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

July 2006 through May 2008 Summary

Prepared for the

ALASKA Department of Environmental Conservation

By

ARRI
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Introduction

Monitoring the effectiveness of forest harvest regulations in the Matanuska-Susitna Borough is necessary due to recent changes to the regulations and increase harvest activity. State support was provided through the Alaska Departments of Environmental Conservation and Natural Resources 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. The FRPA regulations require the evaluation of the implementation and effectiveness of the act and regulations at achieving desired objectives (11 AAC 95.830). Recent modifications to the FRPA and accompanying regulations for Region II have defined how harvest activities are to be conducted adjacent to water bodies in order to protect both 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.

The management intent for riparian areas through the FRPA is the protection from the adverse effects of timber harvest on fish habitat and water quality. Preservation of fish habitat is accomplished through the maintenance of “short- and long-term sources of large woody debris, streambank stability, channel morphology, water temperatures, stream flows, water quality, adequate nutrient cycling, food sources, clean spawning gravels, and sunlight” (AS 41.17.115). Therefore, the effectiveness monitoring and sampling plan was developed to evaluate these stream and riparian characteristics.

The Aquatic Restoration and Research Institute (ARRI) has developed a sampling plan to monitor the effectiveness of the FRPA under the 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 Quality Assurance Project and Sampling Plans (Appendix B) describes the project objectives, statistical approach, sampling locations, frequency, sample parameters, and field methods. In addition, the Quality Assurance Project Plan (QAPP) provides additional detail on data collection, handling, analyses, and evaluation.

The monitoring approach is comparing stream characteristics prior to and following the initiation of forest harvest. Pre-harvest data will serve as a control against which conditions following harvest will be compared. Only minor timber harvest activities, approximately 20 years ago, have occurred within the Willer-Kash harvest area. This report describes reference physical, chemical, and biological conditions for four streams within the Willer-Kash harvest area. Data collection was initiated in July of 2006 and continued through 2007 and into the spring of 2008.

Methods

Study Area and Sampling Locations

Reference stream physical, chemical and biological characteristics were collected from four sampling reaches located on four streams within the Willer-Kash State Harvest Area from July 2006 through June 2008. 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.

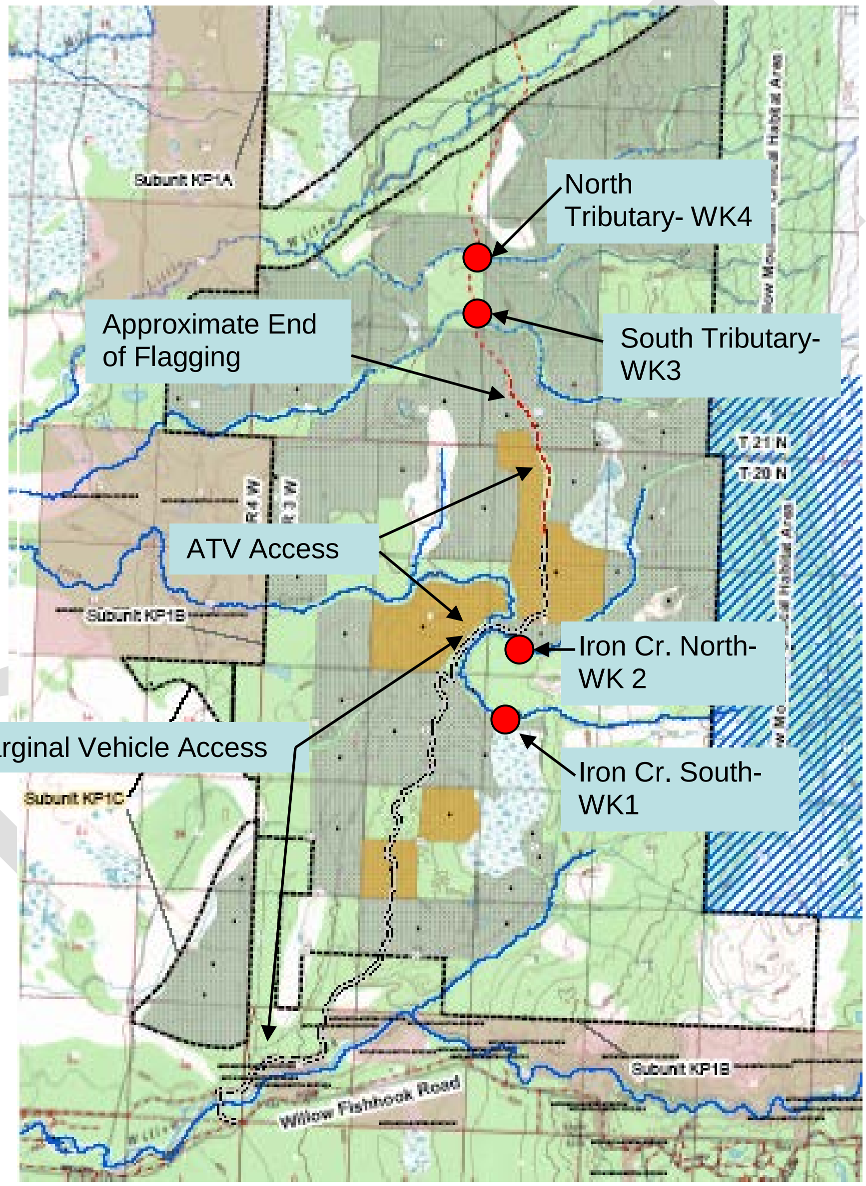

Figure 1. Map showing the access and location of sampling sites. Shaded areas represent proposed timber harvest areas.

Stream sampling locations were selected on four streams based upon similar size and physical characteristics. The stream sampling locations were named from south to north, WK1 through WK4. The four streams are classified as Type IIC (stable streams and glacial water less than 50 feet wide) under the FRPA (AS 41.15.950(37)(B)).

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) (Anadromous Stream No. 247-41-10200-2130-3050) 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 WK4 were accessed by helicopter.

Physical Characteristics

Stream physical characteristics were measured in 2006 and 2007. 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. In 2006, water pressure gauges (Hobo U20 water level loggers (Onset Corporation)) were placed within sand-point well tips driven into the streambed and secured to the bank with plastic coated cable to record water temperature and pressure hourly. In 2007, the temperature and water level loggers were placed within perforated PVC pipe secured to rebar which was driven into the streambed. Water pressure data for both years was corrected by subtracting out atmospheric pressure data recorded at the Talkeetna Airport and obtained from the National Oceanic and Atmospheric Administration web site (www.ncdc.noaa.gov/oa/ncdc.html).

Substrate size distribution was obtained through Wolman pebble counts of 100 stones as modified by Bevenger and King (1995). The 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 ten 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 multiple dates in 2006, 2007, and spring of 2008. Analytical and quality assurance methods are described in the QAPP (Appendix B). 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 sulfuric acid and shipped by Federal Express to AM Test, Inc. in Redmond, Washington for total phosphorus, total dissolved phosphorus, alkalinity, dissolved organic carbon, nitrate and nitrite nitrogen and ammonia nitrogen analyses.

Biotic Characteristics

In 2006, macroinvertebrates and juvenile fish were sampled at all sites on July 12 and 13, and 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).

Fish sampling was conducted at WK1 and WK2 on June 18 and June 19, 2007, and at all sites on September 24 and 25, 2007. In June, fish were sampled using nine baited minnow traps. Traps were placed in each stream extending over approximately 100-m. The traps were removed after 1 hour, all captured fish were identified and measured and then returned to the trap and the trap was returned to the stream. The traps were left in place for an additional 23 hours, upon which all fish were removed, identified, measured, and released. In September, six baited minnow traps were fished for 24 hours.

Fish trapping was repeated at site WK1 and WK2 in the spring of 2008 using 12-baited minnow traps fished for 24 hours. Wet mass of captured fish also was determined in 2008.

Benthic organic matter and periphytic algae were collected on September 18, 2006 at sites WK1 and WK2 and at all sites on August 18, 2007. Benthic organic matter (BOM) was sampled by dislodging material from the streambed 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 concomitantly with BOM. The periphyton enclosed within the diameter of 60-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 phaeophytin through acidification.

Results

Physical Characteristics

Steam channel and substrate characteristics are shown in Table 1. Channel widths among these streams range from 3 to near 5 meters. There were small changes in channel width between years at most sites; however, a 1-m decrease in channel width was measured at WK3 with a corresponding decrease in width/depth ratio. At WK4 we measured a decrease in channel area and average depth and an increase in width/depth ratio. There also were minor differences in the channel substrate size with a loss of the smaller particles at sites WK1 and WK2 (increase in D20). At WK2, there was a decrease in the portion of stones embedded over 30 percent. The amount of fine material less than 2 mm remained consistent between years at all sites. The differences in channel and substrate characteristics did not change significantly between 2006 and 2007 (t-test $p > 0.05$).

Measures of channel large woody debris and riparian coarse wood are shown in Table 2. The number of pieces of woody debris within the channel was calculated as the sum of pieces and 3 times the number of dams (a dam is 3 or more pieces of woody debris). Large woody debris density and the large woody debris index increased from 2006 to

2007 at all sites except for wood density at WK1. The differences in the woody debris index were statistically significant (t-test $p>0.05$).

Table 1. Stream channel and substrate characteristics for the 4 sampling locations in 2006 and 2007.

	WK1		**WK2**		**WK3**		**WK4**	
	2006	**2007**	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**
Channel Width (m)	4.8	4.5	3.7	3.7	4.4	3.1	4.8	4.4
Area (m^2)	1.46	1.24	1.01	0.74	0.96	0.86	1.29	0.57
Mean depth (m)	0.31	0.28	0.26	0.19	0.23	0.28	0.27	0.13
Width to Depth ratio	17	18	16	22	22	11	17.9	34.7
Minimum Bank Height (m)	0.12	0.22	0.12	0.19	0.46	0.37	0.22	0.82
Maximum Bank Height (m)	1.17	0.73	1.1	1.15	0.85	1.61	1.27	1.35
Bank Undercut (m)	0.15	0.28	0.22	0.20	0.27	0.40	0.10	0.35
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	16	8	22.6	18	16	20	16
D50 (mm)	32	32	30	50	33	38	50	60
D70 (mm)	50	50	60	64	55	55	70	70
Embedded >30%	32%	23%	40%	19%	22%	12%	14%	18%
Percent finer than 2 mm	14%	14%	9%	8%	9%	11%	12%	15%

Table 2. Measures of stream channel and riparian coarse wood at all sampling sites in 2006 and 2007.

	WK1		**WK2**		**WK3**		**WK4**	
Large Woody Debris	**2006**	**2007**	**2006**		**2006**	**2007**	**2006**	**2007**
Pieces	16	9	13	12	8	7	10	15
Debris Dams	6	8	1	5	2	2	2	1
LWDI	810	902	320	479	299	332	276	398
Pieces/m^2	0.07	0.07	0.04	0.07	0.03	0.04	0.03	0.04
Riparian Coarse Wood								
Spruce	11	30	11	22	23	18	11	5
Birch	18	12	8	2	8	4	35	30
Alder	0	5	4	12	2	12	11	3
Total	29	47	23	36	33	34	57	38
Pieces/m^2	0.015	0.024	0.012	0.018	0.017	0.017	0.029	0.019

The amount of riparian coarse wood pieces within 200 m^2 area of the riparian area ranged from 23 to 57 pieces among all sites. Riparian coarse wood was dominated by spruce at sites WK1 through WK3 and by birch at WK4. There was not a statistically significant difference in the amount of coarse wood between 2006 and 2007.

Stream discharge data for May 29 through September 24, 2007 are shown in Figures 2 through 5. Due to the loss of data from wildlife and floods, we do not report the 2006 data. Peak flows during 2006 and 2007 occurred during fall storms in September. Stream flows were higher and more variable at WK1 and WK4 (Table 3). Average flows from May through September were 8.7 and 12.0 cfs for WK1 and WK4, respectively. Peak flows in these two streams were greater than 40 cfs. The standard deviation of the logarithms of flows was greater at these two sites compared to WK2 and WK3.

Table 3. Streamflow (cfs) statistics for the four sites for data collected from June through September, 2007. The average is the average of daily values, Q95 is the flow that 95% of the values exceeded, Q50 is the flow that 50% of the values exceeded, and Q5 is the flow that 5% of the values exceeded. SD is the standard deviation of the logarithms of streamflows.

	Average	Q_{95}	Q_{50}	Q_{5}	SD
WK1	8.65	2.2	6.3	24.0	0.32
WK2	5.80	4.0	4.5	12	0.15
WK3	5.26	4.5	5.5	11	0.12
WK4	12.08	4.5	10.0	26.0	0.23

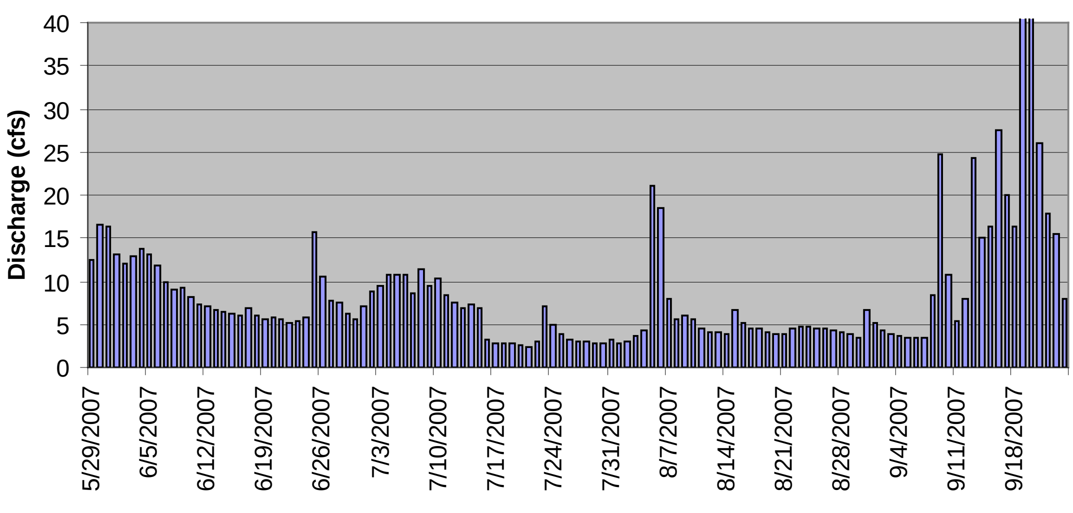

Figure 2. WK1 discharge.

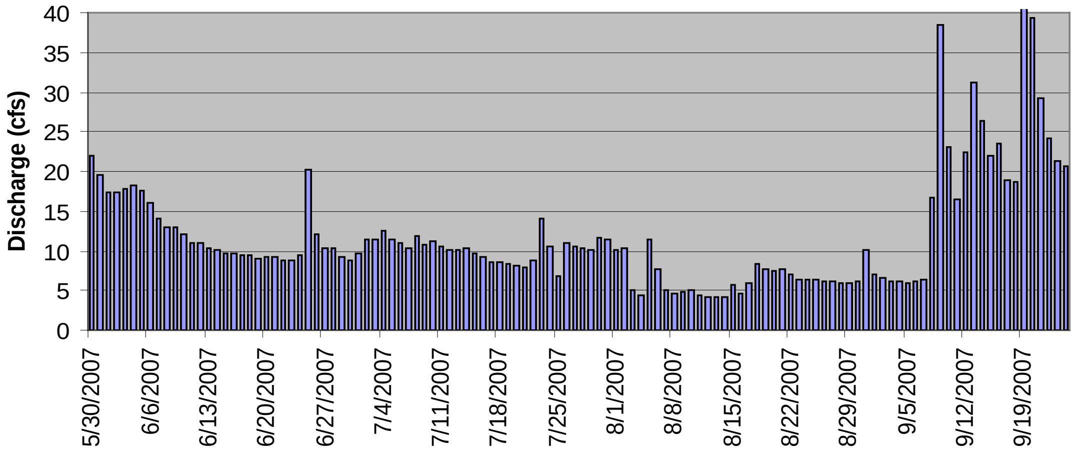

Figure 3. WK4 discharge.

