TEMPERATURE DATA

Temperature Standards

Temperature data for the Study Area are reviewed for exceedences of temperature standards during the summer months. Temperature standards used for review are those adopted by the Colorado Department of Public Health and Environment, Water Quality Control Commission (WQCC). These standards are established to protect the aquatic community from the harmful effects of temperature, based on the thermal requirements of fish species found in Colorado. Segment specific numeric standards were adopted by the WQCC in the upper Colorado River Basin in 2008. The chronic standard is measured as the Maximum Weekly Average Temperature (MWAT), which is the largest mathematical mean of multiple, equally spaced daily temperatures over a seven-day consecutive period with a minimum of three data points spaced equally throughout the day. The acute standard is measured as the Daily Max (DM) which is the highest two-hour average water temperature recorded during a given 24 hour period.

Tiers are used to define segment-specific temperature standards and are generally based on fish species with similar thermal requirements present in river segments. Study reaches for the Stream Management Plan fall into one of two tiers: Cold Stream Tier I and Cold Stream Tier ll. Temperature standards are summarized in Table B1.

Table B1. Temperature Standards for Grand County Stream Reaches in the Stream Management Plan

Temperature Tier	SMP Reaches	Applicable months	Temperature Standard (^{o}C)	
			MWAT	DM
Cold Stream Tier I	Fraser River: F1, F2, F3	June-Sept	17.0	21.2
	Fraser River: F4 to Rendezvous Br Jim Creek: F-JC Vasquez Creek: F-VC-1, F-VC-2 Ranch Creek: F-RC1, F-RC-2 Saint Louis Creek: F-StL Ten Mile Creek: F-TC Colorado River: CR1, CR2 Willow Creek: WC Williams Fork: WR Muddy Creek: MC1, MC2 Blue River: BR Troublesome Creek, TR Reeder Creek, RE	Oct-May	9.0	13.0
Cold Stream Tier II	Fraser River: F4 from Rendezvous Br,	April-Oct	18.2	23.8
	Fraser River: F5, F6, F7, F8, F9, F10 Colorado River: CR3, CR4, CR5, CR6, CR7	Nov-March	9.0	13.0

The U. S. Fish and Wildlife Service (USFWS) recommendations for optimal temperature range for brown and rainbow trout tend to match or approximate the State Standards (Raleigh and others 1984a and b). These are as follows:

- Chronic standards for brown trout adults and juveniles: 12 ^{o} C to 19^{o} C,
- Acute standards for brown : 0 to 27 ^{o} C,
- Chronic standards rainbow trout is 12 to 18 ^{o} C,
- Acute standards for rainbow trout: 0 to 25 ^{o} C.

Given that the State standards are more restrictive than USFWS recommendations, the State standards are used as comparisons for review of available temperature data.

As of April 2010 the State has placed several river segments within Grand County on the 303 (d) list of impaired waters for temperature exceedences. This includes the Colorado River from County Road 578 (immediately downstream of Windy Gap) to the Blue River, and Ranch Creek, both with a high priority; Fraser River from Hammond Ditch to the confluence with the Colorado River, with a low priority; Muddy Creek from Cow Creek to the confluence with the Colorado River, with a high priority; and Muddy Creek from Wolford Reservoir to Cow Creek for monitoring and evaluation.

Data

Temperature data for the Colorado River, the Fraser River, and tributaries were reviewed and compared to the State standards. Much of the data available are instantaneous readings, collected at irregular intervals at a variety of locations, as noted in Table B1 below. Stations, dates, and sources of instantaneous temperature information are included in the table. Plots of these data are presented in Figures B1 and B2 and are discussed in the following sections.

Continuous water temperature data for gages over the past few years (2006 - 2009) are available from the Grand County Water Information Network (GCWIN), the Northern Colorado Water Conservation District (NCWCD), Denver Water (DW), the U.S. Geological Survey (USGS), and Trout Unlimited (TU). Temperature loggers were also installed at the PHABSIM (Physical Habitat Simulation) transects sites surveyed for this study during the summer of 2007 and 2008. These temperature logger plots are included in the Reach Summaries. Table B2 presents the stations, dates and sources of continuous temperature data. Plots of these data are presented in Figures B3 through B9 and are discussed in the following sections.

Table B2. Instantaneous temperature data and sources

	Station	Dates	Source
Colorado	*CO at Gore Trailhead*	2002-2006	DWB, GCWIN
	CO at Kremmling	1968-2006	USGS, DWB, GCWIN
	CO blw Lake Granby	1956-2004	USGS
	CO near Granby	1970-2003	USGS
	CO at Windy Gap	1981-2007	USGS, GCWIN, Riverwatch
	CO at Hot Sulphur Springs	1956-2007	USGS, GCWIN, Riverwatch
	CO near Parshall	2002-2006	DWB, GCWIN
Fraser	*Fraser at Winter Park*	1956-2004	USGS
	Fraser blw St. Louis Crk.	1990-1994	USGS
	Fraser at Tabernash	1990-2004	USGS, DWB
	Fraser at Hwy 40	1958-2005	CRWCD
	Fraser above CO	1991-2002	NCWCD
Tributaries	*Vasquez Crk*	1968-2001	USGS
	Ranch Crk	1976-2004	CRWCD, USGS
	Blue near Kremmling	1969-2005	USGS, Riverwatch
	St. Louis near Fraser	1956-2000	USGS
	Williams Fork blw WFRes	1998-2005	DWB, Riverwatch
	Willow Creek	1956-2002	USGS, NCWCD
	Muddy Creek	1957-2005	USGS, DWB, Riverwatch

