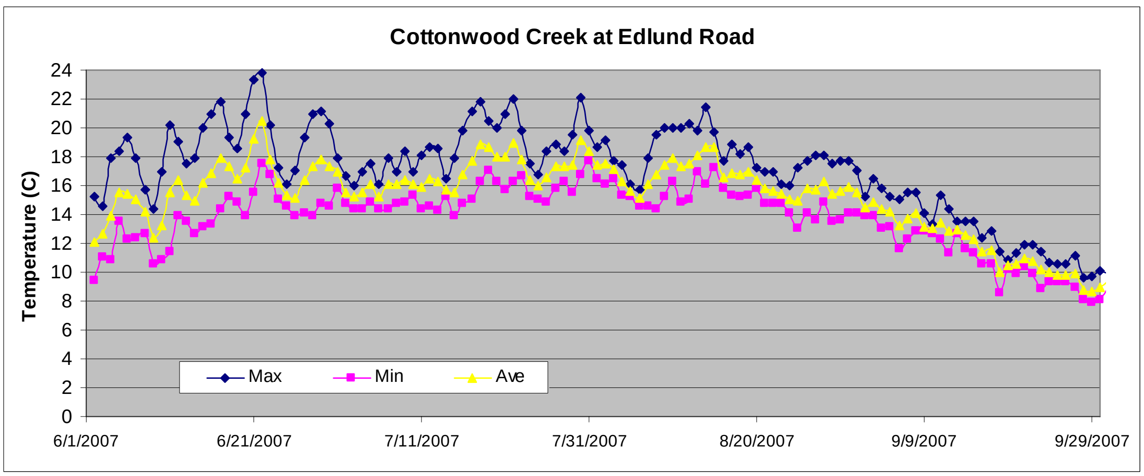
Assessment and Classification of Matanuska-Susitna Fish Habitat—Stream Water Temperature



Jeffrey C. Davis and Gay A. Davis
The Aquatic Restoration and Research Institute
P.O. Box 923, Talkeetna AK, 99676
arri@mtaonline.net 907.733.5432

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Abstract

Stream water temperatures influence most chemical and biological processes in stream ecosystems. However, we have limited water temperature data for streams within Southcentral Alaska. Recent data have shown that stream water temperatures within the Cook Inlet Ecoregion often exceed State Water Quality Standards and approach tolerance values for anadromous salmon. Stream water temperatures vary with regional climate, elevation, vegetation cover, channel shape, ground water input, and other physical features, which differ widely among streams within Cook Inlet. We summarized stream water temperature data collected through a number of different projects within the Matanuska-Susitna Borough from 2001 to 2007 and evaluated the range of stream temperatures, the factors influencing variability, and the relationship to State Water Quality Standards. Three groups of streams were identified based upon this summary. These groups were cold water streams which included small and moderate sized streams draining forested regions of the Talkeetna Mountains; temperate streams, which included the lower portions of larger clear water and semi-glacial streams, and both large and small lowland wetland streams; and warm water streams, which included streams draining small and large lakes. Among the temperate streams, the smaller streams tended to be warmer than the larger streams. Maximum temperatures in cold water streams rarely exceeded 15°C, temperate streams exceeded 15°C often (20% to 60% of the days), and warm water streams exceeded 15°C 75% to 95% of the time and often exceeded 20°C. Stream water temperatures within the Matanuska-Susitna Borough approach tolerance values of fish which could be exceeded with changes to the regional climate or land use practices; however, they also provide a wide array of available habitats for fish and other aquatic organisms. More stream water temperature data are necessary to better understand the relationship with regional climates, spatial variability, and relationship to fish habitat selection and fitness.

Introduction

Steam water temperature has long been understood to be one of the most important physical characteristics of aquatic systems. Temperature affects the metabolic rate of organisms, chemical reactions, gas saturation constants and many other factors either directly or indirectly (Hauer and Hill 2006). Water temperature can increase rates of primary production (Botwell 1988), organic matter decomposition (Peters et al. 1987), the distribution and growth of aquatic insects (Vanotte and Sweeney 1980), and the distribution, migration, and fitness of fish species. Extensive summaries have been produced examining the effects of water temperature on salmonid species (McCullough et al. 2001, Richter and Kolmes 2005).

Stream water temperatures during periods of no surface runoff is mainly a function of groundwater temperatures, which is generally within 1°C of mean annual air temperature, and is relatively stable (Vanotte and Sweeny 1980). Sunlight is the greatest source of heat to most streams. Small forested streams with forest cover are generally cooler, and land use practices that open the canopy can result in rapid increases in water temperatures (Beschta et al. 1987). Multiple different factors can influence the relative amount of heating from sunlight and cooling from groundwater and hyporheic exchange, including substrate porosity, channel width and depth, presence of lakes and other impoundments, and surface runoff (see Poole and Berman 2001). Due to the high specific heat of water, it takes more solar energy to heat larger streams, which also have lower diel variability. The staining of Alaskan lakes, due to dissolved carbon, also has been shown to increase water temperatures relative to other lakes (Edmundson and Mazumder 2002). Much of the work in Alaska has been focused on the larger glacial rivers, which, along with the northern latitude, has promoted the assumption that streams are cool and are not likely to reach levels lethal to salmonids (i.e. Richardon and Milner 2005; Kyle and Brabets 2001). However, salmon die-off has occurred in Southeast Alaska due to low dissolved oxygen, indirectly caused by high temperatures and low flows (Murphy 1985). Recently, water temperatures have been measured in excess of 20°C in Southcentral Alaska streams.

Although water temperatures exert a large influence on aquatic systems and may approach lethal or tolerance levels, we have little information on the distribution of temperatures among Southcentral Alaskan streams. Streams within the Matanuska-Susitna Borough vary widely in the physical characteristics that drive stream water temperatures. These include glacial or semi-glacial streams, small upland forested streams, larger upland clear water streams, large and small lowland brown-water or stained streams, and stream lake complexes. Therefore, there should be differences in water temperatures among these sites. Variability in water temperatures would provide a large range of physical habitats available for fish and other aquatic organisms. These streams also would likely vary in organic matter content and decomposition rates, algal and aquatic plant production, invertebrate production, and fish production and fitness. Understanding the variability in stream temperatures may allow us to better identify highly productive regions and areas of temperature refugia. The objective of this summary is to classify streams within the Matanuska-Susitna Borough based upon temperature differences, and to shed light on the local and watershed level factors that may control the temperature regime.

Methods

Stream water temperatures are summarized from data collected through multiple different projects from 2001 through 2007. Stream water sampling locations are shown in Table 1. Sampling was conducted within 18 different streams and at multiple locations within many streams. Samples were collected at 4 locations in Wasilla Creek in 2001, 7 locations in Cottonwood Creek in 2004, 2005 (partial year) and 2007, two locations on Montana Creek in 2005, and 5 locations in the Little Susitna River in 2007. In 2007 we collected water temperature as part of a Forest Resources and Practices Act effectiveness monitoring project in four small upland streams that drain into Little Willow Creek. We also collected water temperature at multiple locations on Cottonwood Creek and on Little Meadow Creek, Meadow Creek, and Fish Creek (above and below Big Lake) as part of an Alaska Clean Water Actions funded project. Additional sites were selected in 2007 through a National Fish Habitat Initiative, Mat-Su Salmon Partnership grant to build upon these projects by selecting four sites in larger brown water streams, and four sites in small brown water streams. Sites were selected above and below Question Lake and Nancy Lake to increase the sample size for stream/lake systems. Temperature was recorded at two locations in the larger streams, and above and below lakes when present. Therefore, temperature data represents different stream systems including small brown-water wetland streams, small upland streams, larger brown-water streams, stream and lake systems, large clear water streams and semi-glacial streams (Table 1).

Stream water temperatures were recorded using Onset Stowaway or Pro Temp thermometers and data loggers. The data loggers were placed on the stream bed and secured to the bank using plastic coated wire rope. Logger deployment dates, removal dates and recording interval varied among locations. Results represent data collected from June or mid-July through September. Stream water temperature measurements followed sampling methodology outlined with DEC approved Quality Assurance Project Plans for data collection and handling (see Davis et al. 2007).

Daily maximum, minimum, and average water temperatures were derived from multiple measures recorded during a 24 hour period. Sampling frequency ranged from 15 minutes to 1 hour in 2007; however, sampling frequency prior to 2007 ranged from 2 to 4 hours. 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 regional airports in Palmer and Talkeetna, Alaska. 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.

Similar physical, chemical and biological parameters were measured at most locations and were used to further differentiate among stream systems. Stream order, valley slope, elevation, and aspect were taken from U.S.G.S. 1:63000 topographic maps using the

National Geographic Topo computer program. Channel width, depth and water surface slope were measured in the field. Stream water discharge was obtained from U.S.G.S. gauging stations or measured. Stream water samples were collected and measures of pH, specific conductivity, turbidity, and dissolved oxygen are available for all sampling locations. Additional physical, chemical and biological data are available for Montana Creek (Davis et al. 2006a), the Little Susitna River (Davis et al. 2007), Cottonwood Creek (Davis et al. 2005), Wasilla Creek (Davis and Muhlberg 2002), and the Little Willow Creek tributaries (Davis et al. 2006b).

The project objective of 2007 data collection, and this summary, is to determine whether, and to what degree stream water temperatures differ among sites that vary in their physiochemical characteristics. We were interested in how water temperatures related to State Water Quality Standards and tolerance values of rearing anadromous salmon.

Table 1. Steam water temperature sampling locations.

Site Name	Description	Latitude	Longitude	Elev (m)
Wiggle Creek	Near confluence with the Talkeetna River	62°21’00.4”	150°06’11.8”	123
Twister Creek	Near Susitna River at ARRC Culvert	62°18’07.3”	150°06’22.3”	102
Queer Creek	Upstream from confluence with Rabideaux	62°11’31.3”	150°13’04.0”	95
Mile 118	Near Trapper Creek on trail from Parks Highway mile 118.2	62°21’56.0”	150°17’00.8”	151
Trapper Creek Upstream	End of Kula Road off of Petersville Road	62°19’38.9”	150°15’30.5”	135
Trapper Creek Downstream	At the Bradley Road Crossing	62°15’58.9”	150°11’1.7”	104
Rabideaux Upstream	Northern Parks Highway crossing	62°14’35.3”	150°14’59.8”	114
Rabideaux Downstream	Southern Parks Highway crossing near Susitna River	62°11’27.6”	150°12’30.4”	71
Moose Creek Upstream	Petersville Road	62°13’45.4”	150°26’26.4”	151
Moose Creek Downstream	Oilwell Road	62°13’45.3”	150°26’26.3”	115
Kroto Creek Upstream	Petersville Road	62°20’51”	150°37’16.3”	268
Kroto Creek Downstream	Oilwell Road	62°07’58.1”	150°32’11.9”	116
Question Creek Upstream	Above Little Question Lake	62°13’23.3”	150°03’20.1”	120
Question Creek Downstream	Below Talkeetna Spur Road	52°13’20.9”	150°05’09.4”	111
Nancy Lake Upstream	Above Lake, below the Parks Highway and ARRC crossing	61°4’ 06.4”	149°58’15.8”	67
Nancy Lake Downstream	Below the Lake outlet	61°40’15.8”	150°06’11.8”	57

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
Little Susitna R. at Goldmint Trailhead	Upper end of the Goldmint trailhead parking area.			
Little Susitna R. at Mile 12	Mile 12.0 of the Hatcher Pass Road	61°45’59.6”	149°13’47”	566
Little Susitna R. at Sushana Drive	Sushana Drive crossing	61 38 33.0	149°31’”30.0	107
Little Susitna R. at Millers Reach	Downstream of Houston and below the undeveloped boat launch	61°37’16.6”	149°50’57.8”	62
Little Susitna R. at Public Use Site	Below public use boat launch	61°26’07.4”	150°10’21.8”	12
Iron Creek South (WK1)	Upstream of Willer-Kash Road crossing near Willow	61°49’34”	149°50’11”	204
Iron Creek North (WK2)	Upstream of Willer-Kash Road crossing near Willow	61°5’06”	149°49’58”	199
Little Willow Trib South (WK3)	Proposed northern extension of Willer-Kash Road	61°52’37”	149°49’50”	196
Little Willow Trib North (WK4)	Proposed northern extension of Willer-Kash Road	61°53’ 04”	149°50’57”	183
Dry Creek	Upstream of Neklason Lake at Caribou St. crossing	61.62402°	149.31129°	129
Cottonwood Creek above Cornelius Lake	Settlement avenue road crossing	61.63240°	149.24189°	133
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

Site Name	Description	Latitude	Longitude	Elev (m)
Upper Wasilla Creek	End of Herman Road, along Powerline access	61.67141°	149.18133°	198
Wasilla Creek at Bogard Road	Just upstream of the Bogard Road Crossing	61.61449°	149.23913°	109
Wasilla Creek at Upper Hyer Road	Old Petersen Farm downstream from the Palmer Wasilla Hwy	61.58947°	149.25141°	84
Wasilla Creek below ARRC crossing	Approximately 1 km below railroad crossing at trail from Shamrock Septic	61.56683°	149.31310°	41

Results and Discussion

Regression equations between maximum air temperatures at regional airports used either data from the Talkeetna (Nancy Creek and streams north) or Palmer (south of Nancy Creek) airports. These two airports and all of the streams are within the Cook Inlet Ecoregion (Gallant et al. 1995). Ecoregions are based upon similarities in climate data, so temperature data should be comparable between locations. However, to ensure compatible results, we compared air temperatures between the two airports. Maximum daily temperatures were very similar (Figure 1). The average absolute difference in maximum air temperature was 1.46°C. Monthly cumulative degree days were very similar for June through September. In June, cumulative degree days differed by less than 1 and by only 3 in August. Monthly cumulative degree days differed by 20 in June and September with Talkeetna being warmer in the spring and Palmer warmer in the fall. Regression equations for sites above and below Nancy Lake were calculated using both Palmer and Talkeetna air temperatures. The slopes of the regression lines varied by less than 0.01, therefore, use of data from either site would provide the same results.

Summary stream temperature statistics for 2007 are shown in Table 2 (also see Appendix A). There was a large variability in stream temperatures among sampling sites. Maximum water temperatures ranged from 12.8 to 24.6°C. The maximum seasonal daily change was from 3 to 9°C. Some streams rarely exceeded 15°C, while at other sites this temperature was exceeded from 75 to 95% of the days measured. August cumulative degree days ranged from 240 to 542 and regression coefficients 0.24 to 0.80.