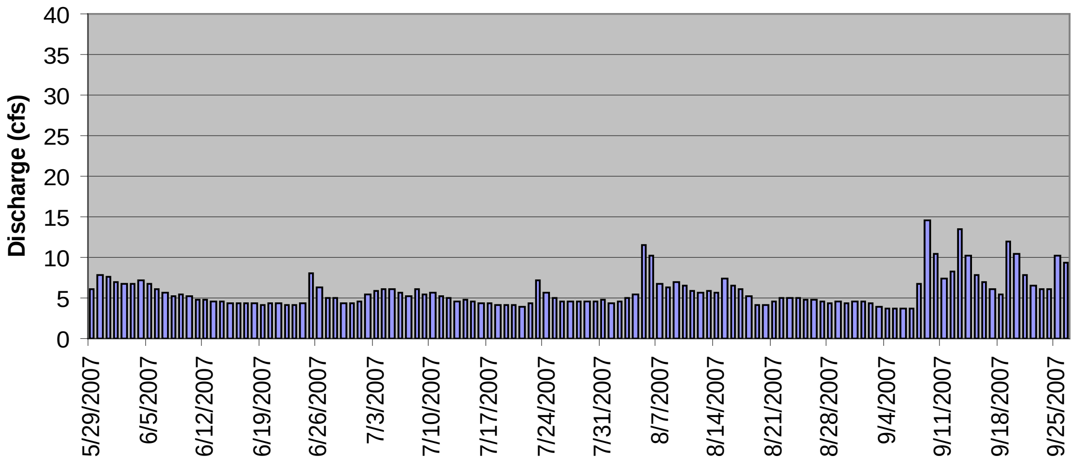

Figure 4. WK2 discharge.

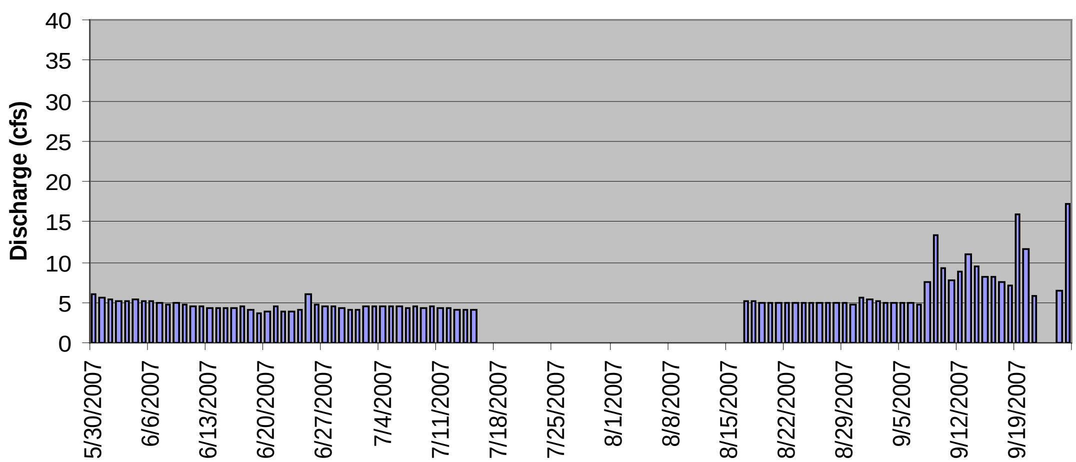

Figure 5. WK3 discharge.

The amount of photosynthetically active radiation reaching the stream surface during the growing season is shown in Figure 6. On average, 40 to 60% of light available for photosynthesis penetrated the riparian canopy.

Stream water temperature data is consistent with the small shaded stream channels. There was only a weak correlation between air and water temperature with regression r^2 values ranging from 0.55 to 0.64 (Table 1). Based upon these regression equations, stream water temperatures increased from 0.3 to 0.4°C for every 1°C increase in air temperatures. Maximum stream water temperatures at all sites occurred during late June (Figures 7 through 10).

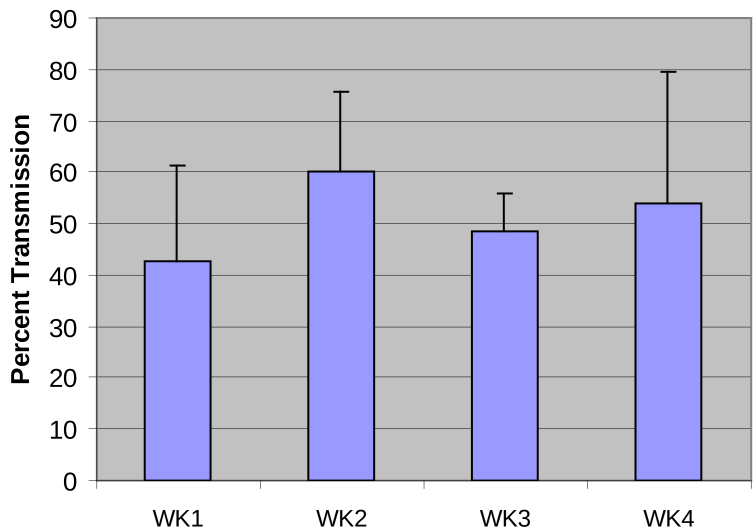

Figure 6. Average (error bars are one standard deviation) percent of PAR reaching the stream surface relative to open areas during the 2006 and 2007 growing seasons.

Table 4. Statistics for 2007 stream water temperature data for all sampling locations.

	WK1	WK2	WK3	WK4
Season Maximum	15.57	12.40	12.79	13.56
Maximum Daily Range	5.12	5.60	5.60	5.89
Total Days	117	117	116	117
Days Max Temp >13°C	12	0	0	2
Days Max Temp >15°C	2	0	0	0
Days Max Temp >20°C	0	0	0	0
June Cumulative Degree Days	288	217	236	244
July Cumulative Degree Days	324	247	118*	282
August Cumulative Degree Days	329	252	125*	290
September Cumulative Degree Days	192	152	174	182
Regression Coefficient	0.37	0.25	0.29	0.31
Regression r^2	0.62	0.55	0.64	0.60

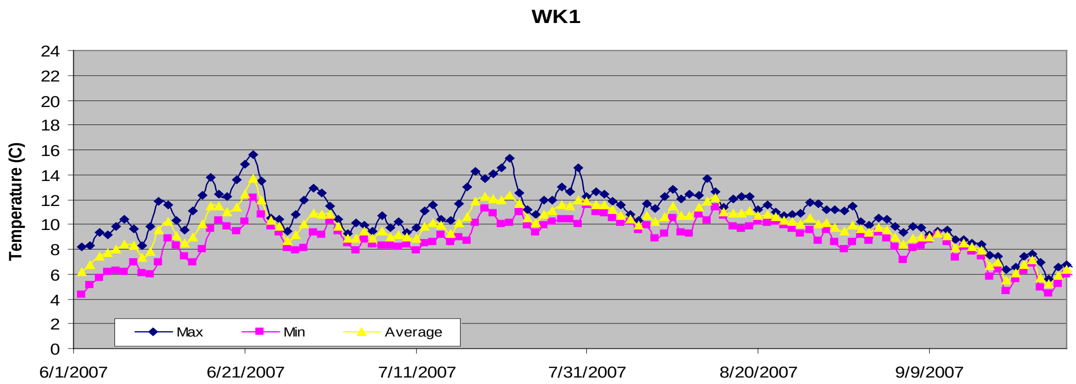

Figure 7. Daily stream water temperature statistics for site WK1.

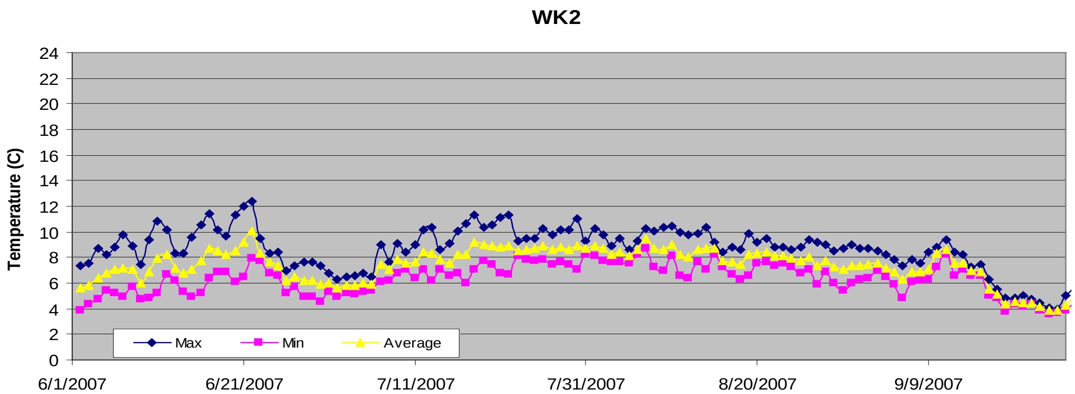

Figure 8. Daily stream water temperature statistics for WK2.

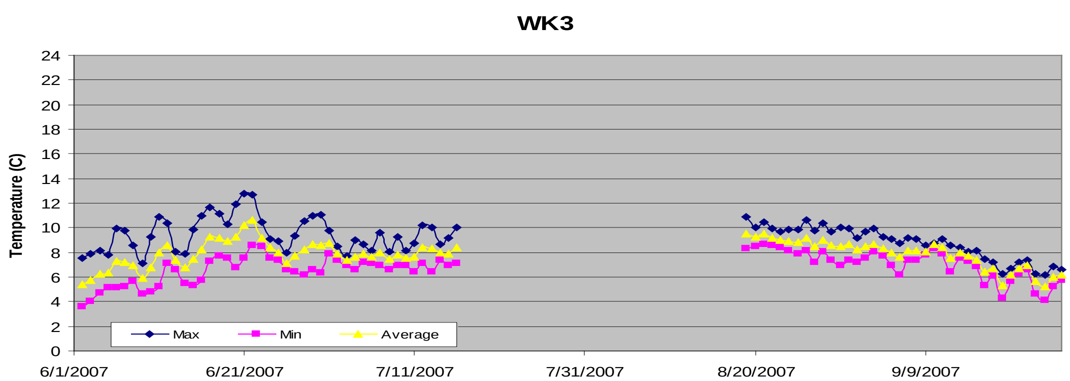

Figure 9. Daily stream water temperature statistics for site WK3.

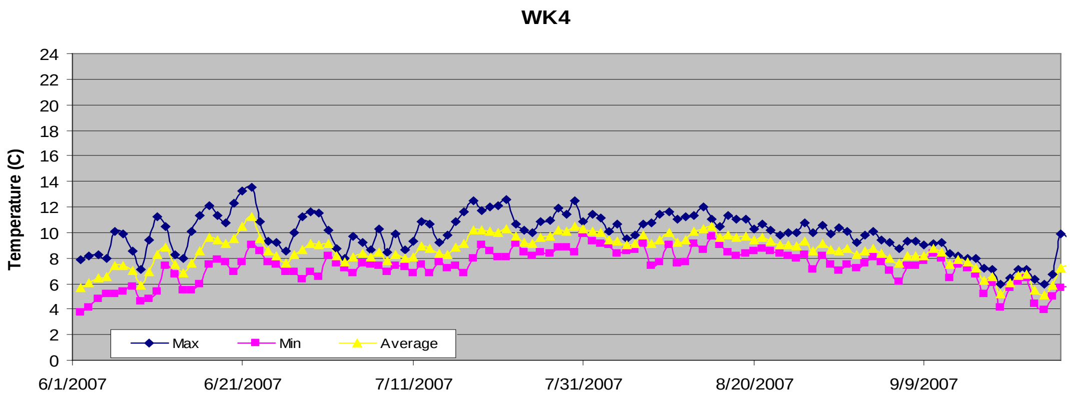

Figure 10. Stream water temperature statistics for WK4.

Chemical Characteristics

The results of stream water nutrient analyses are shown in Figures 7 through 11. Water chemical data are reported as seasonal averages combining 2006 and 2007 data. Average ammonia nitrogen concentrations were below 0.08 mg/L at all sites. There were little difference in concentrations among seasons within sites WK1 and WK2. Summer concentrations of ammonia nitrogen were much greater at WK3 and WK4 relative to spring samples. There were only small seasonal differences in average nitrate+nitrite nitrogen concentrations; however, values were higher in the smaller streams (WK2 and WK3). Average nitrate+nitrite nitrogen concentrations were below 0.07 mg/L in WK1 and WK4 and below 0.23 mg/L in WK2 and WK3.

Average seasonal total phosphorus concentrations were below 0.045 mg/L at all sites, but higher in the spring and fall. During the spring, total concentrations of phosphorus were dominated by the dissolved fraction with ratios of total to total dissolved phosphorus near 1. During the fall, ratios of total to total dissolved phosphorus were near 3, indicating a relative decrease in the dissolved fraction.

During the spring, ratios of total inorganic nitrogen (ammonia+nitrate+nitrite) to total phosphorus or total dissolved phosphorus were below 16 suggesting nitrogen limitation. Nutrient limitation switched to phosphorus during the summer at sites WK2 and WK3 using total phosphorus concentrations and at sites WK2 through WK4 using total dissolved phosphorus concentrations. Using total phosphorus concentrations, nitrogen became limiting again in the fall at all of the sites except WK2. However, phosphorus remained limiting at all of the sites except WK1 when only dissolved phosphorus was used in calculating nitrogen to phosphorus ratios.

Nutrient flux for each site was derived from the product of nutrient concentration and discharge. Average nutrient flux for each site and all sampling dates is shown in Figure 15. The flux of nitrogen and nitrate+nitrite was higher and more variable at all sites compared to fluxes of ammonia nitrogen or phosphorus. Nutrient flux for future comparisons for most constituents was from 1 to 2 kg/day. The average flux of nitrate+nitrite nitrogen ranged from 3 to 5.5 kg/day.

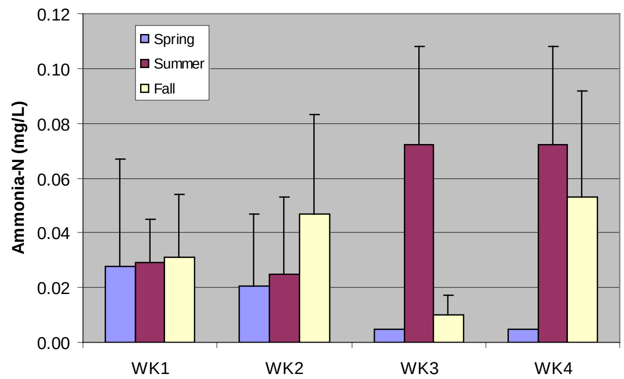

Figure 11. Seasonal ammonia nitrogen concentrations for the 4 sampling locations.

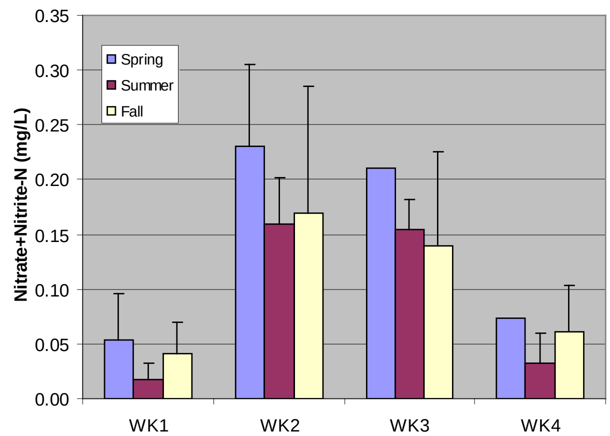

Figure 12. Seasonal nitrate + nitrite nitrogen concentrations (error bars are one standard deviation).

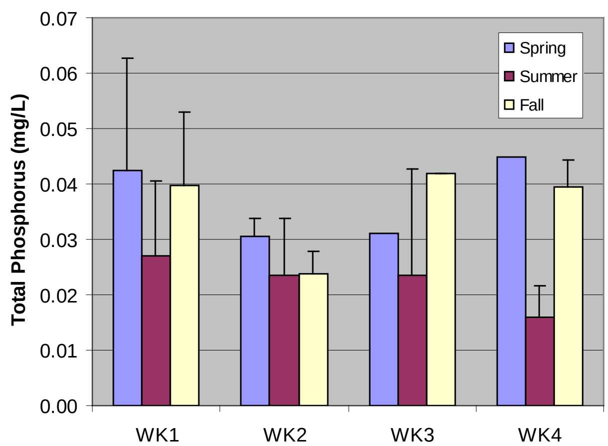

Figure 13. Seasonal average total phosphorus concentrations (error bars are one standard deviation).

