident and anadromous juvenile fish (Murphy and Milner 1997).

Juvenile fish will be collected in baited minnow traps in the Spring and Fall. Fish will be identified to species and fork-length measured. Fish will be inspected for any deformities, eroded fins, lesions, or tumors. Dependent variables will be the total number of juvenile fish by species and the relative amount of different species collected.

Riparian Vegetation and Coarse Woody Debris

The plant community surrounding streams often differs from the surrounding forest. Retaining a buffer of natural vegetation around streams is one of the primary means used to maintain natural water chemistry and physical characteristics of streams draining timber harvest areas. The riparian plant community can intercept groundwater flow and nutrients, provide shade, reduce stream energy and retain sediment and nutrients during floodplain inundation. Coarse wood on the forest floor also provides diverse habitat for terrestrial animals. The riparian plant community and trees can be modified following timber harvest by changes in solar input and wind speed, which can affect soil moisture, humidity, and cause blowdowns.

The riparian plant community within the unharvested buffer zone along a representative reach will be classified and all coarse woody debris on the forest floor within the buffer will be counted, measured and identified by species. The dependent variable will be the amount of coarse wood per area within the buffer zone.

Table 5. Stream sample parameters and sampling frequency.

Sample Parameter	Frequency (prior to and 1-3 years post harvest)	Frequency (3 to 5 years post harvest)	Frequency (5 to 10+ years post harvest)	Methods
Physical				
Substratum	Annual	Annual	Biannual	Wolman Pebble Counts
Percent Fines	Annual	Annual	Biannual	Sieved core samples
Temperature	Continuous (May - Oct)	Continuous (May - Oct)	Continuous (if differences observed)	Data Loggers
Turbidity	Biweekly or Continuous (May – Oct)	Biweekly or Continuous (May – Oct)	Biweekly Every 5 years (May – Oct)	Water Sample Analyses
Flow	Continuous (May – Oct)	Continuous (May – Oct)	Continuous (May – Oct)	Pressure Data Logger and rating curve
Morphometery (cross-section, confinement, sinuosity)	Annual	Annual	Every 5 years	Surveys
Large Woody Debris	Annual	Annual	Every 5 years	Counts/LWDI
Solar Radiation	Continuous (May – Oct)	Biannual (May – Oct)	Every 5 years	Pyranometer or PAR meters with Data Loggers
Water Chemistry				
Dissolved Oxygen	Weekly (Spring), Biweekly or Continuous (May – Oct)	Weekly (Spring), Biweekly or Continuous (May – Oct)	Biweekly Every 5 years (May – Oct)	Water Sample Analyses
pH	Weekly (Spring), Biweekly or Continuous (May – Oct)	Weekly (Spring), Biweekly or Continuous (May – Oct)	Biweekly Every 5 years (May – Oct)	Water Sample Analyses

Sample Parameter	**Frequency (prior to and 1-3 years post harvest)**	**Frequency (3 to 5 years post harvest)**	**Frequency (5 to 10+ years post harvest)**	**Methods**
Specific Conductance	Biweekly or Continuous (May – Oct)	Biweekly or Continuous (May – Oct)	Biweekly Every 5 years (May – Oct)	Water Sample Analyses
Hydrocarbons/Foam	Biweekly (May – Oct)	Biweekly (May – Oct)	Biweekly Every 5 years (May – Oct)	Qualitative Observations
Nutrients (NO_3-N, NH_4-N, Total-P, Diss P)	Weekly (Spring), Biweekly or Continuous (May – Oct)	Weekly (Spring), Biweekly or Continuous (May – Oct)	Biweekly Every 5 years (May – Oct)	Water Sample Analyses
Biological Organisms/Food Sources				
Fish (juvenile)	Biannual (Spring and Fall)	Biannual (Spring and Fall)	Biannual (Spring and Fall)	Baited Minnow Traps
Macroinvertebrates	Annual	Annual	Every 5 years	ASCI
Periphyton Biomass	Annual	Annual	Every 5 years	Accumulation on tiles
Benthic Organic Matter	Annual	Annual	Every 5 years	Substrate Samples (AFDM)
Dissolved Organic Matter	Spring Runoff, Base Flow, and Fall Storm Events (May – Oct)	Spring Runoff, Base Flow, and Fall Storm Events (May – Oct)	Every 5 years	Water sample analyses
Riparian Vegetation Community Composition	Annual	Annual	Every 5 years	Qualitative classification
Riparian Coarse Wood	Annual	Annual	Every 5 years	Counts of Coarse Wood Within Riparian.