Two groups of streams represented the upper and lower range of sites. The small upland streams draining the Talkeetna Mountains were much cooler and the Cottonwood Creek sites and other streams below lakes much warmer than other locations. Lowest water temperatures were found in the small upland streams and the semi-glacial, Little Susitna River, from mile 12 of the Hatcher Pass Road to Houston (Table 2). Maximum stream water temperatures exceeded 13°C up to 20% of the time, but rarely exceeded 15°C. Regression slopes were low, up to 0.4. Therefore, stream temperature within these streams increased up to 0.4 degrees for every degree increase in air temperature.

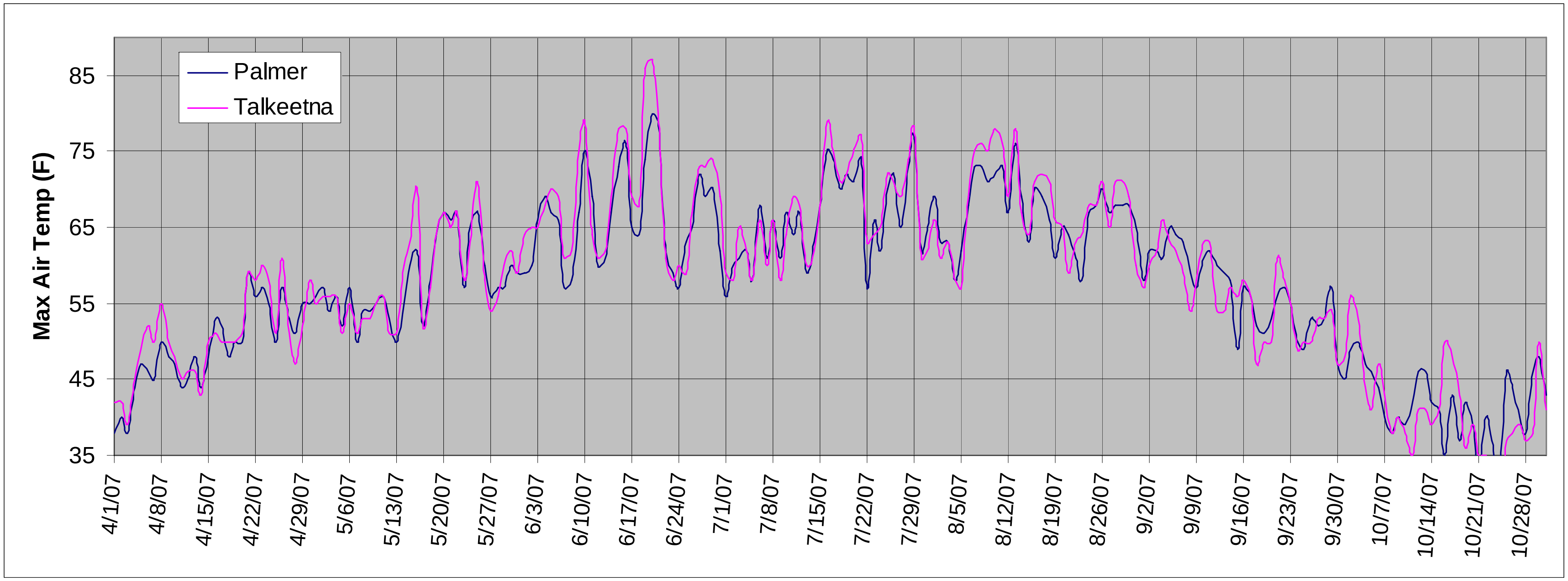

Figure 1. Comparison between maximum daily air temperatures recorded at the Talkeetna and Palmer airports.

Table 2 Summary of 2007 stream water temperature statistics sorted by season maximum. Days exceeding 13 and 15 °C are based upon Alaska Water Quality Standards for the growth and propagation of fish and shellfish. Monthly degree days are the sum of average daily values.

	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 Susitna River-Mile 12 Hatcher Pass Road	13.5	7.4	147	4	3%	0	0%	0	175	249	241	158	0.24	0.29
Iron Creek Trib North (WK2)	12.4	5.6	117	0	0%	0	0%	0	217	247	252	152	0.25	0.55
Little Susitna River at the Sushana D. Bridge	13.9	6.2	120	5	4%	0	0%	0	233	291	N/A	159	0.29	0.34
Little Willow Trib South (WK3)	12.8	5.6	116	0	0%	0	0%	0	236	118*	124*	174	0.29	0.64
Little Willow Trib North (WK4)	13.6	5.9	117	2	2%	0	0%	0	244	282	290	182	0.31	0.60
Iron Creek Trib South (WK1)	15.6	5.1	117	12	10%	2	2%	0	288	324	329	192	0.37	0.62
Little Susitna River at Miller's Reach	15.4	3.9	157	13	8%	3	2%	0	292	353	342	245	0.37	0.45
Nancy Creek above Nancy Lake	15.5	4.3	69	14	20%	1	1%	0	N/A	N/A	350	247	0.41	0.73
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
Rabideaux at North Parks Highway Crossing	19.1	4.9	69	37	54%	16	23%	0	N/A	N/A	420	278	0.53	0.74
Moose Creek at Petersville Road	19.2	4.2	69	37	54%	17	25%	0	N/A	N/A	410	261	0.51	0.71
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
Rabideaux at South Parks Highway Crossing	19.5	4.9	69	37	54%	16	23%	0	N/A	N/A	410	268	0.52	0.73
Trapper Creek above Parks Highway	19.8	4.7	69	44	64%	32	46%	0	N/A	N/A	453	296	0.58	0.75
Twister Creek	19.9	3.1	69	43	62%	27	39%	0	N/A	N/A	450	286	0.56	0.72
Moose Creek at Oilwell Road	20.1	5.1	50	19	38%	8	16%	1	N/A	N/A	154*	265	0.52	0.67
Little Susitna River at Public Use Facility	20.3	5.4	157	87	55%	47	30%	1	380	457	416	266	0.54	0.51
Lower Trapper Creek	20.5	4.1	69	40	58%	30	43%	1	N/A	N/A	452	291	0.57	0.72

	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
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 Surrey Road	20.8	6.4	122	101	83%	82	67%	2	439	484	472	328	0.64	0.79
Mile 118.2 Trail Creek	21.2	6.9	69	47	68%	36	52%	2	N/A	N/A	468	287	0.60	0.72
Queer Creek	21.6	5.5	69	50	72%	38	55%	4	N/A	N/A	480	320	0.64	0.74
Kroto Creek at Oilwell Road	21.7	5.5	68	40	59%	35	51%	2	N/A	N/A	451	269	0.59	0.70
Wiggle Creek	21.8	4.4	69	46	67%	37	54%	4	N/A	N/A	478	289	0.61	0.70
Question Creek above Question Lake	22.3	5.3	69	49	71%	39	57%	8	N/A	N/A	498	310	0.65	0.77
Kroto Creek at Petersville Road	22.4	6.5	52	26	50%	17	33%	5	N/A	N/A	206*	261	0.56	0.64
Cottonwood Creek at Wasilla Lake Outlet	24.3	6.3	122	109	89%	99	81%	34	508	569	557	383	0.72	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
Nancy Creek below Nancy Lake	23.7	4.8	69	56	81%	50	72%	18	N/A	N/A	568	392	0.77	0.77
Cottonwood Creek at Neklason Lake Outlet	24.5	7.6	122	108	89%	98	80%	39	506	552	551	363	0.78	0.71
Question Creek below Question Lake	23.2	3.8	69	60	87%	52	75%	19	N/A	N/A	582	412	0.79	0.71
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
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

*Value based upon incomplete data set.

Table 3. Stream water temperature statistic for Montana Creek and Wasilla Creek for data collected from mid-July through September in 2005 and 2001, respectively.

	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
Montana Creek at Yoder Road (2005)	17.24	6.23	74	32	43%	11	15%	0	N/A	N/A	369	237	0.44	0.64
Montana Creek at ARRC (2005)	19.26	5.81	42	35	83%	22	52%	0	N/A	N/A	390	N/A	0.55	0.16
Wasilla Creek at Moose Range (2001)	12.72	4.03	74	0	0%	0	0%	0	N/A	N/A	303	176	0.30	0.47
Wasilla Creek at Bogard	11.92	2.17	74	0	0%	0	0%	0	N/A	N/A	294	182	0.28	0.49
Wasilla Creek Scott Petersen Farm	12.07	2.01	73	0	0%	0	0%	0	N/A	N/A	312	187	0.30	0.64
Wasilla Creek below ARRC	12.26	2.01	62	0	0%	0	0%	0	N/A	N/A	312	129	0.31	0.22

Monthly cumulative degree days were less than 350 in August and less than 250 in September. Upper Montana Creek at the Yoder Road Crossing, and Wasilla Creek also fit among these colder streams (Table 3). Water temperature in Wasilla Creek was measured from July 19 through September of 2001 (Davis and Muhlberg 2002). Stream water temperatures never exceeded 13°C and August cumulative degree days were near 300 for September, less than 200, and regression coefficients were near 0.30. Montana Creek at Yoder Road is at the upper end of this group of cold water streams. August and September cumulative degree days are within the range of values seen for streams in this category, and the regression slope was 0.44. Montana Creek, a 3rd order stream with channel widths near 25 m, is much larger than most of the streams in this category, excluding the semi-glacial Little Susitna River. However, Montana Creek at Yoder Road is just below the confluence of three smaller forks that drain the forested slopes of the Talkeetna Mountains.

The remaining streams within this cold-water category (Wasilla Creek, Nancy Lake Creek above the Lake, and tributaries of Little Willow Creek) were all 1st or 2nd order streams, with channel widths of 4 to 6 meters, slopes of near 1%, discharge from 10 to 20 cfs, and draining the foothills of the Talkeetna Mountains. All of the streams pass through the mixed birch and spruce forest, with a tall alder scrub along the margins. Wasilla Creek flows to the south and the remaining streams flow to the west.

Lake outlet streams were distinctly warmer than other sites. These included sites on Cottonwood Creek, Fish Creek, Nancy Lake Creek, and Question Creek. Within these streams water temperatures exceeded 15°C from 70 to 95% of the time and maximum daily water temperatures often exceeded 20°C. Monthly cumulative degree days in July and August were well over 500 and in September, from 350 to 400. Slopes of regression lines were high at 0.72 to 0.80. High stream water temperatures occurring below lakes is not surprising due to the exposed surface area. However, among these streams, only a small amount of lake surface area is necessary to increase water temperatures. For example, water temperature in Question Creek below Question Lake with a surface area of 100 acres are nearly identical to similar measures in Fish Creek below Big Lake with a surface area of 2,500 acres. Water temperature in Cottonwood Creek below Neklason Lake also is very similar with an exposed upstream lake surface area of 46.7 acres (sum of Neklason and Cornelius Lakes). A similar comparison could be made for Nancy Lake. Water temperatures in inlet streams to all of these lakes are comparable and quite cool. Water temperature in Nancy Creek above the lake is among one of the cold water streams and water temperature in Cottonwood Creek above Cornelius Lake is an almost consistent 6°C (Davis and Davis 2005).

We have limited data to evaluate the rate at which streams cool below lake outlets. In Cottonwood Creek, there is a slight cooling between the outlet of Wasilla Lake, the lowest lake in the system and Edlund Road, approximately 4 miles downstream. However, stream water temperatures at Edlund Road still place it among the warmest group of sites located below lakes. At Surrey Road, approximately 7 miles downstream from Wasilla Lake, water temperatures have cooled, with August cumulative degree days in the 400s and regression slope at 0.64. Stream water temperature in Fish Creek at

Knik-Goose Bay Road is very similar to those measured in Cottonwood Creek at Surrey Road; however, the distance is near 11 miles.

The remainder of the streams were distinct from both extremes. These sites included all of the small and large lowland or wetland streams, the lowest site on the Little Susitna River, the lower sites on Cottonwood Creek and Fish Creek, and Montana Creek near the Susitna River. Regression coefficients at these sites range from 0.51 to 0.61. Water temperatures exceeded 13°C 40 to 80% of the days, 15°C roughly 50% of the time, and occasionally exceeded 20°C in 2007. August cumulative degree days ranged from 410 to 490 and in September from 260 to 320. Both Cottonwood Creek at Surrey Road and Fish Creek at Knik-Goose Bay Road were within this group, and represent streams cooling as the distance from lake outlets increased. Montana Creek and the Little Susitna River represent clear-water and semi-glacial systems. These two sites are much larger than the remaining locations within this category with stream widths from 25 to 30 m which would allow more sunlight to reach the stream surface. Both of these streams pass through an intact forest with little riparian modification (Davis et al. 2006 and Davis et al. 2007). The tightness of the regression equations between max daily air and max daily water temperatures at these streams were lower than at other sites. This could be explained by the larger volume of water with flows in these streams of 100 to 200 cfs from June through September, which would respond slower to daily temperature changes (see Table 4 for comparison values).

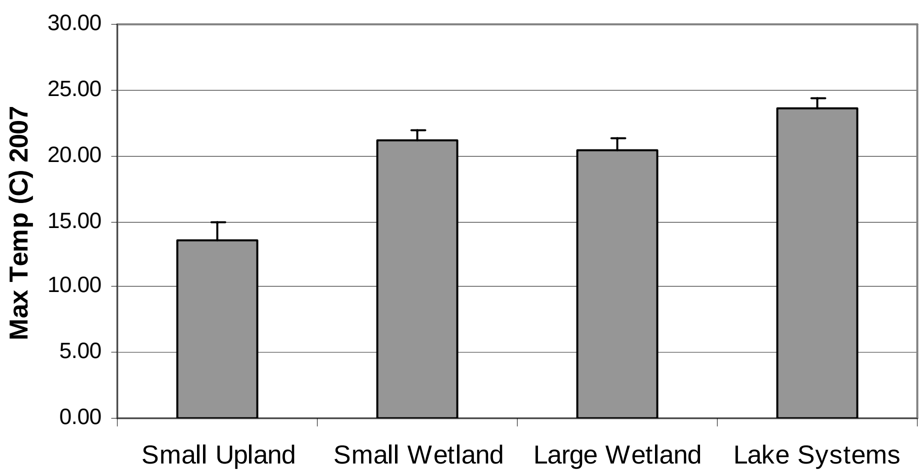

Figure 2. Average maximum stream temperature (N = 4) for the four different stream types. Error bars are one standard deviation.