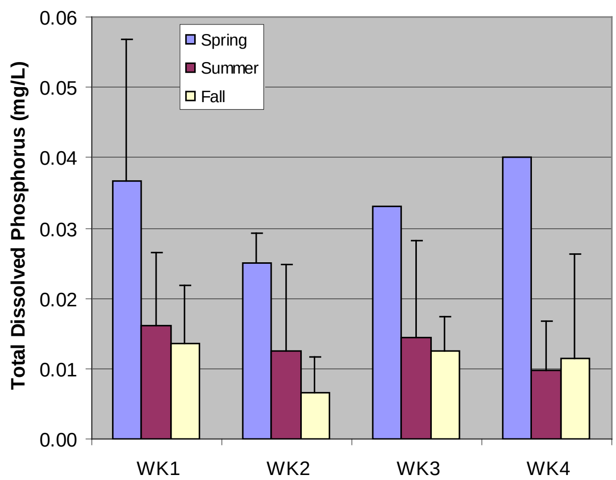

Figure 14. Seasonal average total dissolved phosphorus concentrations (error bars are one standard deviation.)

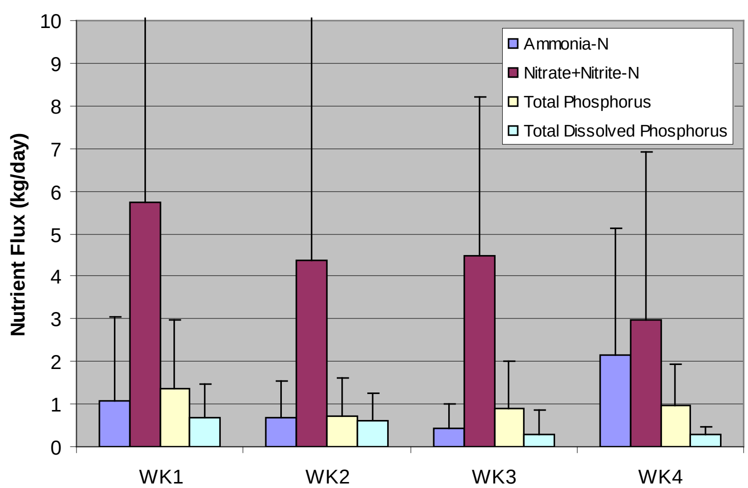

Figure 15. Average nutrient flux from combined 2006 and 2007 data for each sampling station (error bars are one standard deviation).

There were seasonal differences in pH, specific conductivity, and turbidity (Figures 16 through 18). Stream water pH was near neutral at all sites during the spring and summer; however, pH declined in the fall following precipitation events. Average specific conductivity was below 51 μS/cm. All four sampling streams were clear with low turbidity (1-2 NTU) on most sampling dates. Turbidity increases up to 5 NTU were recorded at WK3 and WK4 in the fall following storms and increases in stream flow.

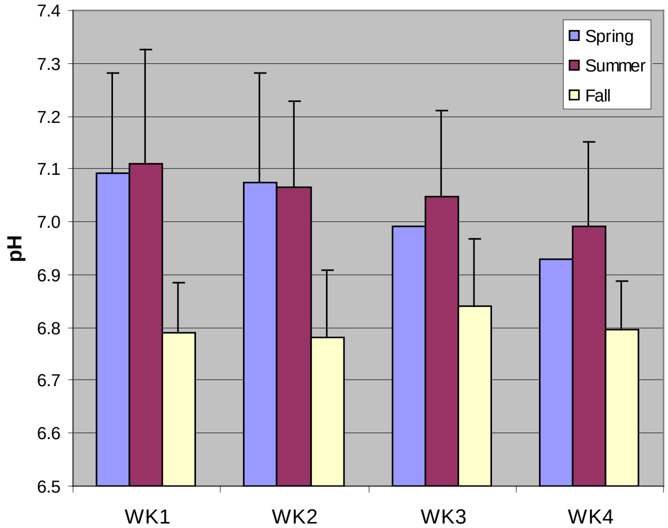

Figure 16. Average seasonal pH for the four sampling sites (error bars are one standard deviation).

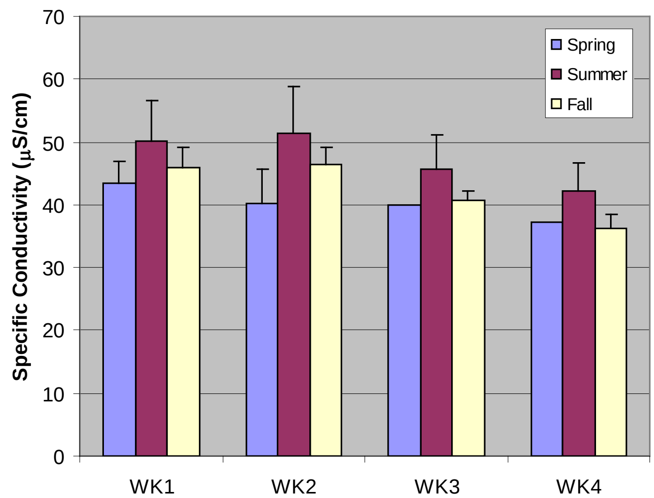

Figure 17. Average seasonal specific conductivity showing slight summer increase (error bars are one standard deviation).

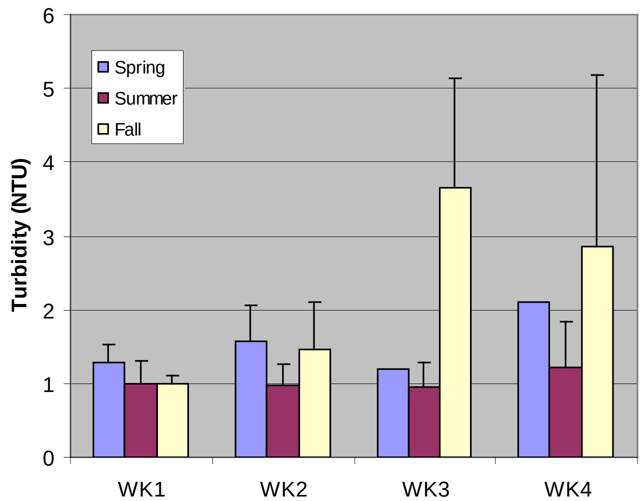

Figure 18. Reference turbidity values by season for the four sampling sites (error bars are one standard deviation).

Biotic Characteristics

Average 2007 concentrations of algal chlorophyll-*a* ranged from 3 to 9 mg/m^2 among the four sampling sites (Figure 19). These values are comparable with 2006 measures at sites WK1 and WK2 that ranged from 3 to 6 mg/m^2. Differences in average chlorophyll-a between 2006 and 2007 were not consistent, increasing at WK1 and decreasing at WK2.

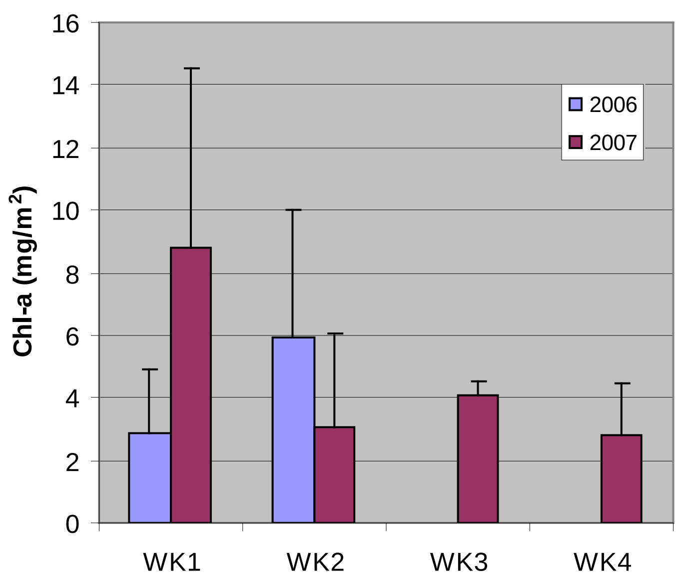

Figure 19. Average (standard deviation) periphyton chlorophyll-a concentrations in 2006 and 2007.

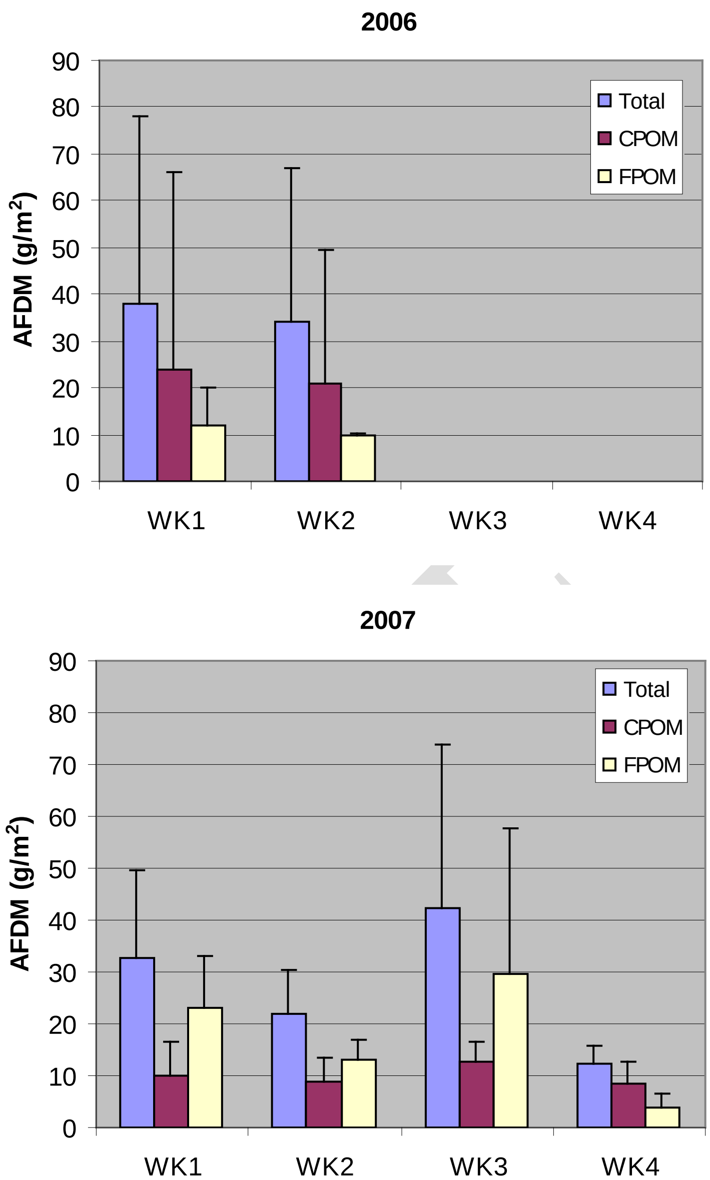

Figure 20. Concentrations of benthic organic matter as total, coarse (CPOM) and fine (FPOM) fractions in 2006 (above) and 2007.

Total benthic organic matter and the organic matter in coarse and fine fractions are shown in Figure 20 for 2006 (WK1 and WK2) and 2007. Total organic matter ranged from 33 to 38 g/m^2 in 2006 and from 12 to 41 g/m^2 in 2007. Comparisons between 2006 and 2007 data show a decrease in coarse matter and a slight increase in fines.

Table 5 presents the results of macroinvertebrate data analyses for the two sampling years. The results are fairly consistent among years with only minor changes in the ASCI scores and no differences in ASCI rankings. ASCI scores increased at WK2 but decreased at the remaining sites. The highest ASCI scores were at site WK1 in both years. Higher scores in WK1 were due to the greater percentages of non-baetid Ephemeroptera and Plecoptera.

Table 5. Numbers, relative abundance and ASCI metrics for the macroinvertebrate community at the four sampling sites in 2006 and 2007.

	WK1		**WK2**		**WK3**		**WK4**	
Community Metrics	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**
Ephemeroptera	86	133	159	142	65	228	85	165
Plecoptera	19	50	8	15	37	24	34	18
Trichoptera	12	10	18	8	54	14	21	16
Diptera	63	65	45	73	45	44	66	53
Richness	12	15	13	14	12	14	12	14
Ephemeroptera Taxa	4	5	3	4	4	3	4	3
Trichoptera Taxa	3	3	4	2	3	4	3	3
% Plectopera	10.5	19.2	3.4	6.3	17.4	7.7	16.2	7.1
% Ephemptera (no Baetidae)	14.9	16.5	6.0	6.3	7.5	6.8	8.1	10.3
% Diptera	34.8	24.9	19.3	30.4	21.1	14.1	31.4	21.0
Baetidae/Ephemeroptera	0.7	0.7	0.9	0.9	0.8	0.9	0.8	0.8
% Non-insects	0.6	1.1	1.3	0.8	5.6	0.3	1.9	0.0
HBI	4.2	3.7	4.0	4.2	3.5	3.7	4.0	3.7
%Scrapers	12.7	0.4	3.9	2.1	4.2	0.3	7.6	3.6
% Collectors	58.6	60.9	74.7	77.5	31.9	76.8	59.0	57.9
% EPT no Baetids or Zapada	23.8	24.9	15.0	13.3	33.8	15.1	20.0	18.3
ASCI Metrics								
Ephemeroptera taxa 100 * X / 5.5	72.7	90.9	54.5	72.7	72.7	54.5	72.7	54.5
% Ephemeroptera (no Baetidae) 100 * X / 20	74.6	82.4	30.0	31.3	37.6	33.8	40.5	51.6
% Plecoptera 100 * X / 14	75.0	100	24.5	44.6	100	55.1	100	51.0
Baetidae / Ephemeroptera 100 * (100 - X) / 100	31.4	32.3	8.8	10.6	24.6	9.2	20.0	15.8
% non-insects 100 * (30 - X) / 30	98.2	96.2	95.7	97.2	81.2	98.9	93.7	100
O/E (family 75%) 2 100 * X	80.0	90.0	90.0	80.0	80.0	90.0	80.0	70.0
% scrapers 100 * X / 15	84.7	2.6	25.8	13.9	28.2	2.1	50.8	23.8
HBI 100 * (6.5 - X) / 2	100	100	100	100	100	100	100	100
Average	**77.1**	**74.3**	**53.7**	**56.3**	**65.5**	**55.5**	**69.7**	**58.3**
Ranking	**Exel**	**Exel**	**Good**	**Good**	**Good**	**Good**	**Good**	**Good**

Four species of salmonids were captured within the four sampling sites; coho and Chinook salmon, Dolly Varden char, and rainbow trout (Table 6). The September 2007 data can be used for comparisons among sites. Total salmonid capture rates ranged from 4.3 to 16 fish/trap. Coho salmon dominated the catch at all sites except WK2 where catch rates of coho and Chinook salmon were similar. All four species of salmonids were captured at WK4, whereas only 2 or 3 of the different salmonids were captured at the remaining sites. Chinook salmon were found at all sites except for WK3 in September of 2007.

Fish capture data from WK1 and WK2 can be used to evaluate differences among sampling dates. On June 18, 2007, catches were dominated by juvenile coho salmon followed by rainbow trout and Dolly Varden char. Coho salmon were composed of two age classes based on the frequency distribution of fork lengths (Figure 21). Chinook salmon, which were absent in June samples, were abundant in September and exceeded catch rates of coho in WK2. In September, only one age class of coho salmon was present. The catch rates were considerably lower on May 16, 2008. In WK1 the catch rate of rainbow trout was similar to the previous sampling dates and greater than the catch rate of other fish. The catch rate of coho salmon was below 1 fish/trap. In WK2, the catch rate of Chinook salmon was greater than the catch rate of coho. Young-of-the-year coho and Chinook salmon were not present on May 16.

Table 6. Average catch/trap by species of fish for each sampling site on three separate sampling dates.

