2018 Aquatic Resource Monitoring Report

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Learning By Doing 2018 Notable Events

The following summary of notable events in 2018 is provided to give context to the ongoing monitoring and cooperative Learning By Doing (LBD) effort in Grand County, Colorado. The "Notable Events" summary is followed by a one page "Monitoring Year 2018 Snapshot" which summarizes monitoring results in the Fraser and Colorado River basins. Additional information on monitoring results for the full LBD cooperative effort area (CEA), are included in the 2018 Aquatic Resource Monitoring Plan Report.

In 2018, LBD made significant strides in operations, monitoring, and stream restoration efforts. The following is not meant to be exclusive or comprehensive, but to highlight some of the most notable events of 2018 that may have had an impact on water quality.

Climate, Hydrology & Impacts

- Grand County experienced average snowpack, but an early runoff. The April 1st snowpack in the Upper Colorado Basin was close to average and provided a near normal supply for the trans-mountain diversions to the Eastern Slope. However, high temperatures in the spring and summer, as well as below-average precipitation, created challenges across the upper Colorado River watershed that are likely to result in the 2018 water year being remembered as one of the driest years on record statewide.
- By mid-summer, Colorado Parks and Wildlife (CPW) imposed fishing restrictions on streams with measured temperatures nearing levels harmful to aquatic life in Grand County and throughout the state.

Coordination Calls

- 2018 was the third year of holding weekly water coordination calls from June through September. Calls allow LBD partners to be responsive to low flow and high water temperature conditions through coordination of environmental water releases, provide a forum to discuss conditions and weekly projected operations, and foster communication, relationships, and trust amongst stakeholders.

Operations

- Windy Gap pumped a total of 26,235 AF, of which 1,000 AF was pumped and stored in Granby Reservoir for Grand County. This is the first time Windy Gap has pumped water for Grand County as a result of the signing of the IGA for the Learning By Doing Cooperative Effort in 2016. The Grand County 1,000 AF was released over 25 days in August at a rate of 20 cfs. Releases were delivered under contract to the Grand Valley Power Plant water right and then to the 15-mile reach.
- USBR and Northern Water delivered irrigation directly out of Willow Creek Reservoir for HUP delivery/substitution rather than pumping into Granby Reservoir and replacing out of Green Mountain Reservoir, providing flow directly to the Colorado River downstream of Windy Gap.
- Denver Water conducted maintenance on the Moffat Collections System and the Jim Creek diversion from July – September and was able to provide 900 AF of bypass flows to the Fraser River.
- Denver Water, Northern Water, and the USBR exchanged water from Williams Fork, Willow Creek, Granby, and Green Mountain Reservoirs to accommodate lowered Williams Fork dam outflows needed for stream restoration work on the Williams Fork River in September. These exchange flows benefitted the Colorado River from Windy Gap to the confluence of the Blue River during the restoration period.

Restoration Projects

- CPW and Trout Unlimited representatives electro-fished the Hammond Ditch and confirmed fish entrainment. This prompted LBD to move forward with a project that will ultimately replace the head gate, install a fish screen, and restore habitat connectivity in the affected reach of the Fraser River.

- Denver Water implemented the first phase of its Williams Fork River Restoration Project, required as mitigation for its Gross Reservoir Expansion Project. The work included 0.88 mile of aquatic habitat restoration in the Williams Fork River on Denver Water property below Williams Fork dam.

Other Factors Impacting Water Quality

- Grand County received notification from a downstream homeowner that on December 2 (Sunday) prior to 9:00 am, Union Pacific Railroad (UPRR) discharged untreated polluted water from its Moffat Tunnel discharge directly to the Fraser River that once again turned the river black. Effects from this discharge are thought to have had negative impacts on macroinvertebrate and fish populations in prior years.

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LEARNING BY DOING – MONITORING YEAR 2018 SNAPSHOT

For its sixth consecutive year, Learning By Doing (LBD) continued to monitor the health of aquatic resources within the Colorado, Fraser, and Williams Fork River basins in 2018. A snapshot of the 2018 results is below, followed by individual metric summaries.

	RESULTS		
	Observations	**Colorado River Basin, including Williams Fork**	**Fraser River Basin, including Ranch Creek**
Stream Temperature	In 2018 there were 65 sites monitored, including sites on the Colorado and Fraser Rivers and 19 tributaries. Of the sites monitored, 11 exceeded the state temperature thresholds: 4 sites in the Colorado River and 7 sites in 4 tributaries. Spikes in temperature occurred in July resulting in exceedances of temperature thresholds. Exceedances also occurred in the spring and fall when the standard value abruptly changed from winter to summer thresholds.	Of the 33 sites monitored in the Colorado River basin, 22 sites were in attainment with state temperature standards Three sites exceeded the state temperature threshold for acute (1-day) exposure: • Colorado River below Shadow Mountain Reservoir to Granby Reservoir (1 of 2 sites) • Willow Creek downstream of Willow Creek Reservoir to Colorado River (2 of 3 sites) Eight sites exceeded the state temperature threshold for chronic (7-day) exposure: • Arapaho Creek downstream of Monarch Lake • Willow Creek downstream of Willow Creek Reservoir to Colorado River (3 sites) • Colorado River downstream of Shadow Mountain Reservoir to Granby Reservoir (2 sites) • Colorado River at Lone Buck • Colorado River upstream of Williams Fork	Of the 32 sites monitored in the Fraser River basin, 29 sites were in attainment with state temperature standards. Three sites exceeded the state temperature threshold for acute (1-day) exposure: • Ranch Creek below CR 8315 • Meadow Creek • Ranch Creek downstream of Meadow Creek
Macroinvertebrates	In 2018, bioassessments were conducted at 23 sites in the CEA. 4 sites had MMI scores that were in the grey zone, a score that falls between the attainment and impairment thresholds. MMI scores in the grey zone require assessment of two auxiliary metrics; HBI and SDI; if these metrics meet an acceptable threshold, the site is not considered impaired. 1 site had a MMI score that indicated impairment for aquatic life.	Of the 14 sites monitored in the Colorado River Basin, 13 sites had MMI scores that were in attainment of state standards. • Sites in this basin not influenced by reservoir releases generally support a relatively healthy macroinvertebrate community. Macroinvertebrate communities are greatly influenced downstream from deep-release reservoirs such as Granby and Williams Fork. • The site downstream of Shadow Mountain Reservoir had a MMI score that indicated impairment, low counts of sensitive species taxa a high number of pollution tolerant species (HBI). Three sites had MMI scores that were in the grey zone, but scores for the auxiliary metrics were in attainment • Colorado River downstream of Granby Reservoir • Colorado River upstream of the Blue River • Williams Fork downstream of Williams Fork Reservoir The site directly below the Williams Fork Reservoir (Macro site WF-2) barely attains state standards, and has low biodiversity (low MMI and SDI), low proportion of sensitive species (%EPT excluding Baetidae), and a high number of pollution tolerant species (HBI). Results were similar for the new Colorado River site (CR 1.7) in the ILVK reach.	Of the 9 sites monitored in the Fraser basin, all were in attainment with state standards in 2018 and appear to support healthy macroinvertebrate populations. • Fraser River at Rendezvous Bridge had a MMI score that was in the grey zone, but scores for the auxiliary metrics were in attainment • Most metrics indicated an increase in stress at the site directly downstream of the Union Pacific Railroad Moffat Tunnel discharge. However, improvements in health of the aquatic communities were observed downstream, especially downstream of the Fraser Flats Restoration Project. • The new Fraser River site upstream of Jim Creek was in attainment and most metrics demonstrate a healthy macroinvertebrate community, however a low diversity index was reported for this site. The other metrics for macroinvertebrate populations at this site indicate a healthy population and do not align with the low SDI number.
Fish	CPW's trout estimates in 2018, as captured in its *Colorado River at Parshall* and *Fraser River Fishery Management Reports*, showed an increase from 2017 in trout biomass estimates (or the last year data was recorded) for all but the Fraser Flats River Habitat Project Site. CPW speculates decline at the Fraser Flats may be attributable to the high level of public fishing pressure that this section experienced in 2018. If public use of this reach becomes increasingly heavy in the future, some form of access management may be advisable in order to maintain the quality of the fishery.[4] See the Fraser River Basin section for further details.	CPW collected trout population data on the two-mile reach of the Colorado River beginning just upstream of the "Parshall Hole" and extending downstream through the Kemp-Breeze State Wildlife Area to the irrigation diversion on the Bureau of Land Management Sunset property. Population estimates are obtained by raft electrofishing using standard mark-recapture methodology. Since 2011, and again in 2018 the trout population estimate has steadily increased. In all years since the data collection began in 2007, this estimate has generously exceeded the minimum Gold Medal criteria of at least 60 lbs/surface acre. During this period brown trout have comprised an average of 95% of this estimate while rainbows have comprised 5%. In 2018, total biomass estimates for brown trout and rainbow trout were 154 lbs/surface acre and 11 lbs/surface acre, respectively.[3]	Similar to past years, CPW collected trout population data on the Fraser River at four locations: Grand County Water and Sanitation District No. 1 property (site of LBD's Fraser Flats River Habitat Project), behind the Safeway in the Town of Fraser, Confluence Park, and at the Idlewild Campground. • Trout biomass estimates at the Safeway site increased compared to 2017 data with 217 lbs/ acre for rainbow, brown, and brook trout. • Confluence Park showed an increase compared to 2017 with 65 lbs/surface acre for rainbow, brown, and brook trout. • Idlewild Campground showed an increase compared to 2016, with 72 lbs/surface acre for rainbow, brown, and brook trout.[4] • For the Fraser Flats River Habitat Project site, CPW observed an immediate benefit after completion of the project, with greatly increased numbers of adult fish and a nearly fourfold increase in total trout biomass from 2016 to 2017. However, in 2018, the total biomass estimate declined by 38% from 127 to 79 lbs/surface acre for rainbow and brown trout.
Pebble Counts	Overall, the condition of the streambed substrate is characterized by low levels of sediment and low to moderate levels of aquatic vegetation. This indicates the fish spawning habitat is in good condition.	Pebble counts associated with the seven macroinvertebrate sites in the Colorado River collected in 2018 indicated between 1% – 8% embeddedness, with all pebbles falling between the 16mm – 512mm range. The percentage of aquatic vegetation at these sites ranged from a low of 2% to a high of 95%.	Pebble counts associated with the seven macroinvertebrate sites in the Fraser River collected in 2018 indicated between 1% – 11% embeddedness, with all pebbles falling between the 8mm – 512mm range. The percentage of aquatic vegetation ranged from a low of 0% to a high of 86%.
Flushing Flows[1]	Spring runoff met the county's recommended flushing flows in all but one stream in 2018.	Of the 4 sites monitored in the Colorado River Basin, only the Colorado River at Kremmling did not meet the county's recommended flushing flows in 2018.	Of the 2 sites monitored in the Fraser River Basin, both met the county's recommended flushing flows in 2018.[5]

Notes and Citations:

[1]Recommended in the Grand County Stream Management Plan (2010)

[2]Colorado's Multi-Metric Index (MMI) version 4.0

[3]Colorado Parks and Wildlife, 2019. Colorado River at Parshall Fishery Management Report. Link here: https://cpw.state.co.us/thingstodo/Fishery%20Survey%20Summaries/ColoradoRivernearParshall.pdf

[4]Colorado Parks and Wildlife, 2019. Fraser River Fishery Management Report. Link here: https://cpw.state.co.us/thingstodo/Fishery%20Survey%20Summaries/FraserRiver.pdf

[5]Tetra Tech, 2019. 2018 Substrate Monitoring, Grand County, Colorado. Technical Memorandum prepared for Learning By Doing. April 9,2019

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Fraser Flats River Habitat Project

2018 Final Annual Monitoring Report

This 2018 annual monitoring report on Learning By Doing's (LBD's) Fraser Flats River Habitat Project establishes a record of the project and its effect on the riparian and aquatic habitat. While not required as part of its U.S. Army Corps of Engineers (Corps) Section 404 Permit for the project (NWP#27; Corps File No. SPK-2017-00179), LBD has voluntarily elected to create a temporary monitoring program, which will follow the measures in the *Monitoring at-a-Glance* table enclosed at the end of this report.

Program Objectives

The objectives of the Fraser Flats River Habitat Project monitoring program include documentation of the following parameters:

- Aquatic habitat features and substrate conditions
- Benthic macroinvertebrate abundance and diversity
- Trout population estimates and quality trout
- Riparian woody habitat
- Instream temperature monitoring

Construction of the project was completed in September 2017. This temporary monitoring program will be performed annually for at least 3 years post-project according to the program's guidelines finalized on October 20, 2017.[1]

Scope of 2018 Monitoring Program

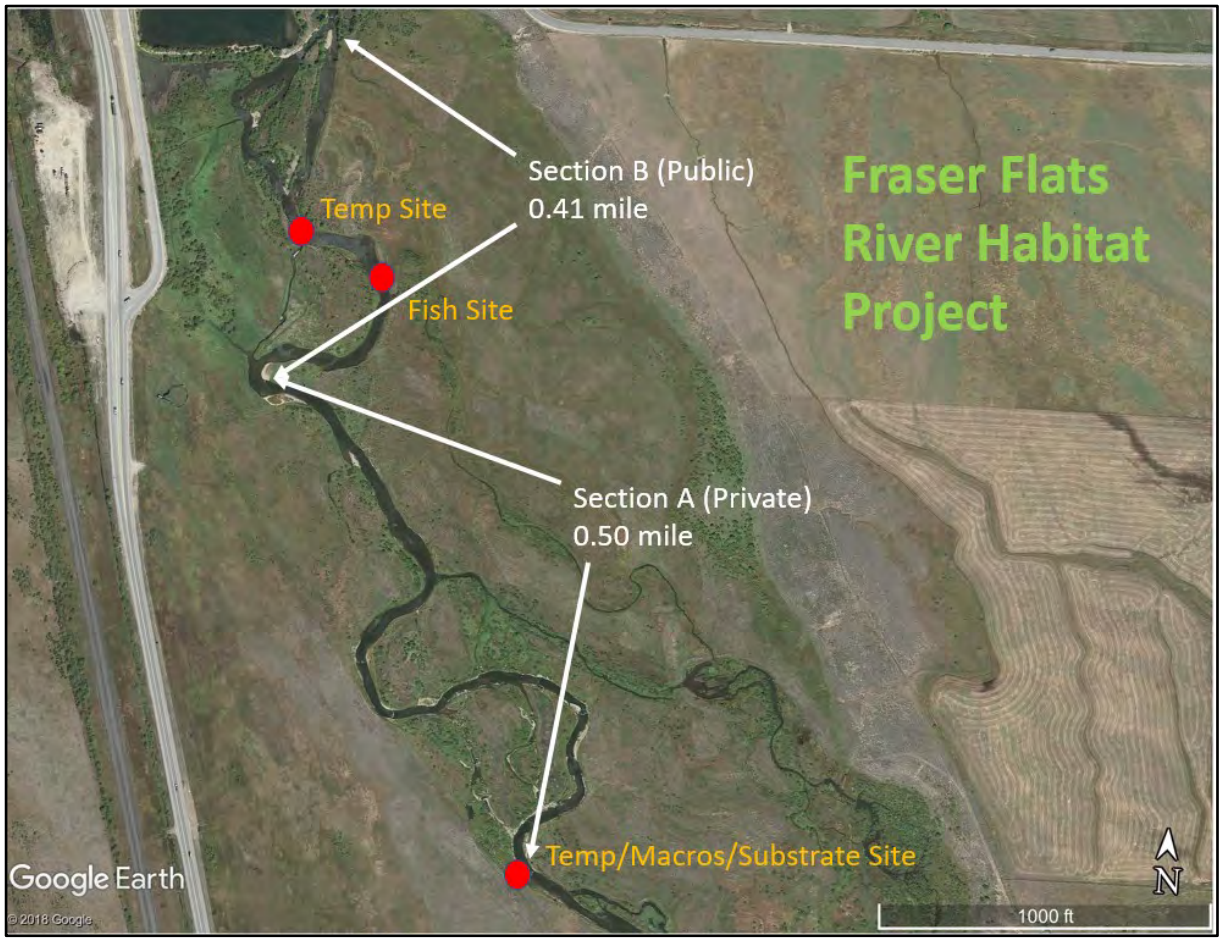
The scope of the 2018 monitoring program is to document and compare the 2018 conditions with the pre-construction (baseline) conditions of the project site.

Monitoring Program Components

The following provides a summary of the monitoring completed in 2018 and includes comparisons to available pre-project data. A map showing the locations of the sampling sites is provided as Figure 1.

[1] LBD Monitoring Subcommittee, 2017. Fraser Flats River Habitat Project Monitoring Program Guidelines. Revised October 20, 2017 based on the August 16, 2016 monitoring plan.

Figure 1 - Map of 2018 Fraser Flats Monitoring Sites



Aquatic Habitat and Substrate Conditions

The data below will be used to document progress made with regards to *Project Goal #1 - An increase in aquatic habitat features and improved substrate conditions.*

Aquatic Habitat Features

The approach for monitoring aquatic habitat features includes pre- and post-construction photographs and inventory of the number of riffles and pools in the project reach. Pre- and post-construction photos of aquatic habitat features are provided in **Attachment 1**. Pre-project aquatic habitat features were inventoried based on field observations, photographs, and Google Earth images for the years 2016-2017. For the post-project inventory, Freestone Aquatics completed an as-built survey of the project reach in October 2017, immediately following the completion of construction. The as-built drawings were used to compare the existing and proposed site conditions detailed in the plan set. As it

was designed and expected, the number of instream habitat features increased after construction of the project as compared to pre-project conditions.

In 2018, the Monitoring Subcommittee purchased a laser level to survey elevations of the constructed instream habitat features, which is scheduled to begin in monitoring year 2019. These measurements will be used for year-to-year comparisons of the quality of the instream habitat features and will be used to determine how they have withstood seasonal high flows over time by conducting measurements such as thalweg and pool depth along the project reach. LBD will continue to monitor the aquatic habitat features in the project reach in 2019.

Summary

Table 1 summarizes the number of 2016 (pre-project) and 2017-2018 (post-project) aquatic habitat features inventoried in the project reach. Although high flows were experienced during snowmelt runoff in 2018, the instream habitat features remained intact as constructed.

Table 1 - Aquatic Habitat Features - Fraser Flats River Habitat Project

	2016 Pre-construction	2017 & 2018 Post-construction
Habitat Feature		
Riffles	26	31
Pools	30	32
Constructed overhanging log habitat for fish shelter	0	2
TOTAL	**56**	**65**
Source: GoogleEarth 2018, Freestone Aquatics 2017a/b		

Pebble counts (i.e. material sizes, presence of fines, embeddedness, and aquatic vegetation) were also sampled in the project reach by Tetra Tech in 2018, post-project. Tetra Tech's 2016 pebble count data for this site was used to document pre-project conditions.

In 2018, Tetra Tech observed small cobble (64-128 mm) as the dominant substrate size in the project reach with large cobble (128-256 mm) as the second-most dominant sized substrate. Sand and finer sediments (<2 mm) at the time of sampling were minimal to non-existent, proving to be well below the threshold of 27.5% identified by Policy 98-1 (CWQCC 2014) for preventing impacts to macroinvertebrate communities in Grand County (Sediment Region 1). Substrate embeddedness showed a decrease to approximately 3% in 2018 as compared to 17% embeddedness recorded in 2017. As compared to LBD's other substrate sampling sites in the Fraser River basin, the highest percentage of aquatic vegetation occurred on the Fraser River at the Fraser Special Project Upstream site (FR-15),

which measured 86% (Tetra Tech 2019). LBD will continue to monitor substrate conditions in the project reach in 2019. Table 2 summarizes the pebble count data for years 2016 (pre-project) and 2017-2018 (post-project).

Table 2 - Pebble Count Data: Fraser Flats River Habitat Project

Site Name: FR-SpProjU or FR-15	2016 Pre-construction	2017 Post-construction	2018 Post-construction
Class size (mm)			
0-2	1	4	
2-4			
4-8			
8-16	1	1	
16-32	2	1	1
32-64	18	25	12
64-128	46	57	55
128-256	29	13	32
256-512	3	2	2
512-1024			
1024-2048			
2048-4096			
TOTAL	**100**	**103**	**102**
% Embedded	**20**	**17**	**3**
% Aquatic Vegetation	**53**	**12**	**86**
Source: Tetra Tech 2018			

Macroinvertebrates

The data below will be used to document progress made with regards to *Project Goal #2 - An increase in benthic macroinvertebrate abundance and diversity.*

Macroinvertebrate Sampling

Macroinvertebrate field sampling was performed by GCWIN and Timberline Aquatics in 2016 and 2017, respectively (pre-project). In 2018, macroinvertebrate sampling was performed by Timberline Aquatics in September. In 2018, Multimetric Index (MMI) results for the FR-SpProjU or FR-15 site (located at the upstream edge of the project reach) were reported in both MMI version 3.0 and version 4.0 values, on account of the Division's recent adoption of MMI v4. This monitoring year is the first year of reporting MMI v4.0 values. In 2018, Timberline Aquatic's results showed that the FR-SpProjU site was in attainment for both MMI v3.0 and v4.0 scores.

In 2016, macroinvertebrate samples were collected by GCWIN (pre-project), and the MMI values for the FR-SpProjU site were "impaired" based on Hilsenoff Biotic Index (HBI) and high Shannon Diversity Index (SDI) scores. The first year of post-project sampling of

macroinvertebrates occurred in 2018, using MMI version 4.0. The pre-project MMI values were conducted using MMI version 3.0, so these scores will be calibrated in the future for ease of comparison of data across years. LBD will continue to monitor macroinvertebrates in the project reach in 2019.

Summary

Table 3 summarizes the data on abundance and diversity of macroinvertebrates for years 2016-2017 (pre-project) and 2018 (post-project).

Table 3 - Macroinvertebrates Data - Fraser Flats River Habitat Project

Site Name: FR-SpProjU or FR-15	2016 Pre-construction[1]	2017 Pre-construction[1]	2018 Post-construction[1]	2018 Post-construction[2]
Sample Type*	1	4	4	4
Metric				
MMI	47.40	48.00	54.8	67.8
Aquatic Life Use Designation	Impaired	Attainment	Attainment	Attainment
HBI[3]	4.99	4.69	3.24	3.15
Shannon[4]	1.82	3.49	3.25	3.25

[1]All scores are based on the MMI (v3) subsampling process
[2]All scores are based on the MMI (v4) subsampling process
[3]Hilsenoff Biotic Index
[4]Shannon Diversity Index
Source: GCWIN 2016; Tetra Tech 2018; Timberline Aquatics 2019

*Shorthand Key to Sample Type		
No.	Sampling Device	Total Organisms Counted in Subsample
1	Hess Sampler	500
2	Kick Net	300
3	Hess Sampler	1500
4	Hess Sampler	Full count
*Adapted from Tetra Tech 2018		

Fish

The data below will be used to document progress made with regards to *Project Goal #3 - An increase in fish counts and quality trout.*

CPW Electrofishing Survey

Colorado Parks and Wildlife (CPW) has an established electrofishing site in Section B (Grand County Water and Sanitation District #1 property) of the project reach (refer to Figure 1). This site was sampled by electrofishing surveys in 2007 and 2016, which provides two years of baseline (pre-project) data. An electrofishing survey was performed by CPW in October of

2017 and 2018, post-project. CPW will continue to monitor the project reach in 2019 with the goal of documenting changes in[2]:

- Biomass (pounds per surface acre of water),
- Density of trout greater than 14 inches, and
- Expected densities of sculpin.

As shown in Table 4 below, CPW observed an immediate benefit after completion of the project, with greatly increased numbers of adult fish and a nearly fourfold increase in total trout biomass from 2016 to 2017. However, in 2018, the total biomass estimate declined by 38% from 127 to 79 lbs./surface acre for rainbow and brown trout. CPW states that this decline may be attributable to the high level of public fishing pressure that this section experienced in 2018. If public use of this reach becomes increasingly heavy in the future, some form of access management may be advisable in order to maintain the quality of the fishery (CPW 2019).

Summary

Table 4 summarizes the fish survey results for fish biomass, density of trout greater than 14 inches, and number of sculpin for years 2007 and 2016 (pre-project) and for 2017-2018 (post-project).

Table 4 - Fish Data - Fraser Flats River Habitat Project

Site Name: GCWSD#1 property	2007 Pre-construction	2016 Pre-construction	2017 Post-construction	2018 Post-construction
Brown trout				
Biomass[1]	33	26	111	60
Fish > 14" per acre	3	6	33	24
Fish > 6" per mile	752	430	923	528
Rainbow trout				
Biomass[1]	9	6	16	19
Fish > 14" per acre	3	2	8	12
Fish > 6" per mile	53	35	70	70
Brook trout				
Biomass[1]	2	1	0	0
Fish > 6" per mile	44	9	0	0
Total trout biomass[1]	44	33	127	79
Total sculpin captured	726	971	264	377
Source: CPW 2018; CPW 2019 [1]Pounds per surface acre				

[2] LBD Monitoring Subcommittee, 2017. Fraser Flats River Habitat Project Monitoring Program Guidelines. Revised October 20, 2017 based on the August 16, 2016 monitoring plan.

Riparian Woody Habitat

The data below will be used to document progress made with regards to *Project Goal #4 - An increase in riparian woody habitat.*

Riparian Woody Vegetation Survey

Pre-project photo points were established by Anna Drexler-Dreis to document canopy cover in 2016 and 2017. A map of the photo point locations is provided in **Attachment 2**. Pre- and post-construction photos of the riparian area are provided in **Attachment 3**. The canopy of willow and cottonwood stakes planted in the revegetated areas in May 2017 is expected to mature over time to provide bank stabilization and increased shade cover, which will benefit the river by helping to provide cool instream habitat.

During the summer of 2016, Ms. Drexler-Dreis established 13 photo points, took pre-project photos and identified the willows present on site. Post-planting, she conducted a stem count to see how many willow and cottonwood stems made it into the ground (Table 5). The actual number of willow stems varied from the expected number of willow stems for a variety of reasons: the area was too rocky to drive a metal stake into the ground, crew leaders expanded sections when they fell short on other sections, groups of willows were already present in the sections, and two rows were planted instead of three rows due to steep hillsides.

Post peak runoff, on June 28, 2017, Ms. Drexler-Dreis took post-project photos to show change and determine success rate. While it is too early to determine success rate, most of the willow stems and cottonwoods had leafed out (see photos at end of post-project photos). In total, approximately 2,500 trees were planted in the project reach.

The pre-project and post-project revegetation data will be evaluated in two ways: (i) spatially using aerial photographs (if available) and photos taken at the established photo points for year to year comparisons of the canopy re-establishment; and (ii) quantifying the number and condition of the willow and cottonwood plantings for year to year comparisons of the survival rate and health of the vegetation community. LBD will continue to monitor the riparian plantings in 2019.

Summary

Table 5 summarizes the 2017 plantings and 2018 (post-project) riparian condition.

Table 5 - Riparian Planting Data - Fraser Flats River Habitat Project

	Site No.*	2017 Number of Trees Planted	2018 Number of Trees Observed
Private Section A	1	117[1]	21
	2	177	93
	3	89	37
	4	96	67
	6	37	35
	7	62	0
	8	160	89
	10 & 14	298	144
	11	160	116
	13	211	0
	15	94	54
	17	315	196
	18	267	248
Public Section B	19	160	131
	20	66	49
	22	112	73
	23	154	123
	TOTAL	**2,458**	**1,476**
% Survival willows + cottonwoods[2]			**60%**

*This list is not consecutive: numbers 5, 9, 12, 16, 21 are not missing sites. Source: Drexler-Dreis (2017)

[1]Note the initial number of 177 may be incorrect based on 2018 observations

[2]Survival defined as Good or Fair health condition assessment rating

Stream Temperature

Stream Temperature Data Collection

The purpose of this task is to compare instream temperatures with pre-project conditions with the goal of documenting changes in instream temperatures over time. GCWIN maintains temperature loggers at the upstream project boundary on Section A (Devil's Thumb Ranch property) and the lower project boundary on Section B (Grand County Water and Sanitation District #1 property) (Figure 1). LBD will continue to collect stream temperature data at these locations in 2019.

Summary

Graphs summarizing the 2013-2016 (pre-project) and 2017-2018 (post-project) temperature data are provided in **Attachment 4**. As the data show, no exceedances have been

recorded at the monitoring sites to date. In 2018, the following findings were noted in the project reach:

- Increased number of aquatic habitat features (riffles and pools) post-construction
- Small cobble and large cobble were the predominant substrate types, with a low degree of embeddedness (3%)
- MMI values for macroinvertebrates were in attainment
- Significant increase in total trout biomass post-construction in 2017; however, 2018 showed a 38% decrease as compared to 2017
- Approximately 2,500 trees planted; 60% survivorship observed in 2018
- No stream temperature exceedances

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Monitoring At-A-Glance[3]

	Method	Agency	Frequency & Duration	Sample Season	Site Location	Notes
Benthic macro-invertebrates	NAMC* protocol	Timberline Aquatics	annual for 3 years post construction	September of each year	1) New site in restoration area 2) County Road 83	Reach-based approach, 8 samples per site, composited, subsampled to 300. Metrics are calculated from these results.
Fish count surveys	Electro-fishing	CPW	annual for 3 years post construction	September of each year	1) In restoration area 2) Fraser Safeway 3) Fraser, Kaibab Park in Granby	All trout species & sculpin will be totaled, and trout biomass (pounds per acre), fish >14" per surface acre, and >6" per mile will be reported.
Riparian survey	Photos and woody stem counts	Trout Unlimited	every 3-5 years for 10 years.	First two years post construction	1) In restoration area	Include: percentage of woody canopy and riparian plant species, monumented photo points and photos.
Substrate conditions	Pebble counts	Tetra Tech	annual for 3 years post construction	September of each year	1) New site in restoration area 2) County Road 83	Document bar material sizes, presence of fines and embeddedness.
Aquatic habitat features	Photo points	LBD/CPW	annual for 3 years post construction	Low flow	To be determined	Pre- and post-construction monitoring using photographs and the inventory of # of riffles, runs, pools in project reach.
Stream Temperature	Temperature loggers	GCWIN**	15-minute interval time-series; annual	Annually during ice off	1) Upstream project boundary 2) downstream project boundary	Measurable results as a result of the project are not anticipated because temperature depends upon several factors, and this is a relatively short, low gradient reach.

*Bureau of Land Management/Utah State University National Aquatic Monitoring Center
**Grand County Water Information Network

[3] This Monitoring At-A-Glance table is based on the 2016 Monitoring Plan guidelines developed by LBD. Some of the agency names and sampling methods may change, and if so, the Subcommittee will evaluate accordingly when comparing year to year data results of the program.

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Learning By Doing

Macroinvertebrates

Table 1. Sites in the Learning By Doing study area (Fraser and Colorado Rivers) sampled in September 2018.

Station ID	Location	Latitude	Longitude	Elevation (m)
FR-27.2	Fraser River abv Jim Creek	39.84536	-105.75177	3048
SLC-0	Saint Louis Creek at Fraser River	39.95175	-105.81471	2630
FR-15	Fraser River abv Fraser Flats Restoration	39.981338	-105.824946	2580
RC-1.1	Ranch Creek blw Meadow Creek	39.99912	-105.82746	2561
WF-13.1	Williams Fork blw Henderson Mill	39.9092	-106.1029	2684
WF-5.5(mod)	Williams Fork abv Williams Fork Reservoir	39.99293	-106.17079	2399
WF-2(mod)	Williams Fork blw Williams Fork Reservoir	40.04308	-106.19832	2325
CR-9.1	Colorado River at CR39 Bridge - KB Ditch	40.05377	-106.28945	2285
CR-7.4	Colorado River blw Troublesome Creek	40.0509	-106.3112	2255
CR-1.7	Colorado River abv Blue River	40.0465	-106.373	2246

Table 2. Individual metrics and MMI scores from benthic macroinvertebrate samples collected in the Learning By Doing study area during September 2018. All metric scores based on MMI (v3) subsampling process.

Metric	Station ID									
	FR-27.2	**SLC-0**	**FR-15**	**RC-1.1**	**WF-13.1**	**WF-5.5 (mod)**	**WF-2 (mod)**	**CR-9.1**	**CR-7.4**	**CR-1.7**
Total Taxa	63.9	--	--	--	--	--	--	--	--	--
Predator-Shredder Taxa	64.3	100.0	50.0	100.0	92.9	71.4	42.9	71.4	92.9	50.0
Clinger Taxa	47.1	56.4	50.9	69.0	36.2	41.9	10.2	100.0	100.0	62.1
%Ephemeroptera	19.6	--	--	--	--	--	--	--	--	--
Beck's Biotic Index	75.8	--	--	--	--	--	--	--	--	--
EP Taxa	--	63.5	34.6	67.8	60.1	32.4	2.8	85.0	86.9	55.4
% Chironomidae	--	92.1	92.3	99.2	64.9	100.0	0.0	81.6	84.4	88.7
Sens. Plains Families	--	43.1	74.7	66.1	16.6	62.5	1.5	65.4	58.5	44.8
Non-Insect %	--	49.1	26.4	19.6	54.1	0.0	25.1	30.5	28.8	0.0
MMI	**54.1**	**67.4**	**54.8**	**70.3**	**54.1**	**51.4**	**13.7**	**72.3**	**75.2**	**50.2**
	Auxiliary Metrics									
Diversity	2.97	3.87	3.25	3.59	3.55	3.56	2.64	4.12	3.98	3.53
HBI	2.44	4.24	3.24	2.79	3.52	3.53	4.64	3.55	3.39	5.12

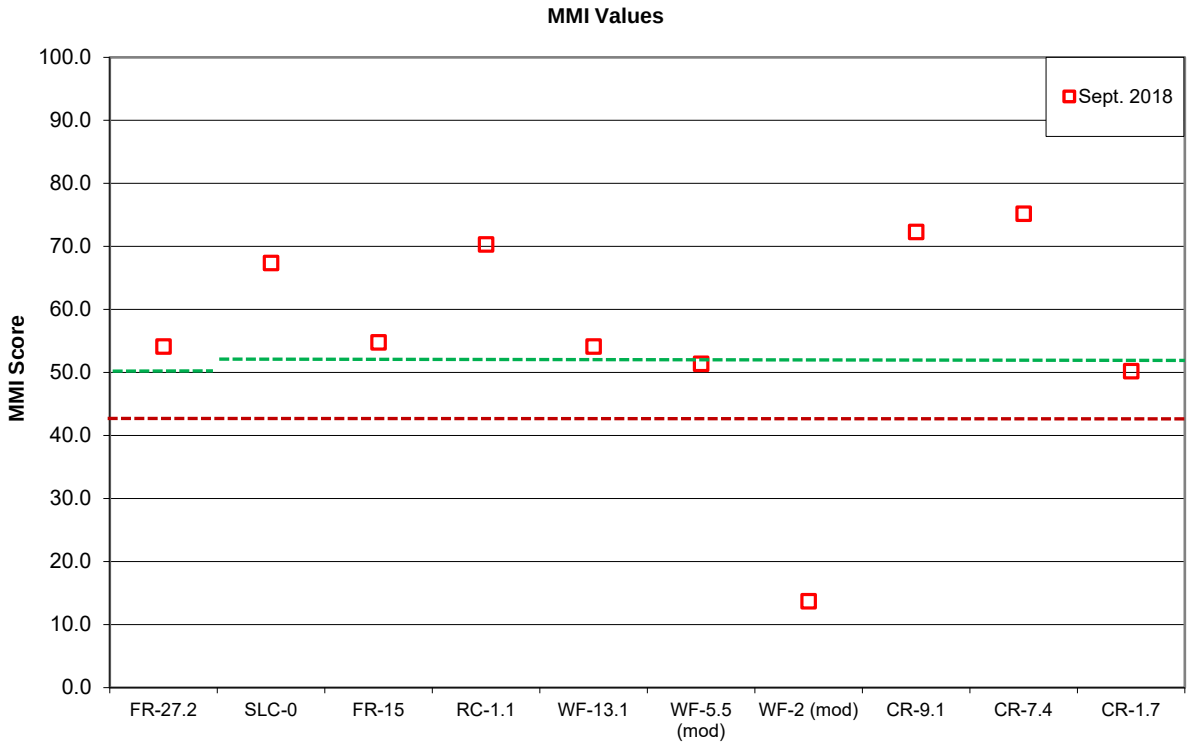

Figure 1. MMI (v3) scores from study sites in the Learning By Doing study area during September 2018. All scores based on MMI (v3) subsampling process.

Table 3. Aquatic life use designations based on MMI (v3) scores from samples at sites in the Learning By Doing study area during September 2018.

Aquatic Life Use Designations in 2018	
Site	
FR-27.2	**Attainment**
SLC-0	**Attainment**
FR-15	**Attainment**
RC-1.1	**Attainment**
WF-13.1	**Attainment**
WF-5.5(mod)	**Attainment**
WF-2(mod)	**Impairment**
CR-9.1	**Attainment**
CR-7.4	**Attainment**
CR-1.7	**Attainment**

Table 4. Individual metrics and MMI scores from benthic macroinvertebrate samples collected in the Learning By Doing study area during September 2018. All metric scores based on MMI (v4) subsampling process.

Metric	Station ID									
	FR-27.2	**SLC-0**	**FR-15**	**RC-1.1**	**WF-13.1**	**WF-5.5 (mod)**	**WF-2 (mod)**	**CR-9.1**	**CR-7.4**	**CR-1.7**
EPT Taxa	65.3	66.7	45.8	70.8	75.0	45.8	29.2	84.8	100.0	52.1
% EPT, no Baetidae	100.0	35.6	72.1	90.6	85.0	62.1	4.3	50.9	58.0	24.9
Clinger Taxa	65.0	81.7	67.3	67.3	72.1	57.7	33.7	100.0	100.0	57.8
Total Taxa	59.5	--	--	--	--	--	--	--	--	--
Intolerant Taxa	81.0	--	--	--	--	--	--	--	--	--
% Increasers, Mountains	63.9	--	--	--	--	--	--	--	--	--
Predator Taxa	61.5	--	--	--	--	--	--	--	--	--
% Scraper individuals	100.0	--	--	--	--	--	--	--	--	--
% Non-Insect individuals	--	70.4	82.2	74.3	86.5	66.6	92.3	76.7	81.7	30.4
% Coleoptera individuals	--	62.6	70.5	46.6	6.2	66.5	0.8	89.4	73.1	67.9
% Intolerant Taxa	--	65.6	62.2	76.8	94.4	43.4	51.8	79.0	94.9	55.0
% Increasers, Mid-Elev.	--	49.7	85.3	87.8	84.2	87.3	98.7	83.5	88.7	0.0
Predator/Shredder taxa	--	100.0	57.1	100.0	100.0	78.6	42.9	71.4	92.9	57.1
MMI	**74.5**	**66.5**	**67.8**	**76.8**	**75.4**	**63.5**	**44.2**	**79.5**	**86.2**	**43.2**
	Auxiliary Metrics									
Diversity	2.98	3.87	3.25	3.66	3.61	3.58	2.64	4.13	4.02	3.54
HBI	2.16	4.05	3.15	2.85	3.23	3.42	4.69	3.42	3.46	5.08
TIV	2.28	6.20	4.79	4.59	4.25	--	--	--	--	--

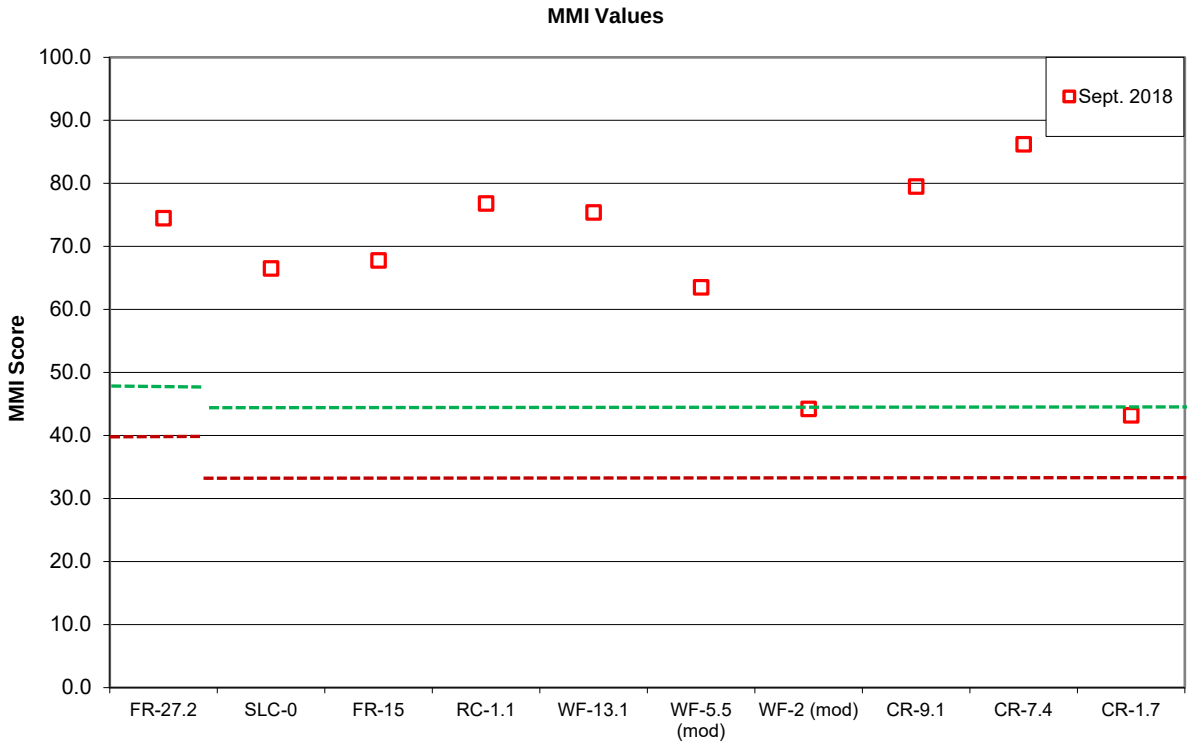

Figure 2. MMI (v4) scores from study sites in the Learning By Doing study area during September 2018. All scores based on MMI (v4) subsampling process.

Table 5. Aquatic life use designations based on MMI (v4) scores from samples at sites in the Learning By Doing study area during September 2018.

Aquatic Life Use Designations in 2018	
Site	
FR-27.2	**Attainment**
SLC-0	**Attainment**
FR-15	**Attainment**
RC-1.1	**Attainment**
WF-13.1	**Attainment**
WF-5.5(mod)	**Attainment**
WF-2(mod)	**Attainment**
CR-9.1	**Attainment**
CR-7.4	**Attainment**
CR-1.7	**Attainment**

Table 6. Additional metrics and comparative values for macroinvertebrate samples collected from the Learning By Doing study area in September 2018. All additional metrics based on full count Hess samples.

Metric	FR-27.2	SLC-0	FR-15	RC-1.1	WF-13.1	WF-5.5 (mod)	WF-2 (mod)	CR-9.1	CR-7.4	CR-1.7
Density (#/m^2)	3,862	3,524	8,770	8,566	3,231	6,429	8,755	7,037	7,384	6,197
Taxa Richness	33	46	42	42	37	45	25	55	56	42
EPT	19	22	16	22	20	12	9	28	28	15
Density of *Pteronarcys californica* (#/m^2)	0	0	0	0	0	0	0	19	0	0
Percent EPT excluding Baetidae	78.85%	28.73%	54.32%	64.10%	61.93%	46.34%	2.62%	35.23%	43.58%	17.68%
Percent Chironomidae	2.01%	5.75%	6.02%	2.77%	23.25%	1.57%	74.34%	12.09%	10.16%	11.72%

Colorado Department of Public Health and Environment

Water Quality Control Division

Benthic Macroinvertebrate Bioassessment Report

StationID:	CR-1.7			Sample Date:	9/20/2018
Waterbody Name:	Colorado River				
Location:	abv Blue River				
Latitude:	40.0465	Reference Status:	Not Reference or Degraded		
Longitude:	-106.373	BenSampID:	1	RepNum:	1
Site Classification:	1	Summer Temp:	14.29	JulianDay:	262

Predictive Model Results

O/E (p>half):	

Model Test:

Multimetric Index Model Results

MMI:	43.2

Metric Name	Metric Value	Metric Score
Ephemeroptera + Plecoptera + Trichoptera taxa *:	11	52.1
Non-Insect, percent individuals:	33.6	30.4
Ephemeroptera + Plecoptera + Trichoptera, no Baetidae, percent individuals:	18.2	24.9
Coleoptera, percent individuals:	26.1	67.9
Intolerant, percent taxa *:	31	55
Increasers, Mid-Elevation, percent individuals:	27.3	0
Clinger taxa *:	11	57.8
Predator + Shredder taxa:	8	57.1
Total taxa:	29	0
Intolerant taxa:	9	0
Increasers, Mountain Trn, percent individuals:	31.2	0
Predator taxa:	6	0
Scraper, percent indivduals:	44.3	0
Non-Insect, percent taxa:	37.9	0
Sprawler taxa *:	2	0
Increasers, plains, percent individuals:	0	0
Total individuals:	253	ok

* = score (not value) adjusted by Summer temperature or Julian day

Colorado Department of Public Health and Environment

Water Quality Control Division

Benthic Macroinvertebrate Bioassessment Report

StationID:	WF-5.5			Sample Date:	9/21/2018
Waterbody Name:	Williams Fork				
Location:	abv Williams Fork Reservoir				
Latitude:	40.0004	Reference Status:	Not Reference or Degraded		
Longitude:	-106.17975	BenSampID:	10	RepNum:	1
Site Classification:	1	Summer Temp:	13.48	JulianDay:	263

Predictive Model Results

O/E (p>half):	

Model Test:

Multimetric Index Model Results

MMI:	63.5

Metric Name	Metric Value	Metric Score
Ephemeroptera + Plecoptera + Trichoptera taxa *:	11	45.8
Non-Insect, percent individuals:	16.1	66.6
Ephemeroptera + Plecoptera + Trichoptera, no Baetidae, percent individuals:	45.3	62.1
Coleoptera, percent individuals:	25.5	66.5
Intolerant, percent taxa *:	26.5	43.4
Increasers, Mid-Elevation, percent individuals:	3	87.3
Clinger taxa *:	12	57.7
Predator + Shredder taxa:	11	78.6
Total taxa:	34	0
Intolerant taxa:	9	0
Increasers, Mountain Trn, percent individuals:	29.2	0
Predator taxa:	7	0
Scraper, percent indivduals:	27.1	0
Non-Insect, percent taxa:	35.3	0
Sprawler taxa *:	1	0
Increasers, plains, percent individuals:	0	0
Total individuals:	329	LARGE

* = score (not value) adjusted by Summer temperature or Julian day

Colorado Department of Public Health and Environment

Water Quality Control Division

Benthic Macroinvertebrate Bioassessment Report

StationID:	CR-7.4			Sample Date:	9/20/2018
Waterbody Name:	Colorado River				
Location:	blw Troublesome Creek				
Latitude:	40.0509	Reference Status:	Not Reference or Degraded		
Longitude:	-106.3112	BenSampID:	2	RepNum:	1
Site Classification:	1	Summer Temp:	15.39	JulianDay:	262

Predictive Model Results

O/E (p>half):	

Model Test:

Multimetric Index Model Results

MMI:	86.2

Metric Name	Metric Value	Metric Score
Ephemeroptera + Plecoptera + Trichoptera taxa *:	20	100
Non-Insect, percent individuals:	8.8	81.7
Ephemeroptera + Plecoptera + Trichoptera, no Baetidae, percent individuals:	42.3	58
Coleoptera, percent individuals:	28.1	73.1
Intolerant, percent taxa *:	47.5	94.9
Increasers, Mid-Elevation, percent individuals:	2.7	88.7
Clinger taxa *:	18	100
Predator + Shredder taxa:	13	92.9
Total taxa:	40	0
Intolerant taxa:	19	0
Increasers, Mountain Trn, percent individuals:	39.6	0
Predator taxa:	9	0
Scraper, percent indivduals:	35.8	0
Non-Insect, percent taxa:	20	0
Sprawler taxa *:	5	0
Increasers, plains, percent individuals:	0	0
Total individuals:	260	ok

* = score (not value) adjusted by Summer temperature or Julian day

Colorado Department of Public Health and Environment

Water Quality Control Division

Benthic Macroinvertebrate Bioassessment Report

StationID:	CR-9.1			Sample Date:	9/20/2018
Waterbody Name:	Colorado River				
Location:	at CR39 Bridge - KB Ditch				
Latitude:	40.05377	Reference Status:	Not Reference or Degraded		
Longitude:	-106.28945	BenSampID:	3	RepNum:	1
Site Classification:	1	Summer Temp:	13.62	JulianDay:	262

Predictive Model Results

O/E (p>half):	

Model Test:

Multimetric Index Model Results

MMI:	79.5

Metric Name	Metric Value	Metric Score
Ephemeroptera + Plecoptera + Trichoptera taxa *:	20	84.8
Non-Insect, percent individuals:	11.2	76.7
Ephemeroptera + Plecoptera + Trichoptera, no Baetidae, percent individuals:	37.1	50.9
Coleoptera, percent individuals:	34.3	89.4
Intolerant, percent taxa *:	47.6	79
Increasers, Mid-Elevation, percent individuals:	4	83.5
Clinger taxa *:	21	100
Predator + Shredder taxa:	10	71.4
Total taxa:	42	0
Intolerant taxa:	20	0
Increasers, Mountain Trn, percent individuals:	41.9	0
Predator taxa:	8	0
Scraper, percent indivduals:	37.1	0
Non-Insect, percent taxa:	19	0
Sprawler taxa *:	5	0
Increasers, plains, percent individuals:	0	0
Total individuals:	329	LARGE

* = score (not value) adjusted by Summer temperature or Julian day

Colorado Department of Public Health and Environment

Water Quality Control Division

Benthic Macroinvertebrate Bioassessment Report

StationID:	FR-15			Sample Date:	9/20/2018
Waterbody Name:	Fraser River				
Location:	abv Fraser Flats Restoration				
Latitude:	39.981338	Reference Status:	Not Reference or Degraded		
Longitude:	-105.824946	BenSampID:	4	RepNum:	1
Site Classification:	1	Summer Temp:	11.94	JulianDay:	262

Predictive Model Results

O/E (p>half):	

Model Test:

Multimetric Index Model Results

MMI:	67.8

Metric Name	Metric Value	Metric Score
Ephemeroptera + Plecoptera + Trichoptera taxa *:	11	45.8
Non-Insect, percent individuals:	8.6	82.2
Ephemeroptera + Plecoptera + Trichoptera, no Baetidae, percent individuals:	52.5	72.1
Coleoptera, percent individuals:	27.1	70.5
Intolerant, percent taxa *:	37.9	62.2
Increasers, Mid-Elevation, percent individuals:	3.5	85.3
Clinger taxa *:	14	67.3
Predator + Shredder taxa:	8	57.1
Total taxa:	29	0
Intolerant taxa:	11	0
Increasers, Mountain Trn, percent individuals:	59.6	0
Predator taxa:	8	0
Scraper, percent indivduals:	29.6	0
Non-Insect, percent taxa:	20.7	0
Sprawler taxa *:	4	0
Increasers, plains, percent individuals:	0	0
Total individuals:	314	LARGE

* = score (not value) adjusted by Summer temperature or Julian day

Colorado Department of Public Health and Environment

Water Quality Control Division

Benthic Macroinvertebrate Bioassessment Report

StationID:	FR-27.2			Sample Date:	9/20/2018
Waterbody Name:	Fraser River				
Location:	abv Jim Creek				
Latitude:	39.84536	Reference Status:	Not Reference or Degraded		
Longitude:	-105.75177	BenSampID:	5	RepNum:	1
Site Classification:	2	Summer Temp:	8.73	JulianDay:	262

Predictive Model Results

O/E (p>half):	

Model Test:

Multimetric Index Model Results

MMI:	74.5

Metric Name	Metric Value	Metric Score
Ephemeroptera + Plecoptera + Trichoptera taxa *:	16	65.3
Non-Insect, percent individuals:	11.3	0
Ephemeroptera + Plecoptera + Trichoptera, no Baetidae, percent individuals:	85.2	100
Coleoptera, percent individuals:	0.6	0
Intolerant, percent taxa *:	68	0
Increasers, Mid-Elevation, percent individuals:	0	0
Clinger taxa *:	13	65
Predator + Shredder taxa:	11	0
Total taxa:	25	59.5
Intolerant taxa:	17	81
Increasers, Mountain Trn, percent individuals:	46.2	63.9
Predator taxa:	8	61.5
Scraper, percent indivduals:	46.5	100
Non-Insect, percent taxa:	12	0
Sprawler taxa *:	6	0
Increasers, plains, percent individuals:	0	0
Total individuals:	318	LARGE

* = score (not value) adjusted by Summer temperature or Julian day

Colorado Department of Public Health and Environment

Water Quality Control Division

Benthic Macroinvertebrate Bioassessment Report

StationID:	RC-1.1			Sample Date:	9/20/2018
Waterbody Name:	Ranch Creek				
Location:	blw Meadow Creek				
Latitude:	39.99912	Reference Status:	Not Reference or Degraded		
Longitude:	-105.82746	BenSampID:	6	RepNum:	1
Site Classification:	1	Summer Temp:	12.24	JulianDay:	262

Predictive Model Results

O/E (p>half):	

Model Test:

Multimetric Index Model Results

MMI:	76.8

Metric Name	Metric Value	Metric Score
Ephemeroptera + Plecoptera + Trichoptera taxa *:	17	70.8
Non-Insect, percent individuals:	12.4	74.3
Ephemeroptera + Plecoptera + Trichoptera, no Baetidae, percent individuals:	66.1	90.6
Coleoptera, percent individuals:	17.9	46.6
Intolerant, percent taxa *:	46.9	76.8
Increasers, Mid-Elevation, percent individuals:	2.9	87.8
Clinger taxa *:	14	67.3
Predator + Shredder taxa:	14	100
Total taxa:	32	0
Intolerant taxa:	15	0
Increasers, Mountain Trn, percent individuals:	30.3	0
Predator taxa:	11	0
Scraper, percent indivduals:	15.3	0
Non-Insect, percent taxa:	21.9	0
Sprawler taxa *:	2	0
Increasers, plains, percent individuals:	0	0
Total individuals:	274	ok

* = score (not value) adjusted by Summer temperature or Julian day

Colorado Department of Public Health and Environment

Water Quality Control Division

Benthic Macroinvertebrate Bioassessment Report

StationID:	SLC-0			Sample Date:	9/20/2018
Waterbody Name:	Saint Louis Creek				
Location:	at Fraser River				
Latitude:	39.95175	Reference Status:	Not Reference or Degraded		
Longitude:	-105.81471	BenSampID:	7	RepNum:	1
Site Classification:	1	Summer Temp:	11.1	JulianDay:	262

Predictive Model Results

O/E (p>half):	

Model Test:

Multimetric Index Model Results

MMI:	66.5

Metric Name	Metric Value	Metric Score
Ephemeroptera + Plecoptera + Trichoptera taxa *:	16	66.7
Non-Insect, percent individuals:	14.3	70.4
Ephemeroptera + Plecoptera + Trichoptera, no Baetidae, percent individuals:	26	35.6
Coleoptera, percent individuals:	24	62.6
Intolerant, percent taxa *:	40	65.6
Increasers, Mid-Elevation, percent individuals:	12	49.7
Clinger taxa *:	17	81.7
Predator + Shredder taxa:	16	100
Total taxa:	35	0
Intolerant taxa:	14	0
Increasers, Mountain Trn, percent individuals:	35.1	0
Predator taxa:	12	0
Scraper, percent indivduals:	7.8	0
Non-Insect, percent taxa:	14.3	0
Sprawler taxa *:	3	0
Increasers, plains, percent individuals:	0	0
Total individuals:	308	LARGE

* = score (not value) adjusted by Summer temperature or Julian day

Colorado Department of Public Health and Environment

Water Quality Control Division

Benthic Macroinvertebrate Bioassessment Report

StationID:	WF-13.1			Sample Date:	9/20/2018
Waterbody Name:	Williams Fork				
Location:	blw Henderson Mill				
Latitude:	39.9092	Reference Status:	Not Reference or Degraded		
Longitude:	-106.1029	BenSampID:	8	RepNum:	1
Site Classification:	1	Summer Temp:	12.31	JulianDay:	262

Predictive Model Results

O/E (p>half):	

Model Test:

Multimetric Index Model Results

MMI:	75.4

Metric Name	Metric Value	Metric Score
Ephemeroptera + Plecoptera + Trichoptera taxa *:	18	75
Non-Insect, percent individuals:	6.5	86.5
Ephemeroptera + Plecoptera + Trichoptera, no Baetidae, percent individuals:	62	85
Coleoptera, percent individuals:	2.4	6.2
Intolerant, percent taxa *:	57.6	94.4
Increasers, Mid-Elevation, percent individuals:	3.8	84.2
Clinger taxa *:	15	72.1
Predator + Shredder taxa:	14	100
Total taxa:	33	0
Intolerant taxa:	19	0
Increasers, Mountain Trn, percent individuals:	50	0
Predator taxa:	13	0
Scraper, percent indivduals:	23.3	0
Non-Insect, percent taxa:	12.1	0
Sprawler taxa *:	5	0
Increasers, plains, percent individuals:	0	0
Total individuals:	292	ok

* = score (not value) adjusted by Summer temperature or Julian day

Colorado Department of Public Health and Environment

Water Quality Control Division

Benthic Macroinvertebrate Bioassessment Report

StationID:	WF-2			Sample Date:	9/21/2018
Waterbody Name:	Williams Fork				
Location:	blw Williams Fork Reservoir				
Latitude:	40.036201	Reference Status:	Not Reference or Degraded		
Longitude:	-106.204893	BenSampID:	9	RepNum:	1
Site Classification:	1	Summer Temp:	12.95	JulianDay:	263

Predictive Model Results

O/E (p>half):	

Model Test:

Multimetric Index Model Results

MMI:	44.2

Metric Name	Metric Value	Metric Score
Ephemeroptera + Plecoptera + Trichoptera taxa *:	7	29.2
Non-Insect, percent individuals:	3.7	92.3
Ephemeroptera + Plecoptera + Trichoptera, no Baetidae, percent individuals:	3.1	4.3
Coleoptera, percent individuals:	0.3	0.8
Intolerant, percent taxa *:	31.6	51.8
Increasers, Mid-Elevation, percent individuals:	0.3	98.7
Clinger taxa *:	7	33.7
Predator + Shredder taxa:	6	42.9
Total taxa:	19	0
Intolerant taxa:	6	0
Increasers, Mountain Trn, percent individuals:	2.5	0
Predator taxa:	4	0
Scraper, percent indivduals:	31.8	0
Non-Insect, percent taxa:	21.1	0
Sprawler taxa *:	2	0
Increasers, plains, percent individuals:	0	0
Total individuals:	321	LARGE

* = score (not value) adjusted by Summer temperature or Julian day

Northern Water

Macroinvertebrates

Timberline Aquatics, Inc.

Memo

To:	Esther Vincent and Jennifer Stephenson, Northern Colorado Water Conservancy District.
From:	David E. Rees, Timberline Aquatics, Inc.
Date:	4/18/2019
Subject:	Results from the Colorado River Benthic Macroinvertebrate Biomonitoring Program, 2018.

Introduction

The structure and function of benthic macroinvertebrate communities in rivers and streams depends on the physical, chemical, and biological components of the associated ecosystem. Most macroinvertebrate taxa have a relatively long aquatic life-stage and limited mobility which results in a dependence on the surrounding environment for survival. These unique features provide an opportunity to monitor the influence of potential stressors at specific locations along the stream channel. Recent studies have emphasized the need for biological monitoring (biomonitoring) in order to evaluate water quality and the overall health of aquatic ecosystems (Barbour et al. 1999, Paul et al. 2005, Bonada et al. 2006).

Evolution and ecological processes have resulted in benthic macroinvertebrate taxa with specific adaptations to natural environmental conditions. Consequently, benthic communities have the ability to detect stress that ranges from local sources of pollution to watershed scale disturbances (Ward et al. 2002). Long-term biomonitoring studies are also essential when evaluating aquatic life in river systems with increasing water demands or changes in land-use practices (Likens and Lambert 1998, Voelz et al. 2005). The biomonitoring and analysis approach used for this study was intended to provide site-specific information describing the health of biological communities, while taking into account natural annual variability.

In the fall of 2018, the Colorado River was sampled for benthic macroinvertebrates at four locations with the intent to monitor potential changes in the health of the aquatic life in the vicinity of Windy Gap Reservoir. Results obtained from this study provided valuable information that could be used to evaluate potential changes in operations of Windy Gap Reservoir, and assess the effects of habitat improvement projects in this segment of the Colorado River. Results from data collected during the fall (September) of 2018 were the focus of this evaluation.

Study Area

Benthic macroinvertebrates were collected from four (4) sampling locations on the Colorado River during the fall of 2018 (Table 1, Figure 1). The most upstream site (CR-WGU) was on the Colorado River immediately upstream from Windy Gap Reservoir (Figure 1). Although this site receives potential influences from upstream reservoir operations (associated with Lake Granby) and some residential development, historical sampling results suggested that this segment of the Colorado River has maintained relatively healthy aquatic communities. Farther downstream, site CR-WGD was located on the Colorado River approximately 1.9 km downstream from Windy Gap Reservoir (Figure 1). This site has the potential to be influenced by aquatic conditions within the reservoir and Windy Gap Reservoir operations. Study sites CR-HSU and CR-WFU were both located even farther downstream on the Colorado River (13.0 km and 19.0 km, respectively) and these two sites were used to monitor the residual impacts from reservoir operations along with habitat improvement projects. Some confounding variables that may also influence the aquatic communities at the two most downstream sites (CR-HSU and CR-WFU) included runoff from an adjacent highway, and urban runoff associated with the Town of Hot Sulphur Springs.

Table 1. Site descriptions, coordinates, and elevations of sample sites on the West Slope sampled in 2018.

Site ID	Description	Latitude	Longitude	Elevation (m)
CR-WGU	Colorado River upstream of Windy Gap Reservoir	40.10045	-105.97248	2,401
CR-WGD	Colorado River downstream of Windy Gap Reservoir	40.10830	-106.00356	2,374
CR-HSU	Colorado River near Hot Sulphur Springs	40.07394	-106.10959	2,341
CR-WFU	Colorado River upstream of Williams Fork	40.04689	-106.14299	2,305

Methods

Stress-induced changes in macroinvertebrate community structure can be best ascertained through analysis of benthic data that has been collected using a standardized quantitative sampling methodology. The objective of this particular study required the collection of three (3) quantitative replicate samples from similar habitat at each station. All benthic macroinvertebrates from each quantitative sample were sorted and identified, and macroinvertebrate data were analyzed using a variety of individual metrics (including the MMI v3 and MMI v4). The following section provides a description of all analysis tools used in this study:

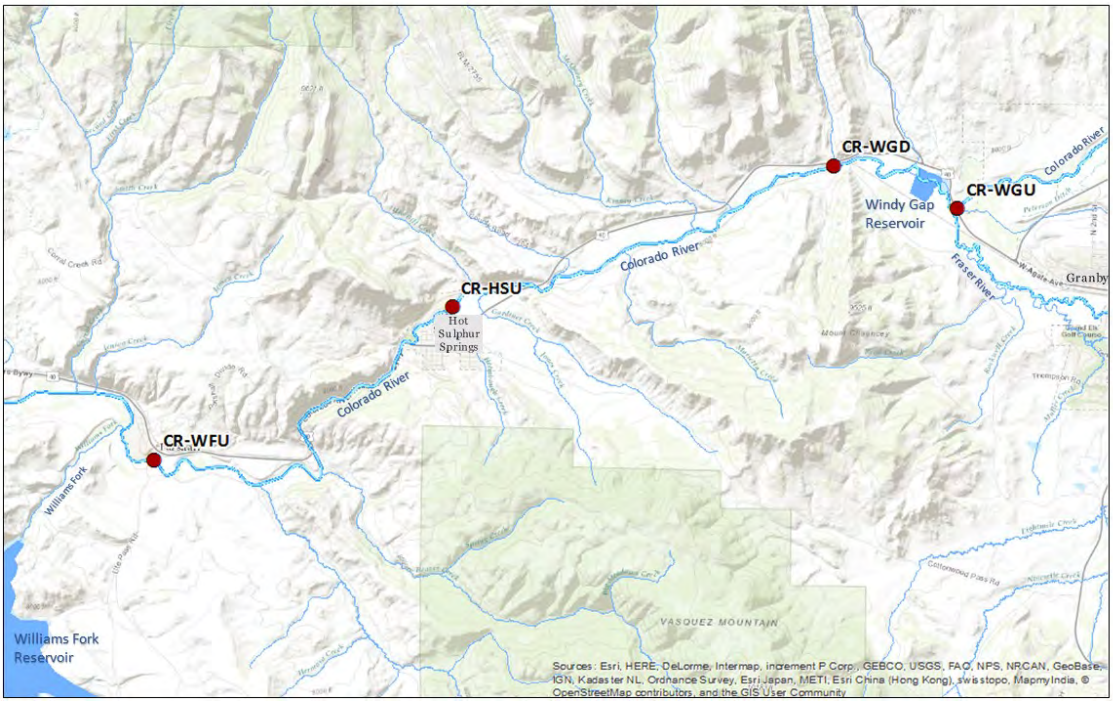

Figure 1. Map of study sites used for the Colorado River Biomonitoring Study.

The Multi-Metric Index (v3)

In the fall of 2010, the CDPHE published specific guidelines for benthic macroinvertebrate sampling and analysis to assist in the evaluation of aquatic life in the State of Colorado (Colorado Department of Public Health and Environment 2010). These guidelines described specific protocols for the analysis of benthic macroinvertebrate data using a Multi-Metric Index (MMI). The group of individual metrics used in MMI calculations depends on the location of the sampling site and corresponding Biotype (Mountains, Transitional, or Plains). All of the sites in this study area (on the Colorado River) were located in Biotype 1 (the Transitional Zone). In Biotype 1, the MMI provides a single score based on six equally weighted metrics. Each of the metrics used in the MMI produces a value that is adjusted to a scale from 1 to 100 based on the range of metric scores found at "reference sites" in the State of Colorado. The thresholds for MMI scores that determine 'attainment' or 'impairment' for aquatic life use in Biotype 1 are as follows:

Biotype	**Attainment Threshold**	**Impairment Threshold**
Transitional (Biotype 1)	52	42

Metric scores that fall between the thresholds for attainment and impairment (the "Grey Zone") require further evaluation using additional metrics in order to determine an aquatic life use designation. The additional metrics include the Shannon Diversity (Diversity) and Hilsenhoff Biotic Index (HBI). The specific thresholds for the auxiliary metrics in Biotype 1 are listed below, followed by descriptions of each metric:

Biotype	HBI	Diversity
Transitional (Biotype 1)	5.4	2.4

Shannon Diversity (Diversity): Diversity was used as an auxiliary metric for the MMI and as an independent metric in this study to evaluate changes in macroinvertebrate community structure. In unpolluted waters, Diversity values typically range from near 3.0 to 4.0. In polluted waters, this value is generally less than 1.0. The Diversity metric provides a measure of macroinvertebrate community balance.

Hilsenhoff Biotic Index (HBI): The HBI is another auxiliary metric used for the MMI; however, it is also valuable as an independent metric and has been widely used and/or recommended in numerous regional biomonitoring studies (Paul et al. 2005). Most of its value lies in the detection of organic pollution, but it is also used to evaluate aquatic conditions in a variety of other circumstances. The HBI was originally developed using macroinvertebrate taxa from streams in Wisconsin; therefore, it may require regional modifications (Hilsenhoff 1988). Tolerance values for taxa occurring in this study area were taken from a list provided by the CDPHE which was derived from a variety of regional sources. Although HBI values may naturally vary among regions, a comparison of the values produced within the same river system should provide information regarding locations impacted by nutrients and/or other aquatic disturbances. Values for the HBI range from 0.0 to 10.0, and increase as water quality decreases.

An additional means of determining an 'attainment' or 'impairment' designation using the MMI (v3) involves the rapid decline of scores from high scoring waters. When MMI scores are available from multiple years at the same sampling location, and a large decline in scores occurs over the span of at least 12 months, a site will automatically be considered impaired for aquatic life use. The requirements for the allowable decline in MMI score for Biotype 1 are as follows:

Biotype	High Scoring Water (MMI score)	Allowable MMI Decline
Transitional (Biotype 1)	>64	-22

The Multi-Metric Index (v4)

In 2017, the MMI was recalibrated and updated to produce a new analysis tool - the MMI v4 (Colorado Department of Public Health and Environment 2017). This most recent version of the MMI was developed in the same way as the MMI v3, but provides a single index score based on

eight equally weighted metrics. In Biotype 1, these metrics include: EPT Taxa, Percent Non-Insect Individuals, Percent EPT Individuals (excluding Baetidae), Percent Coleoptera Individuals, Percent Intolerant Taxa, Percent Increaser Individuals (Mid-Elevation), Clinger Taxa, and Predator/Shredder Taxa. A detailed description of individual metrics and the development of the MMI (v4) can be found in the "Aquatic Life Use Attainment: Methodology to Determine Use Attainment for Rivers and Streams, Policy 10-1" (Colorado Department of Public Health and Environment 2017). Each of the metrics used in the MMI (v4) produces a score that is adjusted to a scale from 1 to 100 based on "reference sites" in the State of Colorado.

Thresholds for the MMI (v4) in Biotype 1 are as follows:

Biotype	**Attainment Threshold**	**Impairment Threshold**
Transitional (Biotype 1)	45.2	33.7

The MMI (v4) scores that fall between the thresholds for 'attainment' and 'impairment' are in the 'grey zone' and require further evaluation using the same two auxiliary metrics (Diversity and HBI) recommended in the MMI (v3). Calculations for these metrics have been previously described; however, thresholds have been adjusted for the new version of the MMI:

Biotype	**HBI**	**Diversity**
Transitional (Biotype 1)	5.8	2.1

Additional metrics used in the study:

In addition to the two MMI tools and their associated 'grey zone' metrics, several other individual metrics were applied in the analysis of macroinvertebrate data from the Colorado River in order to provide a more thorough evaluation of community structure and function. A description of these additional metrics is provided below:

Ephemeroptera Plecoptera Trichoptera (EPT Taxa): The design of this metric is based on the assumption that the orders of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) are generally more sensitive to pollution than other benthic macroinvertebrate orders (Lenat 1988). The EPT metric is currently an important and widely used metric in many regions of the United States (Barbour et al. 1999). The EPT Taxa value is simply given as the total number of distinguishable taxa in the orders Ephemeroptera, Plecoptera, and Trichoptera found at each station. This number will naturally vary among river systems, but it can be an excellent indicator of disturbance within a specific drainage. The EPT value is expected to decrease in response to a variety of stressors including nutrients (Wang et al. 2007).

Shannon Evenness (Evenness): Evenness values were used at all sites in this study to detect changes in macroinvertebrate community structure and balance. Evenness values range between 0.0 and 1.0, and lower values generally indicate greater stress. Values lower than 0.3 are considered indicative of organic pollution or other substantial perturbations (Ward et al. 2002).

Diversity and Taxa Index (DAT): The DAT index was used in this study to evaluate water quality based on benthic community structure and diversity. This metric is unique because it incorporates components of community diversity along with taxa richness. Calculated DAT values fall within a range of numbers that are correlated to a scale describing stream condition (Mangum 1986). The DAT scale (adjusted for Chironomids identified to the genus level) is as follows:

DAT Value	SCALE
24-35	Excellent
17-23	Good
11-16	Fair
0-10	Poor

Insect Taxa: Insect Taxa is an example of a metric that relies on community richness for detection of disturbances. The Insect Taxa value is reported as a total count of distinguishable insect taxa at each site. This metric is similar to the total taxa metric; however, the Insect Taxa metric measures the number of taxa in insect families exclusively, rather than the summation of insects and non-insects. In general, the Insect Taxa value is expected to decrease as water quality becomes more degraded (Weber 1973).

Taxa Richness (Total Taxa): The Total Taxa metric is reported as the total number of identifiable taxa collected from each sampling location. Total Taxa has become one of the most widely used metrics to evaluate stream health, as it provides a general indication of community health and stability (Courtemanch 1996). Total Taxa values are expected to decrease with increased perturbations in the aquatic environment (Resh and Jackson 1993).

Percent Shredders and Scrapers: Scrapers and shredders are often considered sensitive to disturbance because they are specialized feeders (Barbour et al. 1999). Consequently, these sensitive groups are expected to be well-represented in healthy streams. Much of the value in this type of analysis comes from comparison among sites within a specific study area.

Density: Macroinvertebrate abundance (Density) was reported as the mean number of macroinvertebrates per m^2 found at each study site. Density provides a means of measuring and comparing standing crop at each site and this metric provides an indication of productivity for the macroinvertebrate portion of the food web at each sampling location.

Functional Feeding Groups: Most of the previously described metrics use macroinvertebrate information that is related to community structure; however, macroinvertebrate taxa were also separated into functional guilds based on their method of food acquisition to provide a measurement of community function. Aquatic macroinvertebrates were categorized according to feeding strategy to determine the relative proportion of various groups. Some representation of each group usually indicates good aquatic conditions; however, it is normal for certain groups (collector-gatherers) to be more abundant than others (Ward et al. 2002).

Results and Discussion

Benthic macroinvertebrates were collected on 19 September 2018 from four study sites on the upper Colorado River in order to evaluate aquatic conditions based on macroinvertebrate community structure and function. After macroinvertebrate samples were collected in the field using a quantitative (Hess) sampling technique, they were transported to the lab at Timberline Aquatics, Inc. where specimens were sorted, identified, and enumerated (Appendix A; Tables A1-A4). The previously described metrics and analysis tools (including versions 3 and 4 of the MMI) were applied to the macroinvertebrate data in order to provide a comprehensive assessment of aquatic conditions in the Colorado River study area (Tables 2-4). Results provided by select metrics (MMI v3 and v4, Diversity, HBI, and EPT) were also used to illustrate changes (or similarities) in community structure among sites (Figures 2-6). In general, results from 2018 indicated that benthic macroinvertebrate communities were relatively healthy throughout the study area, and detectable changes in aquatic conditions were minimal.