Stream size best explained differences in water temperatures among the small and large wetland streams. Comparisons between maximum small and large wetland streams revealed higher average maximum temperatures in the small streams; however, differences were not significant between these two stream types (Figure 2). Comparison of regression coefficients revealed a relationship with channel width and discharge.

Among the wetland streams open to solar radiation, small streams tended to be warmer and heat more rapidly than the larger streams (Table 4). While larger streams have a greater surface area for intercepting solar radiation, they have a greater volume of water to heat. There were two exceptions to this relationship: Kroto Creek at Oilwell Road, which was warmer than expected, and Twister Creek, a small stream that was cooler than expected. Kroto Creek was the largest among the streams draining the wetlands west of the Susitna River. The primary physical difference with this stream and the other large wetland stream was overall channel width and the width depth ratio. It may be that this high ratio of surface area to stream volume resulted in more rapid heating than expected. Kroto Creek also received tributary input from Amber Lake upstream from the Oilwell Road Crossing, which may be influencing water temperature at this site; however, we do not know the relative volume of water from this tributary. Twister Creek is a small drainage that arises near the Talkeetna Airport in a bend between the Talkeetna and Susitna Rivers.

Table 4. Temperature, channel geometry and slope for small and large lowland wetland streams sorted by regression coefficient.

	Season Maximum (C)	Maximum Daily Range (C)	August Cumulative Degree Days	September Cumulative Degree Days	Regression Coefficient	Elevation (m)	Channel Width (m)	w/d ratio	Discharge (cfs)
Moose Creek at Petersville Road	19.25	4.23	410	261	0.51	151	10.0	24	25.0
Rabideaux at South Parks Highway Crossing	19.46	4.93	410	268	0.52	71	12.2	30	14.6
Moose Creek at Oilwell Road	20.10	5.06	155*	265	0.52	115	10.9	25	31.4
Rabideaux at North Parks Highway Crossing	19.13	4.96	420	278	0.53	114	10.0	22	14.0
Twister Creek	19.89	3.16	450	286	0.56	102	2.2	22	0.8
Kroto Creek at Petersville Road	22.39	6.55	206*	261	0.56	268	10.0	24	35.0
Meadow Creek at Beaver Lakes Road	19.41	5.24	441	284	0.57	50	10.0	22	
Lower Trapper Creek	20.53	4.14	452	291	0.57	104	9.9	32	6.6
Trapper Creek above Parks Highway	19.77	4.73	453	296	0.58	135	9.0		6.0
Kroto Creek at Oilwell Road	21.70	5.47	451	269	0.59	116	20.5	85	48.6
Little Meadow Creek at Meadow Lakes Loop	18.94	5.34	287*	288	0.60	110	2.9	26	2.8
Mile 118.2 Trail Creek	21.15	6.99	468	287	0.60	151	4.7	32	0.9
Wiggle Creek	21.82	4.38	478	289	0.61	123	3.3	10	5.6
Queer Creek	21.60	5.48	480	320	0.64	95	2.4	9	1.6
Question Creek above Question Lake	22.30	5.31	498	310	0.65	120	3.5	15	6.5

Twister Creek may be receiving ground water or subsurface flow from the glacial Talkeetna River which may explain the cooler than expected water temperatures. Specific conductivity within Twister Creek was much higher (105 μS/cm) compared to the other small wetland streams (30 to 70 μS/cm) which also suggests a potential groundwater source.

Summary

This summary of stream temperatures within the Matanuska-Susitna Borough is based upon limited data, and clearly more information is needed to understand the variability among streams and the influencing factors. In particular, we have limited data for glacial and semi-glacial streams. The U.S. Geological Survey present maximum and minimum temperature data for the Susitna River from studies conducted in the 1980s as part of the Susitna-Hydro project (Kyle and Brabets 2001). Maximum water temperatures in the Susitna ranged from 5 to 13.5°C. Many of the tributary streams to the Susitna are glacial or semi-glacial (e.g. Sheep Creek and the Kashwitna River). Run timing of anadromous salmon has been linked to water temperatures and may be an important consideration for these systems.

Additional data are needed for the larger clear-water streams. These could include Willow Creek, Montana Creek, the North Fork of the Kashwitna, Clear Creek, Peters Creek, Cache Creek, Indian River, Portage Creek, and the East and Middle Forks of the Chulitna. Based upon our limited data, these wider streams present a large surface area for solar heating but they have weaker correlations with daily air temperature presumably due to a greater volume of water. All of these streams support the spawning of Chinook salmon and additional temperature information could help better understand variability in spawning timing and success.

Further information is necessary for lake and stream systems to further understand the factors influencing the rate of cooling below lakes. Stream systems below lakes have the highest temperatures and often may exceed tolerance values for anadromous salmon. During warm years the lower reaches of these streams may provide temperature refugia. Stream systems below lakes may be extremely sensitive to land use practices that could change cooling rates in these streams.

Similar to lake and stream systems, further information is needed to understand the temperature regime for the lowland or wetland streams of the Susitna drainage. These stream systems are abundant throughout the lower elevations of the Yentna and Susitna Rivers. These productive wetland stream systems likely provide critical rearing and overwintering habitat for juvenile Chinook and coho salmon. Water temperatures within these streams could easily exceed tolerance values for salmon with increasing air temperatures, changes in stream flow, or channel or riparian modifications.

The regression relationship between maximum daily air temperatures and maximum daily stream temperatures provided a useful tool for comparing stream temperatures among sites and over time. Cottonwood Creek is the only site where multiple years are available for comparisons. The regression slope at the Old Matanuska Road varied only from 0.77 to 0.81 from 2004 to 2007 (Table 5). Regression slopes were calculated for this same site from air and water temperature collected in 1958 (Whitesel 1959). The slope of the regression line for this site in 1958 was 0.82. Therefore, the rate of heating at this site, based upon regression coefficients, has not changed since that time.

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).

The regression slope also can be used to estimate stream temperatures from changes in air temperatures. Three regression slopes are used to estimate maximum daily stream temperature from maximum air temperatures. Slopes were selected that represented the three classifications of streams identified in this study, 0.4, 0.6, and 0.8 (Figure 3). Using these equations, maximum daily stream temperatures will exceed 15°C in the lake outlet and wetland streams when air temperatures exceed 65°F. Maximum water temperatures will exceed 20°C when air temperatures are greater than 80°F. The cold water streams are not likely to exceed 20°C and air temperatures will need to reach 80°F for water temperatures to exceed 15°C. Linear regression lines developed from data collected from June through September is a much more simplistic approach than that used by Kyle and Brabets (2001). However, our regression equations should be comparable to gamma, used in their study, which represented the steepest slope in their temperature model. Most of the sites in that study were in glacial or clear water streams and had low values for gamma as we would have expected. Higher slopes were calculated for the Kenai River below Skilak Lake (0.5) and the Ninilchik River (0.6). The Deshka River; however, had a gamma value of 0.2 and, based upon our data, we would have expected a similar high slope, near 0.6, as calculated for sites within this same drainage upstream (Kroto Creek).

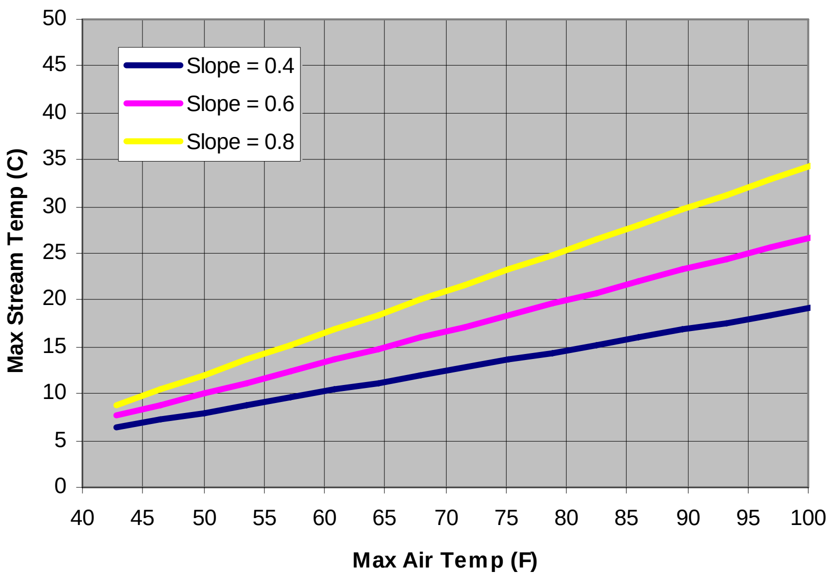

Figure 3. Estimated maximum water temperature as a function of air temperature for three different coefficients.

Streams within the Matanuska-Susitna exhibited a wide array of water temperatures. This wide variability in water temperature may be important for the production of cold water fish. The warmer wetland and lake sites likely are more productive and would provide more stable rearing and overwintering habitat. The small cold upland streams may provide critical spawning habitat and greater health and survival to rearing salmon during warm, dry years. The warmer lake outlet streams and many of the small wetland streams may not be habitable to rearing cold-water fish as air temperatures exceed 80°F. Stream water temperatures in general varied based upon vegetation cover, the presence of lakes, and size; however, channel form and ground water appeared to have a greater influence at some sites. Clearly more information is necessary to understand and further classify the variability in temperature habitats available to fish and other aquatic organisms.

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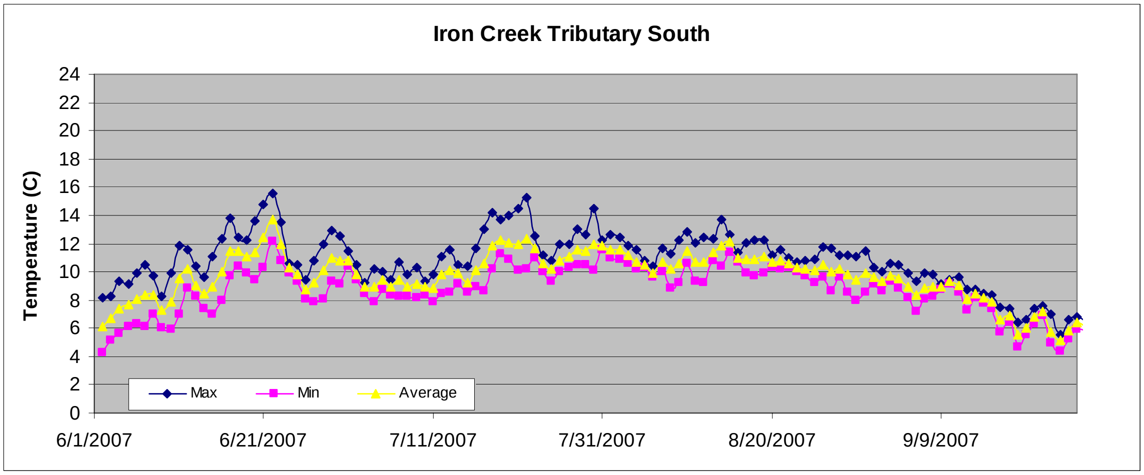
Appendix A—Temperature Graphs