June 2007	Coho	Chinook	Rainbow	Dolly Varden	Total
WK1	5.78	0.00	0.56	0.33	6.67
WK2	5.44	0.00	1.22	0.22	6.89
WK3	N/A	N/A	N/A	N/A	N/A
WK4	N/A	N/A	N/A	N/A	N/A
Sept 2007					
WK1	9.00	2.83	0.33	0.00	12.17
WK2	3.00	3.67	0.00	1.00	4.33
WK3	16.00	0.00	0.17	0.00	16.17
WK4	4.40	1.80	2.00	1.25	6.67
May 2008					
WK1	0.17	0.08	0.58	0.17	1.00
WK2	0.18	0.55	0.45	0.00	1.18
WK3	N/A	N/A	N/A	N/A	N/A
WK4	N/A	N/A	N/A	N/A	N/A

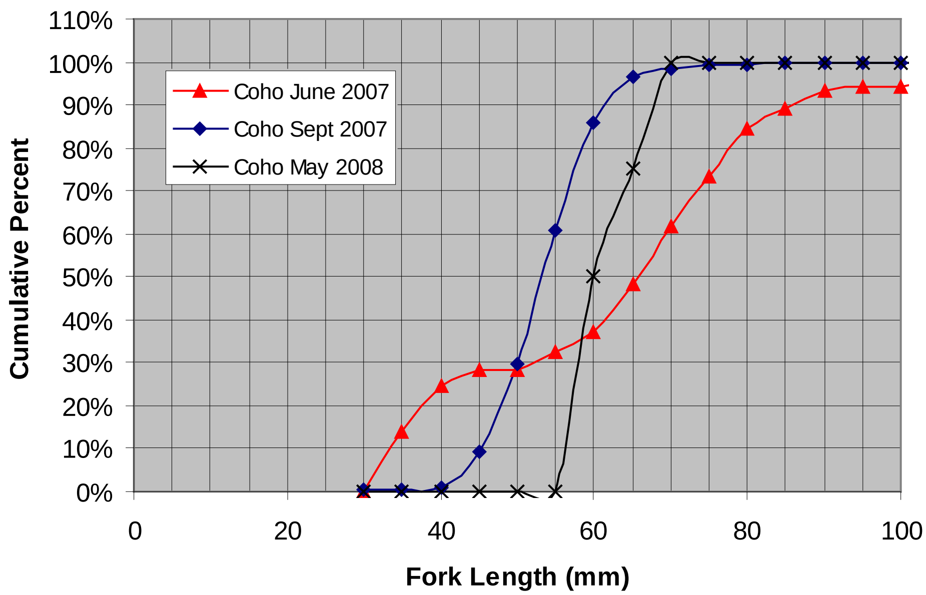

Figure 21. Frequency distribution of coho salmon fork lengths for three sampling dates.

Discussion

The variability in physical, chemical, and biological data among streams can make the evaluation of impacts due to human activities difficult to identify. The four streams described here have the same classification under the FRPA; however, there was considerable variation in stream characteristics. Large woody debris pieces doubled among sites from 8 to 16 pieces per 100-m of stream length and large woody debris index scores doubled from 400 to 800. Average measures of channel width to depth ratio ranged from 11 to 30 and median substrate size from 32 mm to 60 mm. Peak flows and flow variability was much greater at WK1 and WK4. Nitrate+nitrite nitrogen concentrations were 3 fold higher in WK2 and WK3 compared to the other two sites, while average summer ammonia nitrogen concentrations were 3 times higher in WK3 and WK4. Potential nutrient limitation also varied among sites. The biotic community also was different with higher ASCI scores at WK1 and differences in species presence and catch rate among sites. Evaluation of the change in characteristics following potential impacts within a stream can eliminate much of this variability. However, characteristics within a stream also vary over time, and further evaluation of temporal variability is necessary to select the appropriate indices for evaluating impacts.

Stream physical characteristics should not vary more frequently than year to year; therefore, the time of year measurements are collected should not influence results. We measured variability within sites in many of the channel physical characteristics between 2006 and 2007, including channel width, width to depth ratios, and particle size distribution. There was a flood of 50 to 100 year occurrence interval between the 2006 and 2007 sampling (Conway and Meyer 2006), which may account for some of the changes in physical characteristics. Evaluation of changes in stream condition due to forest harvest practices will be based upon the paired or repeated measures statistical approach. Therefore in order for differences to be statistically significant, the treatment effect must be similar among sites. For example, following timber harvest, all sites would need to show an increase in channel width or width depth ratios for differences likely to be statistically significant. However, these types of unidirectional changes were not observed following a large flood event. Among the stream physical characteristics, the large woody debris index was the only parameter that increased significantly from 2006 to 2007. This change is consistent with the input and transportation of woody debris due to a flood.

The seasonal evaluation of stream water nutrient concentrations reduced some of the variability. Concentrations of ammonia and total dissolved phosphorus, in particular were highly variable through the year. In the future, sampling to evaluate potential impacts should be stratified by season. There was also a large seasonal variability in pH and, to a lesser extent, turbidity, and future comparisons of these parameters must account for the effects of season and stream flow.

There was some within site variability in algal abundance as indicated by chlorophyll-*a* concentrations; however, differences from 2006 to 2007 were not unidirectional and these measure still provide a baseline against which future impacts can be evaluated. Similarly, concentrations of benthic organic matter varied among years. The sampling plan called for sampling prior to leaf fall. In 2006, some leaves had begun to senesce and fall prior to sampling on September 16. Sampling in 2007 was conducted on August 18. The difference in sampling time and the presence of whole leaves in the stream accounts for the seasonal differences in benthic organic matter and relative abundance of coarse and fine fractions.

Given the magnitude of the floods in September of 2006 we were surprised by the small differences in the macroinvertebrate ASCI scores within each site. Annual changes in scores were not unidirectional increasing at WK1 and decreasing at WK2 through WK4. The Trichoptera were the only taxa to decrease in numbers at all sites from 2006 to 2007.

Measures of the fish community were highly variable among sampling dates within each site. Catch rates of all fish were extremely low from samples collected in May of 2008. The variability in catch rates could be explained by either fish abundance or catch ability. Low water temperatures may have reduced catch ability during spring 2008 sampling. There was still some shelf ice present during May sampling and water temperatures were 4°C when the traps were set. However, water temperatures were similar to those during September 2007 sampling. Catch rates were considerably higher in June 2007. Young-of-the-year coho made up 30% of the total coho catch. Catch rates also were high during September 2007 sampling and the combination of June and September samples allowed for measures of growth based on changes in median fork length. Additional fish sampling using consistent methods will be necessary to further evaluate the seasonal and annual variability in fish catch rates within each site.

Comparisons between stream characteristics and other regional streams are provided in Davis and Davis 2006. Characteristics are within the range of values observed in other small regional streams. Stream water temperatures are among the regional cold-water streams with temperatures rarely exceeding 13°C (Davis and Davis 2008). These streams have only a weak correlation with air temperatures, so are not expected to vary greatly among years. The slope of the regression line between air and stream temperatures can be used to evaluate potential increases in rates of heating due to modification of the surrounding forest.

These data provide a baseline of the physical, chemical, and biological characteristics of four FRPA type II streams. The FRPA is intended to preserve fish habitat through the maintenance of short- and long-term sources of woody debris, streambank stability, channel morphology, water temperatures, stream flows, water quality, adequate nutrient cycling, food sources, clean spawning gravels, and sunlight. We have quantified the amount of woody debris within reference reaches of four streams and within the riparian area to be used for future comparisons. Channel widths, depths, bank undercut, substrate size distribution and width to depth ratios can be used to evaluate changes in channel morphology and bank stability. Measures of periphyton biomass, benthic organic matter and macroinvertebrates are all indices of sources of food for fish species. Macroinvertebrate metrics and the ASCI scores provide a method to evaluate water quality. Nutrient concentrations, ratios of nitrogen to phosphorus, and nutrient fluxes are parameters important to maintaining nutrient cycling. The percent of solar radiation reaching the stream surface can be used to determine adequate sources of sunlight, and the percent of fines as well as the abundance of young-of-the-year salmon can be used to monitor clean spawning gravels.

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Appendix A. Water Chemistry and Precision Calculations

Site	Date	Measurement	Value	Units
WK1	7/12/2006	Alkalinity	26	mg/L CaCO3
WK1	7/25/2006	Alkalinity	28	mg/L CaCO3
WK1	8/27/2006	Alkalinity	18	mg/L CaCO3
WK1	9/18/2006	Alkalinity	24	mg/L CaCO3
WK1	7/12/2006	Ammonia Nitrogen	0.07	mg/L
WK1	7/25/2006	Ammonia Nitrogen	0.023	mg/L
WK1	8/27/2006	Ammonia Nitrogen	0.62	mg/L
WK1	9/18/2006	Ammonia Nitrogen	0.04	mg/L
WK1	5/29/2007	Ammonia Nitrogen	<0.005	mg/L
WK1	6/6/2007	Ammonia Nitrogen	<0.005	mg/L
WK1	6/11/2007	Ammonia Nitrogen	<0.005	mg/L
WK1	6/19/2007	Ammonia Nitrogen	0.018	mg/L
WK1	8/18/2007	Ammonia Nitrogen	0.011	mg/L
WK1	9/3/2007	Ammonia Nitrogen	0.047	mg/L
WK1	9/15/2007	Ammonia Nitrogen	<0.005	mg/L
WK1	9/26/2007	Ammonia Nitrogen	0.049	mg/L
WK1	5/16/2008	Ammonia Nitrogen	0.073	mg/L
WK1	6/10/2006	D.O.	11.95	mg/L
WK1	7/12/2006	D.O.	10.85	mg/L
WK1	7/25/2006	D.O.	10.73	mg/L
WK1	8/27/2006	D.O.	11.14	mg/L
WK1	9/18/2006	D.O.	12.2	mg/L
WK1	5/29/2007	D.O.	12.12	mg/L
WK1	6/5/2007	D.O.	10.9	mg/L
WK1	6/11/2007	D.O.	11.26	mg/L
WK1	6/19/2007	D.O.	10.4	mg/L
WK1	8/18/2007	D.O.	10.68	mg/L
WK1	9/3/2007	D.O.	11.23	mg/L
WK1	9/15/2007	D.O.	11.17	mg/L
WK1	9/26/2007	D.O.	11.5	mg/L
WK1	5/16/2008	D.O.	14.56	mg/L
WK1	6/10/2006	D.O. %	99.8	Percent Saturation
WK1	7/12/2006	D.O. %	102	Percent Saturation
WK1	8/27/2006	D.O. %	93.6	Percent Saturation
WK1	9/18/2006	D.O. %	95	Percent Saturation
WK1	5/29/2007	D.O. %	96.3	Percent Saturation
WK1	6/5/2007	D.O. %	103	Percent Saturation
WK1	6/11/2007	D.O. %	99.9	Percent Saturation
WK1	6/19/2007	D.O. %	95.9	Percent Saturation
WK1	8/18/2007	D.O. %		
WK1	9/15/2007	D.O. %	91.5	Percent Saturation
WK1	9/26/2007	D.O. %	93.1	Percent Saturation
WK1	7/25/2006	D.O.%	94.6	Percent Saturation

Site	Date	Measurement	Value	Units
WK1	9/3/2007	D.O.%	98.2	Percent Saturation
WK1	5/16/2008	D.O.%	107.7	Percent Saturation
WK1	8/27/2006	Dissolved Organic Carbon	6.4	mg/L
WK1	5/29/2007	Dissolved Organic Carbon	1.4	mg/L
WK1	8/18/2007	Dissolved Organic Carbon	<0.5	mg/L
WK1	9/26/2007	Dissolved Organic Carbon	2.1	mg/L
WK1	7/12/2006	Nitrate + Nitrite	<0.01	mg/L
WK1	7/25/2006	Nitrate + Nitrite	<0.01	mg/L
WK1	8/27/2006	Nitrate + Nitrite	0.05	mg/L
WK1	9/18/2006	Nitrate + Nitrite	0.066	mg/L
WK1	5/29/2007	Nitrate + Nitrite	0.056	mg/L
WK1	6/6/2007	Nitrate + Nitrite	<0.01	mg/L
WK1	6/11/2007	Nitrate + Nitrite	<0.01	mg/L
WK1	6/19/2007	Nitrate + Nitrite	<0.01	mg/L
WK1	8/18/2007	Nitrate + Nitrite	0.023	mg/L
WK1	9/3/2007	Nitrate + Nitrite	0.013	mg/L
WK1	9/15/2007	Nitrate + Nitrite	0.048	mg/L
WK1	9/26/2007	Nitrate + Nitrite	<0.01	mg/L
WK1	5/16/2008	Nitrate + Nitrite	0.094	mg/L
WK1	6/10/2006	pH	7.34	
WK1	7/12/2006	pH	7.3	
WK1	7/25/2006	pH	7.34	
WK1	8/27/2006	pH	6.76	
WK1	9/18/2006	pH	6.73	
WK1	5/29/2007	pH	6.93	
WK1	6/5/2007	pH	7.05	
WK1	6/11/2007	pH	7.04	
WK1	6/19/2007	pH	7.02	
WK1	8/18/2007	pH	7.2	
WK1	9/3/2007	pH	7.34	
WK1	9/15/2007	pH	6.74	
Wk1	9/26/2007	pH	6.9	
WK1	5/16/2008	pH	7.3	
WK1	6/10/2006	Specific Conductivity	46.6	microSems/cm
WK1	7/12/2006	Specific Conductivity	52.8	microSems/cm
WK1	7/25/2006	Specific Conductivity	51.3	microSems/cm
WK1	8/27/2006	Specific Conductivity	36.4	microSems/cm
WK1	9/18/2006	Specific Conductivity	49.5	microSems/cm
WK1	5/29/2007	Specific Conductivity	39.4	microSems/cm
WK1	6/5/2007	Specific Conductivity	44.6	microSems/cm
WK1	6/11/2007	Specific Conductivity	48.5	microSems/cm
WK1	6/19/2007	Specific Conductivity	52.5	microSems/cm
WK1	8/18/2007	Specific Conductivity	55.7	microSems/cm
WK1	9/3/2007	Specific Conductivity	54.3	microSems/cm

Site	Date	Measurement	Value	Units
WK1	9/15/2007	Specific Conductivity	44	microSems/cm
WK1	9/26/2007	Specific Conductivity	44.4	microSems/cm
WK1	5/16/2008	Specific Conductivity	46	microSems/cm
WK1	7/12/2006	Total Phosphorus	0.052	mg/L
WK1	7/25/2006	Total Phosphorus	0.029	mg/L
WK1	8/27/2006	Total Phosphorus	0.033	mg/L
WK1	9/18/2006	Total Phosphorus	0.033	mg/L
WK1	5/29/2007	Total Phosphorus	0.063	mg/L
WK1	6/6/2007	Total Phosphorus	0.042	mg/L
WK1	6/11/2007	Total Phosphorus	0.012	mg/L
WK1	6/19/2007	Total Phosphorus	0.022	mg/L
WK1	8/18/2007	Total Phosphorus	0.015	mg/L
WK1	9/3/2007	Total Phosphorus	0.027	mg/L
WK1	9/15/2007	Total Phosphorus	0.055	mg/L
WK1	9/26/2007	Total Phosphorus	0.031	mg/L
WK1	5/16/2008	Total Phosphorus	0.022	mg/L
WK1	7/12/2006	Tot-Diss Phosphorus	0.015	mg/L
WK1	7/25/2006	Tot-Diss Phosphorus	0.009	mg/L
WK1	8/27/2006	Tot-Diss Phosphorus	0.035	mg/L
WK1	9/18/2006	Tot-Diss Phosphorus	0.01	mg/L
WK1	5/29/2007	Tot-Diss Phosphorus	0.058	mg/L
WK1	6/6/2007	Tot-Diss Phosphorus	0.034	mg/L
WK1	6/11/2007	Tot-Diss Phosphorus	0.009	mg/L
WK1	6/19/2007	Tot-Diss Phosphorus	0.005	mg/L
WK1	8/18/2007	Tot-Diss Phosphorus	0.016	mg/L
WK1	9/3/2007	Tot-Diss Phosphorus	0.024	mg/L
WK1	9/15/2007	Tot-Diss Phosphorus	0.008	mg/L
WK1	9/26/2007	Tot-Diss Phosphorus	0.023	mg/L
WK1	5/16/2008	Tot-Diss Phosphorus	0.018	mg/L
WK1	6/10/2006	Turbidity	0.8	NTU
WK1	7/12/2006	Turbidity	0.8	NTU
WK1	7/25/2006	Turbidity	0.6	NTU
WK1	8/27/2006	Turbidity	1.5	NTU
WK1	9/18/2006	Turbidity	1.1	NTU
WK1	5/29/2007	Turbidity	1.5	NTU
WK1	6/6/2007	Turbidity	1.0	NTU
WK1	6/11/2007	Turbidity	1.0	NTU
WK1	6/19/2007	Turbidity	1.1	NTU
WK1	8/18/2007	Turbidity	1.2	NTU
WK1	9/3/2007	Turbidity	0.7	NTU
WK1	9/15/2007	Turbidity	0.9	NTU
WK1	9/26/2007	Turbidity	1.0	NTU
WK1	5/16/2008	Turbidity	1.34	NTU
WK2	7/12/2006	Alkalinity	26	mg/L CaCO3

