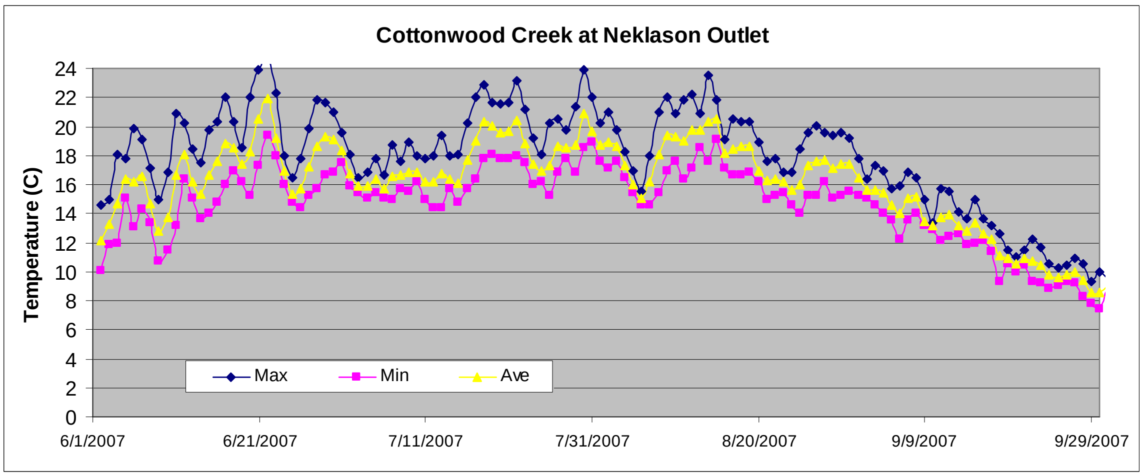
Cottonwood Creek Fecal Coliform and Temperature Evaluation



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Summary

Previous studies conducted by the Aquatic Restoration and Research Institute (ARRI) and the Alaska Department of Environmental Conservation (ADEC) have documented stream water temperatures and the abundance of fecal coliform bacteria within Cottonwood Creek that approach or exceed state water quality criteria (18 AAC 70). Stream water temperatures in Cottonwood Creek often exceed 15°C, and occasionally 20°C, from the outlet of Neklason Lake close to the top of the drainage to near Cook Inlet. Water temperatures are strongly correlated with regional air temperatures. Previous studies had not determined whether the high water temperatures and strong correlations are related to the stream and lake physical characteristics or to local urban development. This study addressed this question by comparing the temporal and spatial temperature regime of Cottonwood Creek with Meadow/Fish Creek, an adjacent similar spring-fed, lake and stream system that contains little urban development within the watershed.

Previous Cottonwood Creek studies conducted by ARRI and ADEC collected samples for fecal coliform bacteria monthly from April through September in 2004 and on four sampling dates in August of 2005. The abundance of fecal coliform bacteria found in these studies exceeded 20 cfu/100 ml and often 200 cfu/100 ml from sites located below the Park's Highway downstream to Surrey Road, which is approximately 2.0 km from the tidewater of Cook Inlet. Previous sampling did not differentiate between samples collected during base flow and those during storm runoff and sampling sites were too far apart to bracket potential sources. This study reports findings from fecal coliform sampling conducted during base flow, fall storm flows, and spring runoff from seven sampling locations distributed from Wasilla Lake to Surrey Road. Sampling locations bracketed a waterfowl concentration area at the outlet of Wasilla Lake, and areas of residential and commercial development.

Maximum water temperatures throughout Cottonwood Creek exceeded 13°C on most dates from June through September 2007. For example, 13°C was exceeded from 83% to 89% of the days, 15°C was exceeded from 67% to 81% of the days, and 20°C was exceeded from 2 to 39 days. Water temperatures were warmest in July and August and coolest in September. In June, average water temperatures exceeded 15°C from 70% to 87% of the days at all sites except Surrey Road where average water temperature exceeded 15°C 43% of the days. In July and August, 15°C was exceeded from 94% to 100% of the days at all sites except Surrey Road, where average water temperature in July and August exceeded 15°C from 51% to 64% of the days. Average water temperature exceeded 15°C from 0 to 20% of the days in September.

Geometric mean concentrations of fecal coliform bacteria were near 0 above and below Wasilla Lake, but increased to over 20 cfu/100 ml between the outlet of Wasilla Lake and Old Matanuska Road. Bacteria counts did not increase significantly (20 to 51 cfu/100 ml) downstream to Marble Way but increased to 176 cfu/100 ml between Marble Way and Surrey Road. Bacterial counts increased at all sites with increasing discharge following storm events with the largest increases occurring at Surrey Road. Bacterial counts during spring runoff were low, less than 20 cfu/100 ml at all locations.

Introduction

Cottonwood Creek, located in Wasilla, Alaska is in Category 5 for non-attainment of the residue standard for foam. Previous sampling conducted by ARRI determined that foam was most likely caused by the flushing of dissolved carbon from wetlands during runoff events. However, concomitant sampling revealed that stream water temperatures and concentrations of total fecal coliform bacteria exceeded state standards at multiple locations. High stream water temperatures in 2004 below Wasilla Lake coincided with a marked decrease in capture rates of juvenile coho salmon. Subsequent temperature sampling in 2005 measured high water temperatures from below Neklason Lake, Mud Lake and Wasilla Lake; with the upper tributaries and the lower creek considerably cooler. Water temperatures were strongly correlated with regional air temperature.

There has been a rapid rate of urban development throughout the Matanuska-Susitna Borough and the Cottonwood Creek watershed. Population growth is one of the fastest in the United States at a rate of 49% from 1990 to 2000 (Smith and Anderson, 2008). Urban and rural development can influence stream temperatures in a number of ways in addition to the removal of riparian vegetation. Removal of wetlands and increasing impervious surfaces can reduce water storage capacity and result in higher high flows and lower low flows. Reducing low flow stream volumes reduces the capacity of water to dissipate heat analogous to the dilution of other pollutants. High flows can also cause bank erosion and increase channel widths. Development increases impervious surfaces which lead to more warm water surface flow and less cool ground water flow. Sediment input in runoff can block the subsurface movement of water and the cooling or buffering effect provided by subsurface flow.

Previous measurements by ARRI and ADEC in 2004 through 2006 recorded water temperatures well above 20° C at multiple locations throughout Cottonwood Creek, specifically downstream from lake outlets. Based upon regression relationships with local air temperatures, stream water temperatures below Neklason Lake, Mud Lake, and Wasilla Lake will exceed 20 degrees Celsius when air temperatures are greater than 21.1°C (70 degrees Fahrenheit). Cooler water temperatures were measured in Dry Creek and Cottonwood Creek upstream of Neklason Lake and within the flowing channel downstream of Wasilla Lake (Davis et al. 2006). These areas likely serve as temperature refugia for juvenile salmon. Regression relationships with air temperatures were also much stronger for sites below lakes compared with stream sites. Poor regression relationships are due to localized buffering of water temperatures. Differences between sites were generally only by a couple of degrees. Therefore, only minor changes in the hydrologic or temperature budget may eliminate refugia sites that currently have lower temperatures.

Comparisons with other similar, but less developed stream and lake systems is one way that human influences can be evaluated. Cottonwood Creek is a groundwater fed system with slightly stained or brown water. In addition to the lakes, there are a number of areas where the stream channel is wide with slow water velocities. The substrate in many locations is composed of fine material colonized by aquatic macrophytes which is typical of systems that do not receive flushing flows during snowmelt or storm events. Similar stream systems within the area include the Meadow Creek/Big Lake/Fish Creek system. This stream and lake system is located approximately 15 miles to the west, is within the same ecoregion, is spring fed, stained, with slow moving open channels. These systems differ however, in the degree of development, which decreases in a northward direction. The water temperature regime within Cottonwood Creek was compared with stream temperatures within the Meadow Creek and Fish Creek system. Comparisons with stream and lake outlet water temperatures and regression relationships with air temperatures in Meadow/Fish Creek was used to determine if conditions in Cottonwood Creek are the result of increased urban development.

Monthly sampling for total fecal coliform bacteria was conducted in 2004. Relatively high concentrations of fecal coliform bacteria were observed in samples collected from below Wasilla Lake to Surrey Road. In 2005, samples were collected on four dates within 30 days in August and September upstream of Wasilla Lake, downstream from Wasilla Lake and at Surrey Road. Geometric means from four samples collected within 30 days were 10 cfu/100 ml upstream from Wasilla Lake, and greater than 100 cfu/100 ml below Wasilla Lake and at Surrey Road, consistent with 2004 sampling.

Fecal coliform bacteria are present in the digestive system of all warm blooded animals. Abundant fecal coliform bacteria may be due to waterfowl, nonfunctioning septic systems, surface runoff of dog waste, or other sources. It has been hypothesized that waterfowl congregations, downstream from the Palmer Wasilla Highway road crossing, may be a source of bacterial contamination. The lake outlet has open water all year and attracts dozens of ducks, particularly during the winter months. .

This project has been designed to address Alaska Water Quality Action Plan (ACWA) (http://www.dec.state.ak.us/water/acwa/ACWA_index.htm) Priority (a), for Cottonwood Creek near Wasilla. Previous data collection has recorded stream water temperature and fecal coliform bacteria concentrations that exceed State Water Quality Standards. Water sampling for total fecal coliform bacteria is necessary to determine the persistence and distribution of high values and to investigate potential sources. Replicate sampling in 2007 is compared with previous sampling in 2004 and 2005. Sampling stratified with storm flows and spring runoff helps to determine whether high counts are associated with surface or ground water sources, or both. Sampling above and below the waterfowl congregation area is conducted to determine if there is a causal relationship. Additional sampling sites are located within the stream reach previously identified to have high values. Sampling results help determine (1) whether waterfowl were the cause of high bacteria counts, (2) if high counts are found during base or storm flows, and (3) whether high counts are consistent among years.

Methods[1]

Water Temperature

Stream water temperatures were measured at six locations on Cottonwood Creek and four locations on Meadow/Fish Creeks (Figures 1 and 2). Cottonwood Creek sites were located below Neklason Lake, the Wasilla Lake inlet, at the Old Matanuska Road site, Edlund Road, Marble Way, and Surrey Road. Temperature loggers in the Big Lake system were placed in Little Meadow Creek upstream of the Park's Highway and near the old Hatchery at the Beaver Lake Road crossing and on Fish Creek below South Big Lake Road and below Knik-Goose Bay Road (Table 1).

Stream water temperature was measured using HOBO ProTemp or Onset Stowaway data loggers. Prior to deployment, loggers were checked for accuracy at 0° and 20°C. Loggers were placed within a well mixed section of the stream and secured to the bank using plastic coated wire rope. The loggers were deployed on May 15, 2007 in Cottonwood Creek and removed on October 10, 2007. The loggers were redeployed on May 15, 2008. The loggers were deployed on July 25, 2007 on Meadow Creek and Fish Creek and removed on October 10, 2007 and were redeployed on May 15, 2008. The loggers recorded water temperature every hour. The loggers were checked and downloaded approximately every other week.

Table 1. Site locations for stream water temperature measurements.

Site Name	Description	Latitude	Longitude	Elev (m)
Meadow Creek Upstream	Little Meadow Creek on Meadow Lakes Loop	61°35'30.9"	149°39'48.8"	110
Meadow Creek Downstream	Above Big Lake on Beaver Lake Road near old Hatchery	61°34'47.5"	149°49'25.9"	50
Fish Creek Upstream	Below Big Lake	61°32'00.0"	149°49'15.4"	56
Fish Creek Downstream	Below Knik Goose Bay Road	61°26'23.5"	149°46'57.7"	13
Cottonwood Creek at Neklason Lake	End of Zephyr Drive	61° 37' 27.58"	149° 17' 8.7"	122
Cottonwood Creek at Wasilla Lake Inlet	Below Seward-Meridian crossing	61 35 46.14	149 21 28.4	101
Cottonwood Creek at Wasilla Lake Outlet	Old Matanuska Road Bridge	61°34'30.14"	149°24'28.2"	95
Cottonwood Creek at Edlund Road	Below Edlund Road crossing	61°33'17.46"	149°29'8.56"	85
Cottonwood Creek at Marble Way	Marble Way Road crossing	61°32'33"	149°31'17"	66
Cottonwood at Surrey Road	Surrey Road crossing	61°31'31.33"	149°31'37.6"	30

[1] Also see Appendix C

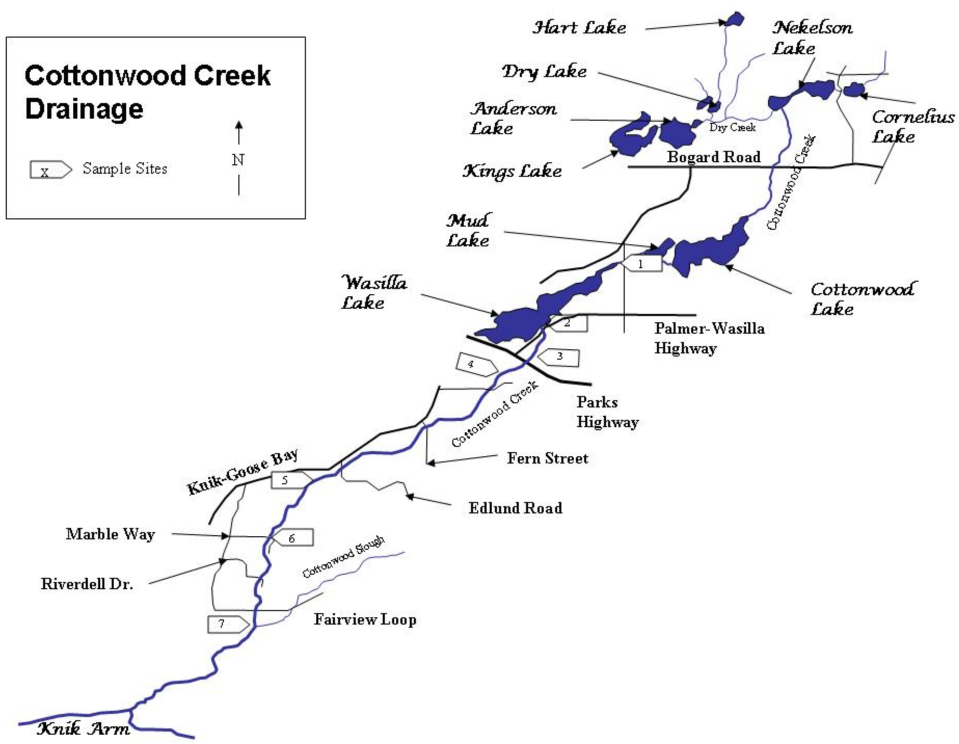

Figure 1. Cottonwood Creek drainage showing water sampling locations (drawing not to scale).

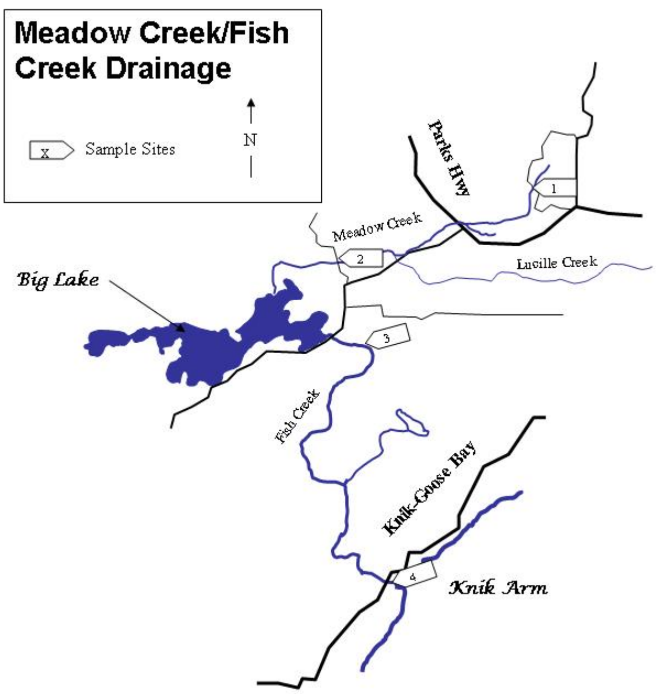

Figure 2. Meadow Creek and Fish Creek drainage showing temperature logger locations (drawing not to scale).

Daily maximum, minimum, and average water temperatures were derived from multiple measures recorded during a 24 hour period. The daily temperature range was taken from the difference between daily maximum and minimum values. Monthly cumulative degree days were calculated as the sum of average daily values (>0°C). The relationship between maximum stream and air temperatures was determined through regressions, with maximum air temperatures recorded at the regional airport in Palmer, Alaska. Regional air temperatures were downloaded from the NOAA web site (http://www.ncdc.noaa.gov/oa/ncdc.html). The slope of the regression line (regression coefficient) and r^2 values were used for comparisons. The intercept was set at 4°C for all regressions so that slopes could be compared among sites.

Fecal Coliform Bacteria

Sampling locations for fecal coliform bacteria analyses were located at the inlet to Wasilla Lake, Wasilla Lake Outlet, upstream from the Park's Highway Crossing, at the Old Matanuska Road, Edlund Road, Marble Way, and Surrey Road (Figure 1). Water samples were collected at these sites on July 30, August 1, 6, and 9 for base flow measures. Water samples were collected at Wasilla Lake Outlet, upstream of the Park's Highway, at the Old Matanuska Road, and at Surrey Road on September 10 and September 20, 2007 following storm events. Spring sampling occurred on April 8, April 23, May 5, and May 7, 2008.

Integrated water samples were collected using 60-ml sterile syringes. Water samples were discharged into sample bottles provided by the analytical laboratory. The water samples were stored within a cooler and transported to SGS in Anchorage within 4 hours of collection. Additional sampling and analytical methods are provided within the Quality Assurance Project Plan in Appendix A.

Other Measurements

Stream water stage height was recorded from a staff gauge located under the Old Matanuska Road crossing bridge. Stream discharge was calculated from a rating curve established previously (Davis and Davis 2006) or measured directly. Daily precipitation was obtained from weather data recorded at the Palmer Airport and downloaded from the NOAA web site referenced above.

Results

Water Temperature

Stream water temperature data for Cottonwood Creek and Meadow and Fish Creeks are shown in Figure 1 and Appendix A. Stream water temperatures within Cottonwood Creek were warm and consistently exceeded State Water Quality Standards from the Outlet of Neklason Lake to Surrey Road form June through September. State Water Quality Standards for the growth and propagation of fish, shellfish, other aquatic life, and wildlife, are found at 18 AAC 70.020(b)(10)(A)(iii) and state that water temperature,

> "May not exceed 20°C at any time. The following maximum temperatures may not be exceeded, where applicable: Migration routes 15°C, Spawning areas 13°C, Rearing areas 15°C, Egg & fry incubation 13°C. For all other waters, the weekly average temperature may not exceed site-specific requirements needed to preserve normal species diversity or to prevent appearance of nuisance organisms."