Iron Creek Tributary South
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22
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7/11/2007
7/31/2007
8/20/2007
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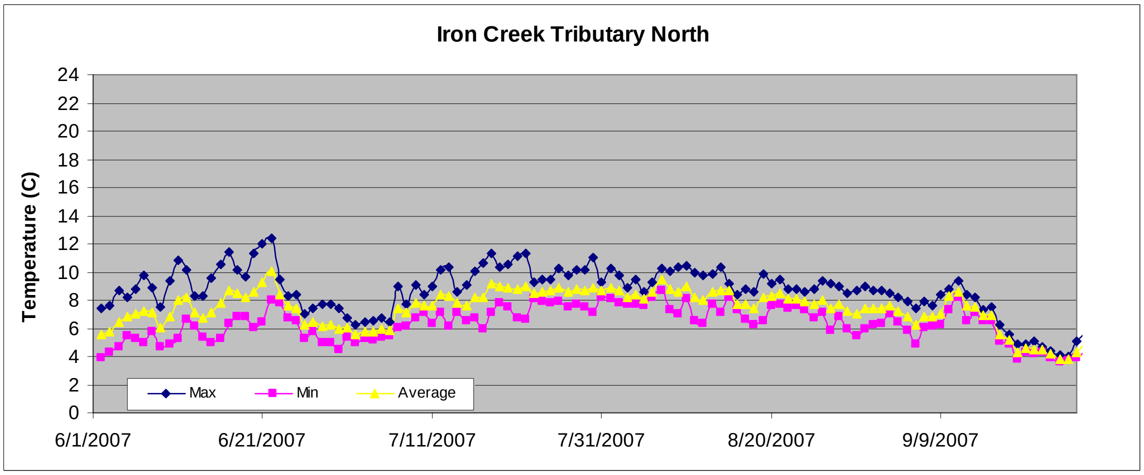
Average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Temperature (C)
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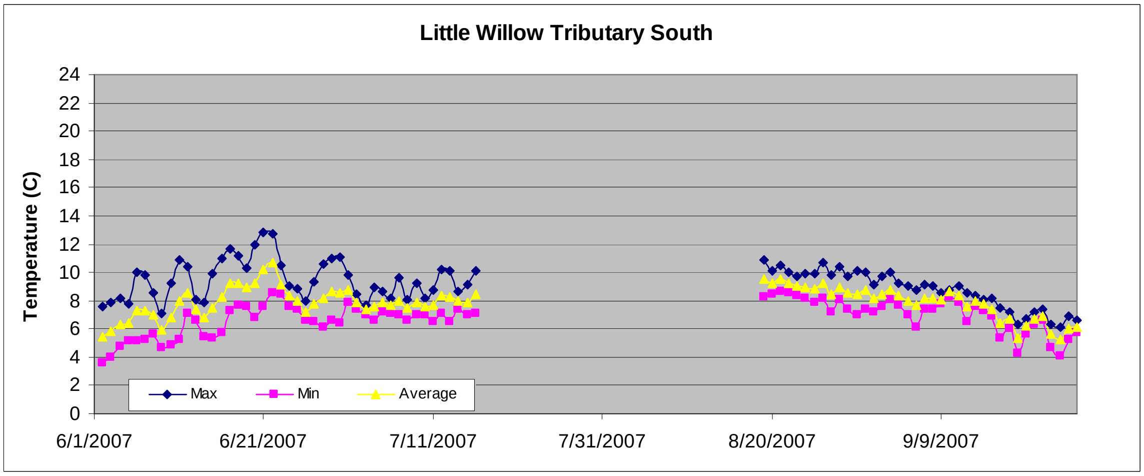
Little Willow Tributary South
Temperature (C)
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Max
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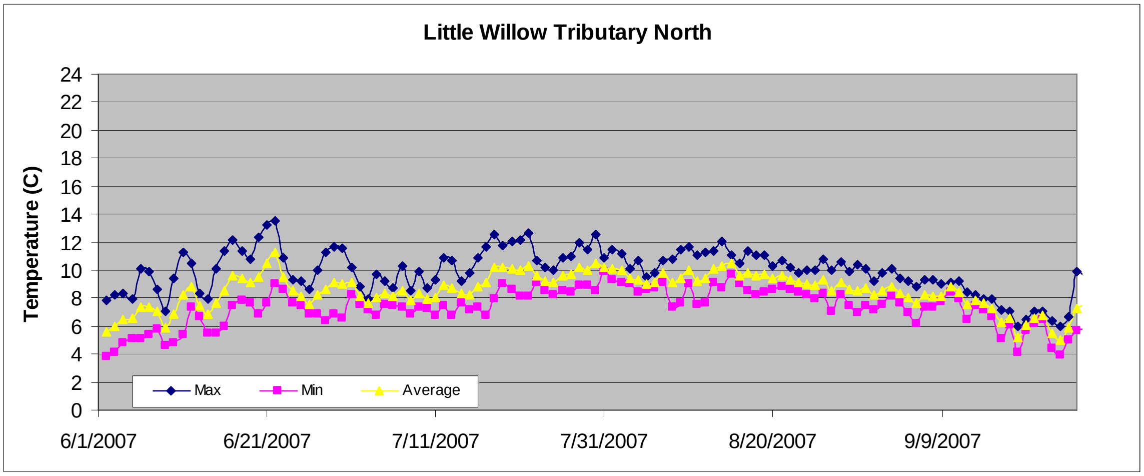
Little Willow Tributary North
Temperature (C)
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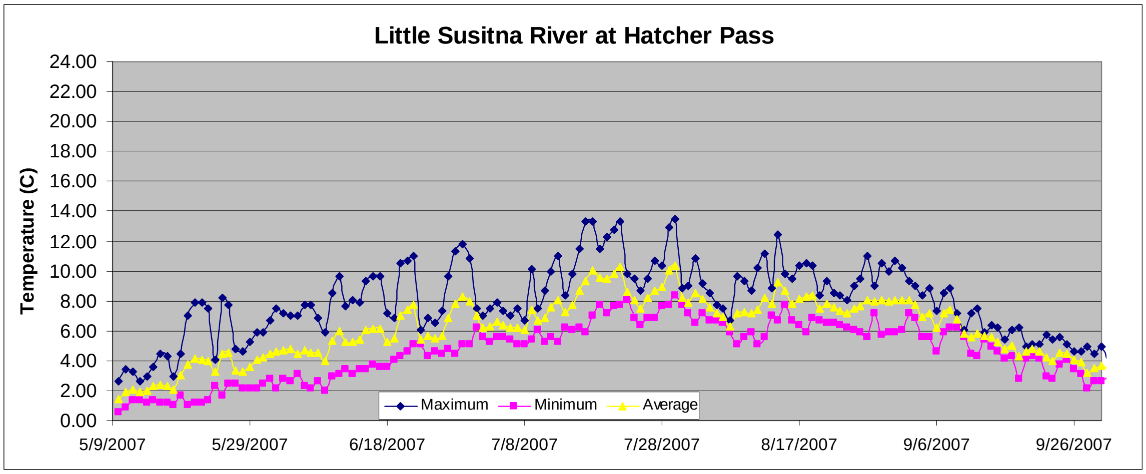
9/9/2007


Little Susitna River at Hatcher Pass
Temperature (C)
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Maximum
Minimum
Average
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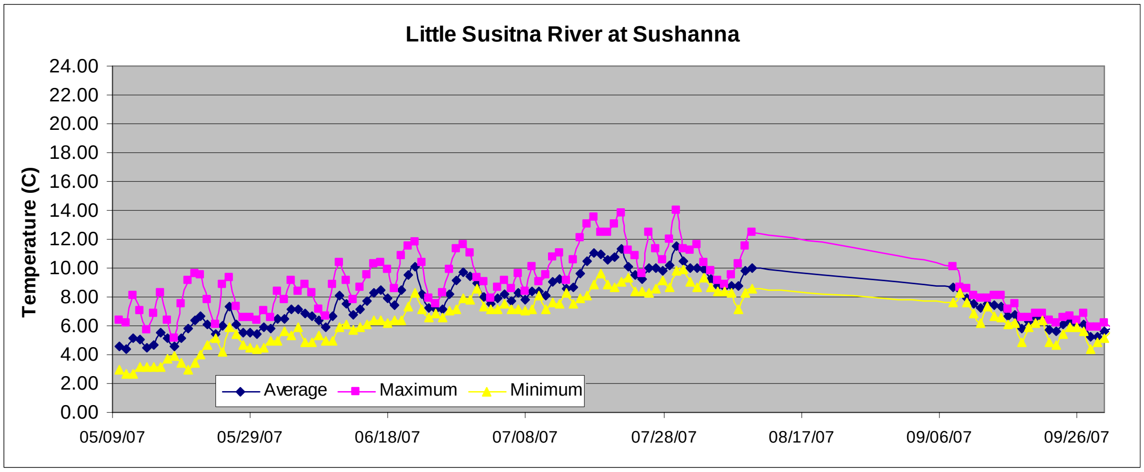
7/28/2007
8/17/2007
9/6/2007
9/26/2007


Little Susitna River at Sushanna
Temperature (C)
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12.00
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8.00
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Average
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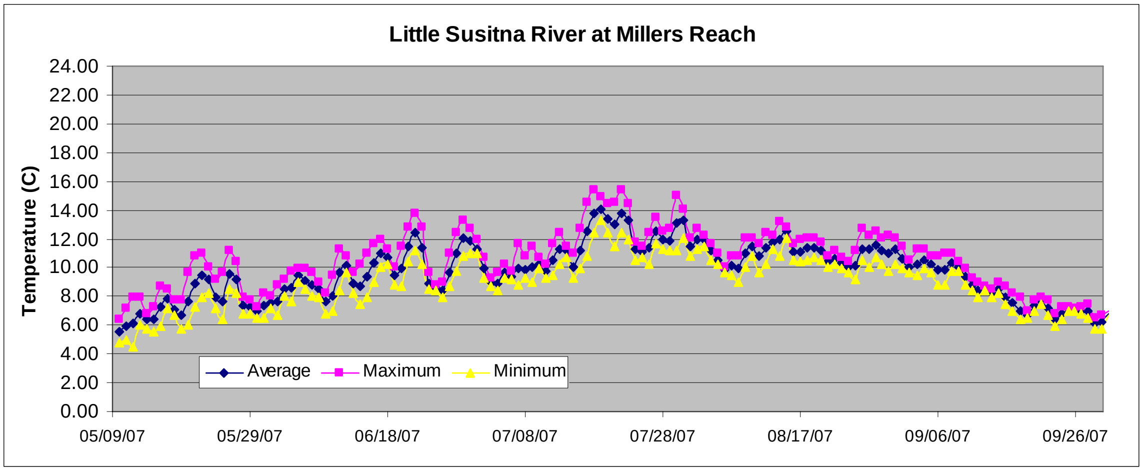
07/28/07
08/17/07
09/06/07
09/26/07


Little Susitna River at Millers Reach
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12.00
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6.00
4.00
2.00
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Average
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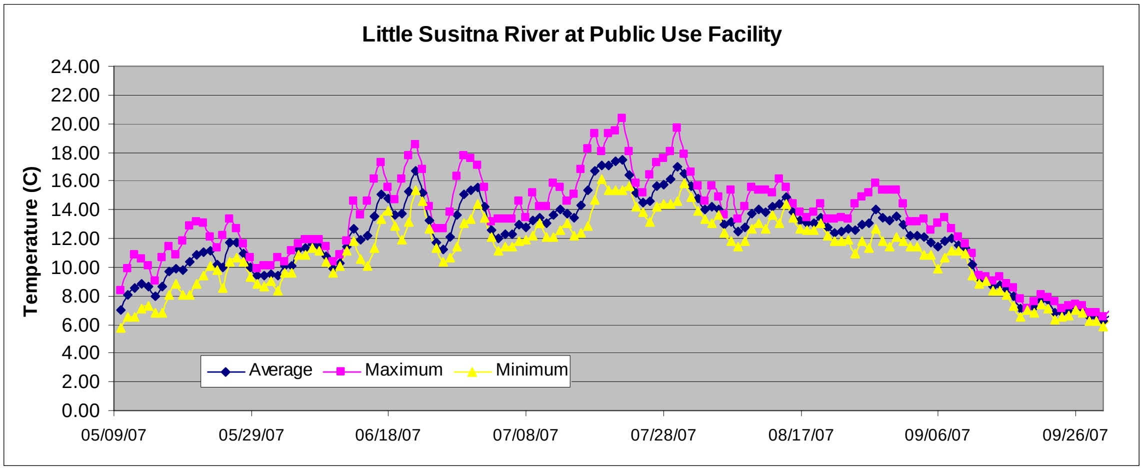
09/06/07
09/26/07


Little Susitna River at Public Use Facility
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4.00
2.00
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Average
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Minimum
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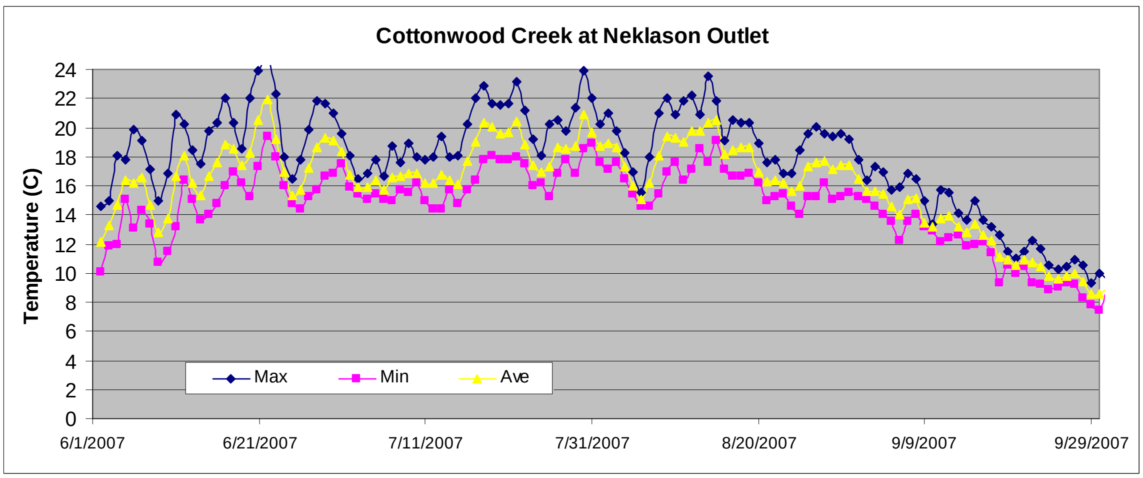
09/06/07
09/26/07


Cottonwood Creek at Neklason Outlet
Temperature (C)
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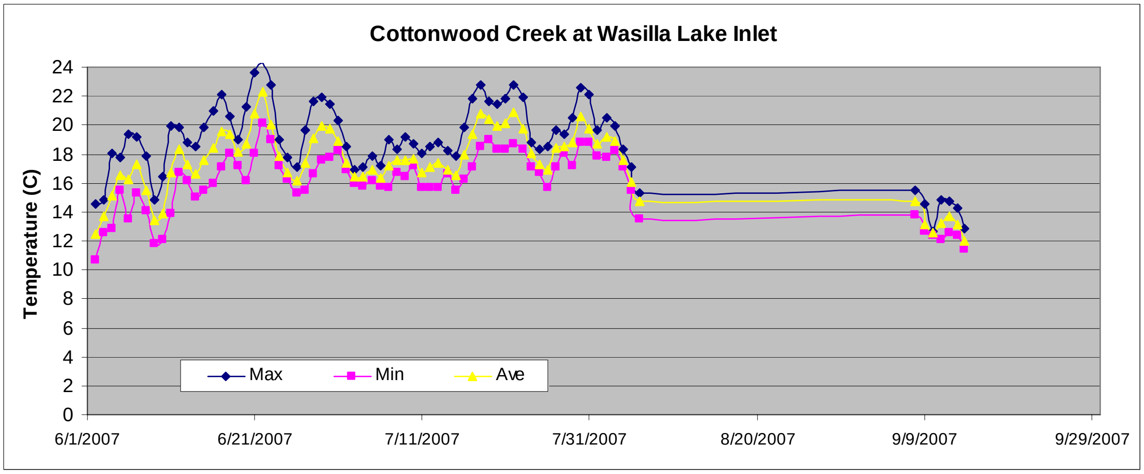
7/31/2007
8/20/2007
9/9/2007
9/29/2007