Study Design

Treatment

The treatment at three of the four sites will be timber harvest conducted under the guidelines of the FRPA and regulations for State land within Region II. Actual timber harvest operations will be determined by the timber operator. Therefore, actual treatment can vary considerably. Sources of variation include the number, location, density, and type of spur roads, landings, and material sites; whether the area will be harvested in summer or winter, how the wood will be processed (on- or off-site), and the harvest's proximity to buffers and stream terraces. Therefore, the type of harvest will be closely monitored and recorded. Information on harvest activities will likely be obtained from the State Forester.

Hypothesis and Statistical Approach

A paired (pre- and post-harvest) sampling approach will be applied. This approach would allow for statistical comparisons using paired T-test or non-parametric alternatives for the first post-treatment measure with repeated measures using ANOVA thereafter. The approach will provide a means for evaluation of BMP effectiveness within the Willer-Kash harvest area that could be expanded over time and space to include harvests occurring along other stream types and over a larger geographical area. In addition, over time, the approach would allow for comparisons of sites for multiple stream types with different levels of area harvested and road construction methods. Under this approach, stream types within a harvest area would be identified through the Forest Land Use Plan (FLUP) development or upon the submission of Detailed Plans of Operation (if the harvest is on private land). Sampling reaches would be identified on each stream type or a subset of available stream types. Sample reaches would be selected with reference to the area of proposed upstream harvest and miles and type of proposed road construction (winter or all season, number of crossings, etc.). Pre-harvest data would be collected from each sampling reach. Following timber harvest, sampling would be repeated. Changes between pre- and post-harvest parameters would be analyzed; however, similar trends would need to be observed among all stream types for differences to be statistically significant. This approach is more cost efficient and more sensitive to change than the comparison of means or variability among reference and treatment groups, and does not require a large set of reference streams within a timber harvest area. In addition, by tracking the amount and type of harvest within each stream drainage, like comparisons can be ensured.

Method Requirements

Field Data Collection

Field data collection will be conducted by Aquatic Restoration and Research Institute (ARRI) staff. Measures of dissolved oxygen, pH, specific conductance and temperature will be conducted in the field. Samples for turbidity and alkalinity will be collected in clean sample bottles and returned to the ARRI Laboratory for analyses. For the two northern tributaries, ph, specific conductance, turbidity, dissolved oxygen, nitrate, and ammonia-nitrogen will be measured using the Hydrolab MS5 in addition to water sample collection and analyses during logger deployment and retrieval. Samples will be collected from a well-mixed area at each sampling site. Water-column integrated samples will be collected by drawing water into a 60 ml syringe while drawing the syringe up from near the stream bottom to near the water surface. The water within the syringes will be discharged into pre-labeled sample bottles.

pH, Specific Conductance, Turbidity, Alkalinity, and Dissolved Oxygen

Depth integrated water samples will be collected in 500 ml sample bottles. The sample bottles will be filled and emptied 3 times before a sample is retained. Water characteristics will be measured using appropriate meters. Meters, pH, Hanna HI 9023, conductivity, SPER Scientific model 840039, and turbidity, HACH Chemical Co. Model 16800. Continuous measures will be collected using the Hydrolab MS5 programed for readings on two hour intervals. Support equipment will include extra batteries and sample bottles. Clean sample bottles will be used. All meters will be tested and calibrated prior to use.

Materials Required: Data book, pencils, sharpie, 500-ml sample bottles (16 minimum), labels, 60-ml syringe, cooler, gel-paks, pH meter with standards, dissolved oxygen meter, thermometer, Hydrolab MS5 and Surveyor, extra batteries, and camera.

Weather Conditions

Weather conditions for the 24 hours previous to sampling will be obtained through direct observations and from on-line National Weather Service Website for Talkeetna.