Maximum water temperatures throughout Cottonwood Creek exceeded 13°C on most dates from June through September, 2007. For example, using only those sites with a complete data set, 13°C was exceeded from 83% to 89% of the days, 15°C was exceeded from 67% to 81% of the days, and 20°C was exceeded from 2 to 39 days (Table 2). Water temperatures were warmest in July and August and coolest in September. In June, average water temperatures exceeded 15°C from 70% to 87% of the days at all sites except Surrey Road where average water temperature exceeded 15°C 43% of the days (Table 3). In July and August 15°C was exceeded from 94% to 100% of the days at all sites except Surrey Road, where average water temperature in July and August exceeded 15°C from 51% to 64% of the days. Average water temperature exceeded 15°C from 0 to 20% of the days in September.

Cottonwood Creek water temperatures were cooler in June of 2008. June cumulative degree days ranged from 402 to 433 among sites in 2008, down from a range of 439 to 508 in 2007 (Table 3). Average June water temperatures exceeded 15°C from 2 to 13 days among sites in 2008 compared to 13 to 26 in 2007. Differences between years likely were due to differences in air temperatures which were cooler in 2008. Stream water temperatures in Little Meadow Creek, Meadow Creek and Fish Creek also exceeded state standards. Maximum water temperatures at the Little Meadow Creek and Meadow Creek sites located upstream of Big Lake exceeded 13°C around 60% of the days from July 24 through September. This increased to 88% of the days at the Fish Creek site below Big Lake, and then decreased to 71% of the days at the site below Knik-Goose Bay Road. Stream water temperatures in Meadow Creek exceeded 15°C near 25% of the days, 50% below Big Lake, and 40% near Knik-Goose Bay Road. Stream water temperatures did not exceed 20°C in Meadow Creek, but exceeded this temperature 18 days below Big Lake, and once at the lower Fish Creek site.

Maximum daily stream water temperatures at all Cottonwood Creek and Meadow/Fish Creek sites were strongly correlated with maximum air temperatures recorded at the Palmer Airport (Figures 3 and 4). Regressions r^2 values were above 0.7 for all sites with complete data sets. While water temperatures at all sites were strongly correlated with air temperatures, this relationship varied among sites. Stream water temperature increased 0.70 to 0.80 degrees for every degree increase in air temperature at all of the Cottonwood Creek sites and the Fish Creek site below Big Lake. Stream water temperature at Surrey Road on Cottonwood Creek, the lower Fish Creek site, and the two Meadow Creek sites remained cooler increasing roughly 0.6 degrees for every degree increase in air temperature.

Table 2. Stream water temperature statistics for the Cottonwood Creek and Meadow Creek sampling sites in 2007.

	Season Maximum	Maximum Daily Range	Total Days	Days Max Temp >13	Percent of Total Days > 13	Days Max Temp >15	Percent of Total Days >15	Days Max Temp >20	June Cumulative Degree Days	July Cumulative Degree Days	August Cumulative *Degree Days	September Cumulative Degree Days	Regression Coefficient	Regression r^2
Little Meadow Creek at Meadow Lakes Loop	18.9	5.3	58	35	60%	24	41%	0	N/A	N/A	287*	288	0.60	0.79
Meadow Creek at Beaver Lakes Road	19.4	5.2	69	42	61%	28	41%	0	N/A	N/A	441	284	0.57	0.76
Fish Creek below Big Lake	22.6	3.7	69	61	88%	52	75%	18	N/A	N/A	578	416	0.79	0.80
Fish Creek below Knik-Goose Bay Road	20.7	4.3	69	49	71%	39	57%	1	N/A	N/A	486	326	0.64	0.76
Cottonwood Creek at Neklason Lake Outlet	24.5	7.6	122	108	89%	98	80%	39	506	552	551	363	0.78	0.71
Cottonwood Creek at Wasilla Lake Inlet	24.3	6.1	73	71	97%	64	88%	22	524	564	N/A	N/A	0.80	0.39*
Cottonwood Creek at Old Matanuska Road	24.3	6.3	122	109	89%	99	81%	34	508	569	557	383	0.78	0.72
Cottonwood Creek at Edlund Road	23.8	8.7	122	106	87%	98	80%	18	479	523	511	350	0.74	0.79
Cottonwood Creek at Marble Way	23.5	8.2	61	61	100%	58	95%	16	472	515	N/A	N/A	0.75	0.49*
Cottonwood Creek at Surrey Road	20.8	6.4	122	101	83%	82	67%	2	439	484	472	328	0.64	0.79

* Regression based upon partial data set.

Table 3. Summary by month of 2007 Cottonwood Creek average daily water temperature relative to State Water Quality Standards for each sampling site.

	Neklason Lake Outlet	Wasilla Lake Inlet	Wasilla Lake Outlet (Old Matanuska Road)	Edlund Road	Marble Way	Surrey Road
June Days Temperature Recorded	30	30	30	30	30	30
June Days Average Temp >13°C	28	29	27	27	27	25
Percent of June Days Average >13°C	93%	97%	90%	90%	90%	83%
June Days Average Temp >15°C	24	26	23	23	21	13
Percent of June Days Average Temp >15°C	80%	87%	77%	77%	70%	43%
June Days Average Temp >20C	2	2	2	1	1	0
July Days Temperature Recorded	31	31	31	31	31	31
July Days Average Temp >13C	31	31	31	31	31	31
Percent of July Days Average >13C	100%	100%	100%	100%	100%	100%
July Days Average Temp >15C	31	31	31	31	29	20
Percent of July Days Average Temp >15C	100%	100%	100%	100%	94%	65%
July Days Average Temp >20C	4	5	4	0	0	0
August Days Temperature Recorded	31	5	31	31	0	31
August Days Average Temp >13C	31	5	31	31	0	31
Percent of August Days Average >13C	100%	100%	100%	100%	N/A	100%
August Days Average Temp >15C	31	4	31	30	0	16
Percent of August Days Average Temp >15C	100%	80%	100%	97%	N/A	52%
August Days Average Temp >20C	2	0	2	0	0	0
Sept Days Temperature Recorded	30	7	30	30	0	30
Sept Days Average Temp >13C	13	5	14	10	0	5
Percent of Sept Days Average >13C	43%	71%	47%	33%	N/A	17%
Sept Days Average Temp >15C	5	0	6	0	0	0
Percent of Sept Days Average Temp >15C	17%	0%	20%	0%	N/A	0%
Sept Days Average Temp >20C	0	0	0	0	0	0
Total Days Temperature Recorded	122	73	122	122	61	122
Total Days Average Temp >13C	103	70	103	99	58	92
Percent of Total Days Average >13C	84%	96%	84%	81%	95%	75%
Total Days Average Temp >15C	91	61	91	84	50	49
Percent of Total Days Average >15C	75%	84%	75%	69%	82%	40%
Total Days Average Temp >20	8	7	8	1	1	0

Table 4. Temperature statistics for stream sampling locations in the spring (5/31 to 7/2) of 2008.

	Season Maximum	Maximum Daily Range	Total Days	Days Max Temp >13	Percent Mac Temp >13	Days Max Temp >15	Percent Max Temp >15	Days Max Temp >20	June Cumulative Degree Days	Days June Ave Temp >15	Percent Ave Temp >15
Old Mat Road	19.5	6.19	54	42	77.7	25	46.3	0	433	13	43.3
Edlund Road	21.0	8.89	54	47	87.0	33	61.1	2	433	13	43.3
Marble Way	19.8	8.04	54	45	83.3	29	53.7	0	417	6	20
Surrey Road	17.7	6.68	54	43	79.6	18	33.3	0	402	4	13.3
L. Meadow Cr.	17.2	6.85	34	23	67.6	11	32.3	0	358	0	0
Meadow Cr.	18.9	6.93	34	32	94.1	21	61.7	0	391	3	8.8
Fish Creek Below Big Lake	20.0	4.40	34	34	100	29	85.3	0	469	18	52.9
Fish Creek at Kink-Goose Bay	18.1	5.37	32	31	96.9	2	6.3	0	408	6	18.8

Using a regression slope of 0.8 and an intercept of 4°C, maximum water temperatures will exceed 13°C, 15°C, and 20°C, when maximum air temperatures exceed 54°F, 57°F, and 68°F, respectively. At a regression slope of 0.6, maximum water temperatures will exceed 13°C, 15°C, and 20°C, when maximum air temperatures exceed 59°F, 65°F, and 78°F, respectively.

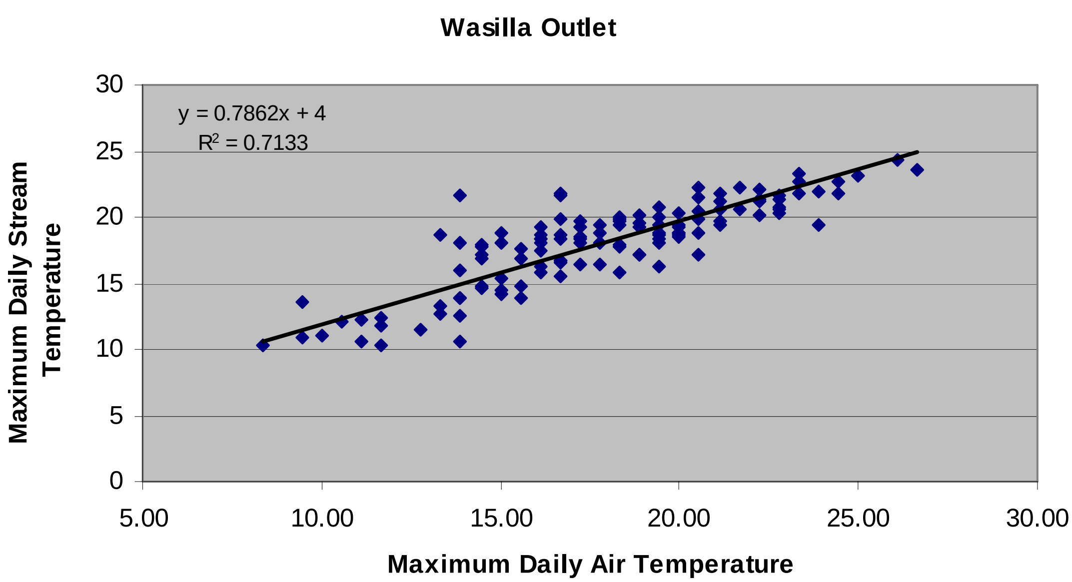

Figure 3. Regression relationship between maximum air and stream temperatures for Cottonwood Creek from data collected in 2007.

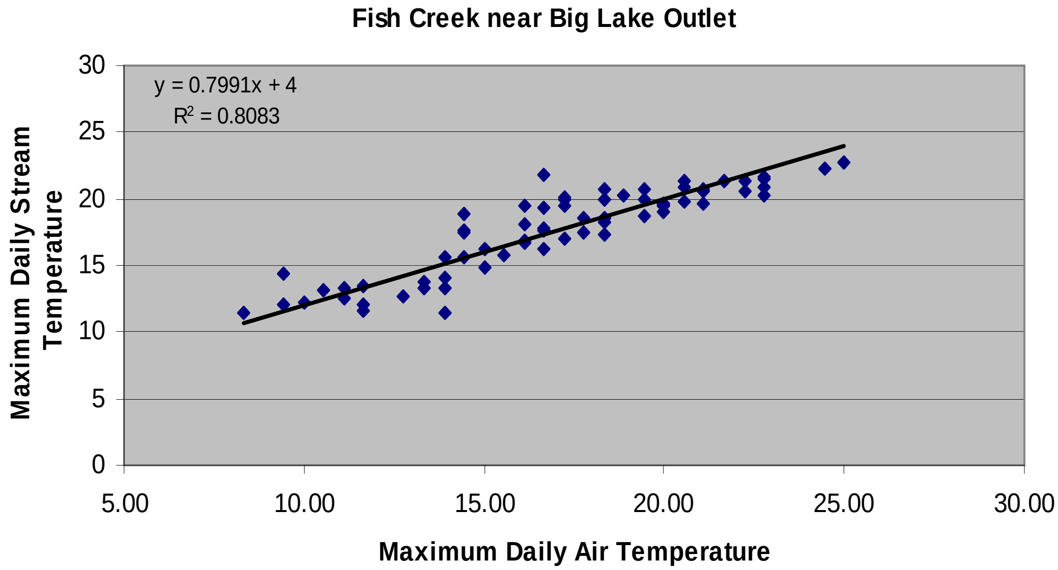

Figure 4. Regression relationships between maximum air temperature and maximum water temperature at Fish Creek from data collected in 2007.

Fecal Coliform Bacteria[2]

Fecal coliform bacteria concentrations exceeded State Water Quality Standards at all of the sampling sites downstream from the Parks Highway during base flow consistent with previous years sampling (Figure 5). Concentrations increased with increasing discharge during fall storms (Figure 6) but were lower during spring runoff. Geometric mean concentrations were highest at Surrey Road during all sampling periods.

The most stringent water quality standard[3] for fecal coliform bacteria in fresh water is found in 18 AAC 70.020(b)(3)(A)(i) for the designated use of water supply for drinking, culinary, and food processing. This standard states that "In a 30-day period, the geometric mean may not exceed 20 FC/100 ml, and not more than 10% of the samples may exceed 40 FC/100 ml." The geometric mean of four samples collected within a 30-day period during base-flow conditions in 2007 exceeded 20 cfu/100ml at the Old Matanuska Road, Edlund Road, Marble Way, and Surrey Road sites (Figure 4). At all of these sites, 25% to 75% of the samples exceeded 40 cfu/100 ml. Water sampling in 2004 was conducted monthly as an initial screening, so 30-day means can not be calculated. However, geometric means calculated from six monthly samples, April through September, exceeded 20 cfu/100 ml at all of the sites from Old Matanuska Road to Surrey Road (Davis and Davis 2005). At least one sample at all of these sites exceeded 40 cfu/100 ml. Sampling in 2005 was conducted at the Old Matanuska Road site, and Surrey Road. Four samples were collected from August 2 through August 30. Geometric means exceeded 20 cfu/100 ml and at least 25% of the samples exceeded 40 cfu/100 ml (Davis et al. 2006).

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[2] See Appendix B for fecal coliform bacteria values for all sites and dates.
[3] State Water Quality Standards only apply to human-caused pollution.

The more applicable designated use for this portion of Cottonwood Creek is contact recreation. The State Water Quality Standard for water recreation, contact recreation (18 AAC 70.020(b)(3)(B)(i)) requires that, "In a 30-day period, the geometric mean of samples may not exceed 100 FC/100 ml, and not more than one sample, or more than 10% of the samples if there are more than 10 samples, may exceed 200 FC/100 ml." This standard was exceeded during base flow conditions at the Surrey Road site where the geometric mean during base flow was 176 cfu/100 ml and 50% of the samples exceeded 200 cfu/100 ml. In 2004 the 30-day mean could not be calculated; however, the geometric mean from monthly samples exceeded 100 cfu/100 ml and at least 1 of 6 samples at Old Matanuska Road and Surrey Road exceeded 200 cfu/100 ml. In 2005, this standard was not exceeded using the four samples collected within a 30-day period in August at Old Matanuska Road and Surrey Road (Figure 6).

Water samples were collected from the outlet of Wasilla Lake above the Palmer Wasilla Highway and upstream from the Parks Highway and analyzed for fecal coliform bacteria to isolate potential impacts from waterfowl that congregate in this area. We compared concentrations of fecal coliform bacteria from these two locations for each sampling date in 2007. There was a significant increase (one tailed paired t-test, $p<0.05$) in fecal coliform bacteria from August and September, 2007 samples. The geometric mean from four samples collected during base flow conditions was 0.71 cfu/100 ml at the Wasilla Lake outlet, and 16.54 upstream from the Park's Highway. During higher flows following fall storms, geometric means (2 samples) increased from 4.6 to 61.9 cfu/100 ml between these two sites. However, we did not observe any waterfowl below the Palmer Wasilla Highway in August and saw only two ducks during the September sampling events.

Comparisons among sites during base flow and storm conditions showed that fecal coliform concentrations increased at two locations: between the outlet of Wasilla Lake and the Parks Highway and again between Marble Way and Surrey Road (Figure 7). Plotting the concentration of fecal coliforms by river mile showed that concentrations were not increasing steadily with distance downstream, but that increases are associated with specific river reaches.

We considered any rapid change in stream discharge following precipitation events storm flows, with base flow occurring at all other times. Comparisons between base flow and storm flow conditions were used to determine potential sources of bacteria. Increases following storm flows are an indication that concentrations in surface storm water runoff are greater than concentrations in receiving waters. Cottonwood Creek discharge increased from 14.9 to 15.7 on September 10, following 0.18 inches of rain recorded at the Palmer Airport. Discharge on September 20 increased from 15.7 to 18.1 cfs following 0.24 inches of rain. Geometric mean concentrations increased significantly (paired t-test, $p<0.05$), using data from the four sites used for storm comparisons, following fall storms. Concentrations increased from a minimum of 4 cfu/100 ml at the Wasilla Lake outlet to 75 cfu/100 ml at Surrey Road (Figure 5).

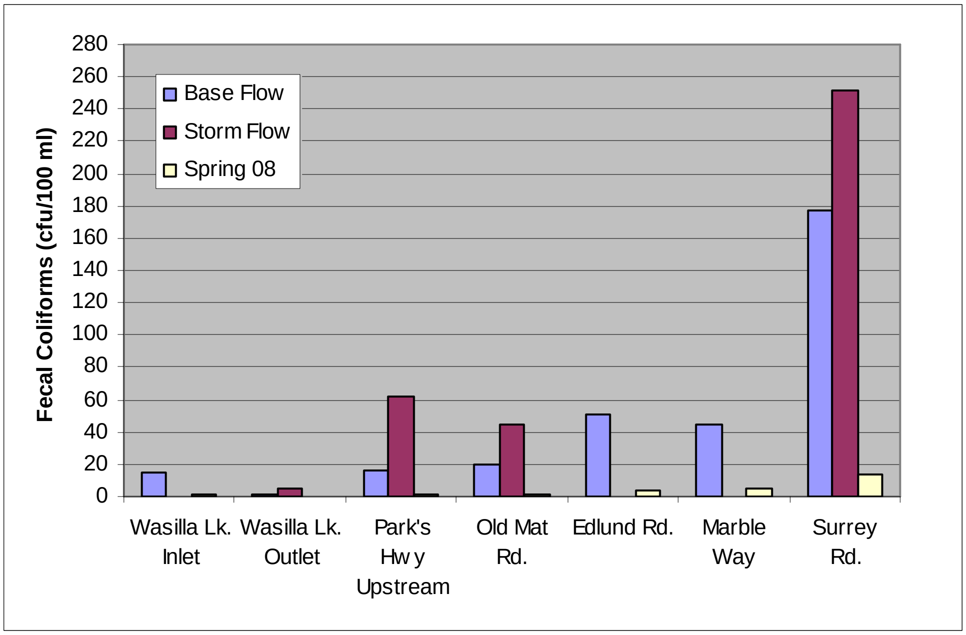


Figure 5. Geometric mean concentrations of fecal coliform bacteria during base flow and following storms at the Cottonwood Creek sampling locations in 2007 and spring 2008.