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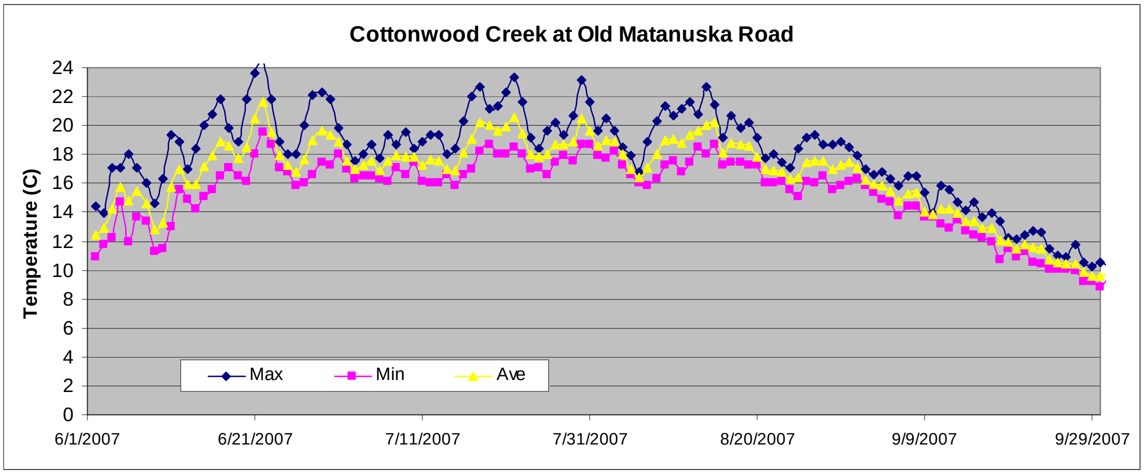
9/29/2007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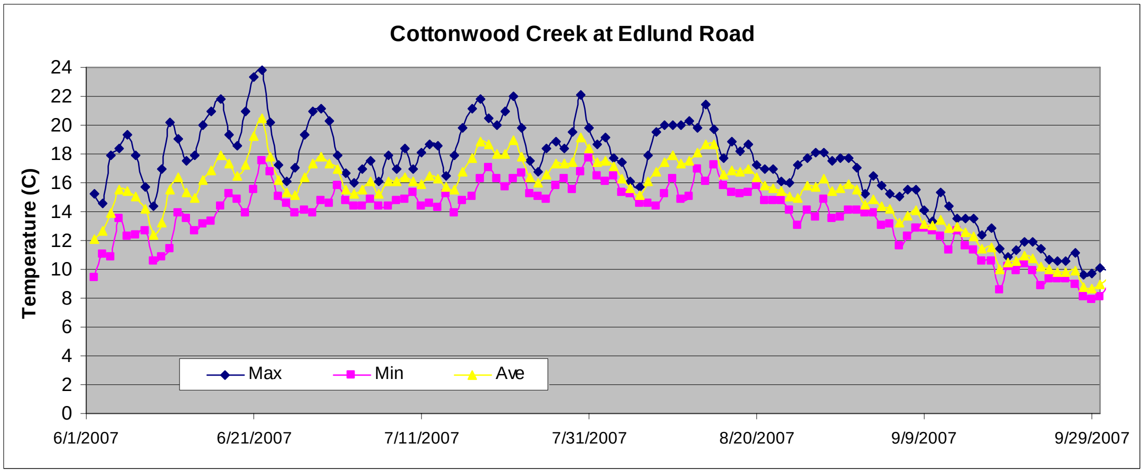
9/29/2007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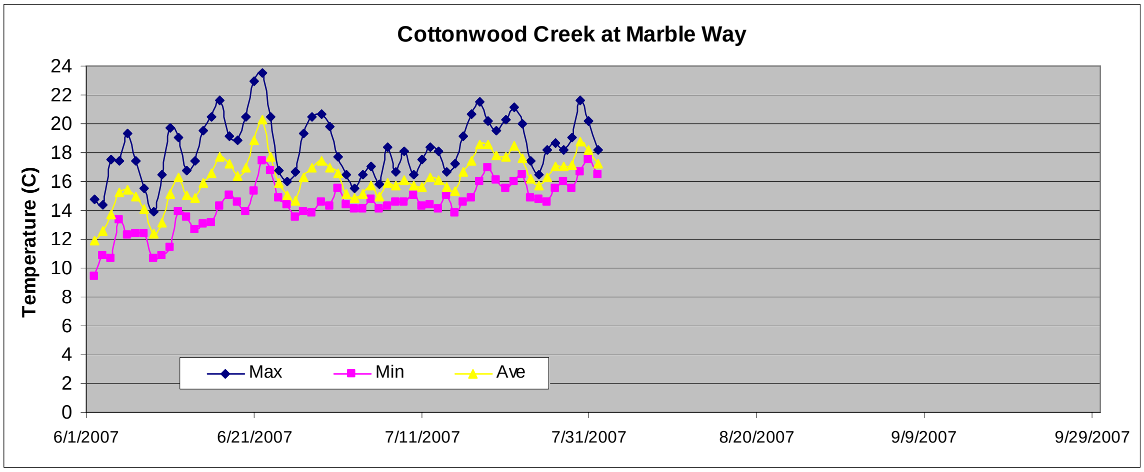
9/29/2007


Cottonwood Creek at Marble Way
Temperature (C)
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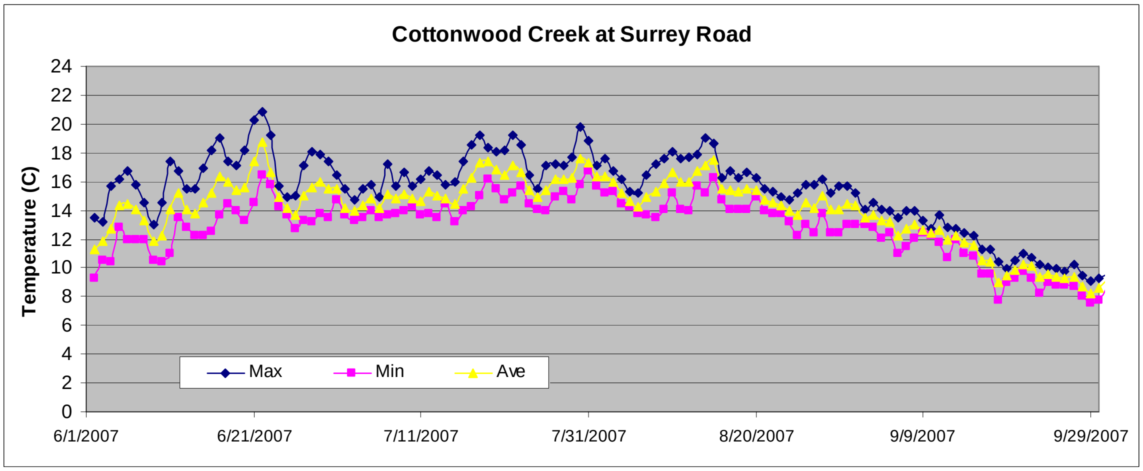
9/9/2007
9/29/2007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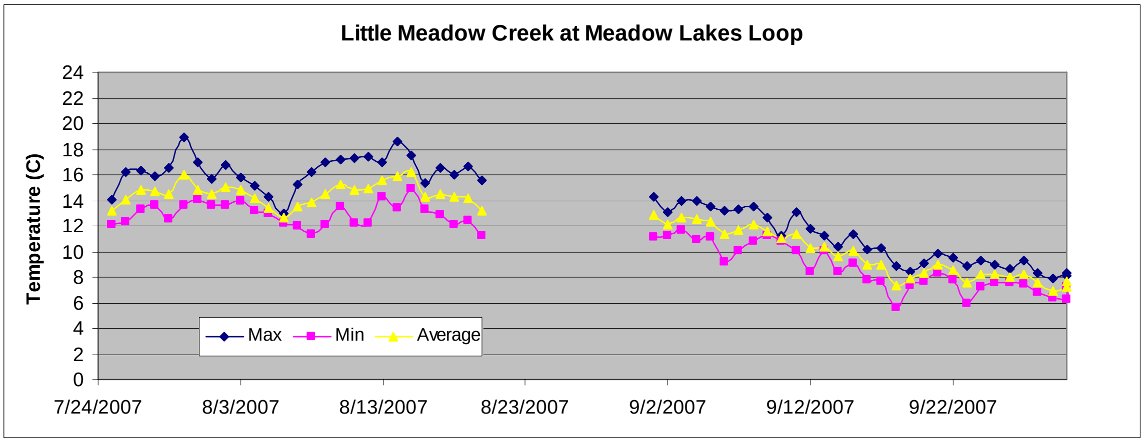
Little Meadow Creek at Meadow Lakes Loop
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Average
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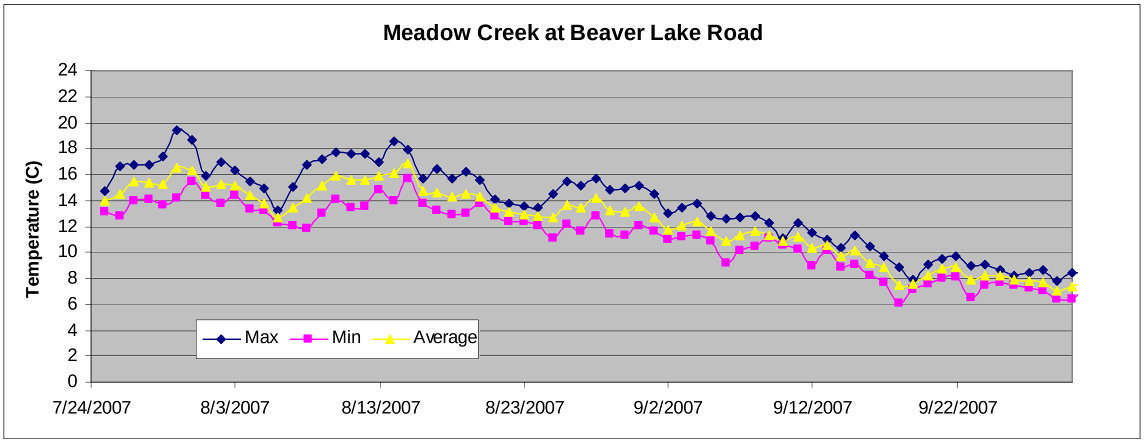
8/13/2007
8/23/2007
9/2/2007
9/12/2007
9/22/2007