Nitrogen and Phosphorus

Water samples will be collected in sample containers provided by AM Test, Inc. Sample bottles will contain preservative where required (H_2SO_4 for nitrogen and total phosphorus, 4°C for dissolved phosphorus). Samples will be collected using the "clean hands" method. This method required two samplers, one to handle sample labels, containers and other equipment. The second sampler, while wearing sterile gloves, collects the sample and within sterile syringes or other sampling device and discharges the sample into the sample container. Sterile procedures are maintained. Samples will be sealed within a cooler with frozen gel-paks and shipped by Federal Express to the laboratory for analyses. Chain of custody forms will be used by ARRI staff and the receiving laboratory to track sample handling.

Materials Required: sample bottles, labels, markers, chain-of-custody forms, cooler, frozen gel-paks (6), 60-cc syringe (9), Hydrolab MS5 and Surveyor, thermometer, and sterile gloves.

Temperature

Stream water temperature data loggers (Stowaway by Onset Corporation) will be placed within each stream at the upstream and downstream end of proposed harvest units.

Loggers will be secured to the bank using plastic coated wire rope. Loggers will be downloaded at least monthly.

Materials Required: 4-m sections of wire rope (3), clamps (6), stowaway temperature data loggers with backup (4), software, base station, coupler, and shuttle.

Discharge

Discharge will be measured using the methods of Rantz et al. (1982). A meter tape will be suspended across the stream. Water velocity will be measured at multiple intervals across the stream using a Price AA velocity meter. The meter will be spin tested prior to use. A top-setting wading rod will be used to ensure velocity is measured at 0.6 depth. Staff gauges will be secured at each discharge sampling points and a rating curve developed to calculate discharge when direct measurements are not possible. Discharge will be measured or estimated from the rating curve on each sampling date.

Materials Required: Rite-in-the-Rain data book, pencils, Onset water level loggers, nylon rope, 2”pvc vented with caps, 100-meter tape, top-setting wading rod, velocity meter, and staff gauges.

Substratum/Embeddedness

Substratum size distribution will be determined through Wolman (Wolman 1954) pebble counts of 100 stones as modified by Bevenger and King (1995). Beginning at the downstream end of the sampling reach, the intermediate axis of rocks is measured at roughly one-meter intervals as the investigator moves upstream, continually moving at an angle from bank to bank. The rock axis will be determined using an aluminum measuring template. The portion of each rock submerged below the substrate will be estimated from differences in algae or other markings on the rock and recorded as percent embedded (Davis et al. 2001).

Materials Required: Rite-in-the-Rain data book, pencils, aluminum template, meter stick.

Morphometry

Stream cross-sections will be measured using a laser level and leveling rod. A meter tape will be secured across the stream channel. Elevations will be measured at 0.5 to 1.0 m intervals beginning and ending above bankfull flows. The location of bankfull flows, ordinary high water and undercut depth will be noted or measured.

Materials Required: Rite-in-the-Rain data book, pencils, 100-meter tape, laser level and tripod, leveling rod, meter stick.

Algae/Benthic Organic Matter

Algae will be sampled by scraping a known area of stone and collecting the dislodged material on to a Whatman GF/C filter with 0.45 µm pore site (Davis et al. 2001). The algal sample will be analyzed for chlorophyll-a and AFDM. Benthic organic matter will be collected in nested nets of different pore size held onto a Surber sampler frame. The sampler will be held on the stream bottom and the substrate from a known area upstream of the sampler will be disturbed, dislodging organic matter from the bottom, which will be carried into the nets by the current. The material from each net will be transferred into 500-ml nalgene bottles and preserved with alcohol. The AFDM of both the large and small size fractions will be determined through weight loss upon combustion at 500 C.

Materials Required. Surber sampler with nested nets, squirt bottle, whirl-pak bags, 500 ml poly bottles, alcohol, sharpies, pencils, labels.

Macroinvertebrates/Habitat Assessment

Macroinvertebrates will be collected, processed, and analyzed using the Standard operating procedures for the Alaska Stream Condition Index (ASCI) (Major and Barbour 2001). Composite invertebrate samples will be placed within pre-labeled 500-ml nalgene bottles. Paper labels will be placed into the bags with the sample and the sample preserved with 95% ethanol. Labels will include date, time, location, and investigators. Stream invertebrate collections will be returned to the ARRI laboratory, sorted, and identified to genus (except for Chironomidae, Simuliidae, and Oligochaeta). .