Table B3. Continuous temperature data and sources

	Gage Name	Entity	2006	2007	2008	2009	Location
Colorado	*CO at Northern Gauge*	GCWIN				X	No Info
	CO above Windy Gap	NCWCD		X			On CO River just above confluence with Fraser
	CO at Miller Ranch	Tt		X			Between Lake Granby and confluence of Colorado with Willow Creek
	CO blw Windy Gap	NCWCD	X	X	X	X	USGS 09034250 station- on right bank 1.1 mi downstream from dam
	CO at Hot Sulphur Springs	GCWIN	X	X	X	X	CO River above Hot Sulphur Springs WWTP
	CO at Lone Buck	GCWIN	X	X	X	X	CO River at Lone Buck below CDOW office
	CO at County Road 3	GCWIN		X	X	X	At County Rd 3 just upstream of Parshall and Williams Fork Confluence
	CO at Kids Pond	GCWIN		X	X	X	Just downstream of Parshall and Williams Fork Confluence appx. 1.5 miles
	CO at KB Ditch	Tt		X			East of CR39 Bridge and east of KB ditch diversion one-third mile
	CO at KB Ditch	GCWIN		X	X	X	East of CR39 Bridge and west of KB ditch in middle of river
	CO at Pumphouse	GCWIN	X				Below Gore Canyon and above Pumphouse
	CO at Kremmling	GCWIN	X	X	X	X	CO River at Hwy 9 bridge above confluence with Blue and Muddy
Fraser	*Fraser at Upper Station*	GCWIN		X	X	X	Near Berthoud Pass
	Fraser above WPSD	GCWIN		X	X	X	Fraser River just above Winter Park Sanitation District above effluent inflow
	Fraser below WPSD	GCWIN		X	X	X	Fraser River just below Winter Park Sanitation District below effluent inflow
	Fraser at Idlewild Bridge	Tt			X		Fraser River at the Idlewild Campground Bridge
	Fraser at WP	GCWIN		X	X	X	Fraser River below Winter Park just upstream of Idlewild campground
	Fraser at County Road 8	GCWIN		X	X	X	Fraser River near Fraser just below confluence with St. Louis Creek
	Fraser above FSD	GCWIN		X	X	X	Fraser River just above Fraser Sanitation District
	Fraser below FSD	GCWIN		X	X	X	Fraser River just below Fraser Sanitation District below effluent inflow
	Fraser at County Road 83	GCWIN		X	X	X	Fraser in Tabernash at County Rd 83 crossing
	Fraser at Granby	GCWIN		X	X	X	Fraser at Hwy 40
	Lower Fraser near Granby	Tt		X			Uupstream of Hwy 40 bridge appx 1.5 miles
	Fraser above GSD	GCWIN		X	X	X	Fraser River below CR57 bridge above Granby Sanitation District
Tributaries	*Upper Ranch Creek*	Tt			X		County Road 8 crossing
	Ranch Creek	GCWIN		X	X	X	Below County Road 8315 bridge
	Ranch Crk blw Meadow Crk	Tt			X		Below County Road 84 bridge
	St. Louis Creek	GCWIN		X	X	X	At Fraser confluence with St. Louis
	St. Louis Creek	Tt		X			Upstream on St. Louis Creek approx. 2.75 miles from confluence with Fraser
	Vasqeuz	GCWIN		X	X	X	Below USGS gage 09025000 in downtown Winter Park
	Vasqeuz	Tt		X			On Vasqueuz Creek approx 3 miles upstream of confluence with Fraser
	Muddy Creek below KSD	GCWIN			X		Muddy Creek below Kremmling Sanitation District
	Willow Creek	NCWCD		X			Just downstream of Willow Creek Reservoir
	Williams Fork	TU		X			At confluence with Colorado River
	Williams Fork	Tt		X			At confluence with Colorado River

Review of Instantaneous Data

The best data available are the continuous readings. However, since the available continuous data span only 1 to 4 years, the long-term instantaneous temperature values, collected primarily between the 1970s and 2000, were reviewed. While the instantaneous data is not helpful in isolating seasonal trends, these data may be useful in observing long-term conditions at particular sites. Instantaneous data for temperature obtained from USGS and GCWIN databases are recorded by USGS, DWB, NCWCD, Riverwatch or CRWCD. A parameter such as temperature can vary greatly depending on time of day and collection location in the stream. Thus the instantaneous values are presented in this section to indicate stream conditions with the caveat that this data represents one point in time in a system that exhibits large diurnal fluctuations, as presented in the following sections of this appendix.

The following plots of the data are shown on Figures B1 and B2 for the Colorado and Fraser River Gages. Review of these instantaneous data points indicate that many readings are below the chronic temperature standards. The exceptions are temperature readings at Hot Sulphur, Windy Gap and Granby on the Colorado River and at Tabernash the Fraser. Approximately 6.5% of the readings on the Colorado River exceed 17^{o} C, 3.4% exceed 18.2 ^{o} C, and a negligible amount of readings exceed 23^{o} C. The Fraser River has generally exceeded temperature standards much less, with readings exceeding 17^{o} C less than 2% of the time and exceeding 18.2^{o} C 1% of the time.