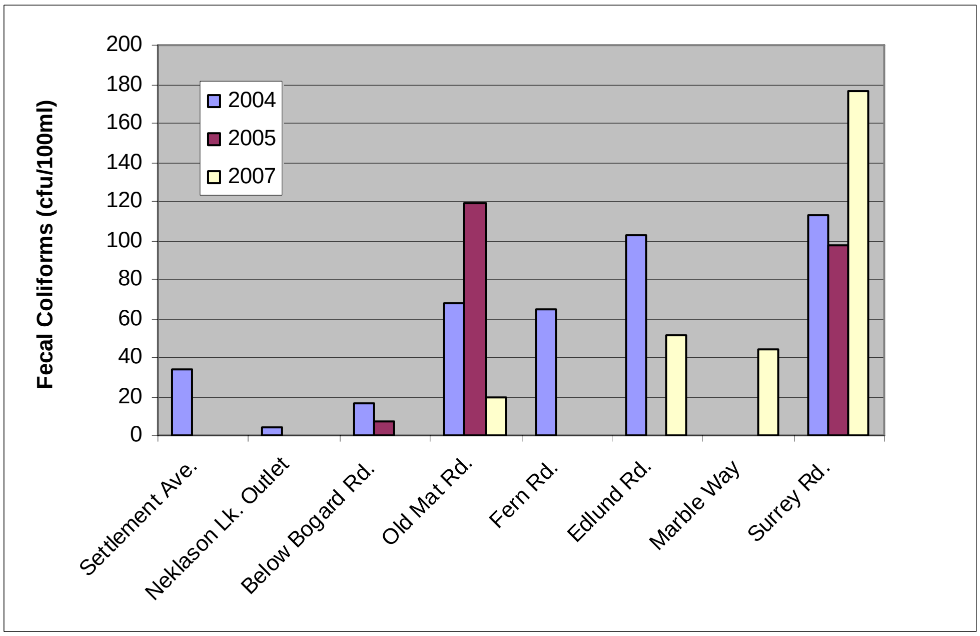


Figure 6. Geometric mean fecal coliform concentrations at Cottonwood Creek sampling locations in 2004 (mean from six monthly samples), 2005 (30-day mean), and 2007 (30-day mean during base flow).

Stream water nutrients were sampled concurrently with fecal coliforms in 2004 and 2005. Nitrogen concentrations were not correlated with increases in fecal coliform bacteria. Concentrations of nitrate+nitrite-N were extremely low and generally below detection limits (Davis et al. 2006). Ammonia-N concentrations were well below acute and chronic toxicity values (acute standard is 5.6 mg/L at pH 8.0 (ADEC 2003)). Maximum ammonium-N concentration measured was 0.34 mg/L. Ammonium concentrations tended to be higher from upstream of Mud Lake to Edlund Road, decreasing at Marble Way and Surrey Road (Figure 8).

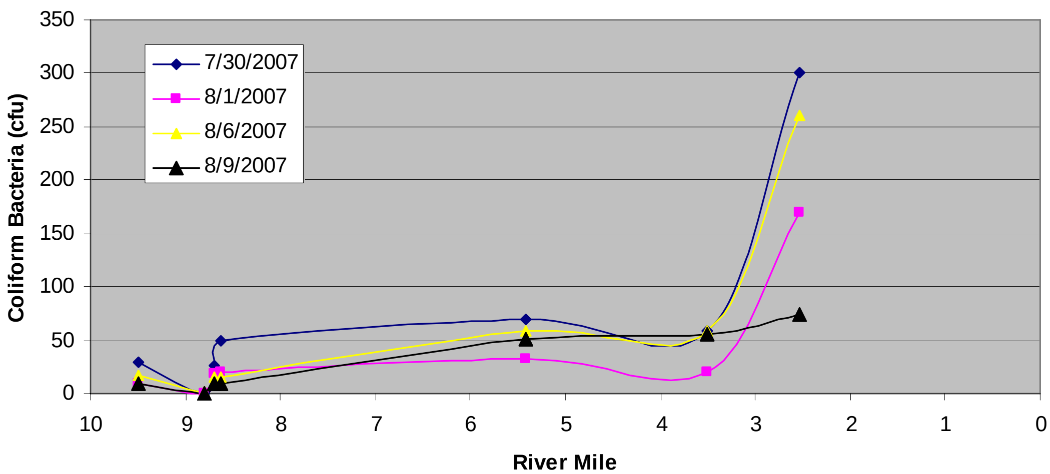


Figure 7. Fecal coliform bacteria concentrations by river mile upstream. Concentrations increase near river mile 8.6 upstream of the Park's Highway and between Marble Way (River Mile 3.5) and Surrey Road (River Mile 2.5).

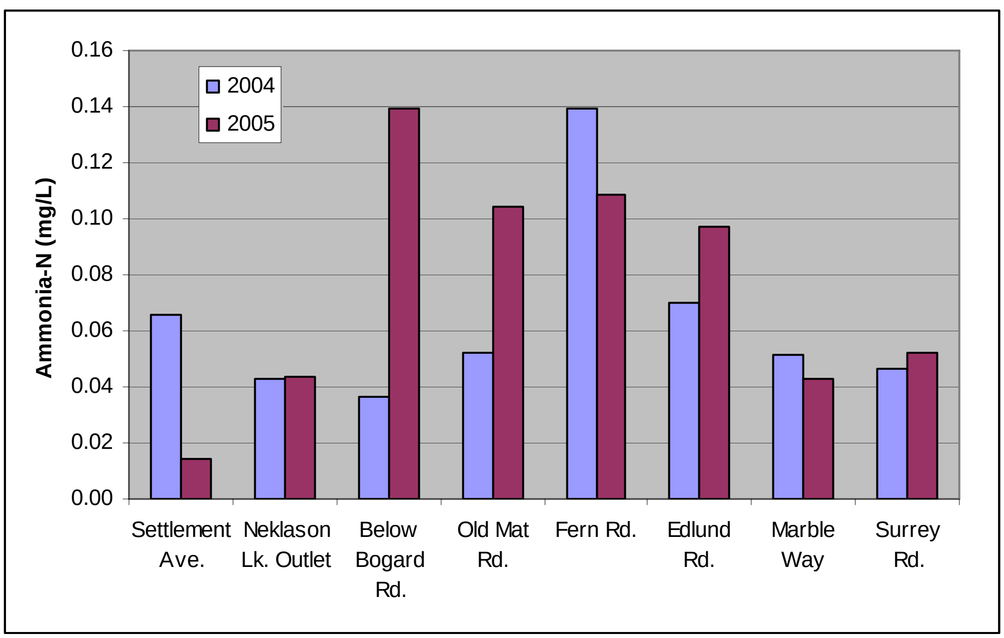


Figure 8. Mean concentrations of ammonia nitrogen for 2004 (six monthly samples) and 2005 (30-day mean).

Discussion

Water Temperature

The high water temperatures within Cottonwood Creek are consistent with other regional lake dominated stream systems and do not appear to be due to local urbanization. The exchange of solar energy occurring at the large surface area of lakes likely masks any potential influence of other development and other processes influencing stream temperatures.

The temperature of stream water is a function of energy inputs from solar radiation, conduction from the surrounding air influenced by convection and advection, and convection through tributary and ground water sources. Changes in stream water temperatures can be buffered by hyporheic and ground water exchange. Removal of the riparian vegetation can increase solar input and can allow for the convection of warm air across the water surface. Increases in channel width and the presence of lakes also can increase the available surface water for energy exchange through solar radiation and conduction between the air and water surface. Decreases in stream discharge reduce the heat dissipative capacity of the receiving water. Stream water temperatures can be reduced by the inflow or convection of relatively cooler water through tributaries or groundwater inputs. The evaporation of surface water also reduces stream temperatures by releasing water with a high temperature load (Poole and Berman 2001).

The slope and tightness of the regression line between daily air and water temperatures allows for comparisons among regional stream systems or within a stream over time that often varies due to differences in regional or annual air temperatures. A strong correlation (high r^2 value) between daily air and stream temperatures indicate a rapid response of streams to changing climate conditions. A strong correlation between daily air and stream temperatures means that solar energy is the major factor controlling water temperatures. The slope of the regression line shows how rapidly energy is transferred from the air to the water.

Cottonwood Creek upstream of Cornelius Lake has a very poor correlation with daily air temperatures and a low r^2 value of 0.26 (Table 5). Water temperature at this location on Cottonwood Creek is controlled by groundwater discharge. A short distance downstream below Cornelius and Neklason Lakes (115 acres of lake surface area) stream water temperatures are strongly correlated with air temperatures with an r^2 value of 0.8. The presence of the two lakes also provides for a rapid change in water temperature with a regression slope of 0.8. This means that the water temperature increases 0.8°C for every degree increase in air temperature. The relationship between air and water temperatures is maintained at the Old Matanuska Road site, located below Wasilla Lake where the regression slope is 0.8 and the r^2 value ranged from 0.7 to 0.9 among years. The response of stream temperatures to changing air temperatures is lower downstream at the Surrey Road crossing where the regression slope is 0.6. The differences between these two sites can be related to the water surface area exposed to direct sunlight. The Old Matanuska Road site is located below Wasilla Lake which has a surface area of 350 acres. The

Surrey Road site is located 6 miles downstream and the stream channel flows through a well developed riparian area of mixed birch and spruce forest.

Fish Creek below Big Lake (2,500 acres of lake surface area) also showed a strong correlation and steep regression line between air and water temperatures. The slope of the regression line and r^2 value was 0.8, the same as in Cottonwood Creek from Neklason Lake to below Wasilla Lake. The slope of the regression line between daily air and water temperatures in Fish Creek downstream at Knik-Goose Bay Road was 0.6 with and r^2 of 0.8, which is the same as Cottonwood Creek at Surrey Road. Therefore, stream water temperatures and the relationship between air and water temperature was the same when comparing Cottonwood Creek which flows through the city of Wasilla and the relatively undeveloped Fish Creek.

Stream water temperature data also is available for Question Creek below Question Lake near Talkeetna, and Nancy Creek below Nancy Lake near Willow (Davis and Davis 2008). Stream water temperatures at these two sites also were strongly correlated with daily air temperatures with r^2 values of 0.8 and responded rapidly to changes in air temperatures with regression slopes of 0.8. Therefore, water temperatures in streams below these two lakes are the same as sites on Cottonwood Creek and Fish Creek.

Stream water temperatures in all of these streams are near the tolerance values for pacific salmon. Based upon a literature review, Richter and Kolmes (2005) found that optimal rearing temperatures for coho salmon juveniles range between 12 and 17°C. Coho salmon growth optimal temperature is near 15°C. Upper lethal temperatures for coho salmon juveniles have been reported from 25.8°C to 29.2°C. However, behavior, swimming speed, and the occurrence of disease can all be affected at temperatures below the lethal range. Richter and Kolmes (2005) report that temperature refugia are important for maintaining salmonid populations, which appears to be the case within Cottonwood Creek. The presence of riparian vegetation along the lower and upper river sites allows for cooling of stream water and likely provides refugia for juvenile salmon. The maintenance of riparian vegetation, therefore, is critical for the survival of salmon within Cottonwood Creek.

Historic Temperatures

Stream water temperatures and the relationship between air and water temperature has not changed relative to previous measures in 1958. Average daily water temperatures for 1958 were recorded and reported by the U.S. Fish and Wildlife Service (Whitesel et al. 1959) (Table 4). Stream water temperatures are very similar to 2007 values. Average stream water temperatures in 1958 exceeded 20°C on 6 dates. In 2007, average water temperature exceeded 20°C on 8 days, very similar to the 1958 data. The slope of the regression line between air and water temperature was the same (0.8) in 1958 as measured in 2007, and the r^2 values also were the same at 0.7.

Table 5. Water temperature statistics for multiple Cottonwood Creek sites.

Site	Season Maximum	Maximum Daily Range	Total Days	Days Max Temp >13	Days Max Temp >15	Days Max Temp >20	June Cumulative Degree Days	July Cumulative Degree Days	August Cumulative Degree Days	September Cumulative Degree Days	Regression Coefficient	R squared
Site 0 Dry Creek (2005)									386		0.65	0.42
Site 1 Above Cornelius Lake (2005)									154		0.08	0.26
Site 1b Neklason Lake Outlet (2005)									431		0.77	0.64
Site 1b Neklason Lake Outlet (2007)	24.6	7.6	122	108	98	39	506	552	551	363	0.79	0.77
Site 3 Below Bogard (2004)	25.0	6.6	107	82	75	29	521	279*	542	262	0.69	0.84
Site 3b Wasilla Lake Inlet (2005)									417		0.79	0.5
Site 3b Wasilla Lake Inlet (2007)	24.3	6.1	73	71	64	22	524	564	N/A	N/A	0.80	0.39
Site 4 Old Mat Road (1958)**	22.8	N/A	72	58	50	6	N/A	510	467	N/A	0.82	0.67
Site 4 Old Mat Road (2004)	26.8	6.5	107	90	84	48	556	302*	586	326	0.77	0.87
Site 4 Old Mat Road (2005)									418		0.81	0.50
Site 4 Old Mat Road (2007)	24.3	6.3	122	109	99	34	508	569	557	383	0.78	0.71
Site 6 Edlund Road (2005)									383		0.72	0.45
Site 6 Edlund Road (2007)	23.8	8.7	122	106	98	18	479	523	511	350	0.74	0.79
Site 6b Marble Way (2007)	23.5	8.2	61	61	58	16	472	514	0	0	0.75	0.49
Site 7 Surrey Road (2004)	21.6	5.4	107	80	68	4	474	257*	486	241	0.59	0.82
Site 7 Surrey Road (2005)									364		0.68	0.44
Site 7 Surrey Road (2007)	20.8	6.4	122	101	82	2	439	484	472	328	0.64	0.71

* based upon incomplete data set.
** calculated from average daily values rather than maximums (Whitesel et al 1959).

Total Fecal Coliform Bacteria

Total fecal coliform bacteria have consistently exceeded State Water Quality Standards from the Old Matanuska Road to Surrey Road. Exceedences measured during base flow conditions are exacerbated during fall storms, but are not observed during spring runoff. We hypothesize that fecal coliform contamination is occurring at specific locations and the bacteria are being carried downstream in the water column and then measures again at downstream locations. Precipitation events likely are causing increased inputs from storm runoff or resuspension of bacteria from the stream bed during increasing stream flows. Low concentrations during spring flows likely are due to frozen soils and colder water that does not support bacterial growth.

We measured a significant increase in fecal coliform bacteria concentrations between the outlet of Wasilla Lake and the Park's Highway. Concentrations did not increase significantly among sites from the Park's Highway to Marble Way. We hypothesize that contamination is resulting from congregations of waterfowl at the Wasilla Lake outlet or from storm runoff at the Park's Highway. The bacteria persist in the water and sediment and are transported downstream in the water column and attached to sediment particles.

Waterfowl were investigated as a potential source of fecal coliform contamination between Wasilla Lake and the Park's Highway. We did not observe large concentrations of waterfowl during our base flow or storm sampling. However, waterfowl may still be the source of contaminates. Fecal coliform bacteria contamination from waterfowl may be accumulating and growing on the organic-rich silt substrate within this stream reach. Studies conducted in other locations have found waterfowl to be the source of fecal coliform bacteria contamination. For example, DNA fingerprinting determined that waterfowl were the source of 68 to 99% of the E. *coli* found living in periphyton communities in Lake Superior (Ksoll et al. 2007). Hyer and Moyer (2008) also using genetic markers found ducks to be a source of *E.* coli in Virginia streams.

The bacteria released by waterfowl can survive within the stream bottom sediments. Many studies have found that fecal coliform bacteria can live within soils, periphyton, or the substrate of fresh water streams, and that bacteria living within or attached to the substrate can be resuspended into the water column. Previous studies have measured an increase in fecal coliform bacteria following dredging projects suggesting the presence of fecal coliform bacteria in bottom sediment and their suspension into the water column when the sediments are disturbed (Grimes 1975). Bacteria have been found to persist in stream sediments for up to 4 months with no additional inputs (Stedtfeld et al. 2006). Persistence within the sediment is related to water temperature, solar radiation, and organic matter content (Duran et al. 2004, Jamieson et al. 2004 as cited in Duran et al. 2004). Survival within the sediments may be greater than within the water column due to constant temperatures, higher nutrient concentrations, less vulnerability to predation, and less ultraviolet radiation (Evanson and Ambrose 2006). Studies have also confirmed that increases in fecal coliform bacteria are associated with the resuspension of bacteria on or associated with bottom sediments (Fries et al. 2006, and 2008). Increasing flows can cause the resuspension of bottom sediment and bacteria, which when suspended in the water column, can be transported downstream.

The increase in fecal coliform bacteria during storm flows can be explained by the resuspension of sediments contaminated by waterfowl, but also could be related to stormwater runoff. Stormwater runoff entering Cottonwood Creek from drainage along the Park's Highway may be causing increases in fecal coliform bacteria. Byappanahalli and Fujioka. (2004) found that fecal coliform can survive in terrestrial soils and be transported during storm runoff. Mallin et al. (2000) evaluated fecal coliform concentrations from a number of watersheds that varied in the degree of urban development. Fecal coliform concentrations were correlated with turbidity and nitrates. Fecal coliforms were positively correlated with impervious surface area and stormwater transport which explained 95% of the variability.

The low concentration of bacteria in spring runoff samples does not rule out stormwater as a source of contamination. The primary difference between spring runoff and other measures of fecal coliform contamination is the surrounding soil conditions. Spring surface runoff occurred primarily during April and May in 2007. Surface water was apparent on street surfaces and in drainage ditches, and there was an increase in stream flow. However, there was still ice present on the surface of Wasilla Lake, and though not measured directly, soils appeared to be frozen. Cold or frozen soils would reduce biotic activity and vertical water movement. Both of these factors could influence the stream concentrations of fecal coliform bacteria. Seasonal variability in fecal coliform bacteria has been documented, with concentrations increasing during warmer summer months (Hyer and Moyer 2008).