The most upstream sampling location on the Colorado River (CR-WGU) provided an opportunity to evaluate aquatic life upstream from Windy Gap Reservoir, while also producing reference information that could be compared throughout the remainder of the study area. Both versions of the MMI (v3 and v4), and most individual components the multi-metric tools, indicated that aquatic conditions were relatively healthy at site CR-WGU (Tables 2 and 3). While most of the individual metrics used in MMI calculations detected healthy community parameters, the Percent Non-Insect Taxa metric from the MMI v3, and the Percent Coleoptera metric in version 4, generated comparatively lower scores. The performance among individual metrics that was observed at site CR-WGU persisted throughout much of the study area suggesting that the influences on aquatic communities remained similar among sites (Tables 2 and 3). Despite some variability among individual metric values, both versions of the MMI indicated that site CR-WGU was in 'attainment' for aquatic life use. Other metrics used in this study generally supported the MMI by detecting healthy aquatic conditions at site CR-WGU (Table 4). The Evenness and DAT metrics suggested that the benthic community was well-balanced, and the EPT, Insect Taxa, and Percent EPT excluding Baetidae metrics detected a high proportion of sensitive taxa. When results from the MMI and select metrics were compared with historical results, most of the analysis tools showed that the aquatic community at site CR-WGU had remained similar (or improved based on Diversity values) since 2016 (Figures 2-6).

Most of the applied metrics suggested that aquatic life at site CR-WGD was similar (or slightly improved) when compared to the macroinvertebrate community structure at site CR-WGU (upstream from Windy Gap Reservoir). Both versions of the MMI produced scores that indicated 'attainment' for aquatic life use at site CR-WGD, and the score for the MMI v4 (80.4) was the highest in the study area (Tables 2 and 3). Despite potential influences from Windy Gap Reservoir, most of the component metrics used for MMI calculations produced similar scores upstream and downstream of the reservoir. Some of the slight improvements detected by the MMI v4 were due to an increase in sensitive species in the order Trichoptera. Other individual metrics showed that the macroinvertebrate community was well-balanced and maintained a variety of sensitive and specialized taxa (Table 4). A comparison with results from previous sampling events showed some improvement in community balance (Diversity) at site CR-WGD, while other metrics (EPT and HBI) detected a slight increase in stress during 2018 (Figures 2-6).

Table 2. Individual metrics and MMI (v3) scores from benthic macroinvertebrate samples collected at Northern Water sampling sites on the Colorado River on 19 September 2018. All metric scores are based on the MMI (v3) subsampling process. Scores associated with the MMI indicating impairment are provided in red.

Metric	Station ID			
	CR-WGU	CR-WGD	CR-HSU	CR-WFU
EP Taxa	88.5	79.5	81.5	83.8
% Chironomidae	80.9	76.4	93.4	99.0
% Sensitive Families	49.3	51.8	57.0	52.2
Predator/Shredder Taxa	71.4	85.7	42.9	64.3
Clinger Taxa	100.0	100.0	90.5	100.0
% Non-Insect Taxa	30.8	40.7	22.1	37.2
MMI	**70.2**	**72.3**	**64.6**	**72.7**
	Auxiliary Metrics			
Diversity	4.42	4.24	3.72	4.21
HBI	3.02	3.21	2.73	3.19

Table 3. Individual metrics and MMI (v4) scores from benthic macroinvertebrate samples collected at Northern Water sampling sites on the Colorado River on 19 September 2018. All metric scores are based on the MMI (v4) subsampling process. Scores associated with the MMI indicating impairment are provided in red.

Metric	Station ID			
	CR-WGU	CR-WGD	CR-HSU	CR-WFU
EPT Taxa	79.2	87.5	79.2	83.3
% Non-Insect Individuals	90.7	91.9	92.3	84.2
% EPT Individuals, no Baetidae	78.1	71.8	88.0	79.3
% Coleoptera Individuals	31.8	36.6	44.6	30.2
% Intolerant Taxa	75.3	80.1	74.5	89.0
% Increaser Individuals, Mid-Elevation	94.9	96.7	97.4	98.8
Clinger Taxa	76.9	100.0	76.9	100.0
Predator/Shredder Taxa	64.3	78.6	50.0	64.3
MMI	**73.9**	**80.4**	**75.4**	**78.6**
	Auxiliary Metrics			
Diversity	4.47	4.37	3.84	4.24
HBI	3.19	3.30	2.74	3.09
TIV (Sediment Region 2)	--	5.58	--	4.12

Table 4. Additional metrics and comparative values for macroinvertebrate samples collected from Northern Water sampling sites on the Colorado River on 19 September 2018. All additional metrics are based on full count Hess samples.

Metric	CR-WGU	CR-WGD	CR-HSU	CR-WFU
EPT	24	24	24	23
Evenness	0.797	0.739	0.709	0.788
DAT	32.4	34.9	31.4	27.9
Insect Taxa	37	42	37	37
Total Taxa	46	52	47	43
Percent Shredder+Scraper	27.05%	32.63%	38.85%	31.19%
Density of *Pteronarcys californica* (#/m^2)	0	0	0	225
Percent EPT excluding Baetidae	59.65%	51.72%	62.53%	57.55%
Density (mean #/m2)	5,802	6,213	6,155	3,853

Farther downstream at site CR-HSU, most of the analysis tools continued to demonstrate healthy macroinvertebrate community structure; however, some metrics detected a slight increase in stress compared to upstream study sites. Site CR-HSU was located approximately 13.0 km downstream from Windy Gap Reservoir, and while this location could be partially influenced by reservoir operations, there were also potential sources of stress associated with the adjacent highway and urban development near the Town of Hot Sulphur Springs. Components from both versions of the MMI responded to a slight decline in clinger taxa and predator/shredder taxa; however, both MMI scores continued to indicate 'attainment' for aquatic life use (Tables 2-3). The abundance of sensitive taxa (based on the EPT, Insect Taxa, and Percent EPT excluding Baetidae) and relatively high proportion of specialized feeding groups (Percent Shredder+Scraper) suggested that the aquatic community at site CR-HSU was healthy despite detectable changes in the fall of 2018 (Table 4). Although *Pteronarcys californica* had been previously observed at this site, this species was not collected during the fall of 2018. Most of the metric values from 2018 were similar to historical results; however, a slight decline in sensitive taxa (compared to previous years) may have been related to low flows that occurred during 2018 (Figures 2-6).

At the downstream boundary of the study area, site CR-WFU was positioned approximately 19.0 km from Windy Gap Reservoir and immediately upstream from the Williams Fork confluence. Results from the applied metrics suggested that the Colorado River continued to support healthy macroinvertebrate communities, and many of the MMI components detected slight improvements at site CR-WFU (Tables 2 and 3). Results from individual metrics that measure community balance (Diversity and Evenness) and metrics that measure the richness of sensitive taxa (EPT and Insect Taxa) showed relatively stable aquatic conditions compared to upstream study sites (Table 4). In general, spatial changes among macroinvertebrate communities have been relatively minor throughout the last three years (Figures 2-6). All study sites have supported healthy aquatic communities with little evidence of anthropogenic stressors.

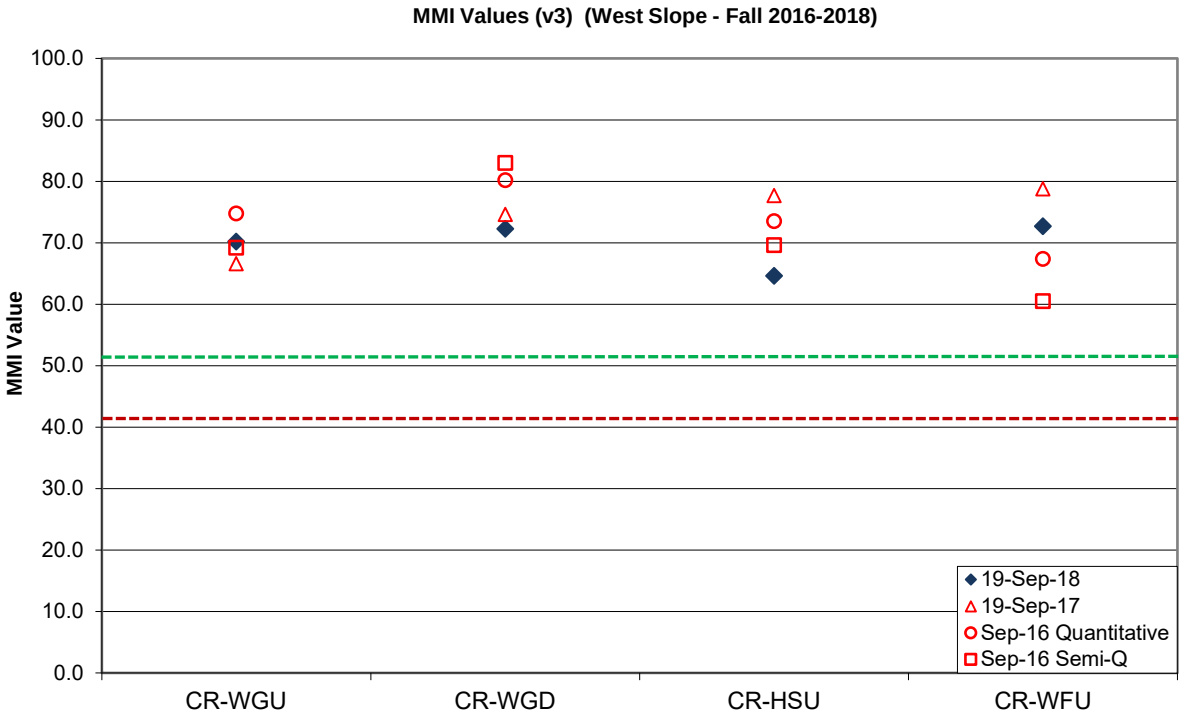

Figure 2. MMI (v3) scores for Colorado River study sites during the fall of 2016, 2017 and 2018. The green line indicates the attainment threshold and the red line indicates the impairment threshold for Biotype 1.

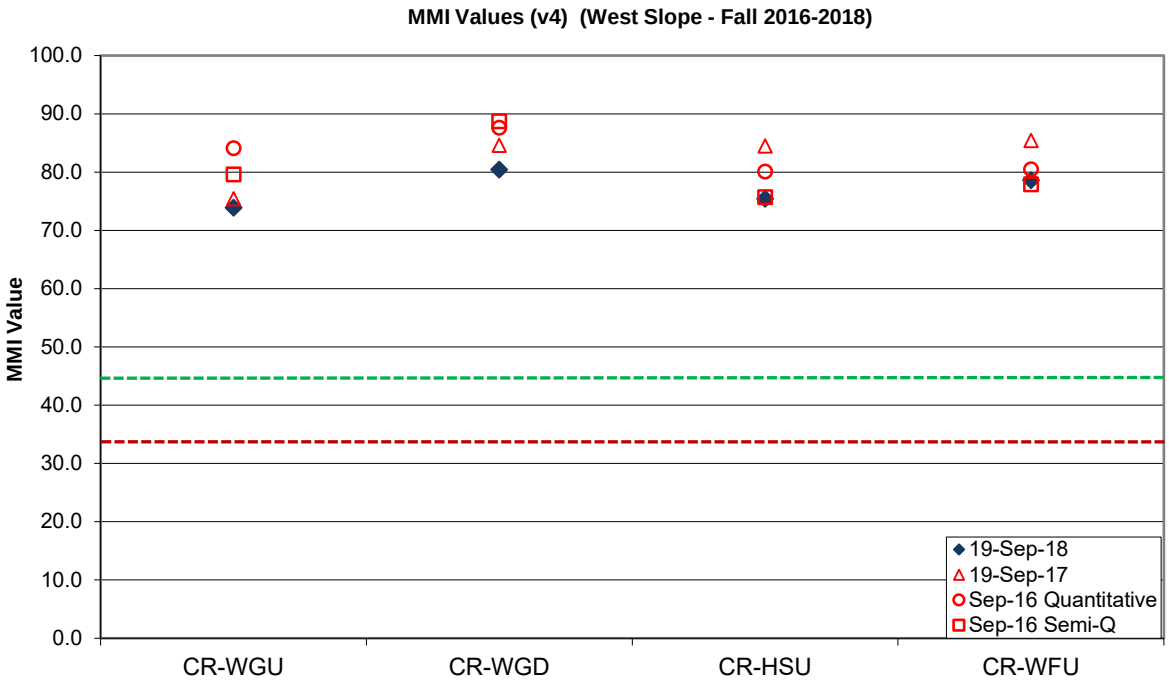

Figure 3. MMI (v4) scores for Colorado River study sites during the fall of 2016, 2017 and 2018. The green line indicates the attainment threshold and the red line indicates the impairment threshold for Biotype 1.

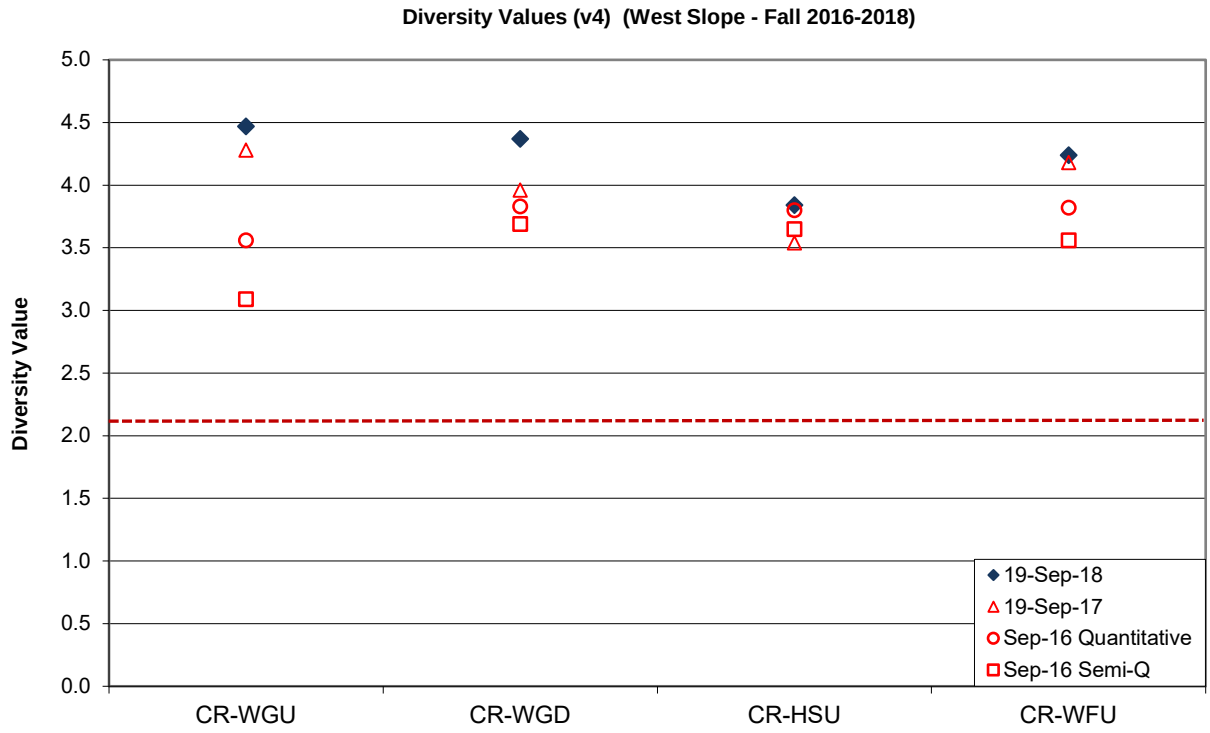

Figure 4. Diversity (v4) values for the Colorado River on the West Slope in fall 2016, 2017 and 2018. The red line indicates the impairment threshold for Biotype 1.

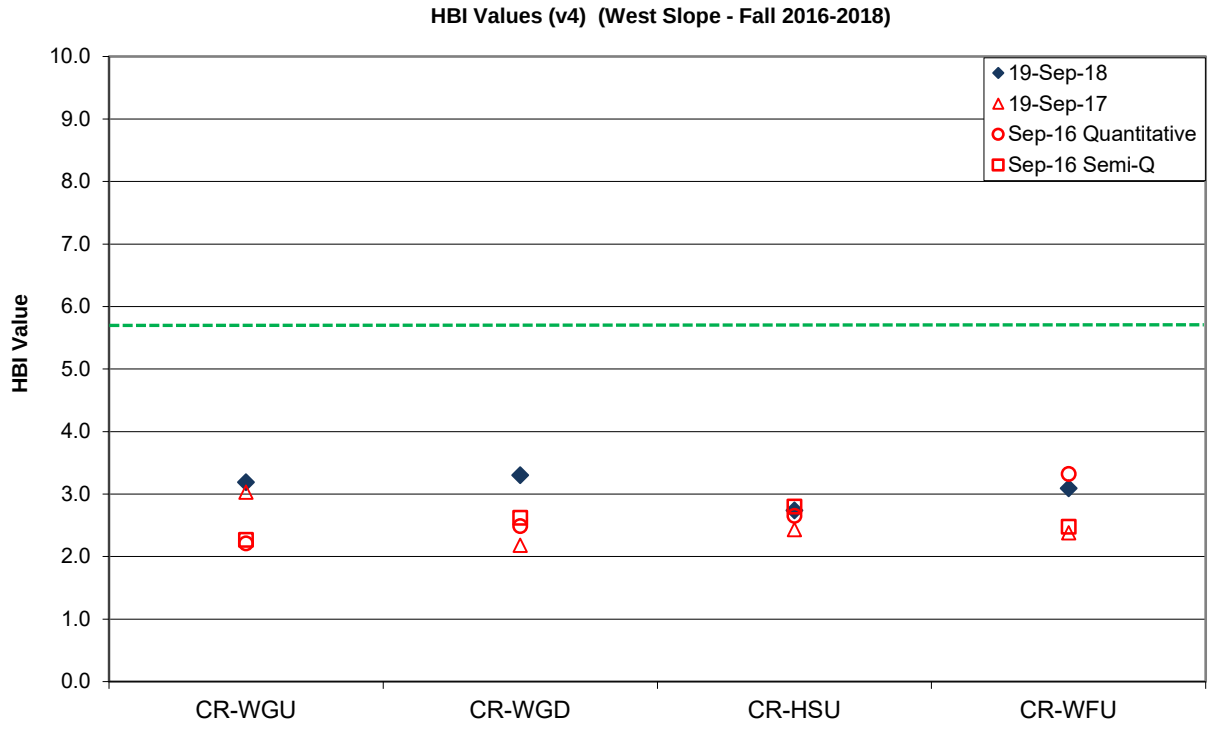

Figure 5. HBI (v4) values for the Colorado River on the West Slope in fall 2016, 2017 and 2018. Exceeding the green line indicates impairment for Biotype 1.

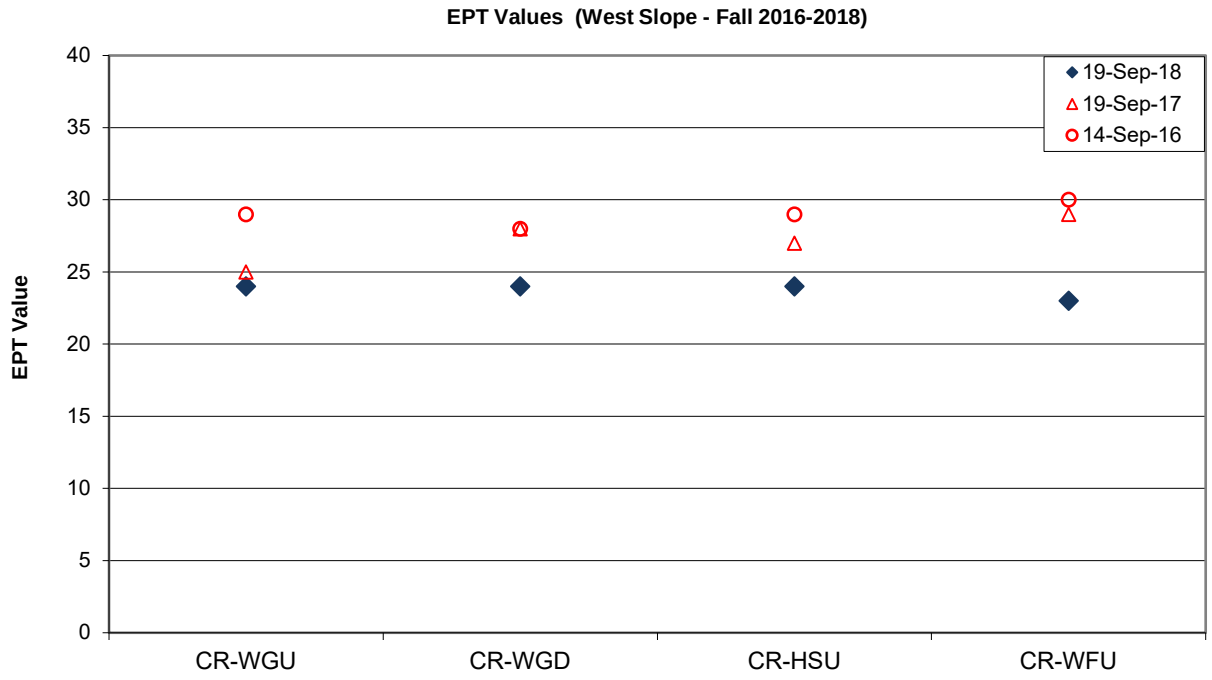

Figure 6. EPT values from quantitative sampling on the Colorado River during the fall of 2016, 2017 and 2018.

Benthic macroinvertebrates collected during the fall of 2018 were also organized into functional feeding groups in order to evaluate the ecological function of aquatic communities at each sampling location in the study area (Table 5, Figure 7). Healthy ecosystems typically support adequate representation from several feeding groups; however, it is common for certain groups (such as collector-gatherers) to be proportionally dominant. During the fall of 2018, all study sites supported a healthy balance among feeding groups. A slight decrease in collector-filterers and predators was observed in a downstream direction, while collector-gatherers and scrapers increased in the downstream portion of the study area (Table 5, Figure 7). Feeding groups that are considered specialized and sensitive to human impacts (shredders and scrapers) were found in relatively high proportions at all of the study sites. Minor shifts in the relative abundance of various feeding groups was likely influenced by gradual changes in the food resources that were occurring in a downstream direction.

The results from 2018 (and historical sampling events) have provided valuable baseline information that has consistently demonstrated healthy aquatic communities throughout this portion of the Colorado River. While most metrics agreed that aquatic communities were relatively healthy, each site exhibited minor variability in MMI scores and individual metric values. The spatial and temporal variability observed at each site can probably be attributed to annual fluctuations in aquatic conditions (flows, temperature, algal growth, etc.). Future sampling events will provide an assessment of any impacts from anthropogenic activities or habitat improvement projects that may occur in this study area.

Table 5. Relative abundance of functional feeding groups at study sites on the Colorado River during the fall of 2018.

Site	Functional Feeding Group					
	Collector-Gatherer	Collector-Filterer	Shredder	Scraper	Predator	Omnivore
CR-WGU	23.51%	31.80%	8.48%	18.57%	17.64%	0.00%
CR-WGD	34.06%	25.95%	12.23%	20.40%	7.30%	0.06%
CR-HSU	37.15%	19.33%	13.60%	25.25%	4.41%	0.25%
CR-WFU	39.54%	21.73%	8.75%	22.43%	3.62%	3.92%

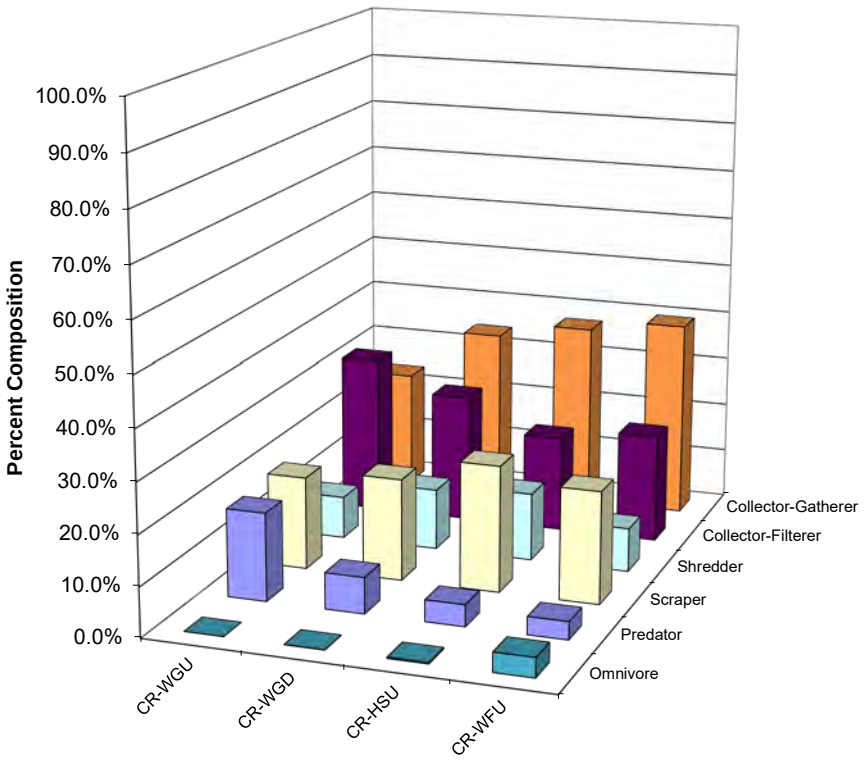

Figure 7: Percent composition of functional feeding groups collected on the Colorado River during the fall of 2018.

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Appendix A

Replicative Quantitative Samples – Fall 2018

Table A1: Macroinvertebrate data collected from West Slope at site CR-WGU on 19 Sept 2018.

Colorado River								
CR-WGU		Sample						
19 Sept. 2018	1	2	3		Mean	Count		HBI
Ephemeroptera								
Acentrella sp.	1		5		2.00	1		0.0160
Baetis flavistriga		1			0.33	1		0.0033
Baetis (*tricaudatus*)	16	9	17		14.00	1		0.1403
Diphetor hageni								
Attenella margarita								
Drunella grandis	9	3	1		4.33	1		0.0000
Ephemerella dorothea infrequens	44	42	27		37.67	1		0.0755
Epeorus sp.								
Rhithrogena sp.								
Tricorythodes explicatus			2		0.67	1		0.0053
Paraleptophlebia sp.	10	3	11		8.00	1		0.0321
Plecoptera								
Paracapnia angulata		9	9		6.00	1		0.0120
Chloroperlidae	54	27	77		52.67	1		0.1055
Sweltsa sp.			1		0.33	1		0.0007
Claassenia sabulosa	5	4	6		5.00	1		0.0301
Perlodidae (*Cultus* sp.)	16	8	11		11.67	1		0.0468
Isoperla sp.		3	1		1.33	1		0.0053
Isoperla fulva	2				0.67	1		0.0027
Skwala americana	1	1	1		1.00	1		0.0040
Pteronarcys californica								
Trichoptera								
Brachycentrus americanus	5	5	1		3.67	1		0.0073
Brachycentrus occidentalis	45	28	14		29.00	1		0.0581
Culoptila sp.								
Glossosoma sp.	38	20	31		29.67	1		0.0000
Protoptila sp.								
Helicopsyche borealis								
Arctopsyche grandis	41	22	9		24.00	1		0.0962
Cheumatopsyche sp.								
Hydropsyche cockerelli	89	25	46		53.33	1		0.4275
Hydropsyche oslari		2			0.67	1		0.0053
Lepidostoma sp.	54	19	8		27.00	1		0.2164
Ceraclea sp.		2			0.67	1		0.0067
Oecetis sp.								
Psychomyia flavida								
Rhyacophila coloradensis	1				0.33	1		0.0000

Table A1 cont.: Macroinvertebrate data collected from West Slope at site CR-WGU on 19 Sept 2018.

Diptera								
Chironomidae								
Cardiocladius sp.								
Cricotopus nostocicola	13	4	11		9.33	1		0.1309
Cricotopus/Orthocladius sp.	9	11	10		10.00	1		0.1202
Eukiefferiella sp.	15	12	19		15.33	1		0.2458
Micropsectra/Tanytarsus sp.								
Microtendipes sp.	21	25	1		15.67	1		0.1884
Pagastia sp.								
Parametriocnemus sp.	4		1		1.67	1		0.0167
Potthastia sp.	1				0.33	1		0.0027
Synorthocladius sp.								
Thienemannimyia group	5	2	1		2.67	1		0.0321
Tvetenia sp.	19	17	10		15.33	1		0.1536
Other Diptera								
Atherix pachypus								
Chelifera/Neoplasta sp.	6	4	4		4.67	1		0.0561
Hemerodromia sp.								
Wiedemannia sp.		1	1		0.67	1		0.0080
Maruina sp.								
Simulium sp.	6	9	82		32.33	1		0.3888
Antocha sp.	10	6	2		6.00	1		0.0361
Coleoptera								
Optioservus sp.	81	63	26		56.67	1		0.4542
Zaitzevia parvula								
Miscellaneous								
Atractides sp.			1		0.33	1		0.0053
Lebertia sp.	4	2			2.00	1		0.0321
Protzia sp.								
Sperchon sp.	8	1	3		4.00	1		0.0641
Caecidotea sp.	9		2		3.67	1		0.0588
Polycelis coronata								
Lymnaeidae								
Physa sp.	1	1	3		1.67	1		0.0267
Gyraulus sp.	1				0.33	1		0.0053
Pisidium sp.								
Crangonyx sp.	1				0.33	1		0.0027
Placobdella sp.								
Enchytraeidae								
Lumbricidae	1	2	1		1.33	1		0.0267
Tubificidae w/o hair chaetae								
Nematoda		2			0.67	1		0.0067
Totals	**646**	**395**	**456**		**499.00**	**46**		**3.36**

Table A2: Macroinvertebrate data collected from West Slope at site CR-WGD on 19 Sept 2018.

Colorado River								
CR-WGD		Sample						
19 Sept. 2018	1	2	3		Mean	Count		HBI
Ephemeroptera								
Acentrella sp.	3	2			1.67	1		0.0125
Baetis flavistriga								
Baetis (*tricaudatus*)	63	36	87		62.00	1		0.5802
Diphetor hageni			1		0.33	1		0.0031
Attenella margarita	1				0.33	1		0.0019
Drunella grandis	2		1		1.00	1		0.0000
Ephemerella dorothea infrequens	24	23	24		23.67	1		0.0443
Epeorus sp.	1	3	10		4.67	1		0.0000
Rhithrogena sp.								
Tricorythodes explicatus								
Paraleptophlebia sp.	8	8	4		6.67	1		0.0250
Plecoptera								
Paracapnia angulata								
Chloroperlidae	4	1			1.67	1		0.0031
Sweltsa sp.								
Claassenia sabulosa	3	5	8		5.33	1		0.0299
Perlodidae (*Cultus* sp.)	4	1	6		3.67	1		0.0137
Isoperla sp.	5	1	4		3.33	1		0.0125
Isoperla fulva								
Skwala americana								
Pteronarcys californica								
Trichoptera								
Brachycentrus americanus	53	32	40		41.67	1		0.0780
Brachycentrus occidentalis								
Culoptila sp.	6	21	23		16.67	1		0.0000
Glossosoma sp.	2				0.67	1		0.0000
Protoptila sp.	16	2	2		6.67	1		0.0125
Helicopsyche borealis			1		0.33	1		0.0019
Arctopsyche grandis	2	7	9		6.00	1		0.0225
Cheumatopsyche sp.								
Hydropsyche cockerelli	26	14	35		25.00	1		0.1871
Hydropsyche oslari	74	54	60		62.67	1		0.4691
Lepidostoma sp.	106	47	32		61.67	1		0.4616
Ceraclea sp.								
Oecetis sp.	1				0.33	1		0.0050
Psychomyia flavida		5	7		4.00	1		0.0150
Rhyacophila coloradensis	1				0.33	1		0.0000

Table A2 cont.: Macroinvertebrate data collected from West Slope at site CR-WGD on 19 Sept 2018.

Diptera								
Chironomidae								
Cardiocladius sp.								
Cricotopus nostocicola	8	1	2		3.67	1		0.0480
Cricotopus/Orthocladius sp.	39	15	28		27.33	1		0.3069
Eukiefferiella sp.	18	10	10		12.67	1		0.1896
Micropsectra/Tanytarsus sp.			3		1.00	1		0.0131
Microtendipes sp.		1			0.33	1		0.0037
Pagastia sp.	3		3		2.00	1		0.0037
Parametriocnemus sp.	3	1			1.33	1		0.0125
Potthastia sp.	1		1		0.67	1		0.0050
Synorthocladius sp.								
Thienemannimyia group	4	2	2		2.67	1		0.0299
Tvetenia sp.	45	17	24		28.67	1		0.2682
Other Diptera								
Atherix pachypus	3	1	1		1.67	1		0.0062
Chelifera/Neoplasta sp.	18	1	9		9.33	1		0.1048
Hemerodromia sp.	2				0.67	1		0.0075
Wiedemannia sp.	3				1.00	1		0.0112
Maruina sp.								
Simulium sp.	2		7		3.00	1		0.0337
Antocha sp.	4	3			2.33	1		0.0131
Coleoptera								
Optioservus sp.	112	57	58		75.67	1		0.5664
Zaitzevia parvula	9	2	1		4.00	1		0.0299
Miscellaneous								
Atractides sp.			1		0.33	1		0.0050
Lebertia sp.			1		0.33	1		0.0050
Protzia sp.	6	1	2		3.00	1		0.0449
Sperchon sp.	4	4	8		5.33	1		0.0799
Caecidotea sp.	2	2	4		2.67	1		0.0399
Polycelis coronata	1				0.33	1		0.0006
Lymnaeidae								
Physa sp.	3				1.00	1		0.0150
Gyraulus sp.	2	1	4		2.33	1		0.0349
Pisidium sp.								
Crangonyx sp.								
Placobdella sp.								
Enchytraeidae								
Lumbricidae		1			0.33	1		0.0062
Tubificidae w/o hair chaetae	1				0.33	1		0.0062
Nematoda								
Totals	**698**	**382**	**523**		**534.33**	**52**		**3.87**

Table A3: Macroinvertebrate data collected from West Slope at site CR-HSU on 19 Sept 2018.

Colorado River								
CR-HSU		Sample						
19 Sept. 2018	1	2	3		Mean	Count		HBI
Ephemeroptera								
Acentrella sp.	6	3	2		3.67	1		0.0277
Baetis flavistriga								
Baetis (*tricaudatus*)	47	41	42		43.33	1		0.4093
Diphetor hageni								
Attenella margarita								
Drunella grandis		3	4		2.33	1		0.0000
Ephemerella dorothea infrequens	95	124	39		86.00	1		0.1625
Epeorus sp.	7	12	4		7.67	1		0.0000
Rhithrogena sp.	1		1		0.67	1		0.0000
Tricorythodes explicatus								
Paraleptophlebia sp.	4	4	9		5.67	1		0.0214
Plecoptera								
Paracapnia angulata	1				0.33	1		0.0006
Chloroperlidae	1	1	6		2.67	1		0.0050
Sweltsa sp.								
Claassenia sabulosa	4	2			2.00	1		0.0113
Perlodidae (*Cultus* sp.)	1	1			0.67	1		0.0025
Isoperla sp.	1				0.33	1		0.0013
Isoperla fulva								
Skwala americana								
Pteronarcys californica								
Trichoptera								
Brachycentrus americanus	2	7	5		4.67	1		0.0088
Brachycentrus occidentalis								
Culoptila sp.	54	47	31		44.00	1		0.0000
Glossosoma sp.	2				0.67	1		0.0000
Protoptila sp.	8	1	6		5.00	1		0.0094
Helicopsyche borealis			1		0.33	1		0.0019
Arctopsyche grandis	3	1	1		1.67	1		0.0063
Cheumatopsyche sp.	4	4	8		5.33	1		0.0504
Hydropsyche cockerelli	11	29	21		20.33	1		0.1537
Hydropsyche oslari	53	81	64		66.00	1		0.4987
Lepidostoma sp.	68	74	72		71.33	1		0.5390
Ceraclea sp.								
Oecetis sp.		1	7		2.67	1		0.0403
Psychomyia flavida	1		1		0.67	1		0.0025
Rhyacophila coloradensis								

Table A3 cont.: Macroinvertebrate data collected from West Slope at site CR-HSU on 19 Sept 2018.

Diptera								
Chironomidae								
Cardiocladius sp.	3		1		1.33	1		0.0126
Cricotopus nostocicola			1		0.33	1		0.0044
Cricotopus/Orthocladius sp.	9	11	6		8.67	1		0.0982
Eukiefferiella sp.	18	20	16		18.00	1		0.2720
Micropsectra/Tanytarsus sp.	1		1		0.67	1		0.0088
Microtendipes sp.								
Pagastia sp.								
Parametriocnemus sp.	1	2	2		1.67	1		0.0157
Potthastia sp.								
Synorthocladius sp.	1				0.33	1		0.0013
Thienemannimyia group	1				0.33	1		0.0038
Tvetenia sp.	26	14	4		14.67	1		0.1385
Other Diptera								
Atherix pachypus								
Chelifera/Neoplasta sp.	1				0.33	1		0.0038
Hemerodromia sp.								
Wiedemannia sp.								
Maruina sp.								
Simulium sp.	8	3	2		4.33	1		0.0491
Antocha sp.								
Coleoptera								
Optioservus sp.	41	80	86		69.00	1		0.5214
Zaitzevia parvula	3	3	25		10.33	1		0.0781
Miscellaneous								
Atractides sp.								
Lebertia sp.			1		0.33	1		0.0050
Protzia sp.	2	3	8		4.33	1		0.0655
Sperchon sp.	6	6	13		8.33	1		0.1259
Caecidotea sp.								
Polycelis coronata	2		2		1.33	1		0.0025
Lymnaeidae	1				0.33	1		0.0050
Physa sp.	1	2	5		2.67	1		0.0403
Gyraulus sp.		1	2		1.00	1		0.0151
Pisidium sp.								
Crangonyx sp.								
Placobdella sp.								
Enchytraeidae	4	1			1.67	1		0.0315
Lumbricidae	1		1		0.67	1		0.0126
Tubificidae w/o hair chaetae			2		0.67	1		0.0126
Nematoda								
Totals	**504**	**582**	**502**		**529.33**	**47**		**3.48**

Table A4: Macroinvertebrate data collected from West Slope at site CR-WFU on 19 Sept 2018.

Colorado River								
CR-WFU		Sample						
19 Sept. 2018	1	2	3		Mean	Count		HBI
Ephemeroptera								
Acentrella sp.	1	4			1.67	1		0.0201
Baetis flavistriga								
Baetis (*tricaudatus*)	32	79	27		46.00	1		0.6942
Diphetor hageni								
Attenella margarita								
Drunella grandis		5	2		2.33	1		0.0000
Ephemerella dorothea infrequens	49	48	19		38.67	1		0.1167
Epeorus sp.	28	24			17.33	1		0.0000
Rhithrogena sp.	5	3	2		3.33	1		0.0000
Tricorythodes explicatus								
Paraleptophlebia sp.	19	16	5		13.33	1		0.0805
Plecoptera								
Paracapnia angulata		1			0.33	1		0.0010
Chloroperlidae		1	1		0.67	1		0.0020
Sweltsa sp.								
Claassenia sabulosa	3		10		4.33	1		0.0392
Perlodidae (*Cultus* sp.)		1	1		0.67	1		0.0040
Isoperla sp.								
Isoperla fulva								
Skwala americana								
Pteronarcys californica	12	24	22		19.33	1		0.0000
Trichoptera								
Brachycentrus americanus	1	4	1		2.00	1		0.0060
Brachycentrus occidentalis								
Culoptila sp.	8	4	12		8.00	1		0.0000
Glossosoma sp.	21	19	10		16.67	1		0.0000
Protoptila sp.	1	9	1		3.67	1		0.0111
Helicopsyche borealis								
Arctopsyche grandis		1			0.33	1		0.0020
Cheumatopsyche sp.	18	13	47		26.00	1		0.3924
Hydropsyche cockerelli	10	29	26		21.67	1		0.2616
Hydropsyche oslari	1	3	1		1.67	1		0.0201
Lepidostoma sp.	14	3	10		9.00	1		0.1087
Ceraclea sp.								
Oecetis sp.								
Psychomyia flavida		1			0.33	1		0.0020
Rhyacophila coloradensis		2	1		1.00	1		0.0000

Table A4 cont.: Macroinvertebrate data collected from West Slope at site CR-WFU on 19 Sept 2018.

Diptera								
Chironomidae								
Cardiocladius sp.	1	2			1.00	1		0.0151
Cricotopus nostocicola			1		0.33	1		0.0070
Cricotopus/Orthocladius sp.		2			0.67	1		0.0121
Eukiefferiella sp.	6	15	4		8.33	1		0.2012
Micropsectra/Tanytarsus sp.								
Microtendipes sp.								
Pagastia sp.		1			0.33	1		0.0010
Parametriocnemus sp.								
Potthastia sp.								
Synorthocladius sp.								
Thienemannimyia group	1	1	2		1.33	1		0.0241
Tvetenia sp.		1			0.33	1		0.0050
Other Diptera								
Atherix pachypus								
Chelifera/Neoplasta sp.		1			0.33	1		0.0060
Hemerodromia sp.		1	2		1.00	1		0.0181
Wiedemannia sp.								
Maruina sp.	2				0.67	1		0.0020
Simulium sp.	7	50	3		20.00	1		0.3622
Antocha sp.			1		0.33	1		0.0030
Coleoptera								
Optioservus sp.	8	20	39		22.33	1		0.2696
Zaitzevia parvula	10	14	26		16.67	1		0.2012
Miscellaneous								
Atractides sp.								
Lebertia sp.								
Protzia sp.								
Sperchon sp.		3	1		1.33	1		0.0322
Caecidotea sp.								
Polycelis coronata	6	27	6		13.00	1		0.0392
Lymnaeidae								
Physa sp.								
Gyraulus sp.								
Pisidium sp.			1		0.33	1		0.0080
Crangonyx sp.								
Placobdella sp.			1		0.33	1		0.0060
Enchytraeidae								
Lumbricidae		5	3		2.67	1		0.0805
Tubificidae w/o hair chaetae	2	3			1.67	1		0.0503
Nematoda								
Totals	**266**	**440**	**288**		**331.33**	**43**		**3.11**

4219 Table Mountain Place, Suite A ◈ Fort Collins, CO 80526
Web: http://www.timberlineaquatics.com ◈ E-mail: drees@timberlineaquatics.com

Denver Water

Macroinvertebrates

Table 1. Study sites in the Denver Water study area sampled during September 2018.

Station ID	Location	Latitude	Longitude	Elevation (m)
FR-abvWPSD	**Fraser River abv Winter Park Sanitation District**	**39.89445**	**-105.76821**	**2878**
VC-WP	**Vasquez Creek at Winter Park**	**39.9203**	**-105.78498**	**2706**
FR-Rendezvous	**Fraser River at Rendezvous Bridge**	**39.93412**	**-105.7896**	**2678**
FR-CR83	**Fraser River at Tabernash below bridge on CR83**	**39.99053**	**-105.8299**	**2558**

Table 2. Individual metrics and MMI (v3) scores from benthic macroinvertebrate samples collected in the Denver Water study area (Fraser River and Vasquez Creek) in September 2018. MMI (v3) scores indicating 'impairment' are provided in red.

Metric	Station ID			
	FR-abvWPSD	**VC-WP**	**FR-Rendezvous**	**FR-CR83**
EP Taxa	37.3	80.2	17.7	68.0
Percent Chironomidae	69.6	80.8	63.5	86.2
Sens. Plains Families	28.6	34.7	18.5	65.1
Predator-Shredder Taxa	64.3	71.4	85.7	64.3
Clinger Taxa	0.0	34.9	19.6	77.7
Non-Insect Percent	43.0	55.5	26.4	47.3
MMI	**40.5**	**59.6**	**38.6**	**68.1**
	Auxiliary Metrics			
Diversity	3.53	3.78	3.43	3.26
HBI	4.33	4.82	4.87	3.10

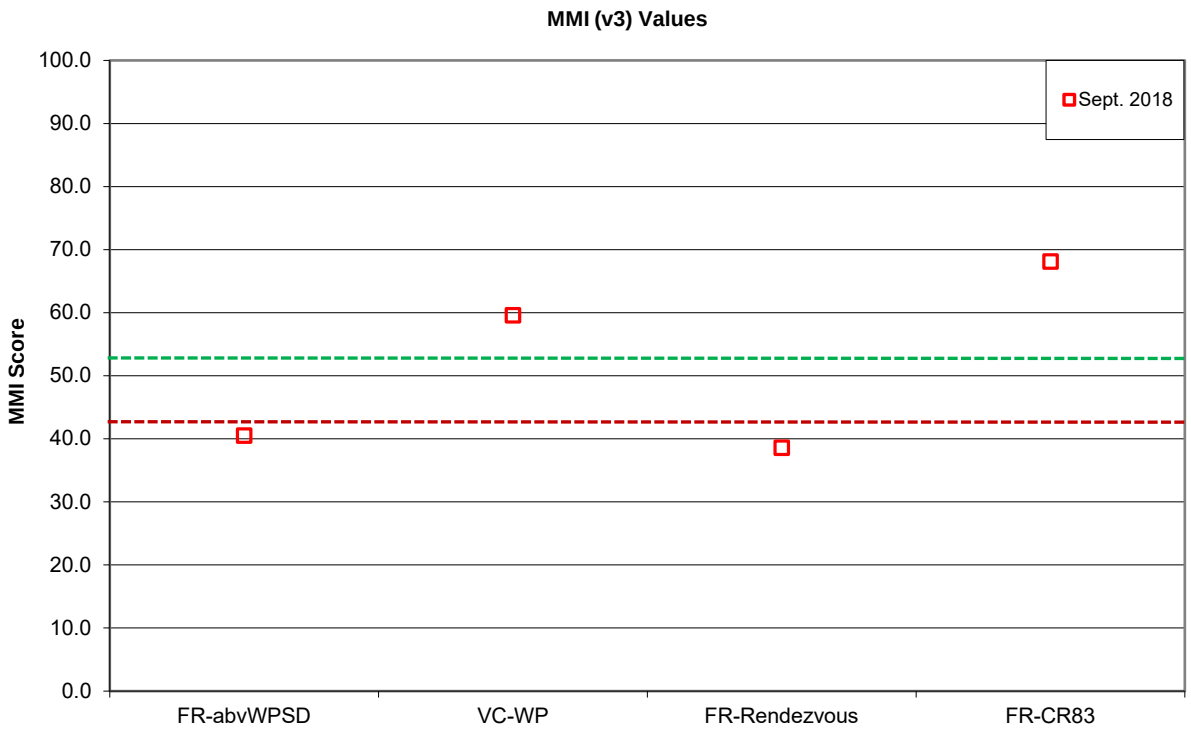

Figure 1. MMI (v3) scores from study sites in the Denver Water study area (Fraser River and Vasquez Creek) during September 2018.

Table 3. Aquatic life use designations based on MMI (v3) scores from samples at sites in the Denver Water study area during September 2018.

Aquatic Life Use Designations in 2018	
Site	
FR-abvWPSD	**Impairment**
VC-WP	**Attainment**
FR-Rendezvous	**Impairment**
FR-CR83	**Attainment**

Table 4. Individual metrics and MMI (v4) scores from benthic macroinvertebrate samples collected in the Denver Water study area (Fraser River and Vasquez Creek) during September 2018. MMI (v4) scores indicating 'impairment' are provided in red.

Metric	Station ID			
	FR-abvWPSD	**VC-WP**	**FR-Rendezvous**	**FR-CR83**
EPT Taxa	54.2	78.3	37.5	79.2
% Non-Insect Individuals	49.8	22.9	28.5	95.9
% EPT Individuals, no Baetidae	19.3	19.6	22.7	85.3
% Coleoptera Individuals	38.2	49.9	21.9	42.5
% Intolerant Taxa	75.7	97.0	56.5	90.4
% Increasers Mid-Elevation	58.7	32.4	42.2	98.3
Clinger Taxa	38.5	69.4	48.1	81.7
Predator/Shredder Taxa	64.3	71.4	78.6	64.3
MMI	**49.8**	**55.1**	**42.0**	**79.7**
	Auxiliary Metrics			
Diversity	3.57	3.80	3.43	3.42
HBI	4.19	4.05	3.62	2.90
TIV (Sediment Region 2)	5.76	5.51	5.47	4.96

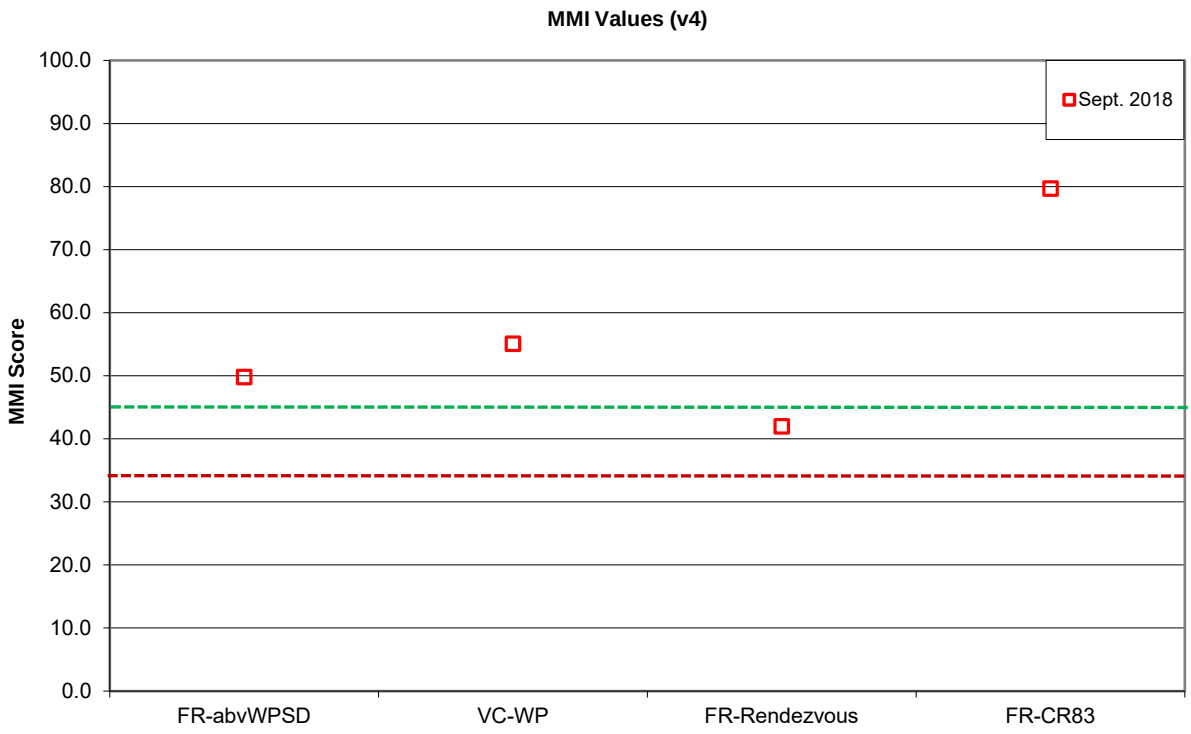

Figure 2. MMI (v4) scores from study sites in the Denver Water study area during September 2018.

Table 5. Aquatic life use designations based on MMI (v4) scores from samples collected in the Denver Water study area (Fraser River and Vasquez Creek) during September 2018.

Aquatic Life Use Designations in 2018	
Site	
FR-abvWPSD	**Attainment**
VC-WP	**Attainment**
FR-Rendezvous	**Attainment**
FR-CR83	**Attainment**

Table 6. Additional metrics and comparative values for macroinvertebrate samples collected from the Denver Water study area (Fraser River and Vasquez Creek) in September 2018. All additional metrics based on full count Hess samples.

Metric	FR-abvWPSD	VC-WP	FR-Rendezvous	FR-CR83
Density (#/m^2)	5,236	3,228	8,449	8,672
Taxa Richness	35	43	39	44
EPT	19	26	14	23
Density of *Pteronarcys californica* (#/m^2)	0	0	0	0
Percent EPT excluding Baetidae	11.72%	13.51%	16.27%	62.38%
Percent Chironomidae	20.25%	12.42%	24.59%	10.79%

Colorado Department of Public Health and Environment

Water Quality Control Division

Benthic Macroinvertebrate Bioassessment Report

StationID:	FR-abvWPSD			Sample Date:	9/21/2018
Waterbody Name:	Fraser River				
Location:	abv Winter Park Sanitation District				
Latitude:	39.89445	Reference Status:	Not Reference or Degraded		
Longitude:	-105.76821	BenSampID:	1	RepNum:	1
Site Classification:	1	Summer Temp:	10.99	JulianDay:	263

Predictive Model Results

O/E (p>half):	

Model Test:

Multimetric Index Model Results

MMI:	49.8

Metric Name	Metric Value	Metric Score
Ephemeroptera + Plecoptera + Trichoptera taxa *:	13	54.2
Non-Insect, percent individuals:	24.3	49.8
Ephemeroptera + Plecoptera + Trichoptera, no Baetidae, percent individuals:	14.1	19.3
Coleoptera, percent individuals:	14.7	38.2
Intolerant, percent taxa *:	46.2	75.7
Increasers, Mid-Elevation, percent individuals:	9.9	58.7
Clinger taxa *:	8	38.5
Predator + Shredder taxa:	9	64.3
Total taxa:	26	0
Intolerant taxa:	12	0
Increasers, Mountain Trn, percent individuals:	23.1	0
Predator taxa:	7	0
Scraper, percent indivduals:	2.4	0
Non-Insect, percent taxa:	15.4	0
Sprawler taxa *:	6	0
Increasers, plains, percent individuals:	0	0
Total individuals:	334	LARGE

* = score (not value) adjusted by Summer temperature or Julian day

Colorado Department of Public Health and Environment

Water Quality Control Division

Benthic Macroinvertebrate Bioassessment Report

StationID:	FR-CR83			Sample Date:	9/20/2018
Waterbody Name:	Fraser River				
Location:	at Tabernash below bridge on CR83				
Latitude:	39.99053	Reference Status:	Not Reference or Degraded		
Longitude:	-105.8299	BenSampID:	2	RepNum:	1
Site Classification:	1	Summer Temp:	12.21	JulianDay:	262

Predictive Model Results

O/E (p>half):	

Model Test:

Multimetric Index Model Results

MMI:	79.7

Metric Name	Metric Value	Metric Score
Ephemeroptera + Plecoptera + Trichoptera taxa *:	19	79.2
Non-Insect, percent individuals:	2	95.9
Ephemeroptera + Plecoptera + Trichoptera, no Baetidae, percent individuals:	62.2	85.3
Coleoptera, percent individuals:	16.3	42.5
Intolerant, percent taxa *:	55.2	90.4
Increasers, Mid-Elevation, percent individuals:	0.4	98.3
Clinger taxa *:	17	81.7
Predator + Shredder taxa:	9	64.3
Total taxa:	29	0
Intolerant taxa:	16	0
Increasers, Mountain Trn, percent individuals:	49.4	0
Predator taxa:	9	0
Scraper, percent indivduals:	19.1	0
Non-Insect, percent taxa:	13.8	0
Sprawler taxa *:	2	0
Increasers, plains, percent individuals:	0	0
Total individuals:	251	ok

* = score (not value) adjusted by Summer temperature or Julian day

Colorado Department of Public Health and Environment

Water Quality Control Division

Benthic Macroinvertebrate Bioassessment Report

StationID:	FR-Rendezvous			Sample Date:	9/21/2018
Waterbody Name:	Fraser River				
Location:	at Rendezvous Bridge				
Latitude:	39.93412	Reference Status:	Not Reference or Degraded		
Longitude:	-105.7896	BenSampID:	3	RepNum:	1
Site Classification:	1	Summer Temp:	11.48	JulianDay:	263

Predictive Model Results

O/E (p>half):	

Model Test:

Multimetric Index Model Results

MMI:	42.0

Metric Name	Metric Value	Metric Score
Ephemeroptera + Plecoptera + Trichoptera taxa *:	9	37.5
Non-Insect, percent individuals:	34.5	28.5
Ephemeroptera + Plecoptera + Trichoptera, no Baetidae, percent individuals:	16.5	22.7
Coleoptera, percent individuals:	8.4	21.9
Intolerant, percent taxa *:	34.5	56.5
Increasers, Mid-Elevation, percent individuals:	13.8	42.2
Clinger taxa *:	10	48.1
Predator + Shredder taxa:	11	78.6
Total taxa:	29	0
Intolerant taxa:	10	0
Increasers, Mountain Trn, percent individuals:	11.1	0
Predator taxa:	9	0
Scraper, percent indivduals:	1.2	0
Non-Insect, percent taxa:	20.7	0
Sprawler taxa *:	5	0
Increasers, plains, percent individuals:	0	0
Total individuals:	333	LARGE

* = score (not value) adjusted by Summer temperature or Julian day

Colorado Department of Public Health and Environment

Water Quality Control Division

Benthic Macroinvertebrate Bioassessment Report

StationID:	VC-WP			Sample Date:	9/21/2018
Waterbody Name:	Vasquez River				
Location:	at Winter Park				
Latitude:	39.9203	Reference Status:	Not Reference or Degraded		
Longitude:	-105.78498	BenSampID:	4	RepNum:	1
Site Classification:	1	Summer Temp:	13.78	JulianDay:	263

Predictive Model Results

O/E (p>half):	

Model Test:

Multimetric Index Model Results

MMI:	55.1

Metric Name	Metric Value	Metric Score
Ephemeroptera + Plecoptera + Trichoptera taxa *:	18	78.3
Non-Insect, percent individuals:	37.2	22.9
Ephemeroptera + Plecoptera + Trichoptera, no Baetidae, percent individuals:	14.3	19.6
Coleoptera, percent individuals:	19.2	49.9
Intolerant, percent taxa *:	57.6	97
Increasers, Mid-Elevation, percent individuals:	16.2	32.4
Clinger taxa *:	14	69.4
Predator + Shredder taxa:	10	71.4
Total taxa:	33	0
Intolerant taxa:	19	0
Increasers, Mountain Trn, percent individuals:	28.6	0
Predator taxa:	9	0
Scraper, percent indivduals:	4.5	0
Non-Insect, percent taxa:	12.1	0
Sprawler taxa *:	5	0
Increasers, plains, percent individuals:	0	0
Total individuals:	266	ok

* = score (not value) adjusted by Summer temperature or Julian day

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To:	Grand County, Colorado Northern Colorado Water Conservancy District Denver Water Trout Unlimited Colorado River Water Conservation District
From:	Peggy Bailey, P.E. Tetra Tech Thomas A. Wesche, PhD. HabiTech, Inc. Lora B. Wesche, HabiTech Inc.
Date:	April 9, 2019
Subject:	2018 Substrate Monitoring, Grand County Colorado

INTRODUCTION/PURPOSE

The purpose of this technical memorandum is to report on the 2018 monitoring efforts which include tasks I through III, as described below. The field sampling, data collection and results are undertaken in support of the draft Grand County Stream Management Plan (SMP) (Tetra Tech et al. 2010) and the "Learning By Doing" (LBD) Cooperative Effort.

Task I

Monitor spawning habitats, particularly the content of finer sediments, at three sites located on the Colorado River. These sites are shown on **Figure 1** and listed in **Table 1**. Perform a pebble count (100 count) and substrate core sampling on the spawning bar and conduct a Riffle Stability Index (RSI) evaluation at each site during the sampling period if spring flows were sufficient to mobilize coarse bed particles and facilitate bar dynamics.

Previous years' spawning habitat monitoring included a site located on the Colorado River at Pump House (CR7 or RM-(9.7)), however, as the LBD cooperative effort area downstream terminus on the Colorado River is the confluence with the Blue River, at the direction of the LBD, this site was removed from the 2018 LBD monitoring effort. Spawning habitat and macroinvertebrate monitoring results for the White Water Feature at Pump House can be found in the annual monitoring report for the White Water Feature (Tetra Tech et al. 2019).

Spawning habitats on the Fraser River, Blue River and Muddy Creek were also not sampled this year. Results from these sites have been relatively consistent from year to year when flows have reached or exceeded recommended flushing flows. Thus, given the relatively high flows anticipated for spring of 2018, additional sampling at these sites was not included in this year's scope of work.

The surface substrate conditions and riffle stability results stemming from Task I can be used to evaluate the draft flushing flow recommendations; assess the condition of spawning gravel environments to promote survival–to-emergence (STE) of larval trout; investigate stream flows that may be needed periodically to maintain riffle habitat quality; and helps evaluate effects of LBD management actions.

Task II

Conduct a 100 count Pebble Count, including embeddedness, at riffles used by or in the vicinity of the LBD macroinvertebrate sample sites on the Fraser River, St. Louis Creek, Ranch Creek

and Colorado River. The macroinvertebrate sampling, listed in **Table 2**, was conducted and is reported by Timberline Aquatics under a separate contract with the LBD.

Task III

Convert the locations of the spawning bar monitoring locations and the SMP reach limits to river miles. This includes the assignment of river miles to the data files for all spawning bar monitoring sites sampled since monitoring began in 2010. The river miles for the spawning bar locations are presented in **Table 3**.

Task IV

Prepare this technical memorandum to describe the methods employed and transmit the results to the LBD Committee.

METHODS

Task I

Field sampling at the three Colorado River spawning bar sites (CR4_RM-22.3; CR5_RM-15.5; CR6_RM-9.6; Table 1 and Figure 1) was conducted on September 6 and 7, 2018 following the procedures described in previous monitoring reports (e.g. TetraTech and HabiTech, 2017). At each site, six bulk core substrate samples were taken to evaluate the composition of the inter-gravel environment using a 15-cm diameter McNeil-Ahnell sampler following procedures described by McNeil and Ahnell (1964) and Kondolph et al. (2008). Each sample was placed in a labeled plastic bucket, covered and transported to Kumar and Associates, Inc. Laboratory in Frisco, Colorado for dry sieve analysis. The sieve series ranged from 75 to 0.150 mm. Also, at each site a GPS location was recorded, photographs were taken, and a pebble count was conducted.

Pebble counts were made at each spawning bar site to describe the composition of the streambed surface and in particular to document the degree of embeddedness by finer sediments for each of the 100 measured particles. Pebble counts were made following the procedure described by Wolman (1954) and Kappesser (2002) with the investigator traversing the spawning bar in an upstream Z-pattern and measuring the intermediate diameter (mm) of 100 equally-spaced particles. This procedure assured spatial coverage of the entire bar and was in accordance with the guidance provided by the Colorado Water Quality Control Commission (CWQCC) in Policy 98-1 (CWQCC 2014) for the sampling of small, targeted stream habitat types such as trout spawning bars specifically identified for this study. A surface particle was recorded as embedded if the particle diameter was more than 50% covered by finer sediments. The 50% criterion was based on the relationship between density of juvenile salmonids and the percent embeddedness of the substrate as reported in Bjornn and Reiser (1991), as well as the embeddedness rating system presented in Bain and Stevenson (1999). In this system, 50% is the lower threshold for the “high” embeddedness classification. The presence of aquatic vegetation at each particle measured was also noted.

The Riffle Stability Index (RSI) (Kappesser 2002) protocol is intended for use only following runoff events of sufficient magnitude and duration to cause scour and deposition of coarse bed material. RSI analyses were not performed in 2018 at the three Colorado River sites because the magnitude and duration of spring runoff flows had not been sufficient to cause substantial bed-material mobilization and point bar deposition. Inspection of several point bars in the vicinity of each spawning bar revealed that no recently deposited coarse particles (e.g. gravel and cobble)

were present. Only fine sediment deposition with encroaching vegetation had occurred on the lower margins of the bars in 2018. These conditions were similar to those encountered in 2012 and 2013 when no RSI analyses could be performed.

Task II

Pebble counts were performed on September 5 and 6, 2018 at the fourteen riffle sites on the Colorado River, Fraser River, Ranch Creek, and St. Louis Creek at the macroinvertebrate sample sites. These sites are described on **Table 2** and their location is provided on Figure 1. Pebble count procedures were the same as those described above under Task 1.

Task III

Tetra Tech was provided with a shape file by LBD, showing the locations of the river miles (RM) previously used by LBD for labeling and identifying the macroinvertebrate sample sites. The shape file was created using Google Earth and drawing an elevation profile to map the distance, or for minor reaches the path function was used to map the river miles. Tetra Tech added the new river miles for the spawning bed habitat sites and reach limits by extending the Google Earth shape file or, where needed, by creating a new shape file using latitude and longitudinal locations and the line work from the SMP GIS data base. In some locations the river miles generated using the SMP data base did not match with the Google Earth river mile extraction. However, none of the deviations where significant and none of these changed the sequential order of the sites. Should additional sites be added in the future, a review of river miles should be undertaken to insure the new locations values provide sufficiently accurate locations and are sequential with the current locations.

A summary of the river miles is provided in **Table 3**. The SMP river reach naming protocol is also retained for use when a given reach is referenced as opposed to a specific location.

RESULTS

2018 streamflow hydrographs for the April through September period are presented in **Figures 2** and **3** for eight gage stations in the Fraser and Colorado River watersheds of Grand County. Comparisons of 2018 with previous monitoring years are included. Annual peak flows for the Fraser River, Ranch Creek and the Colorado River over the monitoring period are compared in **Table 4** with the flushing flow recommendations contained in the SMP (TetraTech et al. 2010). The durations that flows exceeded the flushing flow recommendations are also presented.

Particle size distributions for individual core samples collected at the three Colorado River spawning bar sites in 2018 are presented in **Figures 4, 5 and 6**, while temporal comparisons of these distributions with previous monitoring years are shown in **Figure 7**. 2018 composite median particle size and percent less than 2 mm for core samples is compared among sites in **Figure 8**, while temporal comparisons with previous monitoring years are presented in **Figure 9**. Results of the 2018 spawning bar pebble counts, including embeddedness, are presented in **Table 5**. Spatial and temporal comparisons of embeddedness for the three sites are made in **Table 6** and **Figure 10**.

Summaries of the 2018 pebble count results at the 14 macroinvertebrate sample sites are presented in **Table 7**. Temporal and spatial comparisons of pebble count results are provided for the Fraser River watershed sites in **Table 8** and for the Colorado River sites in **Table 9**.

Location maps and 2018 photographs of the three Colorado River spawning bar sites (Table 1) are presented in **Attachment 1**, while the 14 macroinvertebrate sample sites (Table 2) are presented in **Attachment 2**.

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Table 1. Locations for the three Colorado River spawning bar sites sampled in 2018

SMP Reach	RM	Site Name	Description	Latitude	Longitude	Years
CR4	CR-22.3	CR at Ppark	Colorado River at Pioneer Park	40.072185	-106.111498	2014-18
CR5	CR-15.5	CR Blw WF	Colorado River below Williams Fork	40.062829	-106.186273	2010-18
CR6	CR-9.6	CR Blw KB Ditch	Colorado River below KB Ditch	40.055494	-106.285214	2010-18

Table 2. Locations for the 2018 macroinvertebrate and pebble count sites in the Learning By Doing (LBD) study area sampled September 2018

SMP Reach	River Mile ID	Site Name	Description	Latitude	Longitude	Collected Sample
F2	FR-27.2	FR US JimCk	Fraser River upstream of Jim Creek and Mary Jane Entrance	39.8454	-105.7518	Timberline
F2	FR-23.2	FR abvWPSD	Fraser River upstream of Winter Park Sanitation District	39.8945	-105.7682	Timberline
F4	FR-20	FR Rendezvous	Fraser River at Rendezvous Bridge	39.9341	-105.7896	Timberline
F6	FR-15	FR FrSpProj	Fraser River upstream of Fraser Flats restoration	39.9813	-105.8249	Timberline
F6	FR-14	FR CR83	Fraser River upstream of Tabernash below bridge on CR83	39.9905	-105.8299	Timberline
F-RC2	RC-1.1	RC blwMC	Ranch Creek downstream of Meadow Creek	39.9991	-105.8275	Timberline
F-SLC	STC-0	STC FR	St Louis Creek at Fraser River	39.9518	-105.8147	Timberline
CR3	CR-31	CR WGU	Colorado River upstream of Fraser and Windy Gap	40.1005	- 105.9725	Timberline
CR4	CR-28.7	CR WGD	Colorado River downstream of Windy Gap	40.1083	-106.0036	Timberline
CR4	CR-22.9	CR HSU	Colorado River upstream of Hot Sulfur Springs	40.0803	-106.0986	Timberline
CR4	CR-16.7	CR WFU	Colorado River upstream of Williams Fork	40.0503	-106.1725	Timberline
CR6	CR-9.1	CR KBD	Colorado River at CR39 Bridge at KB Ditch	40.0538	-106.2895	Timberline
CR6	CR-7.4	CR BLW Troublesome	Colorado River downstream of Troublesome Creek	40.0509	-106.3112	Timberline
CR6	CR-1.7	CR US BR	Colorado River upstream of the Blue River	40.0436	-106.3751	Timberline

Table 3. River mile designations, SMP spawning bar locations and reach boundaries

SMP Reach	River Mile ID	Station ID	Description	Latitude	Longitude
FR1_US	FR-28.9		SMP reach boundary	39.82731	-105.76001
F1_DS F2_US	FR-26.3		SMP reach boundary	39.86171	-105.74970
F2	FR-26.2		Fraser River below Denver Water diversion dam	39.862833	-105.74931
F2B	FR-25.9		Downstream of F2, upstream of culvert	39.866972	-105.74958
F2_DS F3_US	FR-23.2		SMP reach boundary	39.89587	-105.769124
F3_DS F4_US	FR-21.2		SMP reach boundary	39.923275	-105.782688
F4-DS F5_US	FR-18.4		SMP reach boundary	39.946189	-105.812169
F5_DS F6_US	FR-17.1		SMP reach boundary	39.960661	-105.814594
F6_DS F7_US	FR-13.2		SMP reach boundary	39.998183	-105.841023
F-RC2_US	RC-10.2		SMP reach boundary	39.999175	-105.828374
F-RC2	RC-0.9	RC Miller	Ranch Creek below Meadow Creek (Miller Property)	39.999722	-105.82958
F-RC2_DS FR7_US	RC-0.0		SMP reach boundary	39.998183	-105.841023
F7_DS F8_US	FR-12.4		SMP reach boundary	40.00842	-105.847715
F8_DS F9_US	FR-7.3		SMP reach boundary	40.064752	-105.879471
F9	FR-5.5	FRGranbyRanch	Fraser River below Granby Ranch below golf course	40.079089	-105.904255
F9_DS F10_US	FR-3.5		SMP reach boundary	40.081472	-105.929433
CR_4 US	CR-31.4		SMP reach boundary	40.100082	-105.973895
CR4[1]	CR-27.7		At Chimney Rock Ranch	40.1006	-106.026767
CR4[3]	CR-22.3		Below Pioneer Park at Hot Sulphur Springs	40.072185	-106.111498
CR4[2]	CR-27.8		At Paul Gilbert Public Access Area	40.101056	-106.025861

Table 3. River mile designations, SMP spawning bar locations and reach boundaries

SMP Reach	River Mile ID	Station ID	Description	Latitude	Longitude
CR4_DS CR5_US	CR-16.3		SMP reach boundary	40.056245	-106.180566
CR5	CR-15.5	CRBlw WF	Colorado River below Williams Fk	40.062829	-106.186273
CR5_DS CR6_US	CR-9.7		SMP reach boundary	40.055591	-106.283928
CR6	CR-9.6	CRBlw KB Ditch	Colorado River below KB Ditch	40.055494	-106.285214
CR6_DS CR7_US	CR-0.20		SMP reach boundary	40.042608	-106.398225
CR7	CR-(9.6)	CR Pumphouse	Colorado River at Pumphouse below campground	39.978197	-106.515681
CR7_DS	CR -(16.0)		SMP reach boundary	39.925019	-106.578889
MC2_US	MC-13.8		SMP reach boundary	40.111025	-106.415562
MC2	MC-9.6		Muddy Creek	40.085233	-106.39885
MC2_DS CR7_US	BR-0/MC-0		SMP reach boundary	40.042608	-106.398225
BR-US	BR-15.3		SMP reach boundary	39.883492	-106.336169
BR-BVR-L	BR-3.3		Blue River, Blue Valley Ranch, lower	40.015837	-106.382918
BR-TR	BR-2.0		Blue River, Trough Road	40.031511	-106.38612
BR_DS CR7_US	BR-3.2		SMP reach boundary	40.042608	-106.398225

Table 4. Comparison of flushing flow recommendations (Q_{FF}) to stream flow records for Grand County monitoring sites, 2010-2018

SMP Reach	River Mile ID		Stream Gage	SMP Recommended Flushing FLow (CFS)	2010		2011		2012		2013		2014		2015		2016		2017		2018	
	From	To			Peak Flow (mean daily cfs)	#Days > Q_{FF}	Peak Flow (mean daily cfs)	#Days > Q_{FF}	Peak Flow (mean daily cfs)	#Days > Q_{FF}	Peak Flow (mean daily cfs)	#Days > Q_{FF}	Peak Flow (mean daily cfs)	#Days> Q_{FF} [1]	Peak Flow (mean daily cfs)	#Days> Q_{FF} [1]	Peak Flow (mean daily cfs)	#Days> Q_{FF} [1]	Peak Flow (mean daily cfs)	#Days> Q_{FF} [1]	Peak Flow (mean daily cfs)	#Days> Q_{FF} [1]
F9	FR-7.3	FR-3.5	FR at Granby	400	1767	41	1519	81	157	0	650	16	2256	76	1425	44	1351	54	1028	21	702	14, 7
CR4	CR-31.4	CR-16.3	CR at Windy Gap	600	2160	40	4930	134	245	0	693	3	3210	10,60,4,4	4140	81	2501	60	2238	8, 28	758	3
CR5	CR-16.3	CR-9.7	CR near Parshall	800	3512	40	5718	137	460	0	1088	3	4419	93,4	4539	80	3206	63	2739	10, 5, 30	986	2, 1, 1
CR6	CR-9.7	CR-0.0	CR at KB	850	3596	38	4993	141	573	0	1119	4	4348	80,4,4	4565	77	3080	61	2972	10, 3, 28	1056	3
CR7	CR-0.0	CR-(16.0)	CR at Kremmling	2500	5870	30	9480	96	1160	0	1680	0	7670	79,3	7820	8,54	4770	49	4280	21	1610	0
F-RC2	RC-10.2	RC-0.0	RC blw MC	150											417	30	404	6, 43	274	12,5	239	6

[1] Consecutive days recommended flushing flow occurred.