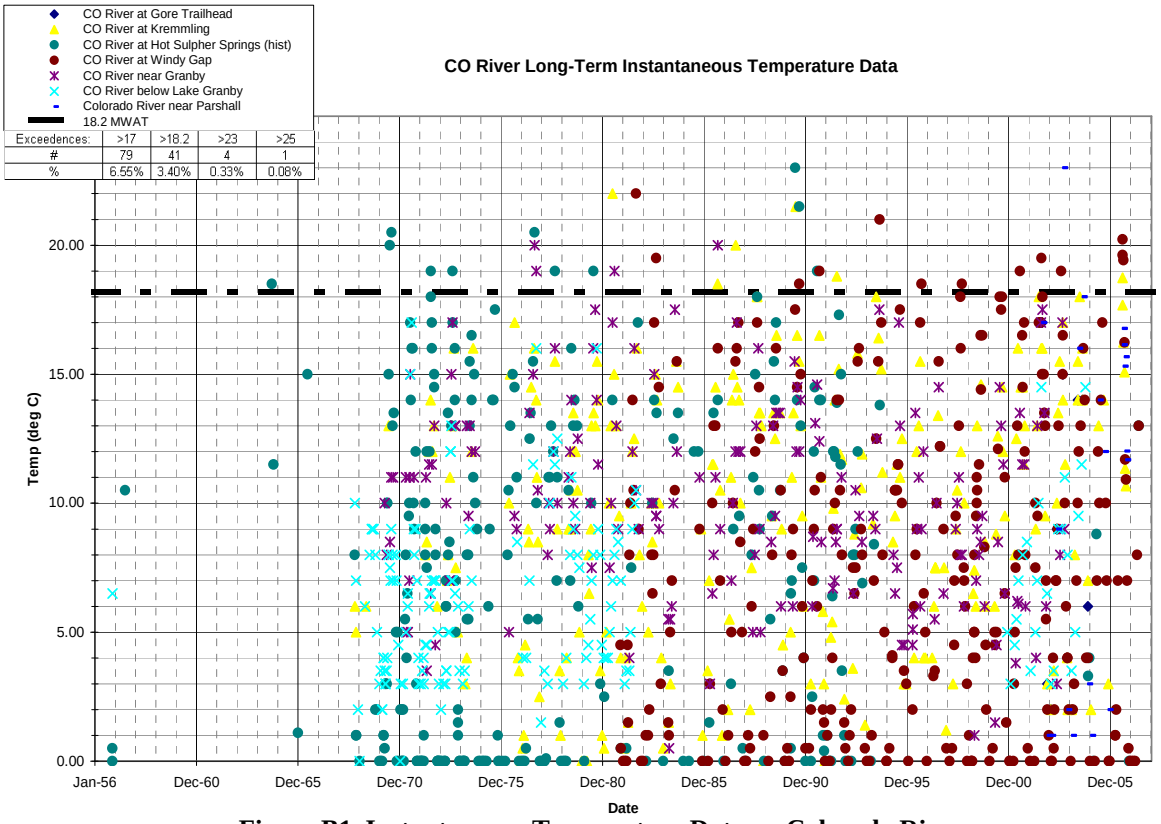

Figure B1. Instantaneous Temperature Data on Colorado River

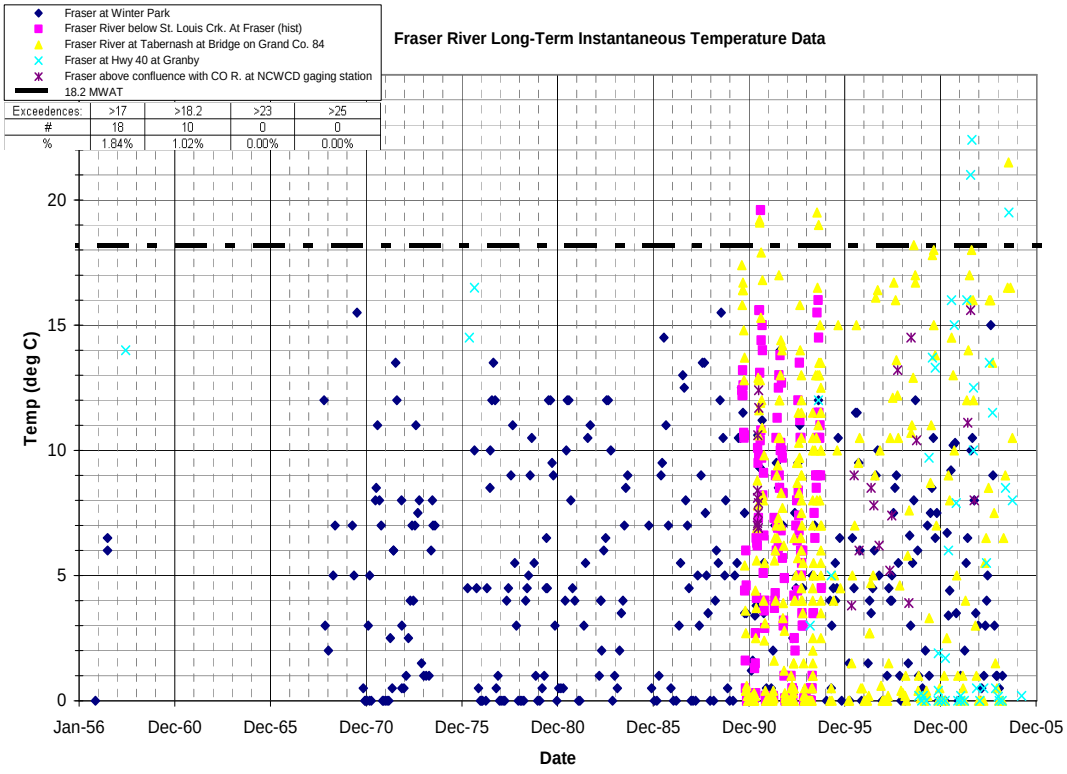

Figure B2. Instantaneous Temperature Data on Fraser River

Review of Continuous Data

Summer temperature trends were also analyzed at sites with the available continuous data. Within each of the study reaches the MWAT and DM temperatures are determined and plotted and compared with the State's temperature standards. Results are presented in the individual Reach Summary and are focused on the data trends for the specific reaches. This appendix presents a more global overview of the temperature data relative to both the MWAT and DM standards.

MWAT: Combined plots for the MWAT for the Colorado and Fraser River for 2006 through 2009 (where available) are presented on Figures B3 through B10. These plots follow. Several conclusions are noted:

1. The MWAT often exceeded State standards at gages in the Colorado River from Windy Gap, downstream to the confluence with Williams Fork. Exceedences occurred in 2006, 2007 and 2008, lasting from approximately one week to one month.
2. The MWAT at gages in the Colorado River generally met State standards in 2009.
3. The MWAT on the Fraser River and tributaries generally meet State standards. Note that the Fraser includes both Tiers I and II with the dividing line located at the Rendezvous Bridge. Both standards are represented on the Fraser River MWAT plots.

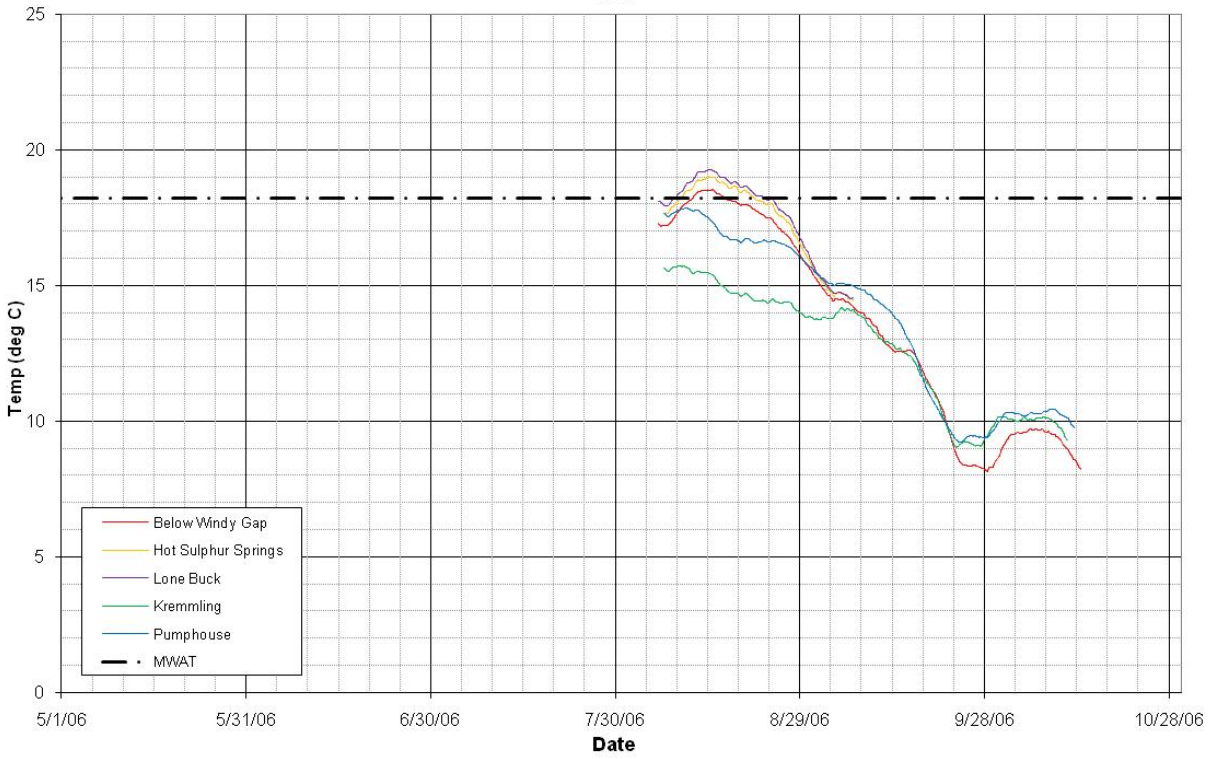

Figure B3. Colorado River Surface Water Temperatures, 7-day rolling average summer 2006