Materials Required: ASCI Habitat Assessment Data Sheets, nalgene bottles, 5-gallon bucket, ethanol, D-Nets, gauntlets, labels, pencils, sieve, and sharpies.

Juvenile Fish

Fish will be collected in 4 baited minnow traps soaked for 4 to 6-hours. Captured fish will be identified, measured to fork length, and observed for deformities, eroded fins, lesions or tumors (DELT anomalies) using the USGS NAWQA methodology (Moulton II et al. 2002).

Materials Required: Minnow traps, salmon roe, buckets (2), small net, plastic bags, collection permit, measuring device.

Quality Objectives and Criteria for Measurement of Data

The parameters in the following table will be measured at the indicated performance level. All parameters are critical to meeting project objectives. Criteria for Measurements of Data are the performance criteria: accuracy, precision, comparability, representativeness and completeness of the tests. These criteria must be met to ensure that the data are verifiable and that project quality objectives are met.

Table 6. Accuracy, precision, and completeness objectives for measurement parameters. HL stands for hydrolab.

Parameter	Method	Resolution/ Limit	Expected Range	Accuracy% *	Precision	Completeness
pH	Meter	0.01	6.5 to 8.5	95 to 105 @ 7.0	5%	95%
Turbidity (NTU)	Meter	0.1	1 to 6	75 to 125	20%	95%
Conductivity	Meter	0.1	100 to 200	95 to 105 @	5%	95%

Parameter	Method	Resolution/ Limit	Expected Range	Accuracy% *	Precision	Completeness
(µS/cm)				100µS/cm		
DO (mg/L)	Meter	0.01	8 to 16	95 to 105 @ 10mg/L	5%	95%
Alkalinity ($CaCO_3$ mg/L)	SM 2320	0.1	50 to 150	75 to 125	10%	95%
Nitrate-N (mg/L)	EPA 353.2	0.010	0.05 to 0.5	75 to 125	20%	95%
Ammonia-N (mg/L)	EPA 350.1	0.005 (0.01 HL)	0.01 to 0.05	75 to 125	20%	95%
Total-P (mg/L)	EPA 365.2	0.005	0.001 to 0.005	75 to 125	20%	95%
Dissolved-P (mg/L)	EPA 365.2	0.001	0.001 to 0.005	75 to 125	20%	95%
Chlorophyll-a (mg/m^2)	SM 1002G	0.03	1 to 50	75 to 125	20%	95%
Substratum (mm)	Counts	N/A	0.2 to 500	N/A	10%	95%
Macroinvertebrates	ASCI	N/A	N/A	N/A	20%	95%
Temperature (°C)	Stowaway	0.1	0 to 15	97 to 103 @ 15°C	5%	95%
Discharge	Measure	1	15 to 40	N/A	10%	95%

Quality Assurance Definitions

Accuracy

Accuracy is a measure of confidence that describes how close a measurement is to its "true" value. Methods to ensure accuracy of field measurements include instrument calibration and maintenance procedures.

$$Accuracy = \frac{MeasuredValue}{TrueValue} \times 100$$

Precision

Precision is the degree of agreement among repeated measurements of the same characteristic, or parameter, and gives information about the consistency of methods. Precision is expressed in terms of the relative percent difference between two measurements (A and B).

$$\Pr ecision = \frac{(A - B)}{((A + B)/2)} \times 100$$

Representativeness

Representativeness is the extent to which measurements actually represent the true condition. Measurements that represent the environmental conditions are related to sample frequency and location relative to spatial and temporal variability of the condition one wishes to describe.

Comparability

Comparability is the degree to which data can be compared directly to similar studies. Standardized sampling and analytical methods and units of reporting with comparable sensitivity will be used to ensure comparability.

Completeness

Completeness is the comparison between the amounts of usable data collected versus the amounts of data called for.

Quality Assurance for Measurement Parameters

Accuracy

The percent accuracy for the acceptance of data is shown for each parameter in Table 2. Accuracy will be determined for those measurements where actual values are known. For pH, conductivity, turbidity, and dissolved oxygen, measurements of commercially purchased standards within the range of expected values will be used. For dissolved oxygen, 100% saturated air will be used as a standard. Measurement accuracy will be determined for each sampling event. Contract laboratories will provide the results of accuracy measures along with chemical analytical reports. Accuracy for Stowaway temperature loggers has been calculated to be 0.40°C by the manufacturer, which at 15°C is 97% to 103%. Accuracy will not be determined where true values are unknown: substratum, macroinvertebrates, and discharge. However, for discharge, the velocity meter will be spin tested as per manufacturer's recommendation prior to each use. Accuracy of discharge rating curves will be determined by comparing measured value (as actual) with calculated value.