Fecal coliform bacteria from septic or sewer systems also must be considered as a potential source of fecal coliform contamination. Only a small portion of Wasilla is serviced by a municipal wastewater system (The Nature Conservancy 2007) which includes the business and residences along the Park's and Palmer Wasilla Highway intersection. Sewer lines pass under Cottonwood Creek at the Old Matanuska Road site and at Glennwood Avenue, just downstream (The Nature Conservancy 2007). Leakage of these main lines would result in high contamination levels at the Old Matanuska Road site or Edlund Road site which are downstream from the Park's Highway. The low bacterial counts obtained through this study are not consistent with sewer line leakage.

Fecal contamination from failing septic systems may be more likely between Marble Way and Surrey Road. This area is not serviced by a Municipal or Borough sewer system and there is a relatively high concentration of homes within developments along Cottonwood Creek in this area. Groundwater transport of fecal coliform bacteria can occur at high velocities through microscopic pathways (Taylor et al. 2004 as cited in Duran et al. 2004). Increases in bacterial counts due to failing septic systems should be accompanied by increases in nitrogen. However, concentrations of nitrogen were lowest at the Surrey Road site, which suggests that high bacterial counts are due to other sources Development also has resulted in an increase in impervious surfaces which may be influencing potential contamination from stormwater runoff. Other possibilities include concentrations of waterfowl or wildlife in more secluded areas that occur through this reach.

Additional work needs to be done to identify the source or sources of fecal coliform bacteria along Cottonwood Creek in order to refine management options. The stream sediment below the waterfowl congregation area at the outlet of Wasilla Lake could be sampled to determine the extent and seasonal variability in fecal coliform bacteria contamination. Measures of genetic markers (i.e. Hyer and Moyer 2008 or Ksoll et al. 2007) could be used to compare with the genetic composition of waterfowl bacteria to further evaluate this source. Evaluation of potential stormwater runoff at the Park's Highway could be investigated by collecting and analyzing runoff during storm events and by sampling upstream and downstream from the discharge site.

Further investigation would be necessary to identify the source of fecal coliform bacteria between Marble Way and Surrey Road. Stream surveys could be conducted to identify locations of potential sources such as septic drain fields in close proximity to the flowing channel, livestock, waterfowl, pets, storm-water outfalls or road-side ditches. Sampling locations should be established that bracket road crossings and other areas of potential stormwater discharge. Sampling at multiple locations throughout this reach bracketing potential sources could further isolate the causes of fecal coliform contamination.

Literature Cited

Alaska Department of Environmental Conservation. 2003. Alaska Water Quality Criteria Manual for Toxic and Other Deleterious Organic and Inorganic Substances.

Byappanahalli, M., and R. Fujioka. 2004. Indigenous soil bacteria and low moisture may limit but allow faecal bacteria to multiply and become a minor population in tropical soils. Water Science Technology 50: 27-32.

Davis, J.C., and G.A. Davis. 2008. Assessment and Classification of Matanuska-Susitna Fish Habitat—Stream Water Temperature. Final Report for the U.S. Fish and Wildlife Service. Aquatic Restoration and Research Institute, Talkeetna, Alaska.

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

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

Duran, M. R.D. Stedtfeld, B.Z. Haznedaroglu, and S.A. Hashsham. 2004. Detection and occurrence of indicator organisms and pathogens. Water Environmental Research 77:659-717.

Evanson, M. and R.G. Ambrose. 2006. Sources and growth dynamics of fecal indicator bacteria in a coastal wetland system and potential impacts to adjacent waters. Water Research 40: 475-486.

Fries, J.S., G.W. Characklis, and R.T. Noble. 2006. Attachment of fecal indicator bacteria to particles in the Neuse River Estuary, N.C. Journal of Environmental Engineering, October 2006: 1338-1345.

Fries, J.S., G.W. Characklis, and R.T. Noble. 2008. Sediment-water exchange of Vibrio sp. And fecal indicator bacteria: Implications for persistence and transport in the Neuse River Estuary, North Carolina, USA. Water Research 42: 941-950.

Grimes, D.J. 975. Release of sediment-bound fecal coliforms by dredging. Applied Microbiology, 29:109-111.

Hyer, K.E., and D.L. Moyer. 2003. Patterns and sources of fecal coliform bacteria in three streams in Virginia, 1999-2000. U.S. Geological Survey, Water-Resources Investigations Report 03-4115.

Jamieson, R.C., J.H. Lee, R. Kostaschuk, R.J. Gordon. 2004. Persistence of enteric bacteria in alluvial streams. Journal of Environmental Engineering Science 3: 203-212.

Ksoll, W.B., S. Ishii, M.J. Sadowsky, and R.E. Hicks. 2007. Presence and sources of fecal coliform bacteria in epilithic periphyton communities of Lake Superior. Applied Environmental Microbiology 73(12):3771-3778.

Mallin, M.A., K.E. Williams, E. C. Esham, and R.P. Lowe. 2000. Effect of human development on bacteriological water quality in coastal watersheds. Ecological Applications 10: 1047-1056.

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

Richter, A. and S.A. Kolmes. 2005. Maximum temperature limits for Chinook, Coho and chum salmon and steelhead trout in the Pacific northwest. Reviews in Fisheries Science 13, 1: 23-49.

Smith, C., and J. Anderson. 2008. Conserving Salmon Habitat in the Mat-Su Basin. The strategic action plan of the Mat-Su Basin Salmon Habitat Partnership, 2008. The Nature Conservancy, Anchorage, AK.

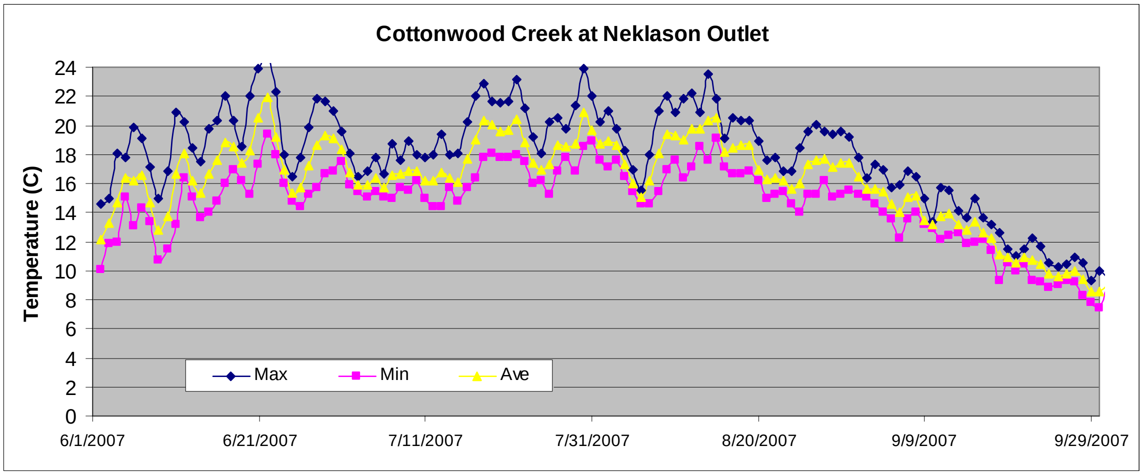
Stedtfeld, R.D., M. Duran, E.W. Alm, and S.A. Hashsham. 2006. Detection and occurrence of indicator organisms and pathogens. Water Environmental Research 78: 1054-1077.

Taylor, R. A. Cronin, S. Pedley, J. Barker, and T. Atkinson. 2004. The implications of groundwater velocity variations on microbial transport and wellhead protection – review of field evidence. FEMS Microbiol Ecology 45: 17-26.

The Nature Conservancy. 2007. Spatial data for priority waterbodies in the Mat-Su Borough. Nature Conservancy, Anchorage, AK.

Whitesel, L.E., R.W. Allin, K. Beisinger, N. Chaberlain, L. McGowan. 1959. Environmental studies of the rainbow trout of Alaska—Wasilla Lake. U.S. Fish and Wildlife Service, Federal Aid in Fish Restoration, Project F-1-R-8, Game Fish Investigations, Volume 8, Report No. 4, Work Plan C, Job (2c). Juneau, AK

Appendix A—Water Temperature Graphs


Cottonwood Creek at Neklason Outlet
Temperature (C)
24
22
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18
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Ave
6/1/2007
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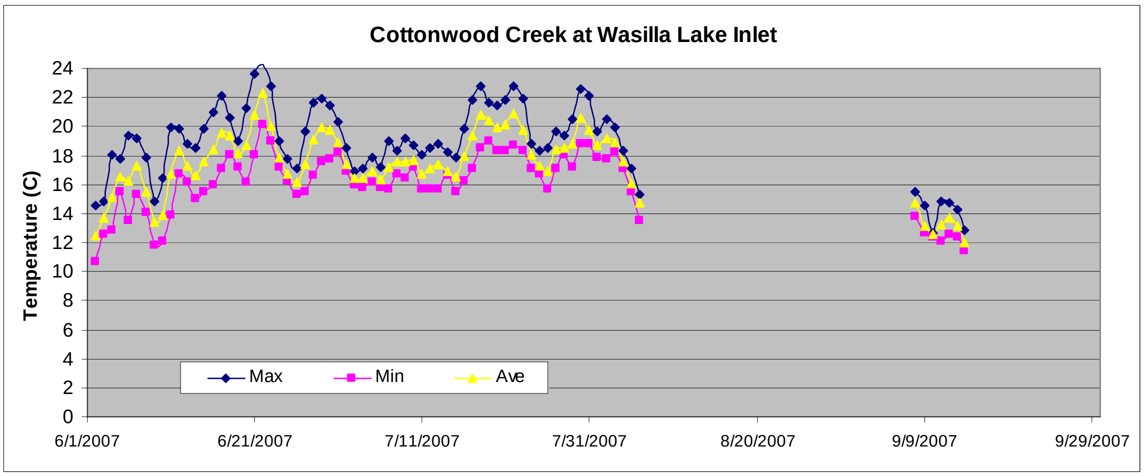
9/9/2007
9/29/2007


Cottonwood Creek at Wasilla Lake Inlet
Temperature (C)
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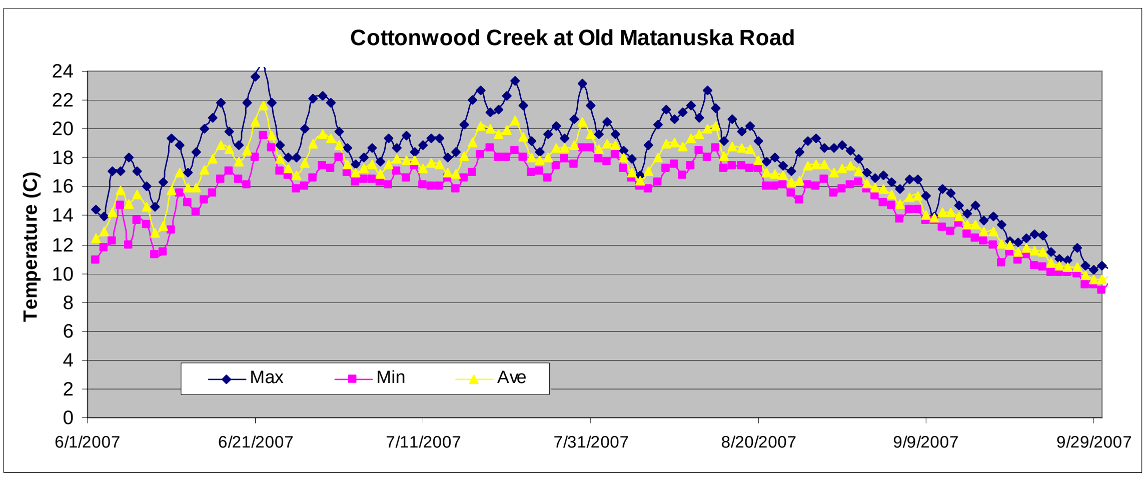
9/9/2007
9/29/2007


Cottonwood Creek at Old Matanuska Road
Temperature (C)
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22
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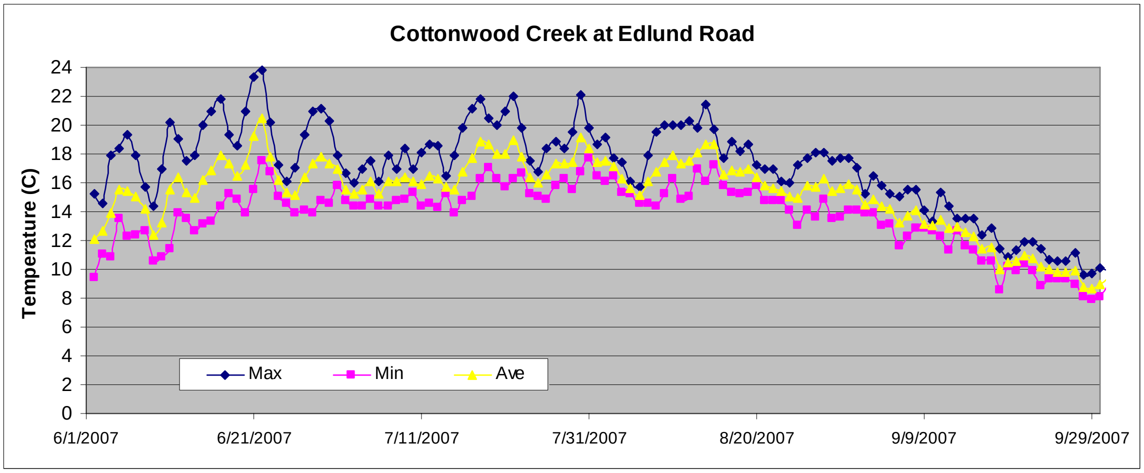
6/1/2007
6/21/2007
7/11/2007
7/31/2007
8/20/2007
9/9/2007
9/29/2007


Cottonwood Creek at Edlund Road
Temperature (C)
24
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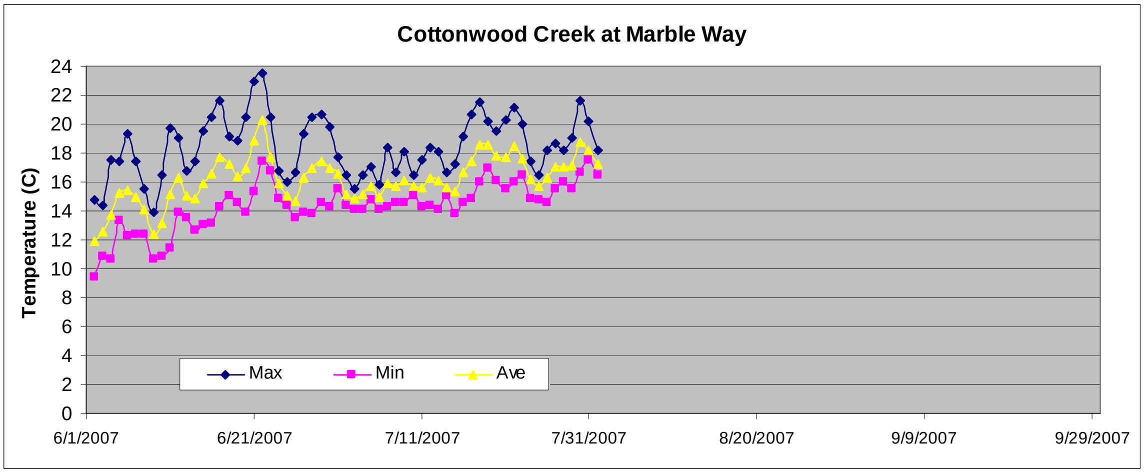
9/9/2007
9/29/2007


Cottonwood Creek at Marble Way
Temperature (C)
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20
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16
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12
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Ave
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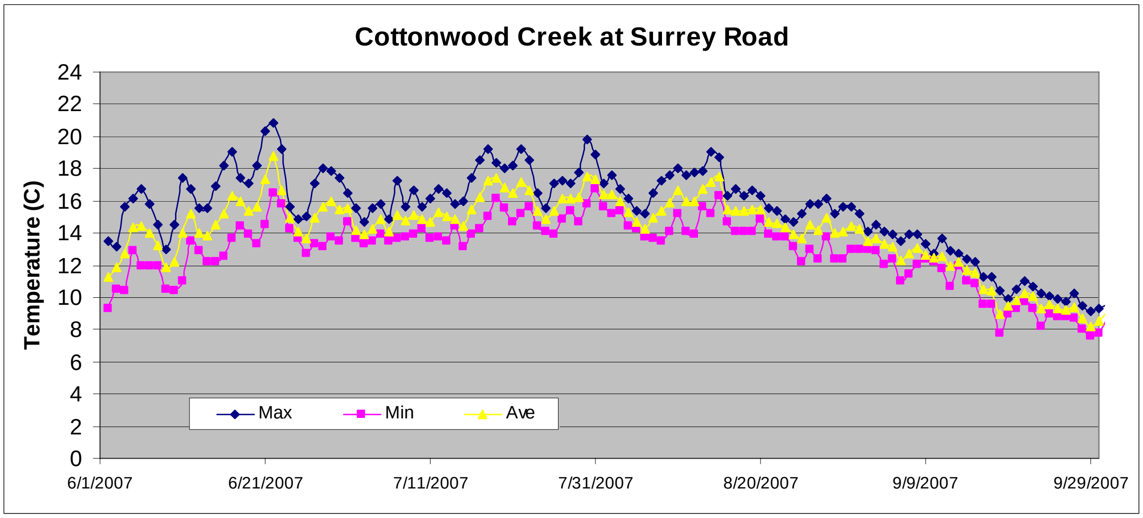
9/9/2007
9/29/2007