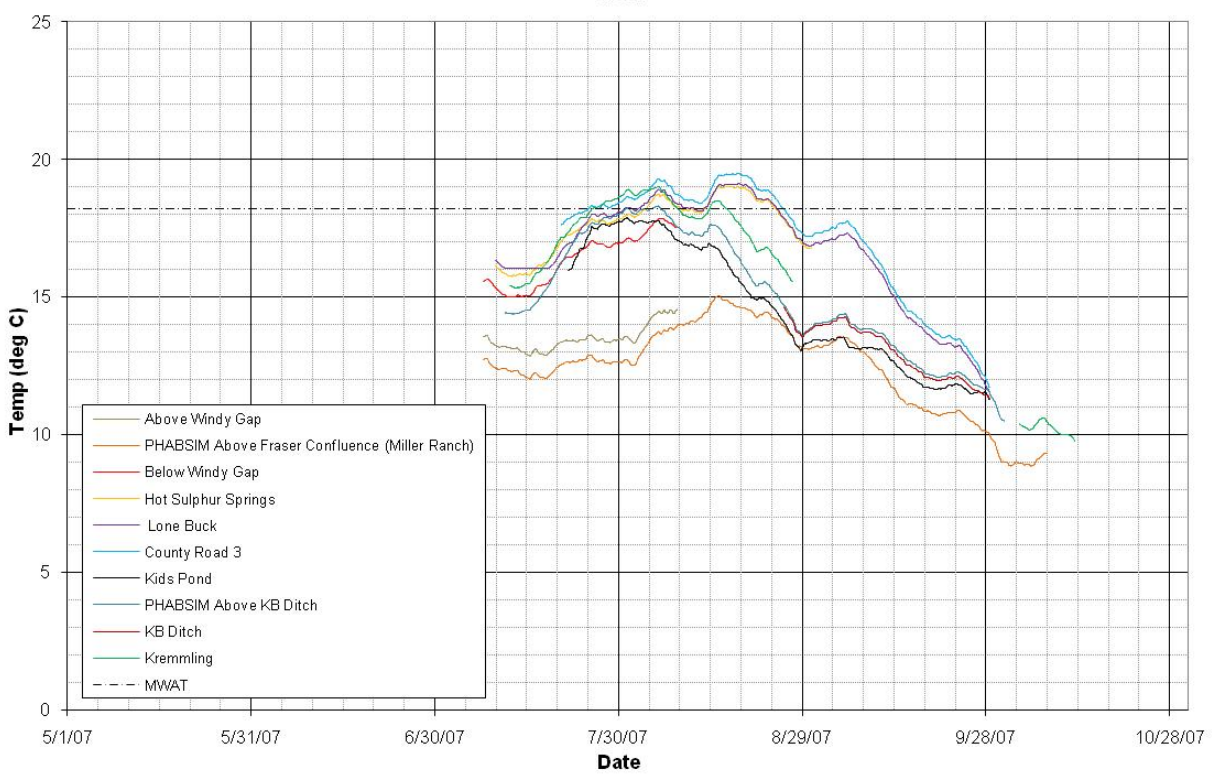

Figure B4. Colorado River Surface Water Temperatures, 7-day rolling average summer 2007

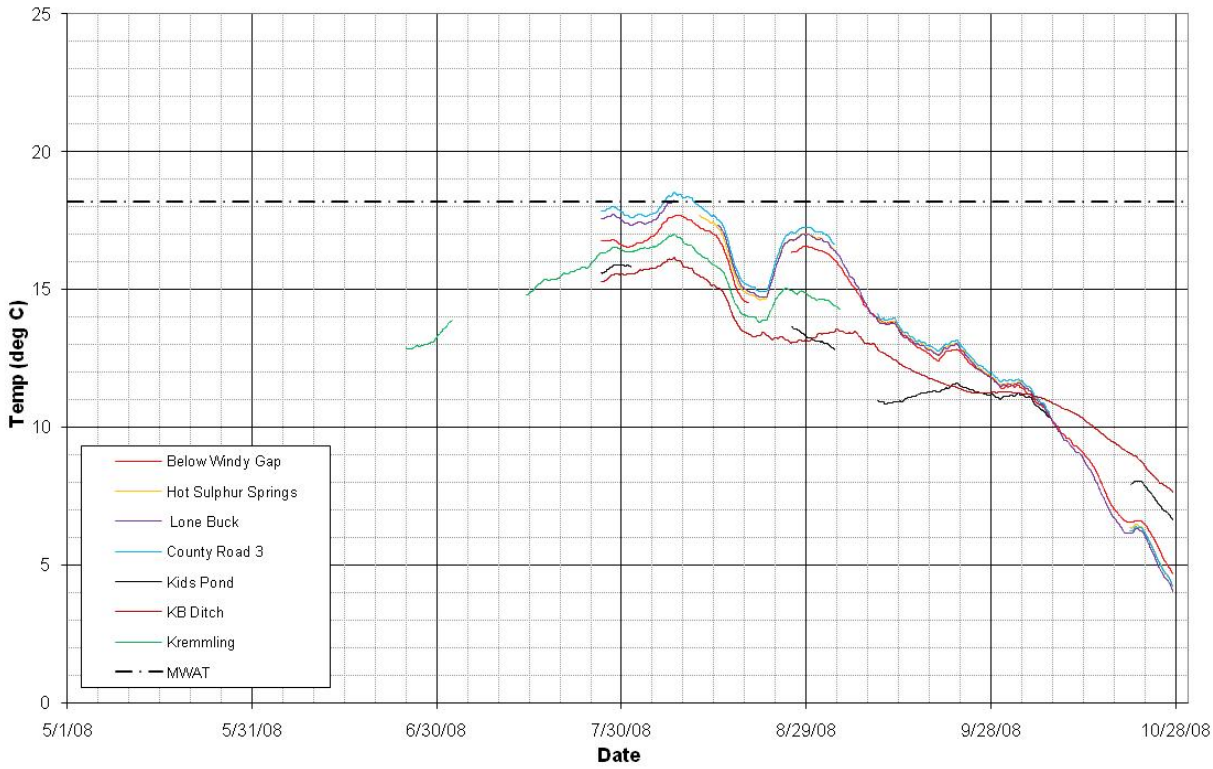

Figure B5. Colorado River Surface Water Temperatures, 7-day rolling average summer 2008