Site	Date	Measurement	Value	Units
WK2	7/25/2006	Alkalinity	28	mg/L CaCO3
WK2	8/27/2006	Alkalinity	16	mg/L CaCO3
WK2	9/18/2006	Alkalinity	22	mg/L CaCO3
WK2	7/12/2006	Ammonia Nitrogen	0.016	mg/L
WK2	7/25/2006	Ammonia Nitrogen	0.043	mg/L
WK2	8/27/2006	Ammonia Nitrogen	<0.005	mg/L
WK2	9/18/2006	Ammonia Nitrogen	0.042	mg/L
WK2	5/29/2007	Ammonia Nitrogen	<0.005	mg/L
WK2	6/6/2007	Ammonia Nitrogen	<0.005	mg/L
WK2	6/11/2007	Ammonia Nitrogen	0.08	mg/L
WK2	6/19/2007	Ammonia Nitrogen	0.02	mg/L
WK2	8/18/2007	Ammonia Nitrogen	<0.005	mg/L
WK2	9/3/2007	Ammonia Nitrogen	<0.005	mg/L
WK2	9/15/2007	Ammonia Nitrogen	0.014	mg/L
WK2	9/26/2007	Ammonia Nitrogen	0.086	mg/L
WK2	5/16/2008	Ammonia Nitrogen	0.051	mg/L
WK2	7/12/2006	D.O.	11.32	mg/L
WK2	7/25/2006	D.O.	11.15	mg/L
WK2	8/27/2006	D.O.	11.16	mg/L
WK2	9/18/2006	D.O.	12.23	mg/L
WK2	5/29/2007	D.O.	12.22	mg/L
WK2	6/5/2007	D.O.	11.2	mg/L
WK2	6/11/2007	D.O.	11.72	mg/L
WK2	6/19/2007	D.O.	11.63	mg/L
WK2	8/18/2007	D.O.	11.64	mg/L
WK2	9/3/2007	D.O.	10.93	mg/L
WK2	9/15/2007	D.O.	11.56	mg/L
WK2	9/26/2007	D.O.	11.71	mg/L
WK2	5/16/2008	D.O.	14.25	mg/L
WK2	7/12/2006	D.O. %	103.3	Percent Saturation
WK2	8/27/2006	D.O. %	94.7	Percent Saturation
WK2	9/18/2006	D.O. %	96.7	Percent Saturation
WK2	5/29/2007	D.O. %	97.3	Percent Saturation
WK2	6/5/2007	D.O. %	103	Percent Saturation
WK2	6/11/2007	D.O. %	100.1	Percent Saturation
WK2	6/19/2007	D.O. %	101.3	Percent Saturation
WK2	9/3/2007	D.O. %	90.5	Percent Saturation
WK2	9/15/2007	D.O. %	93.8	Percent Saturation
WK2	9/26/2007	D.O. %	95.2	Percent Saturation
WK2	7/25/2006	D.O.%	97.4	Percent Saturation
WK2	8/18/2007	D.O.%		Percent Saturation
WK2	5/16/2008	D.O.%	105	Percent Saturation
WK2	8/27/2006	Dissolved Organic Carbon	10	mg/L
WK2	5/29/2007	Dissolved Organic Carbon	2.3	mg/L

Site	Date	Measurement	Value	Units
WK2	8/18/2007	Dissolved Organic Carbon	0.51	mg/L
WK2	9/26/2007	Dissolved Organic Carbon	2.4	mg/L
WK2	7/12/2006	Nitrate + Nitrite	0.18	mg/L
WK2	7/25/2006	Nitrate + Nitrite	0.088	mg/L
WK2	8/27/2006	Nitrate + Nitrite	0.19	mg/L
WK2	9/18/2006	Nitrate + Nitrite	0.3	mg/L
WK2	5/29/2007	Nitrate + Nitrite	0.24	mg/L
WK2	6/6/2007	Nitrate + Nitrite	0.15	mg/L
WK2	6/11/2007	Nitrate + Nitrite	0.14	mg/L
WK2	6/19/2007	Nitrate + Nitrite	0.14	mg/L
WK2	8/18/2007	Nitrate + Nitrite	0.2	mg/L
WK2	9/3/2007	Nitrate + Nitrite	0.2	mg/L
WK2	9/15/2007	Nitrate + Nitrite	0.13	mg/L
WK2	9/26/2007	Nitrate + Nitrite	0.078	mg/L
WK2	5/16/2008	Nitrate + Nitrite	0.3	mg/L
WK2	7/12/2006	pH	7.21	
WK2	7/25/2006	pH	7.25	
WK2	8/27/2006	pH	6.81	
WK2	9/18/2006	pH	6.78	
WK2	5/29/2007	pH	6.92	
WK2	6/5/2007	pH	6.99	
WK2	6/11/2007	pH	6.96	
WK2	6/19/2007	pH	6.98	
WK2	8/18/2007	pH	7.05	
WK2	9/3/2007	pH	7.2	
WK2	9/15/2007	pH	6.65	
WK2	9/26/2007	pH	6.91	
WK2	5/16/2008	pH	7.31	
WK2	7/12/2006	Specific Conductivity	53.4	microSems/cm
WK2	7/25/2006	Specific Conductivity	54.3	microSems/cm
WK2	8/27/2006	Specific Conductivity	36	microSems/cm
WK2	9/18/2006	Specific Conductivity	49.4	microSems/cm
WK2	5/29/2007	Specific Conductivity	41.4	microSems/cm
WK2	6/5/2007	Specific Conductivity	44.9	microSems/cm
WK2	6/11/2007	Specific Conductivity	49.1	microSems/cm
WK2	6/19/2007	Specific Conductivity	52.8	microSems/cm
WK2	8/18/2007	Specific Conductivity	57.7	microSems/cm
WK2	9/3/2007	Specific Conductivity	56.8	microSems/cm
WK2	9/25/2007	Specific Conductivity	45.5	microSems/cm
WK2	9/26/2007	Specific Conductivity	44.2	microSems/cm
WK2	5/16/2008	Specific Conductivity	34	microSems/cm
WK2	7/12/2006	Total Phosphorus	0.042	mg/L
WK2	7/25/2006	Total Phosphorus	0.02	mg/L
WK2	8/27/2006	Total Phosphorus	0.032	mg/L

Site	Date	Measurement	Value	Units
WK2	9/18/2006	Total Phosphorus	0.025	mg/L
WK2	5/29/2007	Total Phosphorus	0.034	mg/L
WK2	6/6/2007	Total Phosphorus	0.03	mg/L
WK2	6/11/2007	Total Phosphorus	0.016	mg/L
WK2	6/19/2007	Total Phosphorus	0.016	mg/L
WK2	8/18/2007	Total Phosphorus	0.024	mg/L
WK2	9/3/2007	Total Phosphorus	0.015	mg/L
WK2	9/15/2007	Total Phosphorus	0.019	mg/L
WK2	9/26/2007	Total Phosphorus	0.027	mg/L
WK2	5/16/2008	Total Phosphorus	0.028	mg/L
WK2	7/12/2006	Tot-Diss Phosphorus	0.026	mg/L
WK2	7/25/2006	Tot-Diss Phosphorus	<0.001	mg/L
WK2	8/27/2006	Tot-Diss Phosphorus	0.03	mg/L
WK2	9/18/2006	Tot-Diss Phosphorus	0.009	mg/L
WK2	5/29/2007	Tot-Diss Phosphorus	0.027	mg/L
WK2	6/6/2007	Tot-Diss Phosphorus	0.028	mg/L
WK2	6/11/2007	Tot-Diss Phosphorus	<0.001	mg/L
WK2	6/19/2007	Tot-Diss Phosphorus	0.007	mg/L
WK2	8/18/2007	Tot-Diss Phosphorus	0.003	mg/L
WK2	9/3/2007	Tot-Diss Phosphorus	0.019	mg/L
WK2	9/15/2007	Tot-Diss Phosphorus	<0.001	mg/L
WK2	9/26/2007	Tot-Diss Phosphorus	0.01	mg/L
WK2	5/16/2008	Tot-Diss Phosphorus	0.02	mg/L
WK2	7/12/2006	Turbidity	0.6	NTU
WK2	7/25/2006	Turbidity	0.8	NTU
WK2	8/27/2006	Turbidity	1.5	NTU
WK2	9/18/2006	Turbidity	1.2	NTU
WK2	5/29/2007	Turbidity	1.5	NTU
WK2	6/6/2007	Turbidity	1.1	NTU
WK2	6/11/2007	Turbidity	0.9	NTU
WK2	6/19/2007	Turbidity	0.9	NTU
WK2	8/18/2007	Turbidity	1	NTU
WK2	9/3/2007	Turbidity	1.1	NTU
WK2	9/15/2007	Turbidity	1	NTU
WK2	9/26/2007	Turbidity	2.2	NTU
WK2	5/16/2008	Turbidity	2.09	NTU
WK3	7/12/2006	Alkalinity	24	mg/L CaCO3
WK3	8/27/2006	Alkalinity	20	mg/L CaCO3
WK3	9/28/2006	Alkalinity	16	mg/L CaCO3
WK3	7/12/2006	Ammonia Nitrogen	<0.005	mg/L
WK3	8/27/2006	Ammonia Nitrogen	0.03	mg/L
WK3	9/28/2006	Ammonia Nitrogen	0.015	mg/L
WK3	5/30/2007	Ammonia Nitrogen	<0.005	mg/L
WK3	6/18/2007	Ammonia Nitrogen	<0.005	mg/L

Site	Date	Measurement	Value	Units
WK3	8/18/2007	Ammonia Nitrogen	0.24	mg/L
WK3	9/25/2007	Ammonia Nitrogen	<0.005	mg/L
WK3	7/13/2006	D.O.	11.7	mg/L
WK3	8/27/2006	D.O.	11.34	mg/L
WK3	9/28/2006	D.O.	11.68	mg/L
WK3	5/30/2007	D.O.	12.56	mg/L
WK3	6/18/2007	D.O.	11.46	mg/L
WK3	8/17/2007	D.O.	11.77	mg/L
WK3	9/25/2007	D.O.	12.02	mg/L
WK3	7/13/2006	D.O. %	102.3	% Saturation
WK3	8/27/2006	D.O. %	95.7	% Saturation
WK3	9/28/2006	D.O. %	95	% Saturation
WK3	5/30/2007	D.O. %	97.3	Percent Saturation
WK3	6/18/2007	D.O. %	98.1	Percent Saturation
WK3	8/17/2007	D.O. %	101.6	Percent Saturation
WK3	9/25/2007	D.O. %	97.1	Percent Saturation
WK3	5/30/2007	Dissolved Organic Carbon	<0.5	mg/L
WK3	8/18/2007	Dissolved Organic Carbon	<0.5	mg/L
WK3	9/25/2007	Dissolved Organic Carbon	1.7	mg/L
WK3	7/12/2006	Nitrate + Nitrite	0.12	mg/L
WK3	8/27/2006	Nitrate + Nitrite	0.18	mg/L
WK3	9/28/2006	Nitrate + Nitrite	0.2	mg/L
WK3	5/30/2007	Nitrate + Nitrite	0.21	mg/L
WK3	6/18/2007	Nitrate + Nitrite	0.15	mg/L
WK3	8/18/2007	Nitrate + Nitrite	0.17	mg/L
WK3	9/25/2007	Nitrate + Nitrite	0.08	mg/L
WK3	7/13/2006	pH	7.26	
WK3	8/27/2006	pH	6.87	
WK3	9/28/2006	pH	6.75	
WK3	5/30/2007	pH	6.99	
WK3	6/18/2007	pH	6.99	
WK3	8/18/2007	pH	7.07	
WK3	9/25/2007	pH	6.93	
WK3	7/13/2006	Specific Conductivity	48.3	microSems/cm
WK3	8/27/2006	Specific Conductivity	38.3	microSems/cm
WK3	9/28/2006	Specific Conductivity	39.5	microSems/cm
WK3	5/30/2007	Specific Conductivity	39.9	microSems/cm
WK3	6/18/2007	Specific Conductivity	45.9	microSems/cm
WK3	8/18/2007	Specific Conductivity	50.6	microSems/cm
WK3	9/25/2007	Specific Conductivity	41.7	microSems/cm
WK3	7/12/2006	Total Phosphorus	0.05	mg/L
WK3	8/27/2006	Total Phosphorus	0.015	mg/L
WK3	9/28/2006	Total Phosphorus	0.042	mg/L
WK3	5/30/2007	Total Phosphorus	0.031	mg/L

Site	Date	Measurement	Value	Units
WK3	6/18/2007	Total Phosphorus	0.024	mg/L
WK3	8/18/2007	Total Phosphorus	<0.005	mg/L
WK3	9/25/2007	Total Phosphorus	0.042	mg/L
WK3	7/12/2006	Tot-Diss Phosphorus	0.032	mg/L
WK3	8/27/2006	Tot-Diss Phosphorus	0.018	mg/L
WK3	9/28/2006	Tot-Diss Phosphorus	0.016	mg/L
WK3	5/30/2007	Tot-Diss Phosphorus	0.033	mg/L
WK3	6/18/2007	Tot-Diss Phosphorus	0.007	mg/L
WK3	8/18/2007	Tot-Diss Phosphorus	0.001	mg/L
WK3	9/25/2007	Tot-Diss Phosphorus	0.009	mg/L
WK3	7/13/2006	Turbidity	0.6	NTU
WK3	8/27/2006	Turbidity	1	NTU
WK3	9/28/2006	Turbidity	4.7	NTU
WK3	5/30/2007	Turbidity	1.2	NTU
WK3	6/18/2007	Turbidity	0.8	NTU
WK3	8/18/2007	Turbidity	1.4	NTU
WK3	9/25/2007	Turbidity	2.6	NTU
WK4	7/13/2006	Alkalinity	20	mg/L CaCO3
WK4	8/27/2006	Alkalinity	18	mg/L CaCO3
WK4	9/28/2006	Alkalinity	14	mg/L CaCO3
WK4	7/13/2006	Ammonia Nitrogen	0.085	mg/L
WK4	8/27/2006	Ammonia Nitrogen	0.1	mg/L
WK4	9/28/2006	Ammonia Nitrogen	0.025	mg/L
WK4	5/30/2007	Ammonia Nitrogen	<0.005	mg/L
WK4	6/18/2007	Ammonia Nitrogen	0.69	mg/L
WK4	8/18/2007	Ammonia Nitrogen	0.032	mg/L
WK4	9/25/2007	Ammonia Nitrogen	0.08	mg/L
WK4	7/13/2006	D.O.	11.79	mg/L
WK4	8/27/2006	D.O.	11.18	mg/L
WK4	9/28/2006	D.O.	11.8	mg/L
WK4	5/30/2007	D.O.	12.28	mg/L
WK4	6/18/2007	D.O.	10.96	mg/L
WK4	8/17/2007	D.O.	11.17	mg/L
WK4	9/25/2007	D.O.	11.84	mg/L
WK4	7/13/2006	D.O. %	105.2	% Saturation
WK4	8/27/2006	D.O. %	95	% Saturation
WK4	9/28/2006	D.O. %	95.1	% Saturation
WK4	5/30/2007	D.O. %	98	Percent Saturation
WK4	6/18/2007	D.O. %	96.6	Percent Saturation
WK4	8/17/2007	D.O. %	99.5	Percent Saturation
WK4	9/25/2007	D.O.%	95.1	Percent Saturation
WK4	5/30/2007	Dissolved Organic Carbon	<0.5	mg/L
WK4	8/18/2007	Dissolved Organic Carbon	<0.5	mg/L
WK4	9/25/2007	Dissolved Organic Carbon	<0.5	mg/L