Table 5. Pebble count summary for the three Colorado River spawning bar study sites, September 2018

SMP Reach	**CR4**	**CR5**	**CR6**
RM	**CR-22.3**	**CR-15.5**	**CR-9.6**
Class Size (mm)	CR at Ppark	CR Blw WF	CR Blw KB Ditch
	Sept 2018	***Sept 2018***	***Sept 2018***
0-2	0	1	0
2-4	0	0	0
4-8	0	0	0
8-16	3	1	2
16-32	17	16	12
32-64	46	31	63
64-128	29	36	19
128-256	6	17	4
256-512			0
512-1024			
1024-2048			
2048-4096			
Sum	101	102	100
% Embedded	9	27	9
%Aquatic veg	40	20	69
Water Temp F	60	50	56
Time	1430	941	1150

Table 6. Percent of embedded pebble count particles at Colorado River spawning bar monitoring sites, 2010-2018

% Embedded													
SMP Reach	**RM**	**Site Name**	**July 2010**	**Aug & Sept 2011**	**June 2012**	**Oct 2012**	**July 2013**	**July & Aug 2014**	**Oct-14**	**Aug & Oct 2015**	**Sept 2016**	**Sept & Oct 2017**	**Sept 2018**
CR4[3]	CR-22.3	Blw WG[1], Paul Gilbert[2],CR at Ppark[3]	30	0	36	78	7	13	30	5	5	0	9
CR5	CR-15.5	CRBlw WF	17	0	37	6	25	28	8	5	13	2.5	27
CR6	CR-9.6	CRBlw KB Ditch	18	1	45	10	10	1	4	5	8	0	9

Table 7. Pebble count summary at macroinvertebrate sites on the Fraser River, Ranch Creek, St Louis and Colorado River, 2018

Fraser River Watershed								Colorado River							
SMP Reach	**F2**	**F2**	**F4**	**F6**	**F6**	**F-StL**	**F-RC2**	**SMP Reach**	**CR3**	**CR4**	**CR4**	**CR4**	**CR6**	**CR6**	**CR6**
RM	**FR-27.2**	**FR-23.2**	**FR-20**	**FR-15**	**FR-14**	**STC-0**	**RC-1.1**	**RM**	**CR-31**	**CR-28.7**	**CR-22.9**	**CR-16.7**	**CR- 9.1**	**CR-7.4**	**CR-1.7**
Site Name	**FR_ab_MJ**	***FR AbvWPSD***	**FR Rendezvous**	**FR FrSpProj**	**FR-CR83**	**St Louis at FR**	**RC blw MC**	**Site Name**	**CR WGU**	**CR WGD**	**CR HSU**	**CR WFU**	**CR-KBD**	**CRbl Troublesome**	**CRabBR**
Class Size (mm)	**2018**	**2018**	**2018**	**2018**	**2018**	**2018**	**2018**	**Class Size (mm)**	**2018**	**2018**	**2018**	**2018**	**2018**	**2018**	**2018**
0-2								0-2							
2-4								2-4							
4-8								4-8							
8-16		1						8-16							
16-32		1		1		1	1	16-32			2	1	2	2	
32-64	30	27	10	12	5	13	31	32-64	1	10	18	10	9	35	10
64-128	60	53	46	55	39	56	56	64-128	56	69	69	58	77	65	62
128-256	10	14	36	32	46	30	10	128-256	42	23	13	31	12	2	23
256-512		4	8	2	10		3	256-512	2			3			8
512-1024								512-1024							
1024-2048								1024-2048							
2048-4096								2048-4096							
Sum	**100**	**100**	**100**	**102**	**100**	**100**	**101**	**Sum**	101	102	102	103	100	104	103
% Embedded	6	11	4	3	1	9	1	% Embedded	1	5	8	5	3	1	1
% Aquatic veg	0	15	6	86	61	2	17	% Aquatic veg	2	42	58	23	82	67	95
H_2O Temp F	44	48	50	50	50	52	50	H_2O Temp F	54	58	60	59	53	50	53
Time	1420	1330	1253	1040	955	1140	920	Time	1520	1548	1430	1155	1108	907	1018
Date	9/5/2018	9/5/2018	9/5/2018	9/5/2018	9/5/2018	9/5/2018	9/5/2018	Date	9/5/2018	9/6/2018	9/6/2018	9/6/2018	9/6/2018	9/6/2018	9/6/2018

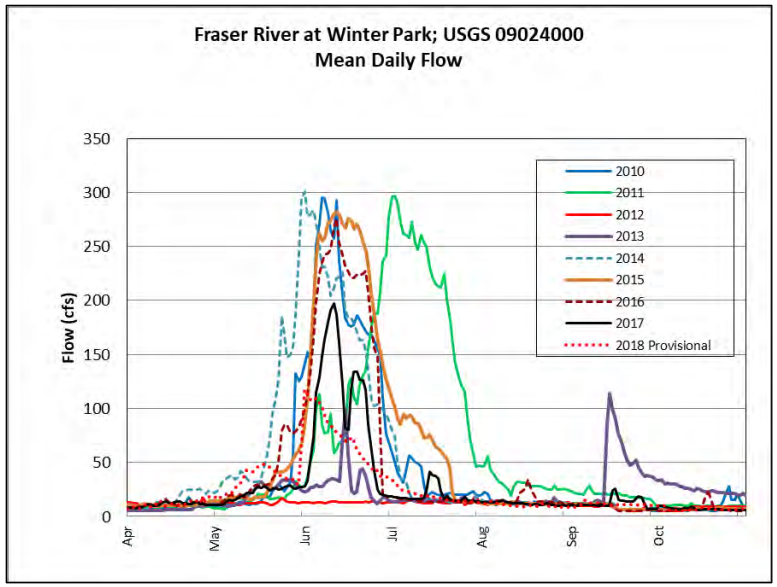
Table 8. Pebble count summary at macroinvertebrate sites on the Fraser River, St. Louis Creek and Ranch Creek, 2015, 2016, 2017, and 2018

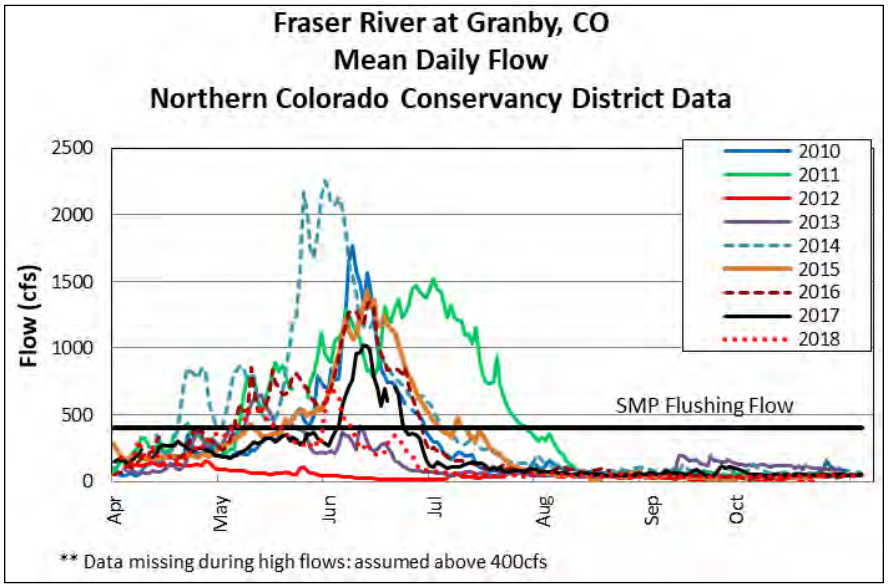
Fraser River Watershed																					
SMP Reach	**F2**	**F2**				**F4**				**F6**			**F6**				**FR-STC**	**F-RC2**			
RM	**FR-27.2**	**FR-23.2**				**FR-20**				**FR-15**			**FR-14**				**STC-0**	**RC-1.1**			
Site Name	**FR_ab_MJ**	**FR AbvWPSD**				**FR Rendezvous**				**FR FrSpProj**			**FR CR83**				**St Louis at FR**	**RC blw MC**			
Class Size (mm)	**2018**	**2015**	**2016**	**2017**	**2018**	**2015**	**2016**	**2017**	**2018**	**2016**	**2017**	**2018**	**2015**	**2016**	**2017**	**2018**	**2018**	**2015**	**2016**	**2017**	**2018**
0-2								1		1	4										
2-4																					
4-8																				1	
8-16				1	1					1	1								5	2	
16-32		5	3	7	1	3		3		2	1	1	2	3			1	2	26	4	1
32-64	30	19	30	27	27	18	11	7	10	18	25	12	9	8	15	5	13	37	58	29	31
64-128	60	56	50	48	53	46	71	53	46	46	57	55	57	57	49	39	56	55	10	44	56
128-256	10	15	16	16	14	27	18	35	36	29	13	32	28	33	35	46	30	6	2	17	10
256-512		8	2	2	4	10	1	4	8	3	2	2	5	5	2	10				4	3
512-1024		1											1	0							
1024-2048																					
2048-4096																					
Sum	100	104	101	101	100	104	101	103	100	100	103	102	102	106	101	100	**100**	100	101	101	**101**
%Embedded	6	27	2	8	11	14	1	4	4	20	17	3	6	10	14	1	9	5	8	13	1
% Aquatic Veg	0	38	0	3	15	18	0	0	6	53	12	86	2	0	69	61	2	1	4	10	17

Table 9. Pebble count summary at Colorado River macroinvertebrate sampling sites, 2015-2018

Colorado River																		
SMP Reach	**CR3**		**CR4**				**CR4**				**CR4**		**CR6**				**CR6**	**CR6**
RM	**CR-31**		**CR-28.7**				**CR-22.9**				**CR-16.7**		**CR-9.1**				**CR-7.4**	**CR-1.7**
Site Name	**CR WGU**		**CR WGD**				**CR HSU**				**CR WFU**		**CR KBDitch**				**CR Blw Troublesome**	**CR US BR**
Class Size (mm)	**2017**	**2018**	**2015**	**2016**	**2017**	**2018**	**2015**	**2016**	**2017**	**2018**	**2017**	**2018**	**2015**	**2016**	**2017**	**2018**	**2018**	**2018**
0-2																		
2-4																		
4-8																		
8-16								2						0				
16-32	2			0			7	16	1	2	1	1		1		2	2	
32-64	8	1	12	8	5	10	40	59	19	18	12	10	14	23	4	9	35	10
64-128	61	56	72	68	71	69	48	19	72	69	59	58	86	71	82	77	65	62
128-256	30	42	20	24	26	23	5	4	9	13	26	31	9	7	16	12	2	23
256-512		2		1	1						2	3						8
512-1024																		
1024-2048																		
2048-4096																		
Sum	101	101	104	101	103	102	100	100	101	102	100	103	109	102	102	100	104	103
% Embedded	2	1	5	3	2	5	7	5	1	8	0	5	0	8	0	3	1	1
% Aquatic Veg	0	2	0	3	7	42	4	0	0	58	0	22	1	0	1	82	70	98

Figure 1. 2018 site map





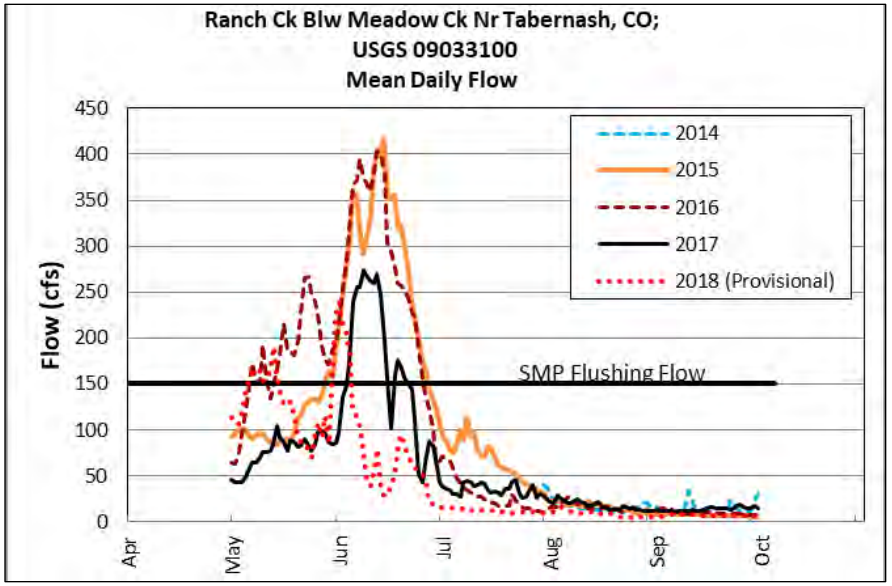
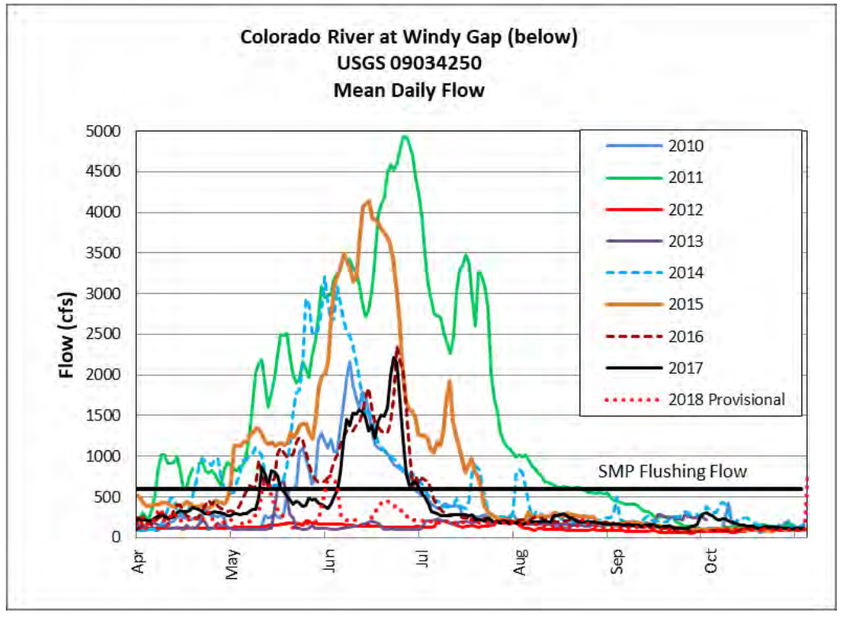
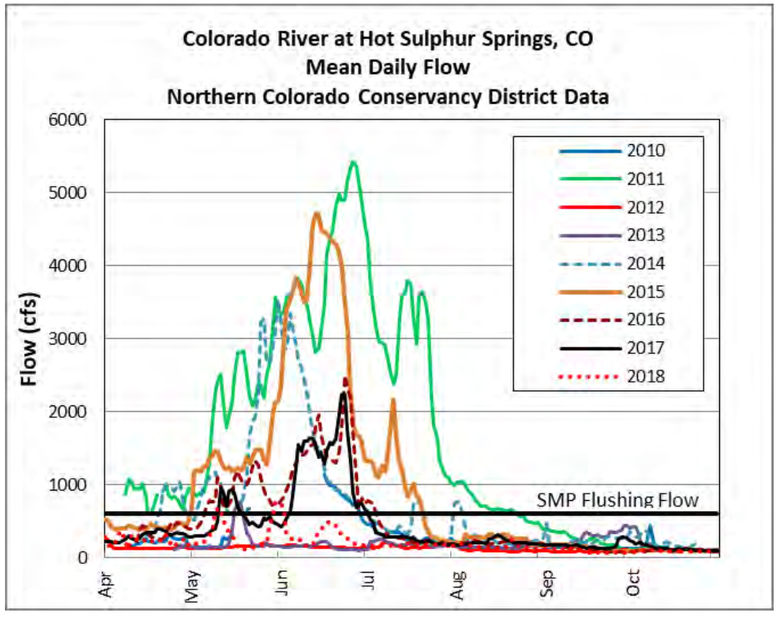
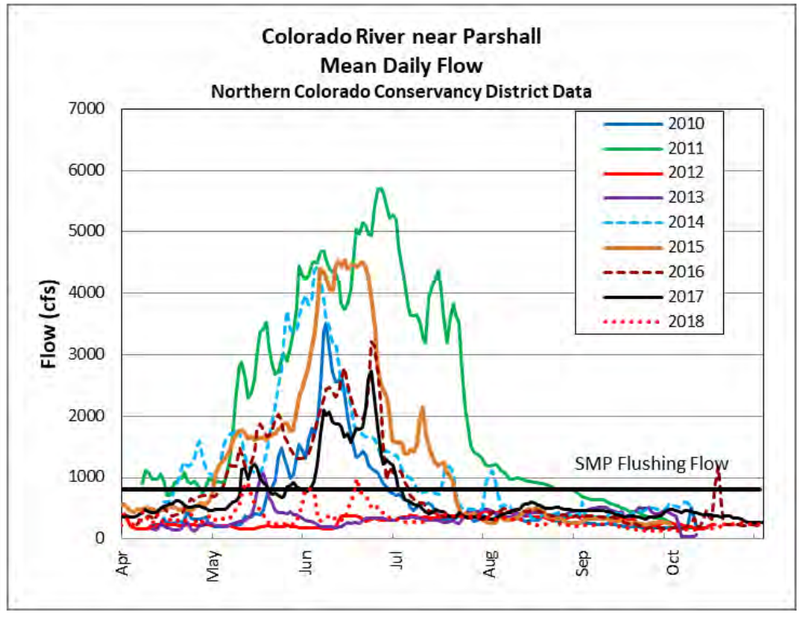
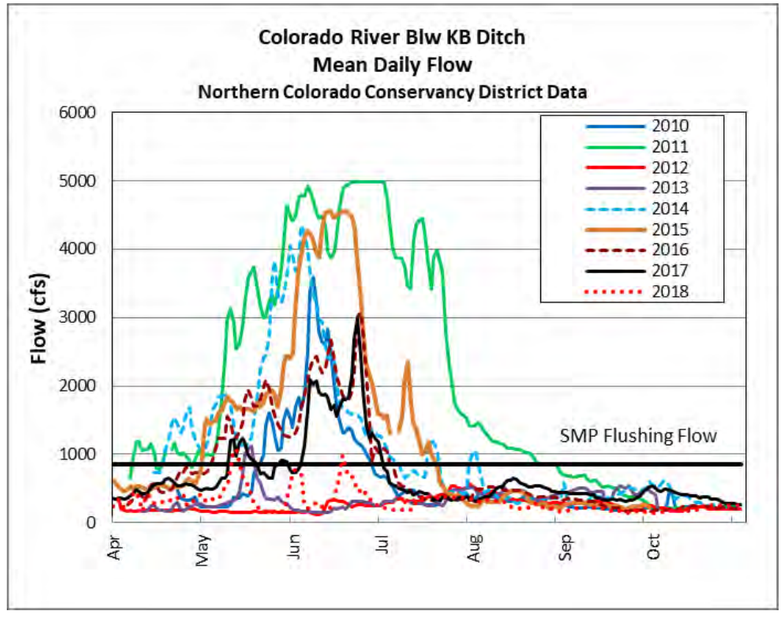


Figure 2. Streamflow hydrographs for Fraser River at Winter Park, Fraser River at Granby, and Ranch Creek blw Meadow Creek.









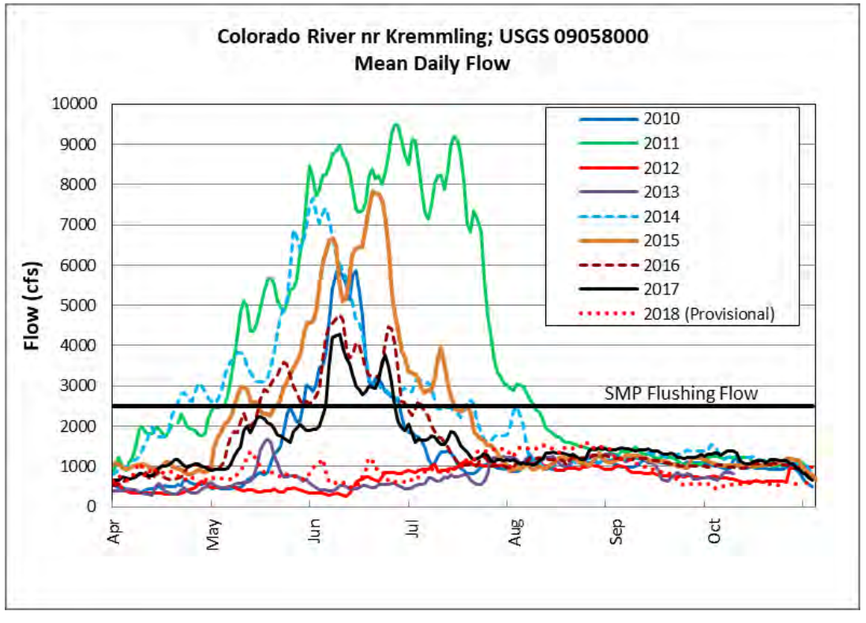
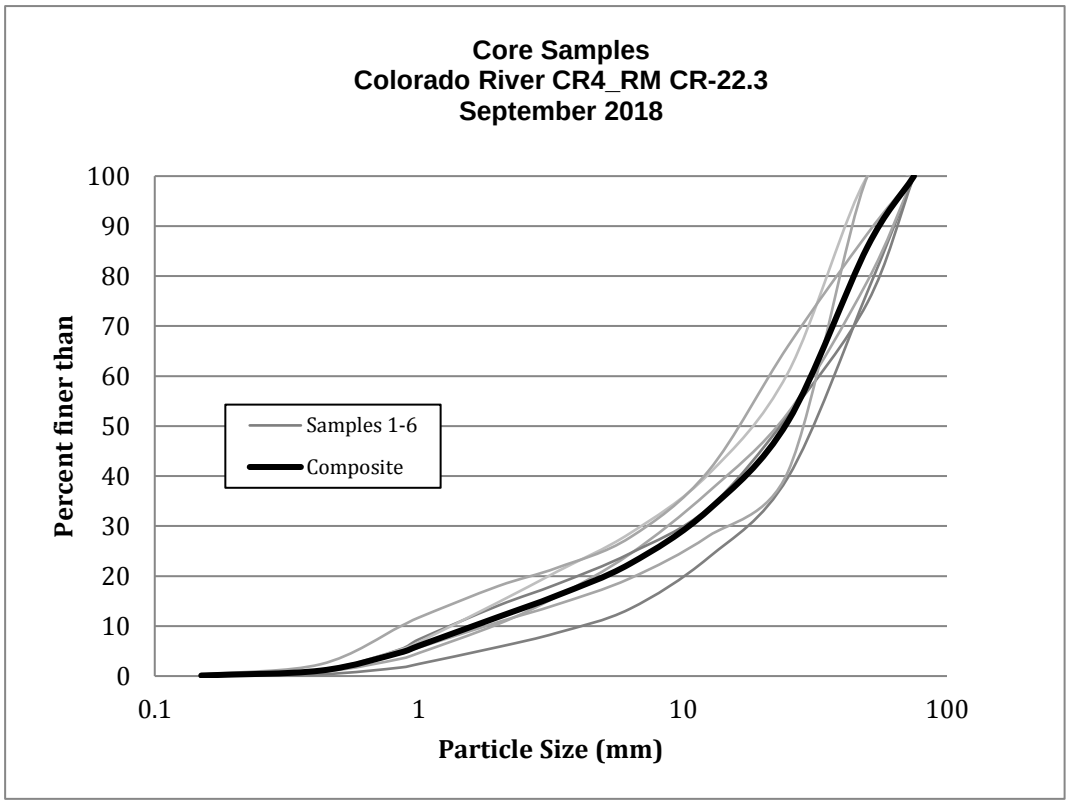
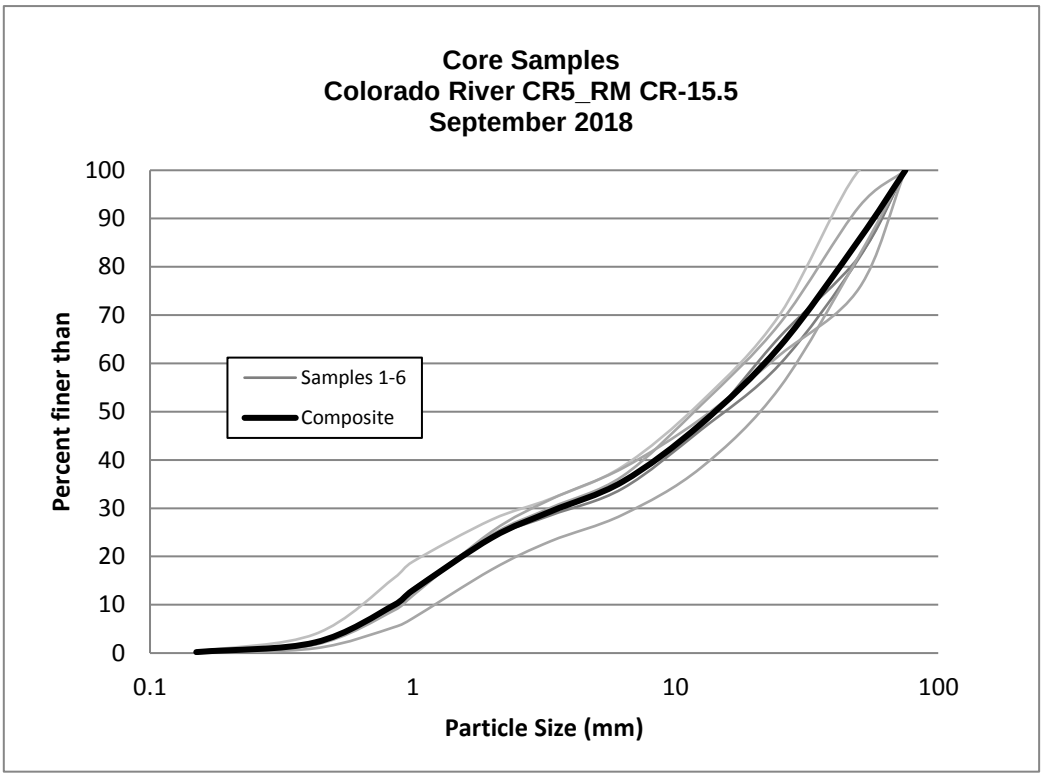


Figure 3. Hydrographs for Colorado River at Windy Gap (below), Colorado River at Hot Sulphur Springs, Colorado River near Parshall, Colorado River blw KB Ditch, and Colorado River nr Kremmling.



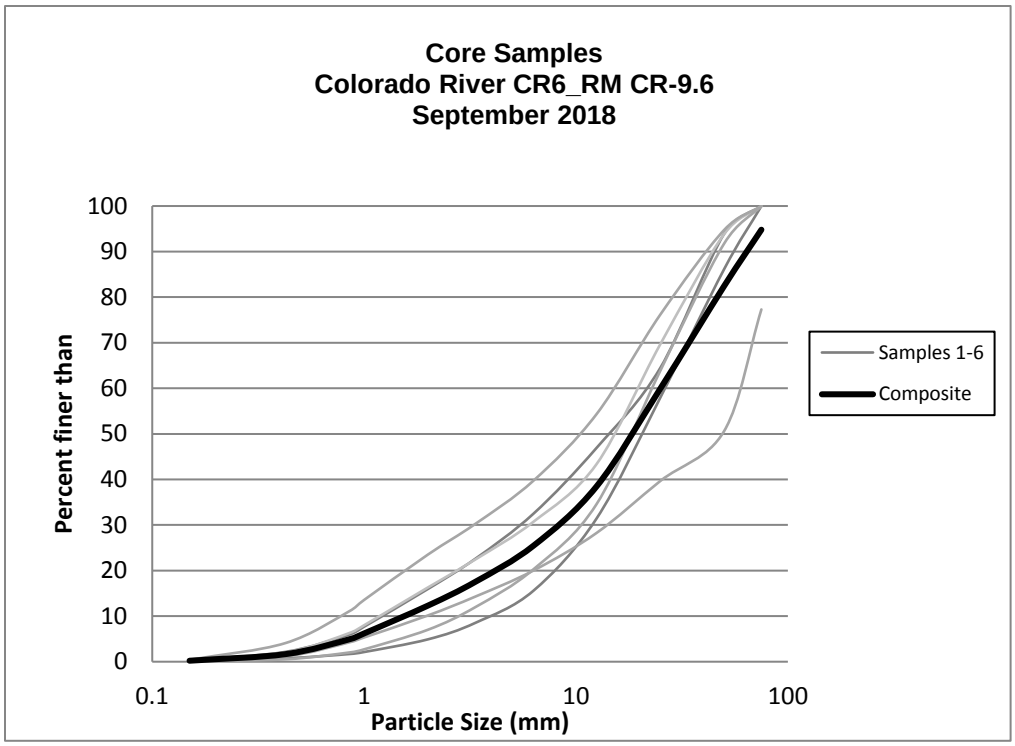
	Colorado River: CR 4_RM CR-22.3 Core Samples percent finer than						
Sieve Size (mm)	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**	**Sample 6**	**Composite**
75	100.0	100.0	100.0	100.0	100.0	100.0	100.0
50	76.9	79.0	74.7	100.0	100.0	88.5	85.9
25	39.7	52.6	52.0	60.7	40.9	66.0	50.9
12.5	23.7	36.8	33.6	40.4	28.0	41.0	33.2
6.3	13.4	24.4	24.5	28.6	19.5	27.7	22.5
3.35	8.7	16.0	18.4	20.9	14.4	21.7	16.2
2	5.8	10.4	14.1	14.8	10.8	18.0	11.8
1	2.4	4.6	7.3	6.8	5.7	11.7	6.1
0.85	1.7	3.4	5.3	5.3	4.5	9.9	4.7
0.425	0.3	0.8	1.1	1.2	1.2	2.4	1.1
0.15	0.0	0.1	0.0	0.1	0.1	0.3	0.1

Figure 4. Particle size distribution of the six McNeil-Ahnell core samples collected from Colorado River at site CR4_RM-22.3 at Pioneer Park, September 2018.



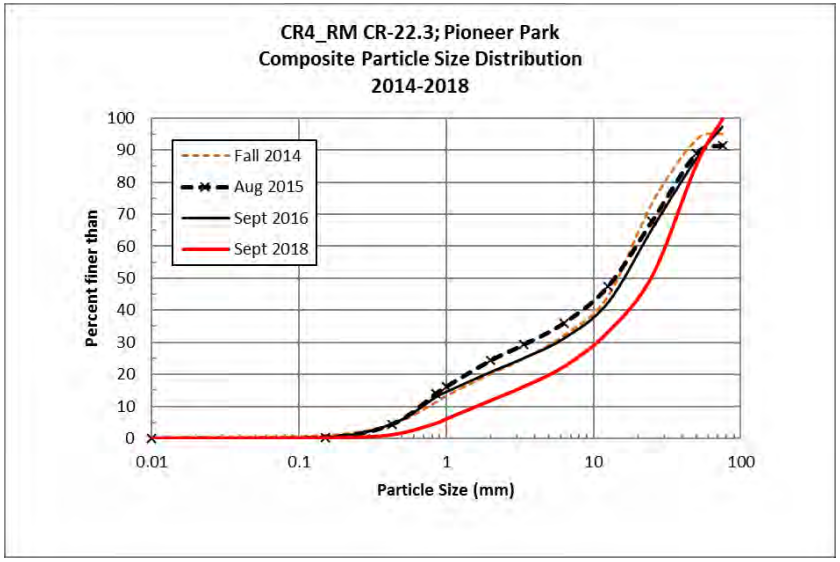
	Colorado River: CR5_RM CR-15.5 Core Samples percent finer than						
Sieve Size (mm)	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**	**Sample 6**	**Composite**
75	100.0	100.0	100.0	100.0	100.0	100.0	100.0
50	81.8	92.5	82.1	100.0	82.4	75.6	85.7
25	59.9	68.3	65.6	70.2	55.1	61.8	63.6
12.5	46.2	51.4	46.8	52.0	38.4	48.5	47.5
6.3	34.1	36.7	35.5	38.7	28.7	38.3	35.5
3.35	28.5	30.1	29.3	32.0	23.2	31.8	29.3
2	23.8	24.5	23.7	27.7	17.3	25.2	23.9
1	13.3	13.0	12.7	18.9	7.2	11.9	13.0
0.85	10.0	9.9	9.3	15.6	5.4	8.9	10.0
0.425	1.8	2.3	2.3	3.9	1.0	1.7	2.2
0.15	0.2	0.2	0.2	0.3	0.1	0.2	0.2

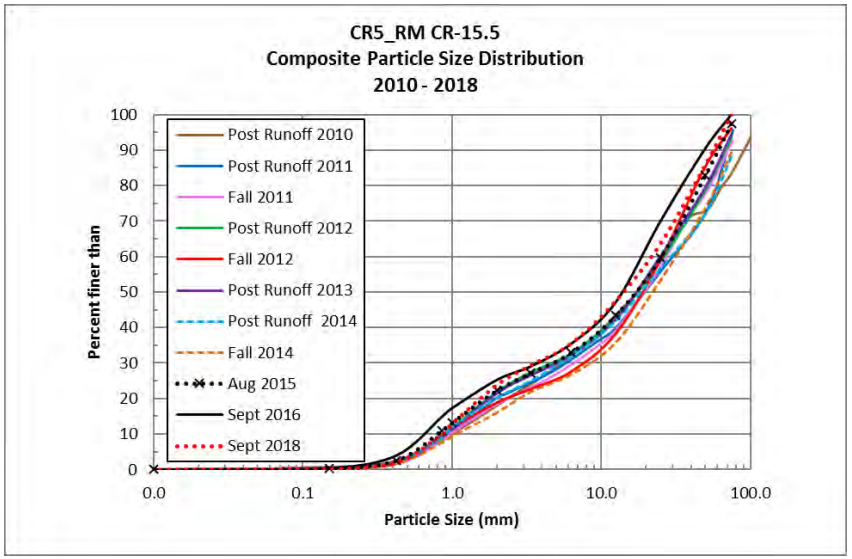
Figure 5. Particle size distribution of the six McNeil-Ahnell core samples collected from Colorado River at site CR4_RM-22.3 at Pioneer Park, September 2018.



	Colorado River: CR6_RM CR-9.6 Core Samples percent finer than						
Sieve Size (mm)	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**	**Sample 6**	**Composite**
75	100.0	77.3	100.0	100.0	100.0	100.0	94.8
50	86.1	50.6	93.9	93.8	94.7	91.7	82.4
25	58.0	39.7	64.5	69.7	76.2	63.8	59.9
12.5	31.4	28.2	46.9	43.4	54.3	34.6	38.5
6.3	15.6	20.0	32.5	30.7	39.7	20.3	25.5
3.35	8.5	14.3	22.6	22.4	30.2	12.0	17.5
2	4.9	10.1	16.0	16.3	23.5	7.0	12.3
1	2.1	5.3	7.7	8.0	13.6	2.7	6.2
0.85	1.7	4.2	5.9	6.3	11.1	2.0	4.9
0.425	0.8	1.2	2.2	2.0	4.1	0.5	1.7
0.15	0.2	0.2	0.3	0.3	0.4	0.1	0.2

Figure 6. Particle size distribution of the six McNeil-Ahnell core samples collected from Colorado River at site CR6_RM-9.6 at the KB Ditch, September 2018.





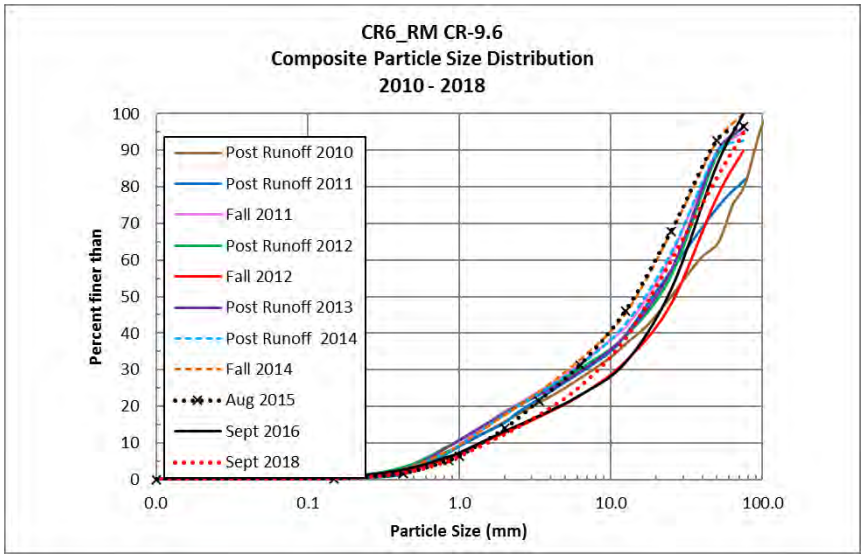
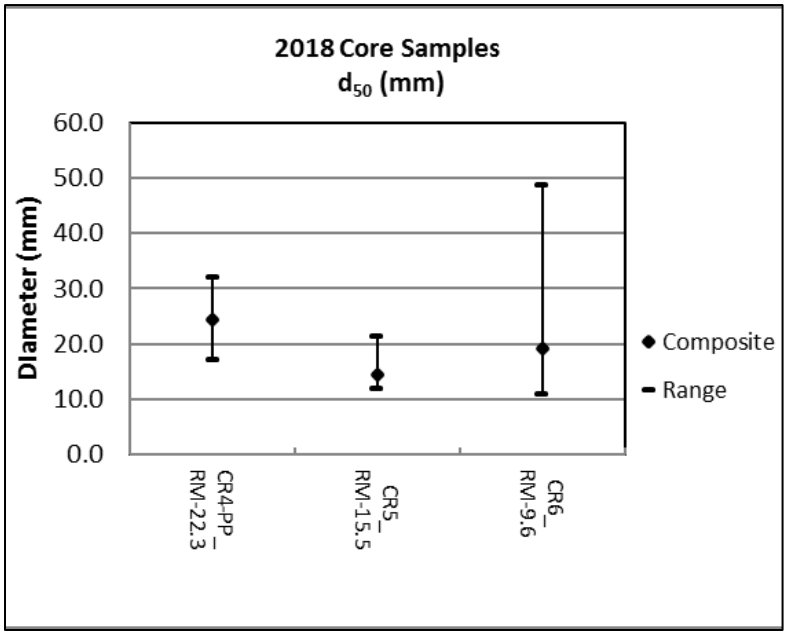


Figure 7. Comparison of the 2018 composite particle size distribution with previous sampling events at each of the three Colorado River spawning bar sites.



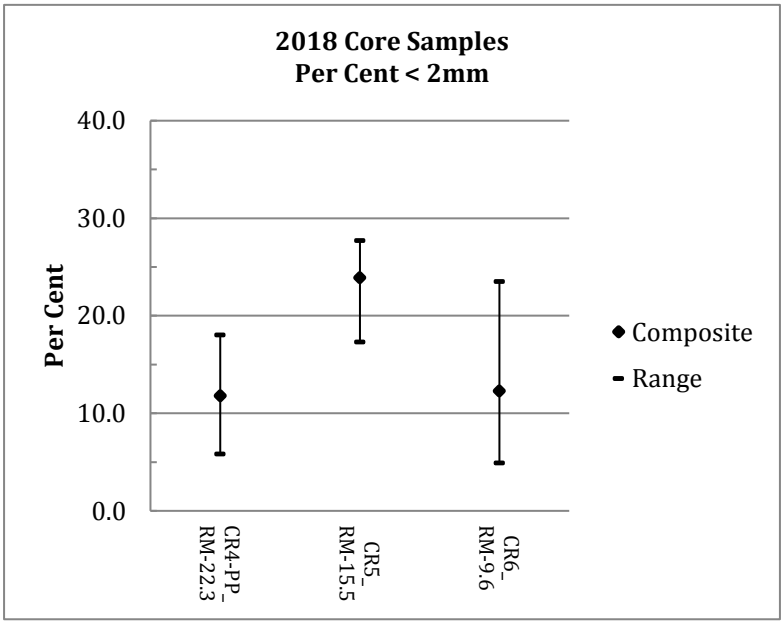
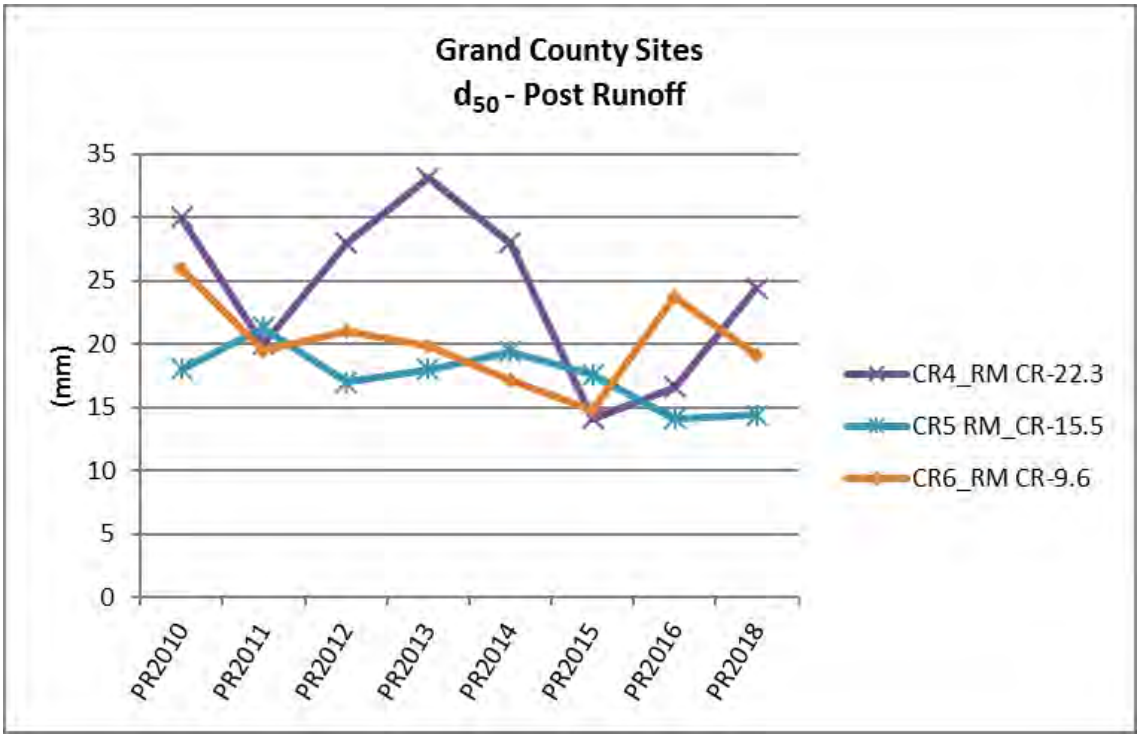


Figure 8. Composite and range of median particle sizes (d50, mm) and percentages of sediment <2mm for the six core samples collected at three Colorado River spawning bar study sites, 2018.



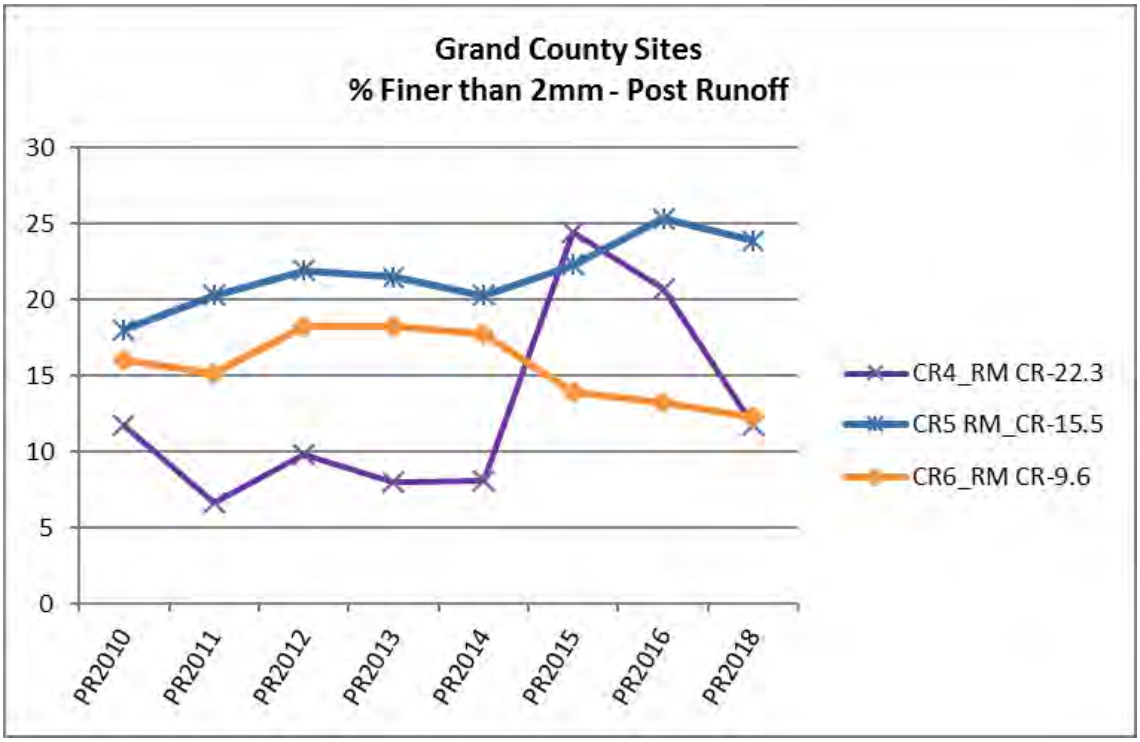


Figure 9. Comparison of composite median particle size (d50, mm) and percent finer <2mm at three Colorado River spawning bar sites, post-runoff 2010-2018.

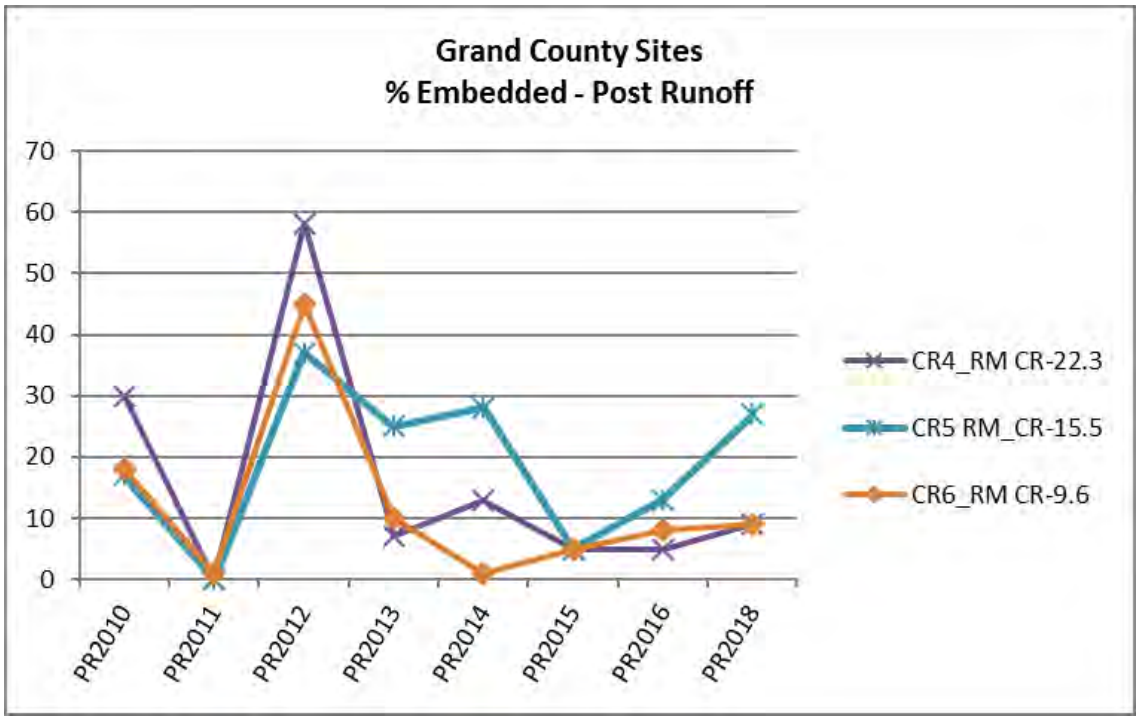


Figure 10. Comparison of % embedded substrate at three Colorado River spawning bar sites, post-runoff 2010-2018.

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Temperature in the LBD Cooperative Effort Area

2014 – 2018 WEEKLY AVERAGE AND DAILY MAXIMUM DATA COMPILATION

Stream Temperature Program Objectives

- Complement existing stream temperature monitoring efforts;
- Provide the LBD operations subcommittee with timely data to make informed decisions about releases of environmental water;
- Provide stream temperature data to evaluate effectiveness of environmental water releases;
- Identify critical stream reaches for water temperature;
- Assess compliance with Colorado's stream temperature standards;
- Monitor and assess impacts of restoration efforts performed by LBD

Temperature Standard Overview

All temperature standards in ^{o}C

Chronic Standard

- Maximum Weekly Average
- 7-day moving average
- CS-I
  - 17.0 (Jun – Sep)
  - 9.0 (Oct – May)
- CS-II
  - 18.3 (Apr – Oct)
  - 9.0 (Nov – Mar)

Acute Standard

- Daily Maximum
- Highest 2-hr average in 24-hrs
- CS-I
  - 21.7 (Jun – Sep)
  - 13.0 (Oct – May)
- CS-II
  - 24.3 (Apr – Oct)
  - 13 (Nov – Mar)

Assessment Period – Previous 5-years

Changes to 2018 Program

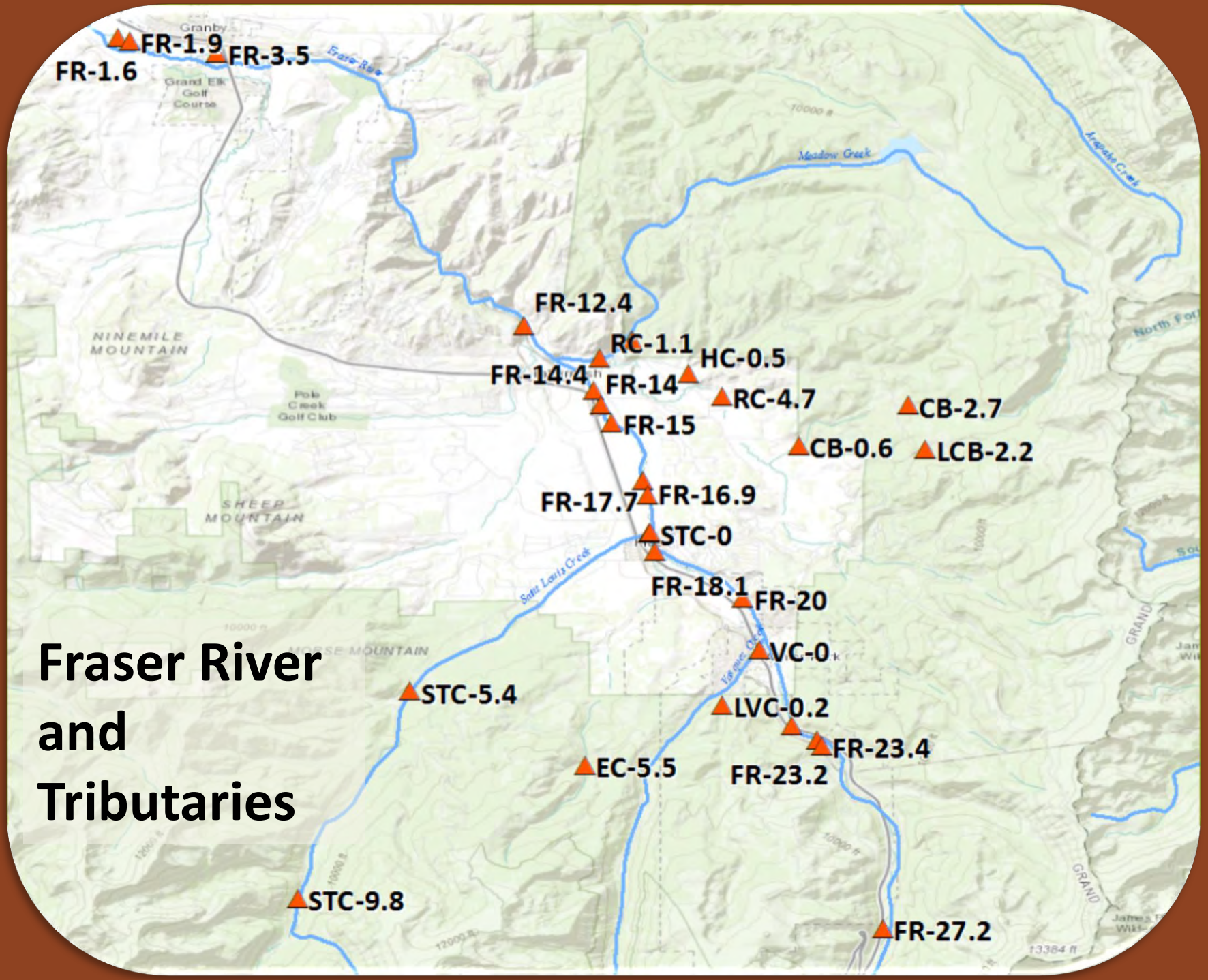
New sites:

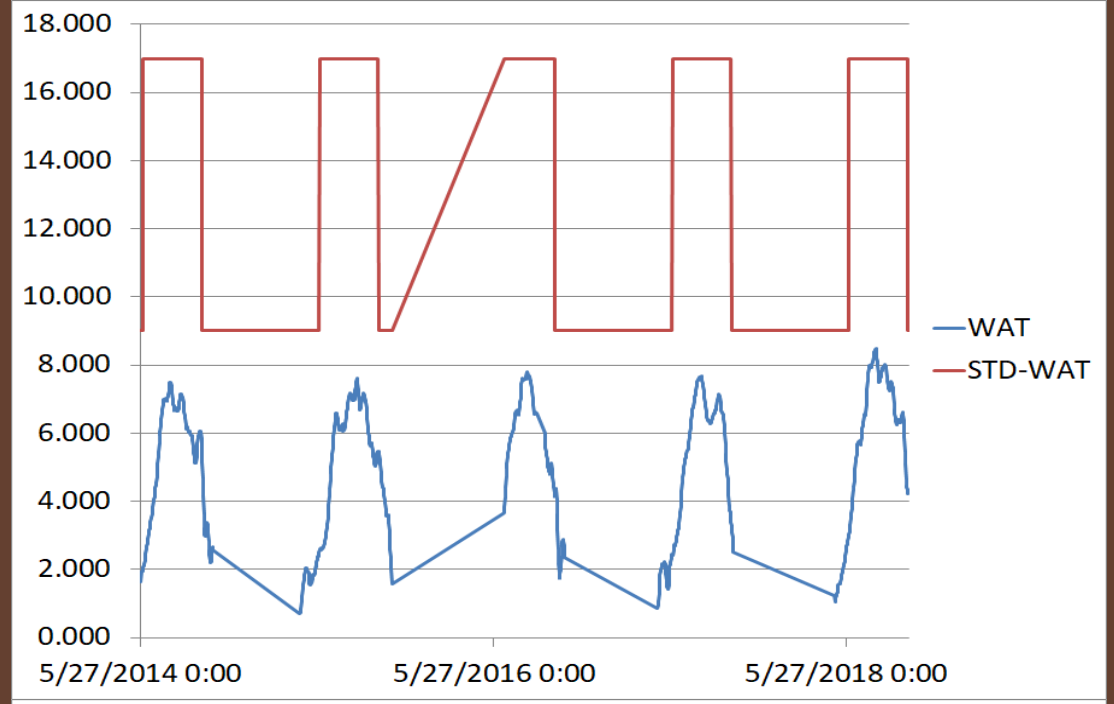
- STC-5.4 (Saint Louis Creek near Fraser Experimental Forest)
- WC-2.3 (Willow Creek above Bunte Highline Ditch)
- WC-0.5 (Willow Creek near confluence of Colorado River)
- WF-5.5 (Williams Fork upstream of the reservoir)

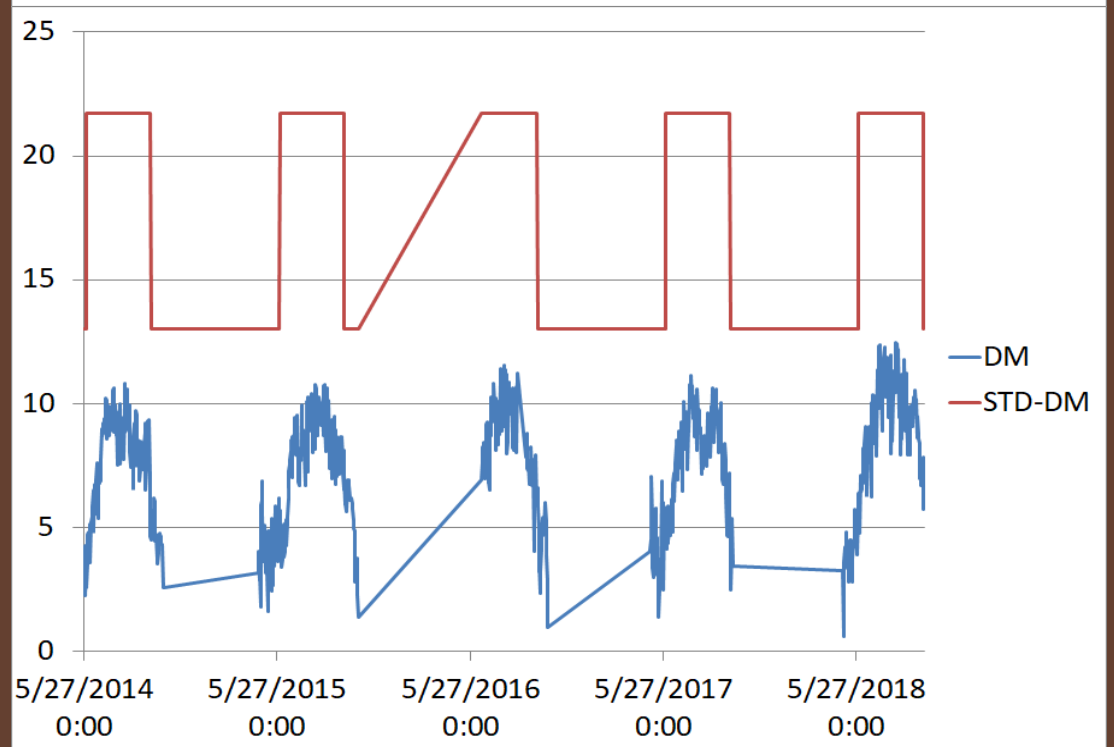
Frequency:

In 2018, four sites were monitored on a weekly basis to inform the Operations Subcommittee

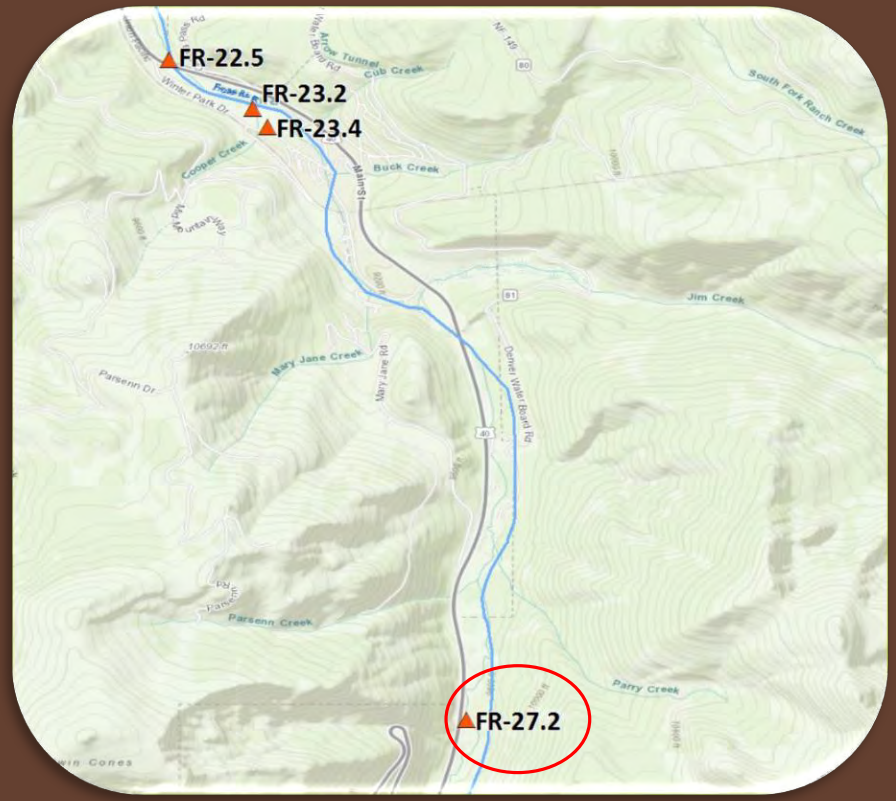
- STC-0 (Saint Louis Creek at confluence of Fraser River)
- FR-3.5 (Fraser River at Hwy 40 in Granby)
- CR-22.1 (Colorado River upstream of Hot Sulphur Water Treatment Plant)
  - Real time sensor provided by Northern
- CR-16.7 (Colorado River upstream of confluence with Williams Fork)
  - Real time sensor provided by Northern

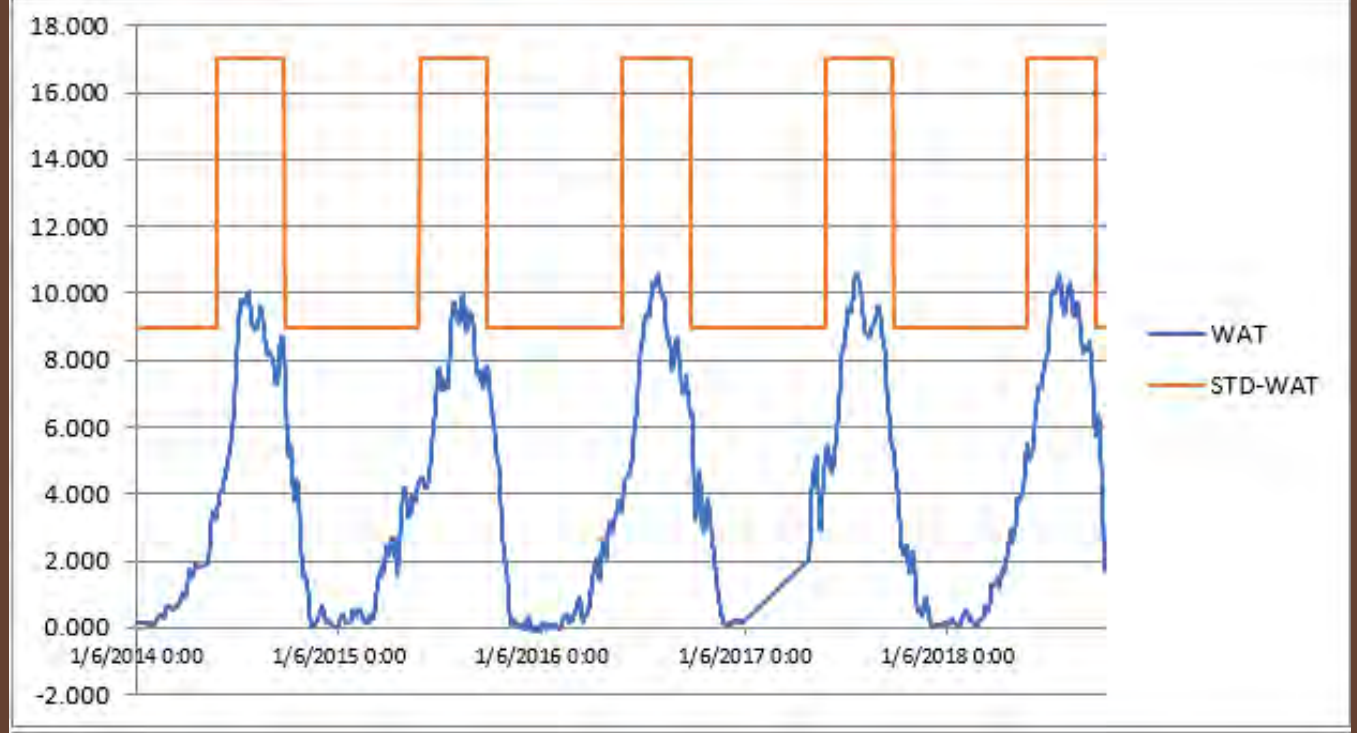

FR-1.9
FR-3.5
FR-1.6
FR-12.4
RC-1.1
HC-0.5
FR-14.4
FR-14
RC-4.7
CB-2.7
FR-15
CB-0.6
LCB-2.2
FR-17.7
FR-16.9
STC-0
FR-18.1
FR-20
VC-0
STC-5.4
LVC-0.2
FR-23.4
EC-5.5
FR-23.2
STC-9.8
FR-27.2
Fraser River and Tributaries