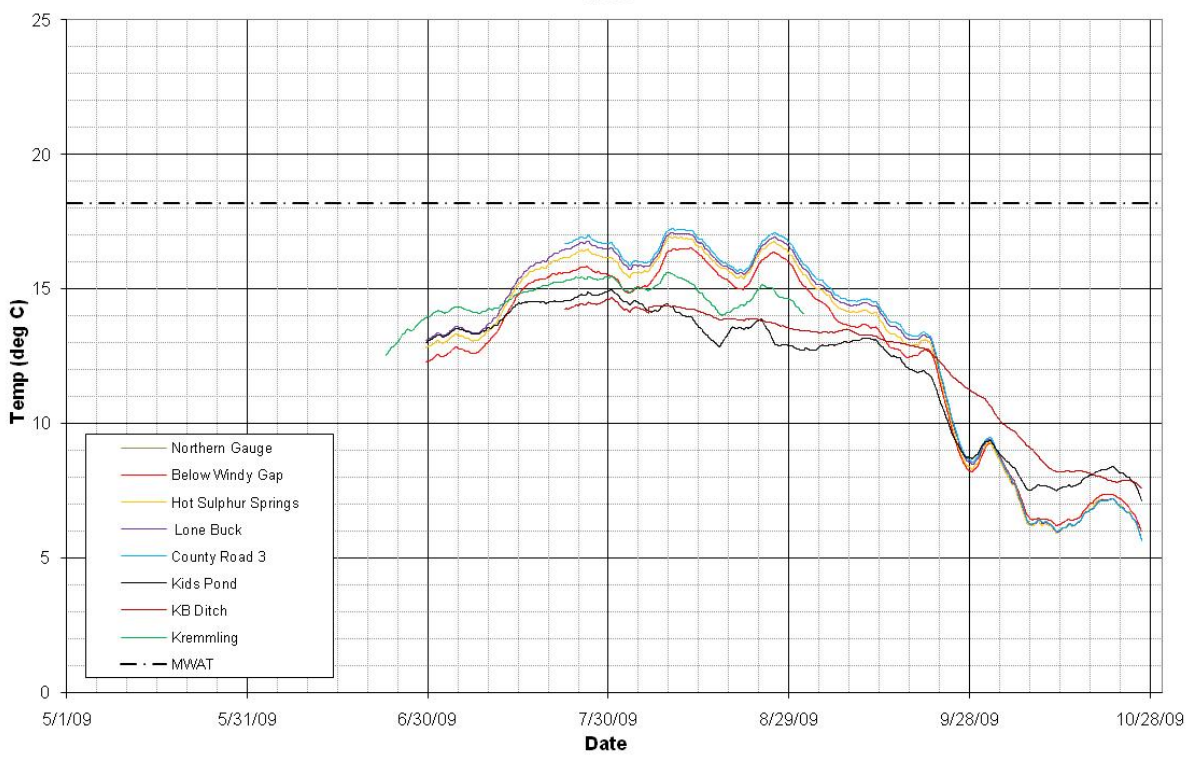

Figure B6. Colorado River Surface Water Temperatures, 7-day rolling average summer 2009