Site	**Date**	**Measurement**	**Value**	**Units**
WK4	7/13/2006	Nitrate + Nitrite	0.016	mg/L
WK4	8/27/2006	Nitrate + Nitrite	0.033	mg/L
WK4	9/28/2006	Nitrate + Nitrite	0.091	mg/L
WK4	5/30/2007	Nitrate + Nitrite	0.074	mg/L
WK4	6/18/2007	Nitrate + Nitrite	0.012	mg/L
WK4	8/18/2007	Nitrate + Nitrite	0.071	mg/L
WK4	9/25/2007	Nitrate + Nitrite	0.031	mg/L
WK4	7/13/2006	pH	7.23	
WK4	8/27/2006	pH	6.87	
WK4	9/28/2006	pH	6.73	
WK4	5/30/2007	pH	6.93	
WK4	6/18/2007	pH	6.93	
WK4	8/18/2007	pH	6.93	
WK4	9/25/2007	pH	6.86	
WK4	7/13/2006	Specific Conductivity	43.8	microSems/cm
WK4	8/27/2006	Specific Conductivity	35.8	microSems/cm
WK4	9/28/2006	Specific Conductivity	34.8	microSems/cm
WK4	5/30/2007	Specific Conductivity	37.2	microSems/cm
WK4	6/18/2007	Specific Conductivity	42.6	microSems/cm
WK4	8/18/2007	Specific Conductivity	46.5	microSems/cm
WK4	9/25/2007	Specific Conductivity	37.9	microSems/cm
WK4	7/13/2006	Total Phosphorus	0.016	mg/L
WK4	8/27/2006	Total Phosphorus	0.021	mg/L
WK4	9/28/2006	Total Phosphorus	0.043	mg/L
WK4	5/30/2007	Total Phosphorus	0.045	mg/L
WK4	6/18/2007	Total Phosphorus	0.019	mg/L
WK4	8/18/2007	Total Phosphorus	0.008	mg/L
WK4	9/25/2007	Total Phosphorus	0.036	mg/L
WK4	7/13/2006	Tot-Diss Phosphorus	0.005	mg/L
WK4	8/27/2006	Tot-Diss Phosphorus	0.02	mg/L
WK4	9/28/2006	Tot-Diss Phosphorus	0.022	mg/L
WK4	5/30/2007	Tot-Diss Phosphorus	0.04	mg/L
WK4	6/18/2007	Tot-Diss Phosphorus	0.009	mg/L
WK4	8/18/2007	Tot-Diss Phosphorus	0.005	mg/L
WK4	9/25/2007	Tot-Diss Phosphorus	<0.001	mg/L
WK4	7/13/2006	Turbidity	0.7	NTU
WK4	8/27/2006	Turbidity	0.95	NTU
WK4	9/28/2006	Turbidity	4.5	NTU
WK4	5/30/2007	Turbidity	2.1	NTU
WK4	6/18/2007	Turbidity	1.1	NTU
WK4	8/18/2007	Turbidity	2.1	NTU
WK4	9/25/2007	Turbidity	1.2	NTU

2007 Quality Assurance Data

Date	Measure	Value	Units	Replicate Value	Precision
6/18/2007	Ammonia Nitrogen	0.69	mg/L	0.005	1.97
5/30/2007	Ammonia Nitrogen	0.005	mg/L	0.005	0.00
8/18/2007	Ammonia Nitrogen	0.011	mg/L	0.005	0.75
9/26/2007	Ammonia Nitrogen	0.049	mg/L	0.054	0.10
5/30/2007	Dissolved Organic Carbon	0.5	mg/L	0.5	0.00
8/18/2007	Dissolved Organic Carbon	0.5	mg/L	0.5	0.00
9/26/2007	Dissolved Organic Carbon	2.1	mg/L	2	0.05
6/18/2007	Nitrate + Nitrite	0.012	mg/L	0.021	0.55
5/30/2007	Nitrate + Nitrite	0.074	mg/L	0.072	0.03
8/18/2007	Nitrate + Nitrite	0.023	mg/L	0.019	0.19
9/26/2007	Nitrate + Nitrite	0.01	mg/L	0.01	0.00
5/30/2007	pH	6.93		6.95	0.00
6/18/2007	pH	6.93		6.95	0.00
8/18/2007	pH	7.2		7.2	0.00
9/26/2007	pH	6.9		6.9	0.00
5/30/2007	Specific Conductivity	37.2	microSems/cm	37	0.01
6/18/2007	Specific Conductivity	42.6	microSems/cm	42.5	0.00
8/18/2007	Specific Conductivity	55.7	microSems/cm	55.6	0.00
9/26/2007	Specific Conductivity	44.4	microSems/cm	41.3	0.07
6/18/2007	Total Phosphorus	0.019	mg/L	0.019	0.00
5/30/2007	Total Phosphorus	0.045	mg/L	0.044	0.02
8/18/2007	Total Phosphorus	0.015	mg/L	0.017	0.13
9/26/2007	Total Phosphorus	0.031	mg/L	0.033	0.06
6/18/2007	Tot-Diss Phosphorus	0.009	mg/L	0.01	0.11
5/30/2007	Tot-Diss Phosphorus	0.04	mg/L	0.041	0.02
8/18/2007	Tot-Diss Phosphorus	0.016	mg/L	0.016	0.00
9/26/2007	Tot-Diss Phosphorus	0.023	mg/L	0.016	0.36
5/30/2007	Turbidity	2.1	NTU	1.6	0.27
6/18/2007	Turbidity	1.1	NTU	1.2	0.09
8/18/2007	Turbidity	1.2	NTU	1.2	0.00
9/26/2007	Turbidity	1.0	NTU	1.0	0.00

Appendix B. QAPP and Sampling Plan

Quality Assurance Project Plan

MAT-SU FRPA Effectiveness Monitoring

(Revision Number 2.0)

Updated May 2007

Aquatic Restoration & Research Institute

P.O. Box 923, Talkeetna, AK.
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May 2007

A1. Mat-Su FRPA Effectiveness Monitoring

Aquatic Restoration and Research Institute

Project Manager: ______________________________ **Date:** ______________

Quality Assurance Officer: _______________________ **Date:** ______________

Alaska Department of Environmental Conservation

Project Manager: ______________________________ **Date:** ______________

Quality Assurance Officer: _______________________ **Date:** ______________

Effective Date:____________________________________

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A3. Distribution List

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A4. Project/Task Organization

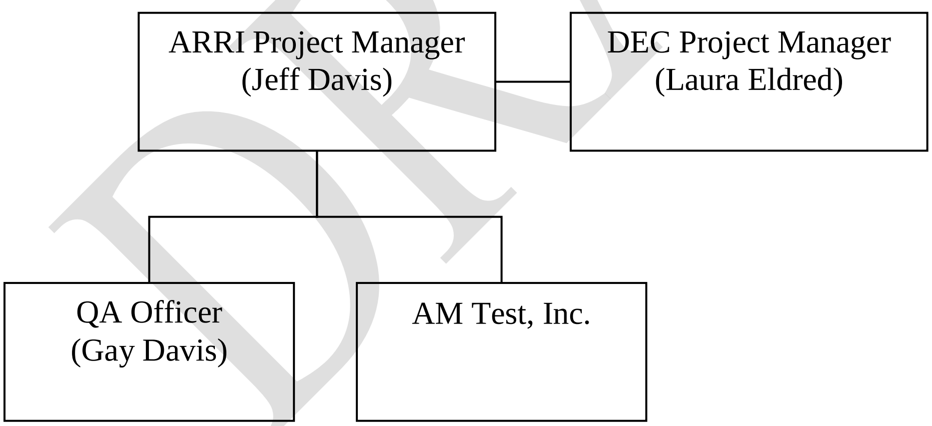
The ARRI project manager listed below will be responsible for all project components including data collection, entry, analyses, and reports.

Laura Eldred (DEC). DEC Project Manager. Ms. Eldred will oversee the project for DEC, provide technical support, QAPP review and approval, review of any proposed sampling plan modifications, and the review of all reports.

Jeffrey C. Davis (ARRI): Project Manager. Mr. Davis will make sure that all field data are collected as specified in the QAPP. He will test and maintain all equipment prior to use and perform the review of data entry and analyses. He will be responsible for preparing all reports.

Gay A. Davis (ARRI) will act as Quality Assurance Officer. Ms. Davis will be responsible for making sure that all data are collected, replicate samples taken and analyzed, and all data entered and analyzed correctly.

AM Test, Inc.—AM Test, Inc. Laboratories, 14603 NE 87th Street, Redmond, WA 98052. AM Testing will be responsible for analyzing all collected water samples for the macronutrients nitrogen and phosphorus and providing quality control and quality assurance reports relative to parameters tested.



A5. Problem Definition/Background

Growing timber industry

Timber harvesting in the Mat-Su is rapidly expanding with the development of new markets for spruce and hardwood chips. As timber harvest increases in the Mat-Su, the opportunities for timber harvest have decreased in other areas of Region II, most notably on the Kenai Peninsula, where spruce bark beetle infestations have devastated the timber supply. While demand for timber in Region I (Southeast AK) remains high, the state's allowable cut limits the amount of timber that can be harvested, and no increase in timber harvest may occur there. Demand for timber in Region III remains relatively low. Timber harvest in the Mat-Su is increasing at a greater rate than anywhere else in Alaska and almost no FRPA BMP effectiveness monitoring research has been conducted in the area.

Population
As timber harvest has increased in the Mat-Su, so has its population. The Mat-Su Valley is home to about 70,000 people, and its abundant wildlife and world-class fisheries provide economic and recreational opportunities to a very large constituency living in the area.

Research deficiency
Due to the limited scale of harvest activity in Region II in the past, little monitoring has been done to determine the effectiveness of the FRPA's best management practices in protecting and maintaining water quality and fish habitat. Most of the work that has been done in Region II has focused on the Kenai Peninsula and its spruce bark beetle infestation. The scarcity of research on the effectiveness of FRPA in Region II (and specifically in Mat-Su) is a problem because conditions in Region II are markedly different from the other regions. A major difference between Region II and the other regions in Alaska are the relatively low values of timber compared to adjacent high-value fish habitat values and recreation opportunities. The risk of impacts to fisheries are greater in Region II than elsewhere because of the greater diversity of fish species, wider distribution of fish, more intense use of the fish populations, and higher productivity of the fish streams.

In 2004, 2005, and 2006, a science and technical committee, followed by an implementation group, developed new riparian standards for Region II. The riparian standards (AS 41.17.116, AS 41.17.118, and AS 41.17.119) apply to State, federal, and private commercial timber lands in the region. Region-wide, timber harvest operations have not been documented to cause adverse effects to fish habitat and water quality. However, neither the old riparian standards nor the new standards have been documented by research to be effective.

The FRPA water quality monitoring approach developed for the Mat-Su Willer-Kash area may have the added benefit of being applicable to other timber harvest areas and studies in southcentral Alaska.

A6. Project/Task Description

Objective 1: *Develop a sampling plan and QAPP to evaluate the effectiveness of the FRPA and regulations for the Willer-Kash Forestry Area of the Matanuska-Susitna Borough.*

Objective 2: *Implement the sampling plan and provide reports describing data methods collection and analyses.*

A sampling plan has been developed for effectiveness monitoring. Effectiveness monitoring has been designed to compare stream characteristics prior to and following timber harvest and at unharvested reference streams. This design allows for statistical testing through paired and repeated measures for harvested drainages and before, after, control, impact (BACI) comparisons. The sampling plan outlines measurements for the primary physical, chemical, and biological stream characteristics.

Stream sampling and evaluation is being implemented within the Willer-Kash Forest Harvest Area. Sampling is being conducted on four similar stream systems, three of which are proposed for timber harvest operations. Sampling frequency is variable for each parameter being measured. Physical parameters that vary annually are measured only once each year, while chemical parameters that vary with season and discharge are measured more frequently. Annual sampling frequency also diminishes over time following timber harvest. More detailed descriptions of the sampling design, measurements, and sampling frequency are found in section B1.

Sampling will be conducted from May through September. Sampling for most parameters is designed to be conducted annually prior to and for the first 3 years following timber harvest completion and once every 5 years thereafter.

Stream sampling includes replicate sampling for calculating quality assurance measures. Project reporting includes field sampling reports that will be used to track project progress and to identify any problems associated with the application of the sampling plan. Draft and Final reports will be completed that will describe the data collection and analytical and statistical methods, and the project results. Data also will be submitted in an electronic format for importing into larger data bases.

A7. 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 7. Accuracy, precision, and completeness objectives for measurement parameters.

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 (µS/cm)	Meter	0.1	100 to 200	95 to 105 @ 100µS/cm	5%	95%

Parameter	Method	Resolution/ Limit	Expected Range	Accuracy%	Precision	Completeness
DO (mg/L)	Meter	0.01	8 to 16	95 to 105 @ 10mg/L	5%	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 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%
Large Woody Debris	Counts/100 -m	1	0 to 20	N/A	N/A	95%
Coarse Woody Debris	Counts	1	1 to 200 per 100m	N/A	25%	95%
Substratum (mm)	Wolman Counts	N/A	0.2 to 500	N/A	10%	95%
Substratum Embeddedness	Visual Estimate	10%	0 to 100%	N/A	N/A	95%
Substratum percent fines	Benthic Grab	0.01 mm	0 to 100 g	N/A	N/A	95%
Macroinvertebrates	ASCI	N/A	N/A	N/A	20%	95%
Juvenile Fish	Minnow Traps	1.0	0 to 20/hr	N/A	25%	95%
Solar Radiaition ($\mu mol/m^2/s$)	Meter	0.01	20 to 2000	75 to 125	N/A	95%
Temperature (°C)	Stowaway	0.1	0 to 15	97 to 103 @ 15°C	5%	95%
Discharge (m^3/s)	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. Measurements of 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 baseflow conditions. 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 the DEC project manager. The DEC project manager will distribute the report for peer review. 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 collected by the project will be provided to DEC in accordance with guidance and templates at, http://www.state.ak.us/dec/water/wqsar/storetdocumentation.htm.

A8. Special Training Requirements/Certification Listed

Jeffrey C. Davis (Project Manager) has a B.S. degree in Biology from University of Alaska Anchorage and a M.S. degree in Aquatic Ecology from Idaho State University. He has 12 years of experience in stream research. Mr. Davis has experience in all of the assessment techniques outlined in this document. He has experience in laboratory chemical analyses, macroinvertebrate collection pursuant to the USGS NAWQA program, the EPA Rapid bioassessment program, modification of these methodologies for Idaho and Alaska. Mr. Davis also has experience in aquatic invertebrate and vertebrate species identification.

Gay Davis (Quality Assurance Officer) has a B.S. degree In Wildlife Biology from the University of Maine. She has 13 years of experience in stream restoration and evaluation. Ms. Davis has over 5 year experience in stream ecological field assessment methods and water quality sampling.

Chemical analyses will be conducted through Analytical International, Inc. laboratory in Anchorage and AM Testing in Redmond Washington.

With the combined experience of these investigators, no additional training will be required to complete this project.

A9. Documentation and Records

Field data including replicates measures for quality assurance will be recorded in Rite-in-the-Rain field books. Upon returning to the laboratory, the field book will be photocopied (daily or weekly). The field data book will be kept and stored by the project manager and the Quality Assurance Officer will store the photocopies. ARRI will maintain records indefinitely. The final data report will include as appendices Excel data sheets, and results of QC checks. Any sampling problems will be recorded on the data sheets and included in the field sampling report. Laboratory reporting and requested laboratory turn around times of 6 to 10 days are discussed in section B4.

Reporting Requirements

Sampling Event Reports

Following each sampling event a brief report will be sent 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.

Pre-Draft and Draft Final Report

ARRI will submit a pre-draft report providing all of the analytical results. ARRI will submit a draft final report to the ADEC project manager. The draft final 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. The DEC project manager will distribute the draft report for peer review.

Final Report

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 and as recommended through the review process.

Project data, photographs, and reports will be delivered in both electronic and hard copies. The format and number of copies will be determined by the ADEC project manager.

B1. Sampling Process Design

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.

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 will be classified as Type IIA streams (large dynamic non-glacial rivers). Proposed timber harvest along Willow Creek and the Kashwitna River will not be sufficient to evaluate BMP effectiveness. Based upon 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.