Precision

Table 2 shows the precision value for the acceptance of data. Precision will be determined for all chemical measures by processing a duplicate for every 8 samples. A discharge measure will be repeated at one site on one occasion to determine measurement precision. Precision of stowaway meters will be determined by placing all meters in one location for 24 hours. Precision for substratum size distribution will be determined by repeating the pebble count at one location and comparing the number of stones within each size class.

Representativeness

The monitoring design site locations, sampling frequency, and timing will ensure that the measurement parameters adequately describe and represent actual stream conditions for the sampling period. Chemical measures should represent two distinct periods within the single annual period, spring runoff and baseflow conditions. Single year data should not be interpreted to be representative of conditions over longer temporal scales. Repeated measures over multiple years are necessary to describe the variability among years.

Comparability and Completeness

The use of standard collection and analytical methods will allow for data comparisons with previous or future studies and data from other locations. We expect to collect all of the samples, ensure proper handling, and ensure that they arrive at the laboratory and that analyses are conducted. Our objective is to achieve 100% completeness for all measures. Sample collection will be repeated if problems arise such as equipment malfunction or lost samples. For spring runoff samples, due to laboratory turnaround time, repeating sample collection may need to occur the following year.

Data Management

Field data will be entered into rite-in-the-rain books. The Quality Assurance Officer will copy the field books and review the data to ensure that it is complete and check for any errors. Field and laboratory data sheets will be given to the project manager. The project manager will enter data into Excel spreadsheets. The Quality Assurance Officer will compare approximately 10% of the field and laboratory data sheets with the Excel files. If any errors are found they will be corrected and the Project Manager will check all of the field and laboratory data sheets with the Excel files. The Quality Assurance Officer will then verify correct entry by comparing another 10% of the sheets. This process will be repeated until all errors are eliminated. The Project Manager will then summarize and compare the data and submit it to a statistician for review or analyses. The Quality Control officer will review any statistical or other comparisons made. The Project Manager will write the final report, which will be proofed by the Quality Assurance Officer and at least three other peer reviewers. The Quality Assurance Officer will check the results in the report and associated statistical error (i.e. standard deviation and confidence interval) against those calculated with computer programs. Any errors found will be corrected by the Project Manager. Any errors will be corrected.

Water quality data will be provided to ADEC in a modernized STORET compatible format. Data will be formatted into STORET compatible files as described at the following ADEC web site.

https://www.state.ak.us/dec/water/wqsar/storetdocumentation.htm

Reporting Requirements

Sampling Event Reports

Following each sampling event ARRI will send a report to the ADEC Project Manager. The report will include: date, time, and location samples were collected, time samples delivered to laboratory, any collection problems or sampling recommendations, the results of field measures, and any laboratory results.

Draft Final Report

Prior to December 1, 2006, ARRI will submit a draft final report to the ADEC project manager. The report will describe the objectives of the project and the methods used to meet project objectives. Monitoring data will be summarized and evaluated for any trends and differences among sites. Data will be compared to previously published data for other similar stream systems. Potential causes of variability in the data will be discussed relative to any potential historic or current causes.

Final Report

Prior to December 31, 2006 ARRI will provide the ADEC project manager with the final report of first season data collection. The final report will be modified to incorporate any editorial, content, or formatting comments to the draft report as requested by the ADEC project manager.

Three unbound hard copies and 5 bound copies and electronic copies of the reports in Microsoft Word and as pdfs will be submitted to ADEC. Data will be provided in a STORET compatible format. Project photographs will be submitted as CD-stored JPEGs.

Citations

Allan, J.D., M.S. Wipfli, J.P. Caouette, A. Prussian, and J. Rodgers. 2003. Influence of streamside vegetation on inputs of terrestrial invertebrates to salmonid food webs. Canadian Journal of Fisheries and Aquatic Sciences. 60: 309-320.