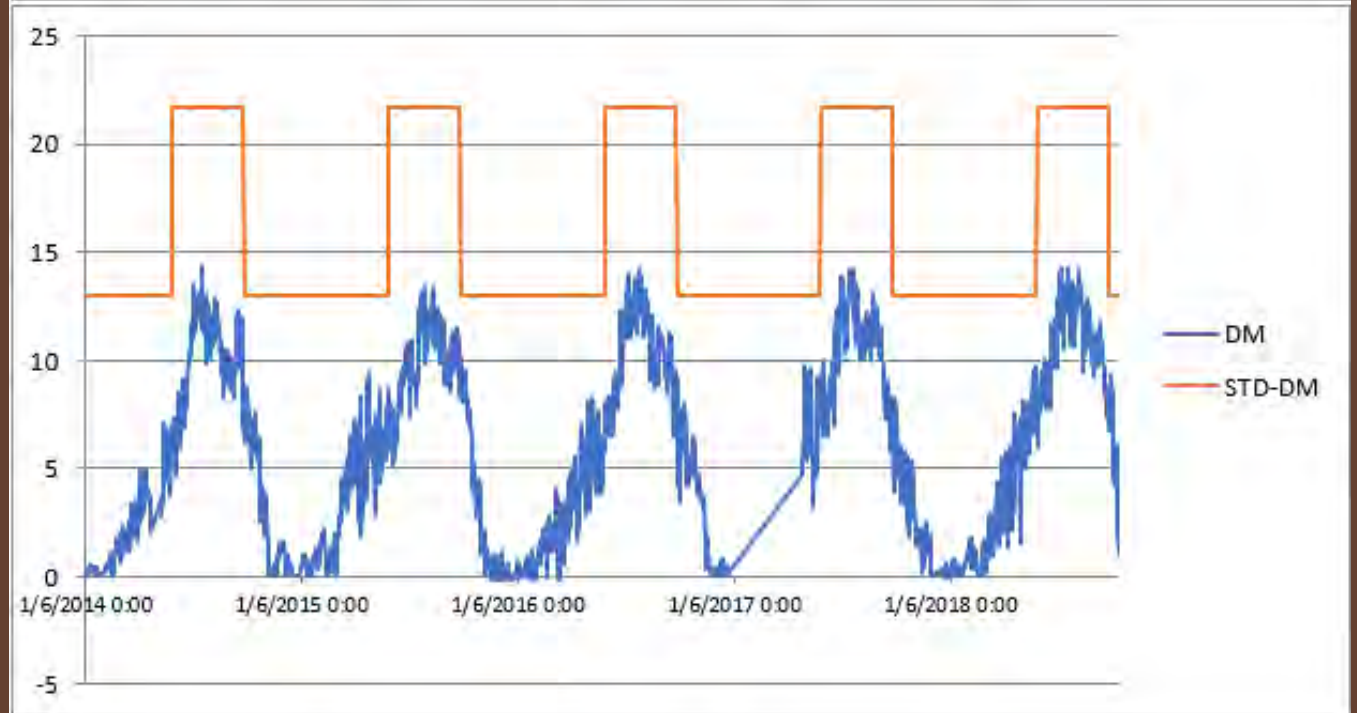




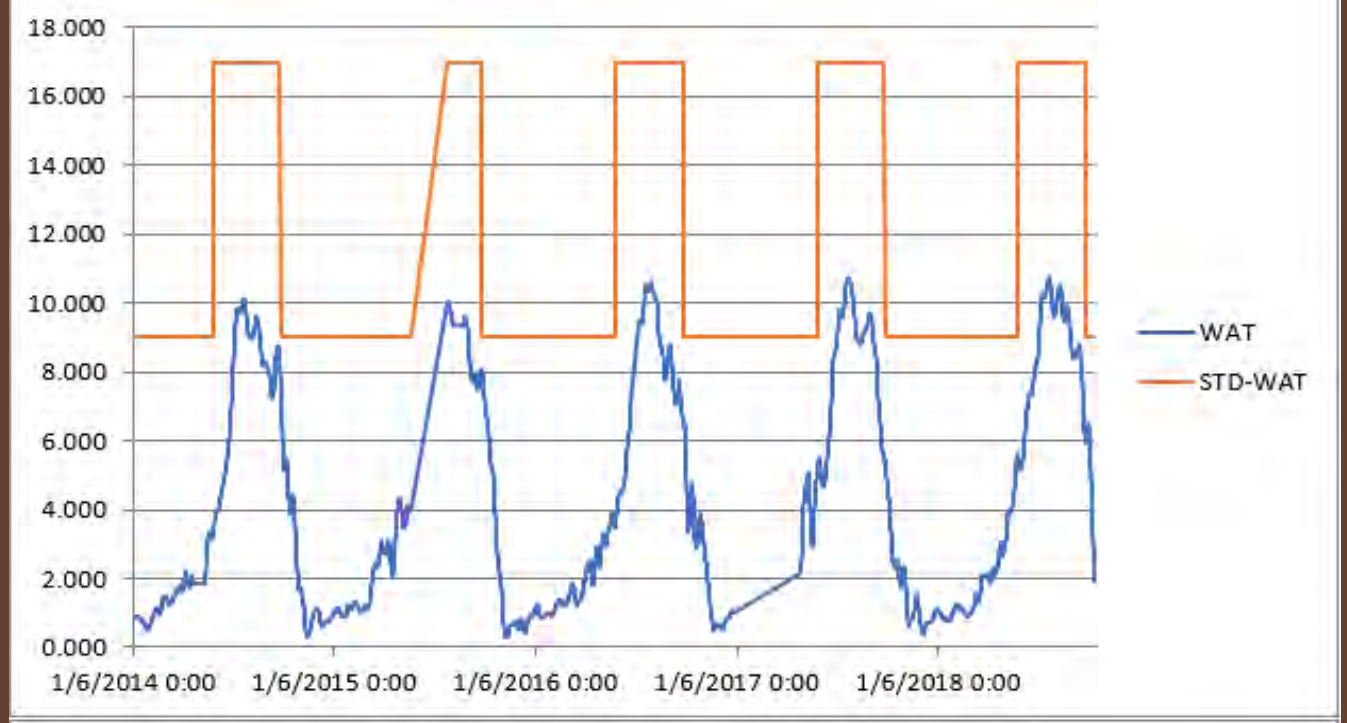
CSI
FR-Upper
FR-27.2

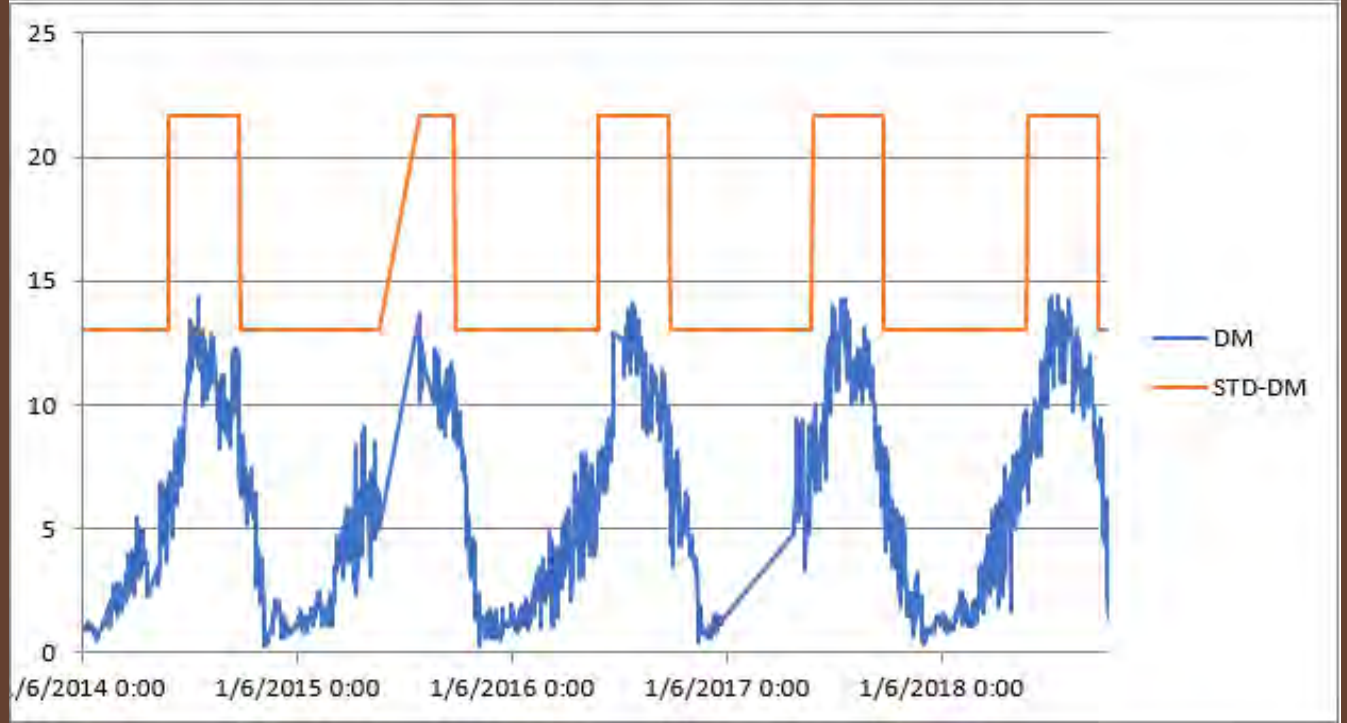




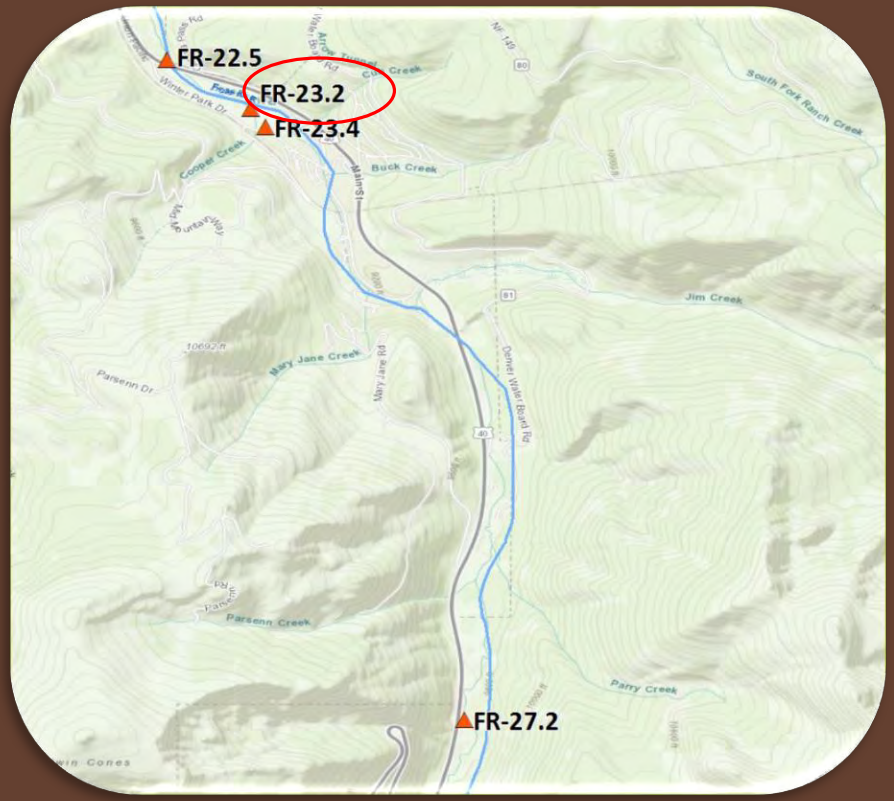


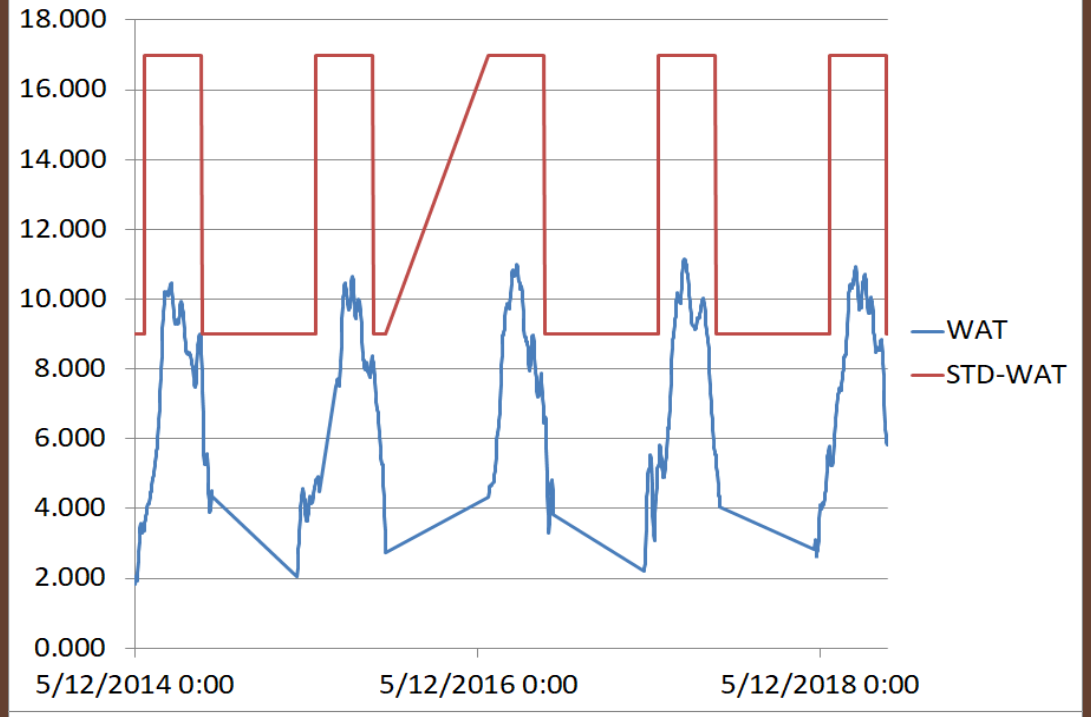
CSI
FR-abvWPSD
FR-23.4

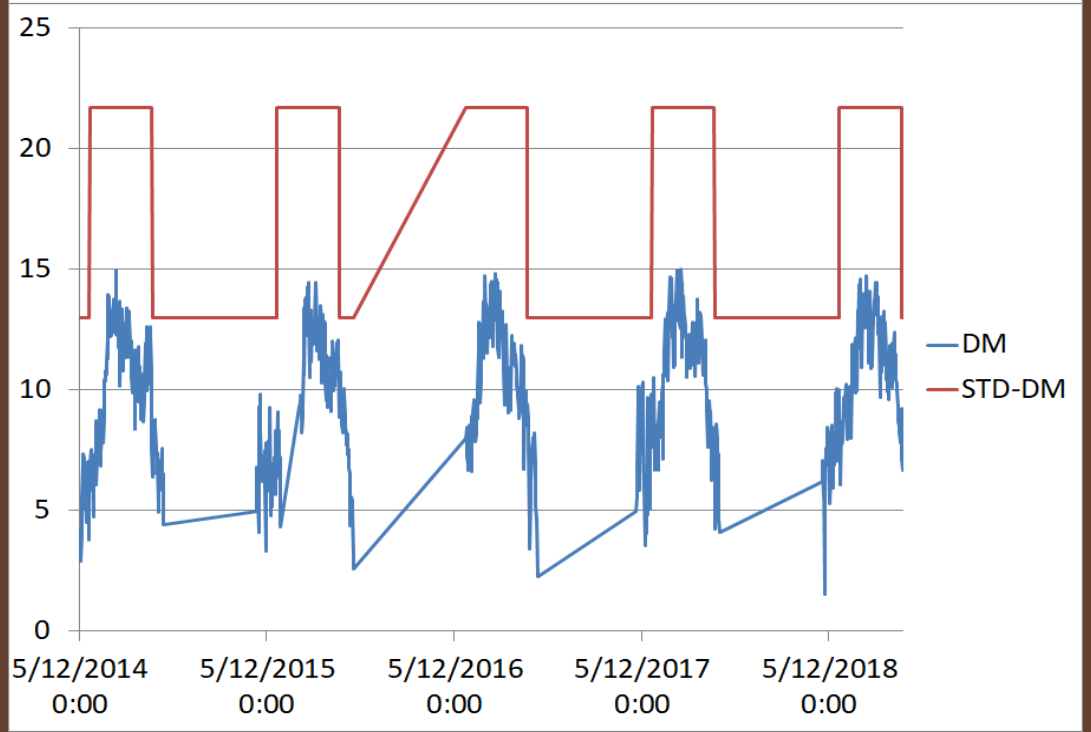




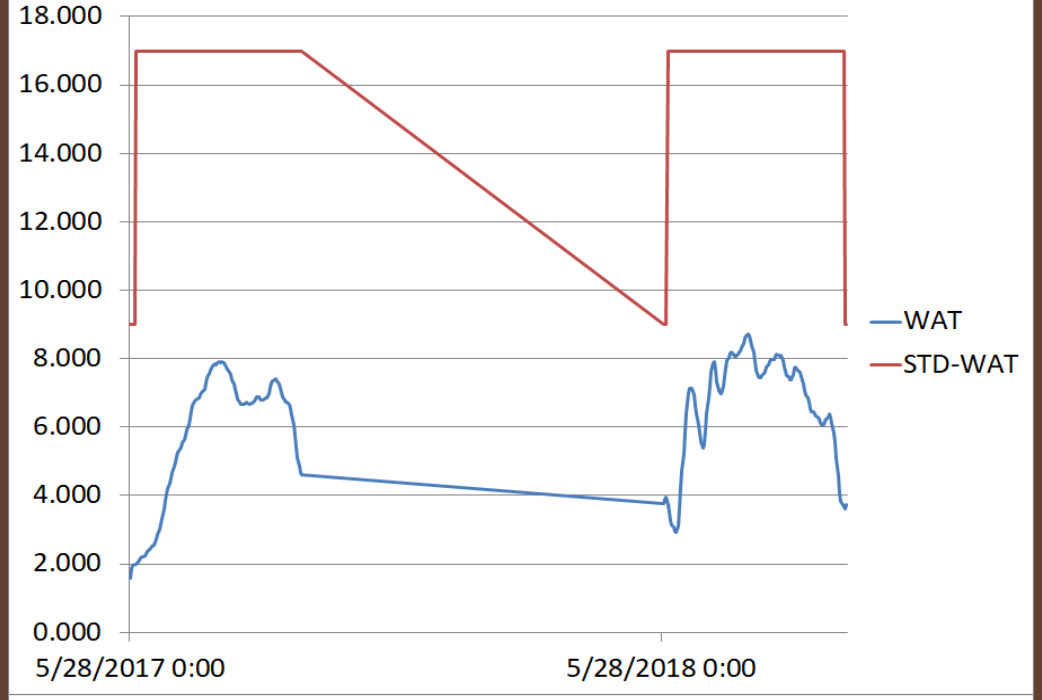
CSI
FR-blwWPSD
FR-23.2

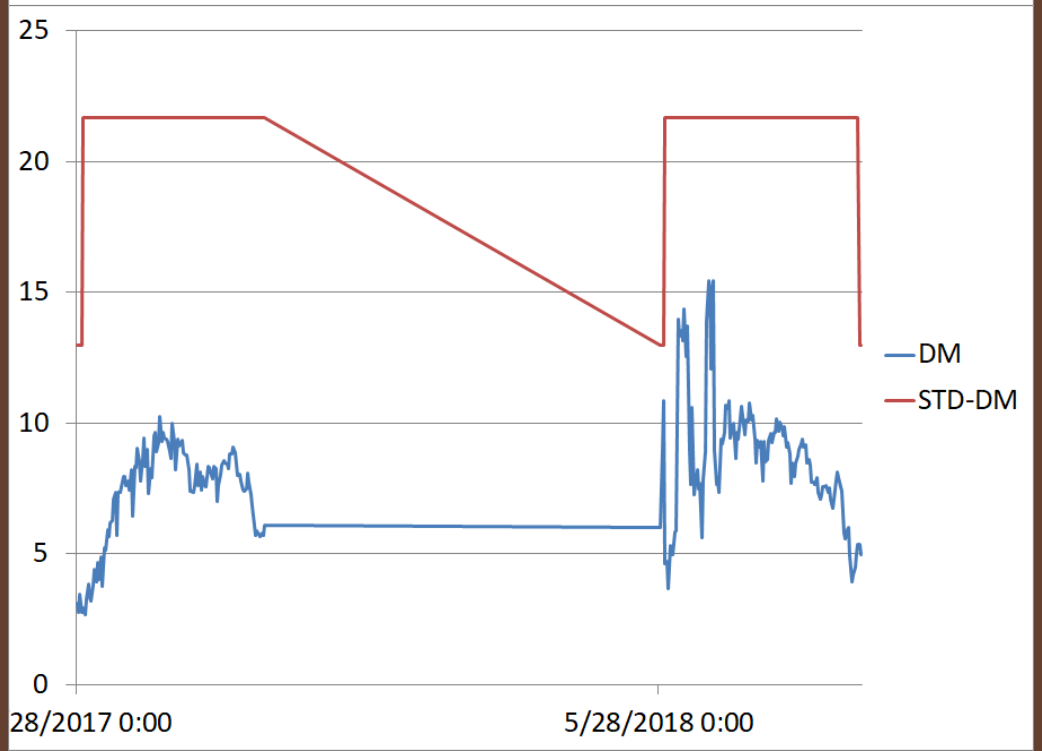




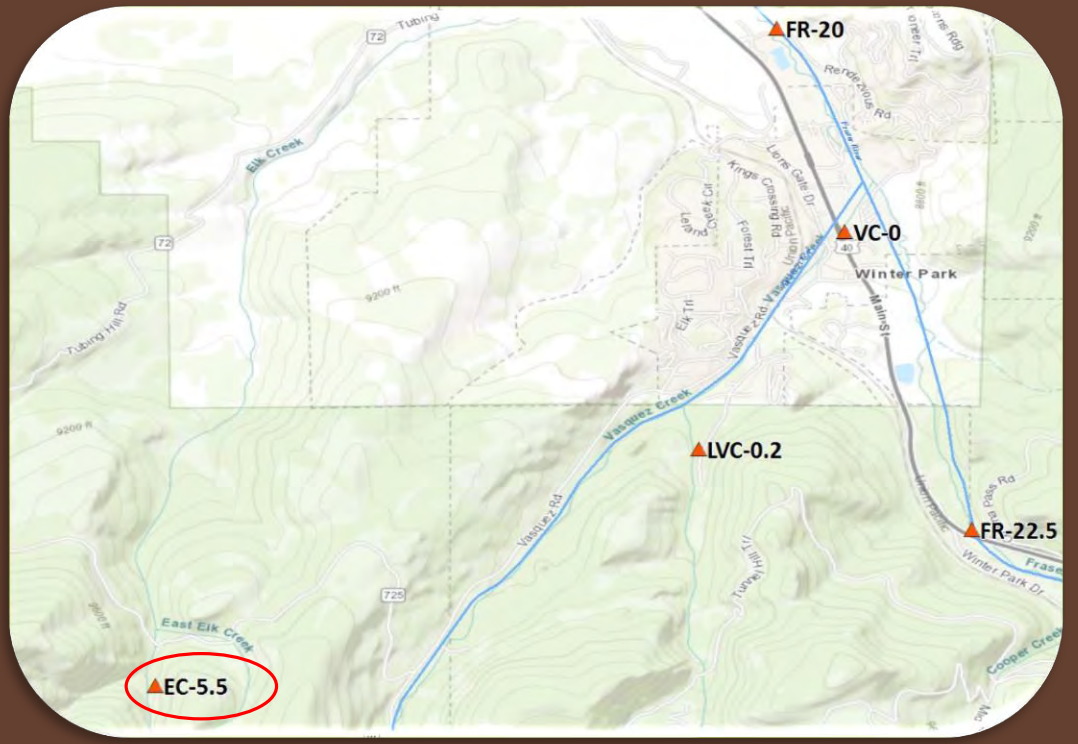


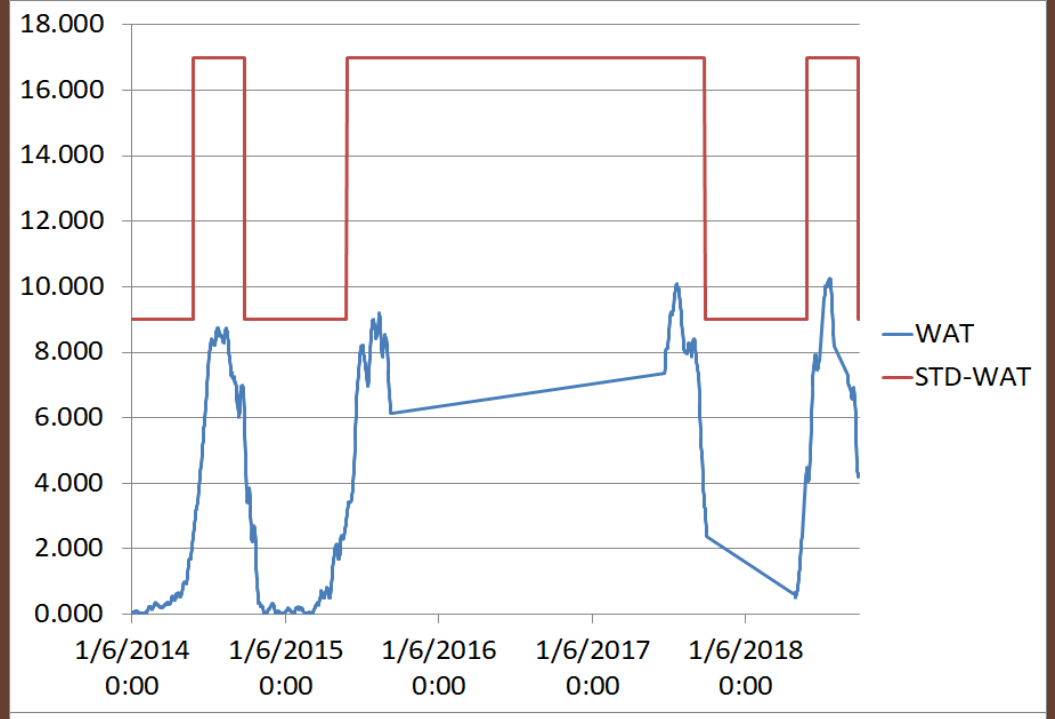
CSI
FR-blwWP
FR-22.5

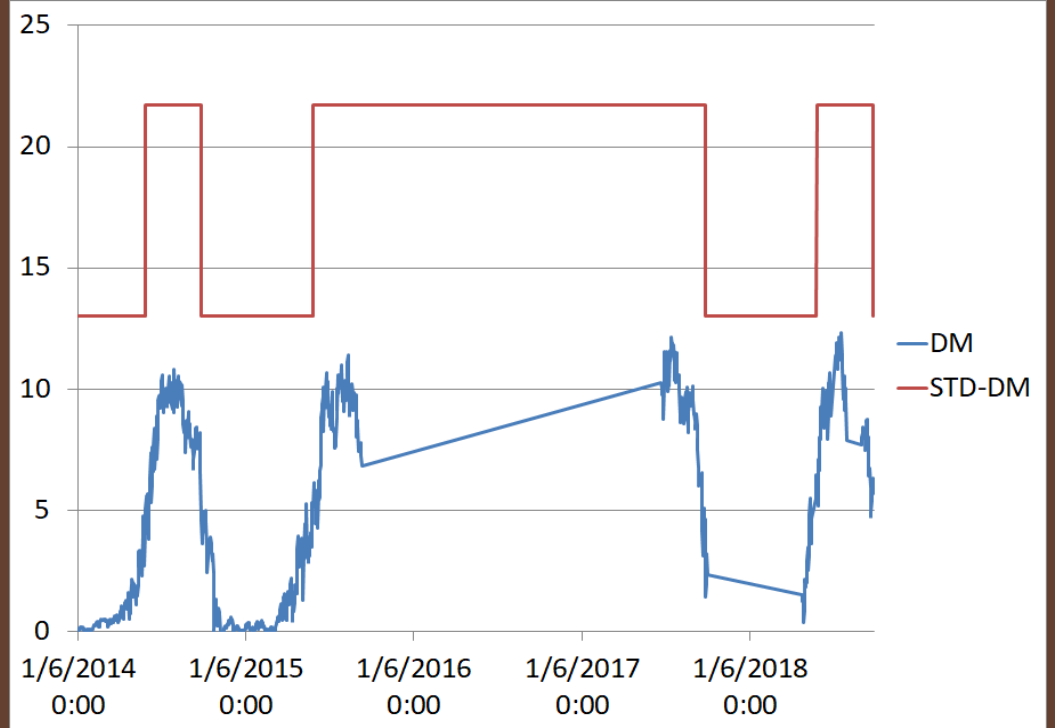




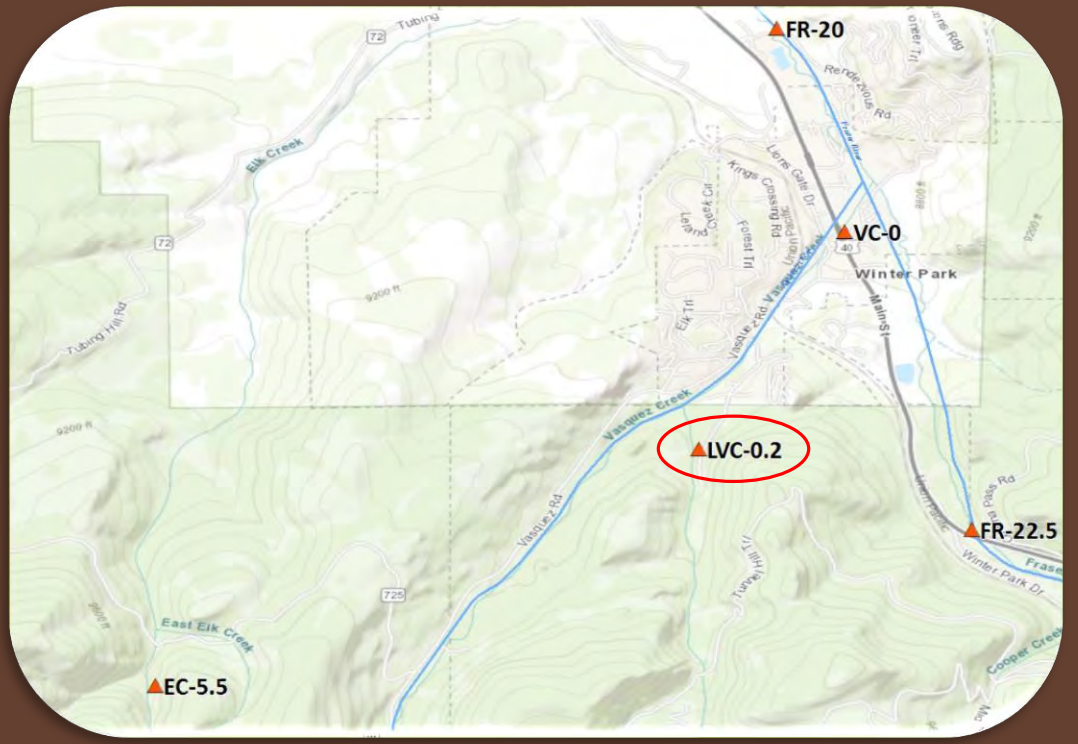
CSI
Elk-blwDWB
EC-5.5

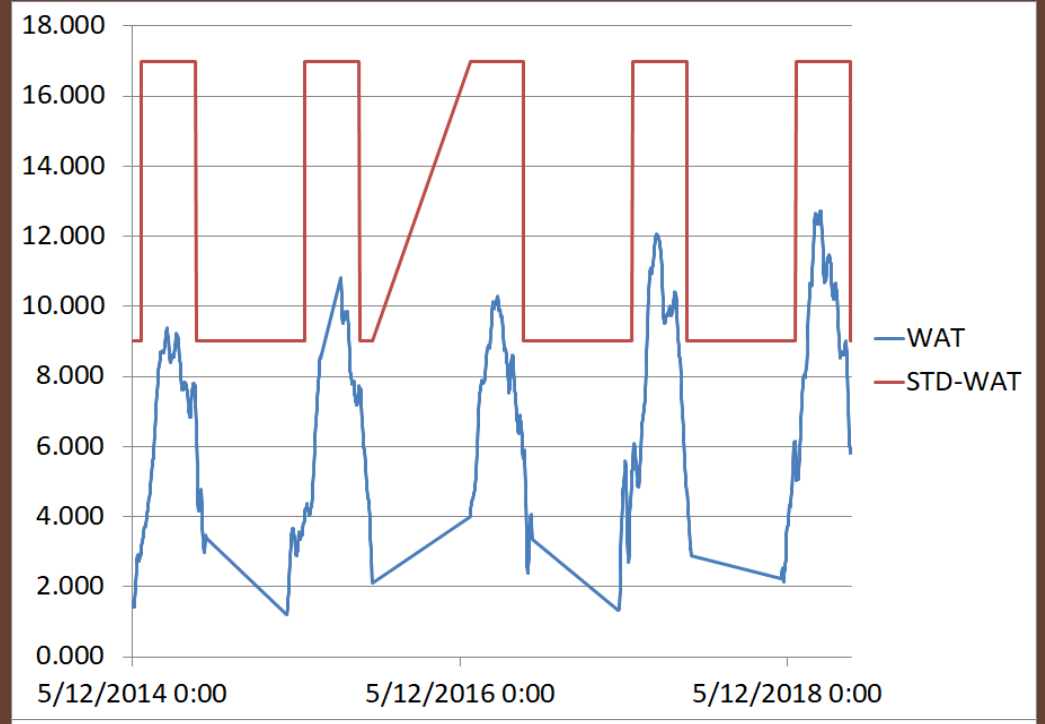






CSI
LVC-abvWP
LVC-0.2




18.000
16.000
14.000
12.000
10.000
8.000
6.000
4.000
2.000
0.000
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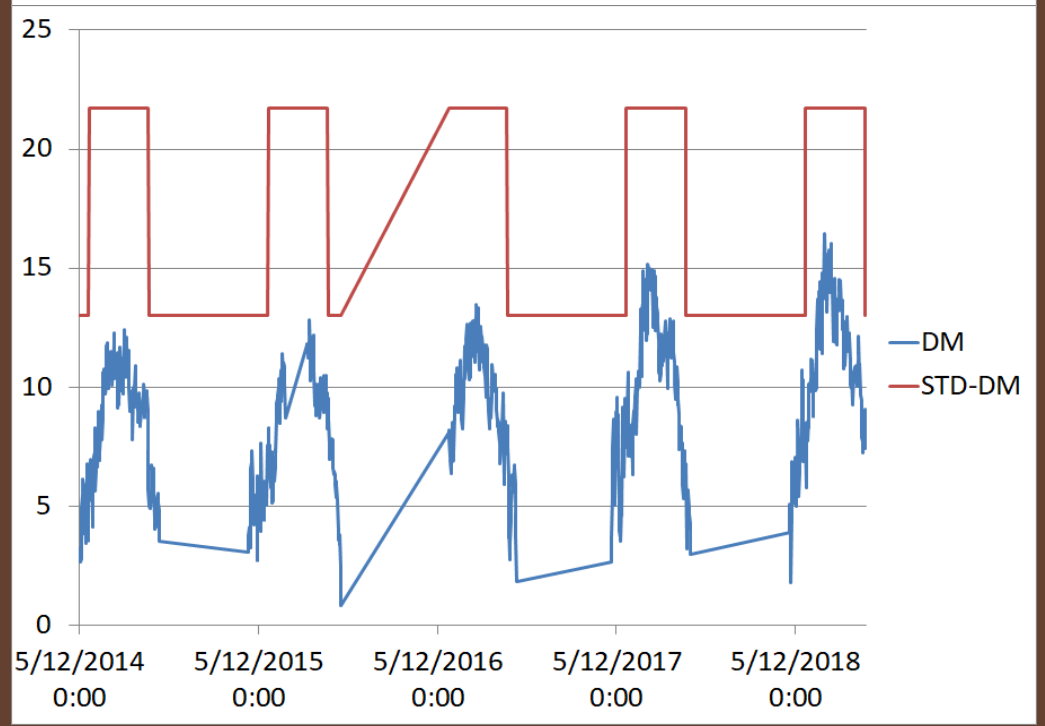
5/12/2016 0:00
5/12/2018 0:00
WAT
STD-WAT


25
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10
5
0
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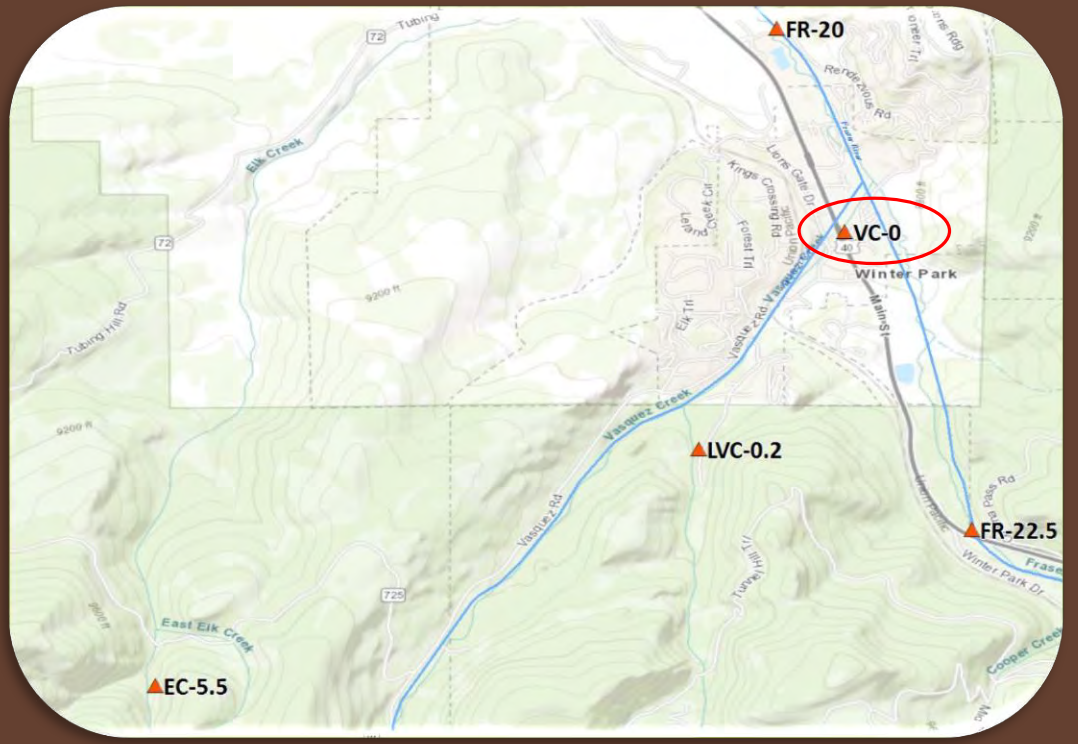
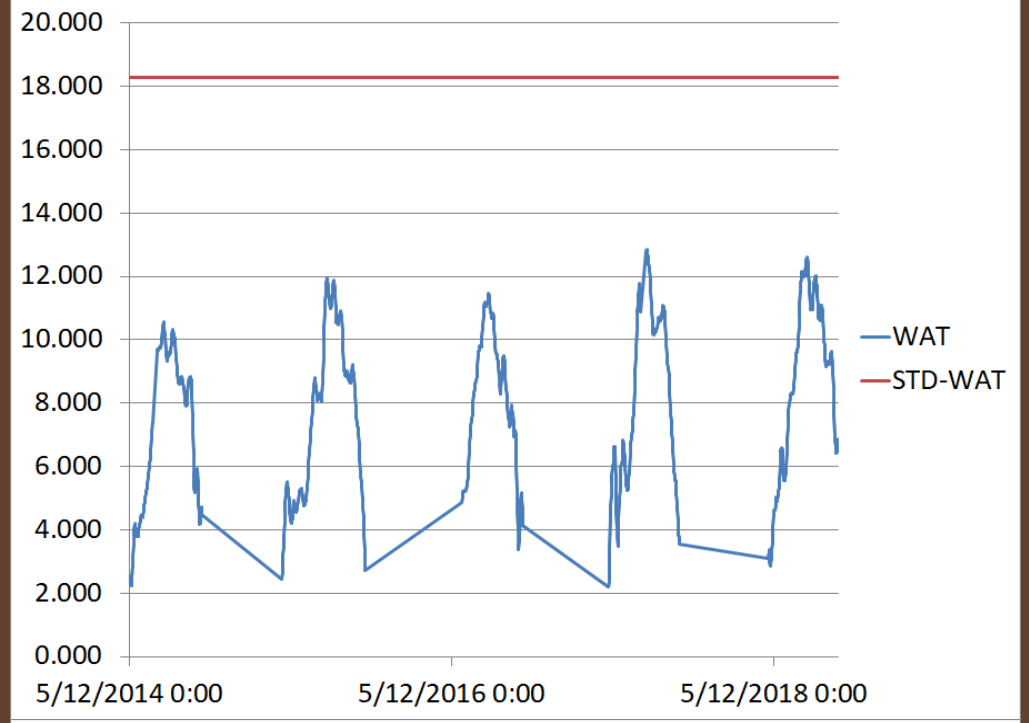
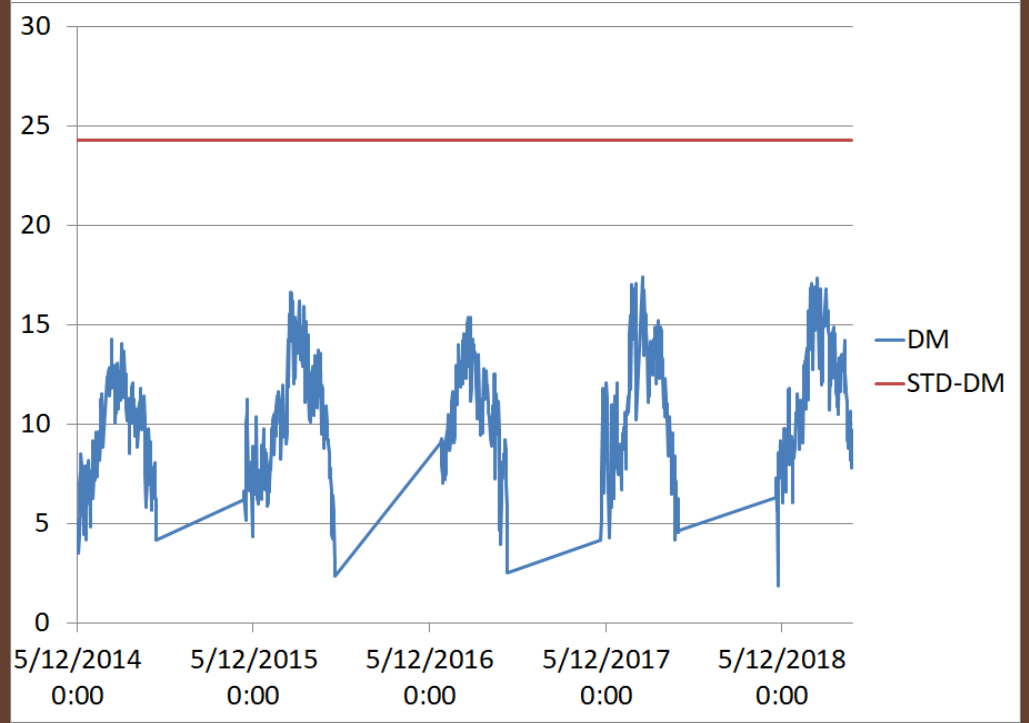
5/12/2016 0:00
5/12/2017 0:00
5/12/2018 0:00
DM
STD-DM

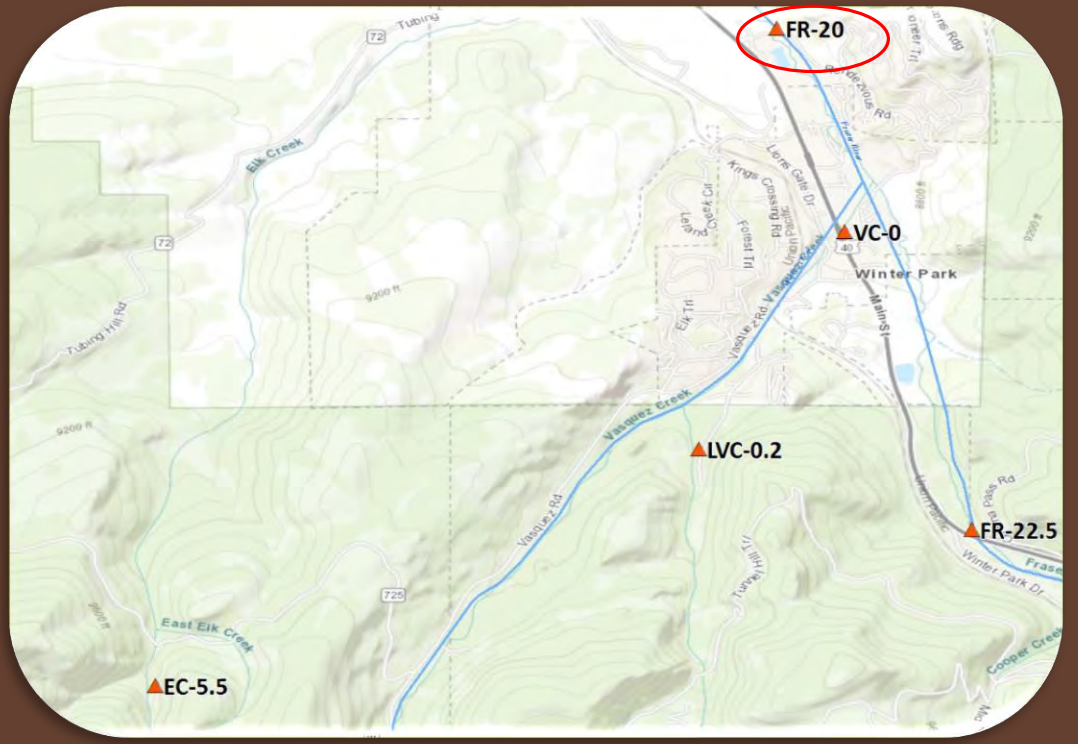
CSI
VC-WP
VC-0

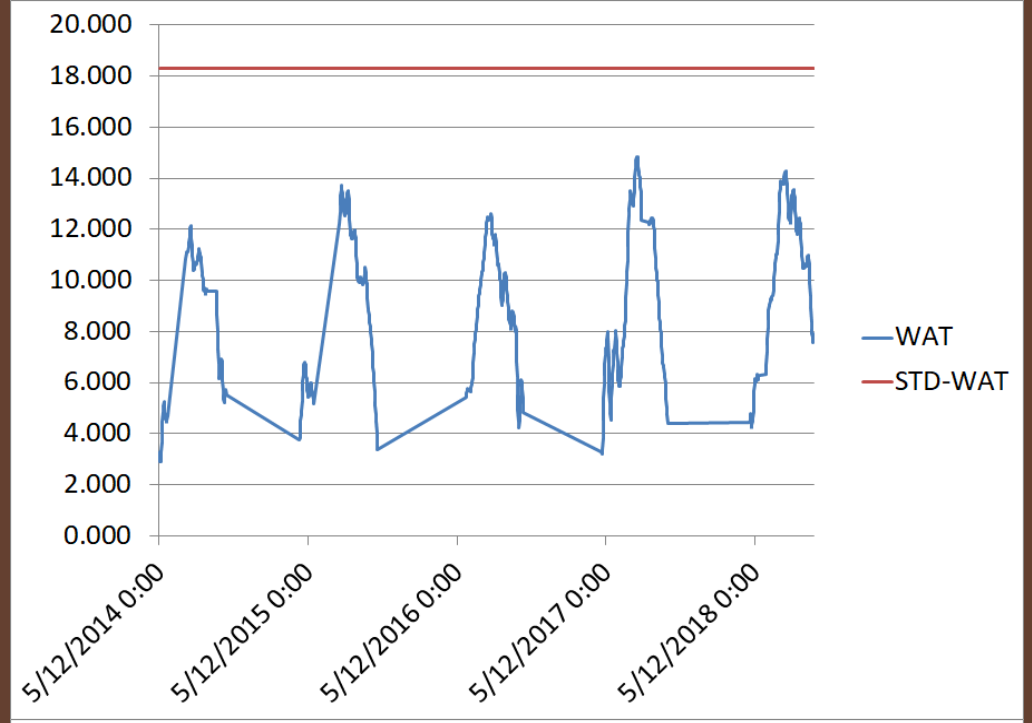

FR-20
VC-0
Winter Park
LVC-0.2
FR-22.5
EC-5.5
Elk Creek
Vasquez Creek
East Elk Creek
Tubing Hill Rd
Vasquez Rd
Main St
Winter Park Dr
Fraser
Cooper Creek
72
725