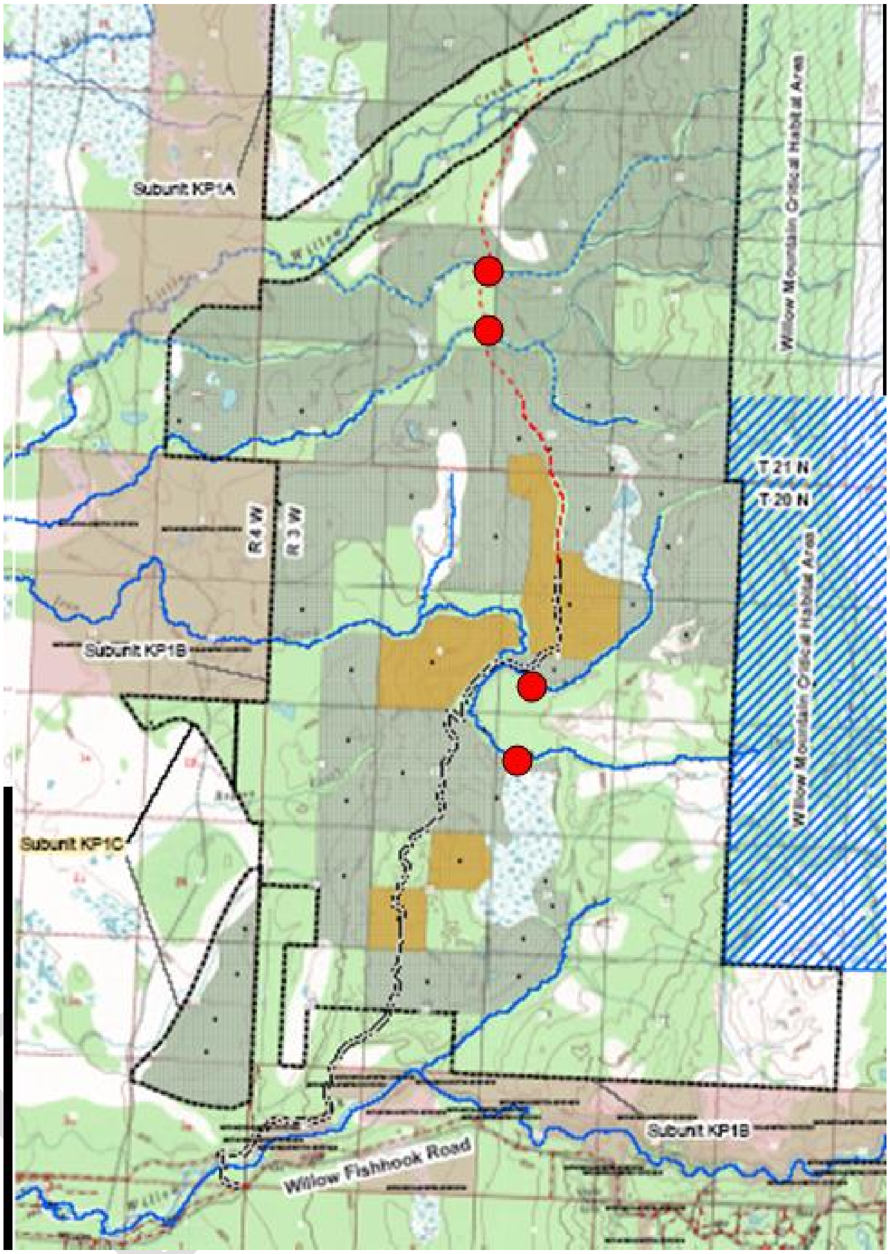


Figure 22. Map of the Willer-Kash Harvest Area showing sampling locations (red dots).

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. Sampling frequency for water chemistry is hierarchical so that level 1 sampling frequency is obtained at all stream sites with more detailed level 2 sampling at a portion of the total sites. For the Willer-Kash Harvest area, level 2 sampling will occur at two of the four sampling locations. However, for general application, level 2 sampling should occur at one of every five sites. Proposed sample parameters, frequency, and measurement methods are listed in Table 3.

Physical Characteristics

<u>Substratum Size Distribution</u>

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 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. 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 5 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) and size distribution relative to critical grain size. For embeddedness, the relative percent of the particles embedded over 30% will be used as the dependent variable.

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 affects most biochemical processes and further defines 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. Loggers will be placed within a well-mixed portion of each stream sampling site within 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. 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 or directly measured concurrent with water sampling. 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 at the stream surface will be obtained by taking 20 measures distributed systematically throughout the 100-m sampling reach. Concurrent measures will be taken of direct solar radiation adjacent to the stream site not shaded by riparian vegetation. 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 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). 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 oily sheen, which may be indicative of hydrocarbon pollution. The presence of an oily sheen prior to road construction and timber harvest will be an indication of natural causes.

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.

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.

<u>Benthic and Dissolved Organic Matter</u>

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 variability in dissolved organic matter with changes in stream flow.

<u>Macroinvertebrates</u>

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 per sample effort.

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 the sampling reach will be classified lateral to channel-morphometry transects to 100 m. Coarse wood surveys will be conducted along one bank. All coarse woody debris (>10 cm diameter and 1-m long) on the forest floor within the riparian area along the 100-m sampling reach and extending 30-m lateral to the channel will be counted and identified by species. Coarse wood will be placed into three distinct diameter categories (greatest diameter is from 10 to 20 cm, 21 to 30 cm, and > 30 cm) and three distinct length categories (1 to 5 m, 6 to 10 m, and > 11 m).

Table 8. Stream sample parameters and sampling frequency.

Sample Parameter	Frequency (prior to and 1-5years post harvest)	Frequency (6 to 10+ years post harvest)	Methods
Physical			
Substratum	Annual	Biannual	Wolman Pebble Counts, Percent Embeddedness
Temperature	Continuous (May - Oct)	Continuous for One Year, Every 5 years.	Data Loggers
Flow (Level 1)	Concurrent with Water Chemistry Sampling	Concurrent with Water Chemistry Sampling, Every 5 years.	Direct Measure
Flow	Continuous (May – Oct)	Continuous (May – Oct)	Pressure Data Logger and rating curve
Morphometery (cross-section, confinement, sinuosity)	Annual	Every 5 years	Surveys
Large Woody Debris	Annual	Every 5 years	Counts/LWDI
Solar Radiation	Three times a year, spring, summer, and fall	Three times a year, spring, summer, and fall, Every 5 years	Pyranometer or PAR meters
Level 1 Water Chemistry			
Turbidity	Three times a year, spring breakup, summer baseflow, and fall storm events)	Three times a year, spring, summer, and fall, Every 5 years	Water Sample Analyses—Meter Measurement
Dissolved Oxygen	Three times a year, spring breakup, summer baseflow, and fall storm events)	Three times a year, spring, summer, and fall, Every 5 years	Water Sample Analyses—Meter Measurement
pH		Three times a year, spring, summer, and fall, Every 5	Water Sample Analyses—Meter Measurement

Sample Parameter	Frequency (prior to and 1-5years post harvest)	Frequency (6 to 10+ years post harvest)	Methods
		years	
Specific Conductance	Three times a year, spring breakup, summer baseflow, and fall storm events)	Three times a year, spring, summer, and fall, Every 5 years	Water Sample Analyses—Meter Measurement
Hydrocarbons/Foam	Concurrent with water sampling	Concurrent with water sampling	Qualitative Observations
Nutrients (NO_3-N, NH_4-N, Total-P, Dissolved P)	Three times a year, spring breakup, summer baseflow, and fall storm events)	Three times a year, spring, summer, and fall, Every 5 years	Water Sample Laboratory Analyses
Level 2 Water Chemistry			
Turbidity	Weekly (Spring) Biweekly or Continuous (May – Oct)	Weekly (Spring) Biweekly Every 5 years (May – Oct)	Water Sample Analyses—Meter Measurement
Dissolved Oxygen	Weekly (Spring), Biweekly (May – Oct)	Weekly (Spring) Biweekly Every 5 years (May – Oct)	Water Sample Analyses—Meter Measurement
pH	Weekly (Spring), Biweekly or Continuous (May – Oct)	Biweekly Every 5 years (May – Oct)	Water Sample Analyses—Meter Measurement
Specific Conductance	Biweekly (May – Oct)	Biweekly Every 5 years (May – Oct)	Water Sample Analyses—Meter Measurement
Hydrocarbons/Foam	Biweekly (May – Oct)	Biweekly Every 5 years (May – Oct)	Qualitative Observations
Nutrients (NO_3-N, NH_4-N, Total-P, Dissolved P)	Weekly (Spring), Biweekly (May – Oct)	Biweekly Every 5 years (May – Oct)	Water Sample Laboratory Analyses
Biological Organisms/Food Sources			
Fish (juvenile)	Biannual (Spring and Fall)	Biannual (Spring and Fall)	Baited Minnow Traps
Macroinvertebrates	Annual	Every 5 years	ASCI
Periphyton Biomass	Annual	Every 5 years	Accumulation on tiles
Benthic Organic Matter	Annual	Every 5 years	Substrate Samples

Sample Parameter	Frequency (prior to and 1-5years post harvest)	Frequency (6 to 10+ years post harvest)	Methods
			(AFDM)
Dissolved Organic Matter	Spring Runoff, Base Flow, and Fall Storm Events (May – Oct)	Every 5 years	Water sample analyses
Riparian Vegetation Community Composition	Annual	Every 5 years	Qualitative classification
Riparian Coarse Wood	Annual	Every 5 years	Counts of Coarse Wood Within Riparian.

External Data
Discharge and weather data will be obtained from U.S. government agency web sites. Weather data downloaded or purchased through the National Oceanic and Atmospheric Administration (NOAA) web site (http://www.ncdc.noaa.gov/oa/ncdc.html).

Sample Timing
To minimize diel variability, water sample collection will be standardized to the time between 10:00 AM to 4:00 PM.

B2. Sampling Methods Requirements

Field Data Collection

Field data collection will be conducted by Aquatic Restoration and Research Institute (ARRI) staff. Latitude and longitude of sampling locations will be recorded using a GPS recorder. Photographs will be used to further identify locations and conditions during field sampling. 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. 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, 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. 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, 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.

Site Locations and Photographs

Latitude and longitude of sampling locations will be recorded using a GPS recorder. Photographs will be used to further identify locations and changing seasonal riparian and stream conditions during field sampling.

Materials Required: Garmin GPS III and Nikon Coolpix L5 digital camera.

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-packs and shipped by Federal Express or UPS 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-packs, 60-cc syringe, syringe filters, thermometer, and sterile gloves.

Temperature

Stream water temperature data loggers (Stowaway by Onset Corporation) will be placed within each stream within the area of proposed harvest units. Loggers will be secured to the bank using plastic coated wire rope. Loggers will be downloaded concurrent with water samples.

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

Solar Radiation

Solar radiation at the stream surface will be obtained by taking 20 measures distributed systematically throughout the 100-m sampling reach. Concurrent measures will be taken of direct solar radiation adjacent to the stream site not shaded by riparian vegetation. Dependent variables will be the portion of total daily solar radiation at stream sites relative to open locations.

Materials Required. Light meter and sensor.

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, and velocity meter.

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).

<u>Materials Required</u>: 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.

<u>Materials Required</u>: 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.

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

Large Woody Debris and Coarse Woody Debris

Large woody debris (LWD) will be measures using the methods described in Davis et al. (2001). All large wood within the bankfull channel will be counted and scored based upon size and position in the stream relative to channel size. All debris dams are counted and scored relative to size and position in the stream. Scored values are converted into a large woody debris index (LWDI).

Coarse wood within the riparian area will be quantified by species within the sampling reach. Coarse wood is counted along one bank for 100-m length of stream extending out 30-m lateral to the channel. Downed coarse wood on the forest floor is identified by species and placed into one of three diameter and length categories (greatest diameter is from 10 to 20 cm, 21 to 30 cm, and > 30 cm) and three distinct length categories (1 to 5 m, 6 to 10 m, and > 11 m)..

Materials Required. Data book, meter stick or calipers, meter tape, distance finder.

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.

B3. Sample Handling and Custody Requirements

Water samples will be labeled in the field. Sample labels will record the date, time, location, preservation, and initials of collector. Chain of custody forms will be initiated in the field and completed each time samples are transferred to a laboratory, or other carrier. Field samples that are to be transferred to the contract laboratory will be placed within a cooler and the cooler sealed closed using plastic packing tape. Samples will be transported to the laboratory where they will be placed in a secure location until analyses are completed.

B4. Analytical Methods Requirements

Sample analytical methods are shown in Table 4. Field samples will be collected by ARRI staff and either delivered to the commercial laboratory for subsequent analyses by the identified standard method. Meter measures will be conducted in the field except for turbidity and alkalinity, which will be measured in the ARRI laboratory.

Table 9. List of Analytical methods and detection limits for study parameters.

Measurement	Collection/ Analyses	Method	Limits	Turnaround Time (days)
Total Phosphorus	ARRI/AM Test Inc.	EPA 365.2	0.005 mg/L	14
Total Dissolved Phosphorus	ARRI/AM Testing	EPA 365.2	0.005 mg/L	14
Ammonia-N	ARRI/AM Test Inc.	EPA 350.1	0.005 mg/L	30
Nitrate + Nitrite-N	ARRI/AM Testing	EPA 353.2	0.01 mg/L	30
pH	ARRI/ARRI	Meter (Hanna HI 9023)	0.01 pH units	1
Algal Chlorophyll-a	ARRI/AM Test Inc.	SM 1002G	0.1 mg/m^2	30
Specific Conductance	ARRI/ARRI	Meter (SPER 840039) Hydrolab MS5	0.2 mhos (0 to 200) 1.0 mhos (>200)	1
Turbidity	ARRI/ARRI	Meter (HACH Model 16800) Hydrolab MS5	0.1 NTU (0 to 10) 1.0 NTU (10 to 100)	1
Dissolved Oxygen	ARRI/ARRI	Meter (YSI Model 55) Hydrolab MS5	0.01 mg/L (0 to 20)	1
Temperature	ARRI	HOBO Stowaway	0.1 Degree C	Monthly Download
Discharge	ARRI	Price AA pygmy	0.1 cfs	Direct Measure

Corrective Action

ARRI will be responsible for ensuring that all samples are collected and delivered to the laboratory. The QA officer will make sure all samples are labeled and stored correctly and that all equipment has been calibrated and accuracy tests completed as needed. The project manager will be informed of any errors and will be responsible for corrective action including repeating sample collection or analyses (for metered measures). If any samples are lost or are determined to be contaminated by the laboratory or if there are any laboratory problems, the project manager will be responsible for collecting new samples and delivering them to the laboratory.

B5. Quality Control Requirements

The following table (Table5) lists the percent of field and laboratory replicates to be used for quality control (See section A7 for discussion on calculation of precision and accuracy). The precision of field and laboratory measures will be calculated using the equation in section A7. Accuracy will be measured using the equation in A7 for known standards. If accuracy and precision are not met for analyses ARRI is conducting, the meters will be recalibrated and measures will be repeated or meters or probes will be replaced. Data measurements that do not meet the limits described in A7 may or may not be used in the final report depending on degree to which limits are not met. However, the report will clearly state if there are any questions regarding used data.

Table 10. Field and laboratory replicates for quality control.

Parameter	**Field Replicates**	**Laboratory Replicates**	**Comments**
pH, Cond, Turb, DO, alkalinity.	10 Percent	10 Percent	Replicate measurements one of every 8 samples.
Nitrogen, Phosphorus, Alkalinitiy	10 Percent	10 Percent	Laboratory replicates may include samples from other locations.
Substrate	25%	None	Pebble counts will be repeated at one site.
Temperature	1%	None	Water temperature will be measured on each sampling event with meters and compared with stowaway readings. Stowaways will be placed in the same location for 24 hours and reading compared.
Solar Radiation	25%	None	Solar radiation measurements will be repeated at one location.
Discharge	None	None	Discharge measurements will be reported as measured.
Morphometry	None	None	Channel characteristic statistics will be reported based upon measures taken at 5 transects.
Algae	None	10 percent	Algal chlorophyll-a will be reported at the average of 5 replicate samples. Standards and laboratory replicates will be used by the laboratory to calculated accuracy and precision.
Benthic Organics	None	None	Benthic organic matter will be reported from the statistics of 5 replicate samples.
Large Woody Debris	25%	None	Large woody debris counts will be repeated at one location.
Coarse Woody Debris	25%	None	Riparian coarse wood counts will be replicated at one location.
Macroinvertebrates	None	None	Macroinvertebrate sampling will not be repeated.
Juvenile Fish	None	None	Fish sampling will not be repeated.

B6. Instrument/Equipment Testing, Inspection, and Maintenance Requirements

Instruments and meters will be tested for proper operation as outlined in respective operating manuals. Inspections and calibration will occur prior to use at each site. Equipment that does not calibrate or is not operating correctly will not be used. For most parameters (temperature, conductivity, and pH), duplicate instruments and meters are available. In the case of complete equipment failure, new equipment will be purchased. The Project Manager will be responsible for calibrating and testing and storing equipment and completing log sheets. All calibrating, testing and storage will follow the manufacturer's recommendations. The QA Officer will inspect the log sheets. Spare batteries and repair equipment will be taken during field sampling events.

B7. Instrument Calibration and Frequency

The pH meter (Hanna HI 9023), conductivity meter (SPER 840039), dissolved oxygen (YSI Model 55), and turbidity meter (HACH Model 16800), and any other analytical equipment will be calibrated in accordance to instructions in the manufacturer's operations manual by the project manager prior to each use and a log will be maintained documenting calibration. Standards are required for pH, and turbidity and will be used for conductivity.

B8. Inspection/Acceptance Requirements for Supplies and Consumables

Sample containers will be obtained from AM Test, Inc. Any needed standards for equipment calibration will be purchased directly from the equipment manufacturer if possible or from a well established chemical company. The QA officer will be responsible for ensuring that standards are not outdated and for the purchase of replacements. The date and source of all purchased materials will be recorded within a separate file for each piece of equipment and kept on file by ARRI along with equipment calibration records.