Bevenger, G. S., and R. M. King. 1995. A pebble count procedure for assessing watershed cumulative effects. USDA Forest Service. Rockey Mountain Forest and Range Experiment Station. Fort Collins, CO. Research Paper RM-RP-319.

Buffington, J.M., and D.R. Montgomery. 1999. Effects of hydraulic roughness on surface textures of gravel-bed rivers. Water Resources Research. 35: 3507-3521.

Davis, J.C., G.W. Minshall, C.T. Robinson, and P. Landres. 2001. Monitoring wilderness stream ecosystems. Gen. Tech. Rep. RMRS-GTR-70. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 137p.

Estep, M.A., and R.L. Beschta. 1985. Transport of bedload sediment and channel morphology of a southeast Alaska stream. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Research Note PNW-430. 15pp.

Johnson, S.L. 2004. Factors influencing stream temperatures in small streams: substrate effects and a shading experiment. *Can. J. Fish. Aquat. Sci.* 61: 913-923.

Major, E.B., and M.T. Barbour. 2001. Standard operating procedures for the Alaska Stream Condition Index: A modification of the U.S. EPA rapid bioassessment protocols, 5th edition. Prepared for the Alaska Department of Environmental Conservation, Anchorage, Alaska.

Martin, D.J. 1995. A preliminary assessment of fish habitat and channel conditions for streams on forested lands of southeast Alaska. Project 44-006 final report written by Pentec Environmental, Inc., Edmonds, Washington. Written for Sealaska Corporation, Juneau, Alaska and the Alaska Forest Association, Ketchikan, Alaska. 88pp

McDonald, L. H., A. W. Smart, and R. C. Wissmar. 1991. Monitoring guidelines to evaluate the effects of forestry activities on streams in the Pacific Northwest and Alaska. U.S. EPA Region 10. EPA/910/9-91-001.

Moulton II, S.R., J.G. Kennen, R. M. Goldstein, and J.A. Hambrook. 2002. Revised protocols for sampling algal, invertebrate, and fish communities as part of the National Water-Quality Assessment Program**.** USGS Open-File Report 02-150.

Murphy, M.L., and A.M. Milner. 1997. Alaska timber harvest and fish habitat. Freshwaters of Alaska. Ecological Syntheses, Springer, New York. Ecological Studies 119: 229-263.

Plafkin, J. L., M. T. Barbour, K. D. Porter, S. K. Gross, and R. M. Hughes. 1989. Rapid Bioassessment Protocols for use in streams and rivers: benthic macroinvertebrates and fish. U.S. Environmental Protection Agency, Washington D.C. EPA-444/4-89-001.

Poole, G.C. and C.H. Berman. 2001. An ecological perspective on in-stream temperature: Natural heat dynamics and mechanisms of human-caused thermal degradation. *Environ. Manage.* 27, 6: 787-802.

Rantz, S. E., and others. 1982. Measurement and computation of streamflow--Volume 1. Measurement of stage and discharge. U.S. Geological Survey Water-Supply Paper 2175, 284p.

Rosgen, D. L. 1994. A classification of natural rivers. Catena 22:169-199.

Wolman, M.G. 1954. A method of sampling coarse river bed material. Transactions of the American Geophysical Union 35:951-956.

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Appendix B—Project Photographs

Photograph 1. Setting up for discharge measurement at WK2 September 2006.

Photograph 2. Hydrolab and pressure transducer at WK2 September 2006.

Photograph 3. WK2, September 2006.

Photograph 4. WK2, September 2006

Photograph 5. Downstream end of WK2 in July of 2006.

Photograph 6. Upstream end of WK1, July 2006.

Photograph 7. WK1, July 2006.

Photograph 8. WK1, July 2006.

Photograph 9. Downstream end of WK1, July 2006.

Photograph 10. Downstream end of WK1, 2006.

Photograph 11. WK1, July 2006.

Photograph 12. WK4, July 12, 2006.

Photograph 13. Aerial view of WK3, August 2006.

Photograph 14. Aerial view of WK4, August 2006.

Photograph 15. Taking discharge measure at WK3 on August 30, 2006.

Photograph 16. WK3 August 30, 2006 following high flows event.

Photograph 17. Downstream end of WK3 in July 12, 2006.