Meadow Creek at Beaver Lake Road
Temperature (C)
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Average
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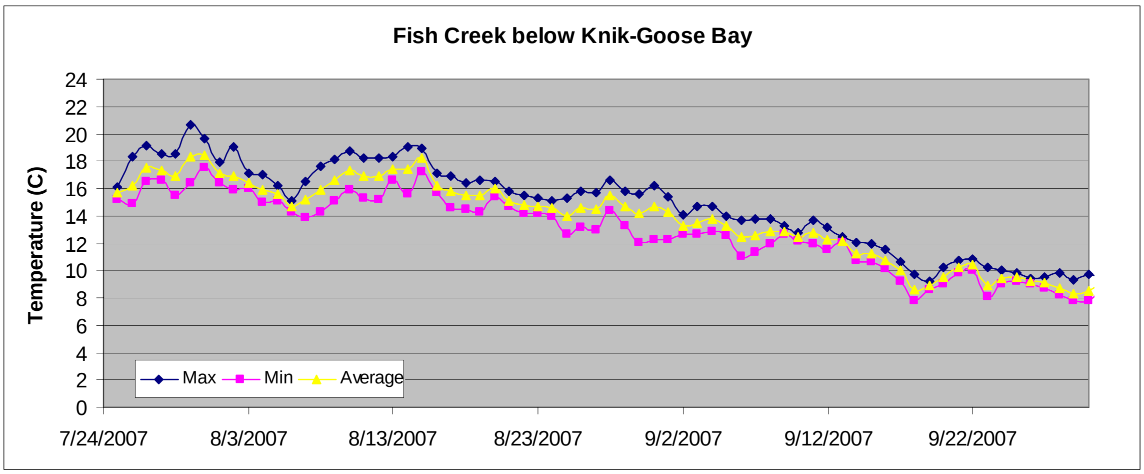
Fish Creek below Knik-Goose Bay
Temperature (C)
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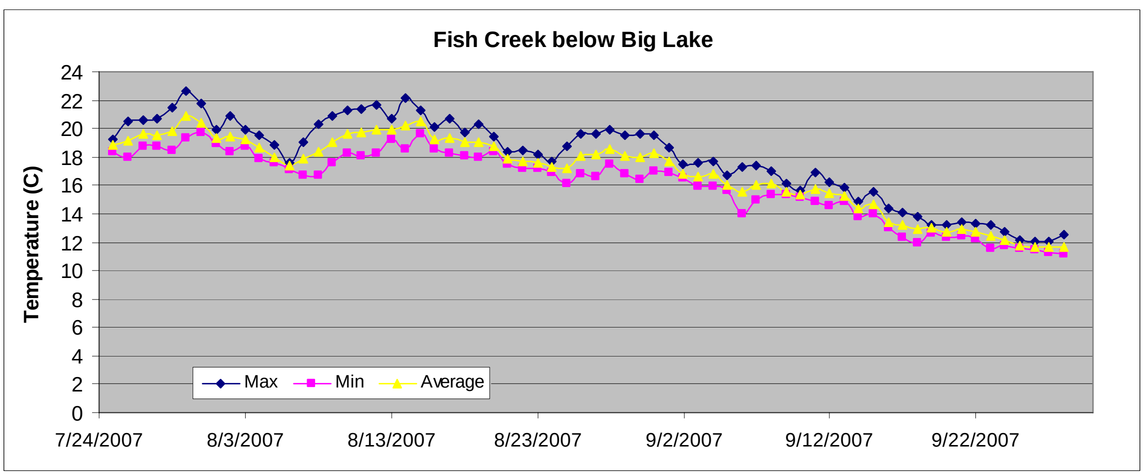
Fish Creek below Big Lake
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Max
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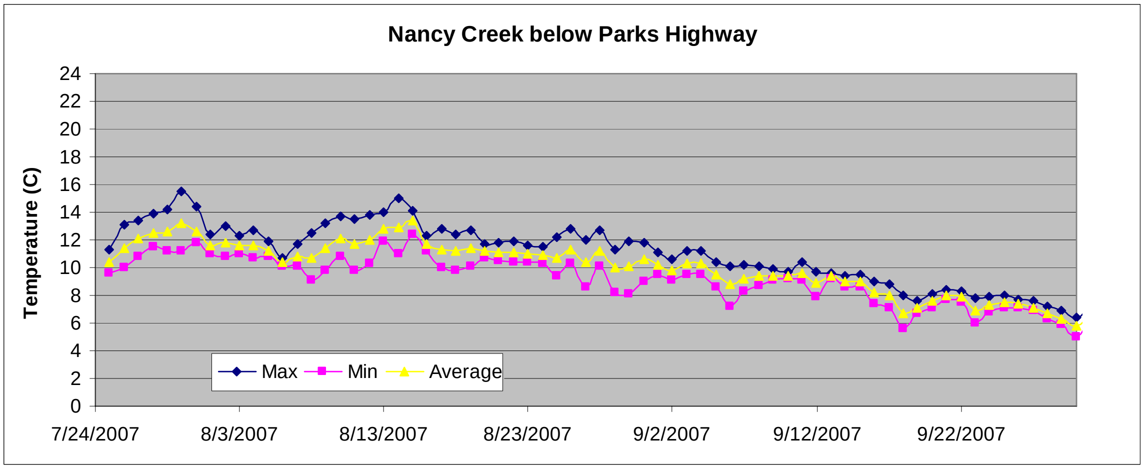
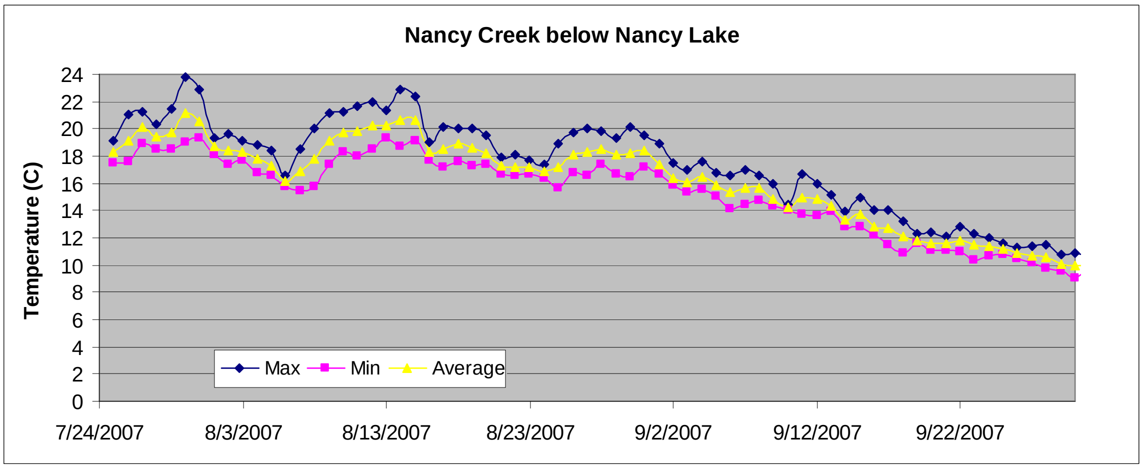
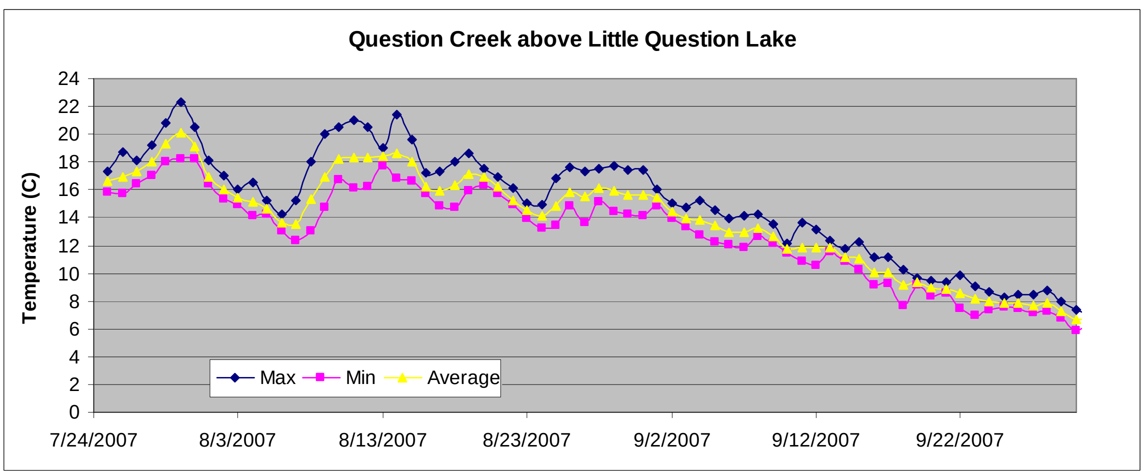
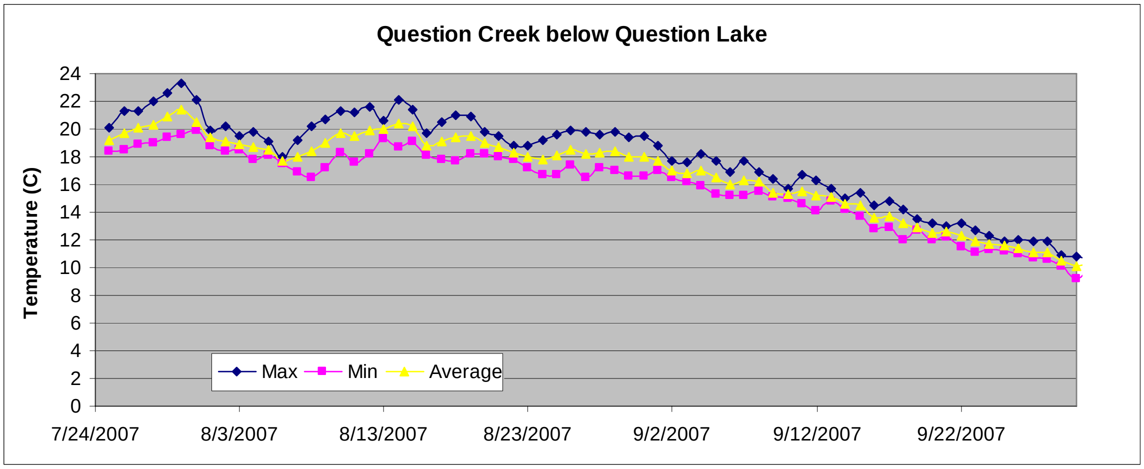
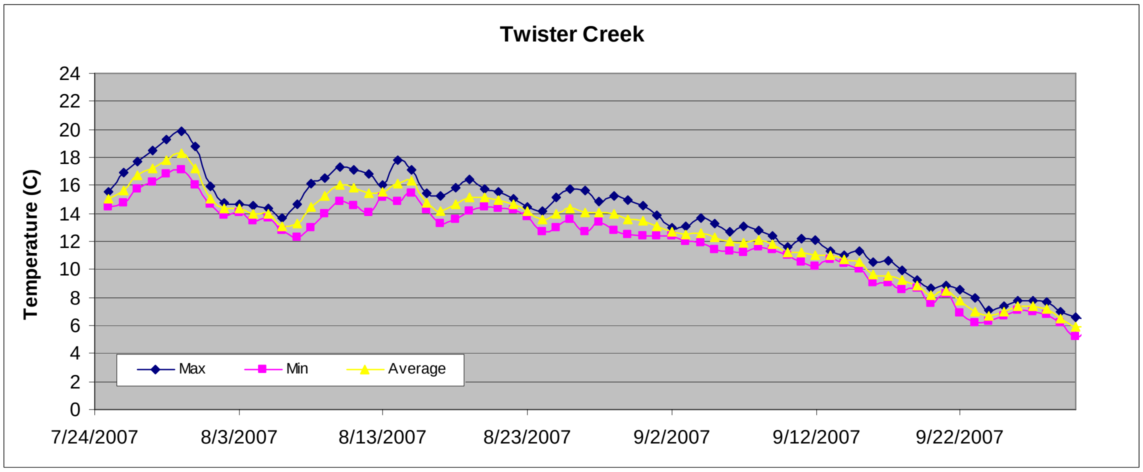
Average
7/24/2007
8/3/2007
8/13/2007
8/23/2007
9/2/2007
9/12/2007
9/22/2007

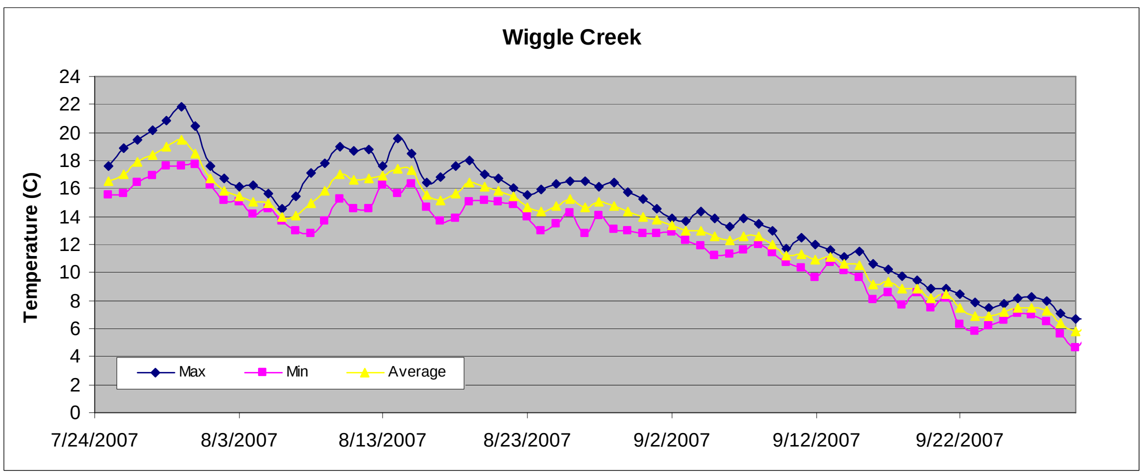

Nancy Creek below Parks Highway
Temperature (C)
24
22
20
18
16
14
12
10
8
6
4
2
0
Max
Min
Average
7/24/2007
8/3/2007
8/13/2007
8/23/2007
9/2/2007
9/12/2007
9/22/2007

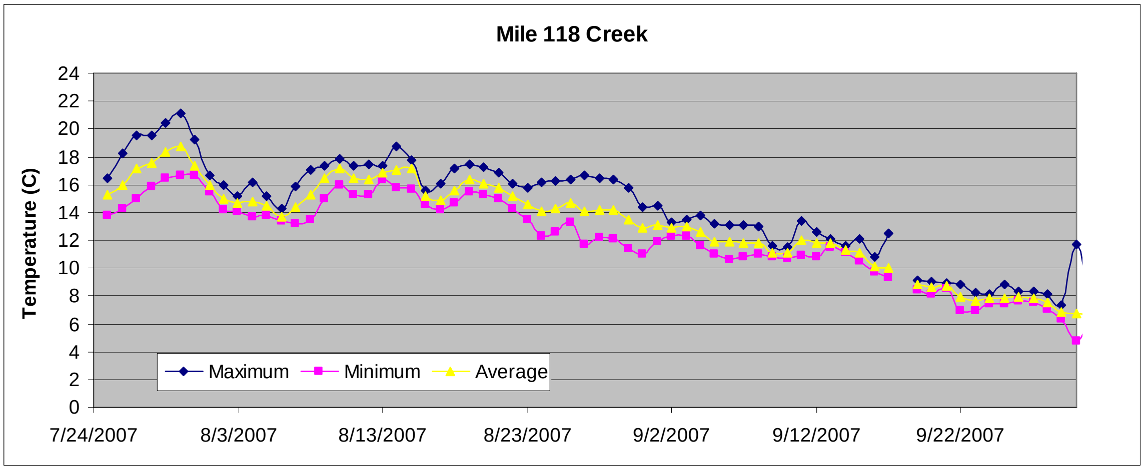

Nancy Creek below Nancy Lake
Temperature (C)
24
22
20
18
16
14
12
10
8
6
4
2
0
Max
Min
Average
7/24/2007
8/3/2007
8/13/2007
8/23/2007
9/2/2007
9/12/2007
9/22/2007

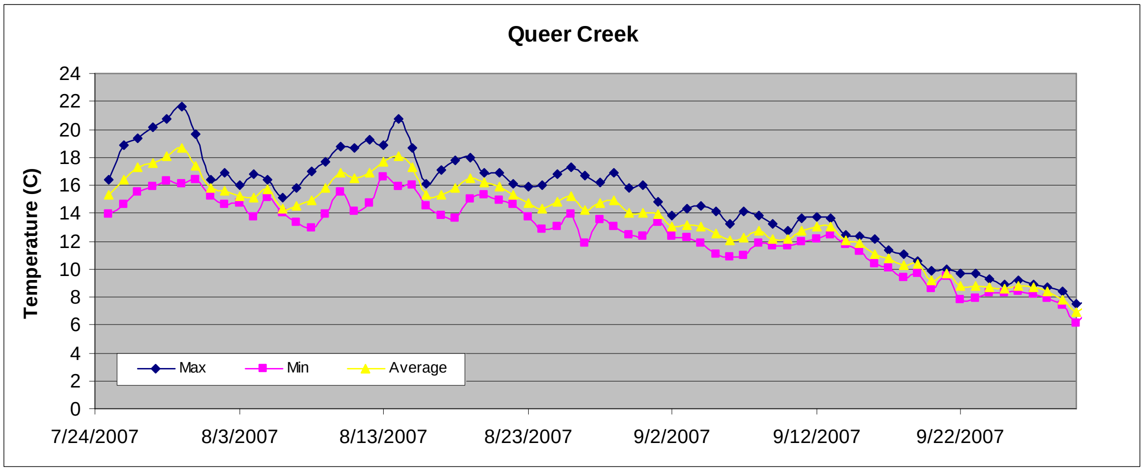

Question Creek above Little Question Lake
Temperature (C)
24
22
20
18
16
14
12
10
8
6
4
2
0
Max
Min
Average
7/24/2007
8/3/2007
8/13/2007
8/23/2007
9/2/2007
9/12/2007
9/22/2007