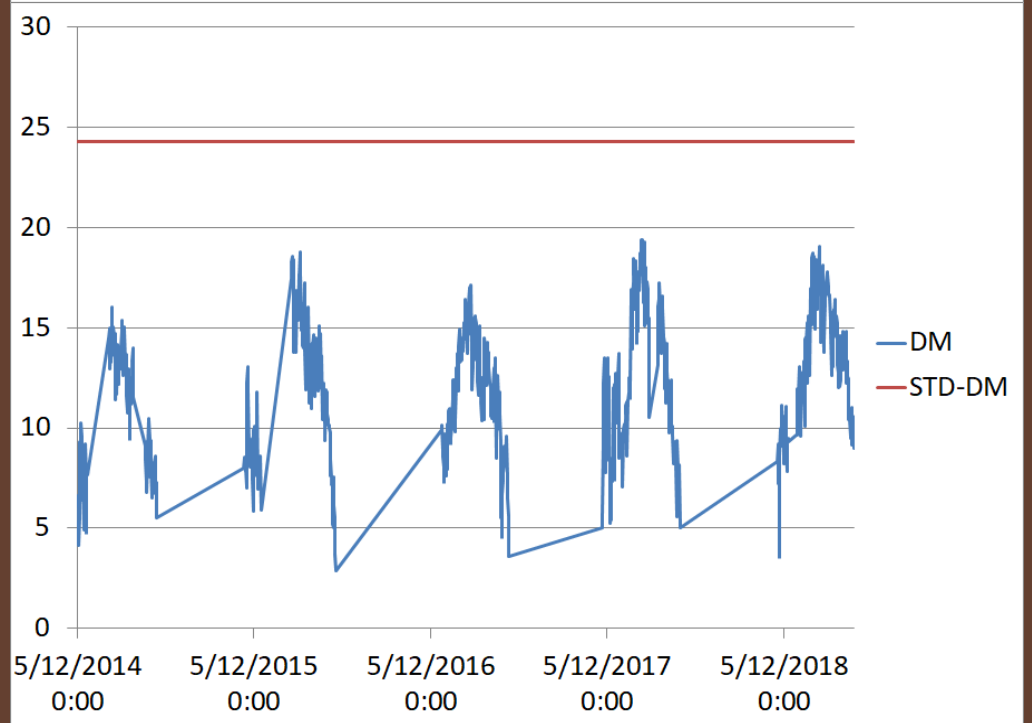




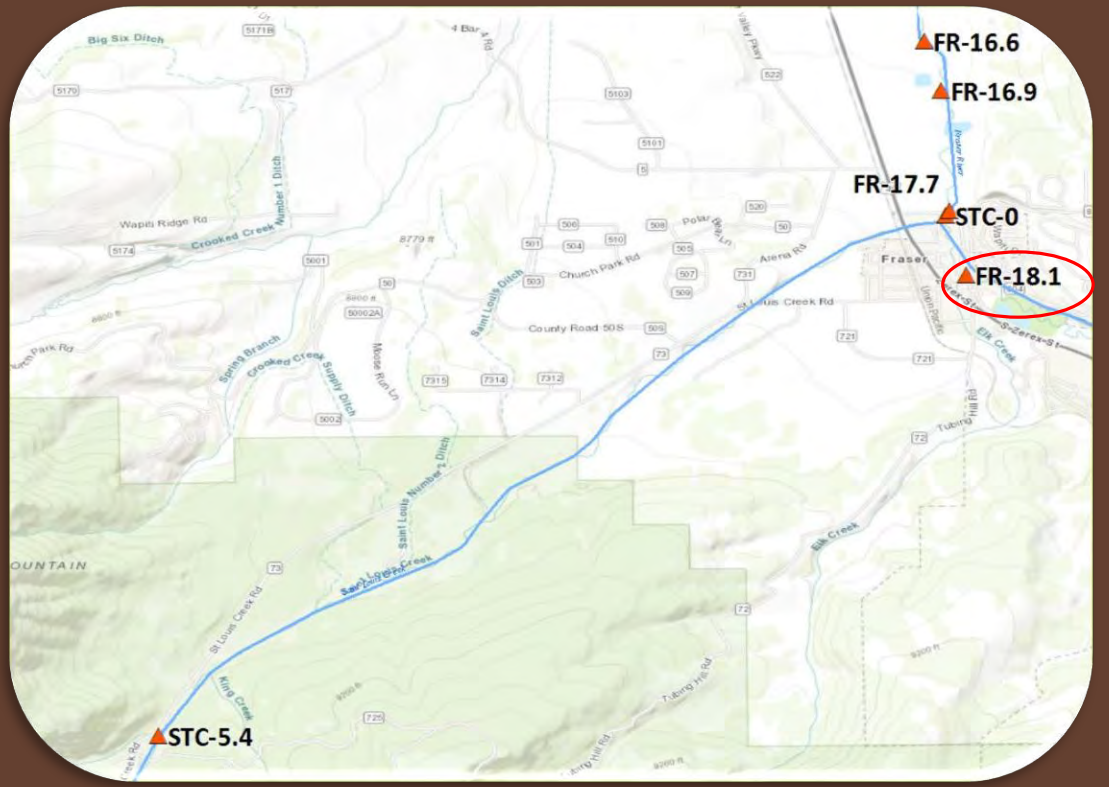
CSII
FR-Rendezvous
FR-20

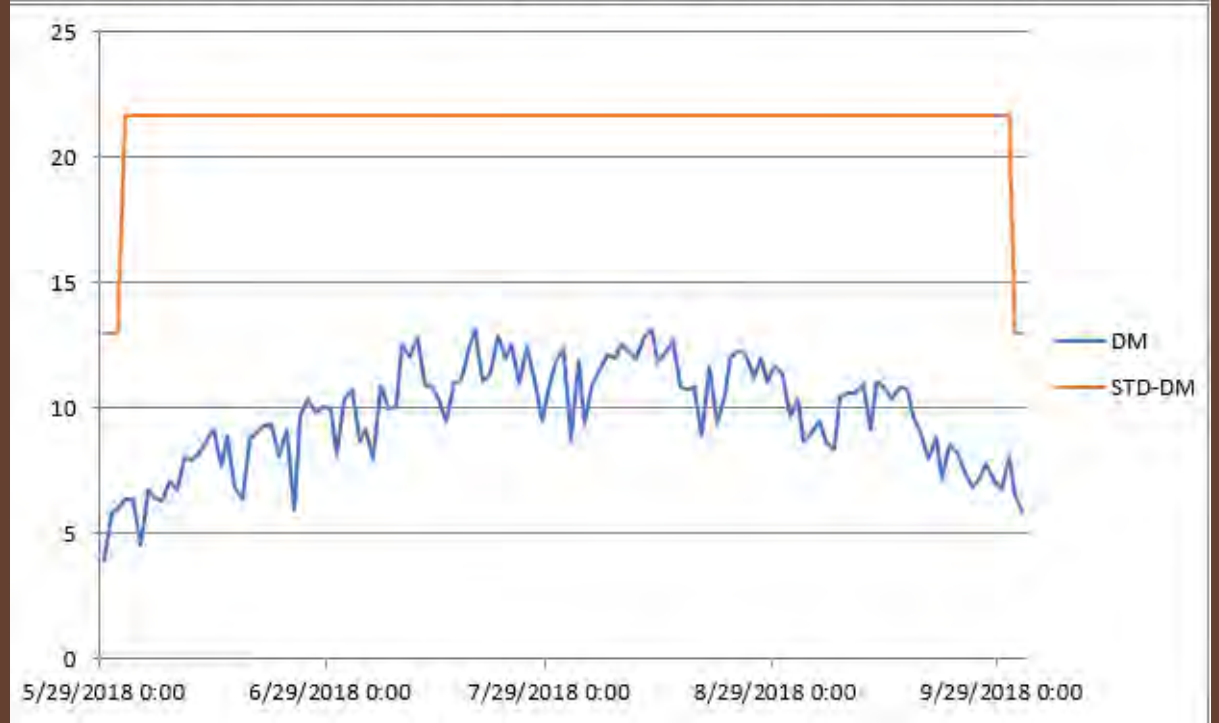




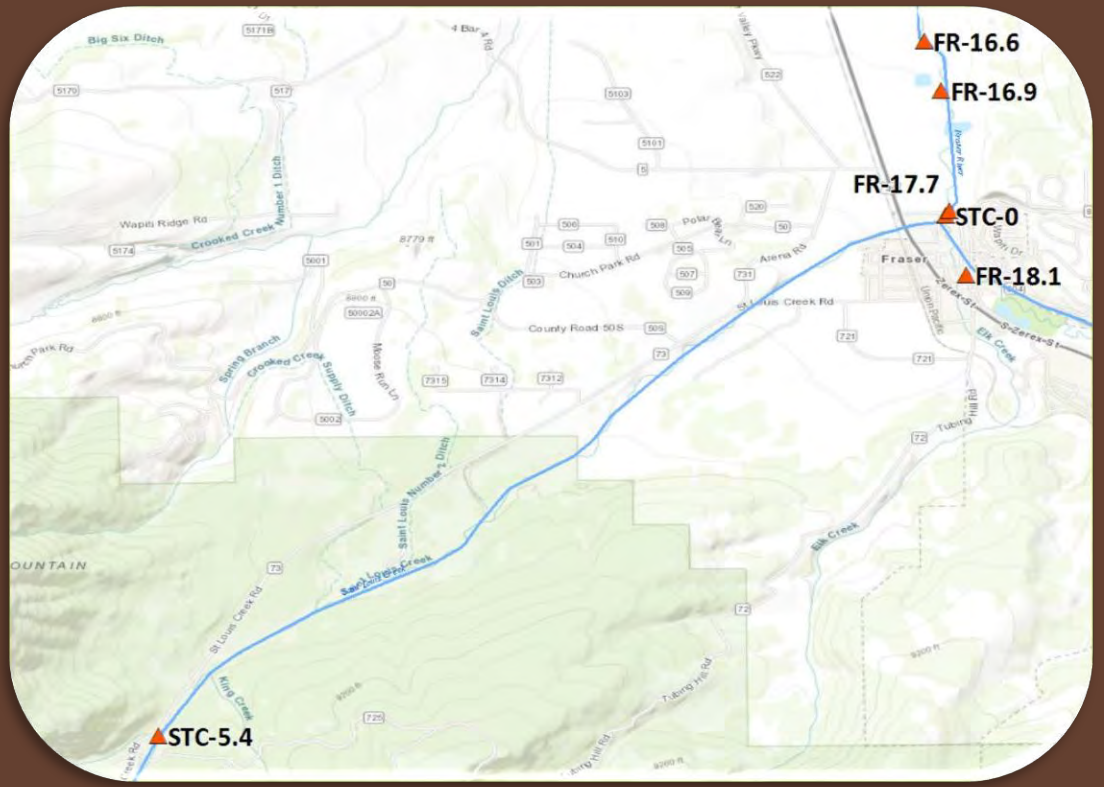


CSII
FR-CR804
FR-18.1

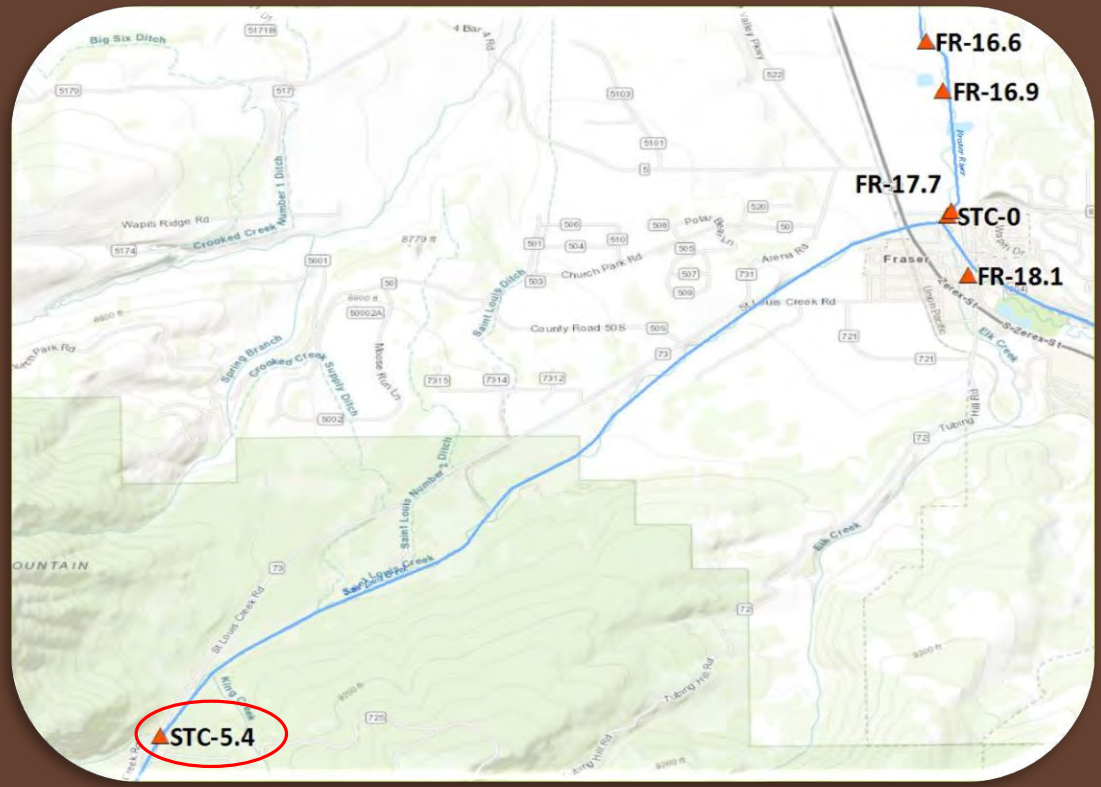


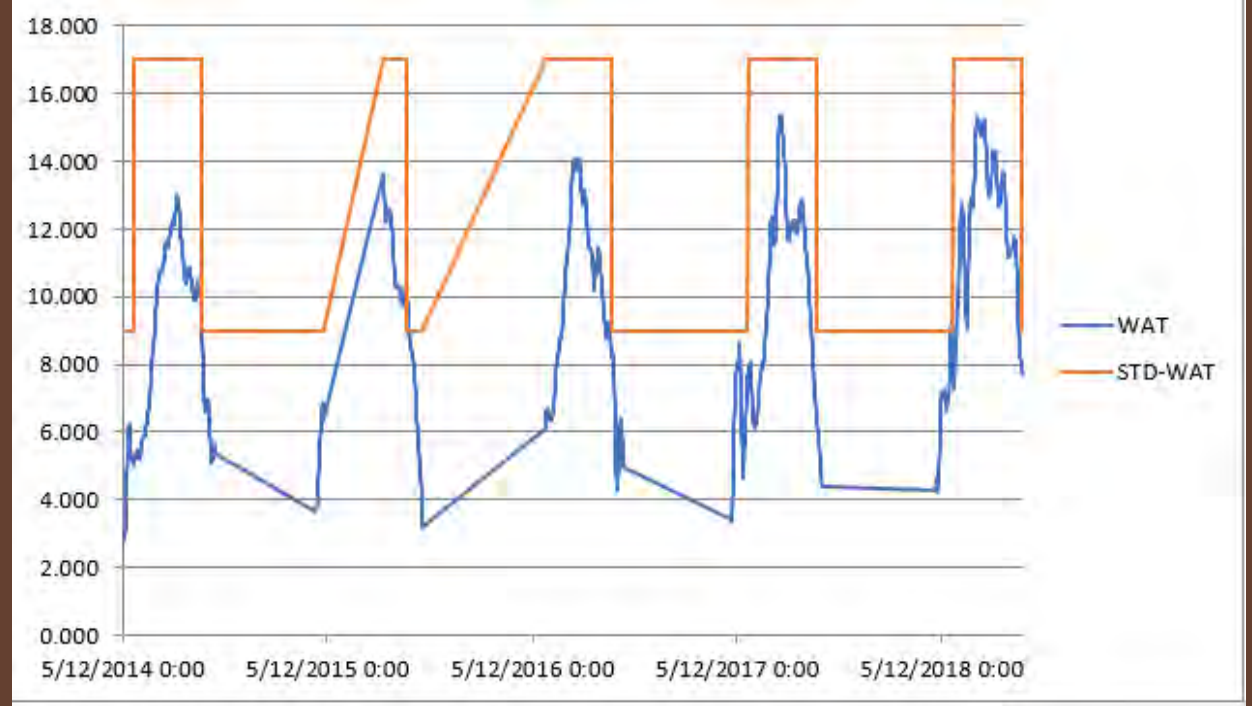


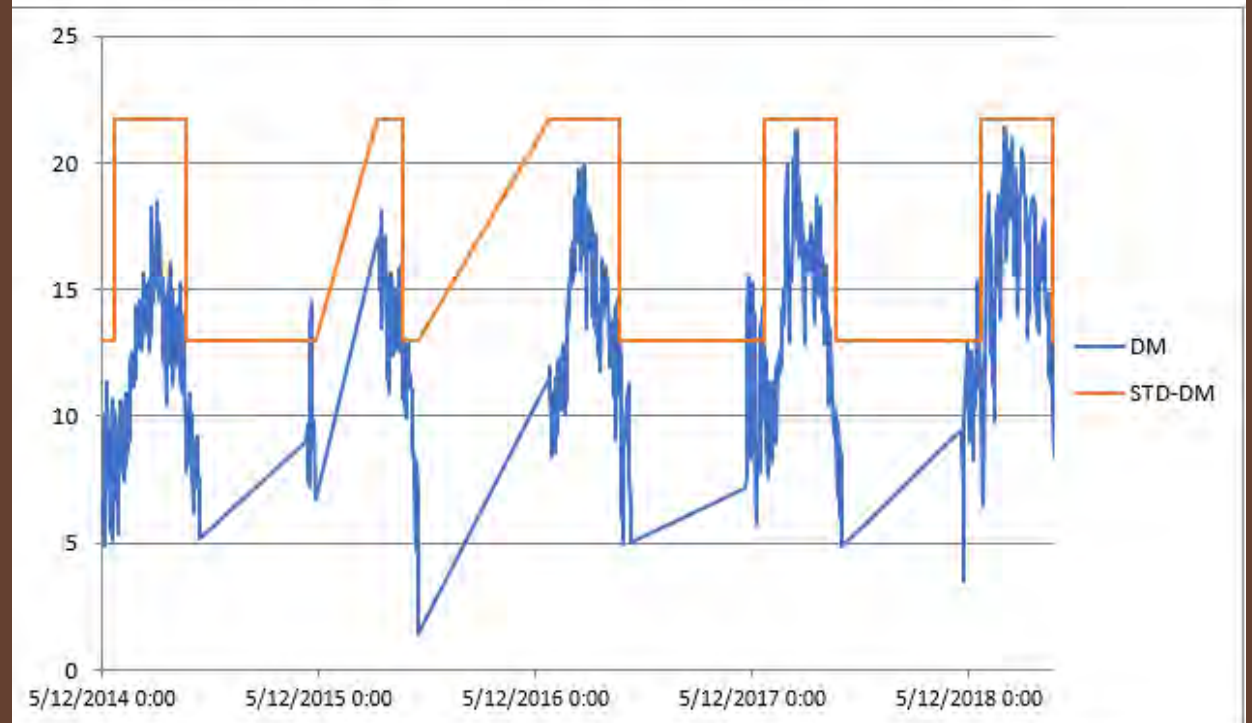
CSI
STC-blwDWB
STC-9.8



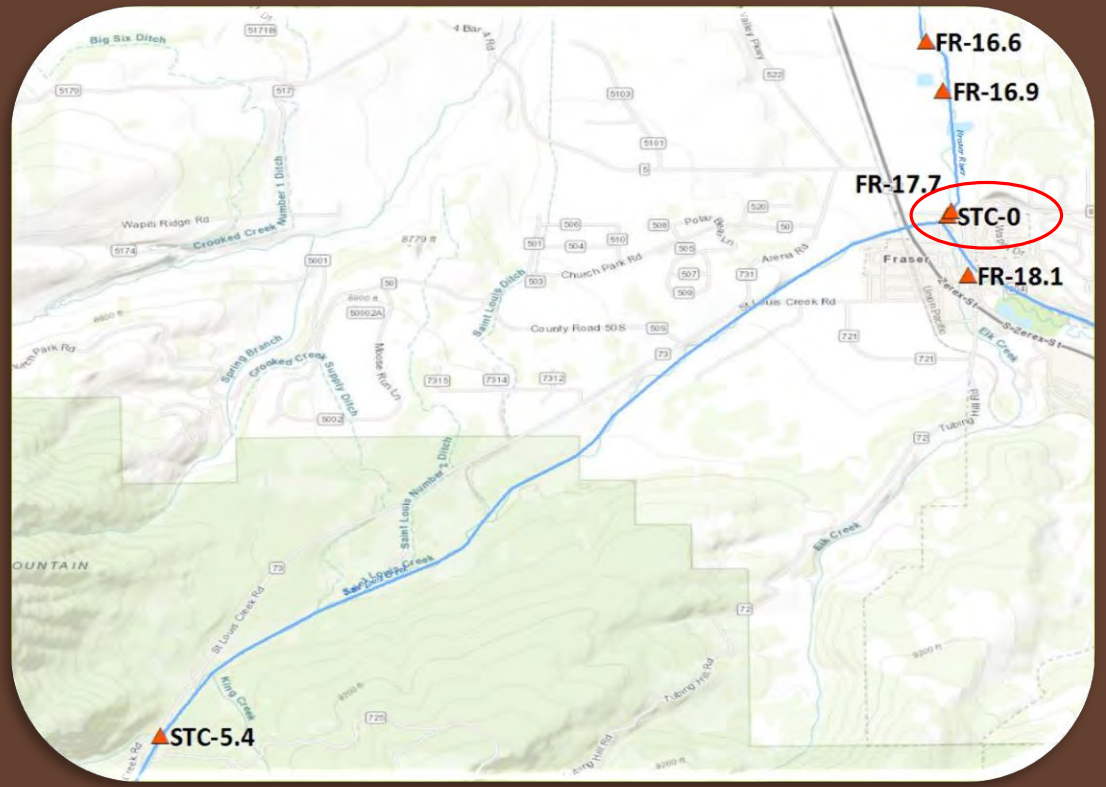
CSI
STC-Mid
STC-5.4

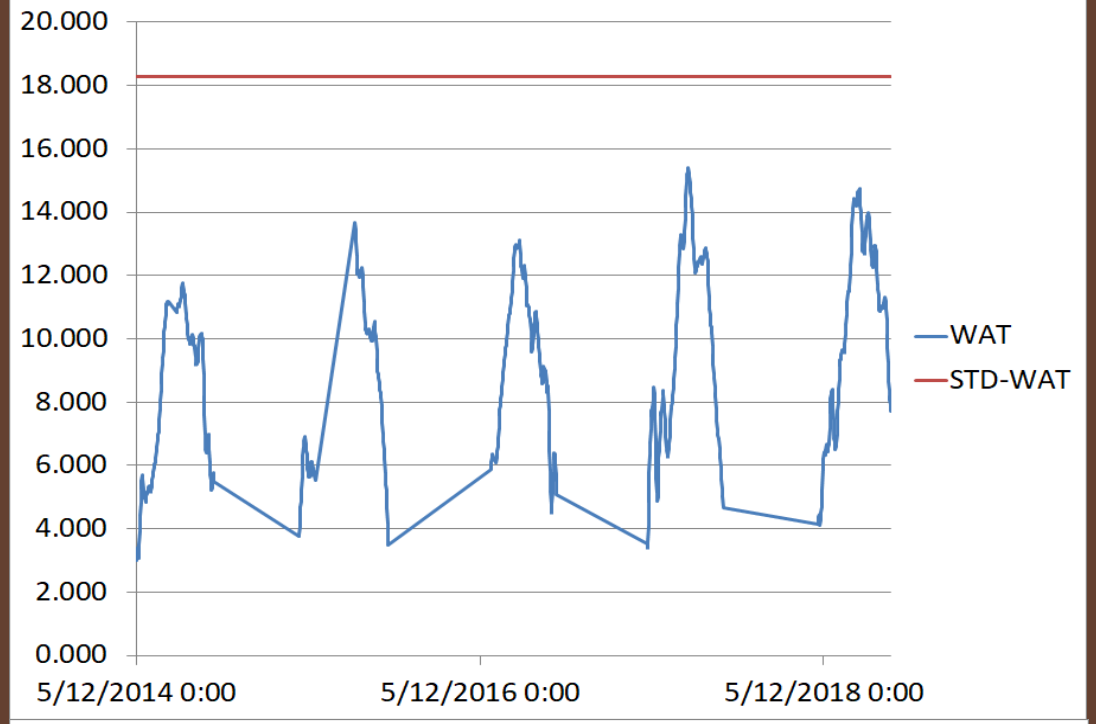


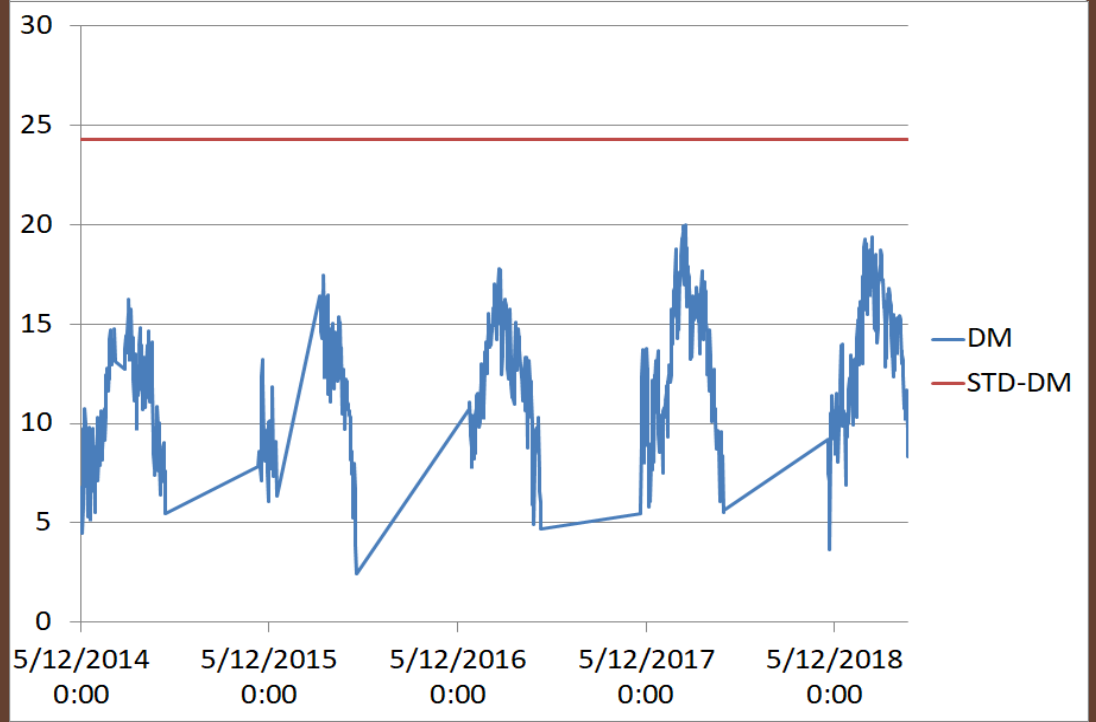




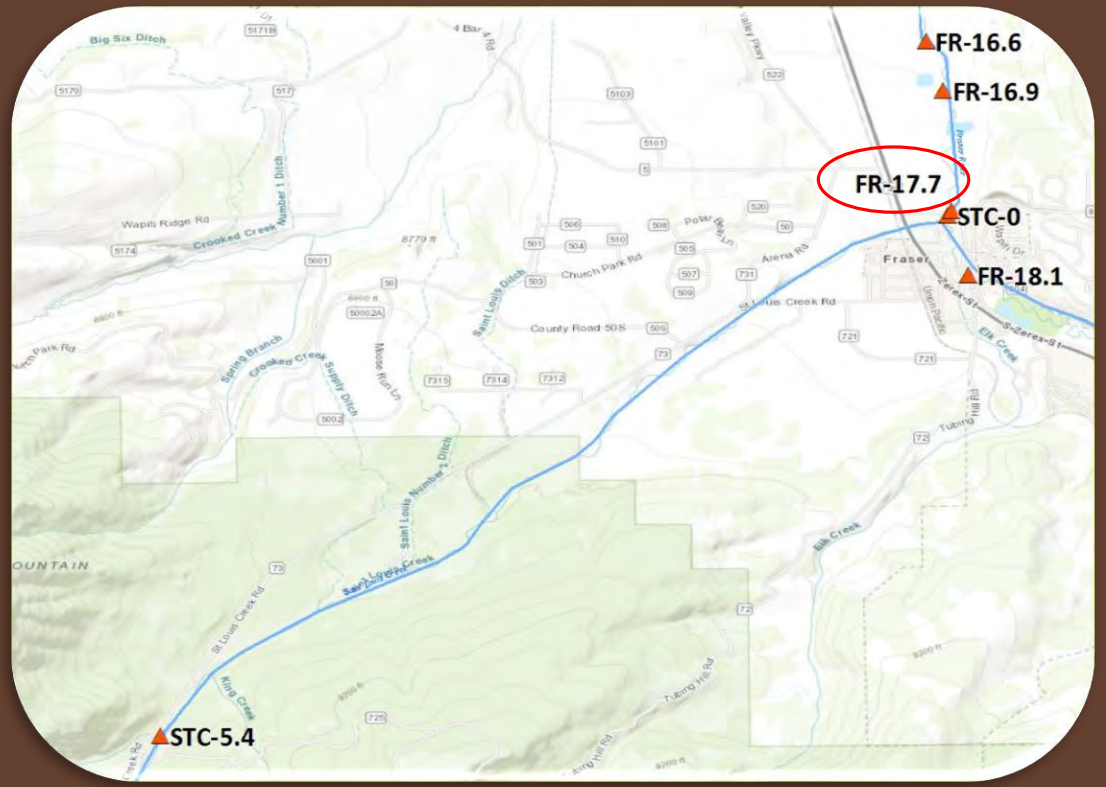
CSI
ST-LC
STC-0

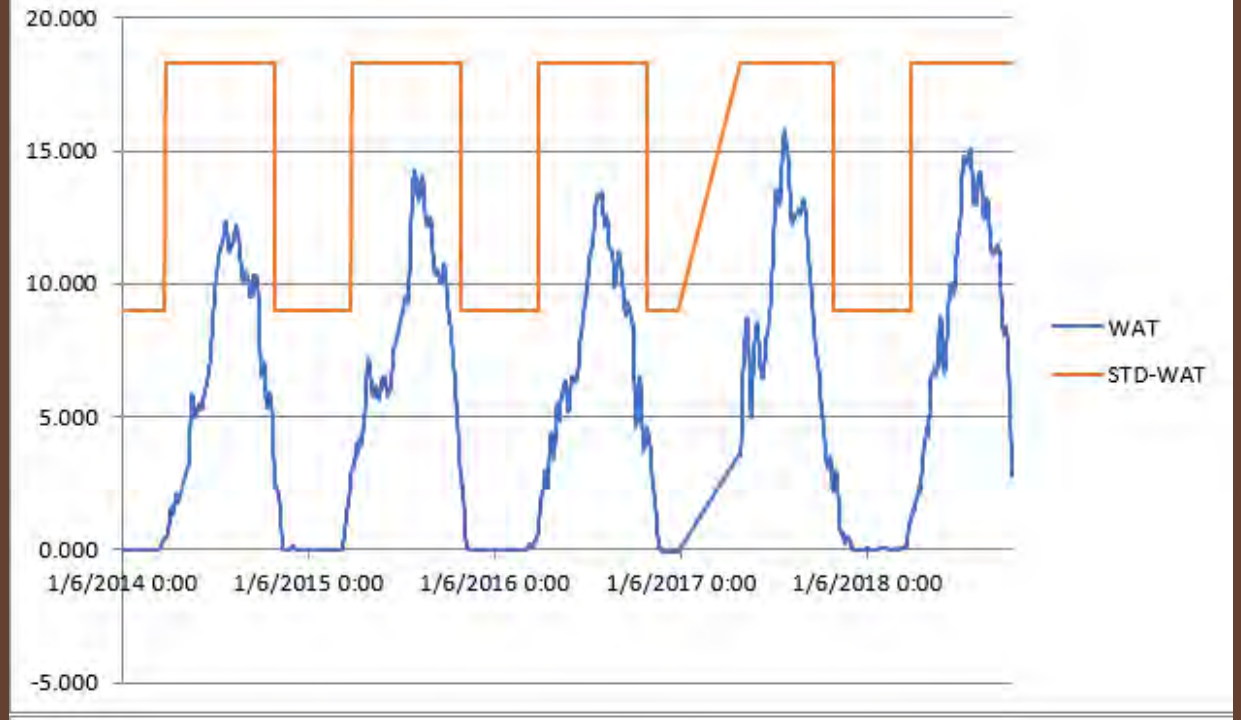


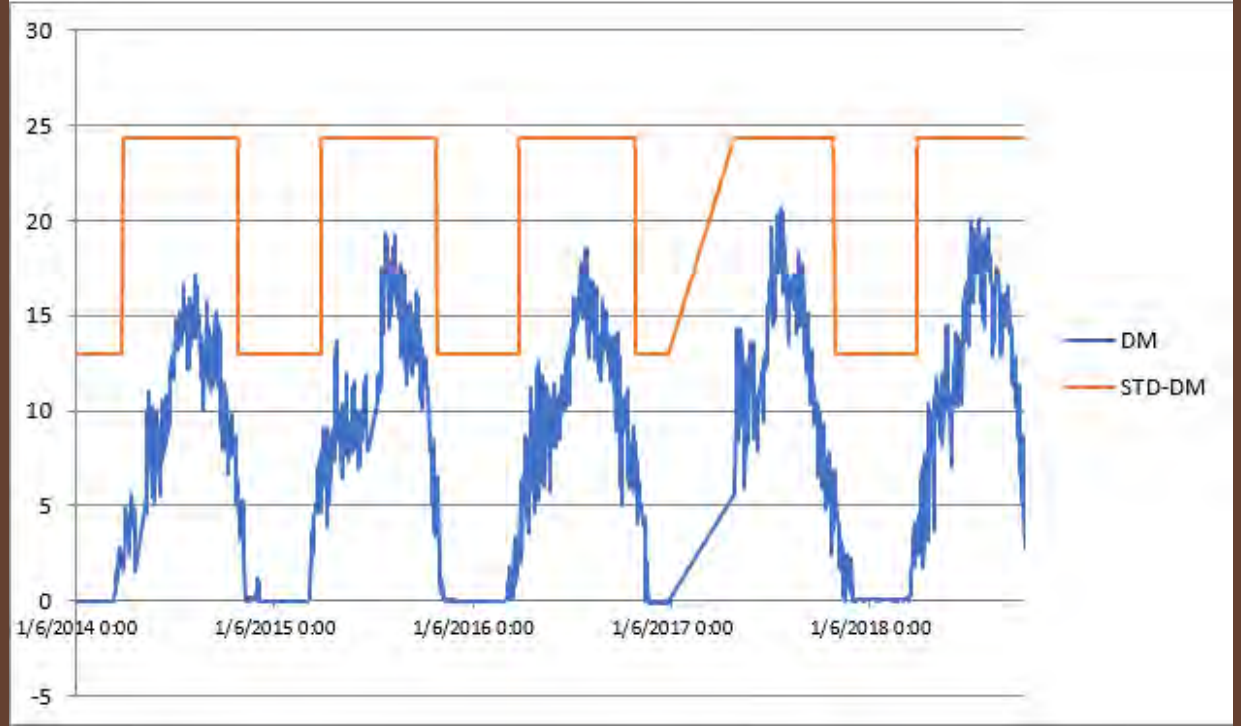




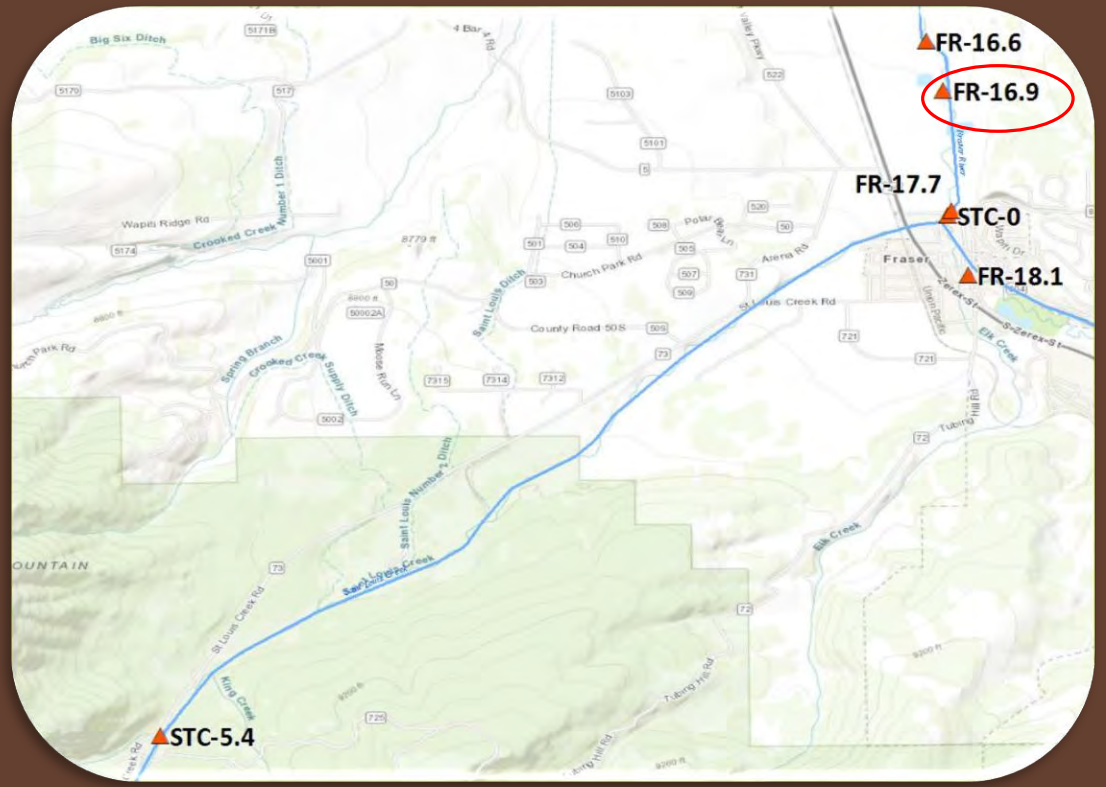
CSII
FR-blwCR8HD
FR-17.7

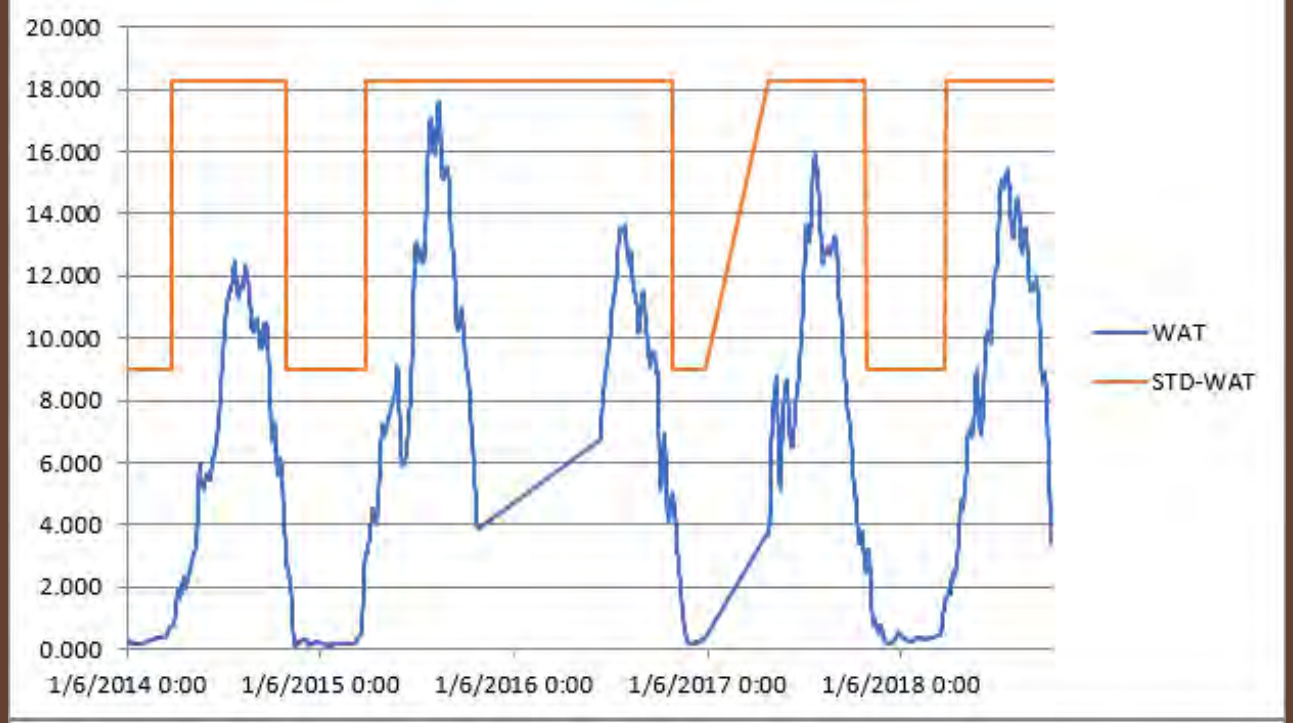


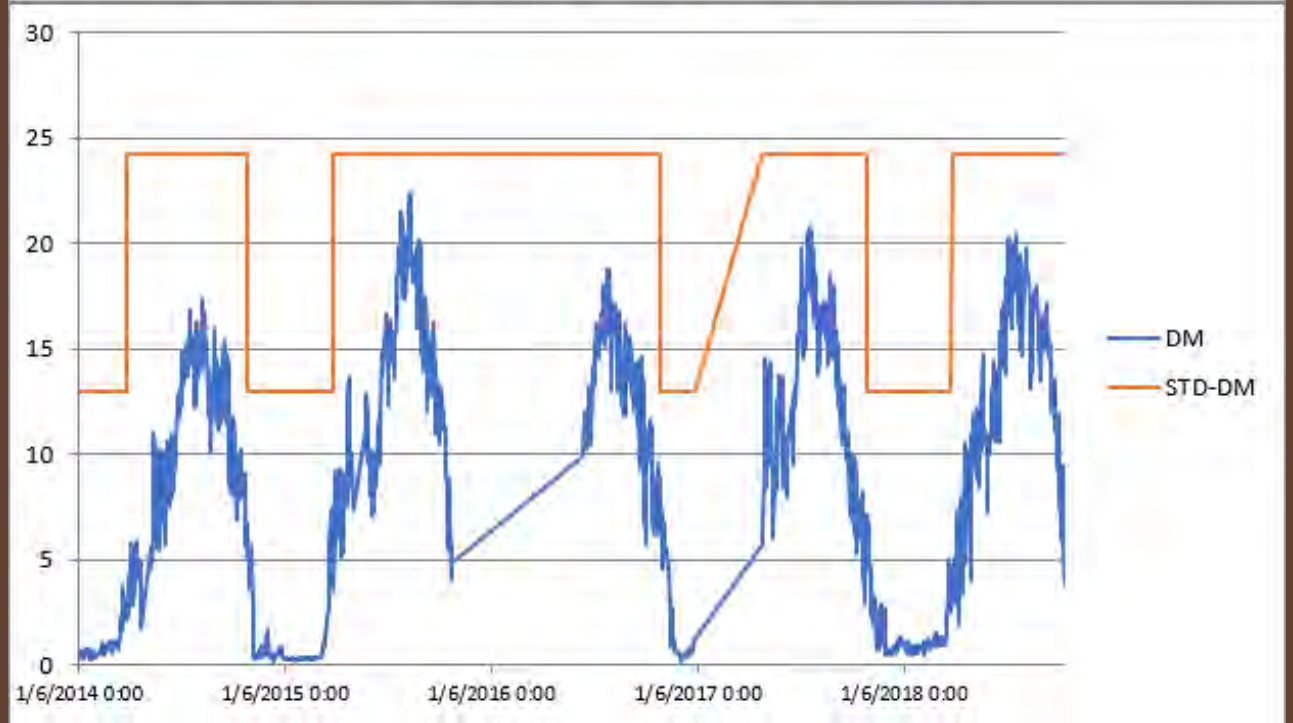




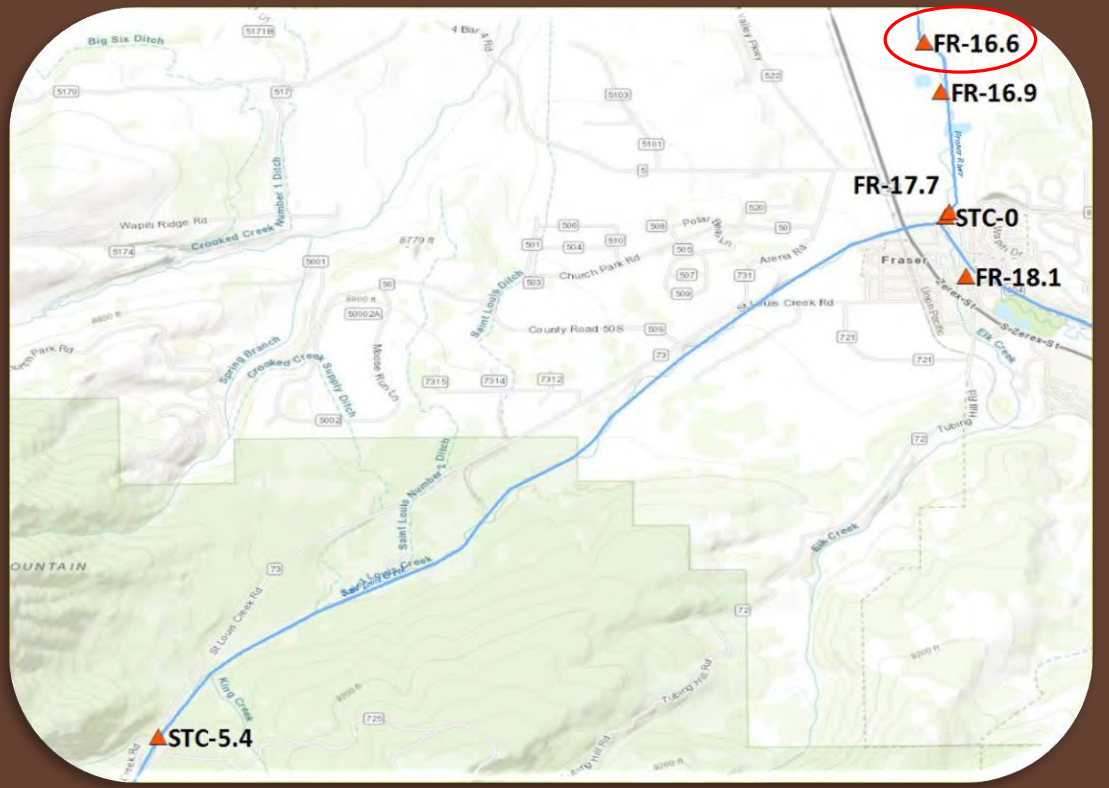
CSII
FR-abvFSD
FR-16.9



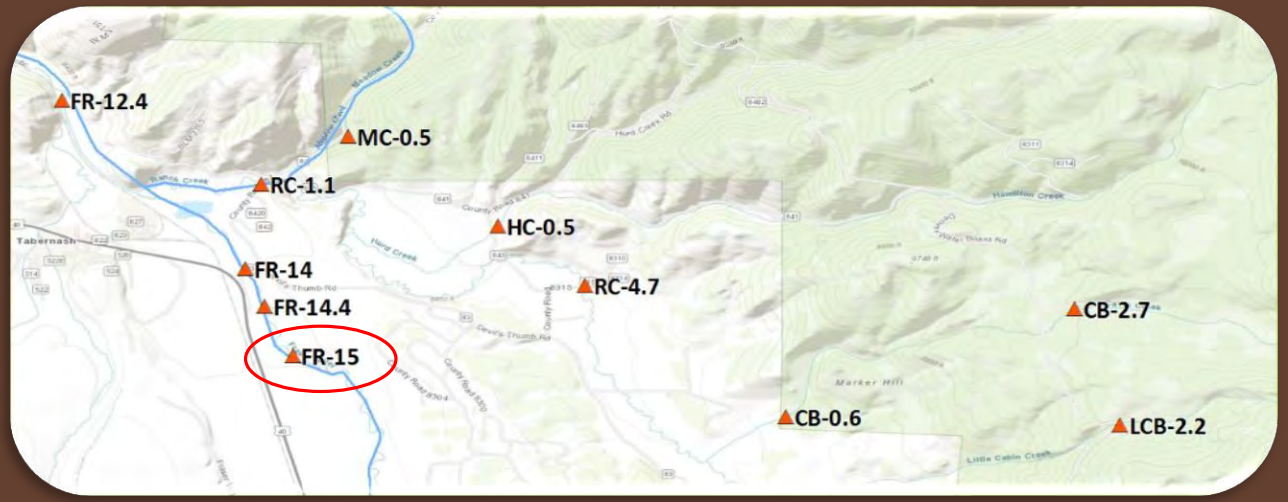




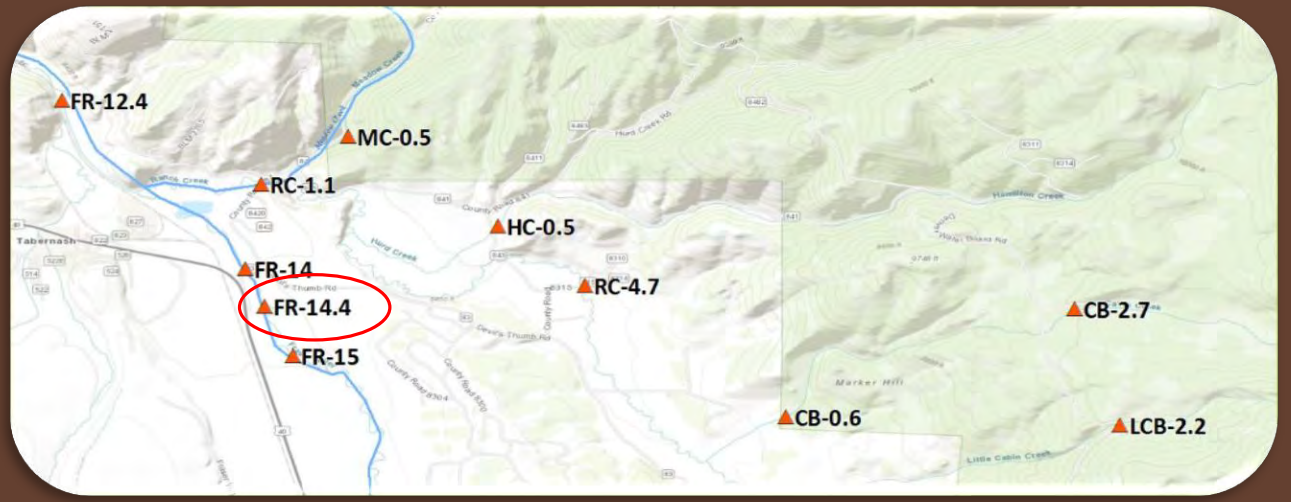
CSII
FR-blwFSD
FR-16.6

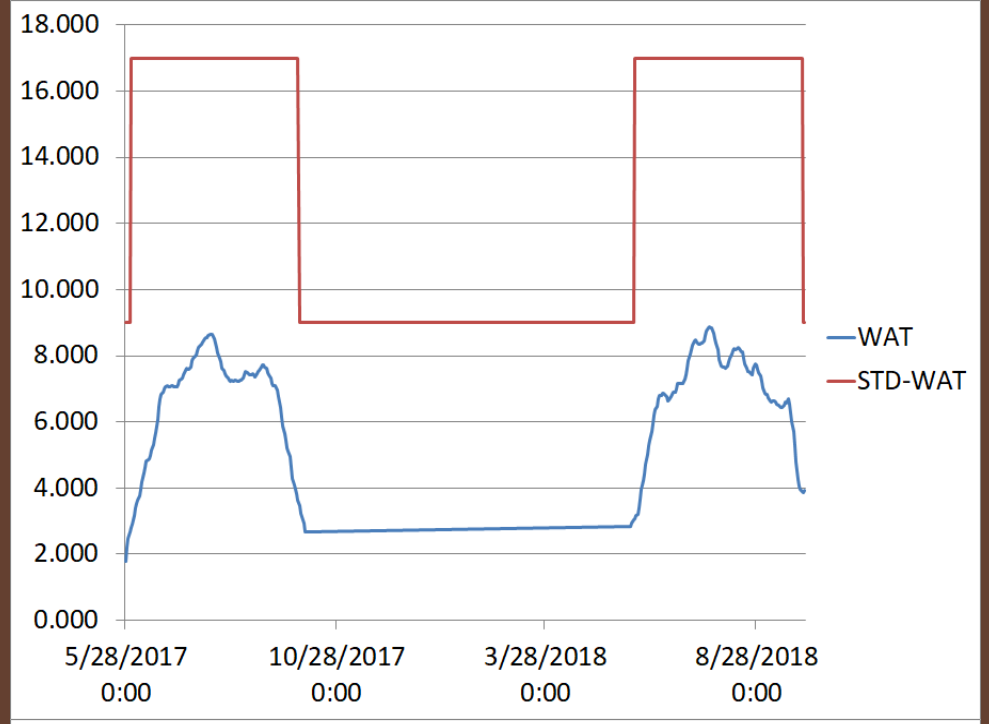


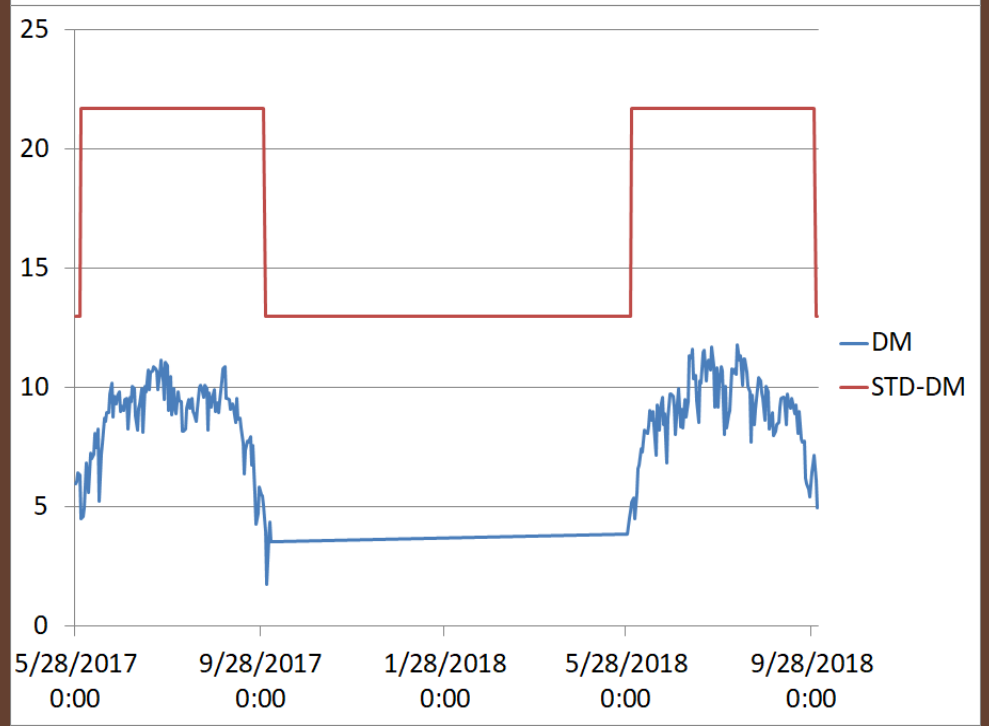
CSII
FR-SpProjU
FR-15



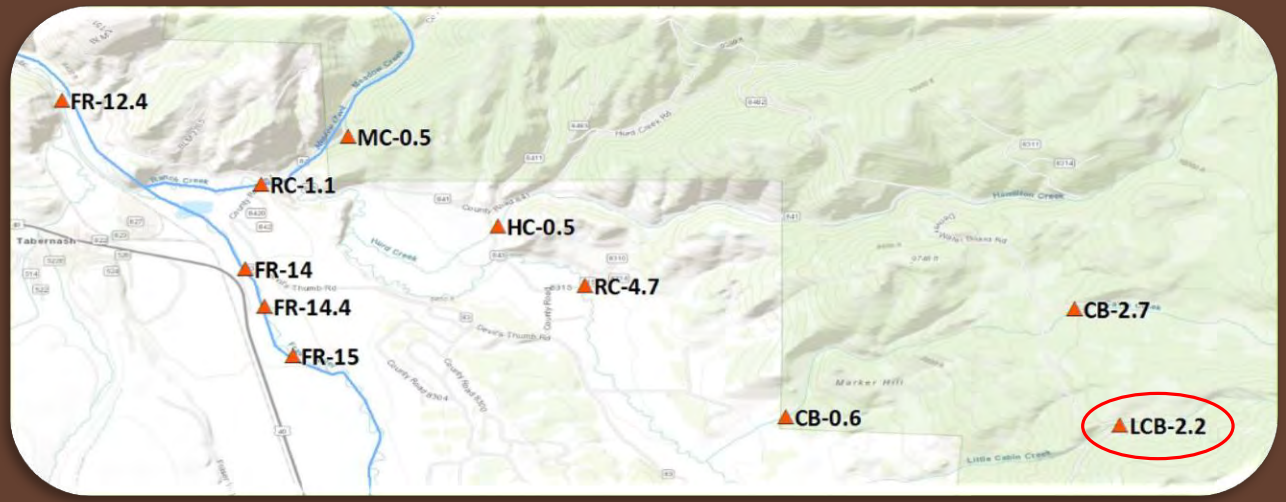
CSII
FR-SpProjD
FR-14.4

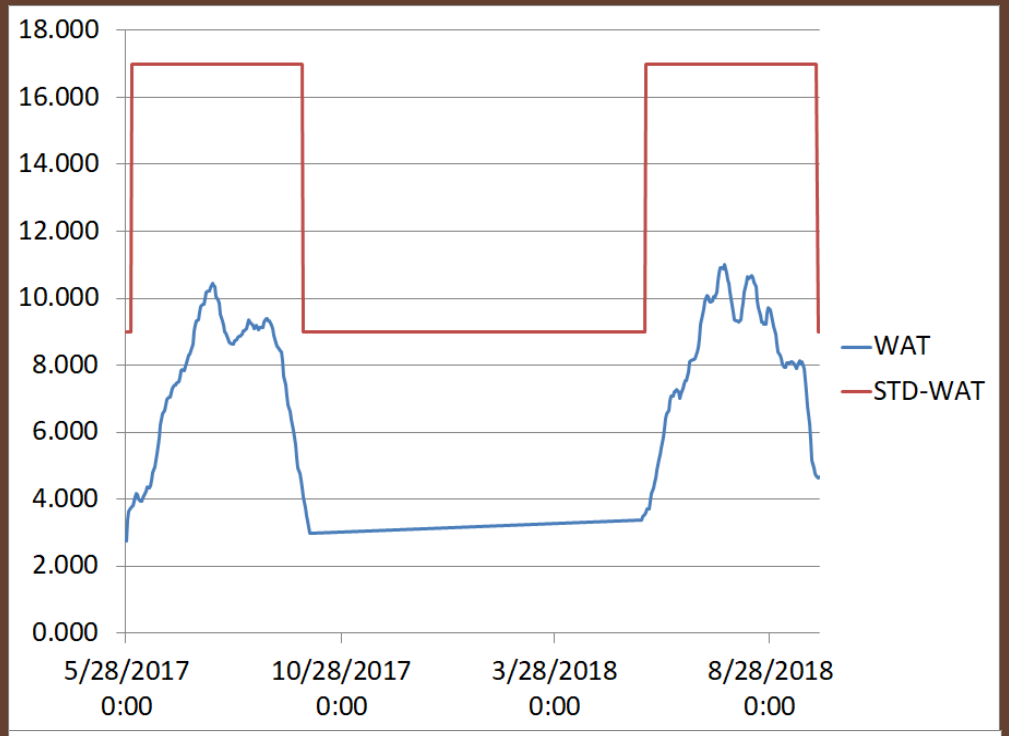


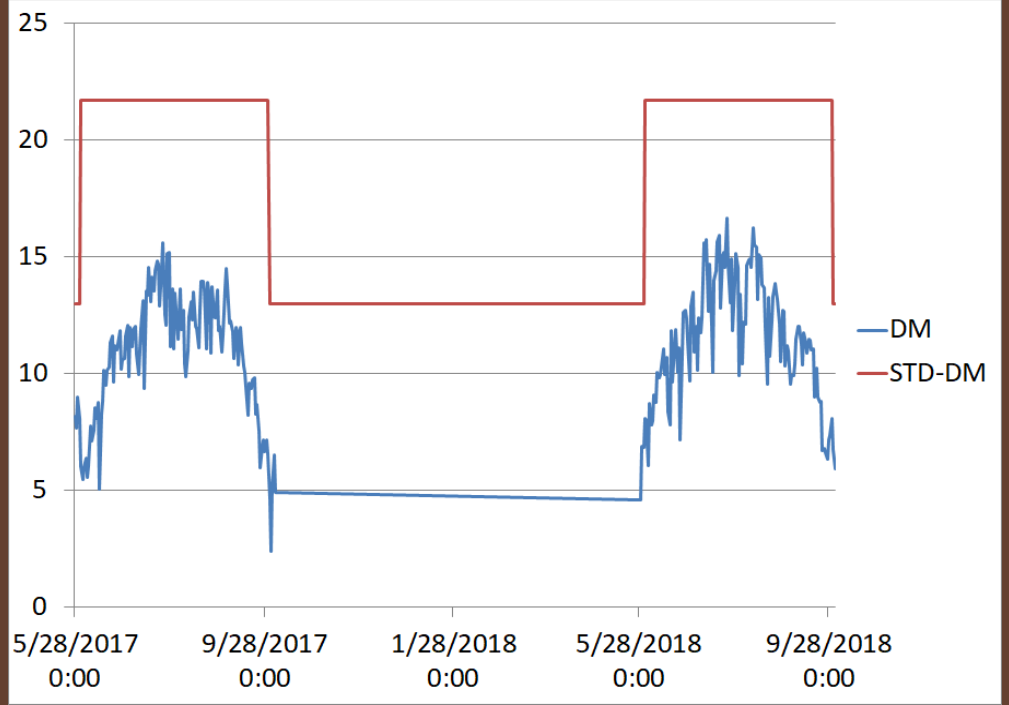




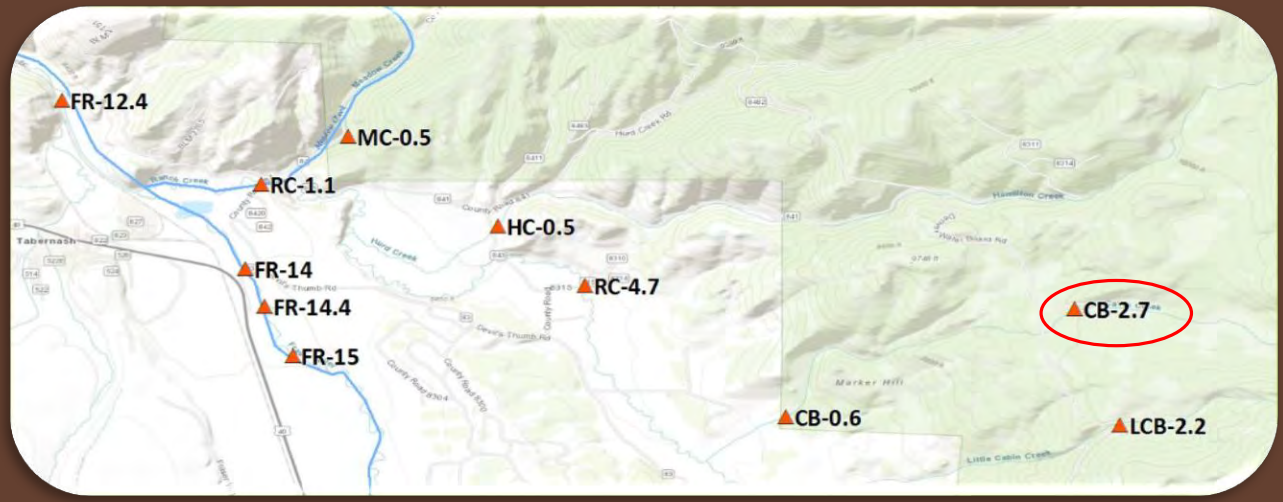
CSI
LCAB-blwDWB
LCB-2.2

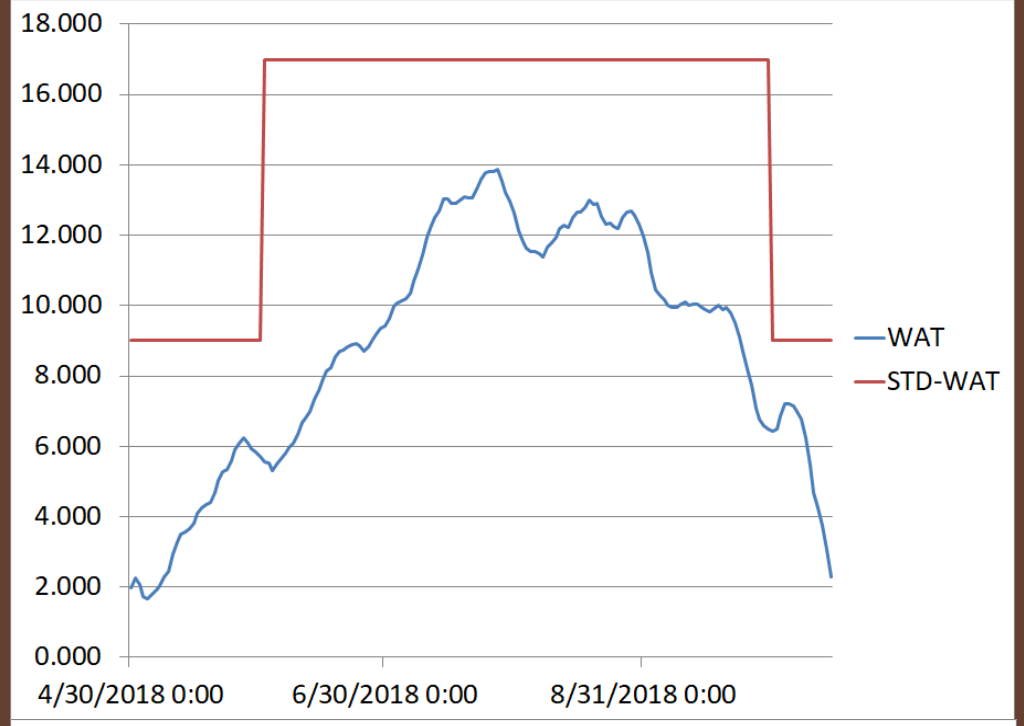


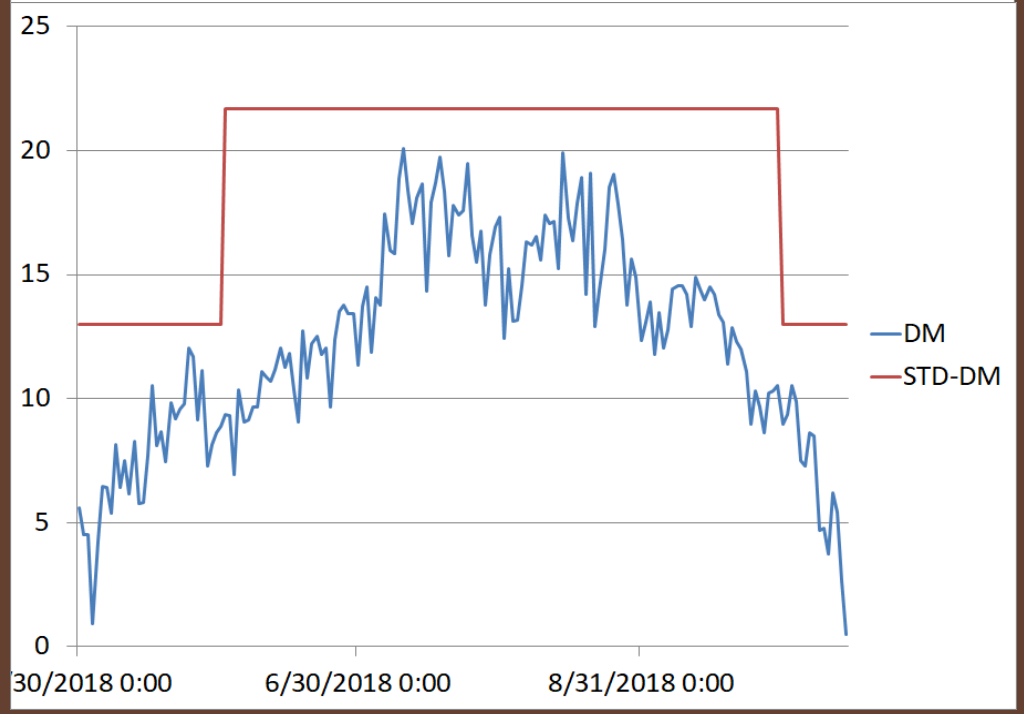




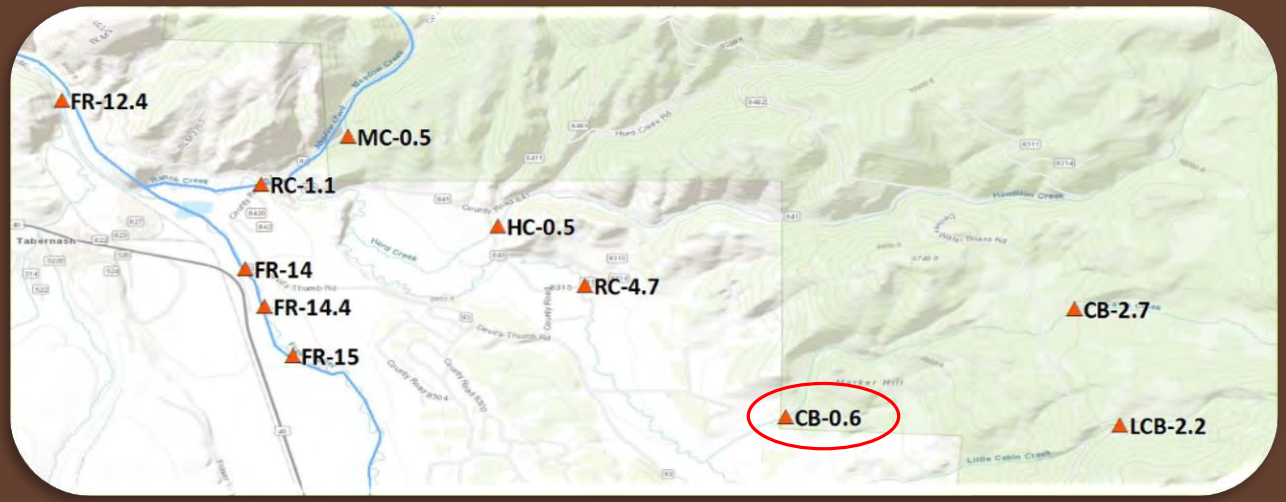
CSI
CAB-blwDWB
CB-2.7

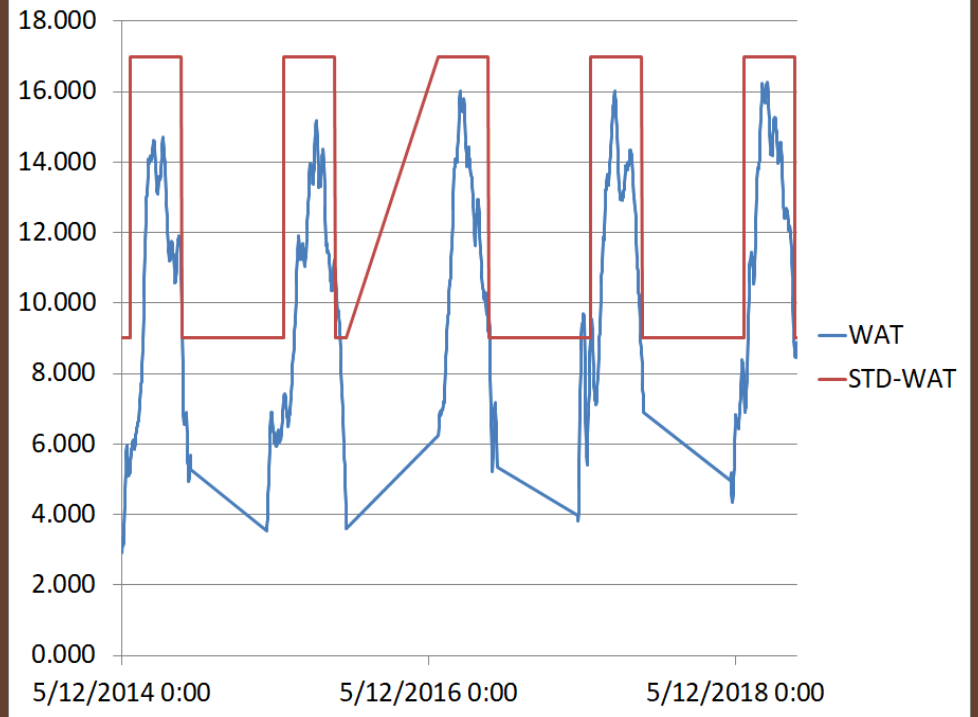


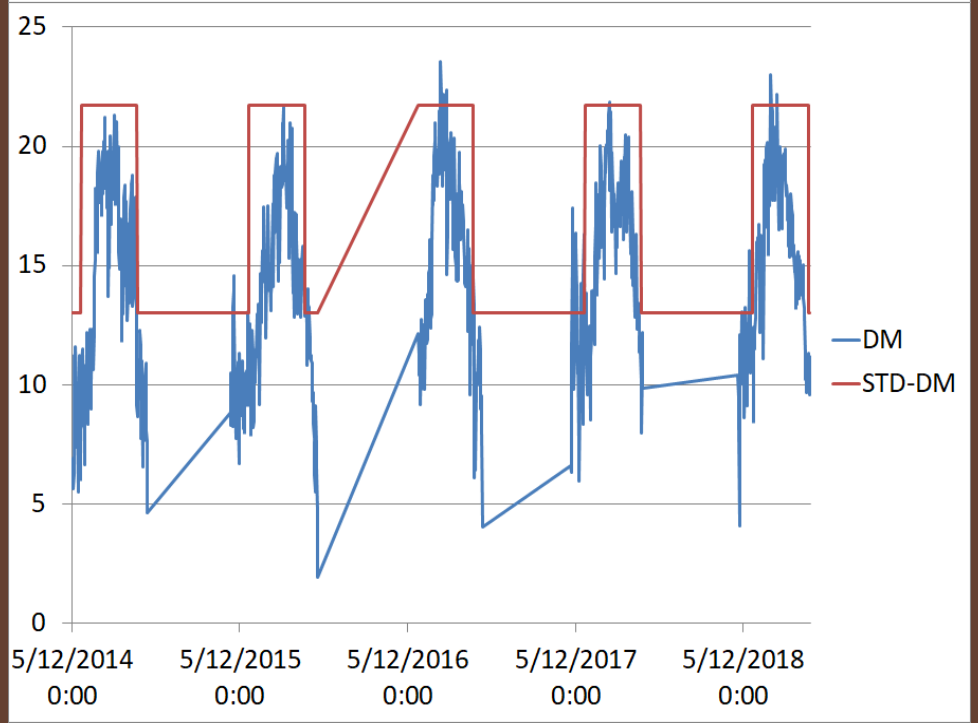




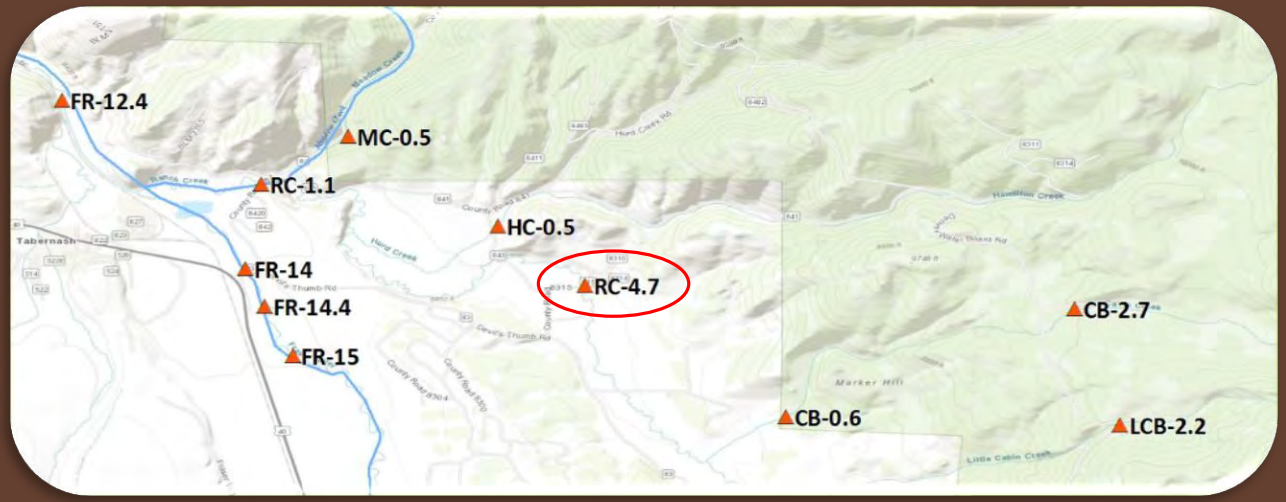
CSI
CAB-abvChan
CB-0.6

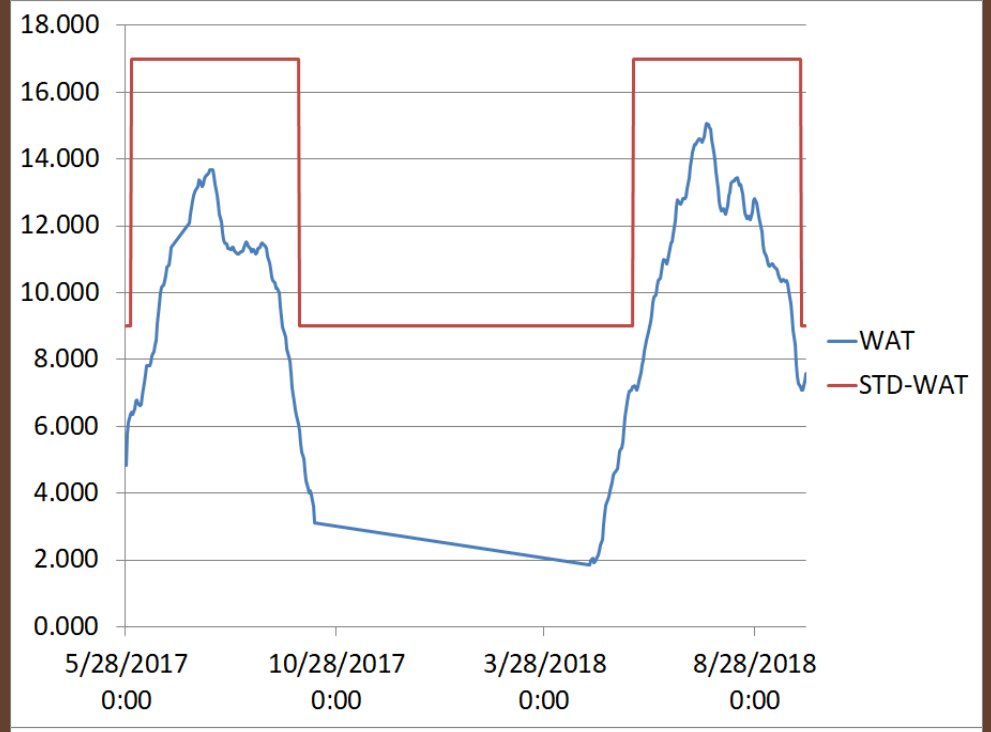


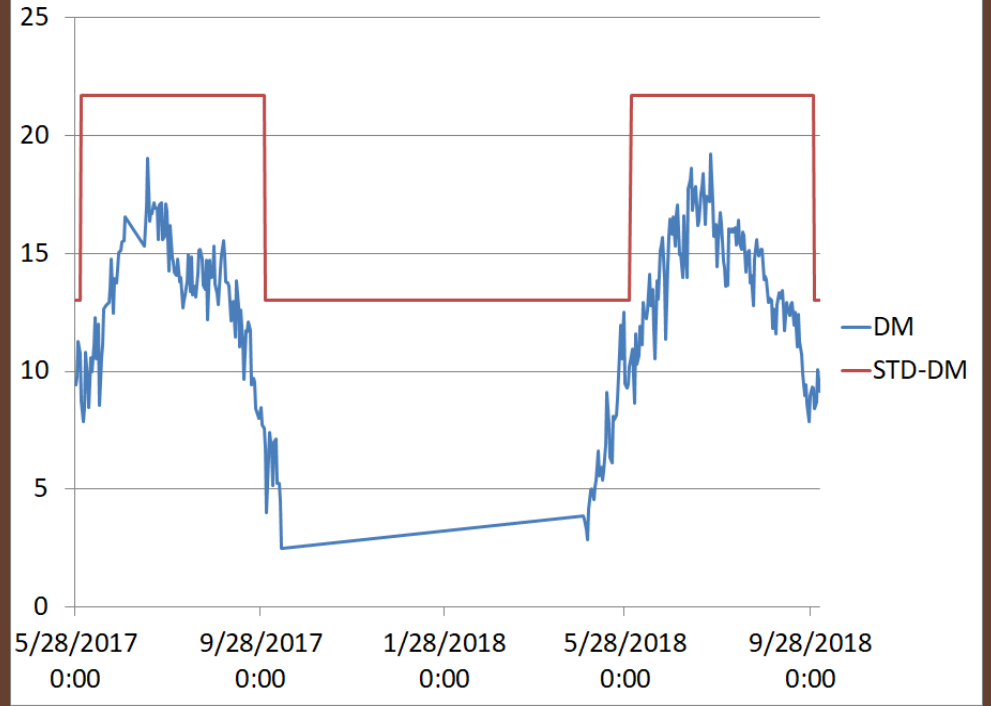




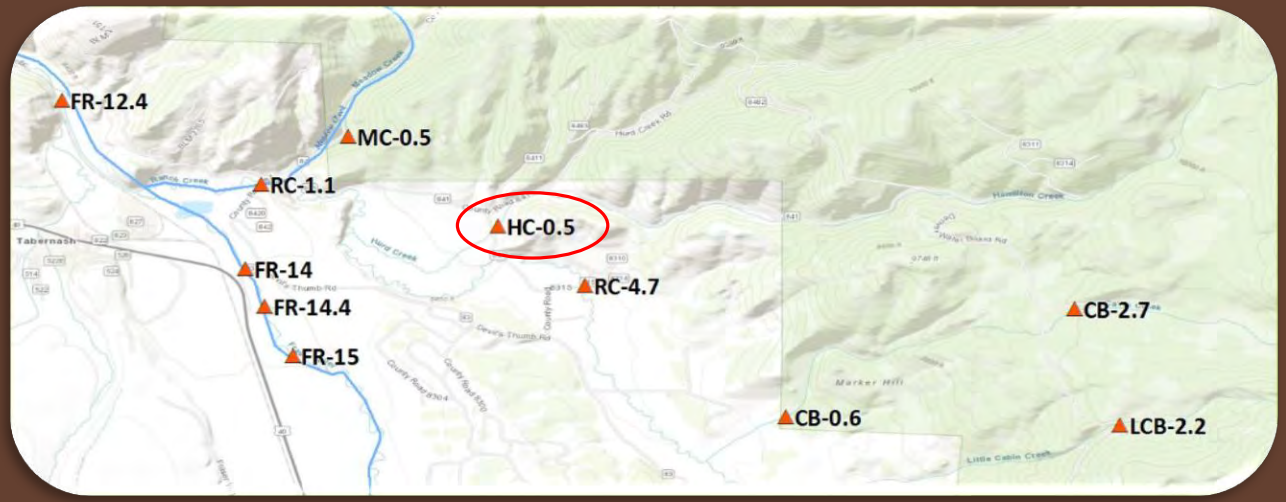
CSI