Cottonwood Creek at Surrey Road
Temperature (C)
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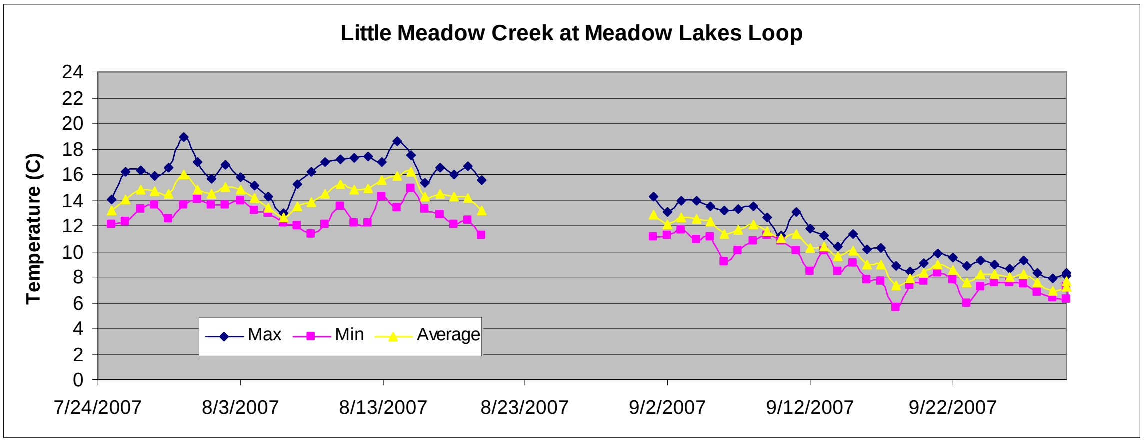
Little Meadow Creek at Meadow Lakes Loop
Temperature (C)
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22
20
18
16
14
12
10
8
6
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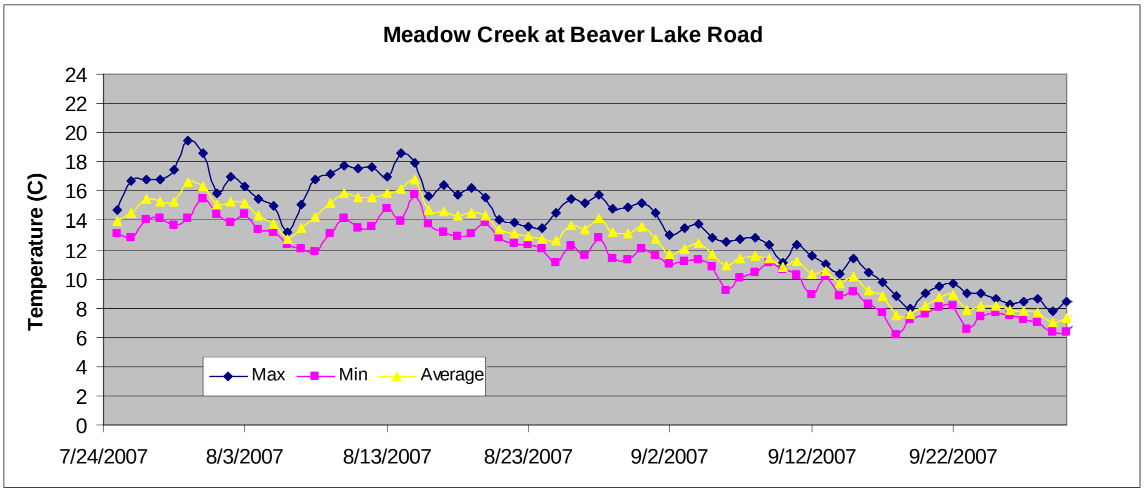
9/22/2007
Max
Min
Average


Meadow Creek at Beaver Lake Road
Temperature (C)
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22
20
18
16
14
12
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6
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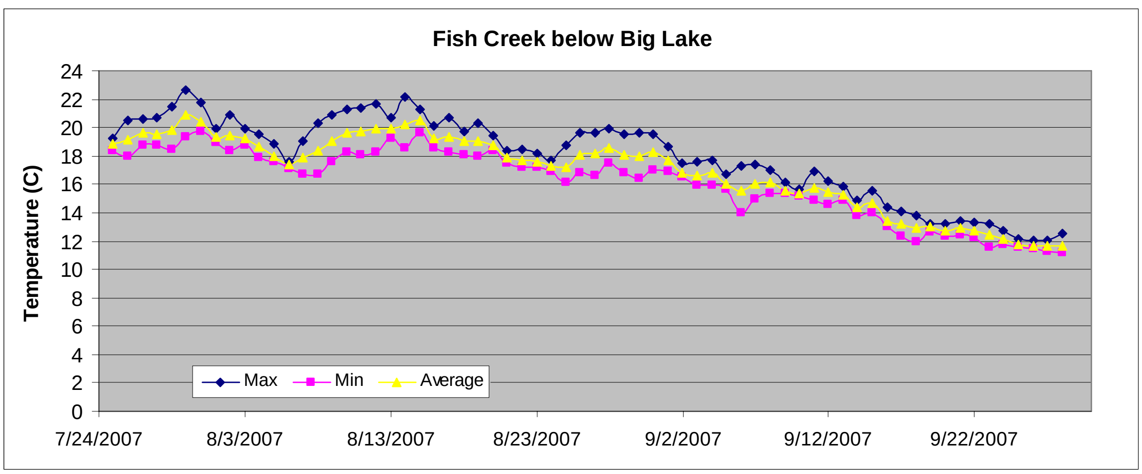
9/22/2007
Max
Min
Average


Fish Creek below Big Lake
Temperature (C)
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22
20
18
16
14
12
10
8
6
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7/24/2007
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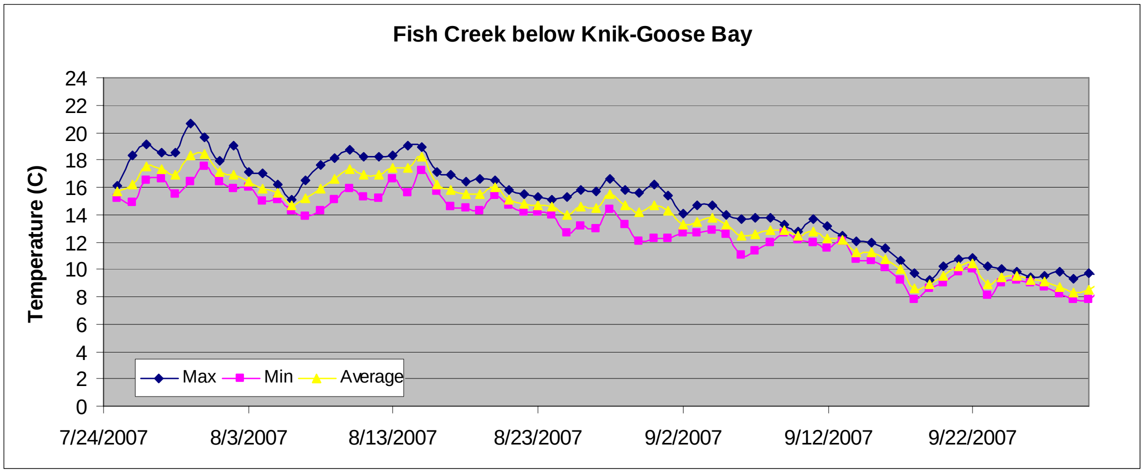
9/22/2007
Max
Min
Average


Fish Creek below Knik-Goose Bay
Temperature (C)
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22
20
18
16
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Max
Min
Average
7/24/2007
8/3/2007
8/13/2007
8/23/2007
9/2/2007
9/12/2007
9/22/2007

Appendix B. Fecal Coliform Bacteria

Location	Date	Value (cfu/100ml)	Geometric Mean	Discharge (cfs)
Settlement Ave.	4/21/2004	0.5		16.1
Settlement Ave.	5/15/2004	3		14.4
Settlement Ave.	6/18/2004	80		10.4
Settlement Ave.	7/20/2004	260		6.5
Settlement Ave.	8/18/2004	1600		5.5
Settlement Ave.	9/14/2004	30	33.82	11.0
Below Bogard	4/21/2004	94		16.1
Below Bogard	5/15/2004	6		14.4
Below Bogard	6/18/2004	14		10.4
Below Bogard	7/20/2004	16		6.5
Below Bogard	8/18/2004	21		5.5
Below Bogard	9/14/2004	8	16.64	11.0
Below Bogard	8/2/2005	2.7		19.0
Below Bogard	8/15/2005	5.3		15.7
Below Bogard	8/23/2005	27		15.3
Below Bogard	8/30/2005	5.3	6.73	20.0
Old Mat Road	4/21/2004	58		16.1
Old Mat Road	5/15/2004	30		14.4
Old Mat Road	6/18/2004	80		10.4
Old Mat Road	7/20/2004	110		6.5
Old Mat Road	8/18/2004	130		5.5
Old Mat Road	9/14/2004	50	68.08	11.0
Old Mat Road	8/2/2005	140		19.0
Old Mat Road	8/15/2005	72		15.7
Old Mat Road	8/23/2005	197.5		15.3
Old Mat Road	8/30/2005	100	118.78	20.0
Fern Crossing	4/21/2004	130		16.1
Fern Crossing	5/15/2004	10		14.4
Fern Crossing	6/18/2004	70		10.4
Fern Crossing	7/20/2004	120		6.5
Fern Crossing	8/18/2004	50		5.5
Fern Crossing	9/14/2004	130	64.35	11.0
Edlund Road	4/21/2004	100		16.1
Edlund Road	5/15/2004	20		14.4
Edlund Road	6/18/2004	110		10.4
Edlund Road	7/20/2004	130		6.5
Edlund Road	8/18/2004	170		5.5
Edlund Road	9/14/2004	240	102.61	11.0
Surrey Road	4/21/2004	93		16.1
Surrey Road	5/15/2004	57		14.4
Surrey Road	6/18/2004	240		10.4
Surrey Road	7/20/2004	250		6.5

Location	Date	Value (cfu/100ml)	Geometric Mean	Discharge (cfs)
Surrey Road	8/18/2004	80		5.5
Surrey Road	9/14/2004	80	112.58	11.0
Surrey Road	8/2/2005	180		19.0
Surrey Road	8/15/2005	120		15.7
Surrey Road	8/23/2005	48		15.3
Surrey Road	8/30/2005	87	97.45	20.0
Neklason Outlet	4/21/2004	0.5		16.1
Neklason Outlet	5/15/2004	0.5		14.4
Neklason Outlet	6/18/2004	8		10.4
Neklason Outlet	7/20/2004	50		6.5
Neklason Outlet	8/18/2004	11		5.5
Neklason Outlet	9/14/2004	4	4.05	11.0
Surrey Replicate	4/21/2004	99		16.1
Surrey Replicate	5/15/2004	100		14.4
Surrey Replicate	6/18/2004	500		10.4
Surrey Replicate	7/20/2004	200		6.5
Surrey Replicate	8/18/2004	80		5.5
Surrey Replicate	9/14/2004	30		11.0
Wasilla Lk. Inlet	7/30/2007	30		14.4
Wasilla Lk. Inlet	8/1/2007	10		14.4
Wasilla Lk. Inlet	8/6/2007	17		16.1
Wasilla Lk. Inlet	8/9/2007	9	14.64	14.9
Wasilla Lk. Inlet	4/8/2008	1		15.3
Wasilla Lk. Inlet	4/23/2008	4		15.7
Wasilla Lk. Inlet	5/5/2008	0.5		17.3
Wasilla Lk. Inlet	5/7/2008	0.5	1.00	17.3
Wasilla Lk. Outlet	7/30/2007	0.5		14.4
Wasilla Lk. Outlet	8/1/2007	0.5		14.4
Wasilla Lk. Outlet	8/6/2007	2		16.1
Wasilla Lk. Outlet	8/9/2007	0.5	0.71	14.9
Wasilla Lk. Outlet	9/10/2007	7		15.7
Wasilla Lk. Outlet	9/20/2007	3	4.58	18.1
Wasilla Lk. Outlet	4/8/2008	0.5		15.3
Wasilla Lk. Outlet	4/23/2008	0.5		15.7
Wasilla Lk. Outlet	5/5/2008	0.5		17.3
Wasilla Lk. Outlet	5/7/2008	0.5	0.50	17.3
Wasilla Lk. Outlet	7/30/2007	0		
Parks Highway	7/30/2007	26		14.4
Parks Highway	8/1/2007	18		14.4
Parks Highway	8/6/2007	16		16.1
Parks Highway	8/9/2007	10	16.54	14.9
Parks Highway	9/10/2007	116		15.7
Parks Highway	9/20/2007	33	61.87	18.1

Location	Date	Value (cfu/100ml)	Geometric Mean	Discharge (cfs)
Parks Highway	4/8/2008	4		15.3
Parks Highway	4/23/2008	0.5		15.7
Parks Highway	5/5/2008	0.5		17.3
Parks Highway	5/7/2008	0.5	0.84	17.3
Old Mat Road	7/30/2007	50		14.4
Old Mat Road	8/1/2007	20		14.4
Old Mat Road	8/6/2007	16		16.1
Old Mat Road	8/9/2007	10	20.00	14.9
Old Mat Road	9/10/2007	63		15.7
Old Mat Road	9/20/2007	32	44.90	18.1
Old Mat Road	4/8/2008	4		15.3
Old Mat Road	4/23/2008	0.5		15.7
Old Mat Road	5/5/2008	0.5		17.3
Old Mat Road	5/7/2008	0.5	0.84	17.3
Old Mat Road	8/1/2007	24		
Edlund Road	7/30/2007	69		14.4
Edlund Road	8/1/2007	33		14.4
Edlund Road	8/6/2007	59		16.1
Edlund Road	8/9/2007	51	51.16	14.9
Edlund Road	4/8/2008	5		15.3
Edlund Road	4/23/2008	7		15.7
Edlund Road	5/5/2008	10		17.3
Edlund Road	5/7/2008	0.5	3.64	17.3
Marble Way	7/30/2007	59		14.4
Marble Way	8/1/2007	20		14.4
Marble Way	8/6/2007	59		16.1
Marble Way	8/9/2007	56	44.44	14.9
Marble Way	4/8/2008	9		15.3
Marble Way	4/23/2008	5		15.7
Marble Way	5/5/2008	6		17.3
Marble Way	5/7/2008	2	4.82	17.3
Surrey Road	7/30/2007	300		14.4
Surrey Road	8/1/2007	169		14.4
Surrey Road	8/6/2007	260		16.1
Surrey Road	8/9/2007	74	176.73	14.9
Surrey Road	9/10/2007	92		15.7
Surrey Road	9/20/2007	690	251.95	18.1
Surrey Road	4/8/2008	9		15.3
Surrey Road	4/23/2008	5		15.7
Surrey Road	5/5/2008	65		17.3
Surrey Road	5/7/2008	13	13.96	17.3
Surrey Road	8/6/2007	300		
Surrey Road	8/9/2007	103		

Location	**Date**	**Value (cfu/100ml)**	**Geometric Mean**	**Discharge (cfs)**
Surrey Road	9/10/2007	135		
Surrey Road	9/20/2007	1200	265.99	
Surrey Replicate	4/8/2008	10		15.3
Surrey Replicate	4/23/2008	4		15.7
Surrey Replicate	5/5/2008	41		17.3
Surrey Replicate	5/7/2008	13	12.08	17.3

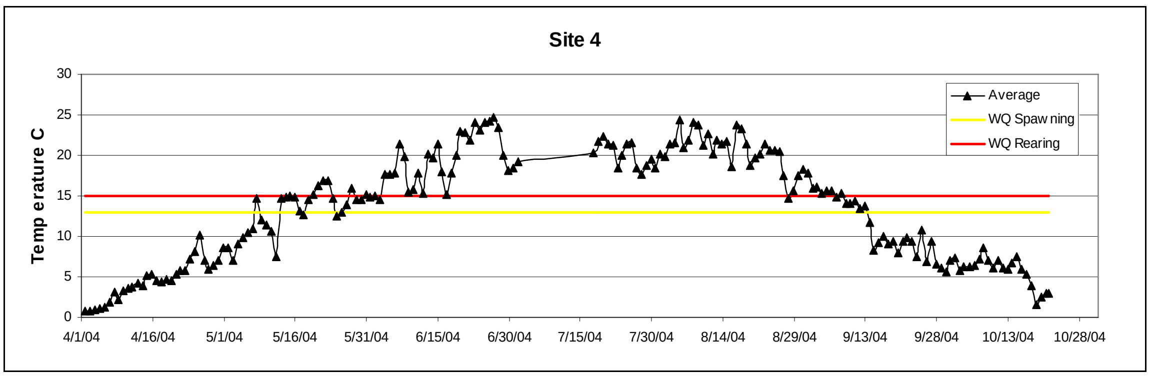
Appendix C. QAPP and Sampling Plan

Quality Assurance Project and Sampling Plan

Cottonwood Creek Fecal Coliform and Temperature Evaluation

Revision Number 1.0

August 2007



ALASKA
Department of
Environmental
Conservation

ARRI
Aquatic Restoration & Research Institute

Jeffrey C. Davis and Gay A. Davis
P.O. Box 923 Talkeetna, Alaska
(907) 733.5432. www.arrialaska.org

A1. Cottonwood Creek Water Quality 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:____

A2. Table of Contents

A3. Distribution List

Ms. Laura Eldred
Alaska Department of Environmental Conservation
1700 E. Bogard Rd., Bldg B, Ste 103
Wasilla, Alaska 99654
Ph: 907-376-1855
laura.eldred@alaska.gov

Mr. Jim Gendron
ADEC Quality Assurance Officer
410 Willoughby Ave., Ste 303
PO Box 111800
Juneau, AK 99811-1800
Ph: 907-465-5305
jim.gendron@alaska.gov

A4. Project/Task Organization

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

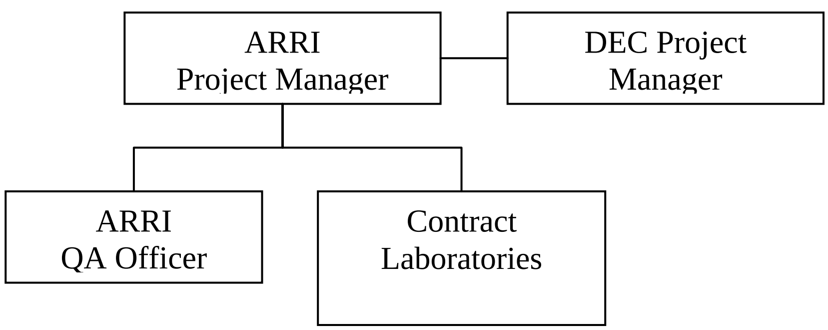
Laura Eldred (DEC). DEC Project Manager. Ms. Eldred will oversee the project for DEC, provide technical support, QAPP review and approval, and the review of all quarterly reports and the final report.

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.

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.

SGS Environmental Services Inc. —Anchorage, AK. The testing laboratory will be responsible for analyzing water samples for total fecal coliform bacteria.

Mat-Su Test Laboratory—Palmer, AK. The Mat-Su Test Laboratory will be used as an alternative location for total fecal coliform analyses.



A5. Problem Definition/Background

This project has been developed to address ACWA FY08 action item a. Cottonwood Creek is in Category 5 for non-attainment of the residue standard for foam. Previous sampling conducted by ARRI determined that foam was most likely caused by the flushing of dissolved carbon from wetlands during runoff events. However, concomitant sampling revealed that stream water temperatures and concentrations of total fecal coliform bacteria exceeded state standards at multiple locations. High stream water temperatures in 2004 below Wasilla Lake coincided with a marked decrease in capture rates of juvenile coho salmon. Subsequent temperature sampling in 2005 measured high water temperatures from below Neklason Lake, Mud Lake and Wasilla Lake; with the upper tributaries and lower creek considerably cooler. Water temperatures were correlated with regional air temperature.