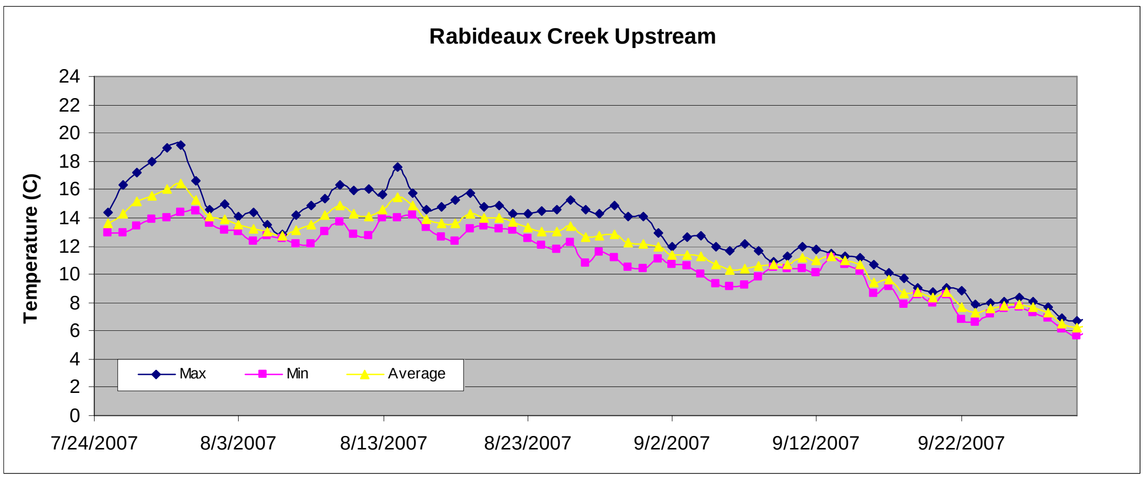

Question Creek below Question Lake
Temperature (C)
0
2
4
6
8
10
12
14
16
18
20
22
24
7/24/2007
8/3/2007
8/13/2007
8/23/2007
9/2/2007
9/12/2007
9/22/2007
Max
Min
Average

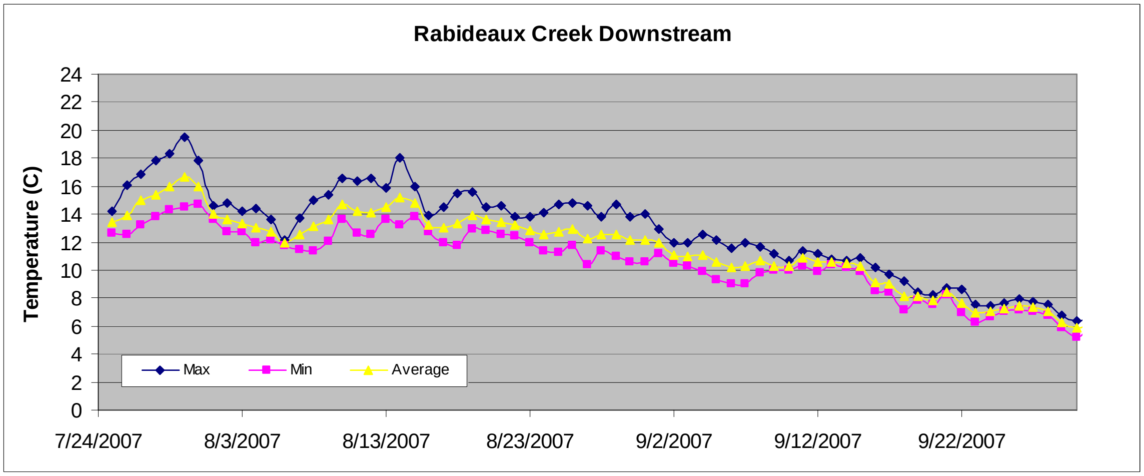

Twister Creek
Temperature (C)
0
2
4
6
8
10
12
14
16
18
20
22
24
7/24/2007
8/3/2007
8/13/2007
8/23/2007
9/2/2007
9/12/2007
9/22/2007
Max
Min
Average

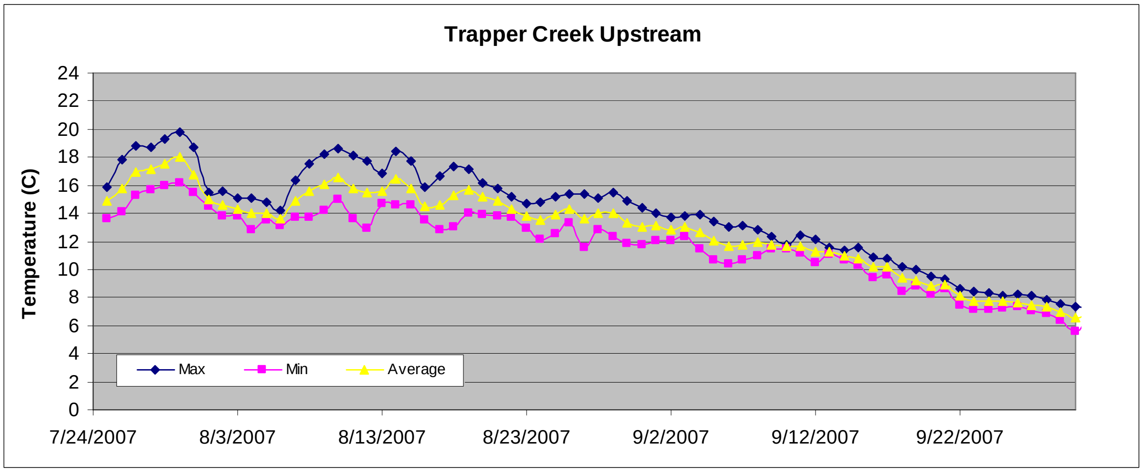

Wiggle Creek
Temperature (C)
0
2
4
6
8
10
12
14
16
18
20
22
24
7/24/2007
8/3/2007
8/13/2007
8/23/2007
9/2/2007
9/12/2007
9/22/2007
Max
Min
Average

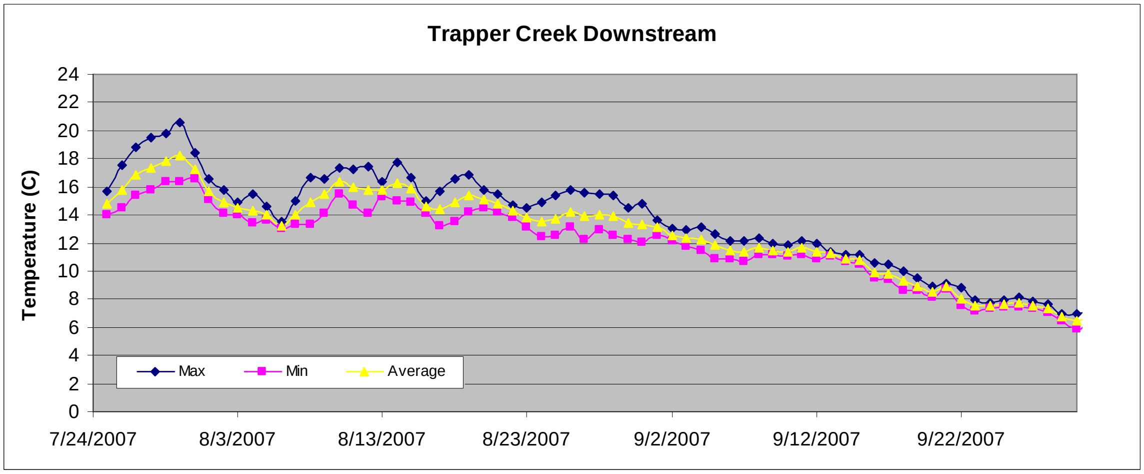

Mile 118 Creek
Temperature (C)
24
22
20
18
16
14
12
10
8
6
4
2
0
Maximum
Minimum
Average
7/24/2007
8/3/2007
8/13/2007
8/23/2007
9/2/2007
9/12/2007
9/22/2007

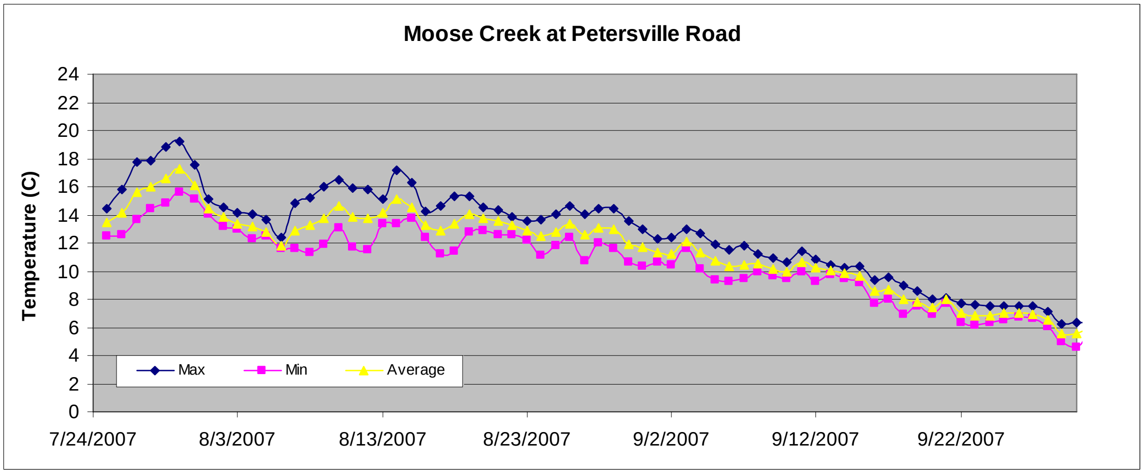

Queer Creek
Temperature (C)
24
22
20
18
16
14
12
10
8
6
4
2
0
Max
Min
Average
7/24/2007
8/3/2007
8/13/2007
8/23/2007
9/2/2007
9/12/2007
9/22/2007

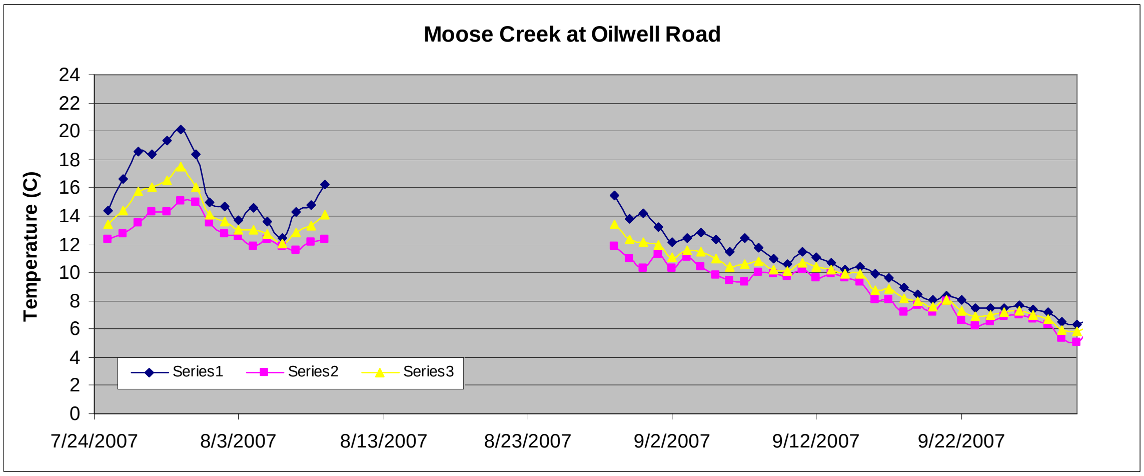

Rabideaux Creek Upstream
Temperature (C)
24
22
20
18
16
14
12
10
8
6
4
2
0
Max
Min
Average
7/24/2007
8/3/2007
8/13/2007
8/23/2007
9/2/2007
9/12/2007
9/22/2007

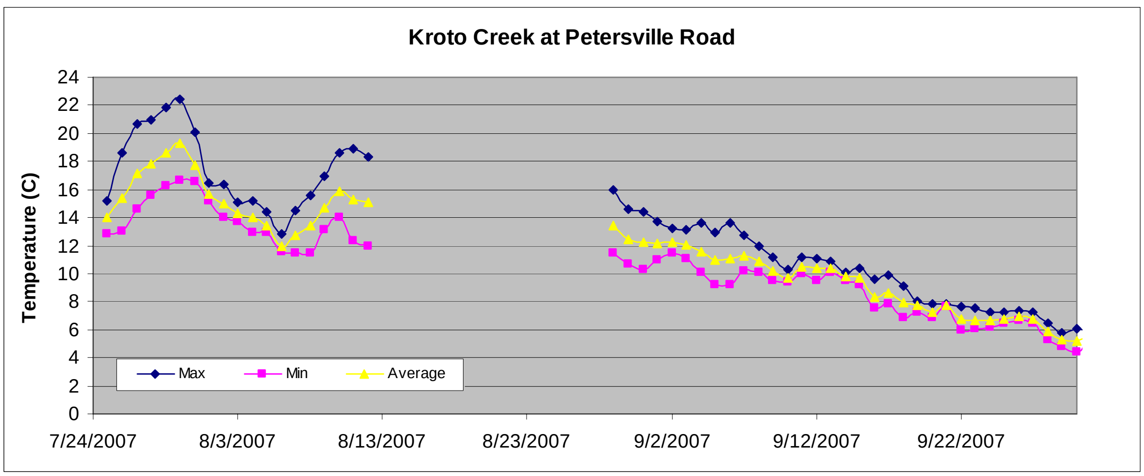

Rabideaux Creek Downstream
Temperature (C)
24
22
20
18
16
14
12
10
8
6
4
2
0
Max
Min
Average
7/24/2007
8/3/2007
8/13/2007
8/23/2007
9/2/2007
9/12/2007
9/22/2007

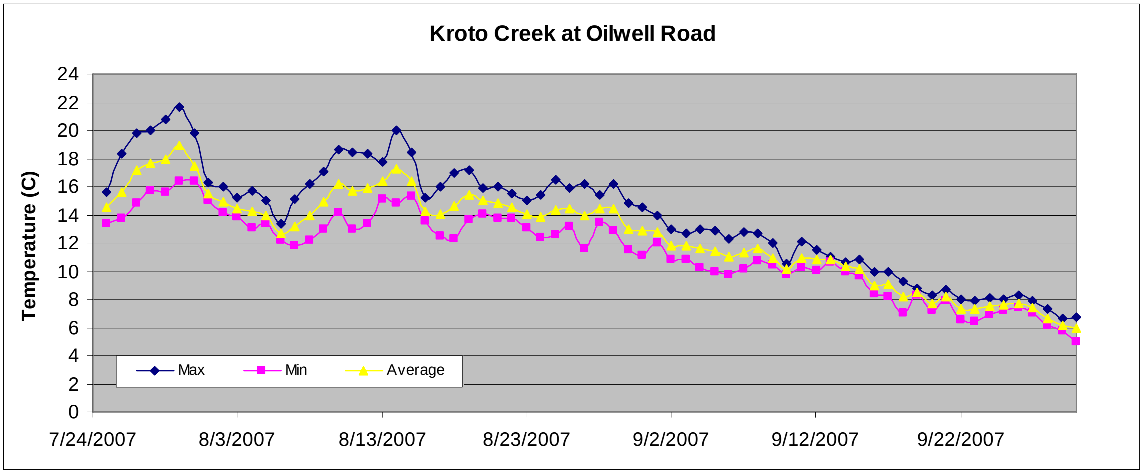

Trapper Creek Upstream
Temperature (C)
24
22
20
18
16
14
12
10
8
6
4
2
0
Max
Min
Average
7/24/2007
8/3/2007
8/13/2007
8/23/2007
9/2/2007
9/12/2007
9/22/2007