RC-blwCR8315
RC-4.7

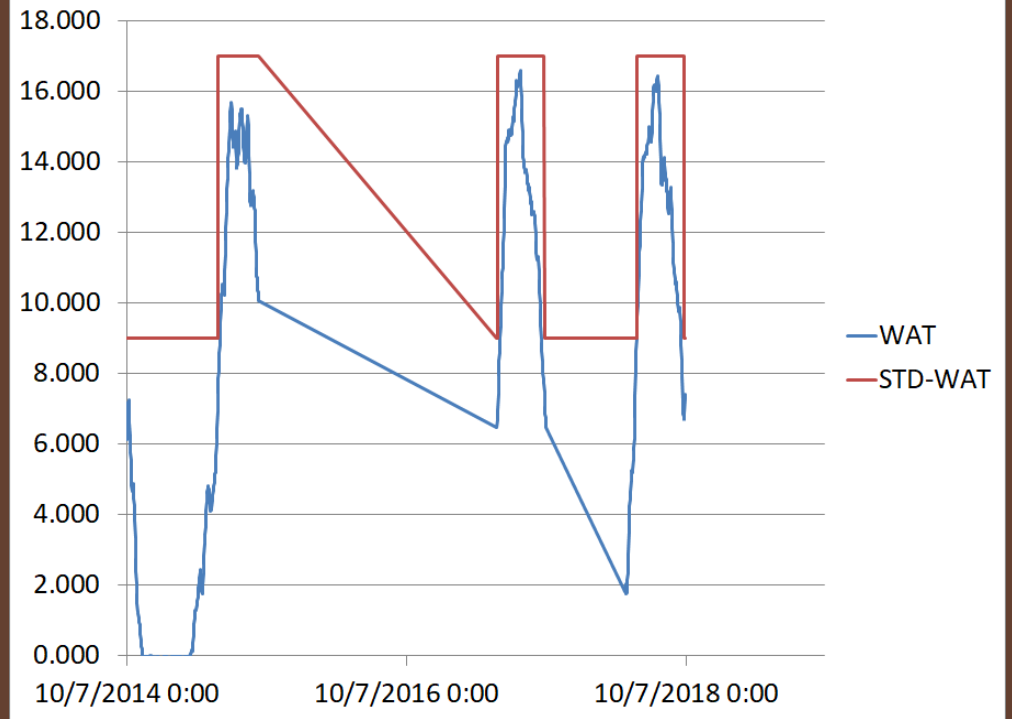


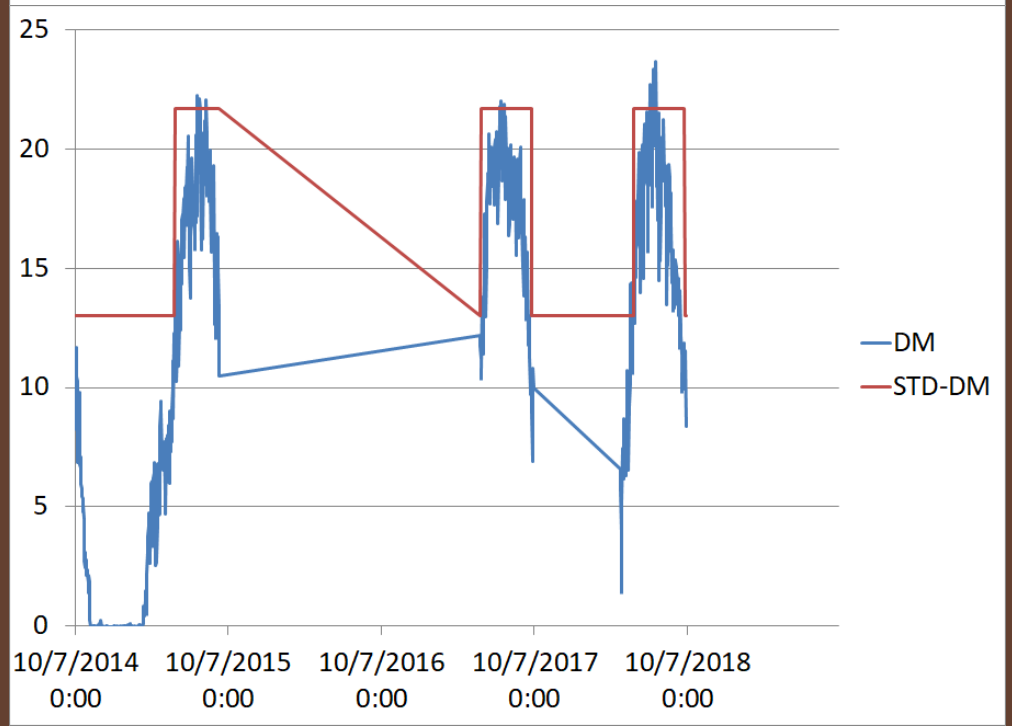




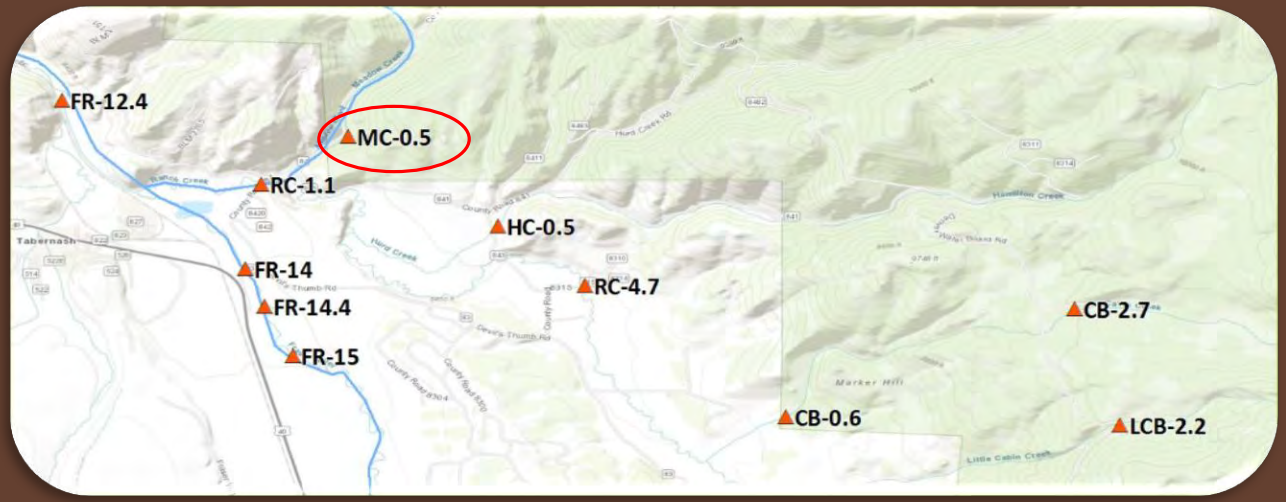
CSI
HRD-atCR843
HC-0.5

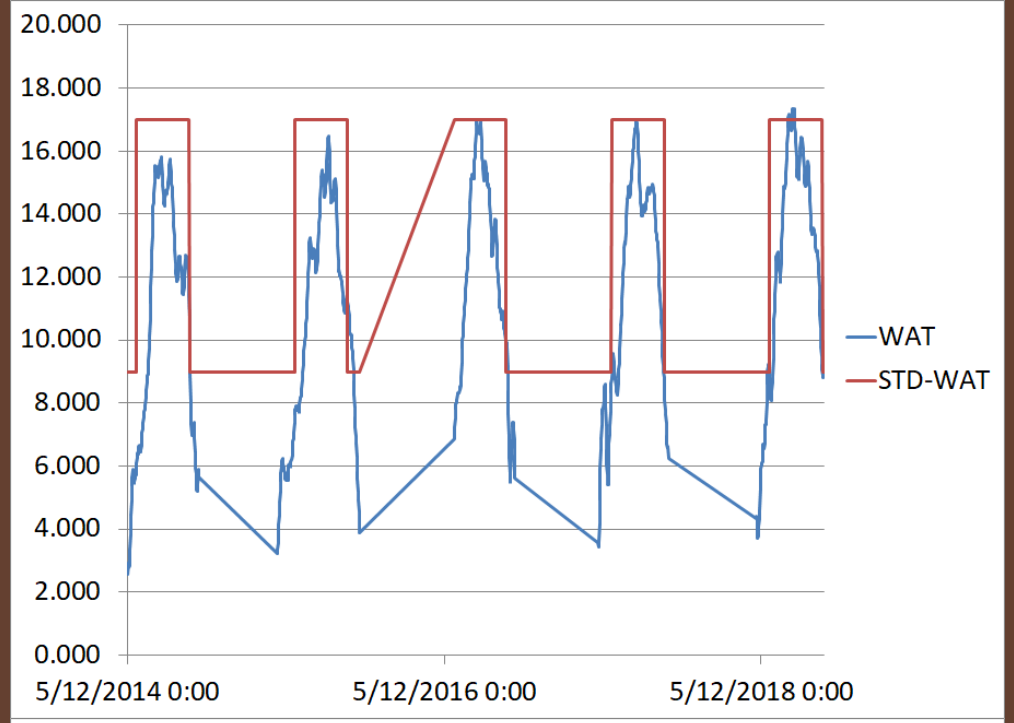


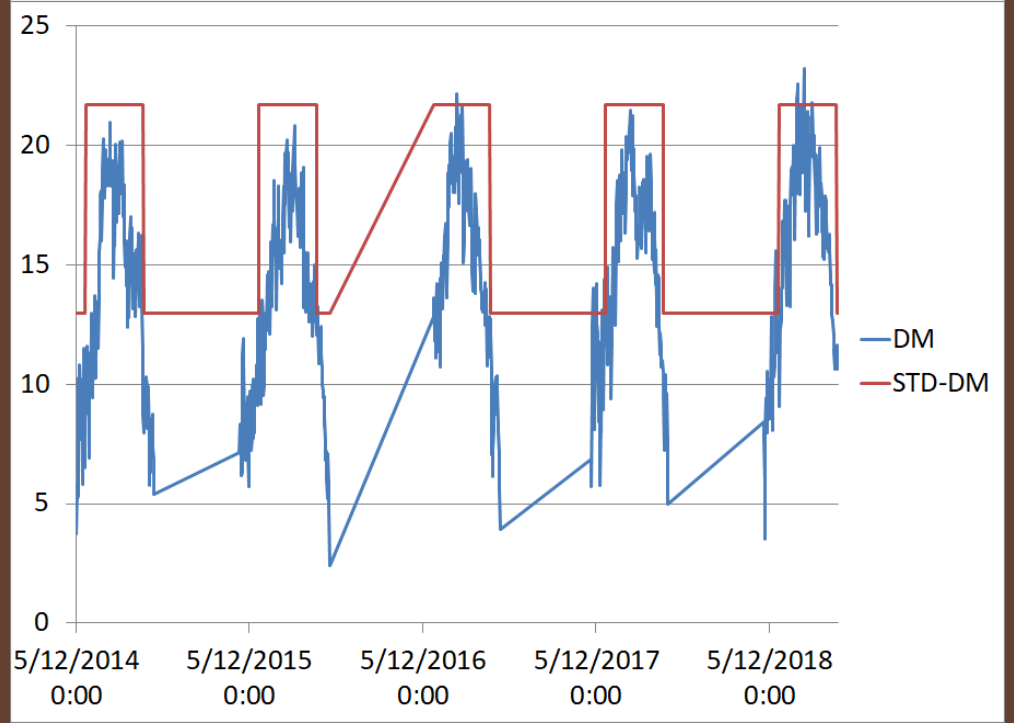




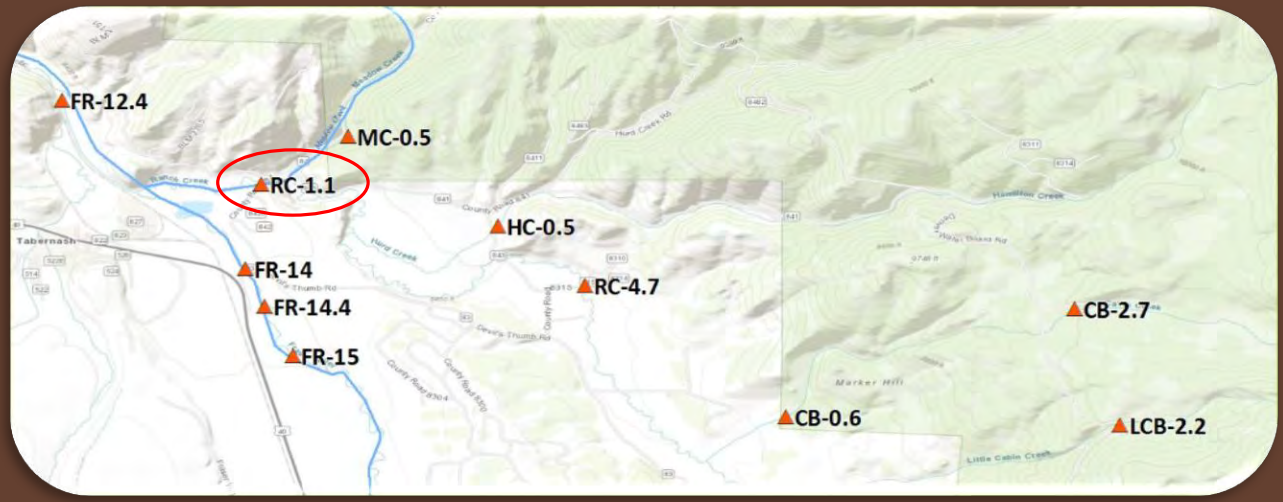
CSI
MEA-atCR84
MC-0.5



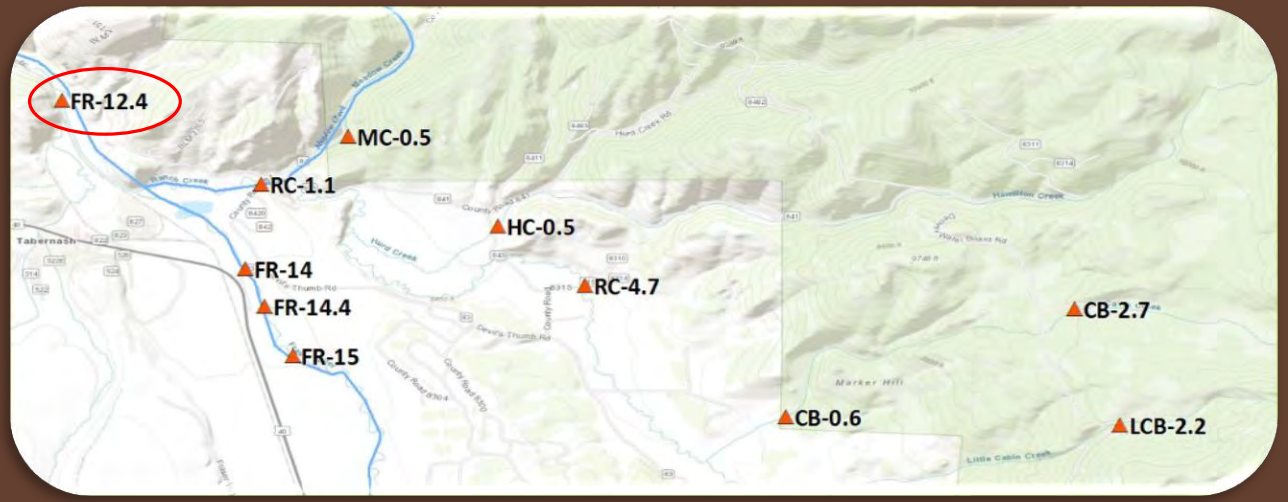




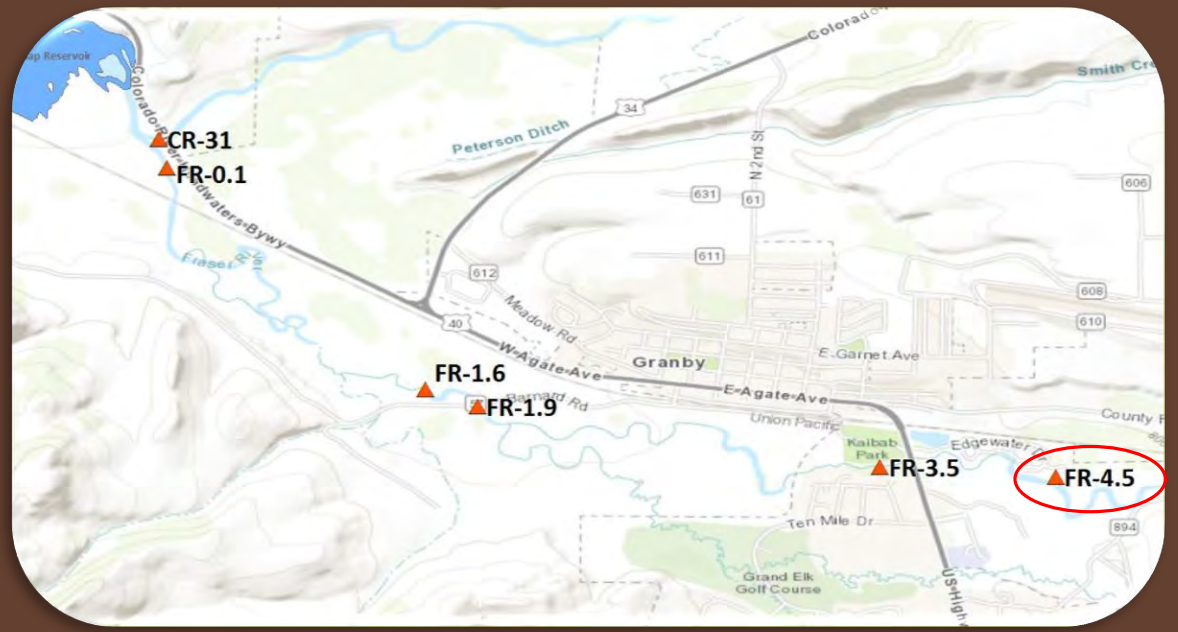
CSI
RC-blwMC
RC-1.1

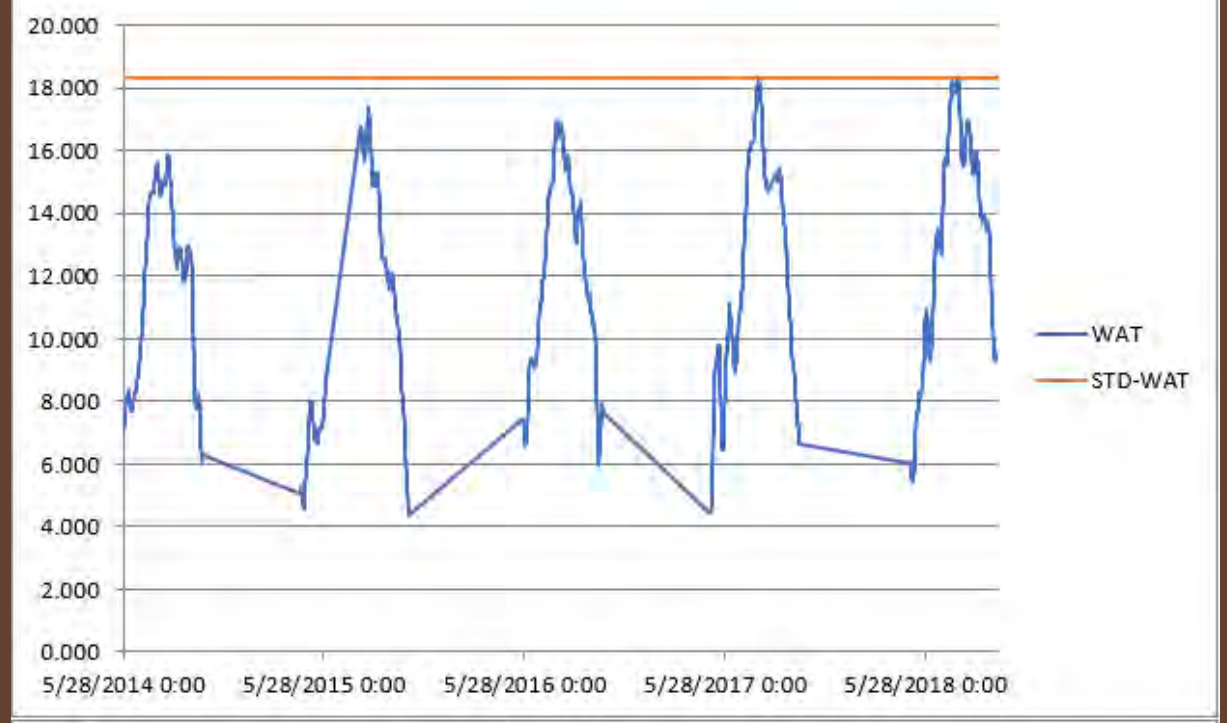


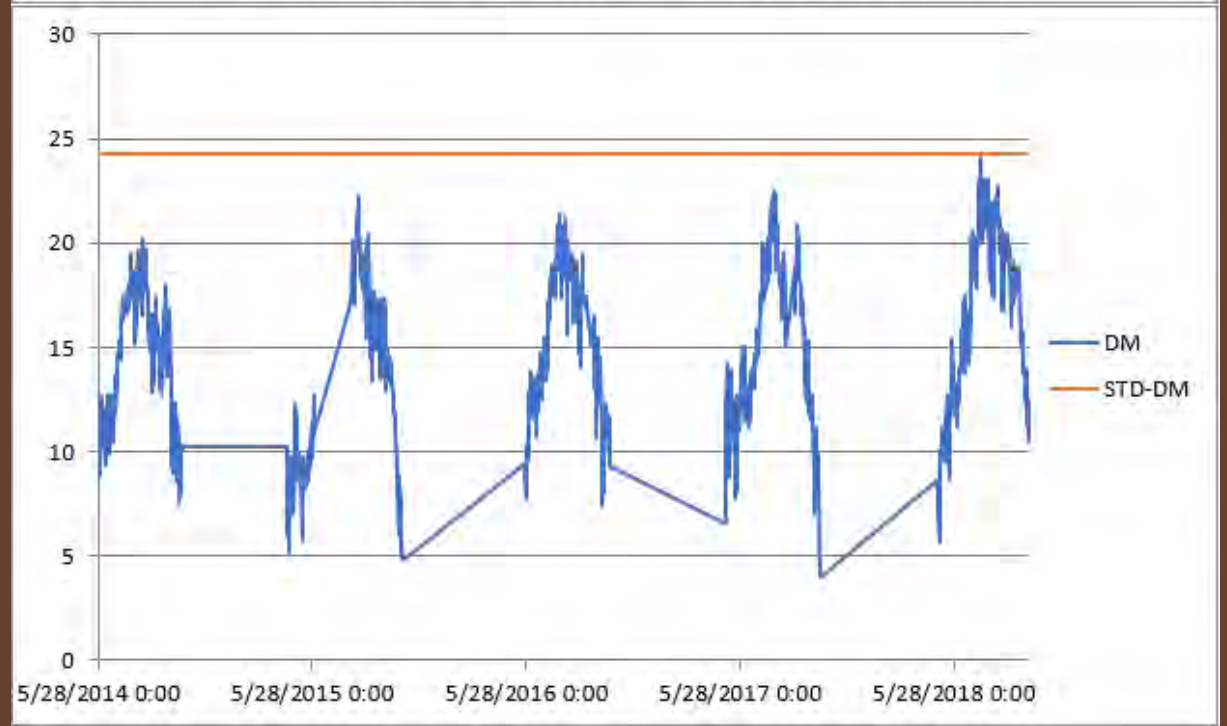
CSII
FR-abvFrCan
FR-12.4



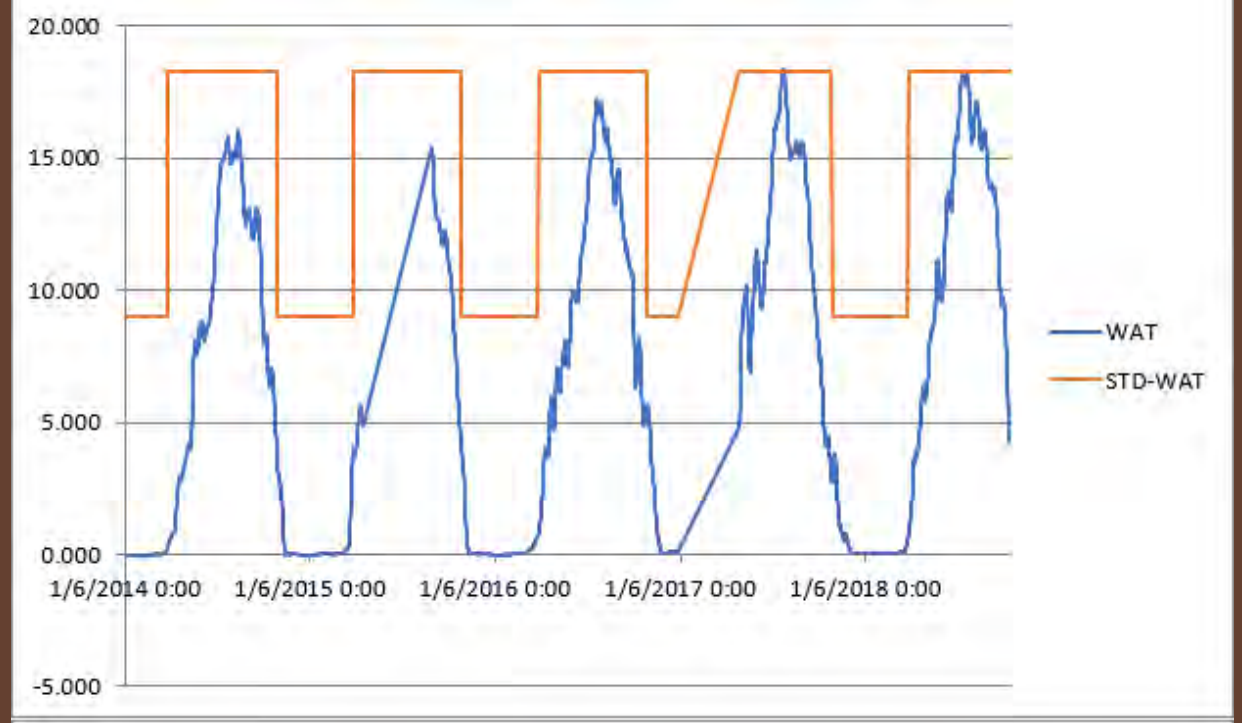
CSII
FR-blwFrCan
FR-4.5

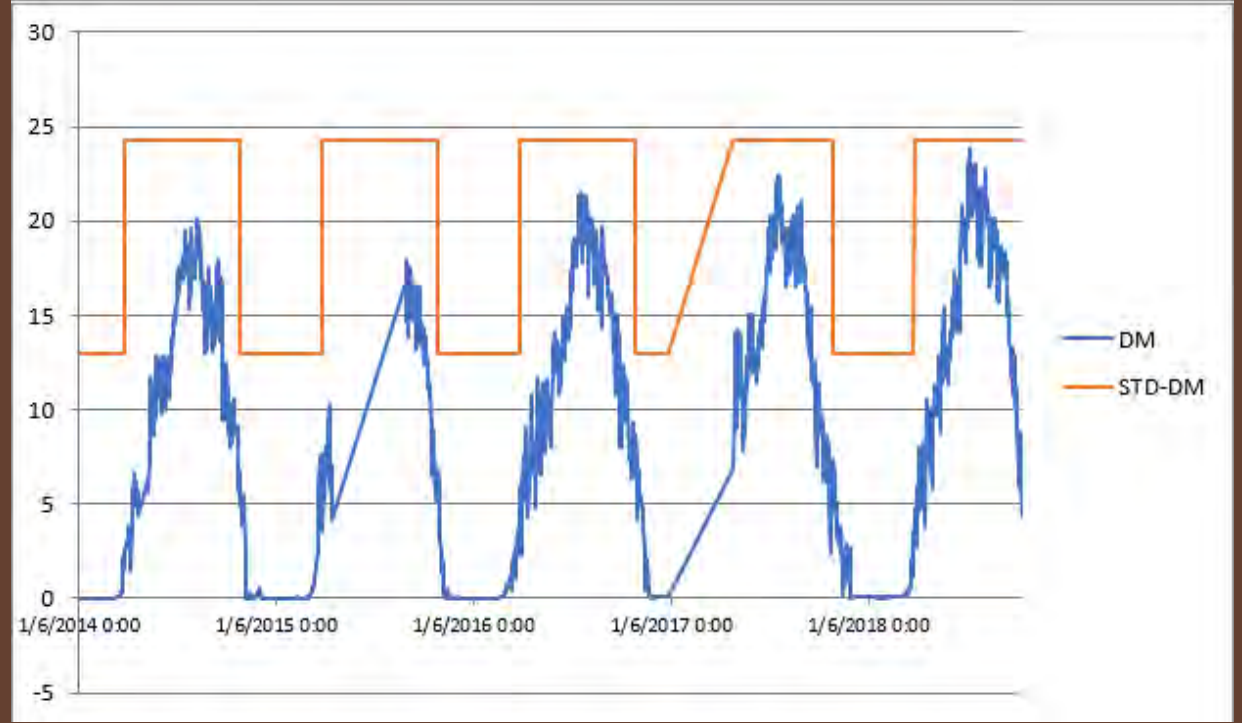




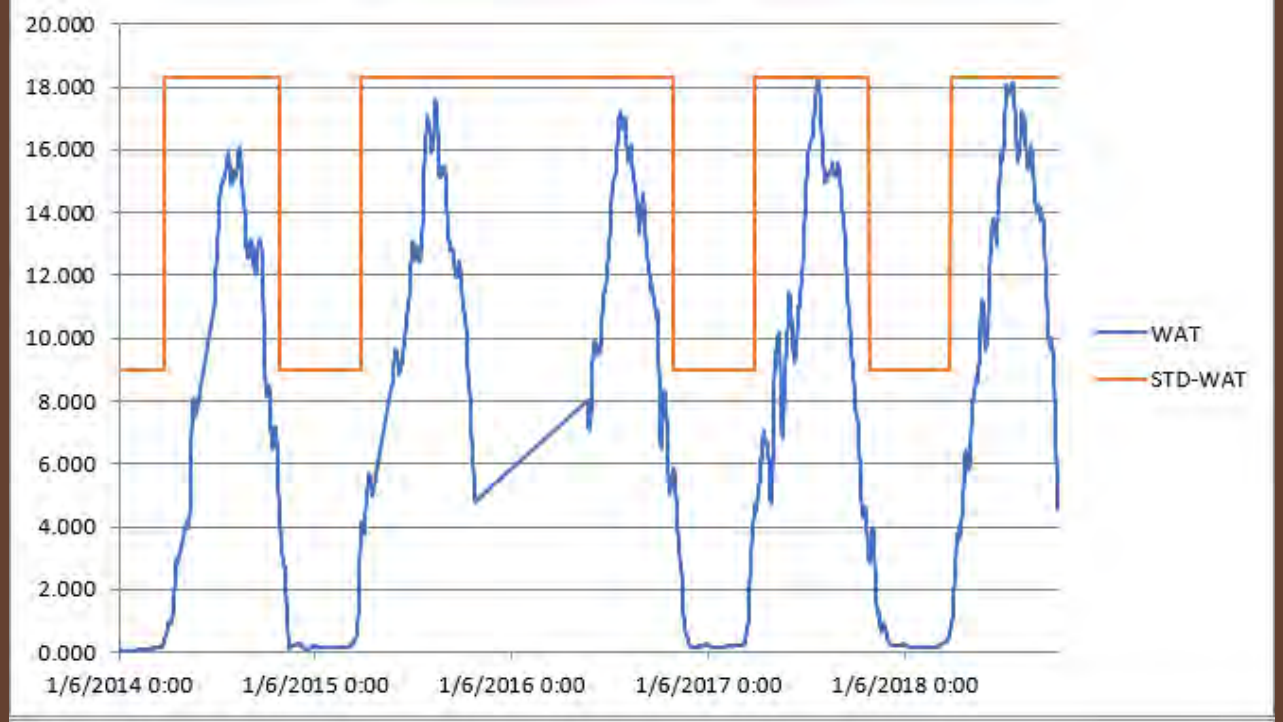


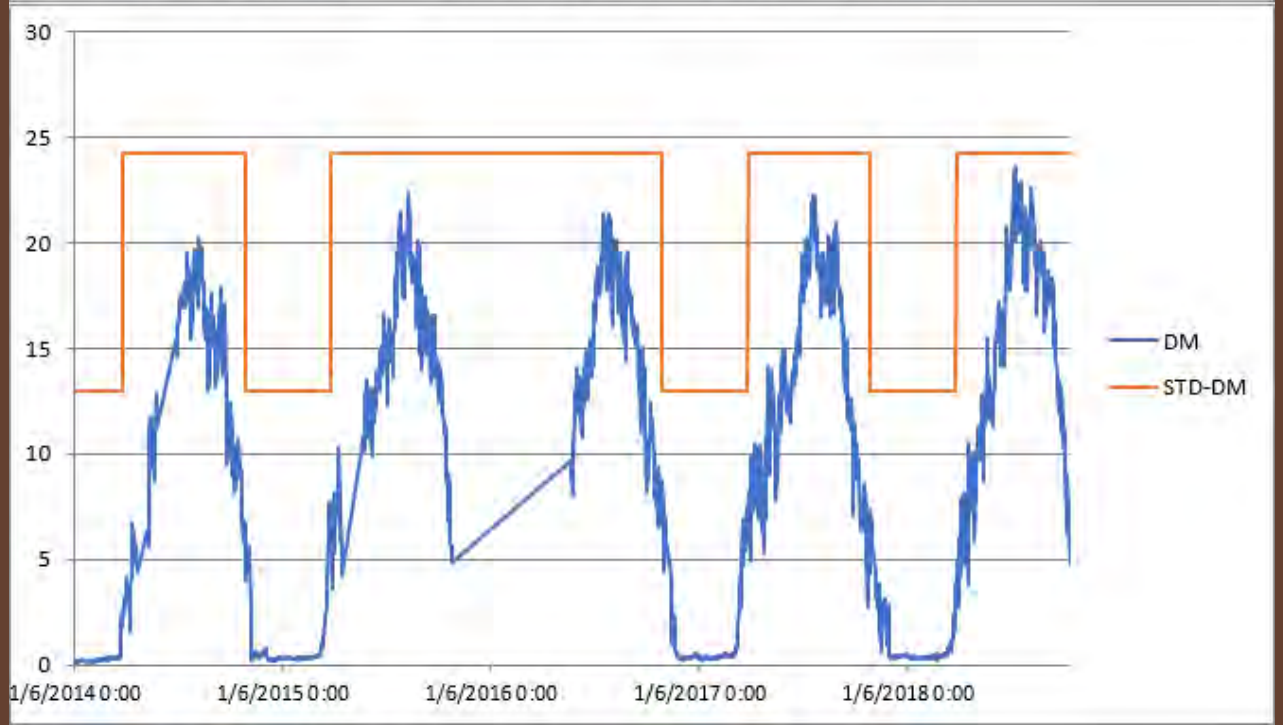
CSII
FR-HWY40GR
FR-3.5





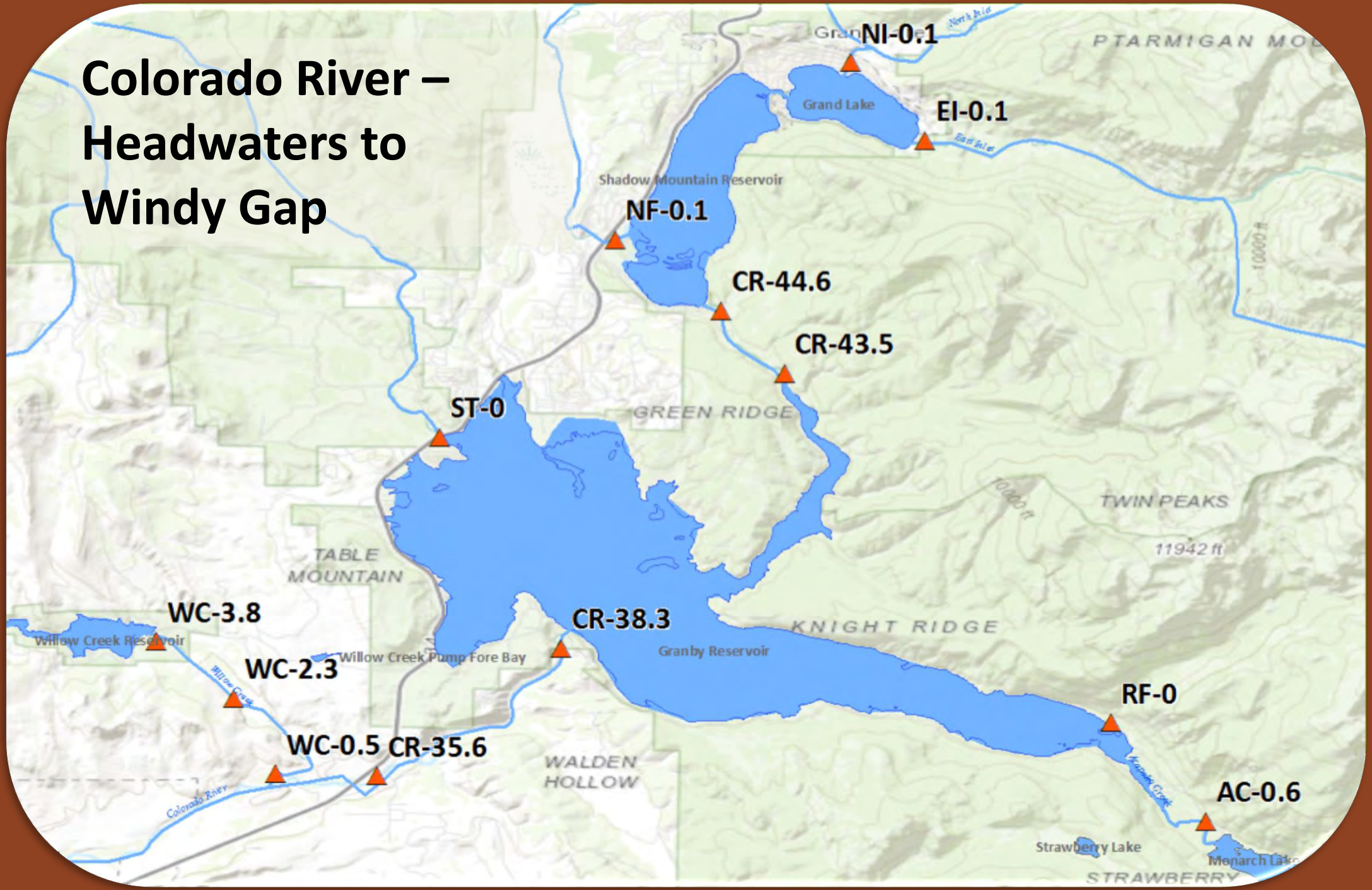
CSII
FR-abvGSD
FR-1.9

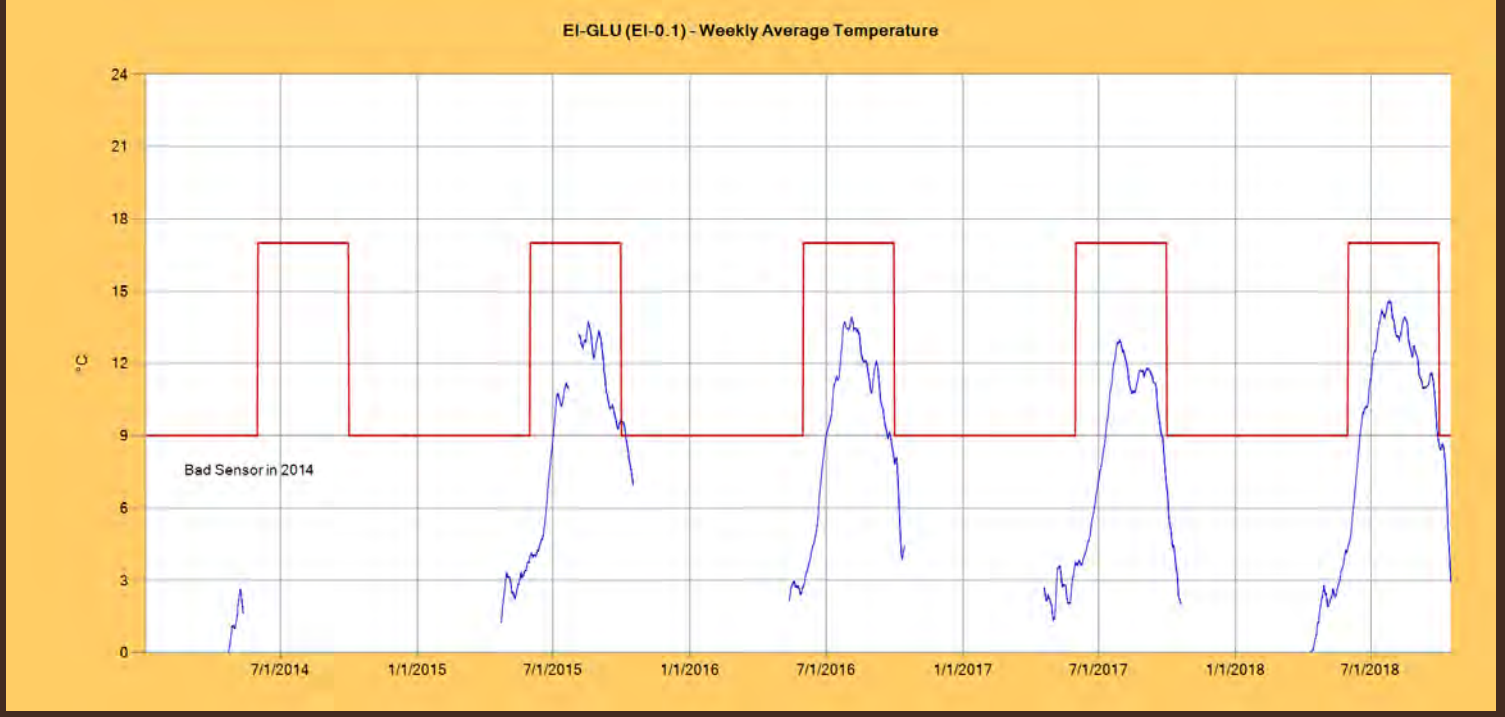


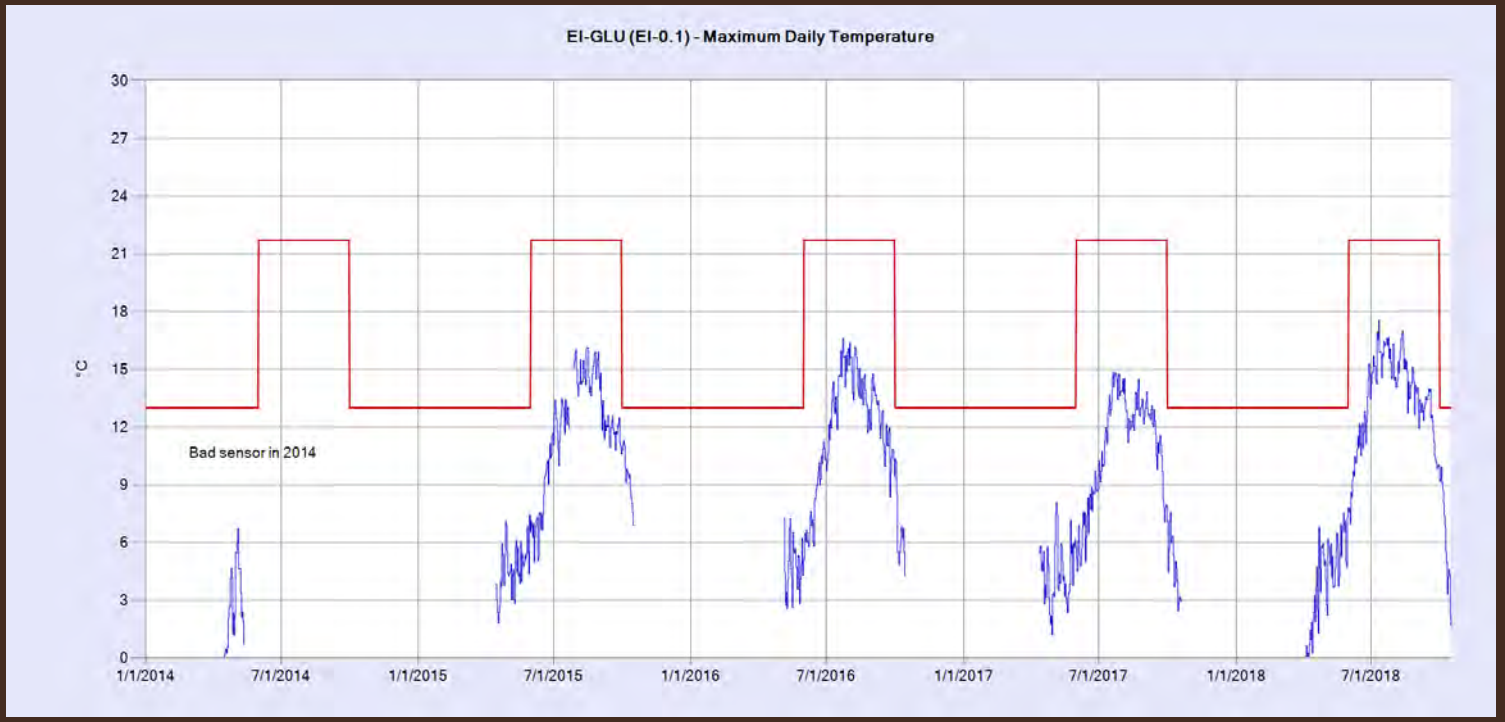


CSII
FR-blwGSD
FR-1.6

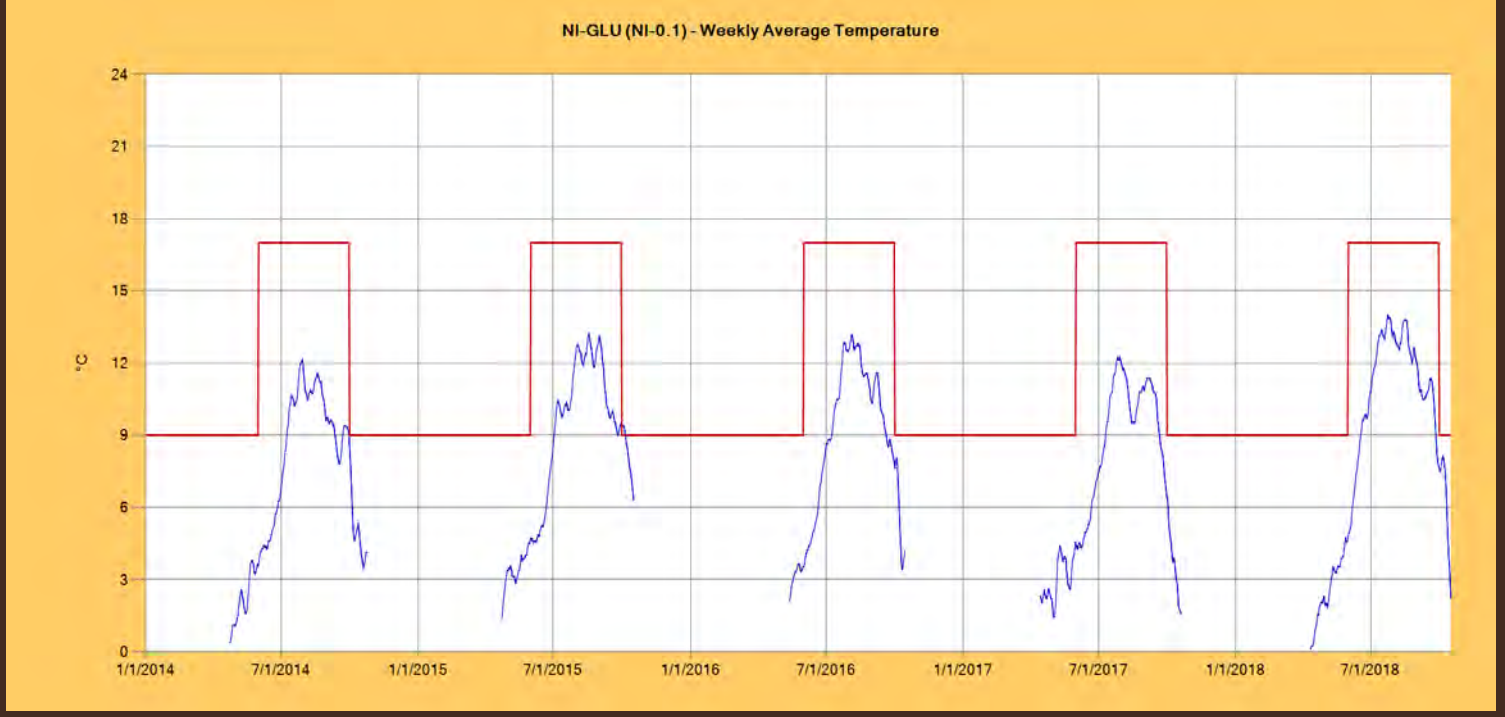
Colorado River – Headwaters to Windy Gap

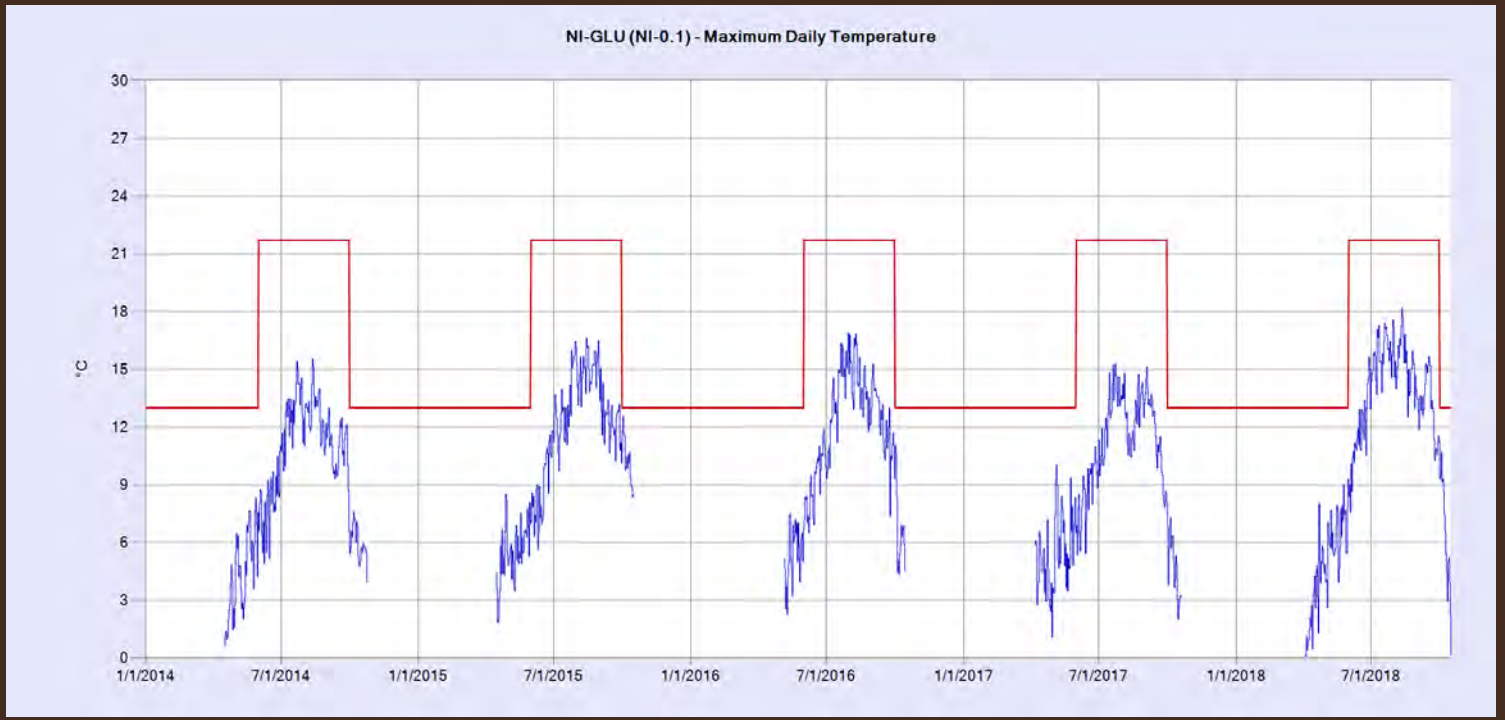




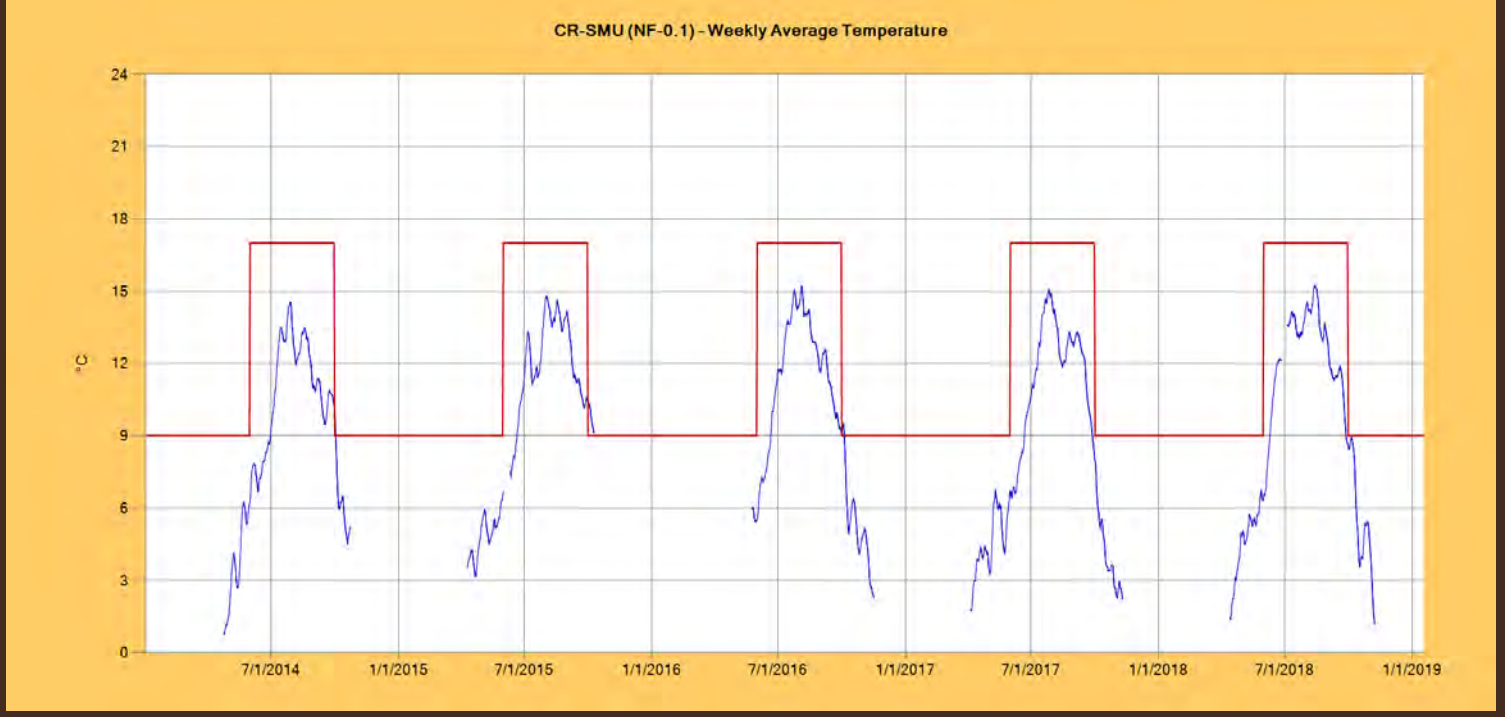


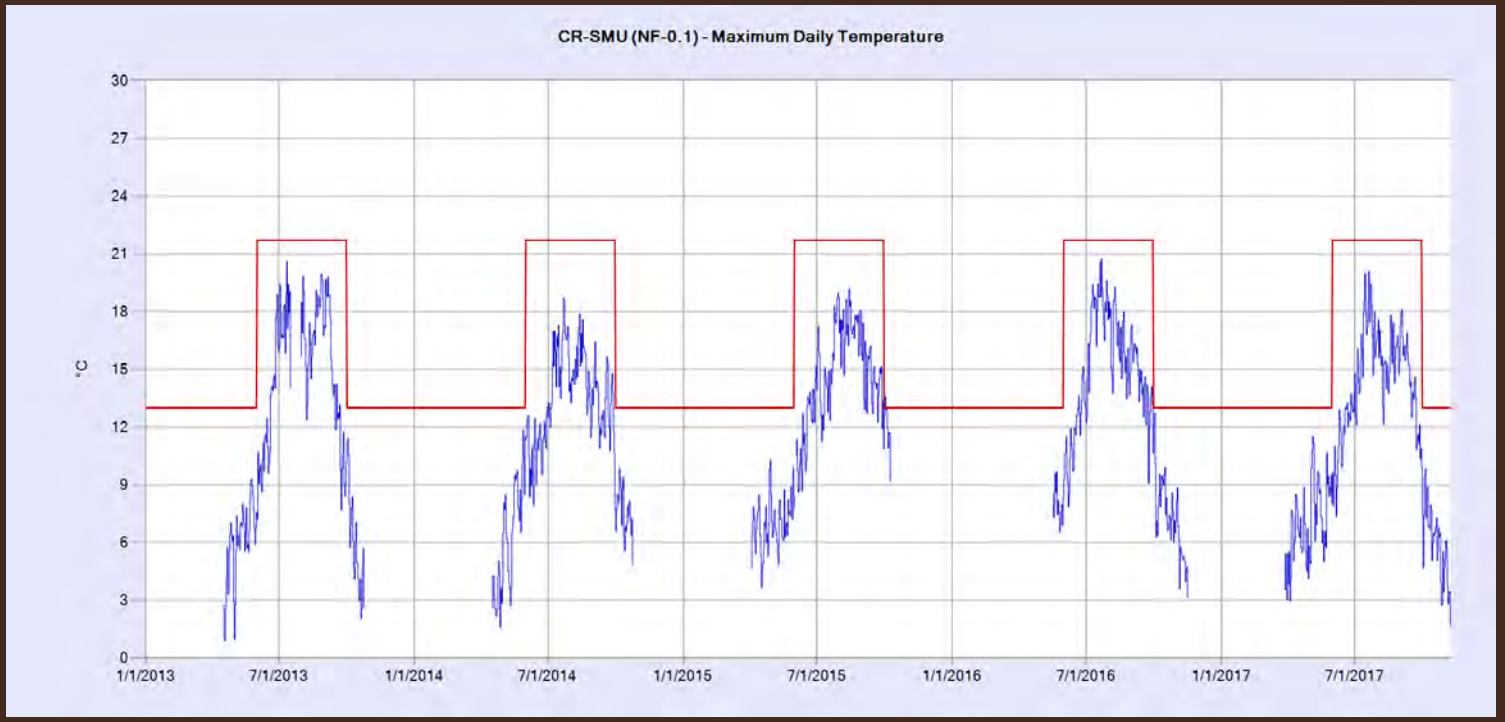
East Inlet - CSI



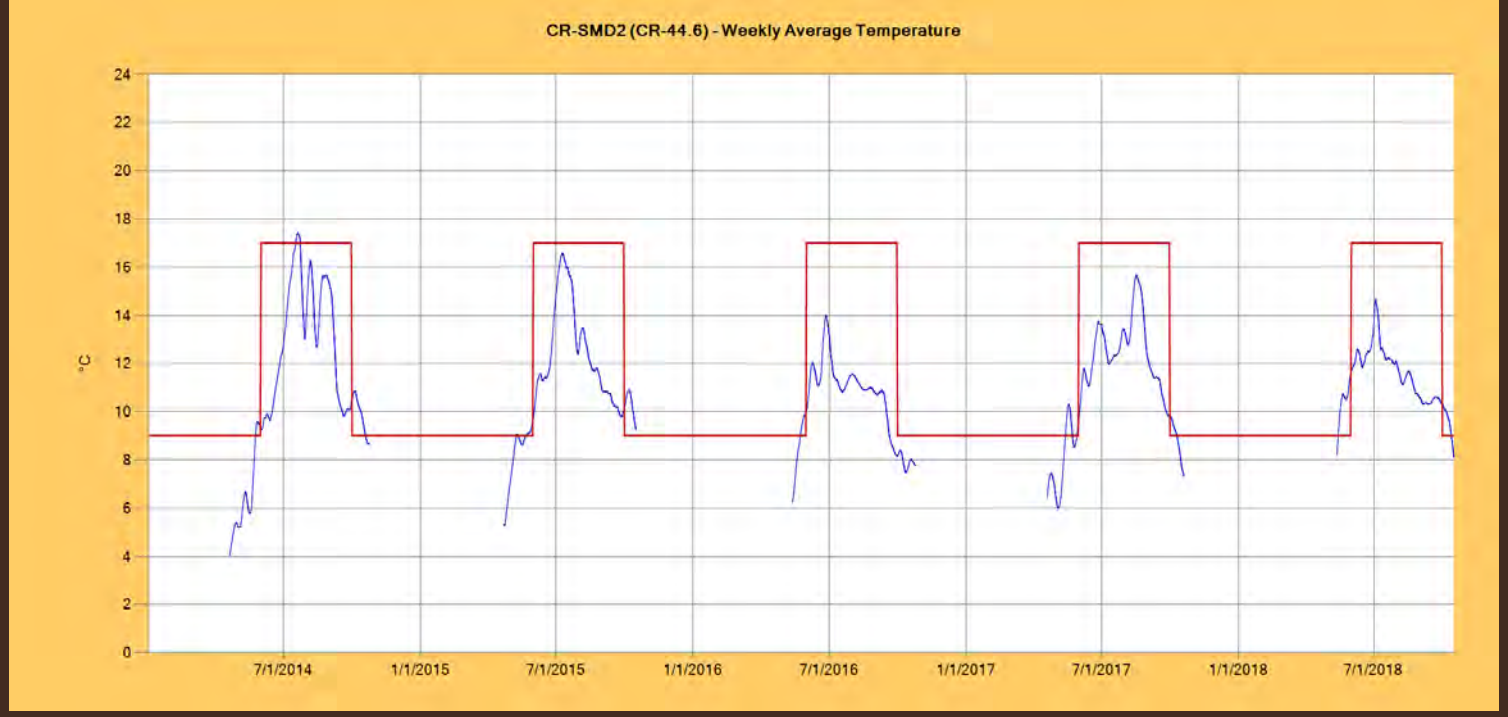


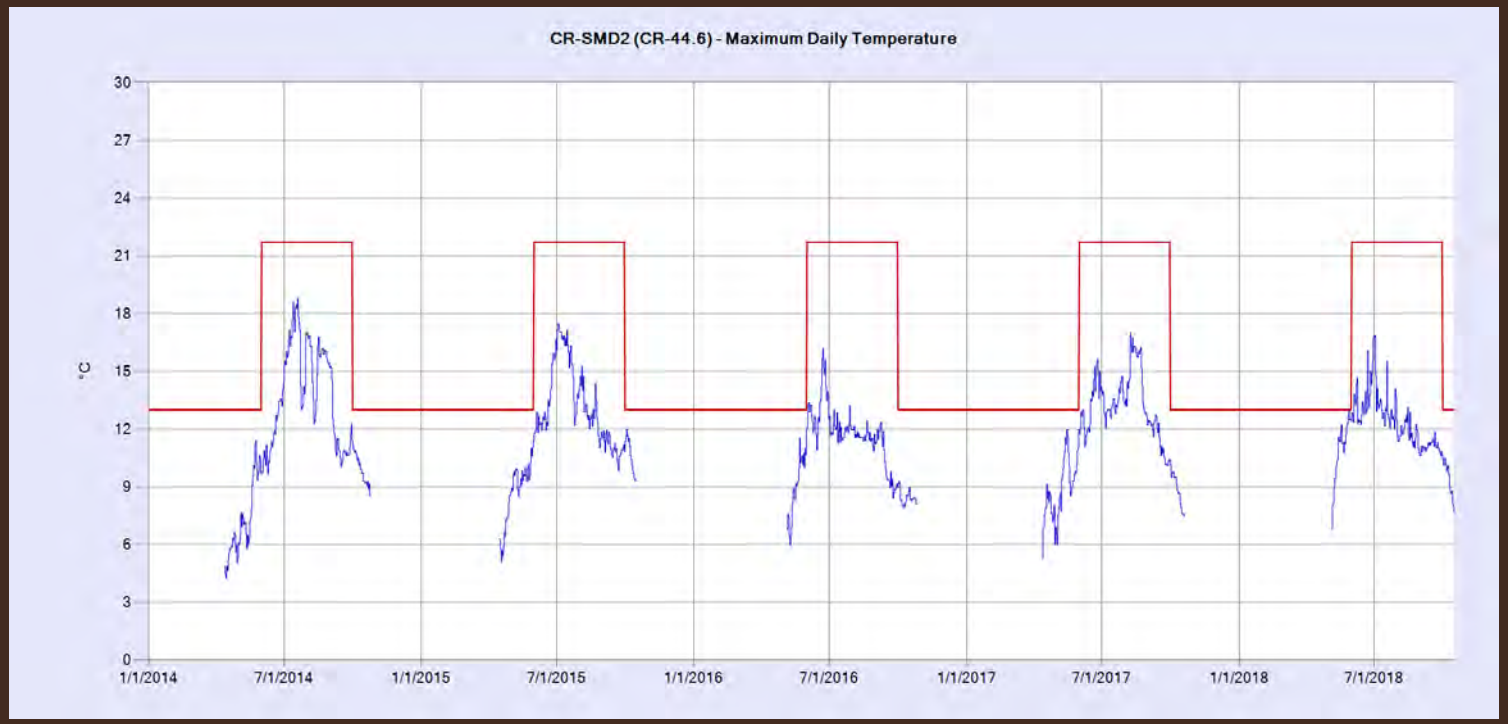
North Inlet - CSI



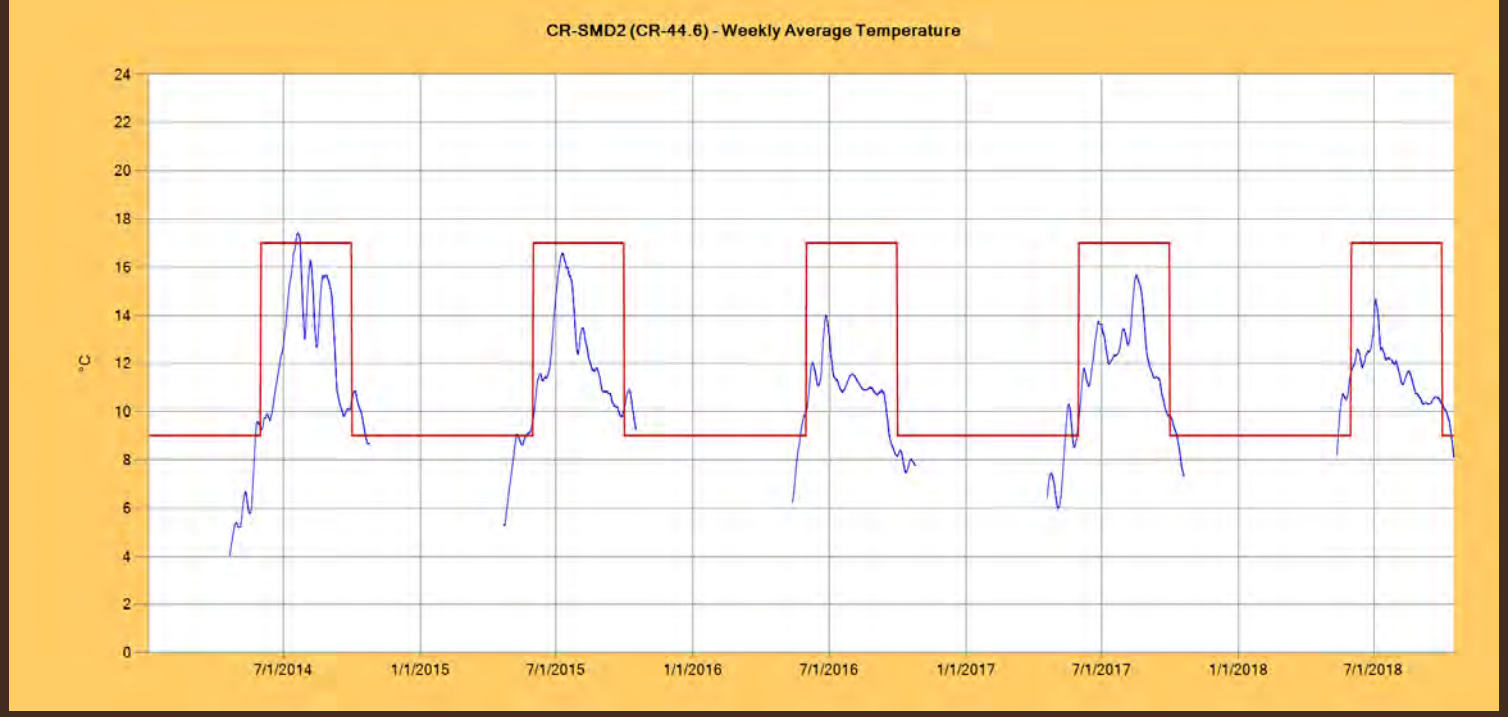


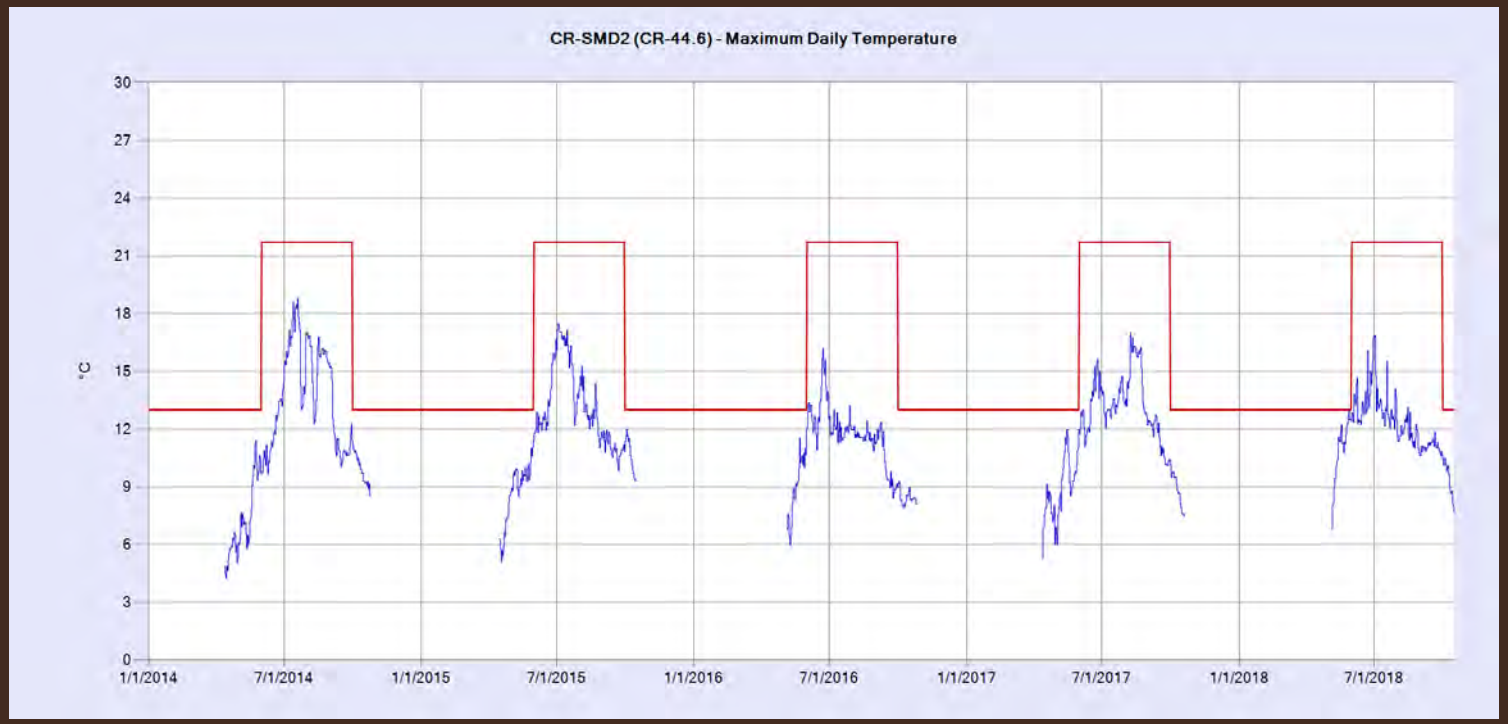
North Fork Colorado - CSI



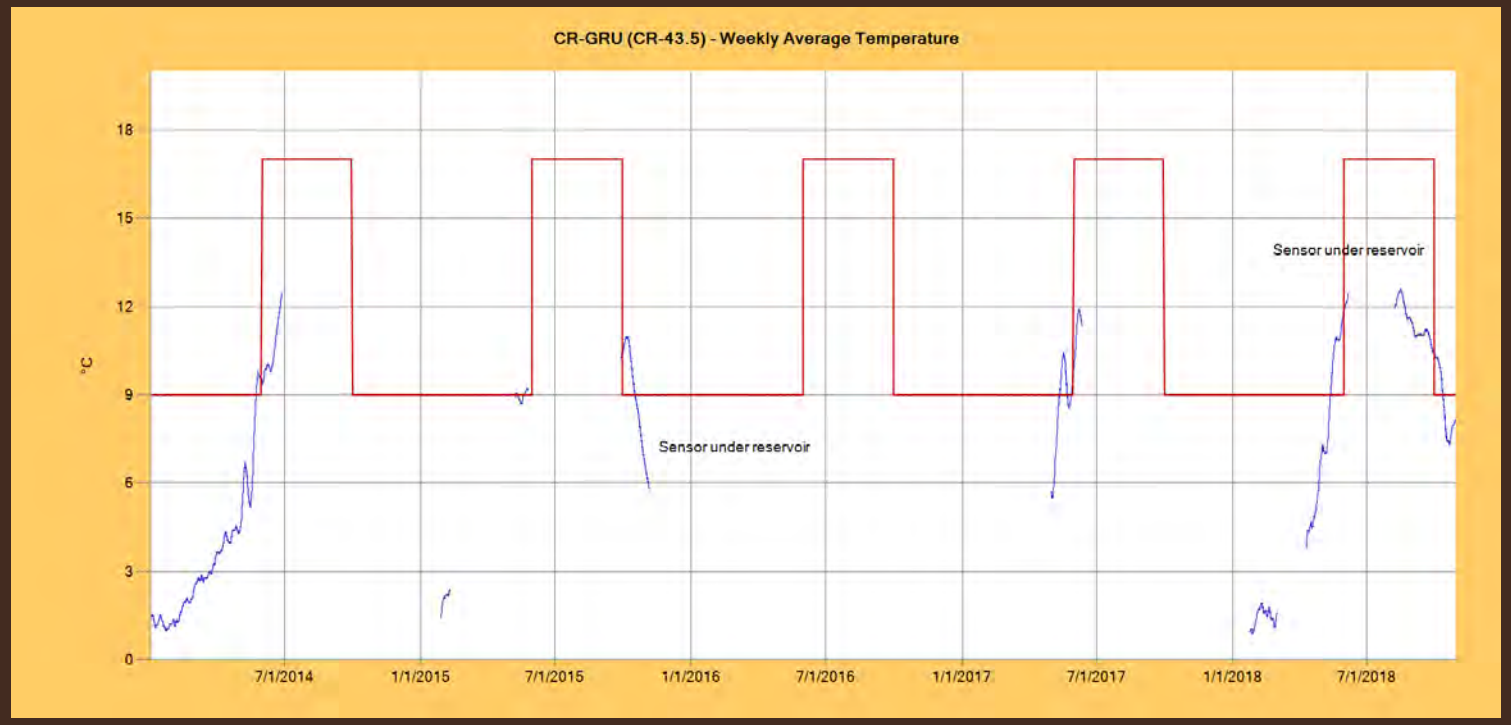


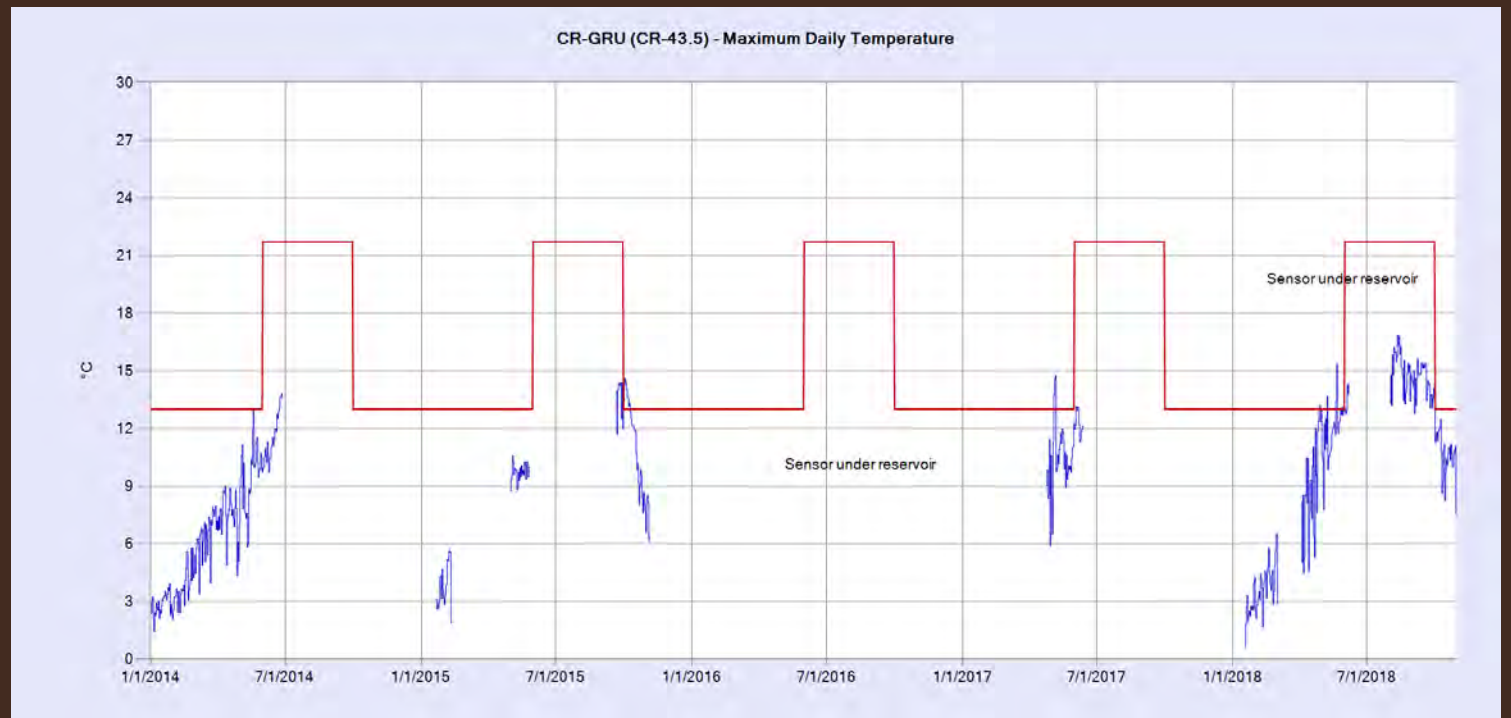
Colorado downstream Shadow Mountain - CSI



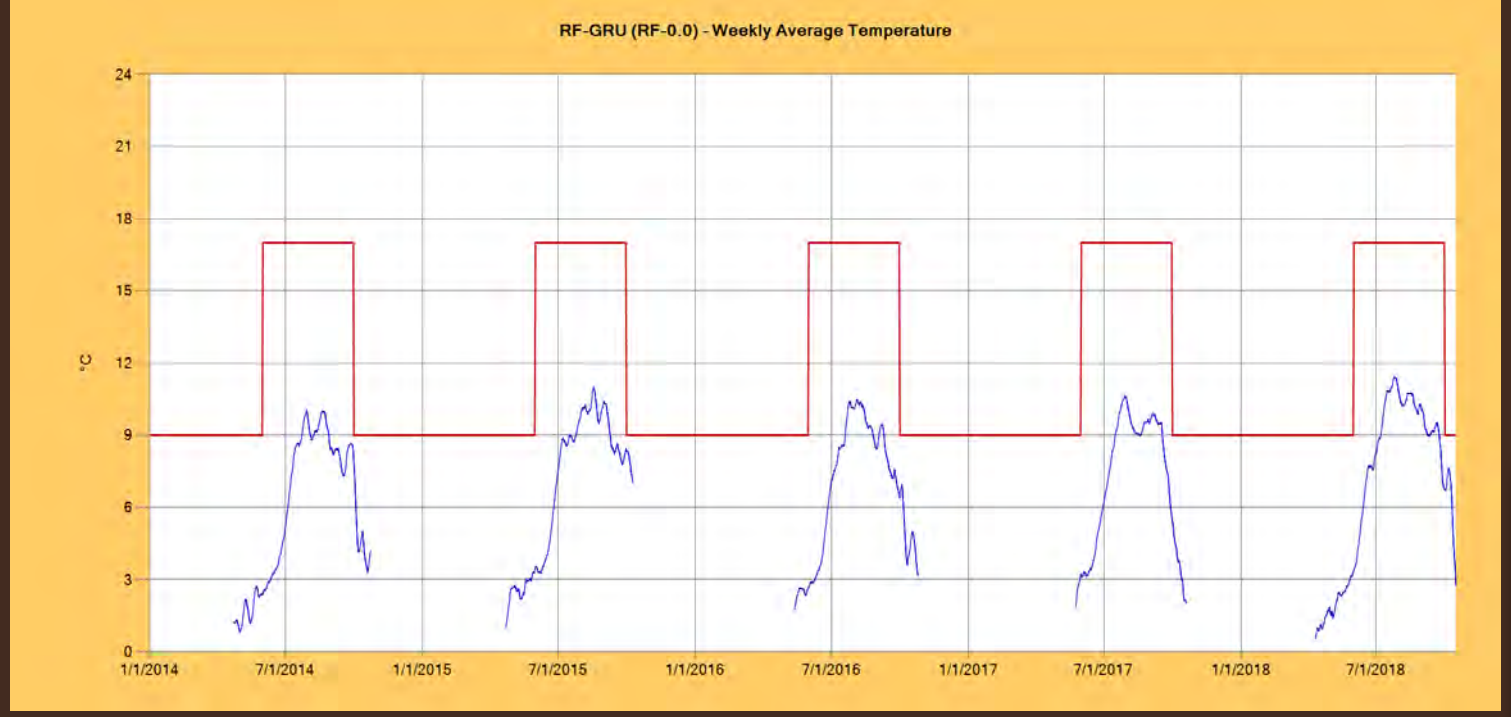


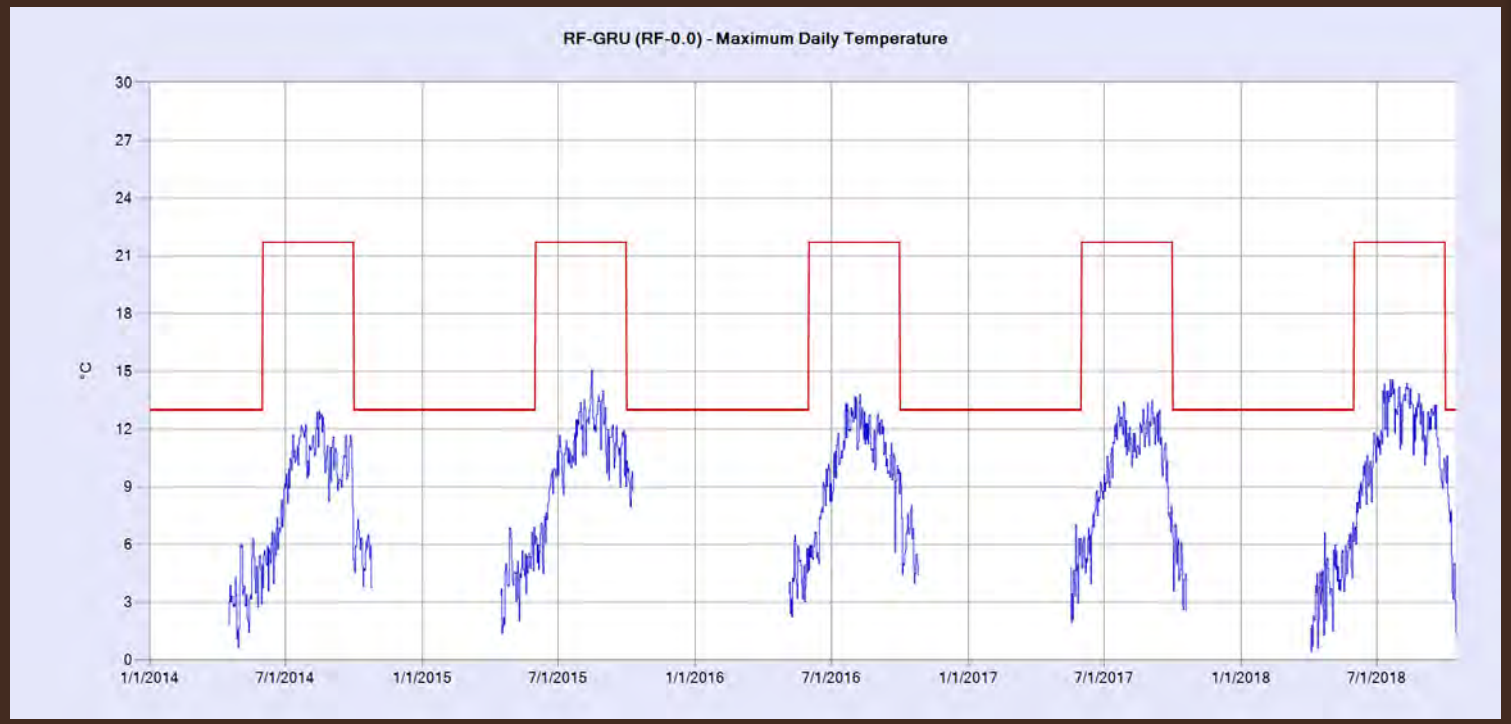
Colorado downstream Shadow Mountain - CSI



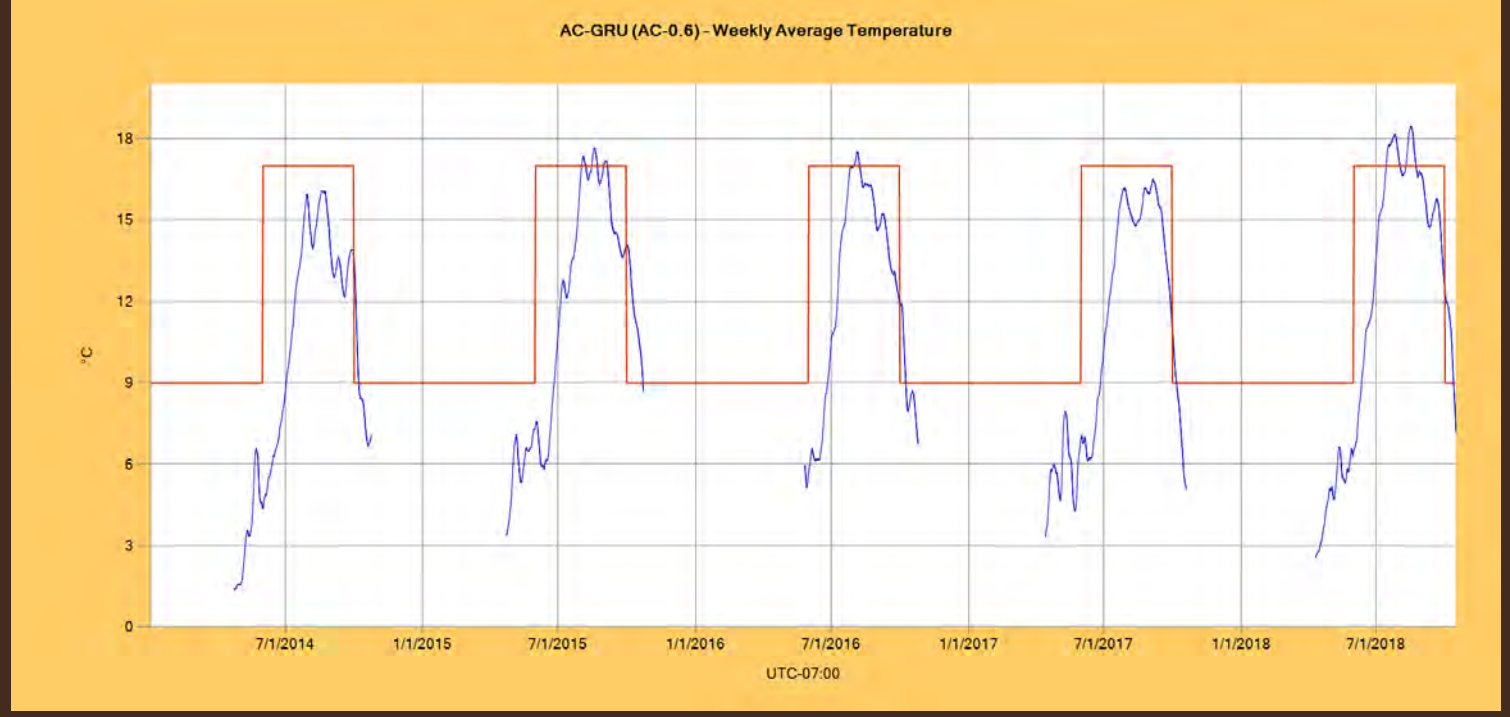


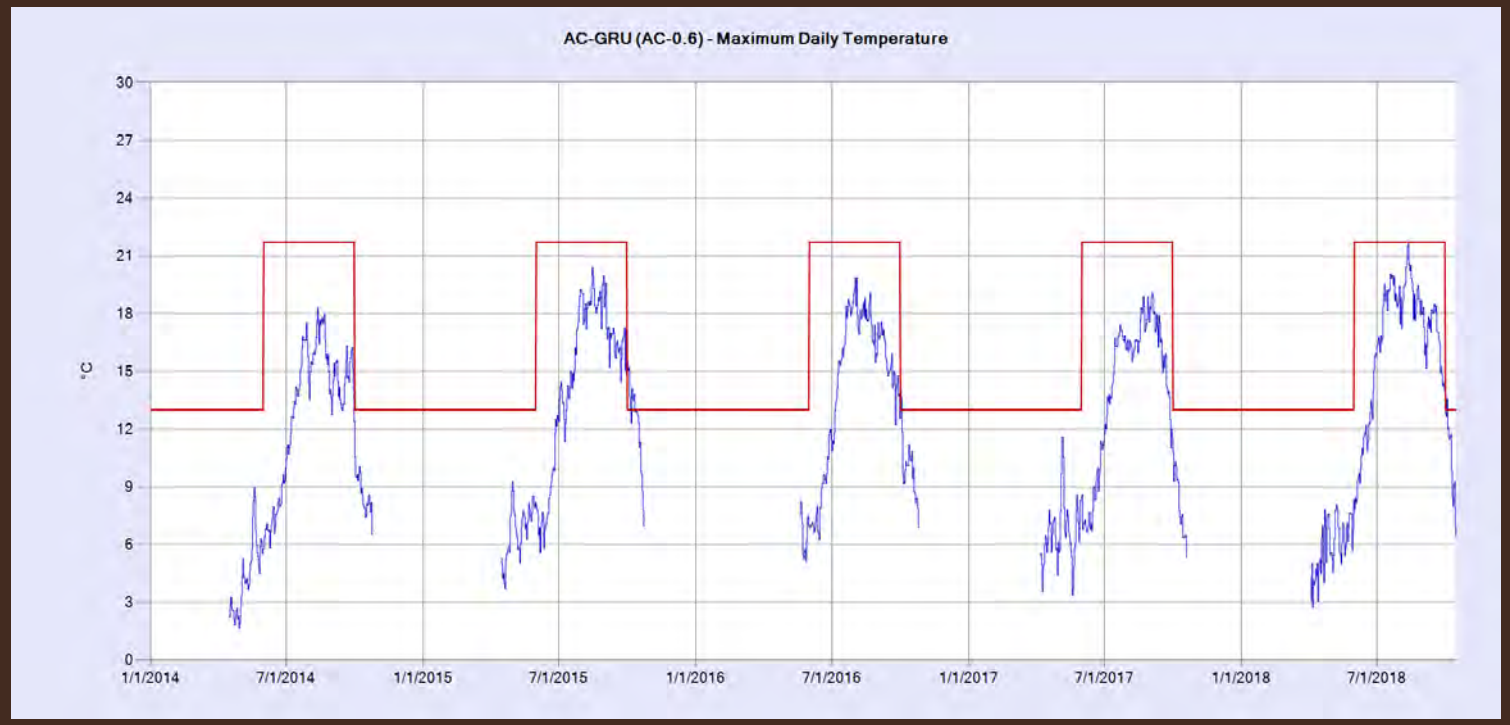
Colorado upstream Granby Reservoir - CSI