The temperature of stream water is a function of energy inputs from solar radiation, conduction from the surrounding air influenced by convection and advection, and convection through tributary and ground water sources. Changes in stream water temperatures can be buffered by hyporheic and ground water exchange. Removal of the riparian vegetation can increase solar input and can allow for the convection of warm air across the water surface. Increases in channel width and the presence of lakes also can increase the available surface water for energy exchange through solar radiation and conduction between the air and water surface. Decreases in stream discharge reduce the heat dissipative capacity of the receiving water. Stream water temperatures can be reduced by the inflow or convection of relatively cooler water through tributaries or groundwater inputs. The evaporation of surface water also reduces stream temperatures by releasing water with a high temperature load.

Urban and rural development can influence stream temperatures in a number of ways in addition to the removal of riparian vegetation. Removal of wetlands and increasing impervious surfaces can reduce water storage capacity and result in higher high flows and lower low flows. Reducing low flow stream volumes reduces the capacity of water to dissipate heat analogous to a streams ability to dilute other pollutants. High flows can also cause bank erosion and increase channel widths. Development increases impervious surfaces which lead to more warm water surface flow and less cool ground water flow. Sediment input in runoff can block the subsurface movement of water and the cooling or buffering effect provided by subsurface flow.

Monthly sampling for total fecal coliform bacteria was conducted in 2004 and more detailed sampling in 2005. In 2004 high concentrations of fecal coliform bacteria were observed in samples collected from below Wasilla Lake to Surrey Road in monthly samples. In 2005, samples were collected upstream of Wasilla Lake, downstream from Wasilla Lake and at Surrey Road. Geometric means from four samples collected within 30 days were 10 cfu upstream from Wasilla Lake, and greater than 100 cfu below Wasilla Lake and at Surrey Road, consistent with 2004 sampling.

Fecal coliform bacteria are present in the digestive system of all warm blooded animals. Abundant fecal coliform bacteria may be due to nonfunctioning septic systems or surface runoff of dog waste or other sources. It has also been hypothesized that ducks that congregate downstream from the Palmer Wasilla Highway road crossing may be a source of bacterial contamination. Wasilla Lake is used for swimming, boating and other water recreational sports. It is therefore important to determine the extent of fecal coliform contamination.

A6. Project/Task Description

This project has been designed to address ACWA Priority (a), for Cottonwood Creek near Wasilla. Previous data collection has recorded stream water temperature and fecal coliform bacteria concentrations that exceed State Water Quality Standards. Additional data are required to determine whether these high values are persistent, the spatial extent, and whether they are due to human or natural causes.

Previous measurements recorded water temperatures well above 20° C at multiple locations throughout Cottonwood Creek, specifically downstream from lake outlets. Based upon regression relationships with local air temperatures, stream water temperatures below Neklason Lake, Mud Lake, and Wasilla Lake will exceed 20 degrees Celsius when air temperatures are greater than 70 degrees Fahrenheit. Lower water temperatures were measured in Dry Creek and Cottonwood Creek upstream of Neklason Lake and within the flowing channel downstream of Wasilla Lake. These areas likely serve as temperature refugia for juvenile salmon. Regression relationships with air temperatures were also much stronger for sites below lakes compared with stream sites. Poor regression relationships are due to localized buffering of water temperatures. Differences between sites were generally only by a couple of degrees. Therefore, only minor changes in the hydrologic or temperature budget may eliminate refugia sites that currently have lower temperatures. However, current regression relationships were built with only limited data. Additional temperature information is necessary to determine if the previously identified relationships are consistent among years.

Comparisons with other similar, but less developed stream and lake systems is one way that human influences can be evaluated. Cottonwood Creek is a groundwater fed system with slightly stained or brown water. In addition to the lakes, there are a number of areas where the stream channel is wide with slow water velocities. The substrate in many locations is composed of fine material colonized by aquatic macrophytes which is typical of systems that do not receive flushing flows during snowmelt or storm events. Similar stream systems within the area include the Meadow Creek/Big Lake/Fish Creek system, Nancy Lake/Nancy Creek near Willow, and Question Creek/Question Lake near Talkeetna. These systems also are spring fed, stained, with slow moving open channels. These systems differ however, in the degree of development, which decreases in a northward direction. The water temperature regime within Cottonwood Creek will be compared with stream temperatures within the Meadow Creek and Fish Creek system. Differences in stream and lake outlet water temperatures and regression relationships with air temperatures would be used to evaluate conditions in Cottonwood Creek.

Water sampling for total fecal coliform bacteria is necessary to determine the persistence and distribution of high values and to investigate potential sources. Replicate sampling in 2007 will be compared with previous sampling in 2005. Sampling will be stratified with storm flows and spring runoff to determine whether high counts were associated with surface or ground water sources. Sampling will be located above and below a waterfowl congregation area to determine if there is a causal relationship. Additional sampling sites would be located within the stream reach previously identified to have high values. Sampling results will determine whether waterfowl were the cause of high bacteria counts, if high counts are found during base or storm flows, and whether high counts are consistent among years.

Objective 1: Measure and Evaluate Cottonwood Creek Water Temperature and Total Fecal Coliform Bacteria.

Task 1: Revise QAPP and Sampling Plan

Start and end date: July 17 to July 31, 2007

Description: The ARRI Project Manager will revise previously approved QAPP and Sampling Plans for the specific project tasks and submit to ADEC for review, comment and approval. These documents will describe in detail the frequency, duration, and location of all proposed sampling. They will identify the equipment that will be used and how the equipment will be calibrated and maintained. It will describe the analytical methods that will be used and who will be handling and analyzing the water samples. The methods that will be used to determine data accuracy, precision, and completeness will be outlined. Data handling, management and reporting will be described. It will detail the responsibilities of all staff members and contractors and who will be responsible for each phase of the project. The Project Manager will coordinate with the ADEC Project Manager to address any inadequacies in the draft documents for completing the final versions. ARRI will focus on completing this task as soon as possible.

Product or deliverable: ADEC approved QAPP and Sampling Plan.

Task 2: Stream Water Temperature Data Collection

Start and end date: July 1, 2007 to June 30, 2008

Description: Water temperature loggers (Onset Stowaway and HOBO) will be placed at 6 different locations on Cottonwood Creek and 4 locations on Meadow Creek/Fish Creek (2 on Meadow Creek and 2 of Fish Creek). The loggers will be secured in a location within the low flow channel that is well mixed, not adjacent to any tributaries or likely upwelling, and out of the direct sunlight. Temperature loggers will be programmed to record every hour. Loggers will be downloaded every other week. Replacement temperature loggers will be available should a logger be stolen or fail to operate correctly. Regional air temperatures will be downloaded from the NOAA web site (http://www.ncdc.noaa.gov/oa/ncdc.html). Temperature data will be downloaded to Excel. Daily maximum, minimum, and average temperatures will be calculated from hourly data. These data will be used to compare stream temperatures with State Water Quality Standards. Daily exceedances will be reported. These parameters will be compared with average and maximum daily air temperatures. Relationships between air and water temperature will also be compared between the watersheds. The final report will document the duration that temperatures exceed State Water Quality Standards.

Product or deliverable: Stream water temperature data at multiple locations to be provided within Final Report.

Task 3: Water Sample Collection for Total Fecal Coliform Analyses

Start and end date: July 27, 2007 to June 1, 2008

Description: Water samples will be collected to document fecal coliform concentrations during spring runoff, summer base flow, and fall storm events. Spring runoff sampling would occur on 4 dates within a 30-day period beginning in April and extending into May. Summer sampling would occur on 4 dates within a 30-day period in July and early August. Storm sampling would occur on two dates most likely in late August and September will be initiated when over 0.5 inches of rain is recorded and sampling will be conducted to coincide with the rising limb of the hydrograph. Sampling will be conducted at 7 locations during spring runoff and summer base flow. These sites will include the inlet to Wasilla Lake, the lake outlet above the Palmer Wasilla Highway, upstream of the Park's Highway, below the Old Matanuska Road Bridge, below Edlund Road, at Marble Way, and at Surrey Road. During storm events, sampling will occur at 4 locations, the inlet to Wasilla Lake, the Wasilla Lake outlet, the Old Matanuska Road Bridge, and Surrey Road (site selection for storm sampling may vary based upon base flow results). Stream discharge and water depth will be measured from a previously installed staff gauge to determine whether the stage discharge rating curve is still accurate and water stage will be recorded on each sampling date.

Product or deliverable: Total fecal coliform bacteria data that will allow for determining 30-day geometric mean values for base flow and increasing flow periods. Data will define the persistence and extent of values and isolate potential natural sources. Data will be reported in the Final Report.

Task 4: STORET Data Formatting

Start and end date: November 1, 2007 to June 30, 2008

Description: Sampling locations, dates, methods, and resulting measurement values will be formatted for uploading into the STORET database. Data will either be transferred to ADEC or uploaded by ARRI staff.

Product or deliverable: Project data in STORET Format.

Task 5: Draft and Final Water Quality Reports

Start and end date: January 1, 2008 – July 31, 2008

Description: Draft and final written reports will be prepared. The draft report will be submitted to the DEC Project Manager for review and comment. The final report will provide background information and describe why the project is necessary, the project objectives and the approach that was taken to meet the objectives. Field methods will be described and the project QAPP and sampling plan will be attached. All of the data results will be presented and described relative to the project objectives. We will make recommendations on further data collection, if necessary, and the potential causes and sources of temperature and fecal coliform pollution. Project success will be determined based upon the completeness of data collection and on whether project objectives were accomplished.

Product or Deliverable: Draft and Final Reports.

A7. Quality Objectives and Criteria for Measurement of Data

The parameters in the Table 1 will be measured at the indicated performance level. All parameters are critical to meeting project objectives. Criteria for Measurements of Data are the performance criteria: accuracy, precision, comparability, representativeness and completeness of the tests. These criteria must be met to ensure that the data are verifiable and that project quality objectives are met.

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

Parameter	Method	Resolution/ Limit	Expected Range	Accuracy%	Precision	Completeness
Fecal Coliforms (cfu)	SM9222D	1	0 to 300	N/A	25%	90%
Temperature (°C)	HOBO Water Temp ProV2	0.1	0 to 25	97 to 103 @ 15°C	5%	90%
Discharge(cfs)	Measure	1	15 to 40	N/A	10%	90%

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 1. Accuracy will be determined for those measurements where actual values are known. Contract laboratories will provide the results of accuracy measures along with analytical reports. Accuracy for Stowaway temperature loggers has been calculated to be 0.20°C by the manufacturer, which at 15°C is 97% to 103%. Prior to deployment and upon removal temperature logger accuracy will be checked at 0°C and approximately 20°C. True values will be obtained from NIST traceable thermometers. 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 1 shows the precision value for the acceptance of data. Precision will be determined for all measures by processing a duplicate on every sampling date. Discharge measure will be repeated at one site on one occasion to determine measurement precision. Precision of temperature meters will be determined by placing all meters in one location for 24 hours.

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. 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 90% completeness for all measures. Sample collection will be repeated if problems arise such as equipment malfunction or lost samples.

A8. Special Training Requirements/Certification Listed

Jeffrey C. Davis (Project Manager) has a B.S. degree in Biology from the 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 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 16 years of experience in stream restoration and evaluation.

Chemical analyses will be conducted through SGS Environmental Services Inc. laboratory located in Anchorage, Alaska.

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 photocopies of the field data book, 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.

The project reporting requirements are as follows:

- Quarterly Reports: Quarterly reports will be submitted to the DEC Project Manager. The reports will describe project progress, summarize field data collection, identify any problems with data collection and provide any received analytical results.

- Monitoring Data Entry. In addition to a written project report, any water quality monitoring data collected by the project will be entered into STORET or provided to DEC in accordance with guidance and templates at: http://www.state.ak.us/dec/water/wqsar/storetdocumentation.htm. The guidance and templates show the layout required for STORET compatible files and detail the valid values for various fields used in STORET (e.g. characteristics, analytic procedures, HUCs, etc). The data will be provided to DEC electronically via email, CD, diskette, or via an FTP website (to be determined). All data collected by Dec 31, 2007 will be furnished to DEC by March 31, 2008, and all data collected by the project will be furnished to DEC by July 31, 2008.
- Project Photographs. At least 3 electronic photograph(s) of the project will be submitted in a format suitable for publishing. Additional project photos are appreciated. These photos will represent all of the following: the problem the project addresses, the project in progress, and the environmental benefit of the project. At least one of these photos must be submitted with the first quarterly report; the remainder will be submitted with the final report or sooner if available. Each photo will be at least 800 x 600 pixels in size and in JPEG format or other format acceptable to the department. Included will be background information on what the photo represents and when and where it was taken. If possible, the information will be in the photo's file name, such as "Fish_Ck_samplesite1_iron_floc_101603". Alternatively, it may be provided with a caption that states the date, location, and describes the subject: for example "MCV-023X.JPG. Taken 10-3-02, Ditch along south side of Alaska Highway that empties into Fish Creek: Note channelization." The grantee agrees that these photos may be used in publications and distributed widely as the department determines, and that it has obtained any necessary permissions of individuals that appear

- Final Report Evaluating Project Accomplishments and Benefits:
  The final report will include data presentation and discussion in tabular, graphical, and narrative formats along with QA validation and discussion. The final report will describe the project accomplishments and their environmental benefit. These environmental benefits will be determined by a description of the fecal coliform bacteria concentrations relative to State Water Quality Standards and multiple locations and at multiple seasons. Environmental benefits will be obtained through an understanding of human influences on stream temperatures.

- Deliverables: (at least 1 electronic and 3 hard copies of each)
  In addition to submitting the information identified in the reporting requirements, the following products will be delivered to the Department. All written products will be submitted to the department in both hard copy and electronic format.

QAPP and Sampling Plan ....July 31, 2007
Data in STORET Format ....July 31, 2008
Final Report .... ……….July 31, 2007

B1. Sampling Process Design

Total Fecal Coliform Bacteria

Water sampling for total fecal coliform bacteria will be conducted to determine whether concentrations exceed State Water Quality Standards. State standards are based upon the geometric mean of samples collected within 30 days. Sampling will be conducted at multiple locations to determine the spatial extent of potential exceedances and to evaluate a potential source and downstream impacts: a waterfowl concentration area at the outlet of Wasilla Lake. Sampling will be conducted during times of predominant groundwater flow and during times of increased surface flow to determine potential sources of contamination. Water samples will be collected do document fecal coliform concentrations during spring runoff, summer base flow, and fall storm events. Spring runoff sampling would occur on 4 dates within a 30-day period beginning in April and extending into May. Summer sampling would occur on 4 dates within a 30-day period in July and early August. Storm sampling would occur on two dates most likely in late August and September will be initiated when over 0.5 inches of rain is recorded based upon previous 24 hour summaries from the Wasilla or Palmer airports. Sampling will be conducted to coincide with the rising limb of the hydrograph where possible.

Sampling Locations

Sampling will be conducted at 7 locations during spring runoff and summer base flow. These sites will include the inlet to Wasilla Lake, the lake outlet above the Palmer Wasilla Highway, upstream of the Park's Highway, below the Old Matanuska Road Bridge, below Edlund Road, at Marble Way, and at Surrey Road. During storm events sampling will occur at 4 locations, the inlet to Wasilla Lake, the Wasilla Lake outlet, the Old Matanuska Road Bridge, and Surrey Road (site selection for storm sampling may vary based upon base flow results).

Sampling Frequency

Samples will be collected on 4 sampling dates within a 30 day period during summer base flow and during spring runoff and on two occasions during fall storms. Sampling will be conducted haphazardly by day. Sampling must occur early enough in the day for the samples to be transported to SGS laboratory in Anchorage and processed within the 6 hour holding time.

Water Temperature

Stream water temperatures will be measured using data loggers to determine temperature exceedances of State Water Quality Standards and to evaluate whether high water temperatures are related to urban development. Temperature data loggers will be placed at multiple locations along Cottonwood Creek that has considerable urban development throughout the drainage. Loggers also will be placed at multiple locations along Meadow Creek (above Big Lake) and Fish Creek (below Big Lake). The Meadow Creek and Fish Creek area has some rural development. Regional air temperatures will be downloaded from the NOAA web site (http://www.ncdc.noaa.gov/oa/ncdc.html). Temperature data will be downloaded to Excel. Daily maximum, minimum, and average temperatures will be calculated from hourly data. These data will be used to compare stream temperatures with State Water Quality Standards. Daily exceedances will be reported along with the duration of the exceedance. These parameters will be compared with average and maximum daily air temperatures. Relationships between air and water temperature will also be compared between the watersheds.

Sampling Locations

Temperature data loggers in Cottonwood Creek will be placed below Neklason Lake, the Wasilla Lake inlet, at the Old Matanuska Road site, Edlund Road, Marble Way, and Surrey Road. Temperature loggers in the Big Lake system will be place in Meadow Creek upstream of the Park's Highway and near the old Hatchery at the Beaver Lake Road crossing, and on Fish Creek below South Big Lake Road and below Knik-Goose Bay Road.

Sampling Frequency

Temperature loggers will be deployed immediately upon plan approval in July or August of 2007 and removed prior to freezing. The loggers will be re-deployed in May of 2008 and removed prior to the contract ending date of July 30, 2008. Loggers will record temperature every hour. Data will be downloaded every other week.

Sample Parameters

Sample parameters, as well as proposed methods, are as follows (Table 2).

- Fecal Coliform Bacteria (cfu/100 ml). Water samples will be submitted to a commercial laboratory for analyses using SM 9222-D. SGS Environmental Services Inc. will be the proposed subcontractor.
- Temperature (°C). Water temperature will be measured at one hour intervals using data loggers (Onset Stowaway or HOBO Water temp ProV2).
- Discharge. Stream discharge will be through direct measures and estimated from a discharge rating curve at the Old Matanuska Road Bridge.

External Data

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

See sampling frequency above.

Table 7. Sampling frequency, location, and timing for each measurement parameter.

Parameter	Locations	Frequency/samples	Timing	Total Samples
Fecal Coliforms	7	Approximately weekly/10	Random	80
Water Temperature	11	July-Sept 07, May-June 08	Hourly	

Discharge	1	Concurrent with water sample collection for Fecal Coliforms	N/A	6

B2. Sampling Methods Requirements

Field Data Collection
Field data collection will be conducted by ARRI staff. The latitude and longitude of sampling locations will be recorded and photographs taken.

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

Fecal Coliform Bacteria
Water samples will be collected in containers provided by SGS Environmental Services Inc. The sample bottles will be sterile. Samples for fecal coliforms will be collected from mid channel-mixed sites. Samples will be depth integrated as described above using only new packaged sterile syringes for each sample. The "clean hands" method will be used to avoid contamination. Sterile or near sterile procedures are used to collect the sample. Sterile gloves are used and contact only the collection bottle and the source water until the sample bottle is sealed. Once the sample is collected, the sample is labeled, and placed in a cooler and gel-paks are used to bring the sample temperature down to and maintained at 4-degrees Celsius. The sample will be labeled with the site ID, sample time and date and any additional information needed by the laboratory. The sample will be returned to the laboratory within 6 hours of collection.