B9. Data Acquisition Requirements for Non-Direct Measurements

Weather data downloaded or purchased through the National Oceanic and Atmospheric Administration (NOAA) web site (http://www.ncdc.noaa.gov/oa/ncdc.html) also will be used and assumed accurate. Maps and information on proposed road and harvest locations will be obtained from the Alaska Department of Natural Resources, Division of Forestry. Some supplemental data such as maps, water quality data, may be obtained from other currently unknown sources for comparisons.

B10. Data Management

Field data will be entered onto 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. The Quality Assurance officer will review any statistical or other comparisons made. Any errors will be corrected. The Project Manager will write the final report, which will be proofed by the Quality Assurance officer and submitted to the DEC project manager.

Parameters from stream characteristics will be compared with repeated measures following timber harvest. Statistical tests (student's t-test or repeated measures ANOVA) will be used for comparisons. Parameters from the unharvested site will be used to identify any variables that are changing in the absence of timber harvest.

Water quality data will be provided to DEC in a modernized STORET compatible format. Data will be formatted into STORET compatible files as described at the following DEC web site http://www.state.ak.us/dec/water/wqsar/storetdocumentation.htm.

C1. Assessments and Response Actions

Project assessment will primarily be conducted through the preparation of field sampling event reports for DEC by the project manager. Section A6 contains more information on the type and date of each required report. At that time the project manager will review all of the tasks accomplished against the project Sample Plan to ensure that all tasks are being completed. The project manager will review all data sheets and entered data to make sure that data collection is complete. If necessary, data collection processes or data entry will be modified as necessary. Any modifications of the data collection methods will be reviewed against the processes described within the QAPP to determine whether the document needs to be updated.

The Project Manager will check on contractor's laboratory practices to ensure that samples are handled correctly and consistently. The final report will contain an appendix that will detail all of the QA procedures showing precision and accuracy. Representativeness, completeness, and comparability will be discussed in the body of the report. Any QA problems will be outlined and discussed relative to the validity of the conclusions in the report. Any corrective actions will be discussed as well as any actions that were not correctable, if any.

The QA officer will report to ARRI management any consistent problems in data collection, analyses, or entry identified either internally or through a 3rd party audit. ARRI management will be responsible for developing and implementing a course of action to correct these problems. Where consistent problems may have affected project validity, these will be identified and reported to the DEC project manager directly and included in project reports as directed. Field sampling problems will also be included in the sampling event report submitted to the DEC project manager following each sampling event.

C2. Reports to Management

Reports will be prepared by the ARRI Project Manager and distributed to the Department of Environmental Conservation Project Manager. Reports will update the status of the project relative to the schedule and tasks of the work plan. Reports include Sampling Event Reports, , Draft Final Report, and Final Report. Any field QA problems will be identified and reported in the sampling event reports. The Project Manager will prepare the draft and final reports. The final report also will be submitted in electronic format. Any potential problems with data due to QA will be identified and reported in all submitted reports.

D1. Data Review, Validation, and Verification

The Project Manager and the Quality Assurance Officer will conduct data review and validation. Data errors can occur during collection, laboratory analyses, data entry, and reporting. The QA officer will review all field data sheets to ensure that field measures and sample collection followed the QAPP and sampling plan procedures. The QA officer will ensure that all field replicate samples and measures were collected. The QA officer will review and store copies of all chain of custody forms to ensure proper sample handling and delivery.

The QA officer will be responsible for reviewing data received from contract laboratories. The review will include an evaluation of the laboratory quality control measures including laboratory controls, duplicates, and spikes. The review will check to make sure the proper analytical methods were used. Site names and dates will be compared to field notes.

For samples analyzed by ARRI the QA officer will check to make sure that all meters are calibrated and operating correctly and that the calibration and measures of standards is being recorded.

The QA officer will conduct reviews of data entry, analyses, and reporting to ensure that there are no errors in data entry and reporting.

Data that are obtained using equipment that has been stored and calibrated correctly and that meets the accuracy and precision limits will be used. Data that does not meet the accuracy and precision limits may be used; however, we will clearly identify these data and indicate the limitations.

D2. Validation and Verification Methods

Data Collection

The Project Manager will be responsible for field physical and biotic measures and water sampling and handling. Field data collection will be conducted as described in the approved sampling plan and QAPP. Any variation in methods or problems in data collection will be reported to the ADEC project manager. The Project Manger will ensure that the samples for laboratory analyses are identified by the correct site location name, date, and sampling personnel. The Project Manager will ensure proper sample storage and handling and will fill out and sign all chain of custody forms. Copies of chain of custody forms will be turned over to the QA officer. A log of sampling locations, personnel, labeling, and handling will be kept within the field data book.

Analytical Methods

The QA officer will be responsible for quality control from all contract laboratories. This will include review of sample labeling, analytical method used, turn around time, and laboratory quality control measures. The QA officer will work with the contract laboratory to correct or clarify any errors. Analytical results that are below the method detection limit will be reported as such with no numeric value.

The Project Manager will conduct all precision calculations for field replicates. The QA officer will review the resulting values relative to data criteria. Data accuracy, precision, and completeness results will be presented within the Final Project Report.

Data Entry and Statistical Analyses

The Project Manager and the Quality Assurance Officer will conduct data validation and verification. The Project Manager will enter all data from laboratory and field data sheets into Excel worksheets. The Project Manager will double-check all entries to ensure that they are correct. The Quality Assurance Officer will compare 10% of the laboratory and field data sheets with the Excel worksheets. The Project Manager will enter all formulas for calculation of parameters and basic statistics. All of these formulas will be checked by the Quality Assurance Officer. If any errors are found, the Project Manager will correct the errors and then check all entries. The Quality Assurance Officer will then repeat a check of 10% of the data entry and all of the formulas and statistics. This process will be repeated until any errors are eliminated.

Data Reporting

The Project Manager will organize and write the final report. 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 Manger. The Project Manager will review and respond or incorporate all comments received from the ADEC project manager and other reviewers. The QA officer will check the final report to ensure that all review comments were addressed.

D3. Reconciliation with User Requirements

The project results and associated variability, accuracy, precision, and completeness will be compared with project objectives. If results do not meet criteria established at the beginning of the project, this will be explicitly stated in the final report. Based upon data accuracy some data may be discarded. If so the problems associated with data collection and analysis, or completeness, reasons data were discarded, and potential ways to correct sampling problems will be reported. In some cases accuracy project criteria may be modified. In this case the justification for modification, problems associated with collecting and analyzing data, as well as potential solutions will be reported in the project Final Report.

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.

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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.

MAT-SU FRPA EFFECTIVENESS MONITORING

WILLER-KASH STATE HARVEST AREA

Contract 18-2011-21

Version 4.0

Prepared For

ALASKA Department of Environmental Conservation

by

ARRI Aquatic Restoration & Research Institute

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May 2007

<u>Aquatic Restoration and Research Institute</u>

Project Manager: ________________________________ **Date:** ______________

<u>Alaska Department of Environmental Conservation</u>

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 will be classified as Type IIA streams (large dynamic non-glacial rivers).

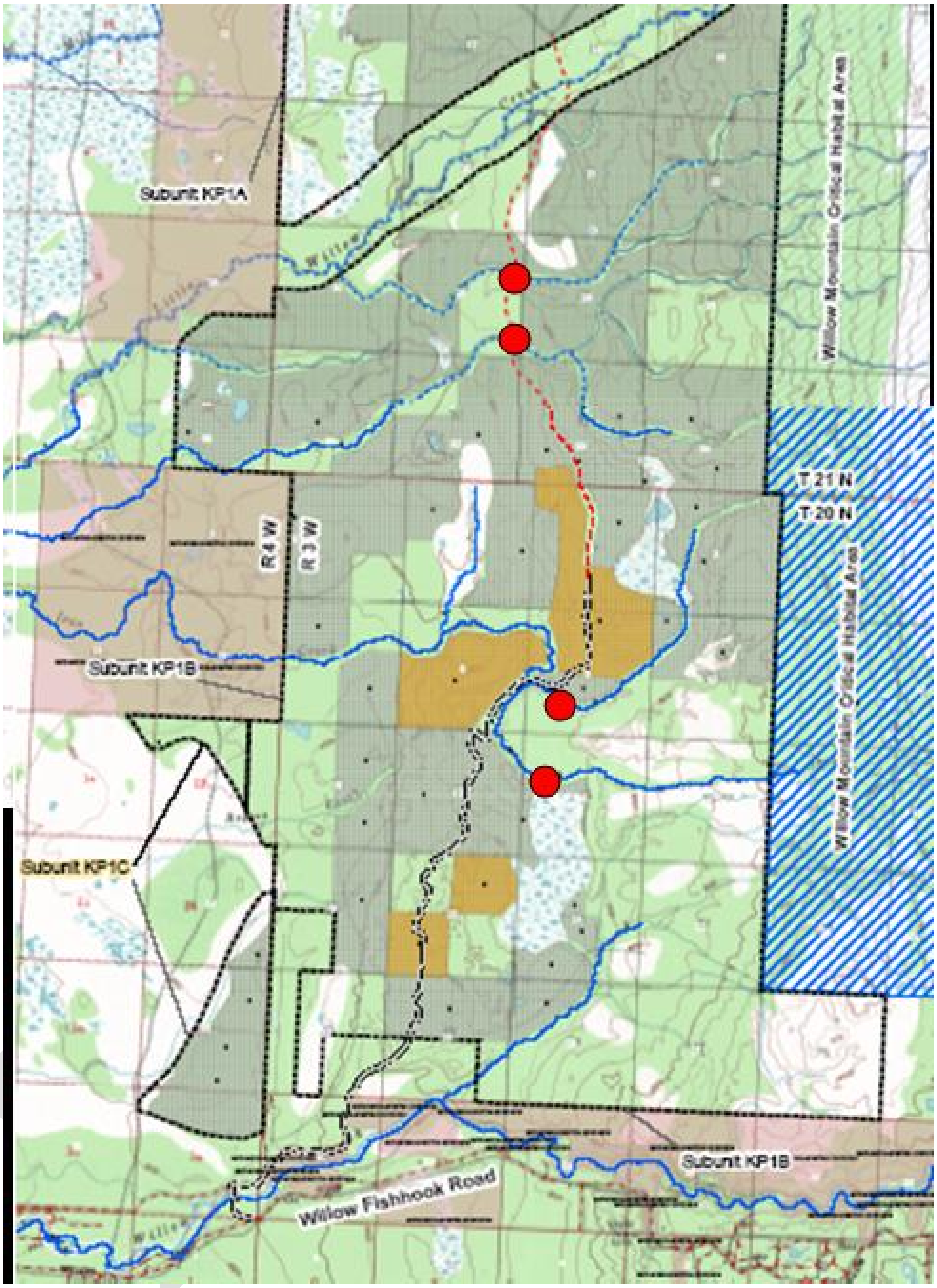

Figure 23. Map of the Willer-Kash Harvest Area showing sampling locations (red dots).

Proposed timber harvest along Willow Creek and the Kashwitna River will not be sufficient to evaluate BMP effectiveness. Based upon 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. Sampling frequency for water chemistry is hierarchical so that level 1 sampling frequency is obtained at all stream sites with more detailed level 2 sampling at a portion of the total sites. For the Willer-Kash Harvest area, level 2 sampling will occur at two of the four sampling locations. However, for general application, level 2 sampling should occur at one of every five sites. Proposed sample parameters, frequency, and measurement methods are listed in Table 2.

Physical Characteristics

<u>Substratum Size Distribution</u>

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 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. 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 5 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) and size distribution relative to critical grain size. For embeddedness, the relative percent of the particles embedded over 30% will be used as the dependent variable.

<u>Large Woody Debris</u>
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).

<u>Water Temperature</u>
Stream water temperatures affects most biochemical processes and further defines 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. Loggers will be placed within a well-mixed portion of each stream sampling site within 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. 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 or directly measured concurrent with water sampling. 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 at the stream surface will be obtained by taking 20 measures distributed systematically throughout the 100-m sampling reach. Concurrent measures will be taken of direct solar radiation adjacent to the stream site not shaded by riparian vegetation. 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 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). 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.

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 per sample effort.

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 11. Stream sample parameters and sampling frequency.

Sample Parameter	Frequency (prior to and 1-5years post harvest)	Frequency (6 to 10+ years post harvest)	Methods
Physical			
Substratum	Annual	Biannual	Wolman Pebble Counts, Percent Embeddedness
Temperature	Continuous (May - Oct)	Continuous for One Year, Every 5 years.	Data Loggers
Flow (Level 1)	Concurrent with Water Chemistry Sampling	Concurrent with Water Chemistry Sampling, Every 5 years.	Direct Measure
Flow	Continuous (May – Oct)	Continuous (May – Oct)	Pressure Data Logger and rating curve
Morphometery (cross-section, confinement, sinuosity)	Annual	Every 5 years	Surveys
Large Woody Debris	Annual	Every 5 years	Counts/LWDI
Solar Radiation	Three times a year, spring, summer, and fall	Three times a year, spring, summer, and fall, Every 5 years	Pyranometer or PAR meters with Data Loggers
Level 1 Water Chemistry			
Turbidity	Three times a year, spring breakup, summer baseflow, and fall storm events)	Three times a year, spring, summer, and fall, Every 5 years	Water Sample Analyses—Meter Measurement
Dissolved Oxygen	Three times a year, spring breakup, summer baseflow, and fall storm events)		Water Sample Analyses—Meter Measurement
pH			Water Sample Analyses—Meter Measurement

Sample Parameter	Frequency (prior to and 1-5years post harvest)	Frequency (6 to 10+ years post harvest)	Methods
Specific Conductance	Three times a year, spring breakup, summer baseflow, and fall storm events)		Water Sample Analyses—Meter Measurement
Hydrocarbons/Foam	Concurrent with water sampling		Qualitative Observations
Nutrients (NO_3-N, NH_4-N, Total-P, Dissolved P)	Three times a year, spring breakup, summer baseflow, and fall storm events)		Water Sample Laboratory Analyses
Level 2 Water Chemistry			
Turbidity	Weekly (Spring) Biweekly or Continuous (May – Oct)	Weekly (Spring) Biweekly Every 5 years (May – Oct)	Water Sample Analyses—Meter Measurement
Dissolved Oxygen	Weekly (Spring), Biweekly (May – Oct)	Weekly (Spring) Biweekly Every 5 years (May – Oct)	Water Sample Analyses—Meter Measurement
pH	Weekly (Spring), Biweekly or Continuous (May – Oct)	Biweekly Every 5 years (May – Oct)	Water Sample Analyses—Meter Measurement
Specific Conductance	Biweekly (May – Oct)	Biweekly Every 5 years (May – Oct)	Water Sample Analyses—Meter Measurement
Hydrocarbons/Foam	Biweekly (May – Oct)	Biweekly Every 5 years (May – Oct)	Qualitative Observations
Nutrients (NO_3-N, NH_4-N, Total-P, Dissolved P)	Weekly (Spring), Biweekly (May – Oct)	Biweekly Every 5 years (May – Oct)	Water Sample Laboratory Analyses
Biological Organisms/Food Sources			
Fish (juvenile)	Biannual (Spring and Fall)	Biannual (Spring and Fall)	Baited Minnow Traps
Macroinvertebrates	Annual	Every 5 years	ASCI
Periphyton Biomass	Annual	Every 5 years	Accumulation on tiles
Benthic Organic Matter	Annual	Every 5 years	Substrate Samples (AFDM)
Dissolved Organic Matter	Spring Runoff, Base Flow, and	Every 5 years	Water sample analyses

Sample Parameter	Frequency (prior to and 1-5years post harvest)	Frequency (6 to 10+ years post harvest)	Methods
	Fall Storm Events (May – Oct)		
Riparian Vegetation Community Composition	Annual	Every 5 years	Qualitative classification
Riparian Coarse Wood	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. 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. 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, 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 or UPS 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, 60-cc syringe, syringe filters, thermometer, and sterile gloves.

Temperature

Stream water temperature data loggers (Stowaway by Onset Corporation) will be placed within each stream within the area of proposed harvest units. Loggers will be secured to the bank using plastic coated wire rope. Loggers will be downloaded concurrent with water samples.

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, and velocity meter.

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 12. 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 (µS/cm)	Meter	0.1	100 to 200	95 to 105 @ 100µS/cm	5%	95%
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%

Parameter	Method	Resolution/ Limit	Expected Range	Accuracy% *	Precision	Completeness
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 June 30, ARRI will submit a pre-draft report providing analytical results. Prior to July 15, 2007 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 July 31, 2007 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.

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