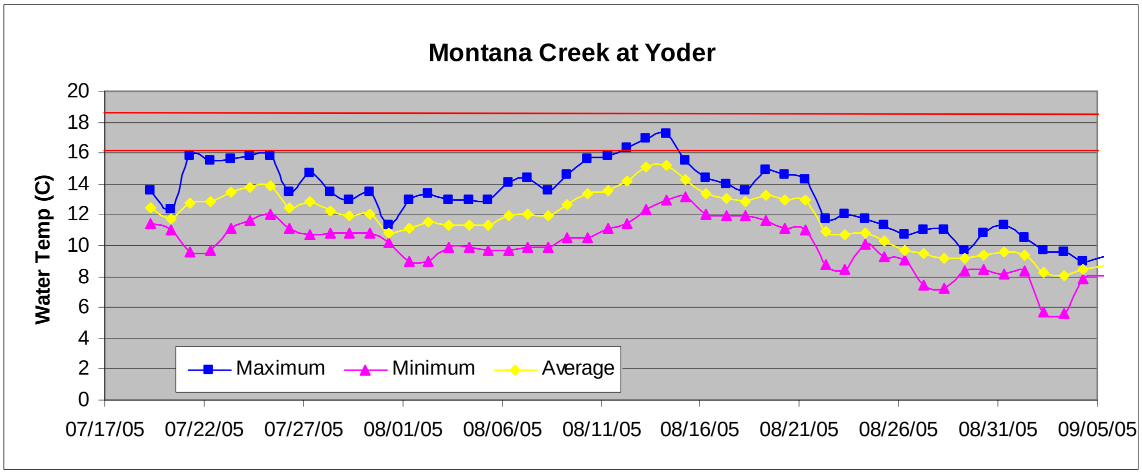

Trapper Creek Downstream
Temperature (C)
24
22
20
18
16
14
12
10
8
6
4
2
0
Max
Min
Average
7/24/2007
8/3/2007
8/13/2007
8/23/2007
9/2/2007
9/12/2007
9/22/2007

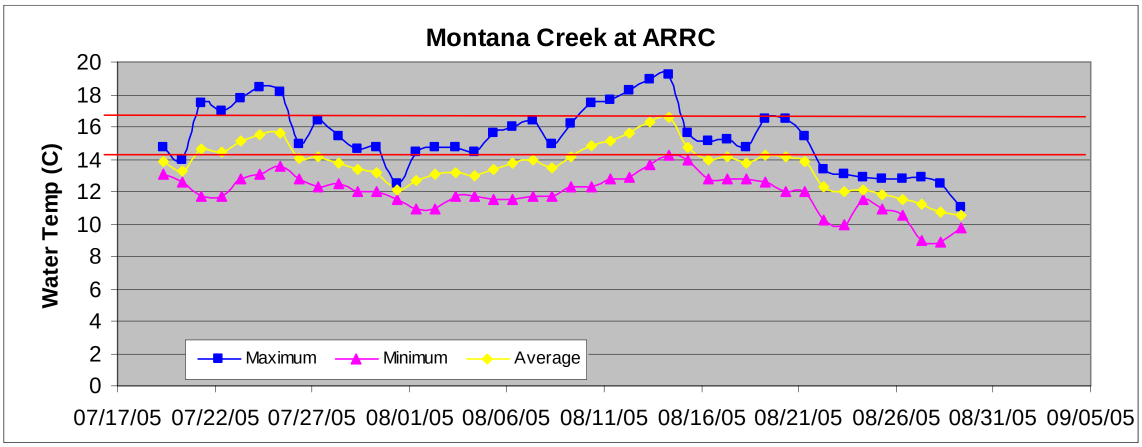

Moose Creek at Petersville Road
Temperature (C)
24
22
20
18
16
14
12
10
8
6
4
2
0
7/24/2007
8/3/2007
8/13/2007
8/23/2007
9/2/2007
9/12/2007
9/22/2007
Max
Min
Average

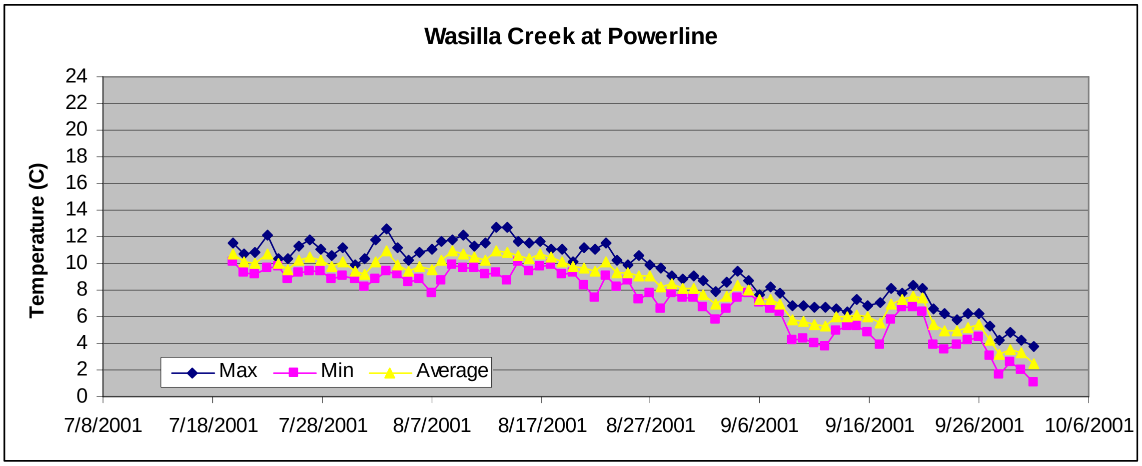

Moose Creek at Oilwell Road
Temperature (C)
24
22
20
18
16
14
12
10
8
6
4
2
0
7/24/2007
8/3/2007
8/13/2007
8/23/2007
9/2/2007
9/12/2007
9/22/2007
Series1
Series2
Series3

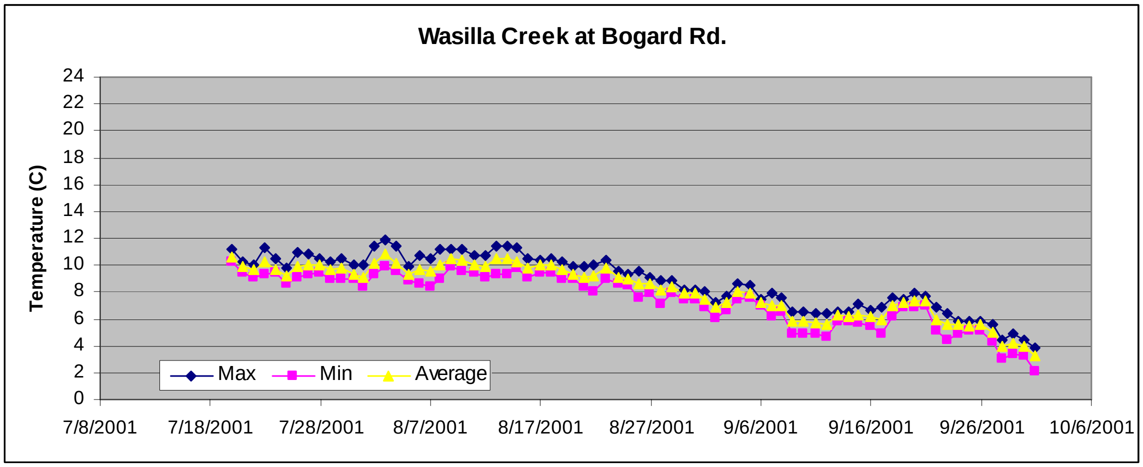

Kroto Creek at Petersville Road
Temperature (C)
24
22
20
18
16
14
12
10
8
6
4
2
0
7/24/2007
8/3/2007
8/13/2007
8/23/2007
9/2/2007
9/12/2007
9/22/2007
Max
Min
Average

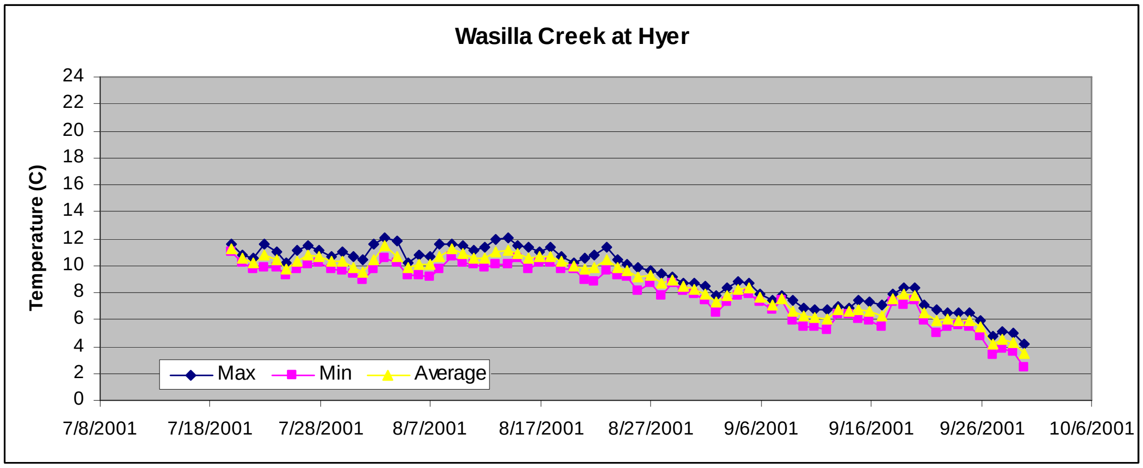

Kroto Creek at Oilwell Road
Temperature (C)
24
22
20
18
16
14
12
10
8
6
4
2
0
7/24/2007
8/3/2007
8/13/2007
8/23/2007
9/2/2007
9/12/2007
9/22/2007
Max
Min
Average

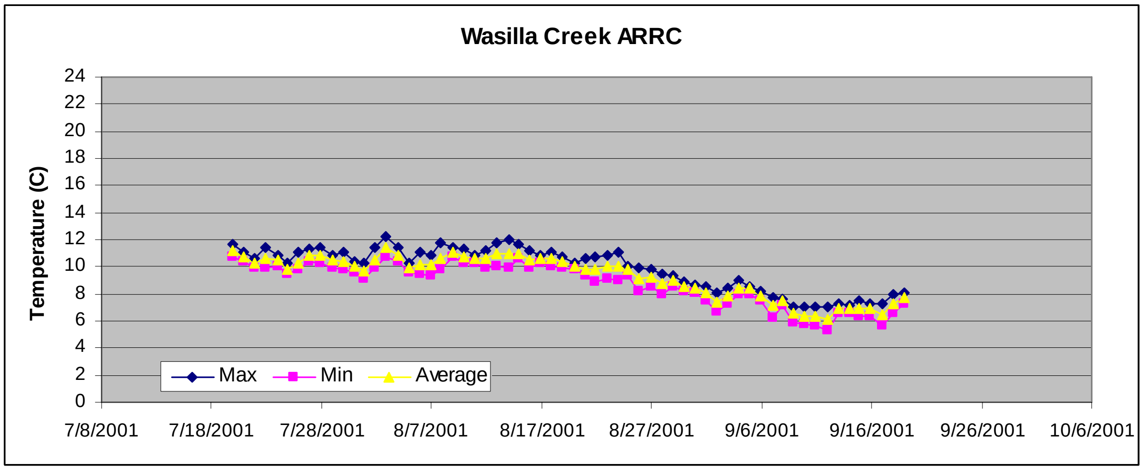

Montana Creek at Yoder
Water Temp (C)
20
18
16
14
12
10
8
6
4
2
0
07/17/05
07/22/05
07/27/05
08/01/05
08/06/05
08/11/05
08/16/05
08/21/05
08/26/05
08/31/05
09/05/05
Maximum
Minimum
Average


Montana Creek at ARRC
Water Temp (C)
20
18
16
14
12
10
8
6
4
2
0
07/17/05
07/22/05
07/27/05
08/01/05
08/06/05
08/11/05
08/16/05
08/21/05
08/26/05
08/31/05
09/05/05
Maximum
Minimum
Average


Wasilla Creek at Powerline
Temperature (C)
24
22
20
18
16
14
12
10
8
6
4
2
0
Max
Min
Average
7/8/2001
7/18/2001
7/28/2001
8/7/2001
8/17/2001
8/27/2001
9/6/2001
9/16/2001
9/26/2001
10/6/2001


Wasilla Creek at Bogard Rd.
Temperature (C)
24
22
20
18
16
14
12
10
8
6
4
2
0
Max
Min
Average
7/8/2001
7/18/2001
7/28/2001
8/7/2001
8/17/2001
8/27/2001
9/6/2001
9/16/2001
9/26/2001
10/6/2001


Wasilla Creek at Hyer
Temperature (C)
24
22
20
18
16
14
12
10
8
6
4
2
0
Max
Min
Average
7/8/2001
7/18/2001
7/28/2001
8/7/2001
8/17/2001
8/27/2001
9/6/2001
9/16/2001
9/26/2001
10/6/2001


Wasilla Creek ARRC
Temperature (C)
24
22
20
18
16
14
12
10
8
6
4
2
0
7/8/2001
7/18/2001
7/28/2001
8/7/2001
8/17/2001
8/27/2001
9/6/2001
9/16/2001
9/26/2001
10/6/2001
Max
Min
Average