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

Temperature
Stream water temperature data loggers will be secured to the bank using plastic coated wire rope. Loggers will be secured in an area that is well mixed and is likely to remain under water during changing flows. Prior to placement, stream water temperature will be measured across the channel and at multiple depths to ensure that the location is not subject to areas of upwelling. Loggers will be downloaded at least monthly using a shuttle, which will be returned to the laboratory and downloaded.

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

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.

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. A staff gauge will be secured under the Matanuska Road Bridge and a rating curve developed. Discharge will be measured or estimated from the rating curve on each sampling date.

Materials Required: Rite-in-the-Rain data book, pencils, Staff gauge, 25-meter tape, top-setting wading rod, and velocity meter.

Corrective Actions
The QA officer will ensure that all equipment is prepared and ready for sampling and that all samples are collected as described. The QA officer will inform the Project Manager of any problems with equipment or any missing data due to collection or laboratory errors. The Project Manager will be responsible for repairing or replacing equipment, taking additional samples, or replicating measurements as needed.

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. Carbon copies of chain of custody forms and forms returned with processed samples will be retained on file. Field samples that are to be transferred to either of the contract laboratories 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 3. Field samples will be collected by ARRI staff and delivered to the commercial laboratory for subsequent analyses by the identified standard method.

Table 8. List of Analytical methods and detection limits for study parameters.

Measurement	Collection/ Analyses	Method	Limits	Turnaround Time (days)
Fecal Coliforms	ARRI/SGS Inc.	SM 9222-D	n/a	6 to 10
Temperature	ARRI	Temperature logger	0.1 Degree C	Monthly Download

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 (Table 4) 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). 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 9. Field and laboratory replicates for quality control.

Parameter	Field Replicates	Laboratory Replicates	Comments
Fecal Coliform	10 Percent	None	Duplicate sample collected at one of the sites every sampling event.
Temperature	1%	None	Water temperature will be measured on each sampling event with meters and compared with logger readings. Loggers will be placed in the same location for 24 hours and reading compared.

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), duplicate instruments and loggers 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

Temperature loggers will be checked for accuracy and precision prior to deployment and upon retrieval.

B8. Inspection/Acceptance Requirements for Supplies and Consumables

Sample containers will be obtained from SGS Environmental Services 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. Some supplemental data such as maps and watershed areas serviced by city water and sewer may be obtained from local government sources.

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.

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 approved workplan 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.

C2. Reports to Management

Reports will be prepared by the ARRI Project Manager and distributed to the DEC Project Manager. Reports will update the status of the project relative to the schedule and tasks of the work plan. Reports include Quarterly Reports, Draft Report, and Final Report. Any field QA problems will be identified or other sampling problems or concerns, or unanticipated analytical results will be reported to the DEC Project Manager as soon as possible. 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. This process for data review is described under section B10 and A7. 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

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. 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.

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

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.

Appendix D—Laboratory Data

SGS

SGS Ref.#	1073729001		**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI		**Printed Date/Time**	08/01/2007 14:05
Project Name/#	Cottonwood CRK		**Collected Date/Time**	07/30/2007 12:15
Client Sample ID	Site 6		**Received Date/Time**	07/30/2007 14:35
Matrix	Water (Surface, Eff., Ground)		**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	59		col/100mL	SM20 9222D	A			07/30/07	SDP

SGS

SGS Ref.#	1073729002	**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI	**Printed Date/Time**	08/01/2007 14:05
Project Name/#	Cottonwood CRK	**Collected Date/Time**	07/30/2007 12:27
Client Sample ID	Site 7	**Received Date/Time**	07/30/2007 14:35
Matrix	Water (Surface, Eff., Ground)	**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	300		col/100mL	SM20 9222D	A			07/30/07	SDP

SGS Ref.# 1073729003
Client Name ARRI
Project Name/# Cottonwood CRK
Client Sample ID Site 5
Matrix Water (Surface, Eff., Ground)

All Dates/Times are Alaska Standard Time
Printed Date/Time 08/01/2007 14:05
Collected Date/Time 07/30/2007 12:35
Received Date/Time 07/30/2007 14:35
Technical Director **Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	69		col/100mL	SM20 9222D	A			07/30/07	SDP

SGS Ref.#	1073729004
Client Name	ARRI
Project Name/#	Cottonwood CRK
Client Sample ID	Site 4
Matrix	Water (Surface, Eff., Ground)

All Dates/Times are Alaska Standard Time

Printed Date/Time	08/01/2007 14:05
Collected Date/Time	07/30/2007 12:50
Received Date/Time	07/30/2007 14:35
Technical Director	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	50		col/100mL	SM20 9222D	A			07/30/07	SDP

SGS

SGS Ref.#	1073729005		**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI		**Printed Date/Time**	08/01/2007 14:05
Project Name/#	Cottonwood CRK		**Collected Date/Time**	07/30/2007 13:05
Client Sample ID	Site 3		**Received Date/Time**	07/30/2007 14:35
Matrix	Water (Surface, Eff., Ground)		**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	26		col/100mL	SM20 9222D	A			07/30/07	SDP

SGS

SGS Ref.#	1073729006
Client Name	ARRI
Project Name/#	Cottonwood CRK
Client Sample ID	Site 2
Matrix	Water (Surface, Eff., Ground)

All Dates/Times are Alaska Standard Time

Printed Date/Time	08/01/2007 14:05
Collected Date/Time	07/30/2007 13:15
Received Date/Time	07/30/2007 14:35
Technical Director	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	0		col/100mL	SM20 9222D	A			07/30/07	SDP

SGS Ref.#	1073729007
Client Name	ARRI
Project Name/#	Cottonwood CRK
Client Sample ID	Site X
Matrix	Water (Surface, Eff., Ground)

All Dates/Times are Alaska Standard Time

Printed Date/Time	08/01/2007 14:05
Collected Date/Time	07/30/2007 13:20
Received Date/Time	07/30/2007 14:35
Technical Director	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	0		col/100mL	SM20 9222D	A			07/30/07	SDP

SGS

SGS Ref.#	1073729008	**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI	**Printed Date/Time**	08/01/2007 14:05
Project Name/#	Cottonwood CRK	**Collected Date/Time**	07/30/2007 13:30
Client Sample ID	Site 1	**Received Date/Time**	07/30/2007 14:35
Matrix	Water (Surface, Eff., Ground)	**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	30		col/100mL	SM20 9222D	A			07/30/07	SDP

SGS

SGS Ref.#	1073777001
Client Name	ARRI
Project Name/#	Cottonwood CR
Client Sample ID	Site 1
Matrix	Water (Surface, Eff., Ground)

All Dates/Times are Alaska Standard Time

Printed Date/Time	08/03/2007 15:23
Collected Date/Time	08/01/2007 12:30
Received Date/Time	08/01/2007 13:50
Technical Director	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	10		col/100mL	SM20 9222D	A			08/01/07	SDP

SGS

SGS Ref.#	1073777002	**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI	**Printed Date/Time**	08/03/2007 15:23
Project Name/#	Cottonwood CR	**Collected Date/Time**	08/01/2007 12:15
Client Sample ID	Site 2	**Received Date/Time**	08/01/2007 13:50
Matrix	Water (Surface, Eff., Ground)	**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	0		col/100mL	SM20 9222D	A			08/01/07	SDP

SGS

SGS Ref.#	1073777003
Client Name	ARRI
Project Name/#	Cottonwood CR
Client Sample ID	Site 3
Matrix	Water (Surface, Eff., Ground)

All Dates/Times are Alaska Standard Time

Printed Date/Time	08/03/2007 15:23
Collected Date/Time	08/01/2007 12:05
Received Date/Time	08/01/2007 13:50
Technical Director	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	18		col/100mL	SM20 9222D	A			08/01/07	SDP

SGS

SGS Ref.#	1073777004	**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI	**Printed Date/Time**	08/03/2007 15:23
Project Name/#	Cottonwood CR	**Collected Date/Time**	08/01/2007 11:55
Client Sample ID	Site 4	**Received Date/Time**	08/01/2007 13:50
Matrix	Water (Surface, Eff., Ground)	**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	20		col/100mL	SM20 9222D	A			08/01/07	SDP

SGS Ref.# 1073777005
Client Name ARRI
Project Name/# Cottonwood CR
Client Sample ID Site 4x
Matrix Water (Surface, Eff., Ground)

All Dates/Times are Alaska Standard Time

Printed Date/Time 08/03/2007 15:23
Collected Date/Time 08/01/2007 12:00
Received Date/Time 08/01/2007 13:50
Technical Director **Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	24		col/100mL	SM20 9222D	A			08/01/07	SDP

SGS

SGS Ref.#	1073777006
Client Name	ARRI
Project Name/#	Cottonwood CR
Client Sample ID	Site 5
Matrix	Water (Surface, Eff., Ground)

All Dates/Times are Alaska Standard Time

Printed Date/Time	08/03/2007 15:23
Collected Date/Time	08/01/2007 11:40
Received Date/Time	08/01/2007 13:50
Technical Director	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	33		col/100mL	SM20 9222D	A			08/01/07	SDP

SGS Ref.# 1073777007
Client Name ARRI
Project Name/# Cottonwood CR
Client Sample ID Site 6
Matrix Water (Surface, Eff., Ground)

All Dates/Times are Alaska Standard Time
Printed Date/Time 08/03/2007 15:23
Collected Date/Time 08/01/2007 11:15
Received Date/Time 08/01/2007 13:50
Technical Director **Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	20		col/100mL	SM20 9222D	A			08/01/07	SDP

SGS

SGS Ref.#	1073777008	**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI	**Printed Date/Time**	08/03/2007 15:23
Project Name/#	Cottonwood CR	**Collected Date/Time**	08/01/2007 11:25
Client Sample ID	Site 7	**Received Date/Time**	08/01/2007 13:50
Matrix	Water (Surface, Eff., Ground)	**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	169		col/100mL	SM20 9222D	A			08/01/07	SDP

SGS

SGS Ref.#	1073936001
Client Name	ARRI
Project Name/#	Cottonwood Creek
Client Sample ID	Site 1
Matrix	Water (Surface, Eff., Ground)

All Dates/Times are Alaska Standard Time

Printed Date/Time	08/08/2007 15:47
Collected Date/Time	08/06/2007 12:50
Received Date/Time	08/06/2007 14:10
Technical Director	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	17		col/100mL	SM20 9222D	A			08/06/07	SDP

SGS Ref.#	1073936002	**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI	**Printed Date/Time**	08/08/2007 15:47
Project Name/#	Cottonwood Creek	**Collected Date/Time**	08/06/2007 12:35
Client Sample ID	Site 2	**Received Date/Time**	08/06/2007 14:10
Matrix	Water (Surface, Eff., Ground)	**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	2		col/100mL	SM20 9222D	A			08/06/07	SDP

SGS

SGS Ref.#	1073936003	**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI	**Printed Date/Time**	08/08/2007 15:47
Project Name/#	Cottonwood Creek	**Collected Date/Time**	08/06/2007 12:20
Client Sample ID	Site 3	**Received Date/Time**	08/06/2007 14:10
Matrix	Water (Surface, Eff., Ground)	**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	16		col/100mL	SM20 9222D	A			08/06/07	SDP

SGS Ref.# 1073936004
Client Name ARRI
Project Name/# Cottonwood Creek
Client Sample ID Site 4
Matrix Water (Surface, Eff., Ground)

All Dates/Times are Alaska Standard Time
Printed Date/Time 08/08/2007 15:47
Collected Date/Time 08/06/2007 12:05
Received Date/Time 08/06/2007 14:10
Technical Director **Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	16		col/100mL	SM20 9222D	A			08/06/07	SDP

SGS

SGS Ref.#	1073936005
Client Name	ARRI
Project Name/#	Cottonwood Creek
Client Sample ID	Site 5
Matrix	Water (Surface, Eff., Ground)

All Dates/Times are Alaska Standard Time

Printed Date/Time	08/08/2007 15:47
Collected Date/Time	08/06/2007 11:50
Received Date/Time	08/06/2007 14:10
Technical Director	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	59		col/100mL	SM20 9222D	A			08/06/07	SDP

SGS Ref.# 1073936006
Client Name ARRI
Project Name/# Cottonwood Creek
Client Sample ID Site 6
Matrix Water (Surface, Eff., Ground)

All Dates/Times are Alaska Standard Time
Printed Date/Time 08/08/2007 15:47
Collected Date/Time 08/06/2007 11:25
Received Date/Time 08/06/2007 14:10
Technical Director **Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	59		col/100mL	SM20 9222D	A			08/06/07	SDP

SGS Ref.#	1073936007	**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI	**Printed Date/Time**	08/08/2007 15:47
Project Name/#	Cottonwood Creek	**Collected Date/Time**	08/06/2007 11:35
Client Sample ID	Site 7	**Received Date/Time**	08/06/2007 14:10
Matrix	Water (Surface, Eff., Ground)	**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	260		col/100mL	SM20 9222D	A			08/06/07	SDP

SGS Ref.#	1073936008	**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI	**Printed Date/Time**	08/08/2007 15:47
Project Name/#	Cottonwood Creek	**Collected Date/Time**	08/06/2007 11:40
Client Sample ID	Site X	**Received Date/Time**	08/06/2007 14:10
Matrix	Water (Surface, Eff., Ground)	**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	300		col/100mL	SM20 9222D	A			08/06/07	SDP

SGS Ref.# 1073843001
Client Name ARRI
Project Name/# Cottonwood Lrk
Client Sample ID Site 1
Matrix Water (Surface, Eff., Ground)

All Dates/Times are Alaska Standard Time
Printed Date/Time 08/13/2007 14:22
Collected Date/Time 08/09/2007 12:25
Received Date/Time 08/09/2007 13:40
Technical Director Stephen C. Ede

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	9		col/100mL	SM20 9222D	A			08/09/07	SDP

SGS Ref.# 1073843002
Client Name ARRI
Project Name/# Cottonwood Lrk
Client Sample ID Site 2
Matrix Water (Surface, Eff., Ground)

All Dates/Times are Alaska Standard Time
Printed Date/Time 08/13/2007 14:22
Collected Date/Time 08/09/2007 12:15
Received Date/Time 08/09/2007 13:40
Technical Director **Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	0		col/100mL	SM20 9222D	A			08/09/07	SDP

SGS Ref.#	1073843003	**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI	**Printed Date/Time**	08/13/2007 14:22
Project Name/#	Cottonwood Lrk	**Collected Date/Time**	08/09/2007 12:05
Client Sample ID	Site 3	**Received Date/Time**	08/09/2007 13:40
Matrix	Water (Surface, Eff., Ground)	**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	10		col/100mL	SM20 9222D	A			08/09/07	SDP

SGS Ref.#	1073843004		**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI		**Printed Date/Time**	08/13/2007 14:22
Project Name/#	Cottonwood Lrk		**Collected Date/Time**	08/09/2007 12:00
Client Sample ID	Site 4		**Received Date/Time**	08/09/2007 13:40
Matrix	Water (Surface, Eff., Ground)		**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	10		col/100mL	SM20 9222D	A			08/09/07	SDP

SGS

SGS Ref.#	1073843005	**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI	**Printed Date/Time**	08/13/2007 14:22
Project Name/#	Cottonwood Lrk	**Collected Date/Time**	08/09/2007 11:25
Client Sample ID	Site 5	**Received Date/Time**	08/09/2007 13:40
Matrix	Water (Surface, Eff., Ground)	**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	51		col/100mL	SM20 9222D	A			08/09/07	SDP

SGS

SGS Ref.#	1073843006
Client Name	ARRI
Project Name/#	Cottonwood Lrk
Client Sample ID	Site 6
Matrix	Water (Surface, Eff., Ground)

All Dates/Times are Alaska Standard Time

Printed Date/Time	08/13/2007 14:22
Collected Date/Time	08/09/2007 11:00
Received Date/Time	08/09/2007 13:40
Technical Director	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	56		col/100mL	SM20 9222D	A			08/09/07	SDP

SGS Ref.#	1073843007	**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI	**Printed Date/Time**	08/13/2007 14:22
Project Name/#	Cottonwood Lrk	**Collected Date/Time**	08/09/2007 11:05
Client Sample ID	Site 7	**Received Date/Time**	08/09/2007 13:40
Matrix	Water (Surface, Eff., Ground)	**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	74		col/100mL	SM20 9222D	A			08/09/07	SDP

SGS Ref.#	1073843008
Client Name	ARRI
Project Name/#	Cottonwood Lrk
Client Sample ID	Site X
Matrix	Water (Surface, Eff., Ground)

All Dates/Times are Alaska Standard Time

Printed Date/Time	08/13/2007 14:22
Collected Date/Time	08/09/2007 11:10
Received Date/Time	08/09/2007 13:40
Technical Director	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	103		col/100mL	SM20 9222D	A			08/09/07	SDP

SGS Ref.# 1074731001
Client Name ARRI
Project Name/# Cottonwood Cr
Client Sample ID CW Site 2
Matrix Water (Surface, Eff., Ground)

All Dates/Times are Alaska Standard Time
Printed Date/Time 09/18/2007 9:52
Collected Date/Time 09/10/2007 8:45
Received Date/Time 09/10/2007 11:25
Technical Director **Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	7		col/100mL	SM20 9222D	A			09/10/07	SDP

SGS

SGS Ref.#	1074731002
Client Name	ARRI
Project Name/#	Cottonwood Cr
Client Sample ID	CW Site 3
Matrix	Water (Surface, Eff., Ground)

All Dates/Times are Alaska Standard Time

Printed Date/Time	09/18/2007 9:52
Collected Date/Time	09/10/2007 9:00
Received Date/Time	09/10/2007 11:25
Technical Director	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	116		col/100mL	SM20 9222D	A			09/10/07	SDP

SGS

SGS Ref.#	1074731003
Client Name	ARRI
Project Name/#	Cottonwood Cr
Client Sample ID	CW Site 4
Matrix	Water (Surface, Eff., Ground)

All Dates/Times are Alaska Standard Time

Printed Date/Time	09/18/2007 9:52
Collected Date/Time	09/10/2007 8:30
Received Date/Time	09/10/2007 11:25
Technical Director	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	63		col/100mL	SM20 9222D	A			09/10/07	SDP

SGS

SGS Ref.#	1074731004		**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI		**Printed Date/Time**	09/18/2007 9:52
Project Name/#	Cottonwood Cr		**Collected Date/Time**	09/10/2007 8:40
Client Sample ID	CW Site 7		**Received Date/Time**	09/10/2007 11:25
Matrix	Water (Surface, Eff., Ground)		**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	92		col/100mL	SM20 9222D	A			09/10/07	SDP