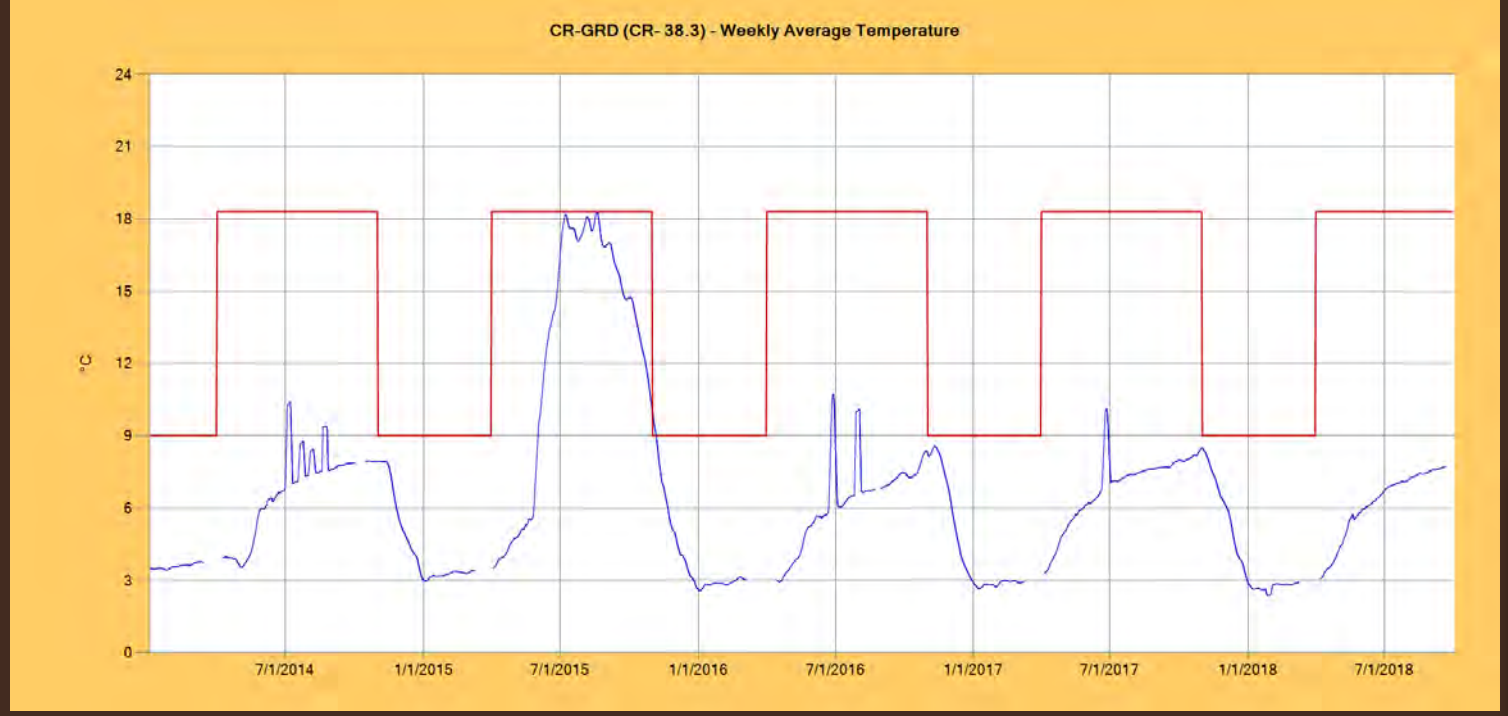


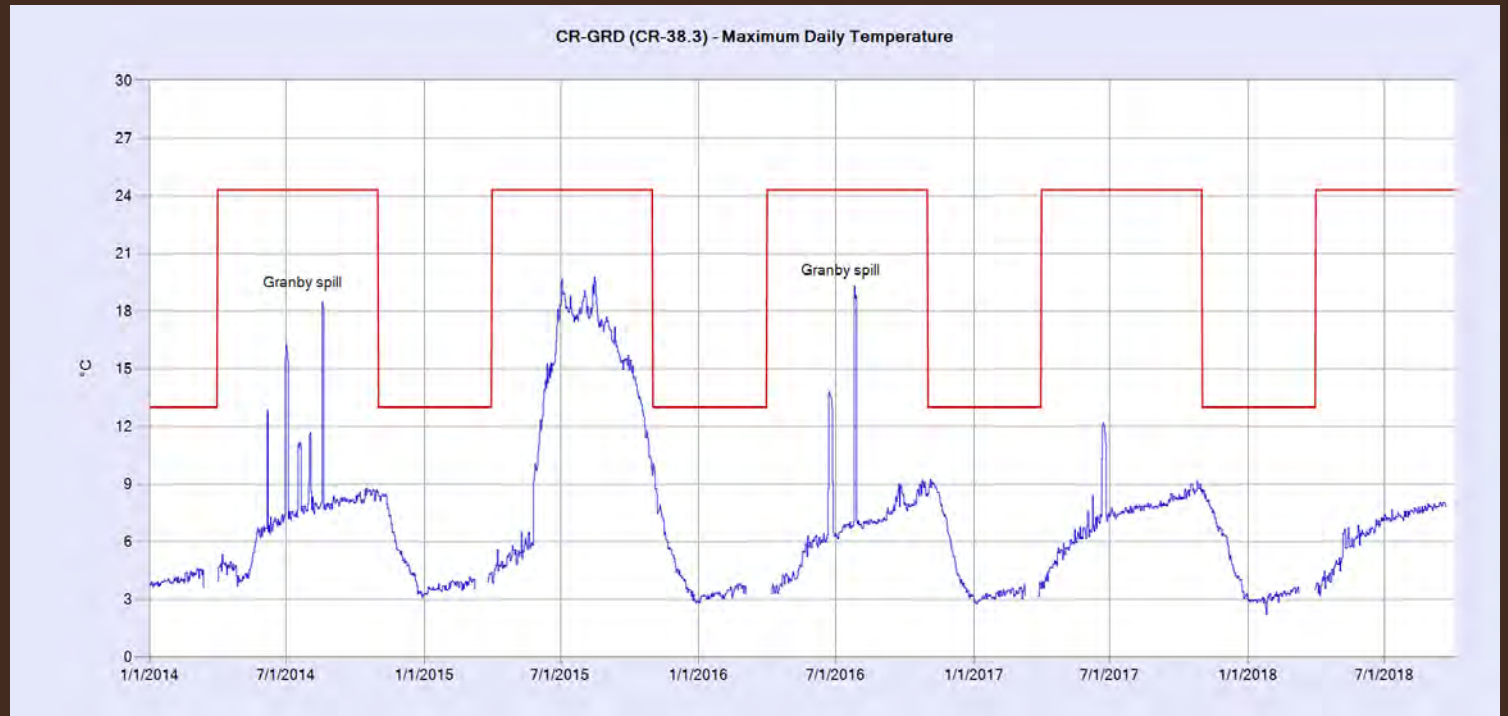
Roaring Fork - CSI



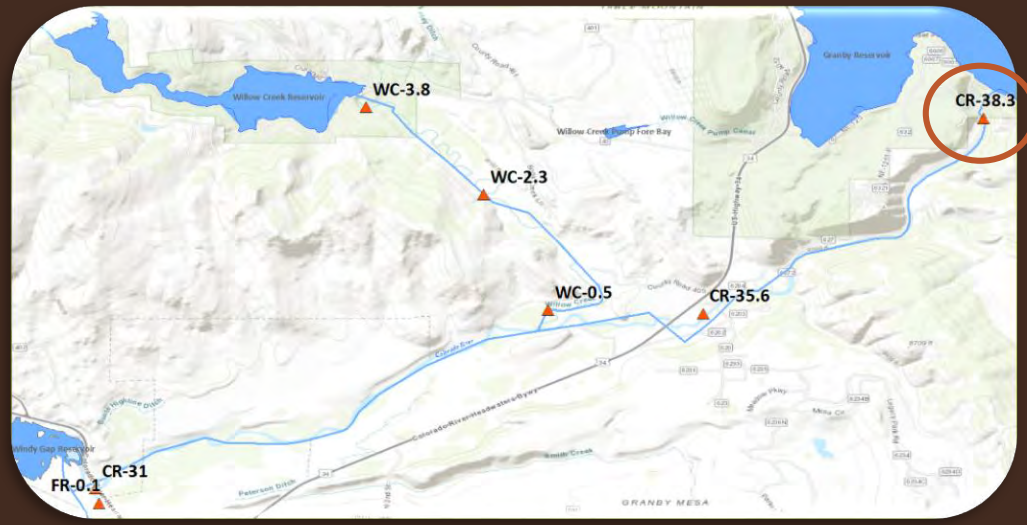


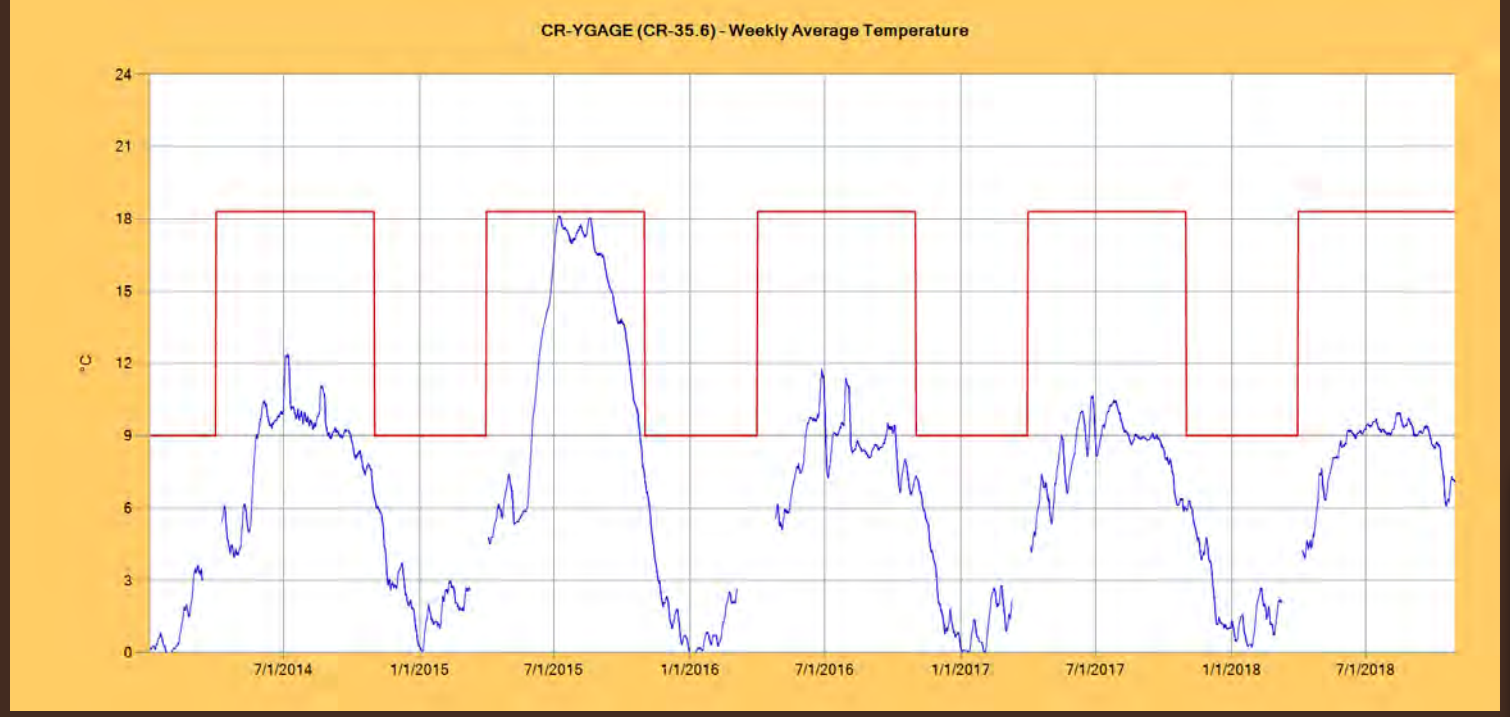
Arapaho Creek - CSI

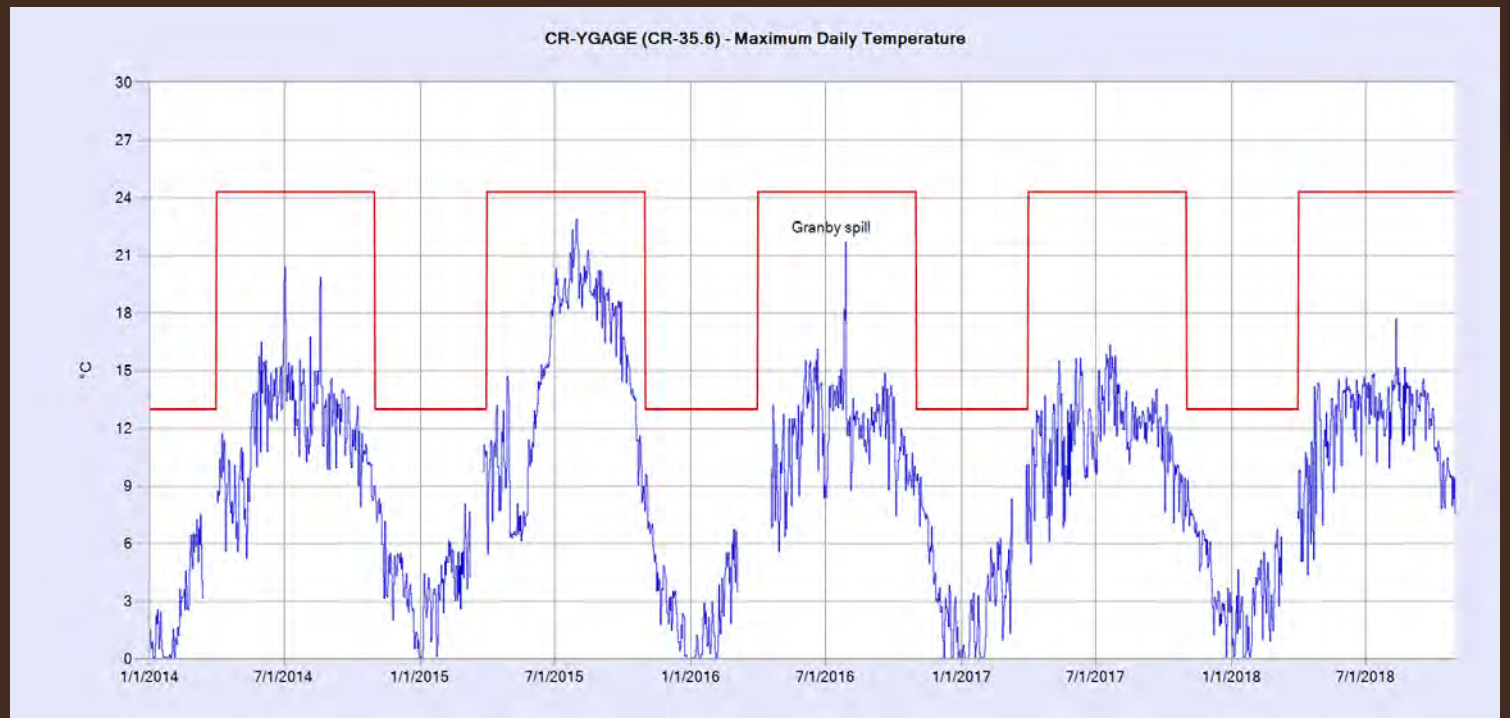




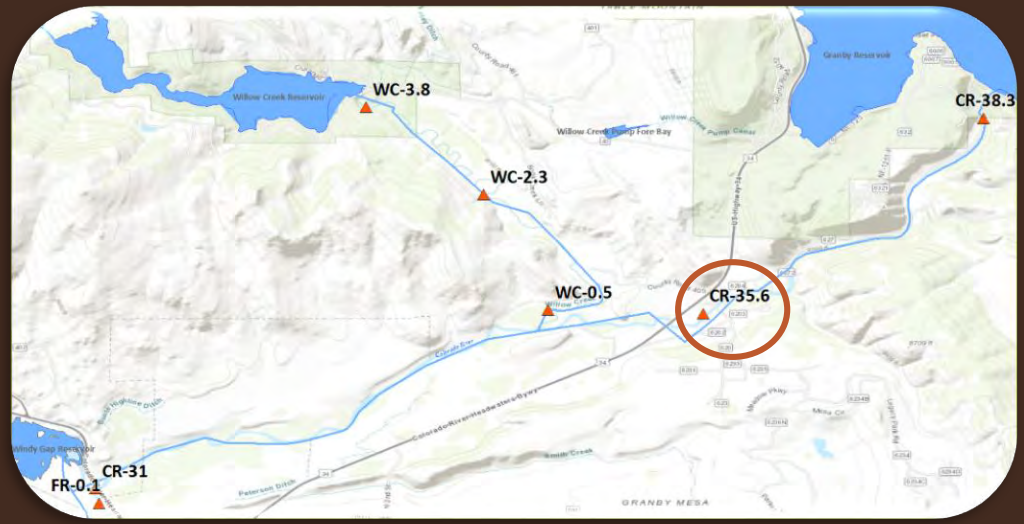
Colorado River downstream of Granby Reservoir- CSII

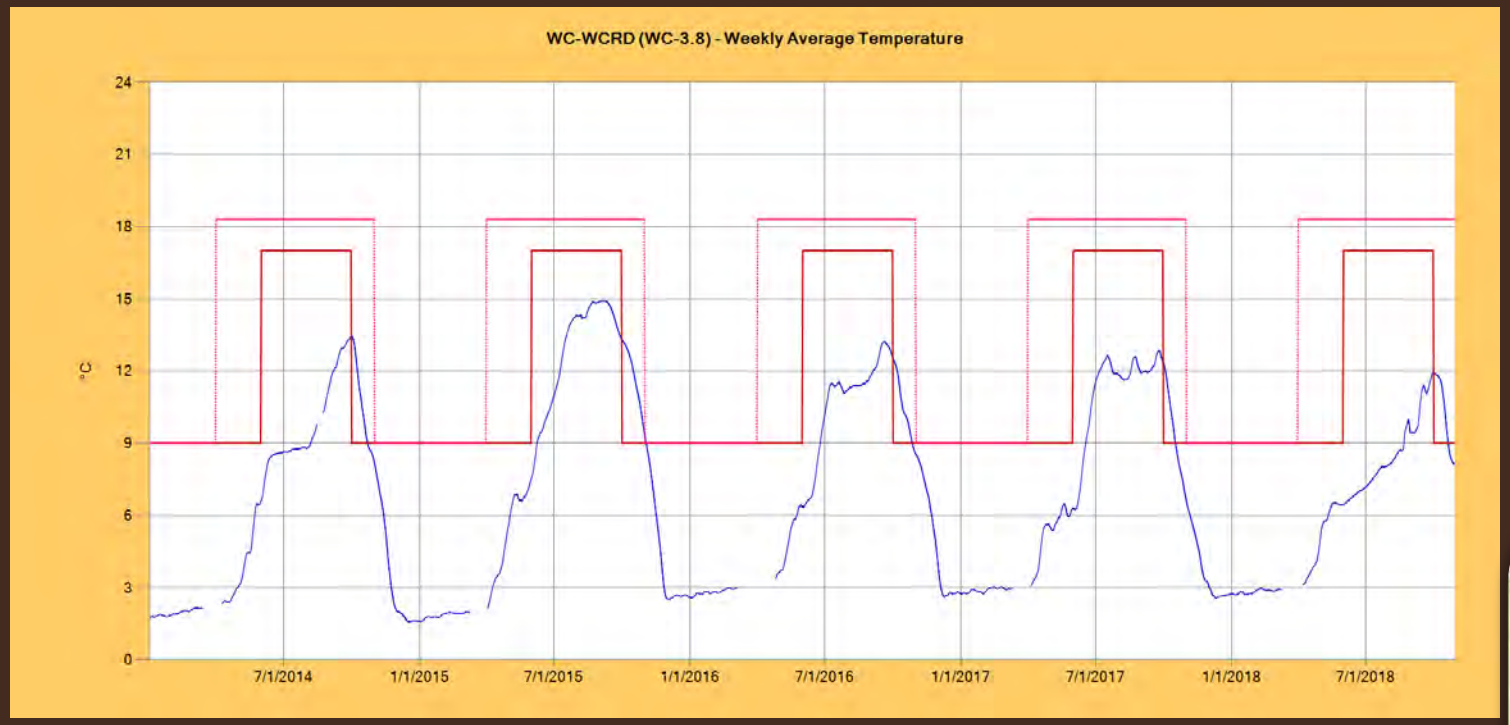


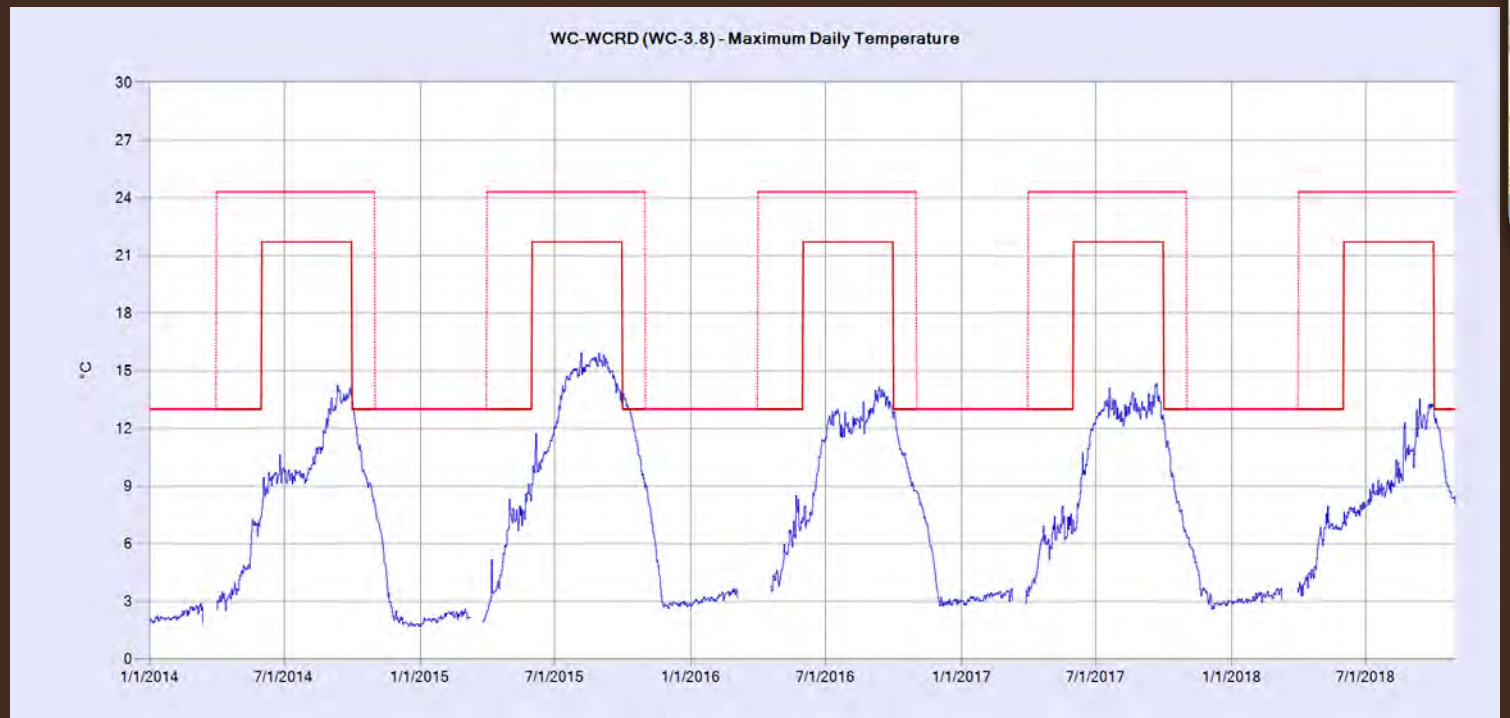




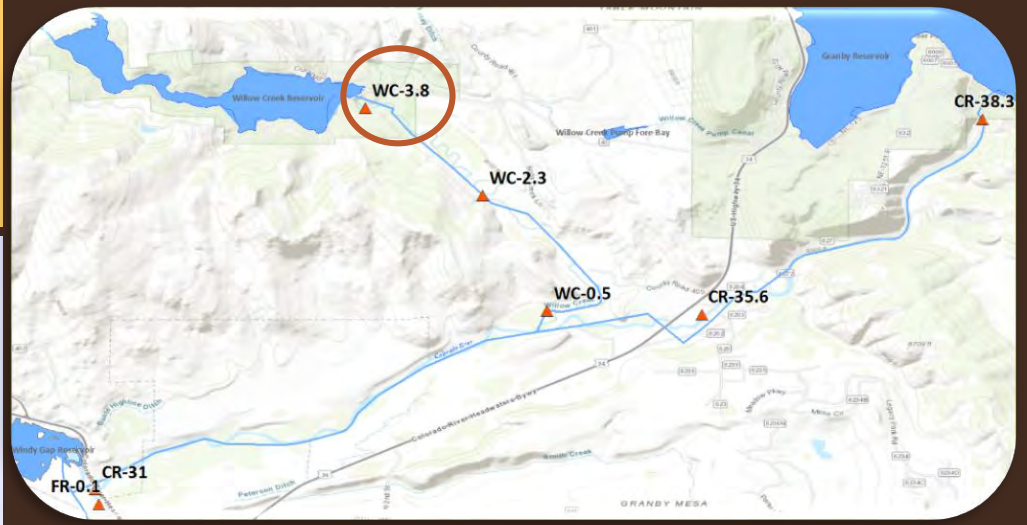
Colorado River at Y-Gage - CSII

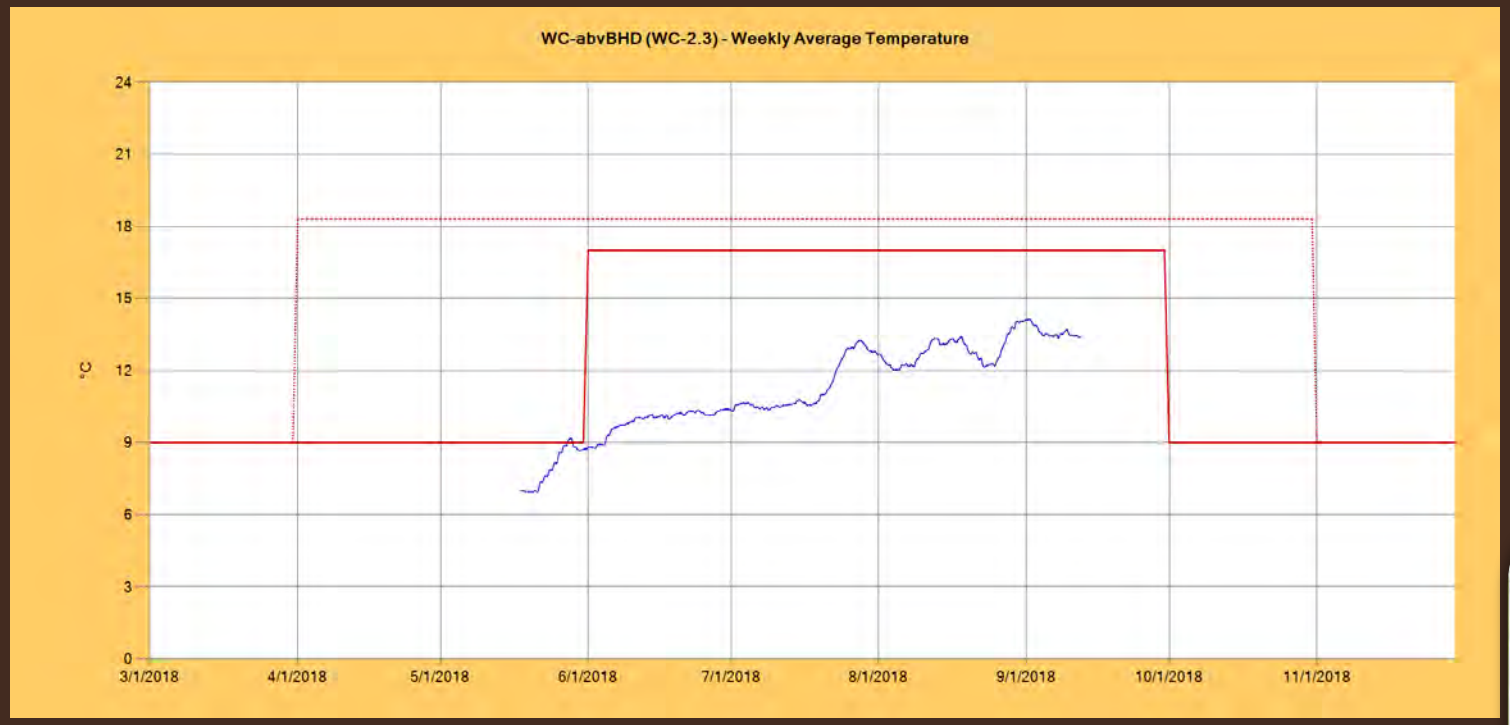


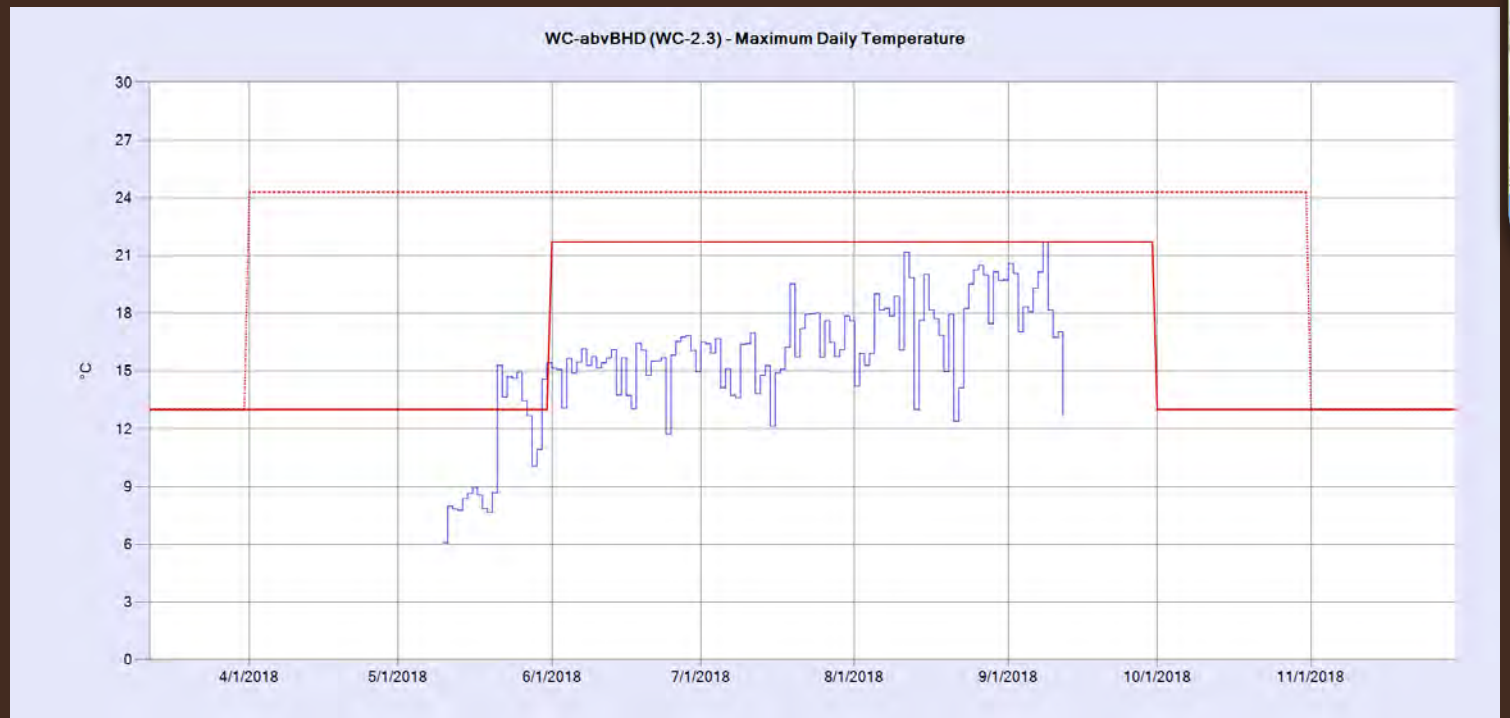




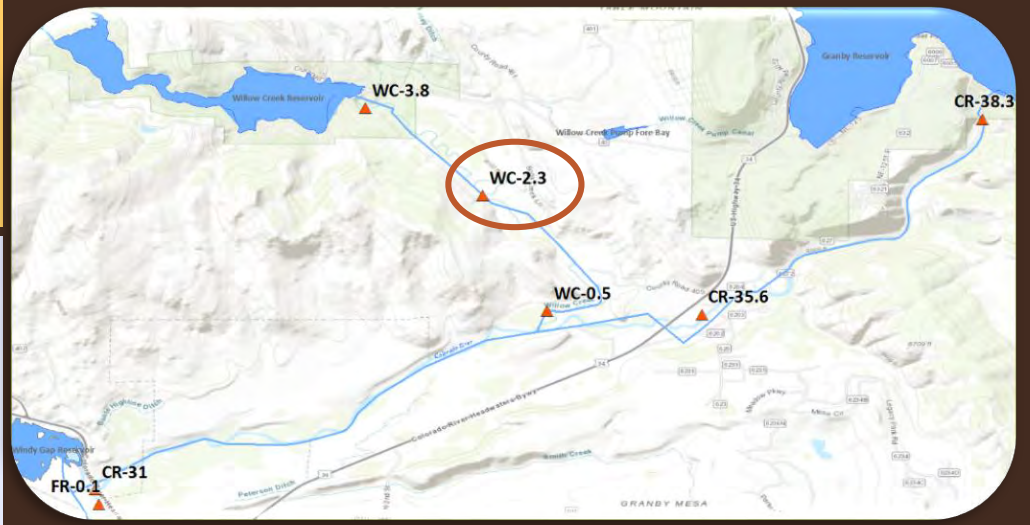
Willow Creek downstream of Reservoir – CSI
WQCD Proposed CS-II

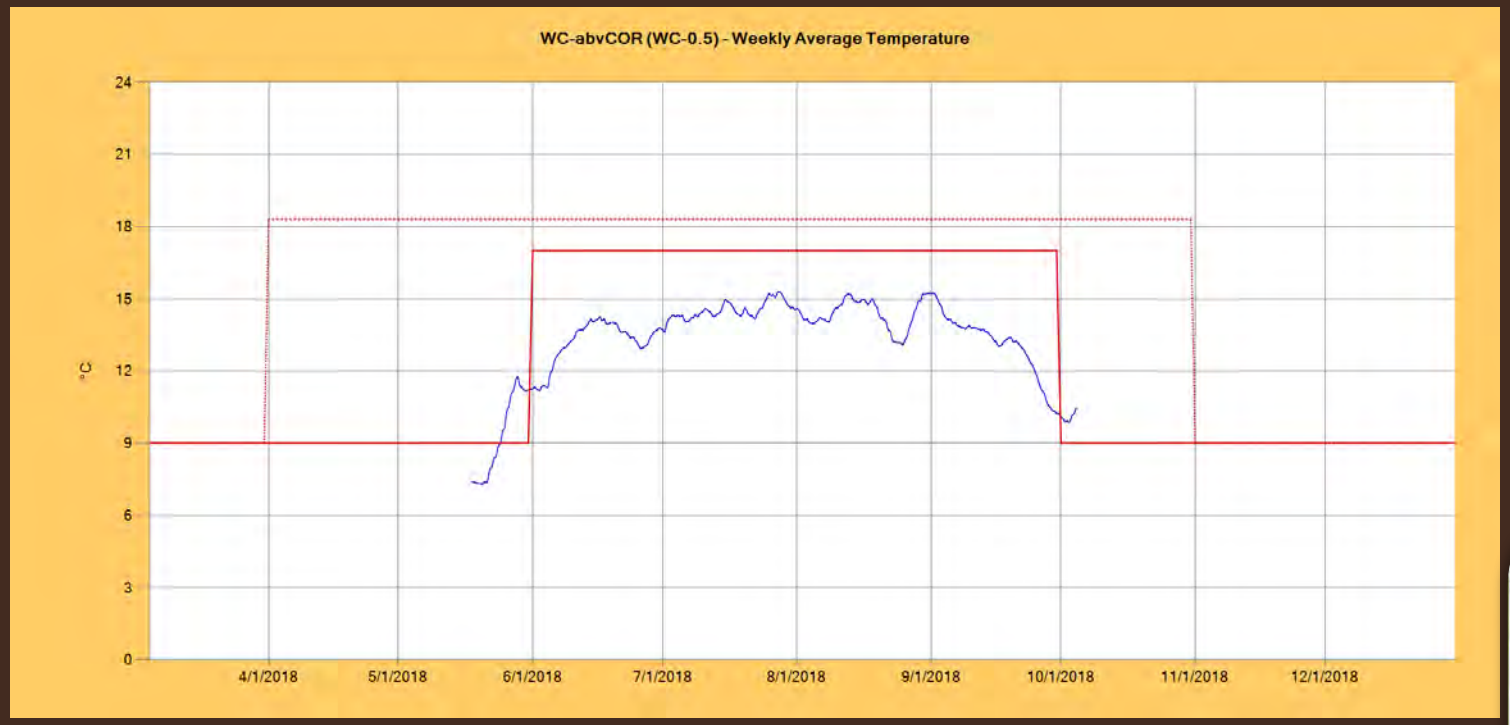


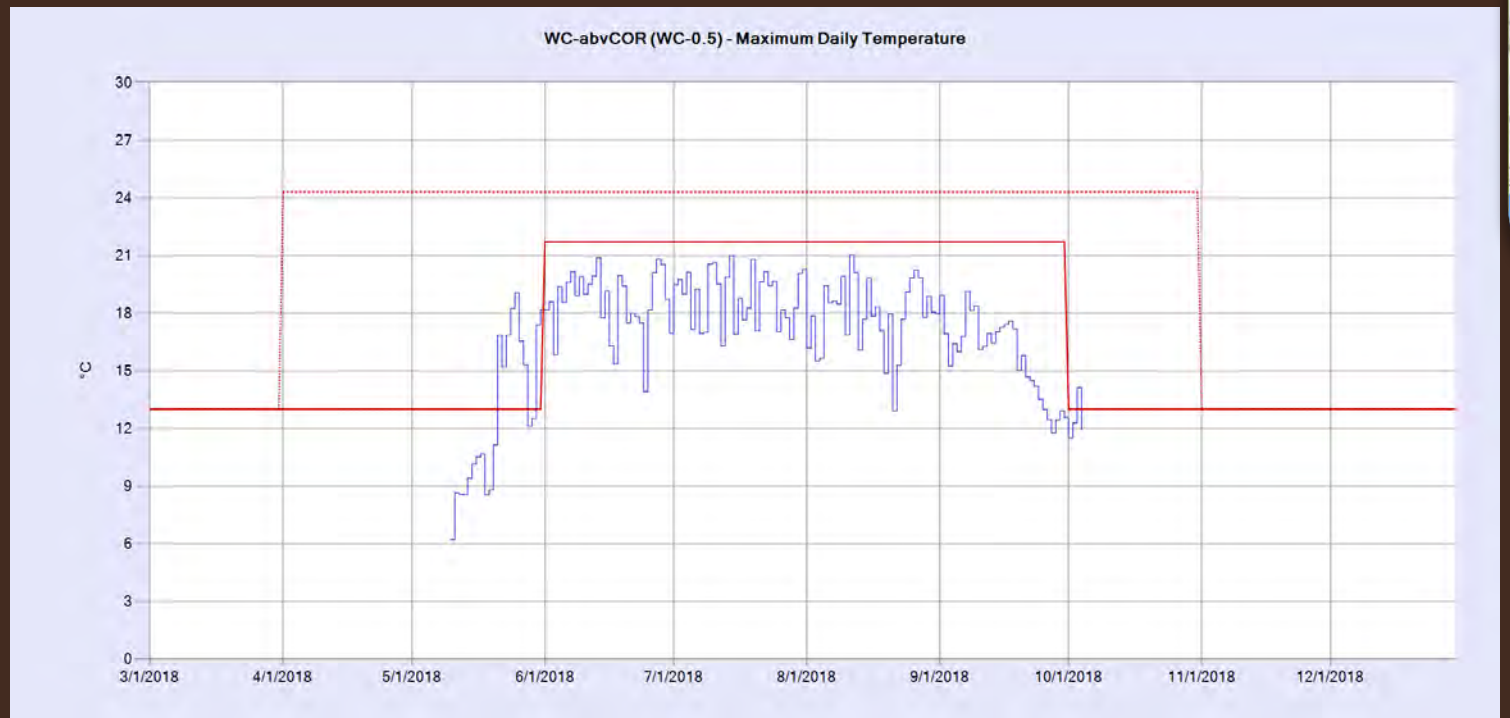




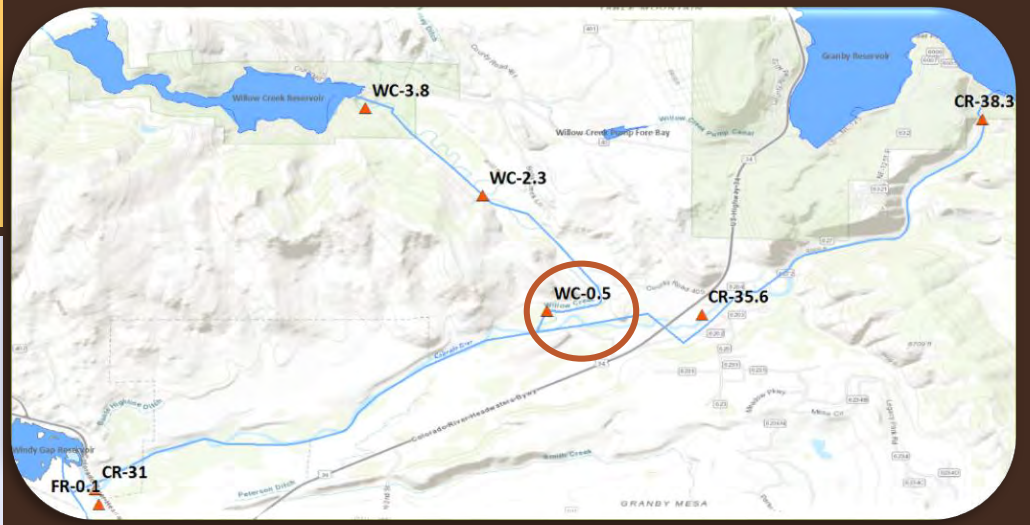
Willow Creek upstream Bunte Highline – CSI
WQCD Proposed CS-II

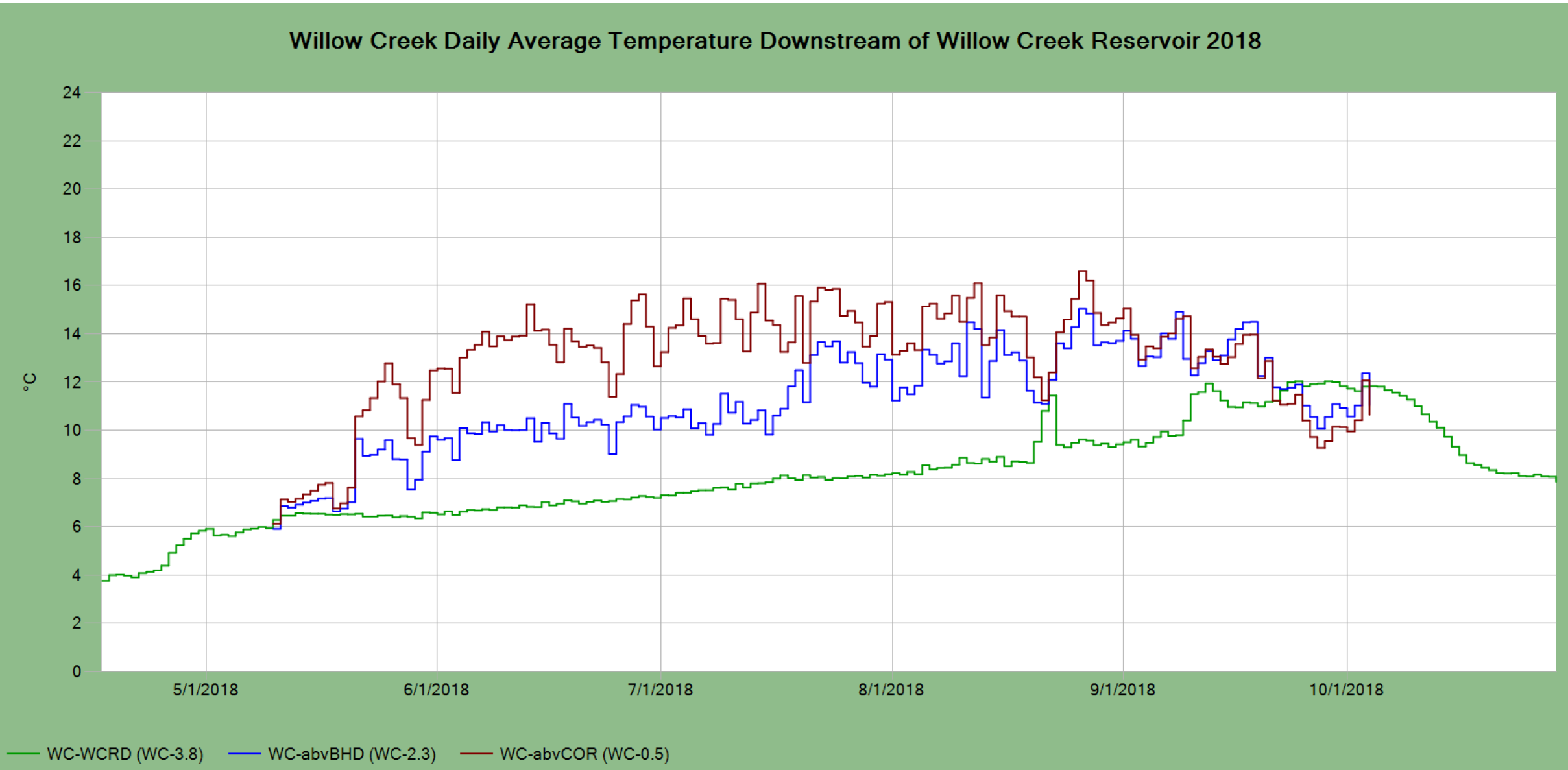


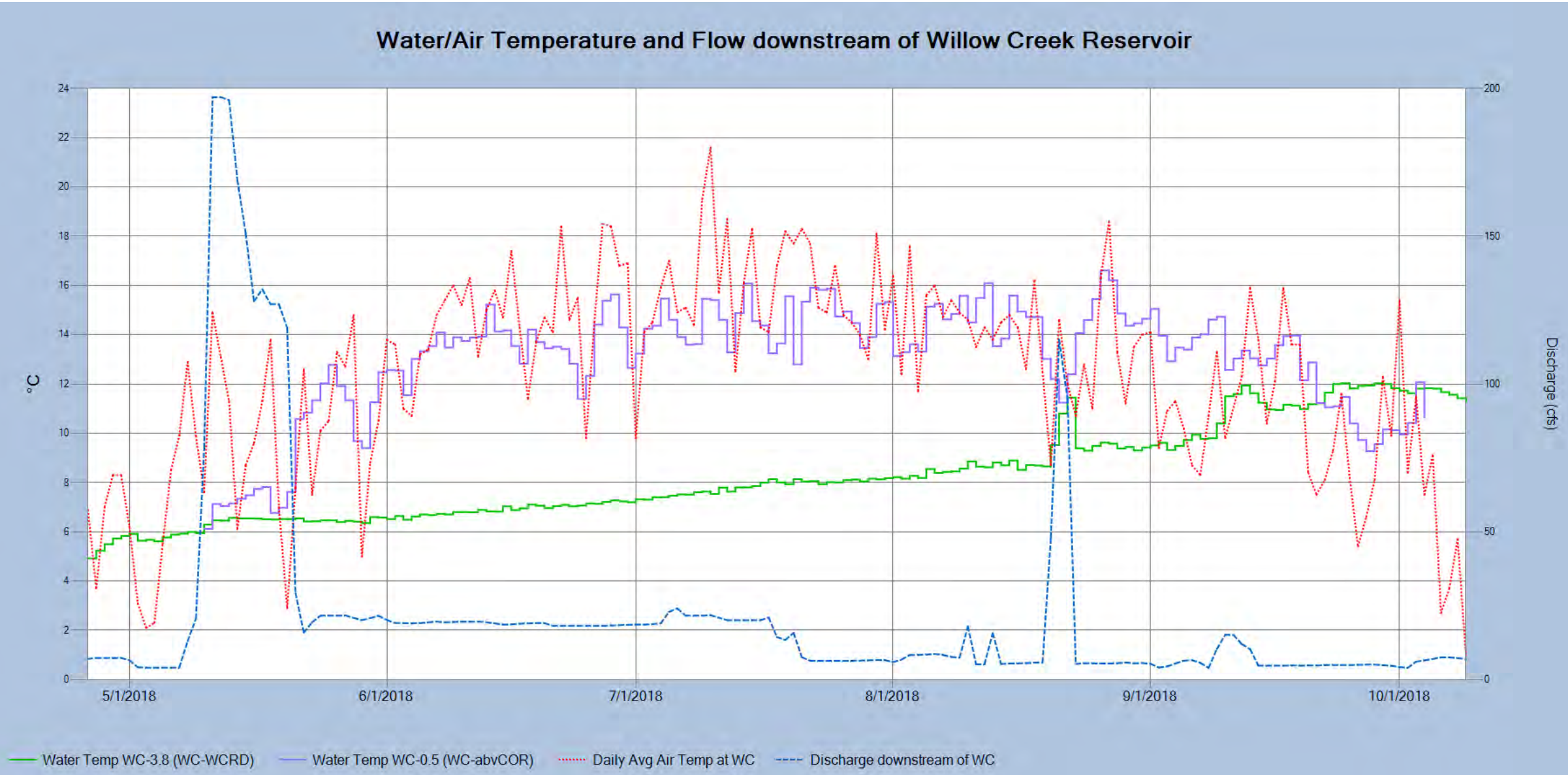


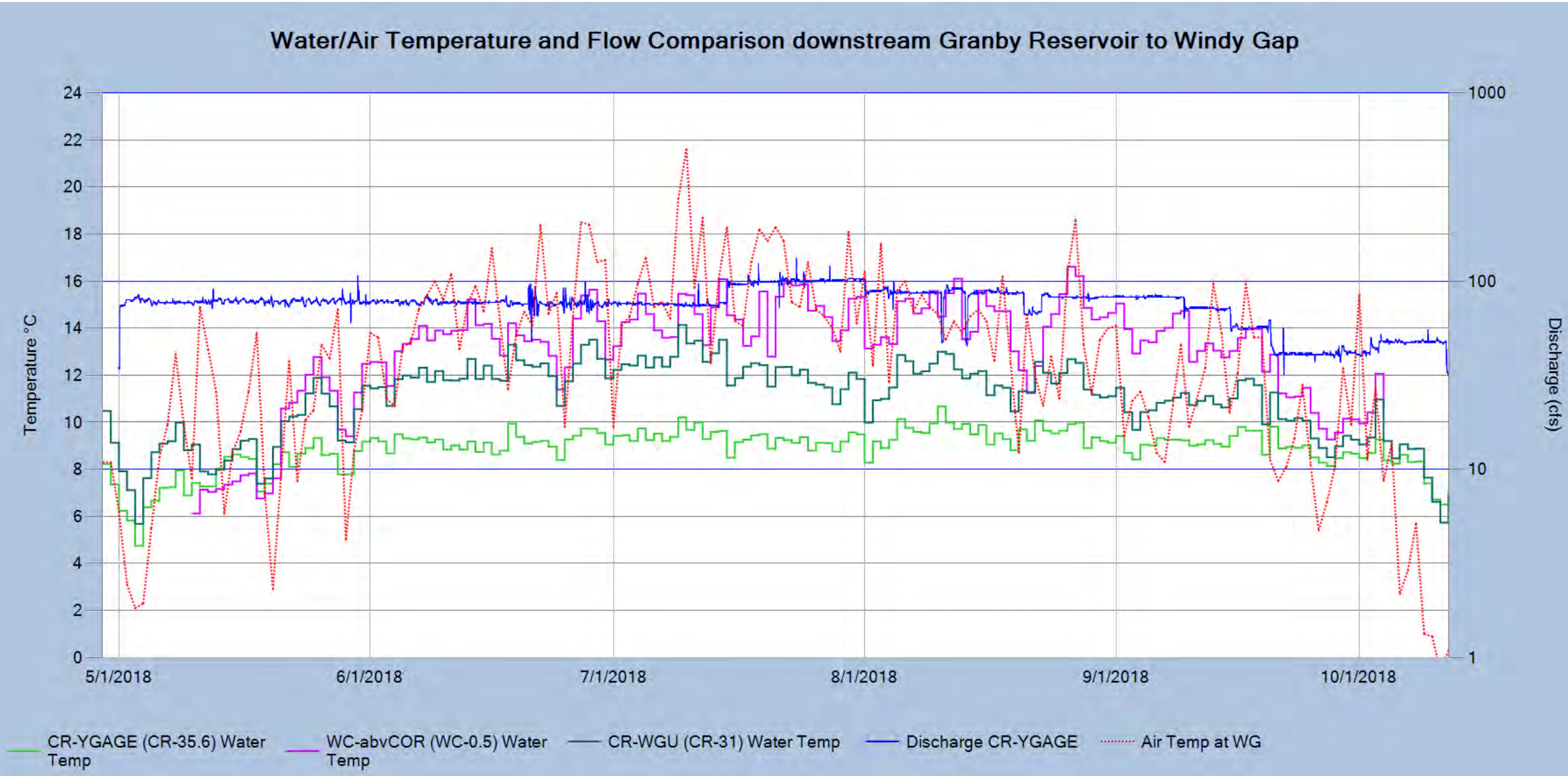


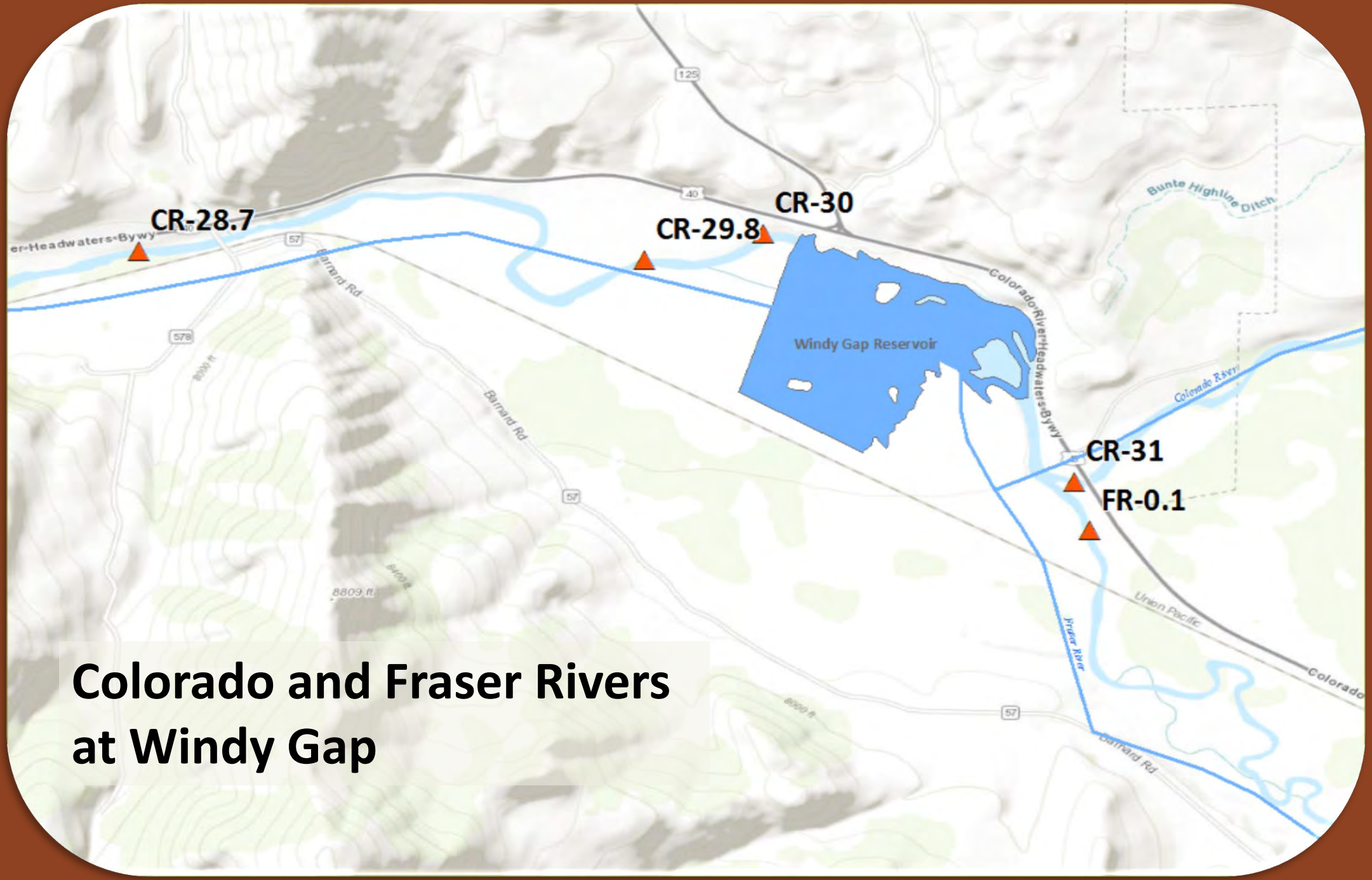
Willow Creek upstream Colorado River – CSI WQCD Proposed CS-II



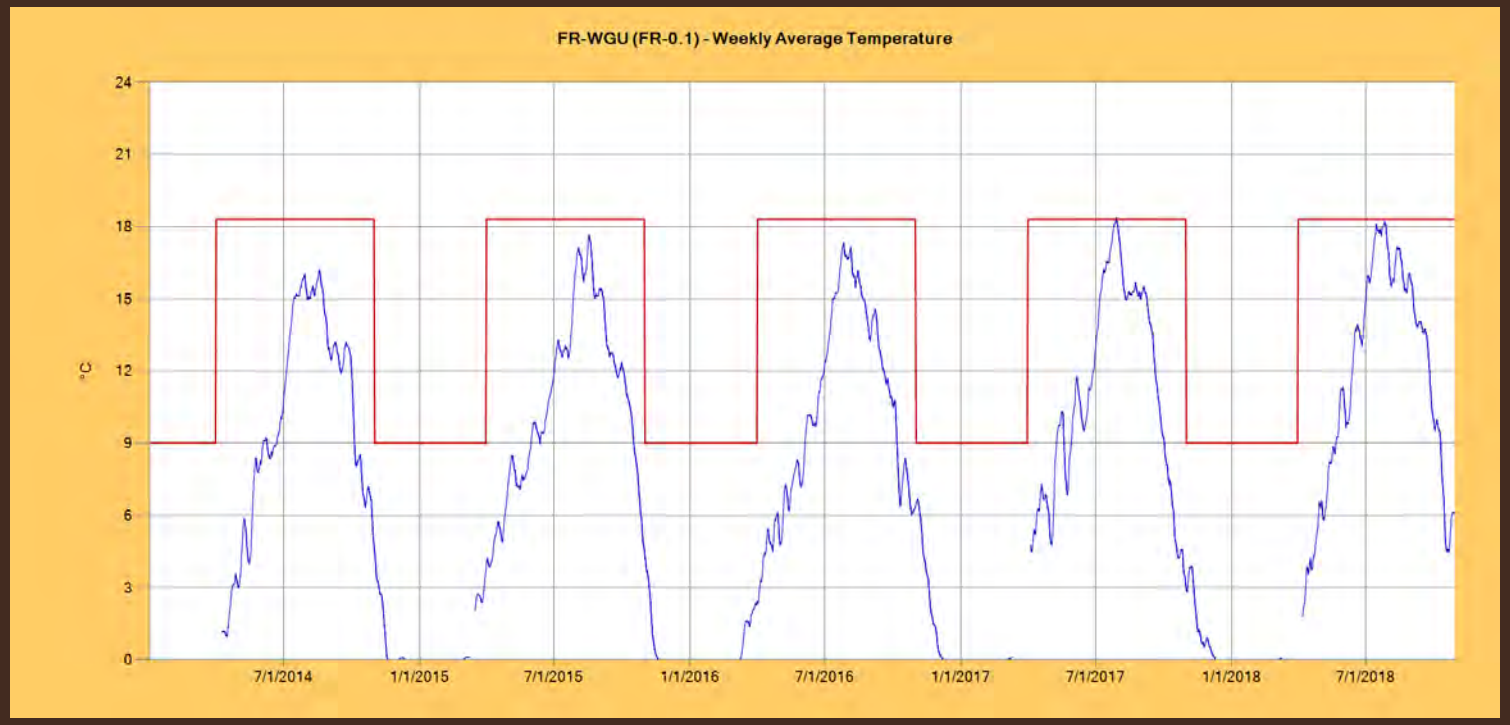

Willow Creek Daily Average Temperature Downstream of Willow Creek Reservoir 2018
°C
24
22
20
18
16
14
12
10
8
6
4
2
0
5/1/2018
6/1/2018
7/1/2018
8/1/2018
9/1/2018
10/1/2018
WC-WCRD (WC-3.8)
WC-abvBHD (WC-2.3)
WC-abvCOR (WC-0.5)

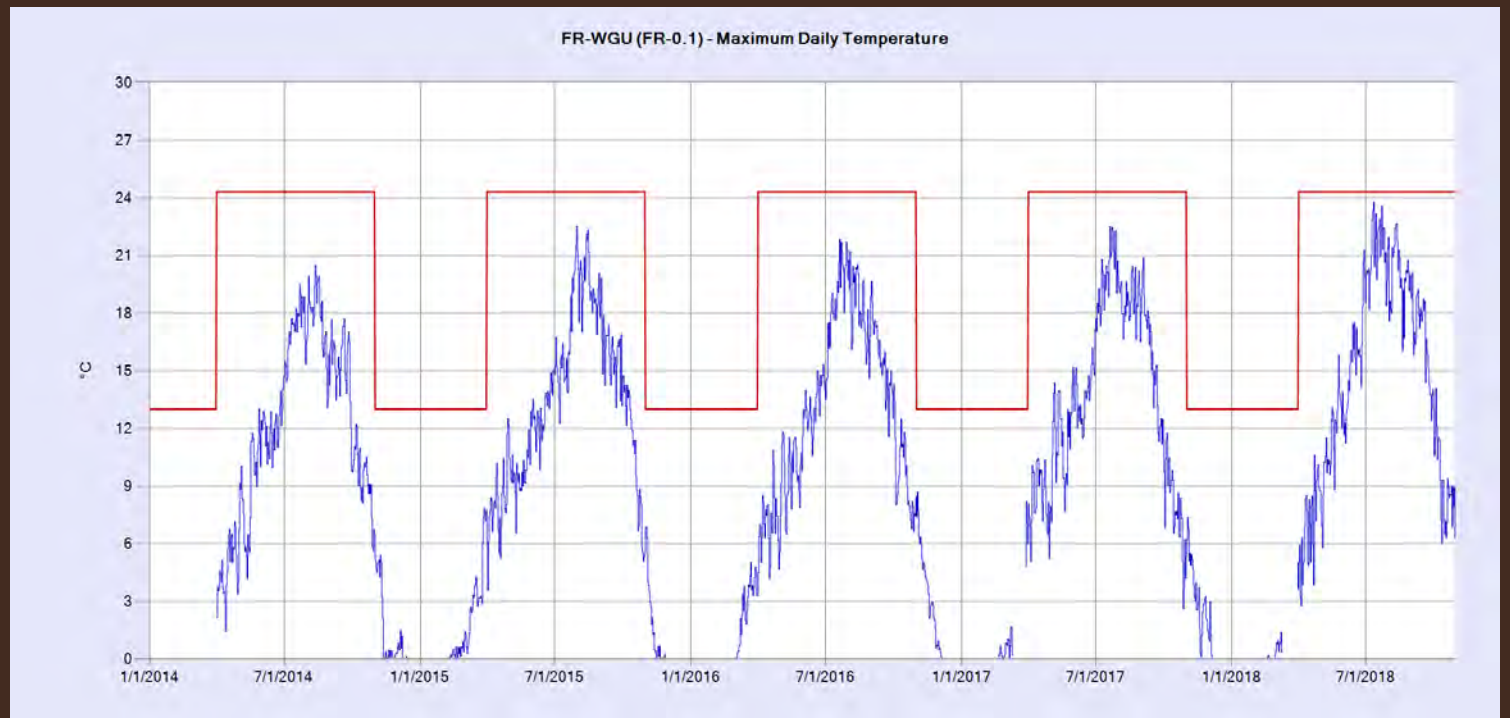

Water/Air Temperature and Flow downstream of Willow Creek Reservoir
°C
Discharge (cfs)
0
2
4
6
8
10
12
14
16
18
20
22
24
0
50
100
150
200
5/1/2018
6/1/2018
7/1/2018
8/1/2018
9/1/2018
10/1/2018
Water Temp WC-3.8 (WC-WCRD)
Water Temp WC-0.5 (WC-abvCOR)
Daily Avg Air Temp at WC
Discharge downstream of WC


Water/Air Temperature and Flow Comparison downstream Granby Reservoir to Windy Gap
Temperature °C
Discharge (cfs)
24
22
20
18
16
14
12
10
8
6
4
2
0
1000
100
10
1
5/1/2018
6/1/2018
7/1/2018
8/1/2018
9/1/2018
10/1/2018
CR-YGAGE (CR-35.6) Water Temp
WC-abvCOR (WC-0.5) Water Temp
CR-WGU (CR-31) Water Temp
Discharge CR-YGAGE
Air Temp at WG

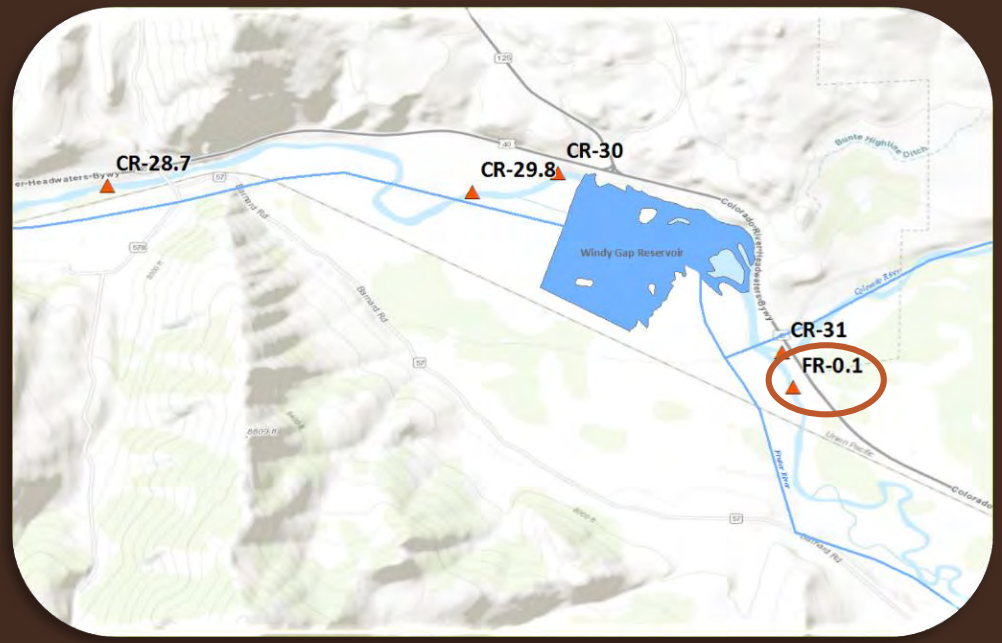


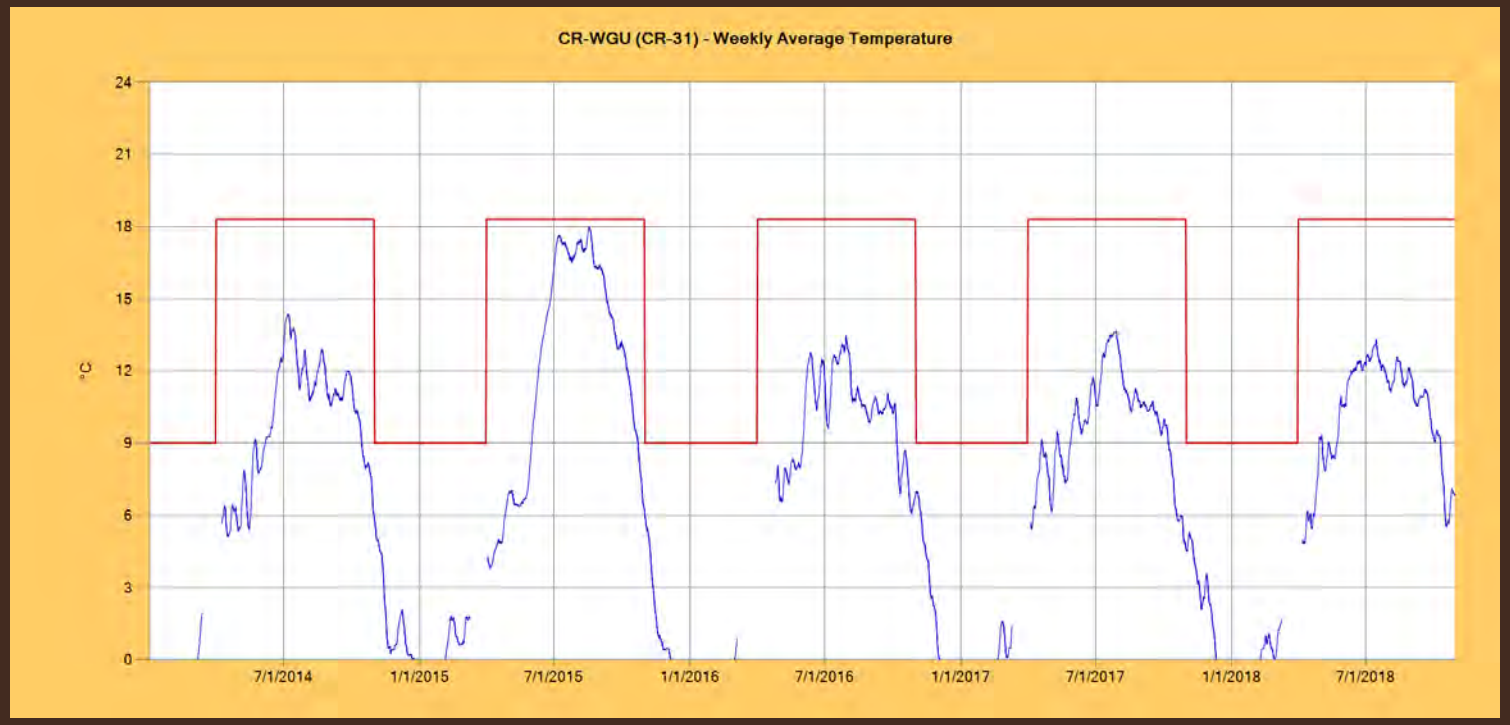
Colorado and Fraser Rivers at Windy Gap

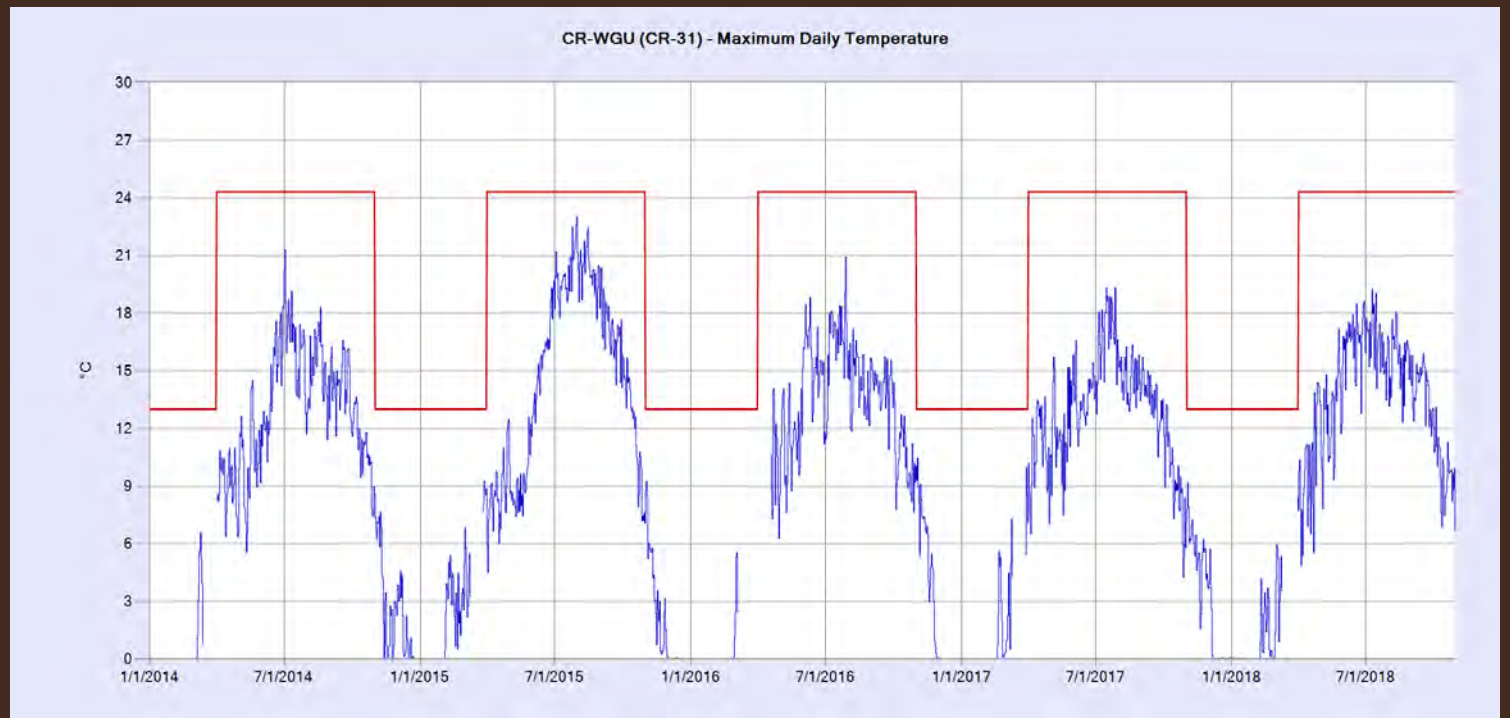




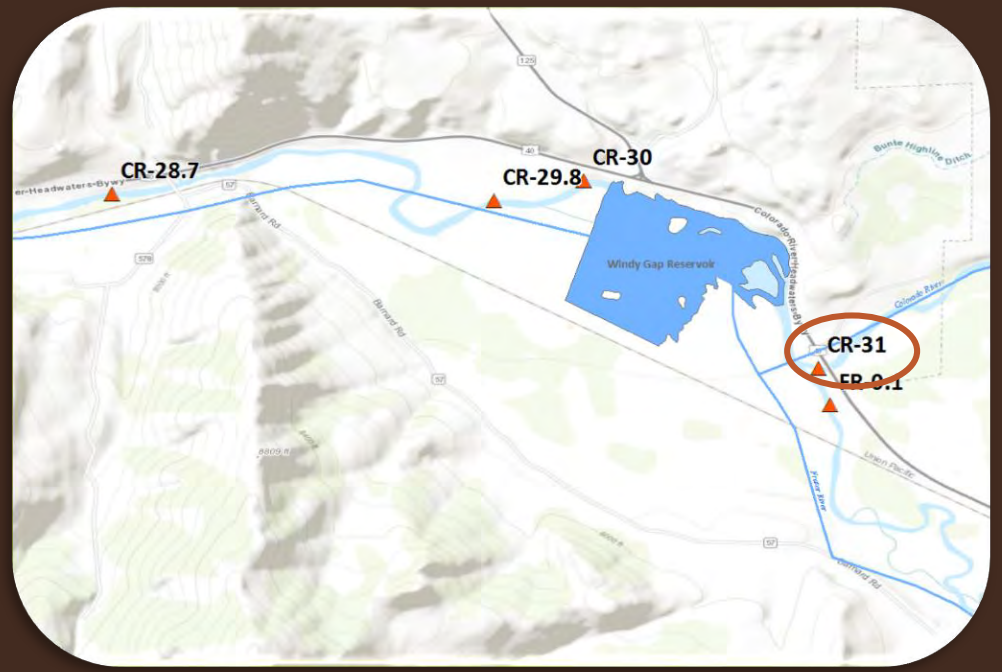
Fraser River upstream of Windy Gap – CSII

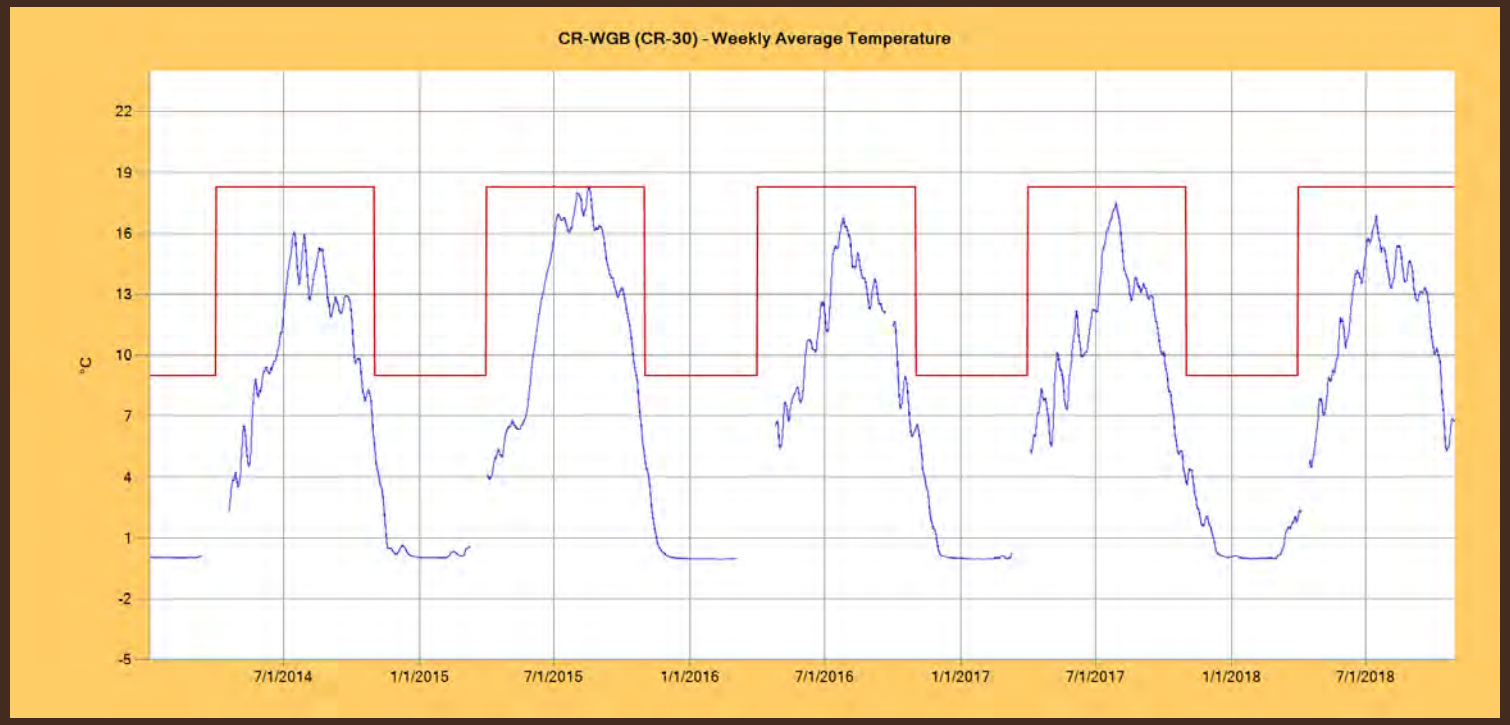


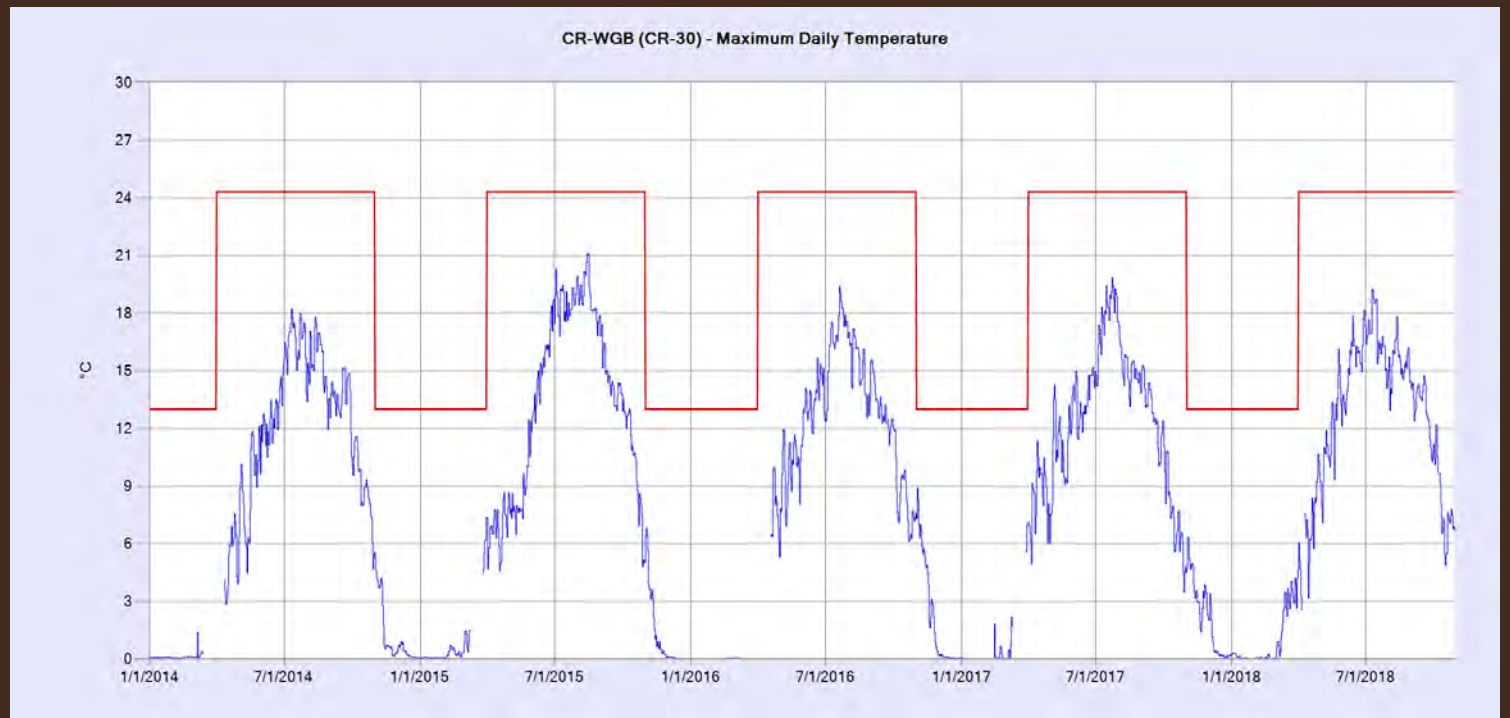




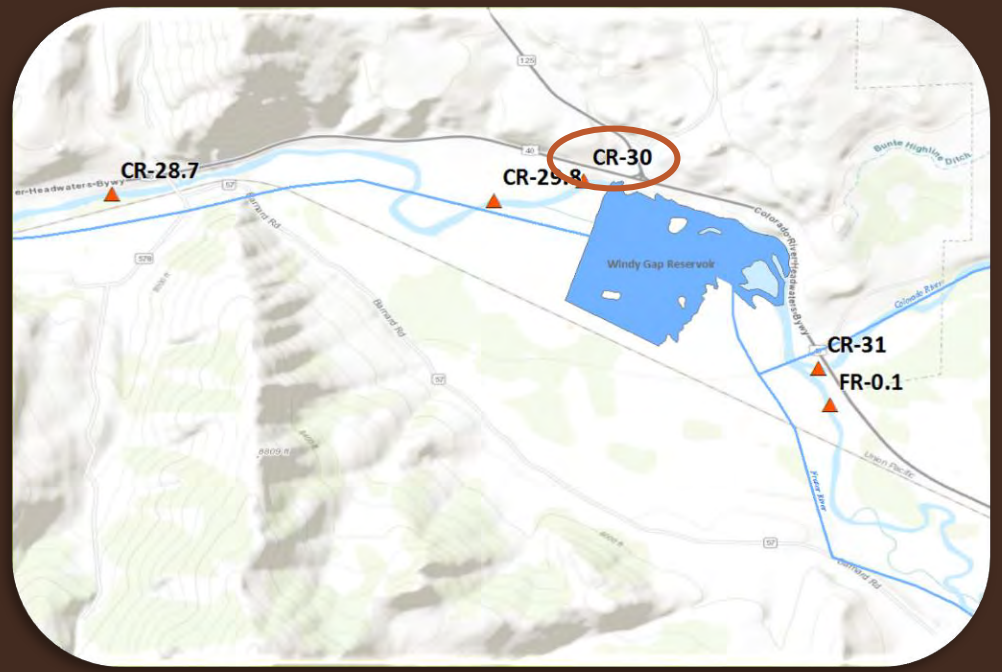
Colorado River upstream of Windy Gap – CSII