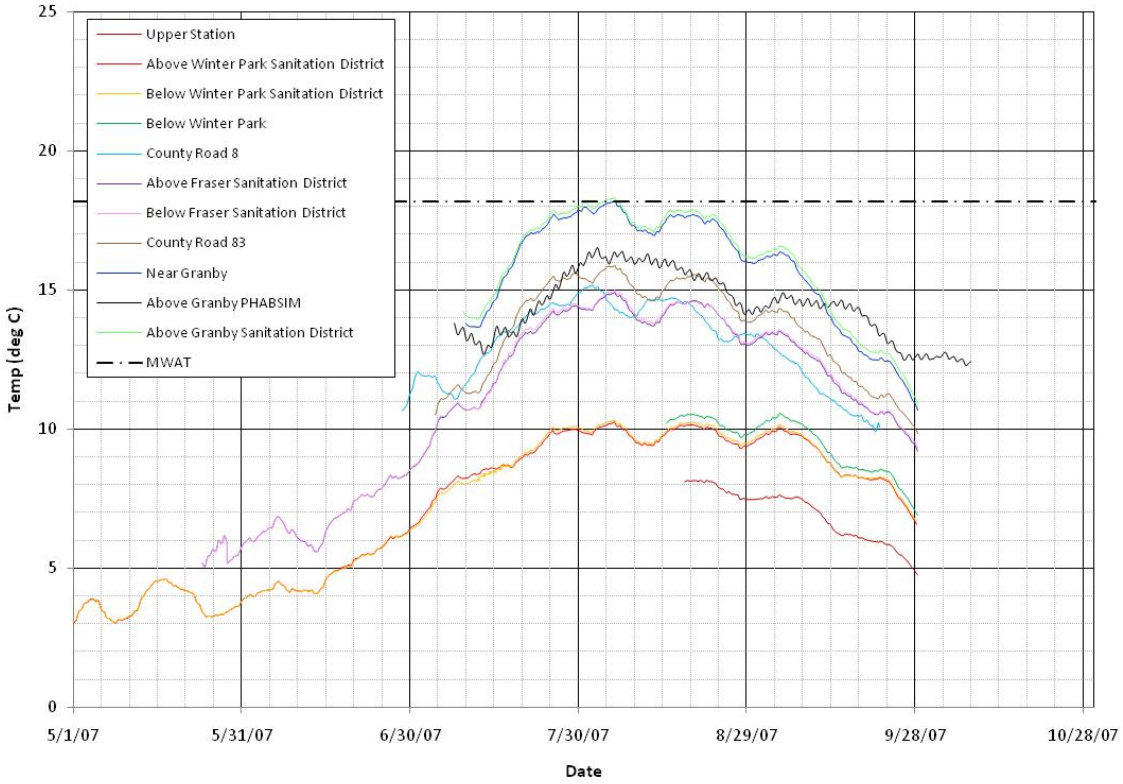

Figure B7. Fraser Surface Water Temperatures, 7-day rolling average, summer 2007

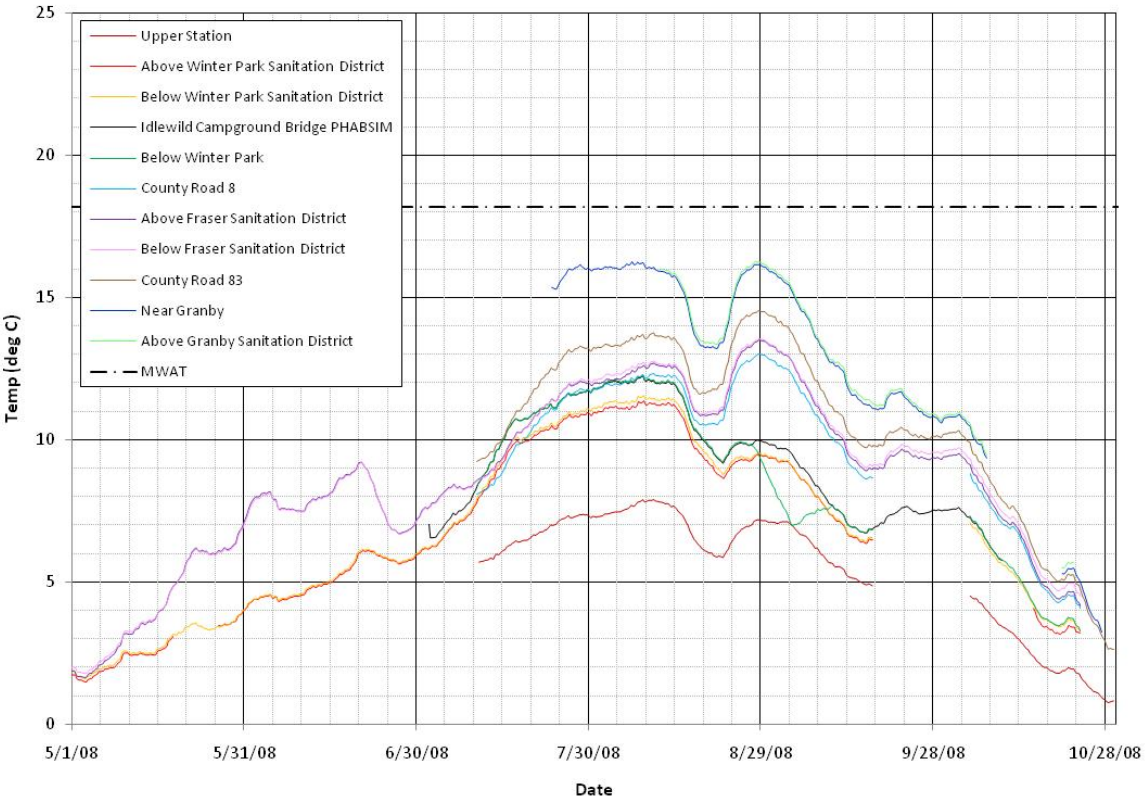

Figure B8. Fraser Surface Water Temperatures, 7-day rolling average, summer 2007

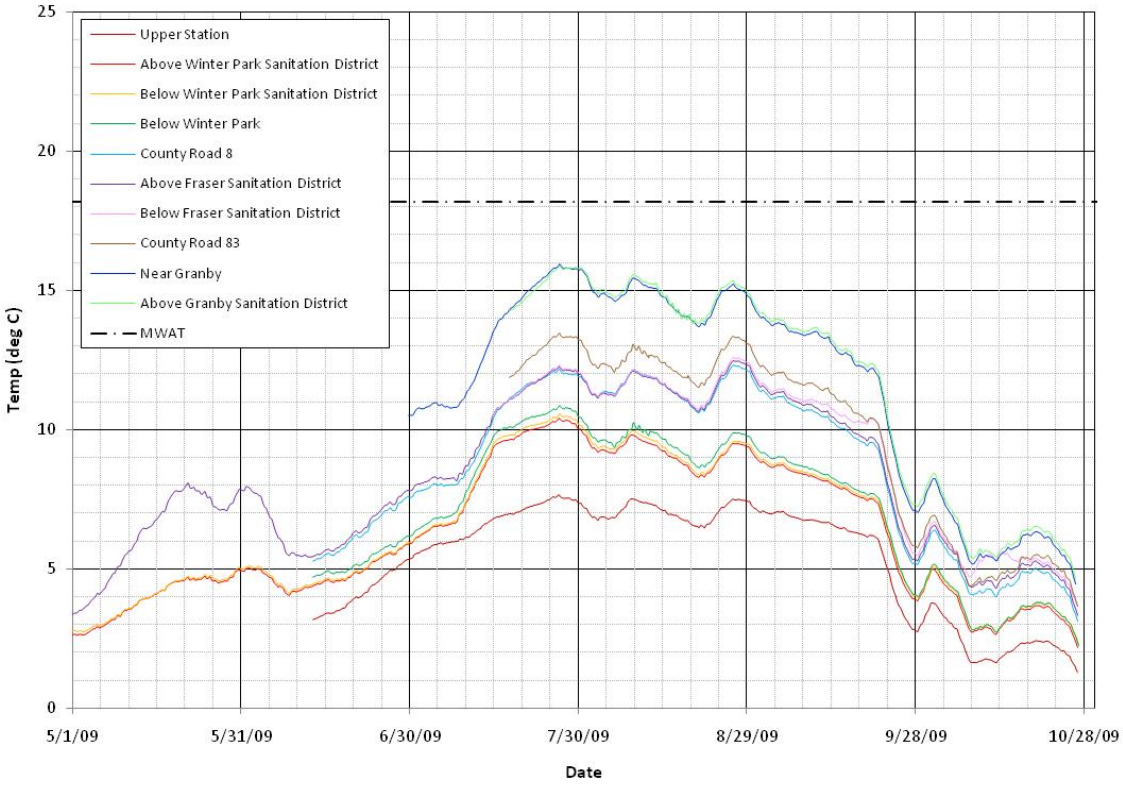

Figure B9. Fraser Surface Water Temperatures, 7-day rolling average, summer 2007

DM: The DM temperatures were also compared to the State's acute standards. In general most of the continuous temperature data indicate compliance with State standards. The exception is Ranch Creek where exceedences of the DM occurred frequently day in June and July in 2006, 2007, 2008 and 2009. An example is shown on Figure B10 with a plot of Ranch Creek temperatures in 2007. See the Reach Summary sections of this report for all plots of the 2-hour rolling averages.

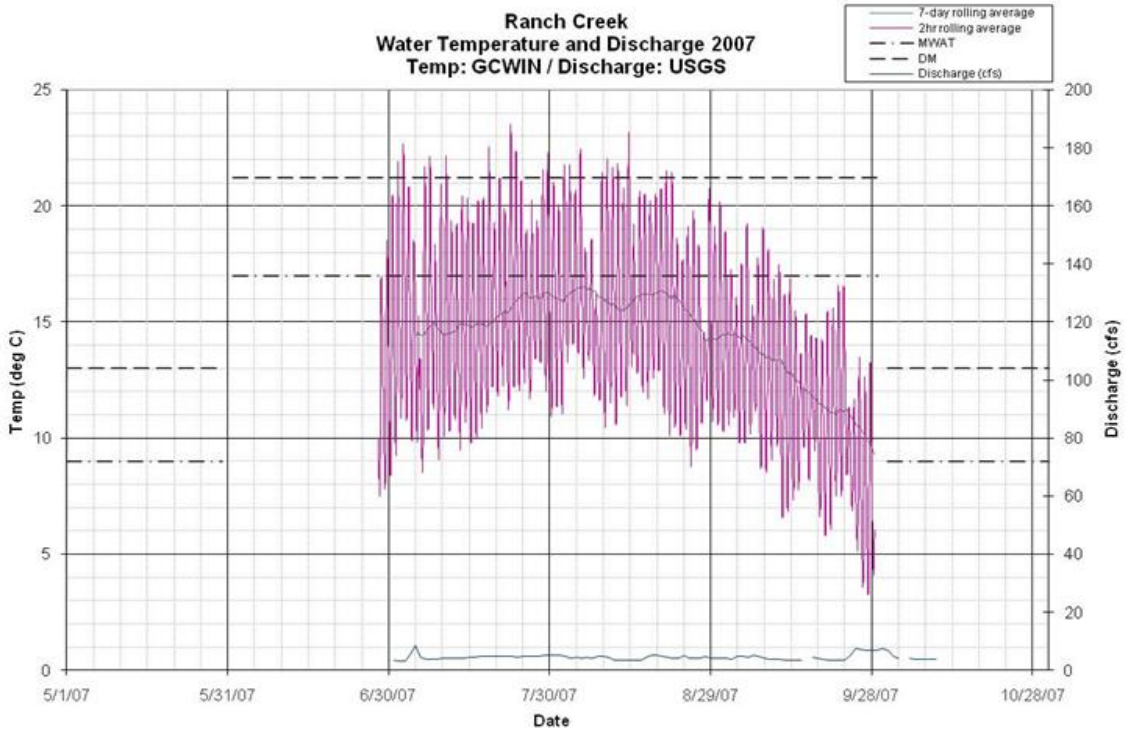

Figure B10. Fraser Surface Water Temperatures, 2-hour rolling average summer 2007

TEMPERATURE TRENDS

An attempt was made to correlate stream temperatures with several other parameters at several of the gage sites. Given the limited data available, this exercise is presented only to show examples for possible future data collection efforts. Factors that are believed to affect stream temperatures include discharge, source of flows such as reservoir releases versus rainfall, influence of snow melt, and air temperatures. In addition, temporal trends are also reviewed and discussed to present as an example of how future monitoring efforts could help with management strategies.