SGS Ref.#	1074731005	**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI	**Printed Date/Time**	09/18/2007 9:52
Project Name/#	Cottonwood Cr	**Collected Date/Time**	09/10/2007 8:40
Client Sample ID	CW Site 7X	**Received Date/Time**	09/10/2007 11:25
Matrix	Water (Surface, Eff., Ground)	**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	135		col/100mL	SM20 9222D	A			09/10/07	SDP

SGS

SGS Ref.#	1074987001	**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI	**Printed Date/Time**	09/24/2007 15:08
Project Name/#	Cottonwood Cr	**Collected Date/Time**	09/20/2007 9:50
Client Sample ID	CW Site 2	**Received Date/Time**	09/20/2007 13:40
Matrix	Water (Surface, Eff., Ground)	**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	3		col/100mL	SM20 9222D	A			09/20/07	SDP

SGS

SGS Ref.#	1074987002	**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI	**Printed Date/Time**	09/24/2007 15:08
Project Name/#	Cottonwood Cr	**Collected Date/Time**	09/20/2007 10:05
Client Sample ID	CW Site 3	**Received Date/Time**	09/20/2007 13:40
Matrix	Water (Surface, Eff., Ground)	**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	33		col/100mL	SM20 9222D	A			09/20/07	SDP

SGS Ref.#	1074987003	**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI	**Printed Date/Time**	09/24/2007 15:08
Project Name/#	Cottonwood Cr	**Collected Date/Time**	09/20/2007 10:20
Client Sample ID	CW Site 4	**Received Date/Time**	09/20/2007 13:40
Matrix	Water (Surface, Eff., Ground)	**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	32		col/100mL	SM20 9222D	A			09/20/07	SDP

SGS Ref.#	1074987004	**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI	**Printed Date/Time**	09/24/2007 15:08
Project Name/#	Cottonwood Cr	**Collected Date/Time**	09/20/2007 10:40
Client Sample ID	CW Site 7	**Received Date/Time**	09/20/2007 13:40
Matrix	Water (Surface, Eff., Ground)	**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	690		col/100mL	SM20 9222D	A			09/20/07	SDP

SGS

SGS Ref.#	1074987005	**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI	**Printed Date/Time**	09/24/2007 15:08
Project Name/#	Cottonwood Cr	**Collected Date/Time**	09/20/2007 10:45
Client Sample ID	CW Site 7X	**Received Date/Time**	09/20/2007 13:40
Matrix	Water (Surface, Eff., Ground)	**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	1200		col/100mL	SM20 9222D	A			09/20/07	SDP

SGS Ref.#	1081418001	**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI	**Printed Date/Time**	04/11/2008 8:46
Project Name/#	Cottonwood Cr.	**Collected Date/Time**	04/08/2008 11:15
Client Sample ID	CW 7	**Received Date/Time**	04/08/2008 13:30
Matrix	Water (Surface, Eff., Ground)	**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	9		col/100mL	SM20 9222D	A			04/08/08	DLC

SGS Ref.# 1081418002
Client Name ARRI
Project Name/# Cottonwood Cr.
Client Sample ID CW 7X
Matrix Water (Surface, Eff., Ground)

All Dates/Times are Alaska Standard Time
Printed Date/Time 04/11/2008 8:46
Collected Date/Time 04/08/2008 11:15
Received Date/Time 04/08/2008 13:30
Technical Director **Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	10		col/100mL	SM20 9222D	A			04/08/08	DLC

SGS

SGS Ref.# 1081418003
Client Name ARRI
Project Name/# Cottonwood Cr.
Client Sample ID CW 6
Matrix Water (Surface, Eff., Ground)

All Dates/Times are Alaska Standard Time
Printed Date/Time 04/11/2008 8:46
Collected Date/Time 04/08/2008 11:30
Received Date/Time 04/08/2008 13:30
Technical Director **Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	9		col/100mL	SM20 9222D	A			04/08/08	DLC

SGS

SGS Ref.#	1081418004
Client Name	ARRI
Project Name/#	Cottonwood Cr.
Client Sample ID	CW 5
Matrix	Water (Surface, Eff., Ground)

All Dates/Times are Alaska Standard Time

Printed Date/Time	04/11/2008 8:46
Collected Date/Time	04/08/2008 11:40
Received Date/Time	04/08/2008 13:30
Technical Director	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	5		col/100mL	SM20 9222D	A			04/08/08	DLC

SGS

SGS Ref.#	1081418005	**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI	**Printed Date/Time**	04/11/2008 8:46
Project Name/#	Cottonwood Cr.	**Collected Date/Time**	04/08/2008 12:00
Client Sample ID	CW 4	**Received Date/Time**	04/08/2008 13:30
Matrix	Water (Surface, Eff., Ground)	**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	4		col/100mL	SM20 9222D	A			04/08/08	DLC

SGS Ref.# 1081418006
Client Name ARRI
Project Name/# Cottonwood Cr.
Client Sample ID CW 3
Matrix Water (Surface, Eff., Ground)

All Dates/Times are Alaska Standard Time
Printed Date/Time 04/11/2008 8:46
Collected Date/Time 04/08/2008 12:05
Received Date/Time 04/08/2008 13:30
Technical Director **Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	4		col/100mL	SM20 9222D	A			04/08/08	DLC

SGS Ref.#	1081418007	**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI	**Printed Date/Time**	04/11/2008 8:46
Project Name/#	Cottonwood Cr.	**Collected Date/Time**	04/08/2008 12:15
Client Sample ID	CW 2	**Received Date/Time**	04/08/2008 13:30
Matrix	Water (Surface, Eff., Ground)	**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	0		col/100mL	SM20 9222D	A			04/08/08	DLC

SGS

SGS Ref.#	1081418008
Client Name	ARRI
Project Name/#	Cottonwood Cr.
Client Sample ID	CW 1
Matrix	Water (Surface, Eff., Ground)

All Dates/Times are Alaska Standard Time

Printed Date/Time	04/11/2008 8:46
Collected Date/Time	04/08/2008 12:30
Received Date/Time	04/08/2008 13:30
Technical Director	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	1		col/100mL	SM20 9222D	A			04/08/08	DLC

SGS Ref.#	1081629001	**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI	**Printed Date/Time**	04/24/2008 16:27
Project Name/#	Cottonwood Creek	**Collected Date/Time**	04/23/2008 10:00
Client Sample ID	CW1	**Received Date/Time**	04/23/2008 12:50
Matrix	Water (Surface, Eff., Ground)	**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	4		col/100mL	SM20 9222D	A			04/23/08	DLC

SGS

SGS Ref.#	1081629002
Client Name	ARRI
Project Name/#	Cottonwood Creek
Client Sample ID	CW2
Matrix	Water (Surface, Eff., Ground)

All Dates/Times are Alaska Standard Time

Printed Date/Time	04/24/2008 16:27
Collected Date/Time	04/23/2008 10:10
Received Date/Time	04/23/2008 12:50
Technical Director	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	0		col/100mL	SM20 9222D	A			04/23/08	DLC

SGS Ref.#	1081629003	**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI	**Printed Date/Time**	04/24/2008 16:27
Project Name/#	Cottonwood Creek	**Collected Date/Time**	04/23/2008 10:20
Client Sample ID	CW3	**Received Date/Time**	04/23/2008 12:50
Matrix	Water (Surface, Eff., Ground)	**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	0		col/100mL	SM20 9222D	A			04/23/08	DLC

SGS Ref.#	1081629004		**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI		**Printed Date/Time**	04/24/2008 16:27
Project Name/#	Cottonwood Creek		**Collected Date/Time**	04/23/2008 10:30
Client Sample ID	CW4		**Received Date/Time**	04/23/2008 12:50
Matrix	Water (Surface, Eff., Ground)		**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	0		col/100mL	SM20 9222D	A			04/23/08	DLC

SGS Ref.# 1081629005
Client Name ARRI
Project Name/# Cottonwood Creek
Client Sample ID CW5
Matrix Water (Surface, Eff., Ground)

All Dates/Times are Alaska Standard Time
Printed Date/Time 04/24/2008 16:27
Collected Date/Time 04/23/2008 10:40
Received Date/Time 04/23/2008 12:50
Technical Director **Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	7		col/100mL	SM20 9222D	A			04/23/08	DLC

SGS

SGS Ref.#	1081629006	**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI	**Printed Date/Time**	04/24/2008 16:27
Project Name/#	Cottonwood Creek	**Collected Date/Time**	04/23/2008 10:50
Client Sample ID	CW6	**Received Date/Time**	04/23/2008 12:50
Matrix	Water (Surface, Eff., Ground)	**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	5		col/100mL	SM20 9222D	A			04/23/08	DLC

SGS Ref.#	1081629007	**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI	**Printed Date/Time**	04/24/2008 16:27
Project Name/#	Cottonwood Creek	**Collected Date/Time**	04/23/2008 10:55
Client Sample ID	CW7	**Received Date/Time**	04/23/2008 12:50
Matrix	Water (Surface, Eff., Ground)	**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	5		col/100mL	SM20 9222D	A			04/23/08	DLC

SGS Ref.#	1081629008	**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI	**Printed Date/Time**	04/24/2008 16:27
Project Name/#	Cottonwood Creek	**Collected Date/Time**	04/23/2008 11:00
Client Sample ID	CW7X	**Received Date/Time**	04/23/2008 12:50
Matrix	Water (Surface, Eff., Ground)	**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	4		col/100mL	SM20 9222D	A			04/23/08	DLC

SGS Ref.#	1081822001	**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI	**Printed Date/Time**	05/08/2008 10:29
Project Name/#	Cotton Wood	**Collected Date/Time**	05/05/2008 13:50
Client Sample ID	CW 1	**Received Date/Time**	05/05/2008 15:00
Matrix	Water (Surface, Eff., Ground)	**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	0		col/100mL	SM20 9222D	A			05/05/08	DLC

SGS

SGS Ref.#	1081822002	**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI	**Printed Date/Time**	05/08/2008 10:29
Project Name/#	Cotton Wood	**Collected Date/Time**	05/05/2008 13:40
Client Sample ID	CW 2	**Received Date/Time**	05/05/2008 15:00
Matrix	Water (Surface, Eff., Ground)	**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	0		col/100mL	SM20 9222D	A			05/05/08	DLC

SGS

SGS Ref.#	1081822003	**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI	**Printed Date/Time**	05/08/2008 10:29
Project Name/#	Cotton Wood	**Collected Date/Time**	05/05/2008 13:30
Client Sample ID	CW 3	**Received Date/Time**	05/05/2008 15:00
Matrix	Water (Surface, Eff., Ground)	**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	0		col/100mL	SM20 9222D	A			05/05/08	DLC

SGS

SGS Ref.#	1081822004	**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI	**Printed Date/Time**	05/08/2008 10:29
Project Name/#	Cotton Wood	**Collected Date/Time**	05/05/2008 13:15
Client Sample ID	CW 4	**Received Date/Time**	05/05/2008 15:00
Matrix	Water (Surface, Eff., Ground)	**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	0		col/100mL	SM20 9222D	A			05/05/08	DLC

SGS

SGS Ref.#	1081822005	**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI	**Printed Date/Time**	05/08/2008 10:29
Project Name/#	Cotton Wood	**Collected Date/Time**	05/05/2008 12:55
Client Sample ID	CW 5	**Received Date/Time**	05/05/2008 15:00
Matrix	Water (Surface, Eff., Ground)	**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	10		col/100mL	SM20 9222D	A			05/05/08	DLC

SGS Ref.# 1081822006
Client Name ARRI
Project Name/# Cotton Wood
Client Sample ID CW 6
Matrix Water (Surface, Eff., Ground)

All Dates/Times are Alaska Standard Time
Printed Date/Time 05/08/2008 10:29
Collected Date/Time 05/05/2008 12:35
Received Date/Time 05/05/2008 15:00
Technical Director **Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	6		col/100mL	SM20 9222D	A			05/05/08	DLC

SGS Ref.# 1081822007
Client Name ARRI
Project Name/# Cotton Wood
Client Sample ID CW 7
Matrix Water (Surface, Eff., Ground)

All Dates/Times are Alaska Standard Time
Printed Date/Time 05/08/2008 10:29
Collected Date/Time 05/05/2008 12:40
Received Date/Time 05/05/2008 15:00
Technical Director **Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	65		col/100mL	SM20 9222D	A			05/05/08	DLC

SGS

SGS Ref.#	1081822008
Client Name	ARRI
Project Name/#	Cotton Wood
Client Sample ID	CW 7X
Matrix	Water (Surface, Eff., Ground)

All Dates/Times are Alaska Standard Time

Printed Date/Time	05/08/2008 10:29
Collected Date/Time	05/05/2008 12:45
Received Date/Time	05/05/2008 15:00
Technical Director	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	41		col/100mL	SM20 9222D	A			05/05/08	DLC

SGS

SGS Ref.#	1081869001
Client Name	ARRI
Project Name/#	Cottonwood Creek
Client Sample ID	CW 1
Matrix	Water (Surface, Eff., Ground)

All Dates/Times are Alaska Standard Time

Printed Date/Time	05/12/2008 8:53
Collected Date/Time	05/07/2008 14:10
Received Date/Time	05/07/2008 16:45
Technical Director	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	0		col/100mL	SM20 9222D	A			05/07/08	DLC

SGS Ref.#	1081869002
Client Name	ARRI
Project Name/#	Cottonwood Creek
Client Sample ID	CW 2
Matrix	Water (Surface, Eff., Ground)

All Dates/Times are Alaska Standard Time

Printed Date/Time	05/12/2008 8:53
Collected Date/Time	05/07/2008 14:00
Received Date/Time	05/07/2008 16:45
Technical Director	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	0		col/100mL	SM20 9222D	A			05/07/08	DLC

SGS

SGS Ref.#	1081869003	**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI	**Printed Date/Time**	05/12/2008 8:53
Project Name/#	Cottonwood Creek	**Collected Date/Time**	05/07/2008 13:55
Client Sample ID	CW 3	**Received Date/Time**	05/07/2008 16:45
Matrix	Water (Surface, Eff., Ground)	**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	0		col/100mL	SM20 9222D	A			05/07/08	DLC

SGS Ref.#	1081869004
Client Name	ARRI
Project Name/#	Cottonwood Creek
Client Sample ID	CW 4
Matrix	Water (Surface, Eff., Ground)

All Dates/Times are Alaska Standard Time

Printed Date/Time	05/12/2008 8:53
Collected Date/Time	05/07/2008 13:50
Received Date/Time	05/07/2008 16:45
Technical Director	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	0		col/100mL	SM20 9222D	A			05/07/08	DLC

SGS

SGS Ref.#	1081869005	**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI	**Printed Date/Time**	05/12/2008 8:53
Project Name/#	Cottonwood Creek	**Collected Date/Time**	05/07/2008 13:40
Client Sample ID	CW 5	**Received Date/Time**	05/07/2008 16:45
Matrix	Water (Surface, Eff., Ground)	**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	0		col/100mL	SM20 9222D	A			05/07/08	DLC

SGS Ref.# 1081869006
Client Name ARRI
Project Name/# Cottonwood Creek
Client Sample ID CW 6
Matrix Water (Surface, Eff., Ground)

All Dates/Times are Alaska Standard Time
Printed Date/Time 05/12/2008 8:53
Collected Date/Time 05/07/2008 13:20
Received Date/Time 05/07/2008 16:45
Technical Director **Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	2		col/100mL	SM20 9222D	A			05/07/08	DLC

SGS Ref.# 1081869007
Client Name ARRI
Project Name/# Cottonwood Creek
Client Sample ID CW 7
Matrix Water (Surface, Eff., Ground)

All Dates/Times are Alaska Standard Time

Printed Date/Time 05/12/2008 8:53
Collected Date/Time 05/07/2008 13:30
Received Date/Time 05/07/2008 16:45
Technical Director **Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	13		col/100mL	SM20 9222D	A			05/07/08	DLC

SGS Ref.# 1081869008
Client Name ARRI
Project Name/# Cottonwood Creek
Client Sample ID CW 7X
Matrix Water (Surface, Eff., Ground)

All Dates/Times are Alaska Standard Time
Printed Date/Time 05/12/2008 8:53
Collected Date/Time 05/07/2008 13:35
Received Date/Time 05/07/2008 16:45
Technical Director **Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	13		col/100mL	SM20 9222D	A			05/07/08	DLC

SGS

SGS Ref.#	1082546001	**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI	**Printed Date/Time**	06/11/2008 8:14
Project Name/#	Hatcher Pass	**Collected Date/Time**	06/09/2008 13:30
Client Sample ID	HP1	**Received Date/Time**	06/09/2008 15:55
Matrix	Water (Surface, Eff., Ground)	**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	0		col/100mL	SM20 9222D	A			06/09/08	DLC

SGS

SGS Ref.#	1082546002	**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI	**Printed Date/Time**	06/11/2008 8:14
Project Name/#	Hatcher Pass	**Collected Date/Time**	06/09/2008 13:51
Client Sample ID	HP2	**Received Date/Time**	06/09/2008 15:55
Matrix	Water (Surface, Eff., Ground)	**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	0		col/100mL	SM20 9222D	A			06/09/08	DLC

SGS

SGS Ref.#	1082546003		**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI		**Printed Date/Time**	06/11/2008 8:14
Project Name/#	Hatcher Pass		**Collected Date/Time**	06/09/2008 14:12
Client Sample ID	HP3		**Received Date/Time**	06/09/2008 15:55
Matrix	Water (Surface, Eff., Ground)		**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	2		col/100mL	SM20 9222D	A			06/09/08	DLC

SGS

SGS Ref.#	1082546004
Client Name	ARRI
Project Name/#	Hatcher Pass
Client Sample ID	HP4
Matrix	Water (Surface, Eff., Ground)

All Dates/Times are Alaska Standard Time

Printed Date/Time	06/11/2008 8:14
Collected Date/Time	06/09/2008 14:26
Received Date/Time	06/09/2008 15:55
Technical Director	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	1		col/100mL	SM20 9222D	A			06/09/08	DLC

SGS Ref.#	1082546005	**All Dates/Times are Alaska Standard Time**	
Client Name	ARRI	**Printed Date/Time**	06/11/2008 8:14
Project Name/#	Hatcher Pass	**Collected Date/Time**	06/09/2008 14:37
Client Sample ID	HP5	**Received Date/Time**	06/09/2008 15:55
Matrix	Water (Surface, Eff., Ground)	**Technical Director**	**Stephen C. Ede**

Sample Remarks:

Parameter	Results	PQL	Units	Method	Container ID	Allowable Limits	Prep Date	Analysis Date	Init
Microbiology Laboratory									
Fecal Coliform	0		col/100mL	SM20 9222D	A			06/09/08	DLC