Temperature- Discharge Relationships

An attempt was made to correlate temperature and discharge at the KB Ditch and Hot Sulphur Springs for 2007 data. In these examples, a lower temperature is obtained with increased flows. At Hot Sulphur in 2007 the trend line appears to be approximately 2^{o}C for every 100 cubic feet per second (cfs) where as the KB Ditch indicates little to no change in temperature with increased flows. Comparison by years support the inverse correlation of flows and temperatures as can be seen by the high flows in 2009 and lower temperature readings.

Other factors that could affect water temperatures include the source of the increased flows such as reservoir releases versus rainfall, influence of cool spring snow melt, and air temperatures. A combined

plot is developed for the Colorado River at Kremmling that compares flows, air temperature, and water temperature and precipitation occurrences. There appears to be strong correlations between air and water temperature, both decreasing toward the end of the summer and early fall. It is possible that the Blue River and Muddy Creek flows are also influencing water temperatures through the later part of the summer. On a smaller scale, temperatures appear to be somewhat influenced by cool precipitation events. In the early spring, snowmelt dominates temperatures in the river. Plots are presented in Figures B11 through B14.

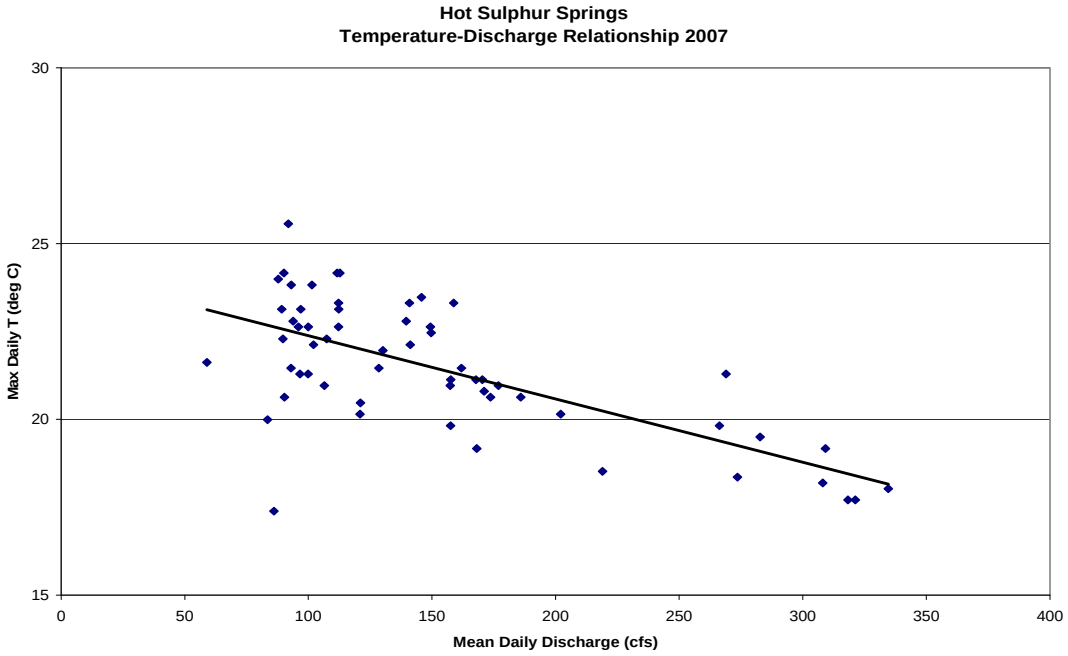

Figure B11. The temperature-discharge relationship for the summer 2007 at Hot Sulphur Springs

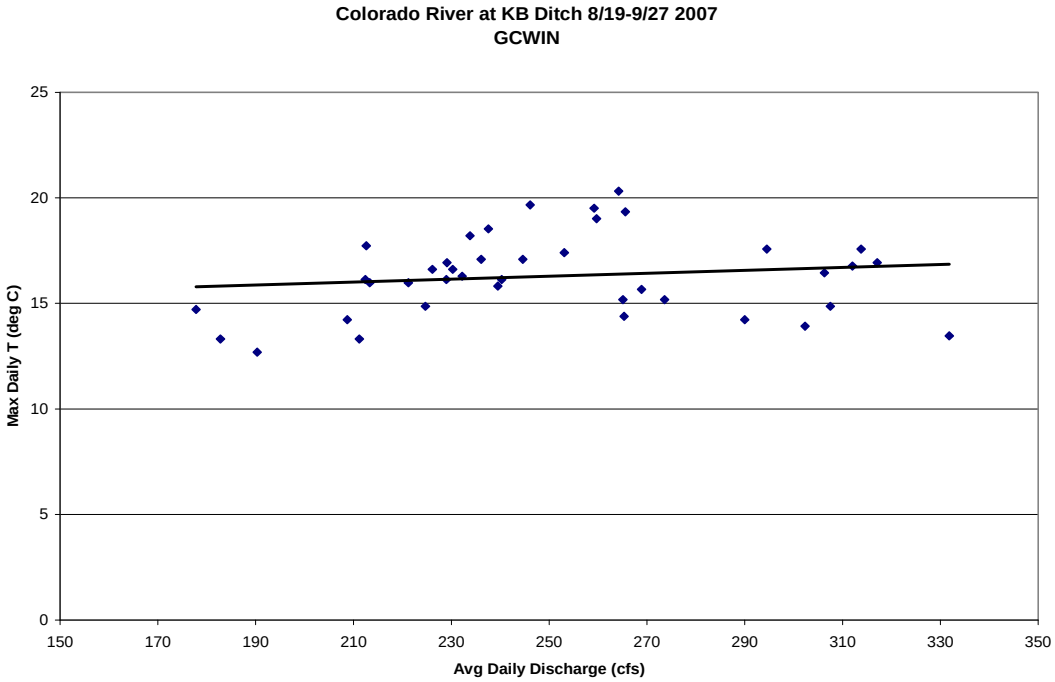

Figure B12. The temperature-discharge relationship for Colorado River at KB Ditch

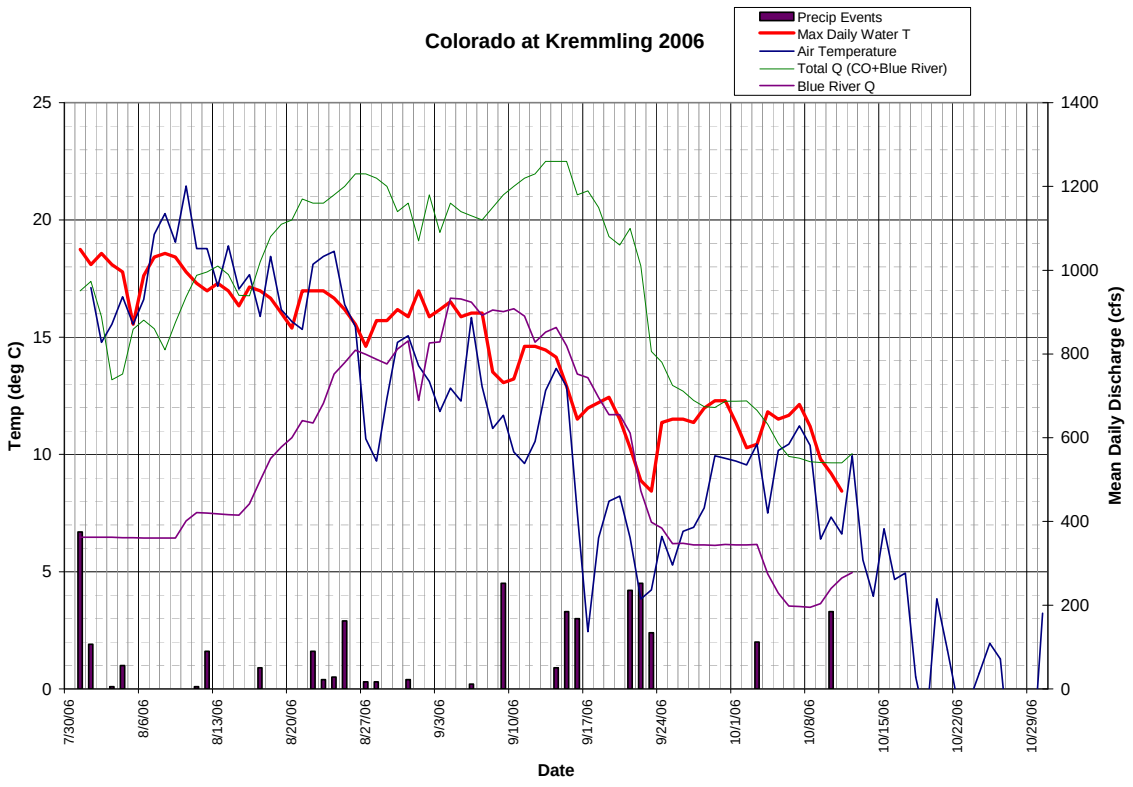

Figure B13. Colorado at Kremmling in 2006 comparing the discharge from the Colorado, the Blue, as well as precipitation and air temperature

Temporal Temperature Trends

Using the 2007 continuous data available from above Windy Gap on the Fraser River at Granby, through Windy Gap to Kremmling, temperatures were reviewed for 8 separate days to depict differences in water temperature along the length of the river. The maximum daily 2-hour rolling average for each site is plotted and shown on Figure B14.

Based on these the plots, the following observations are made for temperature temporal trends in 2007:

1. River temperatures in the Fraser River cool at the confluence with the Colorado River upstream of Windy Gap.
2. The Colorado River warms as it travels through Windy Gap. A warming trend continues through the entire stretch from Windy Gap to Hot Sulphur Springs.
3. From Hot Sulphur Springs to Williams Fork, changes in river temperatures vary. Of the five dates plotted, two days show a decrease, two days show an increase and one day, Aug 1, shows only a slight decrease.
4. Flows released from Williams Fork reservoir tend to cool water temperatures below the confluence.
5. From KB Ditch to Kremmling river temperatures remain relatively unchanged.

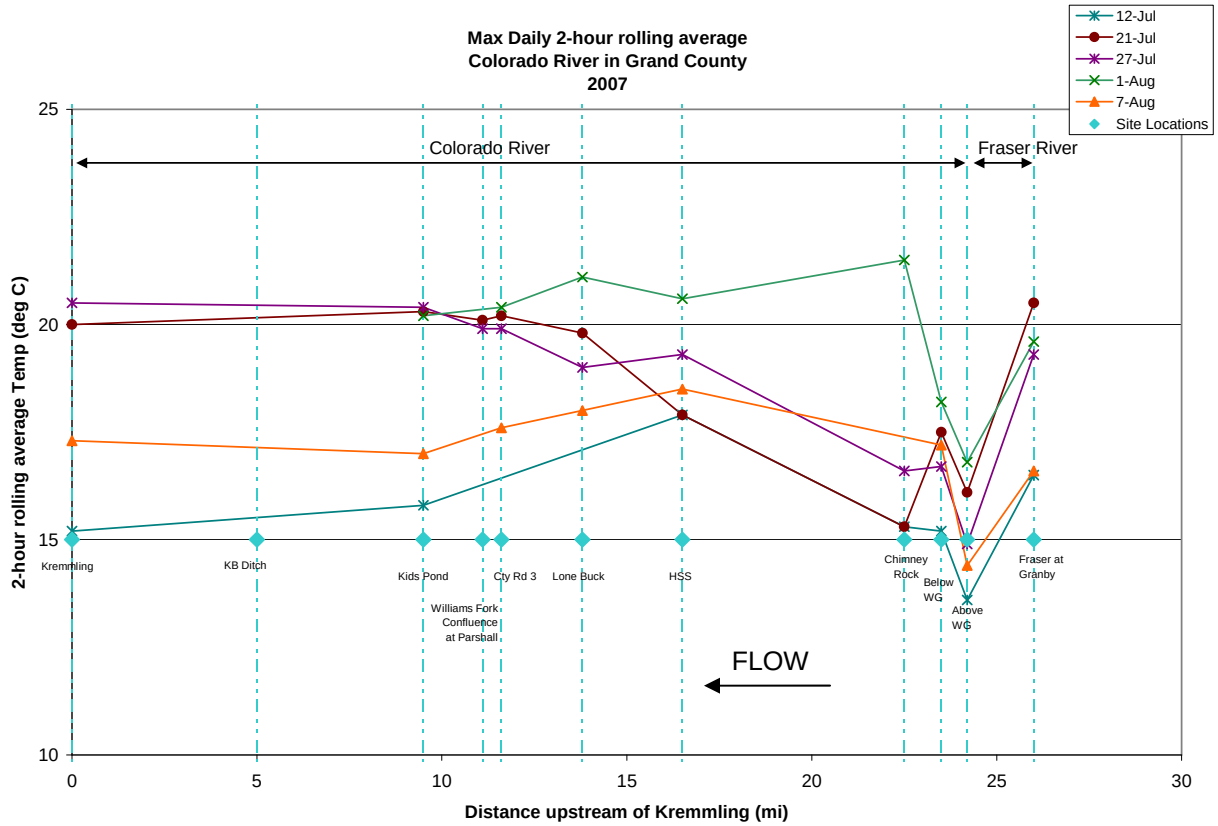

Figure B14. Maximum daily 2-hour rolling average for the Colorado River in Grand County, 2007

Air Temperatures

Stream temperature modeling was researched for information linking air temperature to stream temperatures. Several methods were found to use air temperature as a significant component in their models.

Stream temperature modeling such as the USFWS stream temperature model is a one-dimensional heat-transport model that predicts the daily mean and maximum water temperature as a function of stream distance and environmental heat flux. Net heat flux is calculated as the sum of heat to or from the atmosphere, direct solar radiation, convection, conduction, evaporation, streamside vegetation, streambed friction, and back-radiation from the water. Air temperature is one factor in determining the attenuation radiation caused by its travel through the earth's atmosphere. Other important factors include cloud cover, local topography, wind speed, relative humidity, atmospheric pressure and streamside vegetation. However, air temperature is believed to be the most important meteorological component in controlling mean daily water temperature, typically followed by relative humidity. (Bartholow, 2000).

A stream-temperature modeling of the Cache La Poudre River in Poudre Canyon, near Fort Collins, Colorado suggested that increasing the riparian shade would result in little improvement in water temperature but that decreasing the stream width would result in significant temperature reductions. In addition, construction of deep pools for thermal refugia may be beneficial in times of stream temperature maxima (Bartholow, 1991).

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