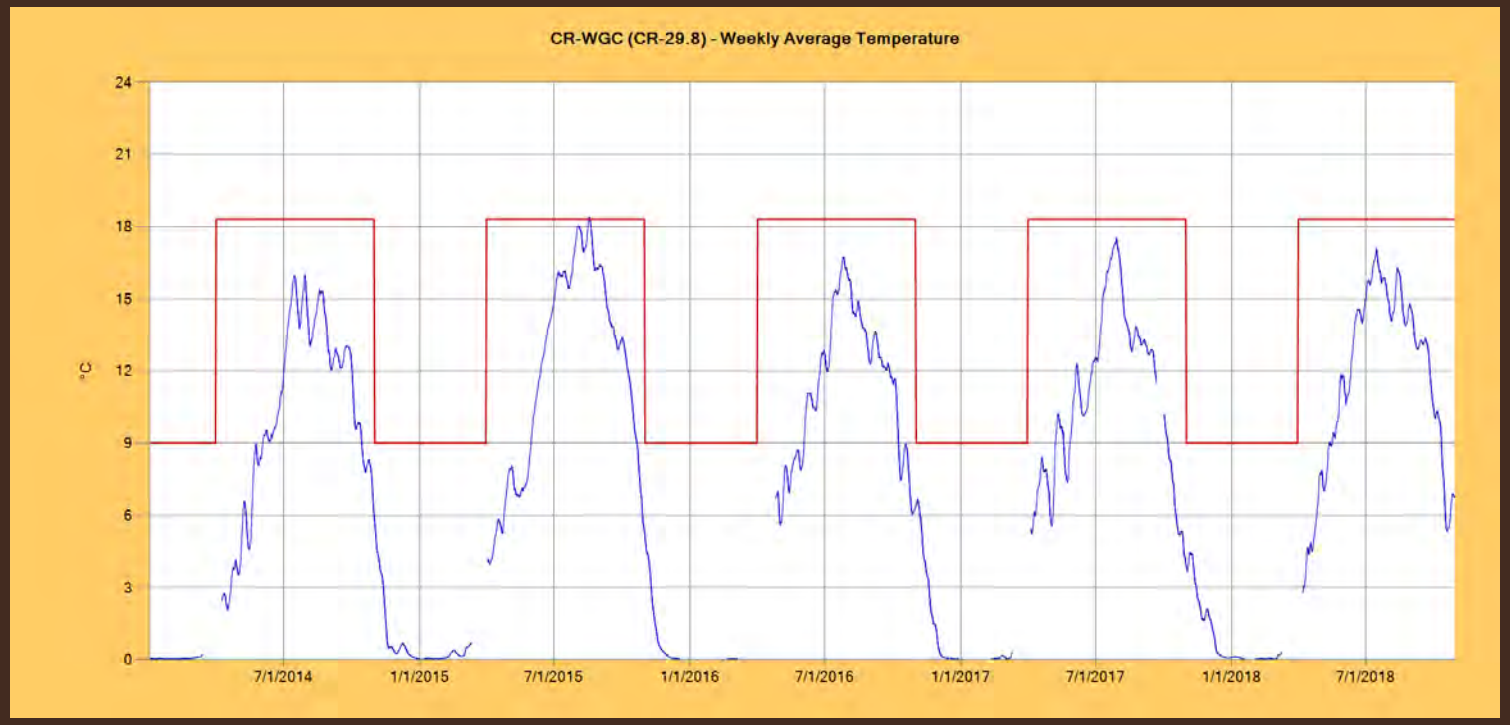


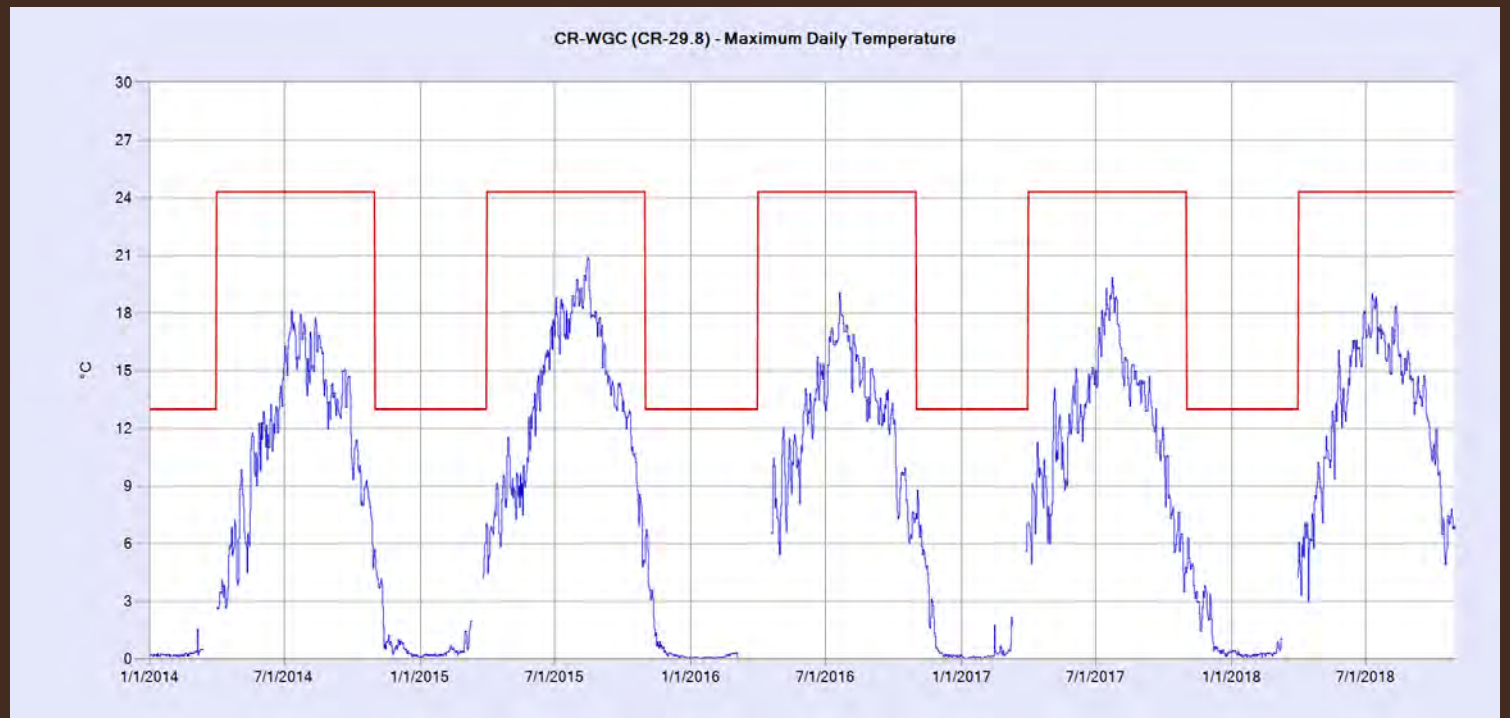




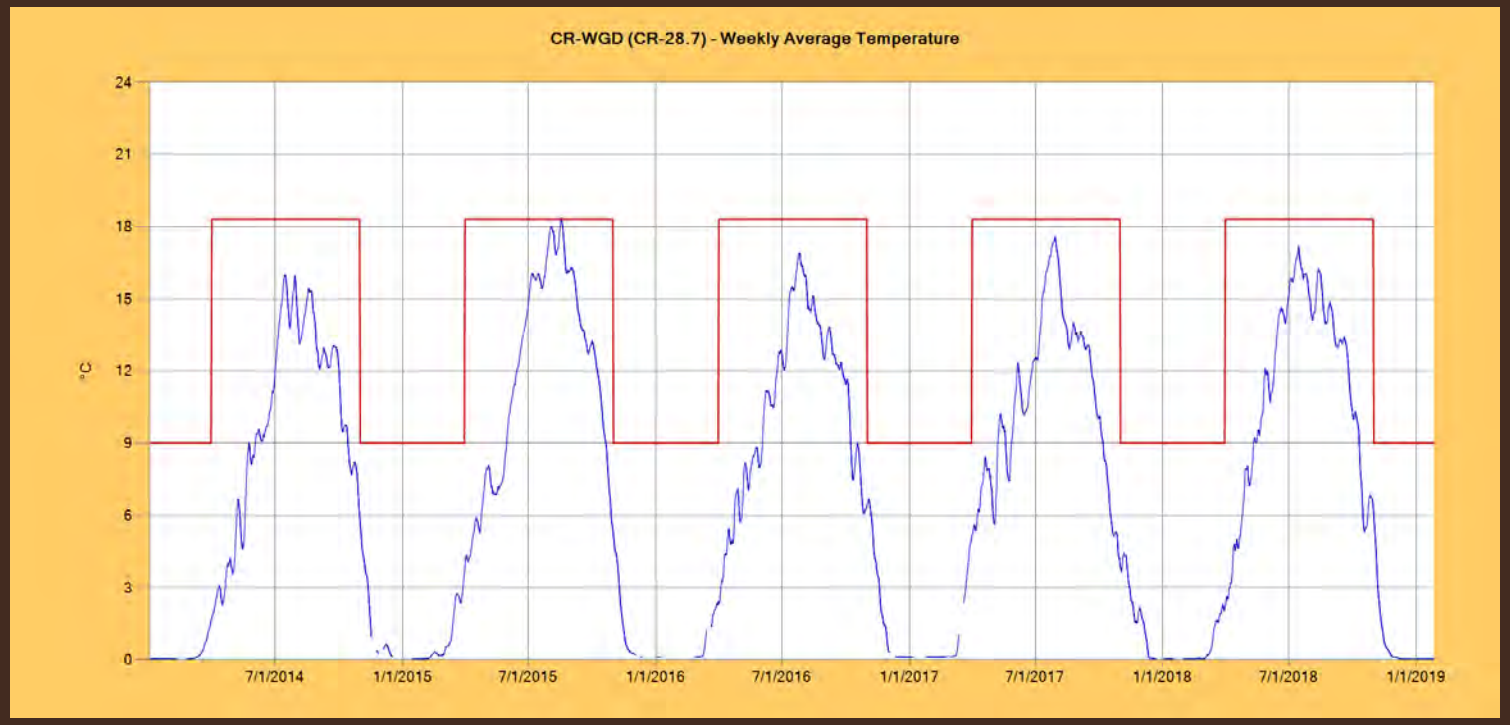
Windy Gap Bypass – CSII

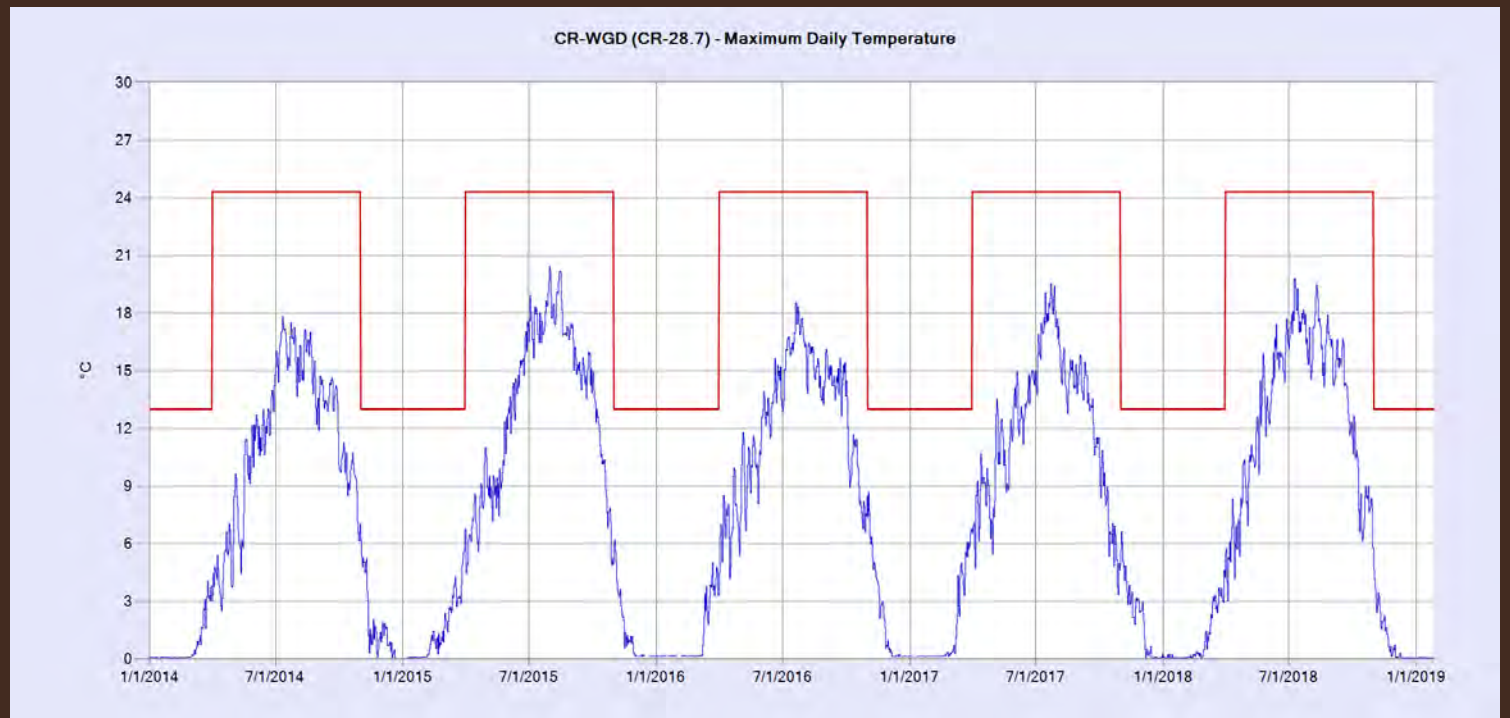




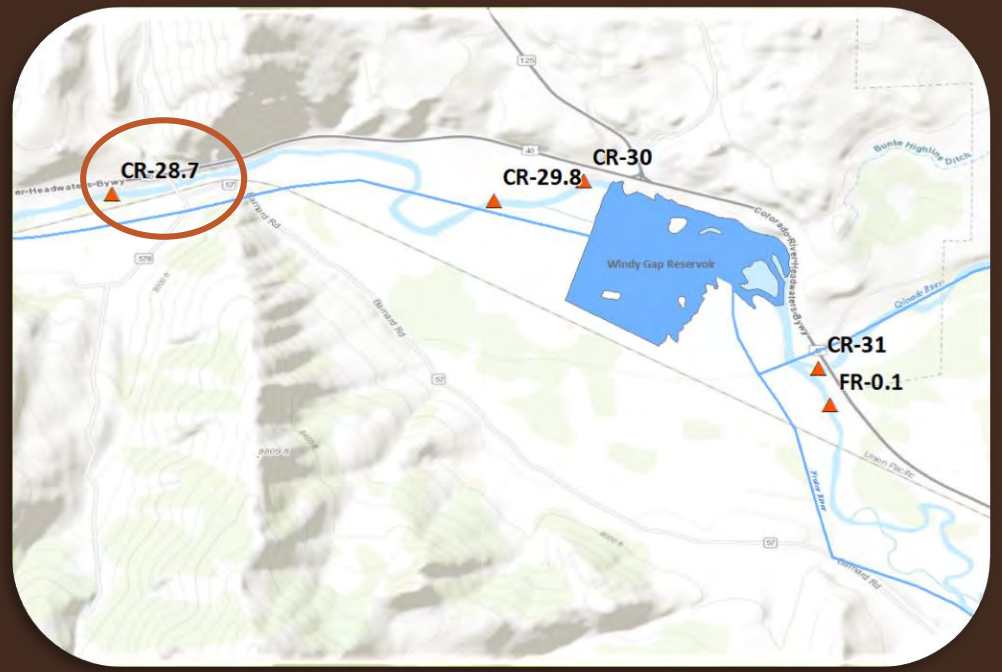


Windy Gap confluence of Bypass and Spillway – CSII



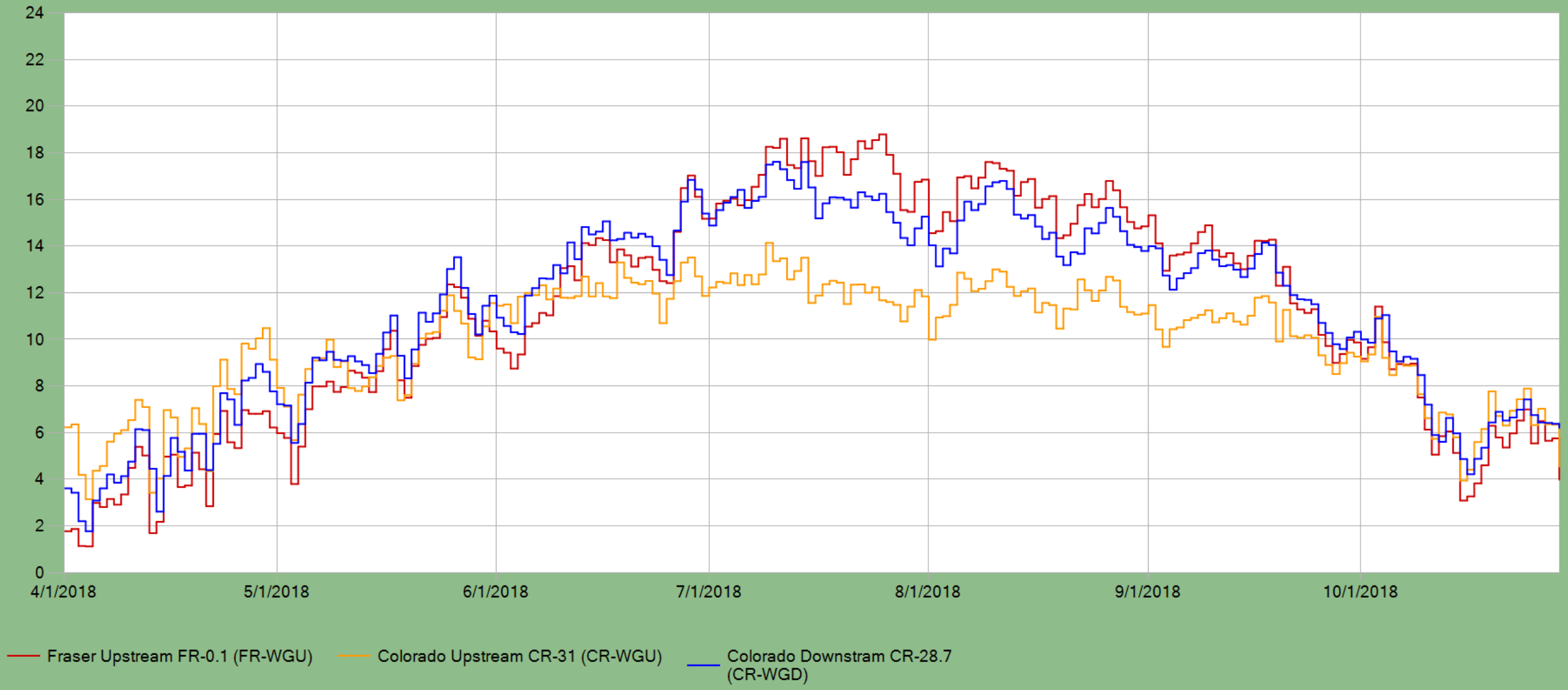


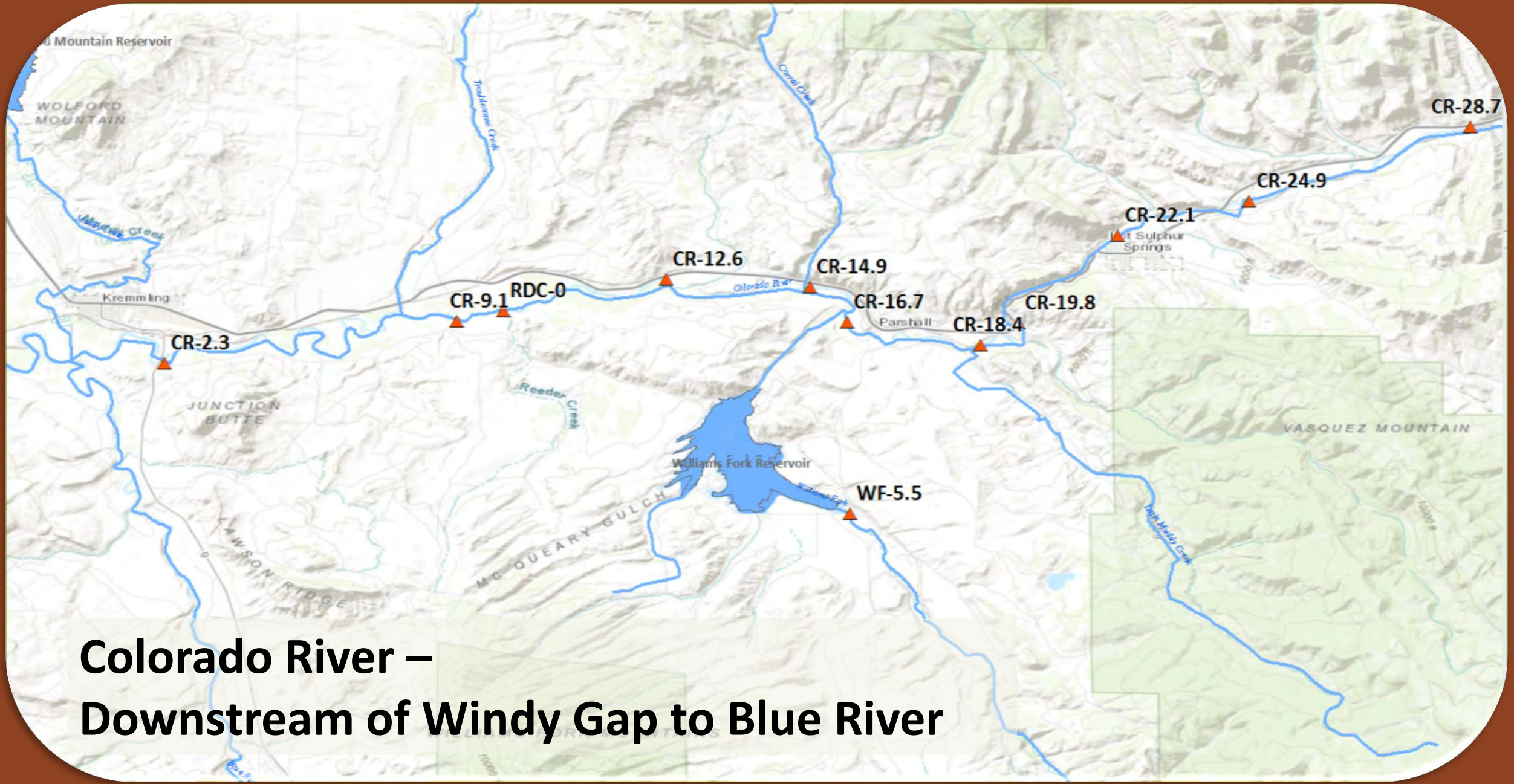
Colorado River downstream of Windy Gap – CSII



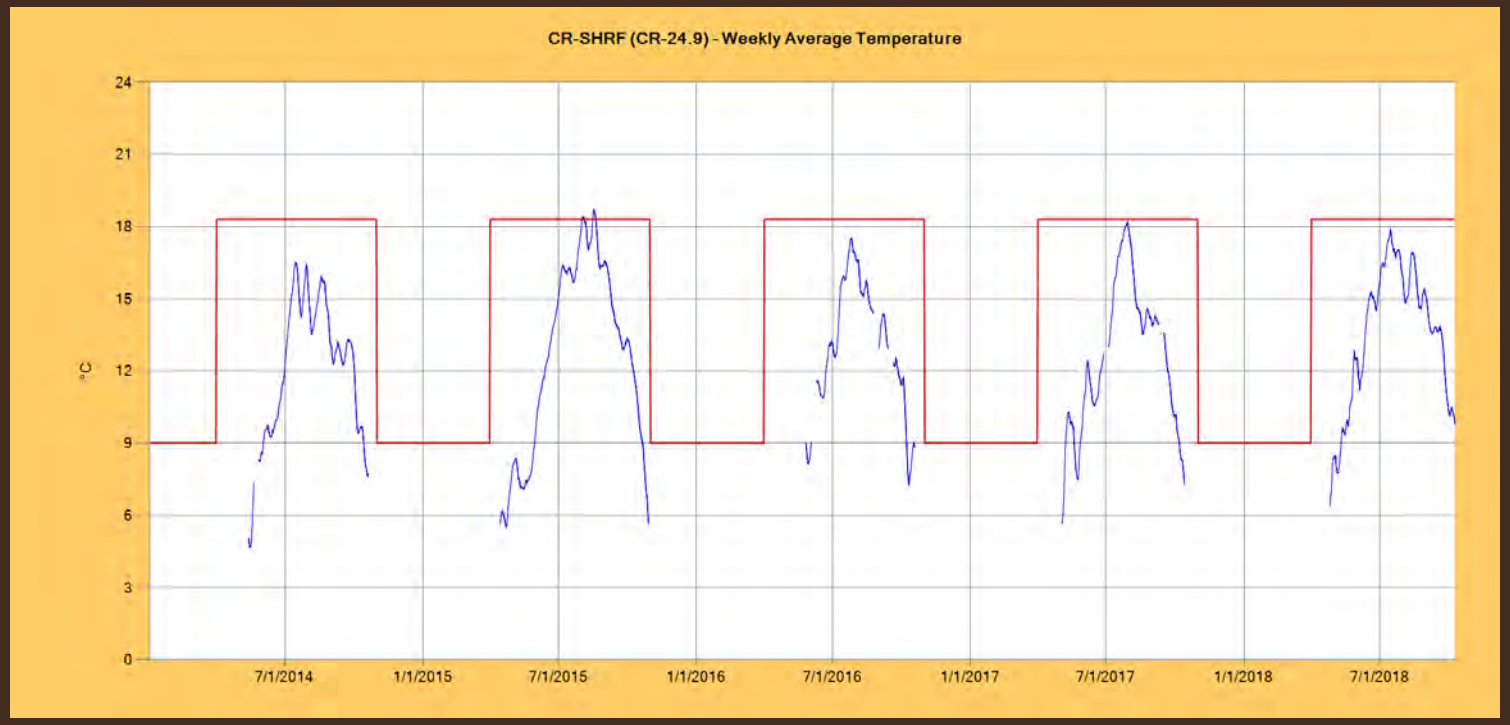
Northern Waters real-time site

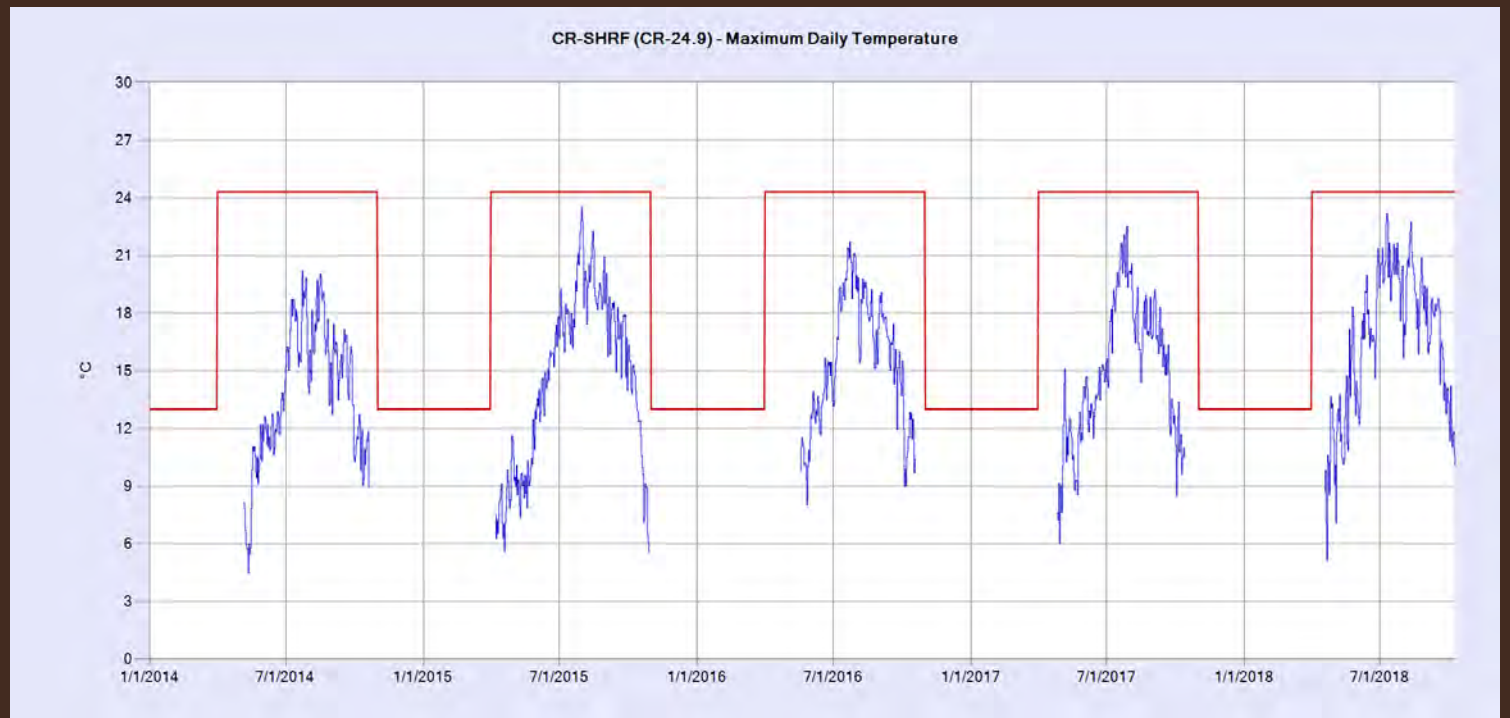
Colorado River Daily Average Temperature Upstream and Downstream of Windy Gap Reservoir



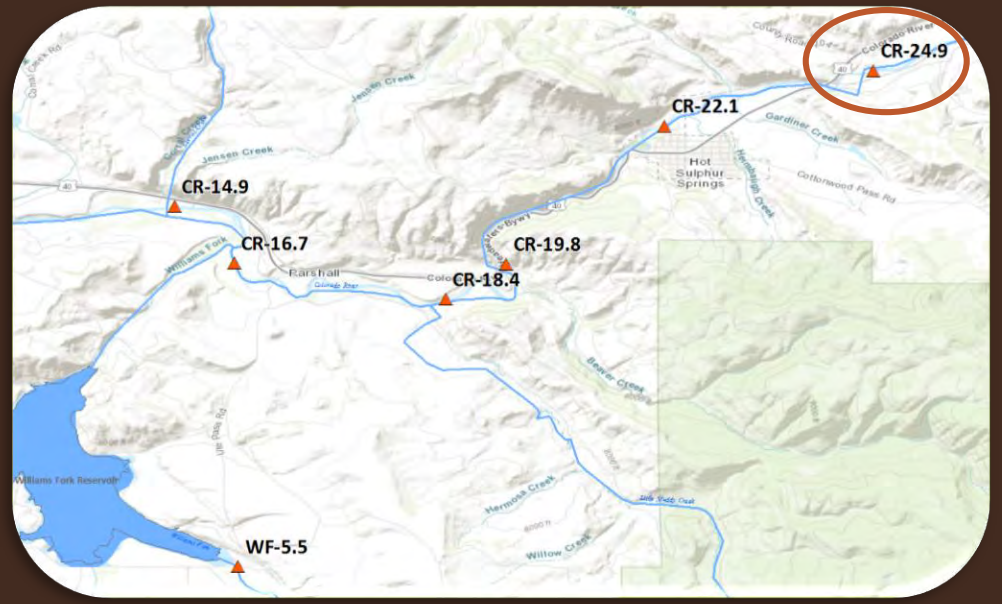


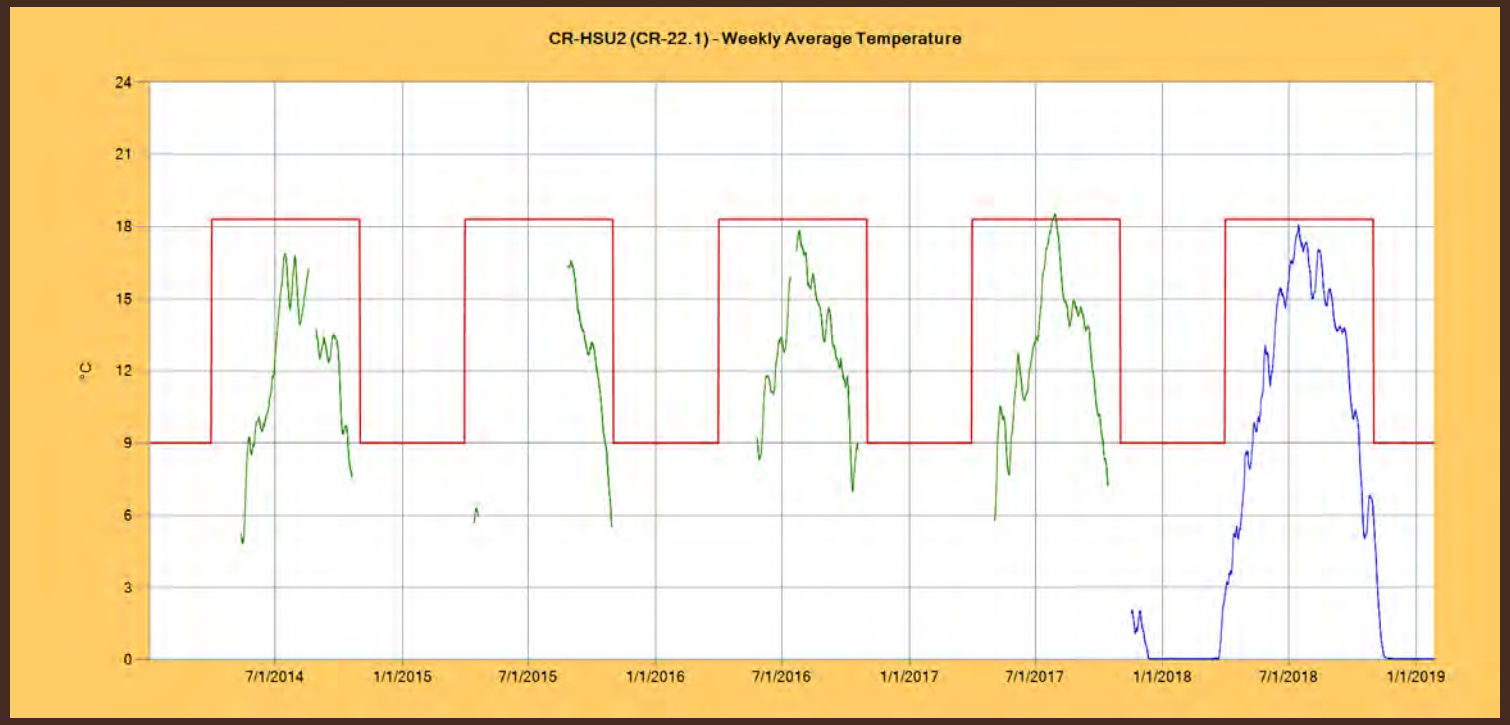
Colorado River – Downstream of Windy Gap to Blue River

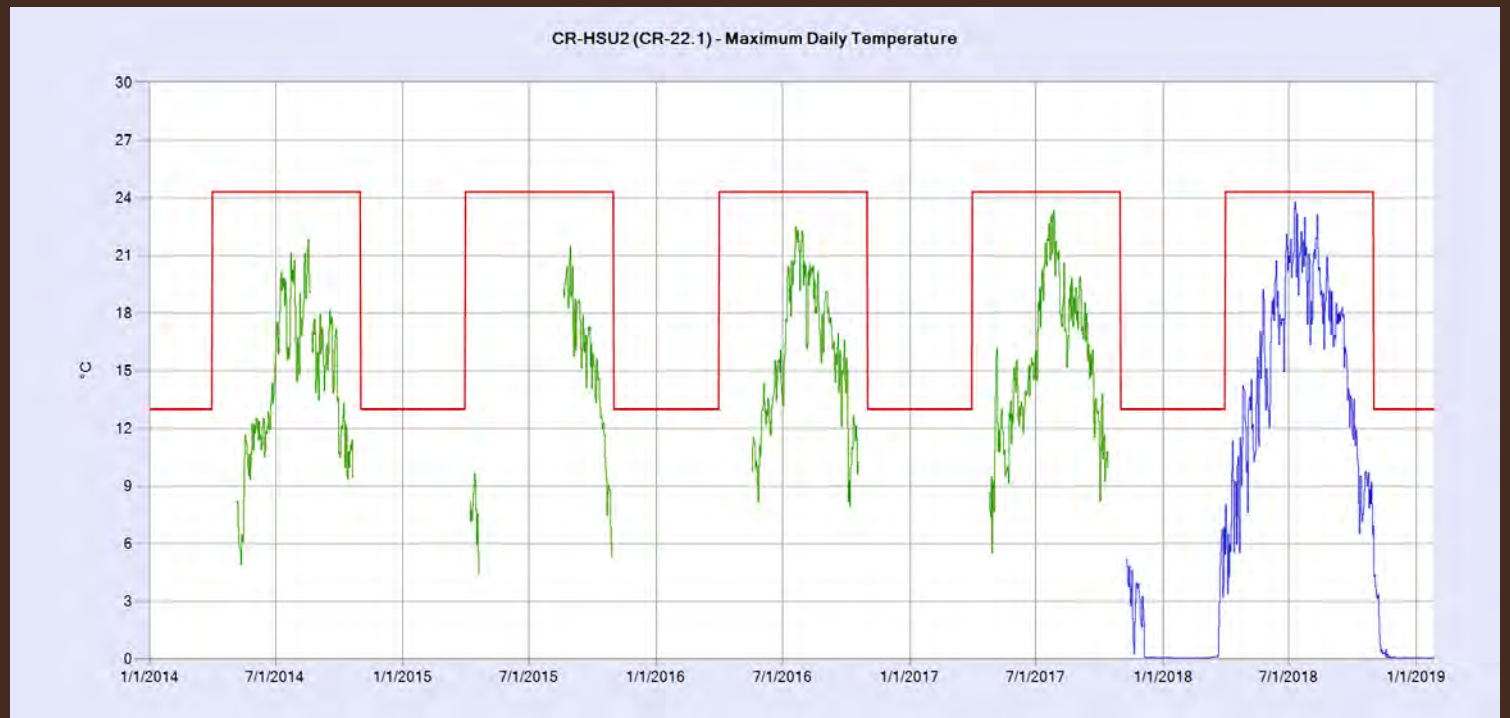




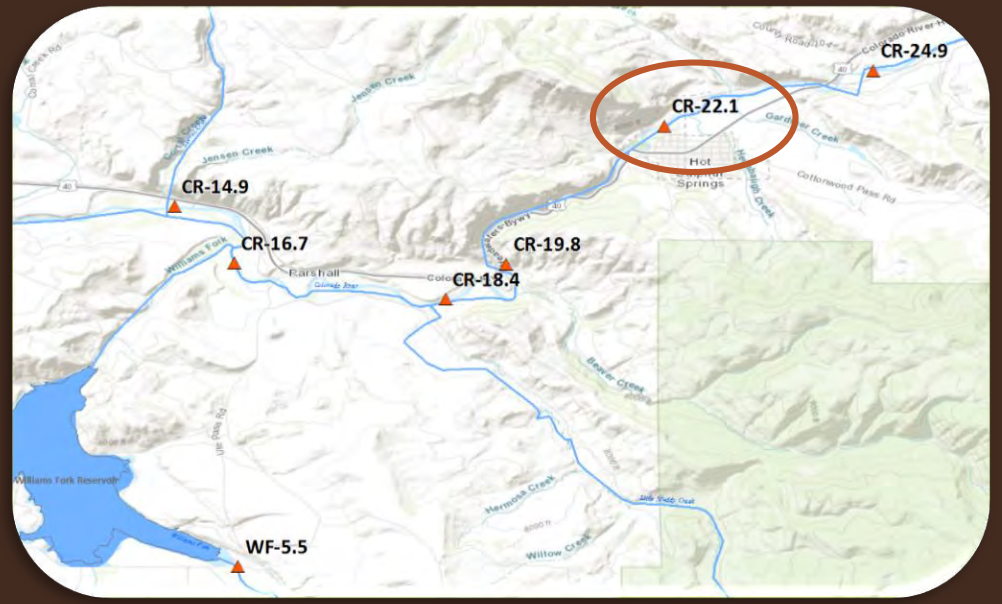
Colorado River at Sheriff Ranch – CSII



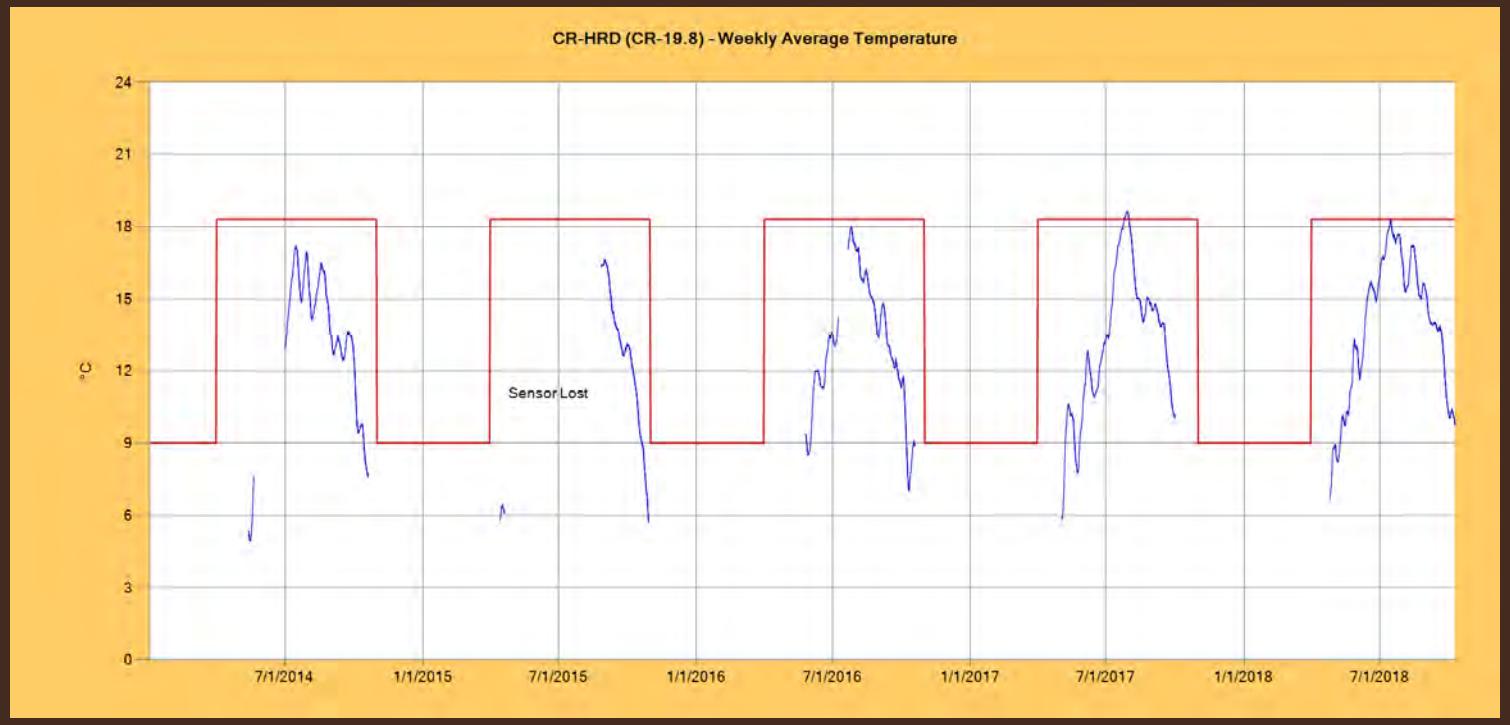


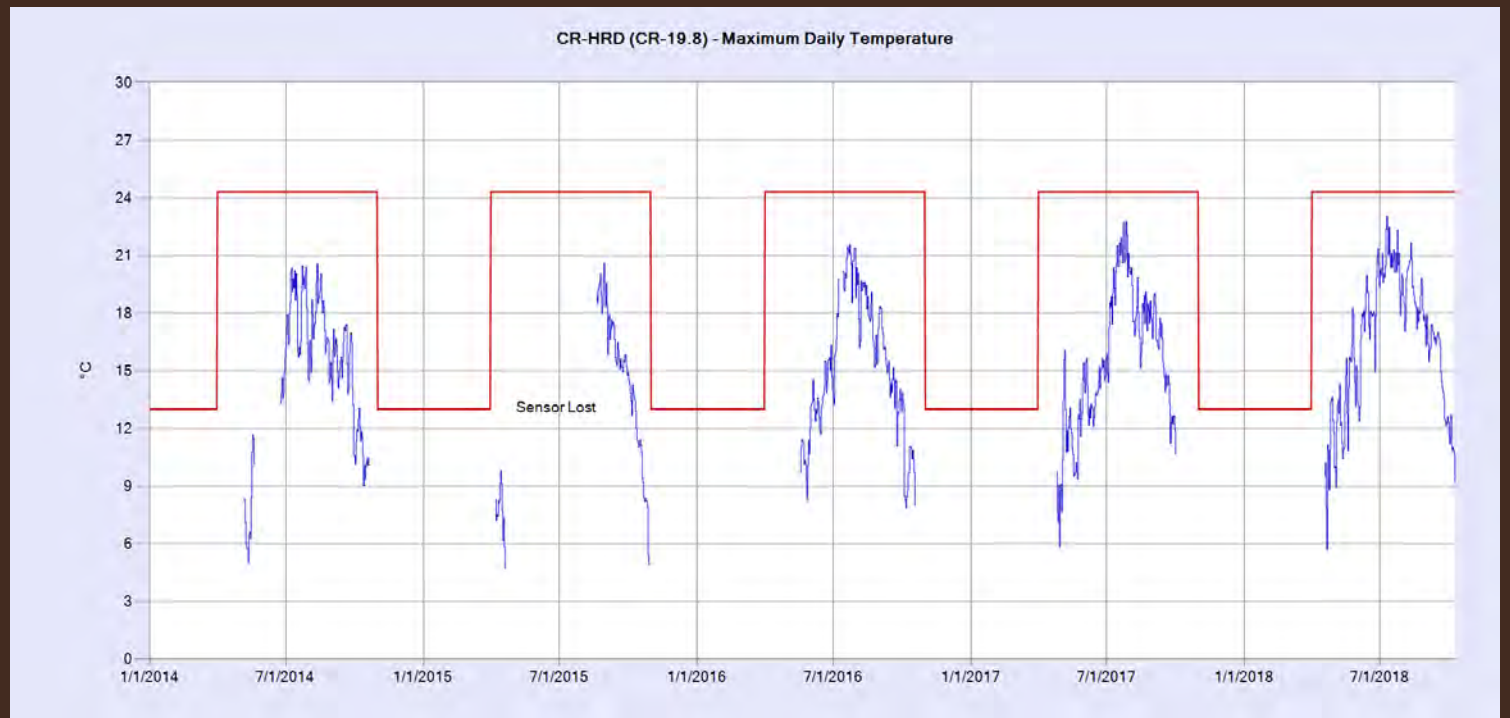


Colorado River upstream Hot Sulphur Springs – CSII

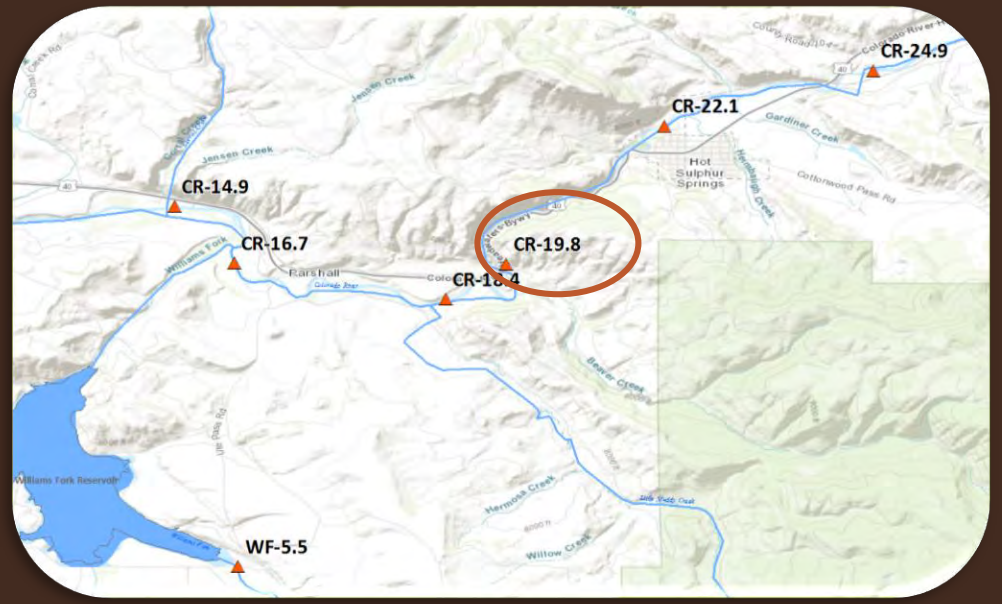


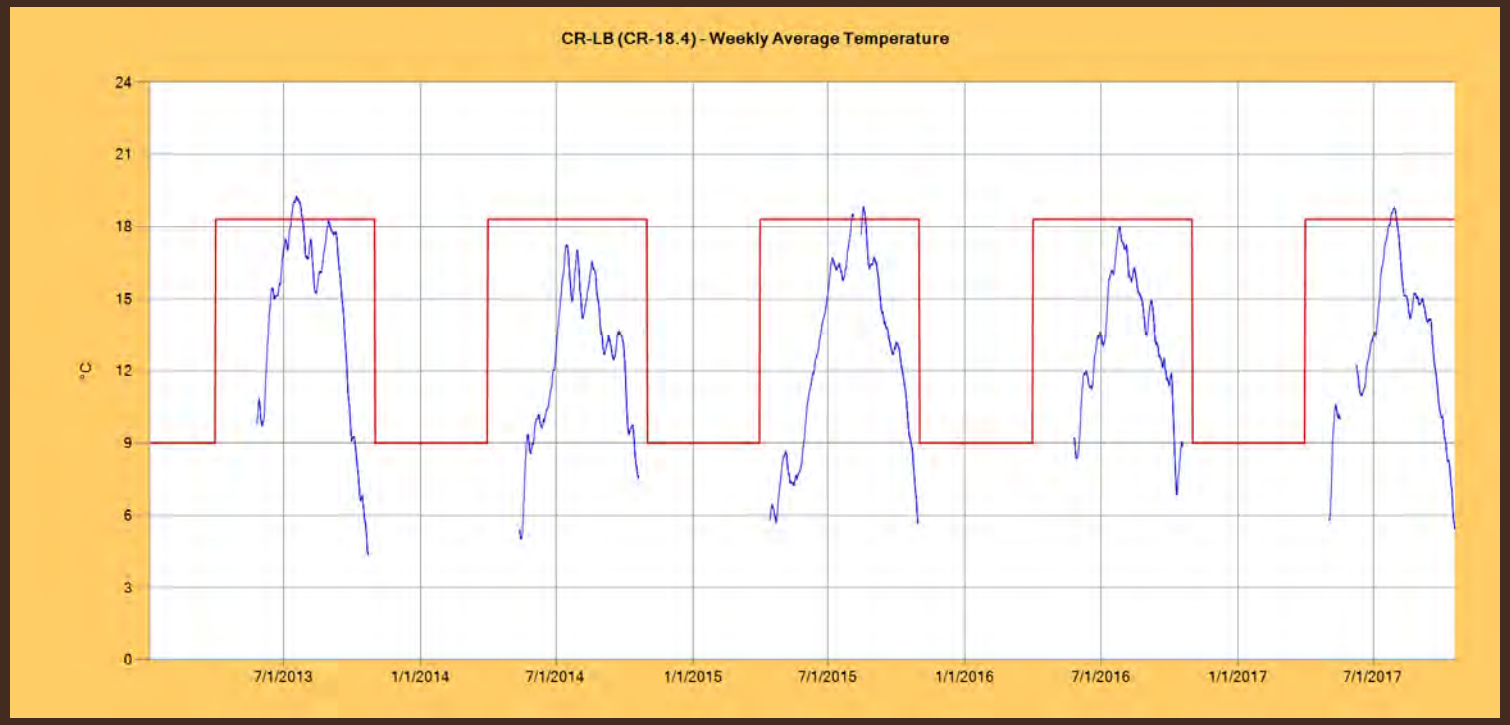
Northern Waters real-time site

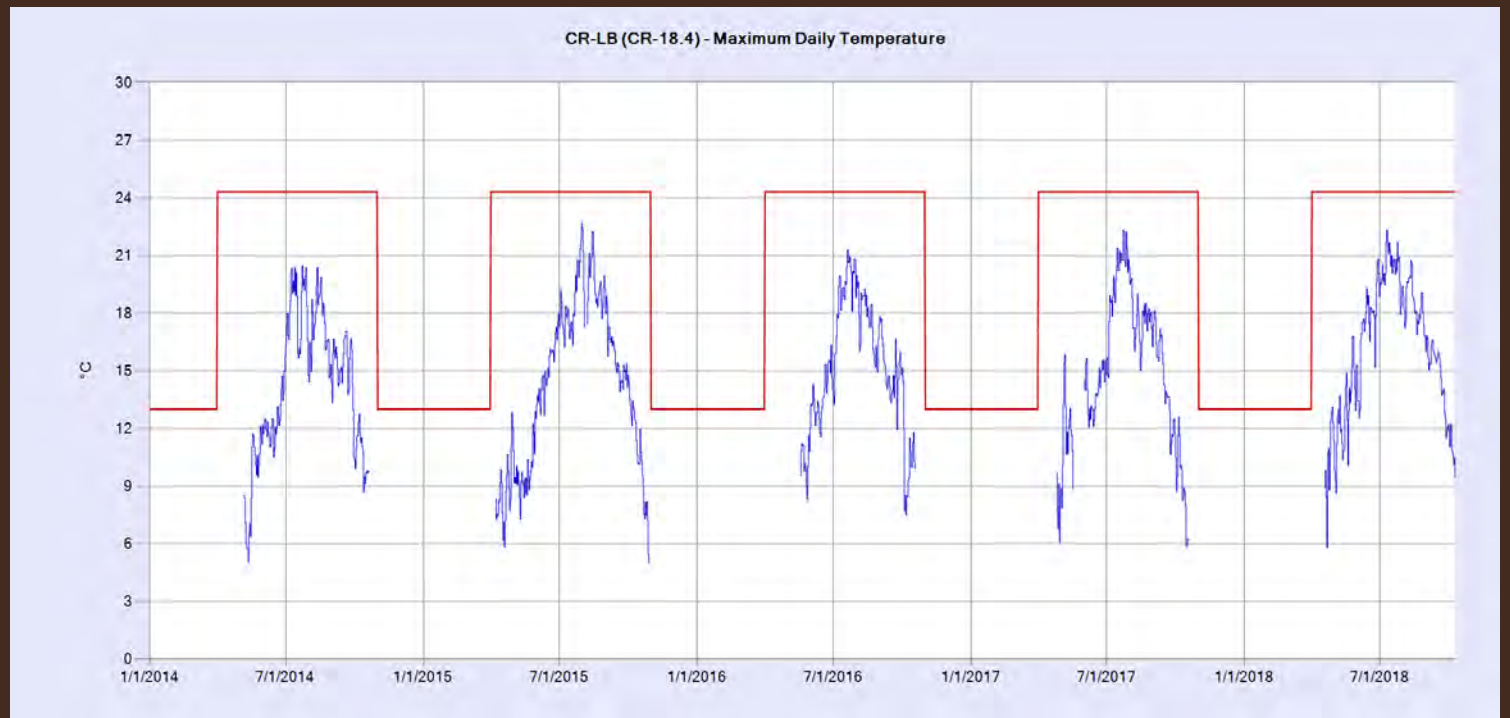




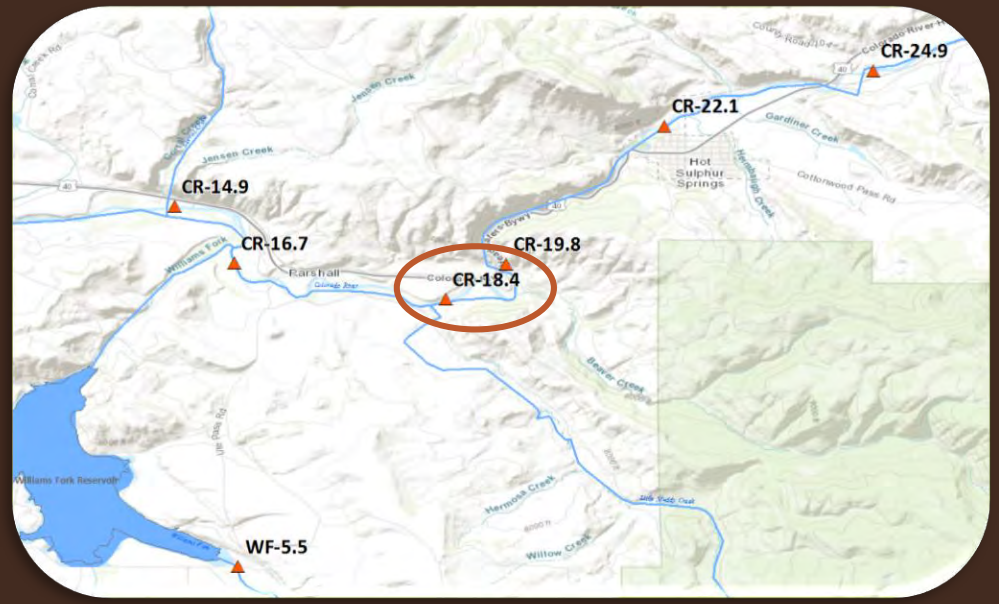
Colorado River downstream Byers Canyon– CSII

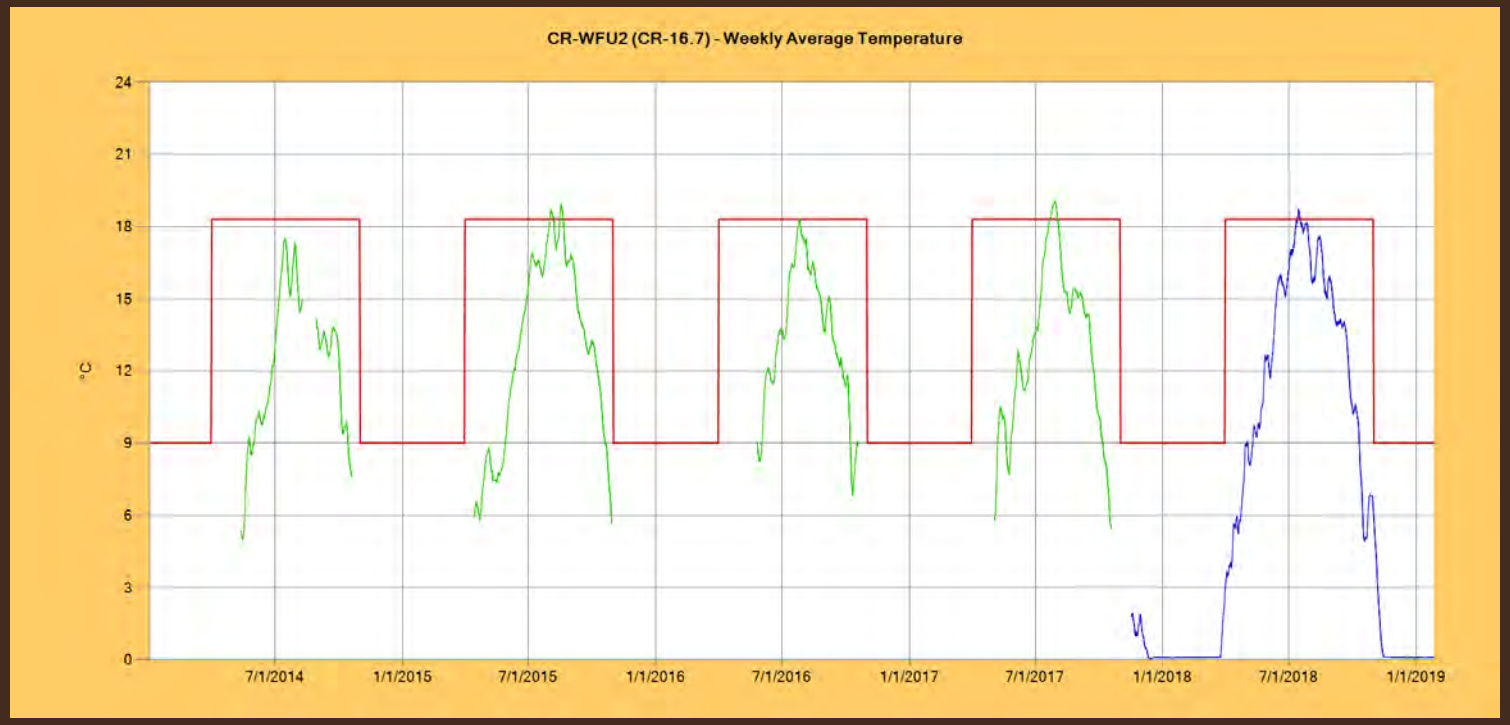


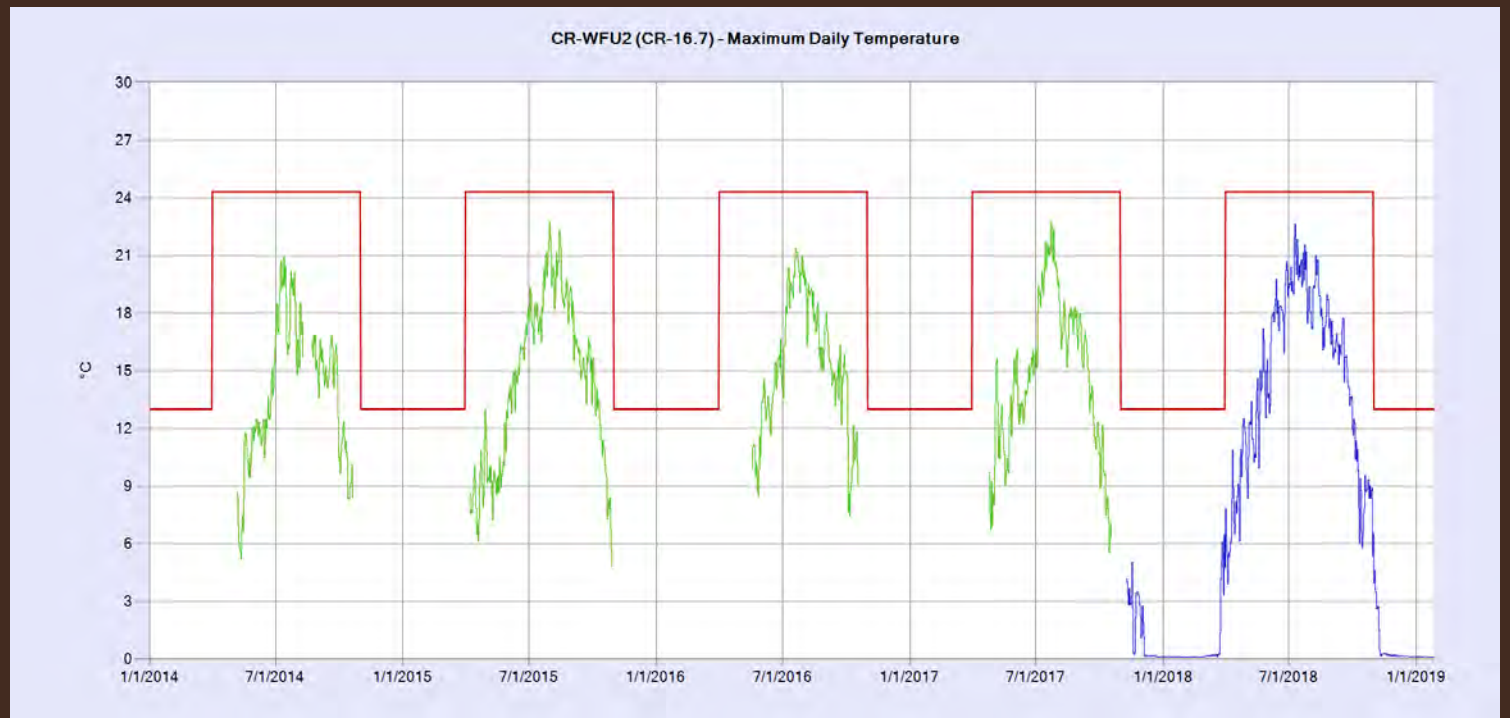




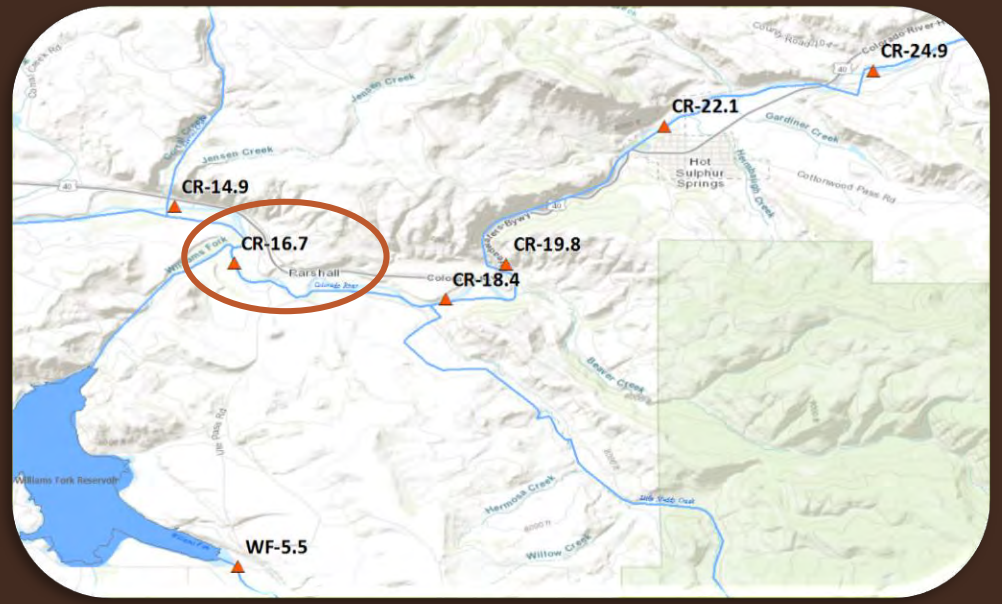
Colorado River at Lone Buck – CSII



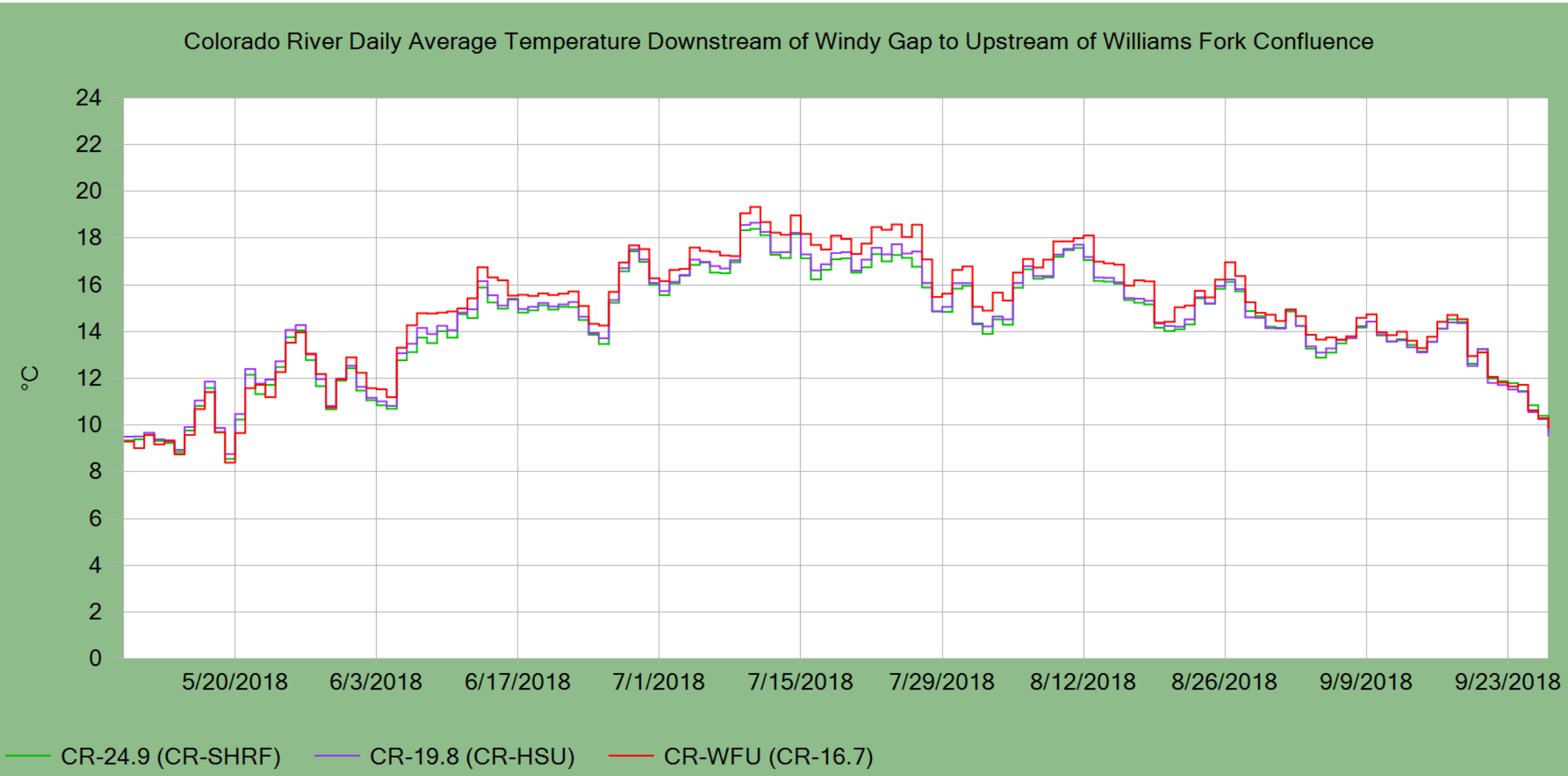


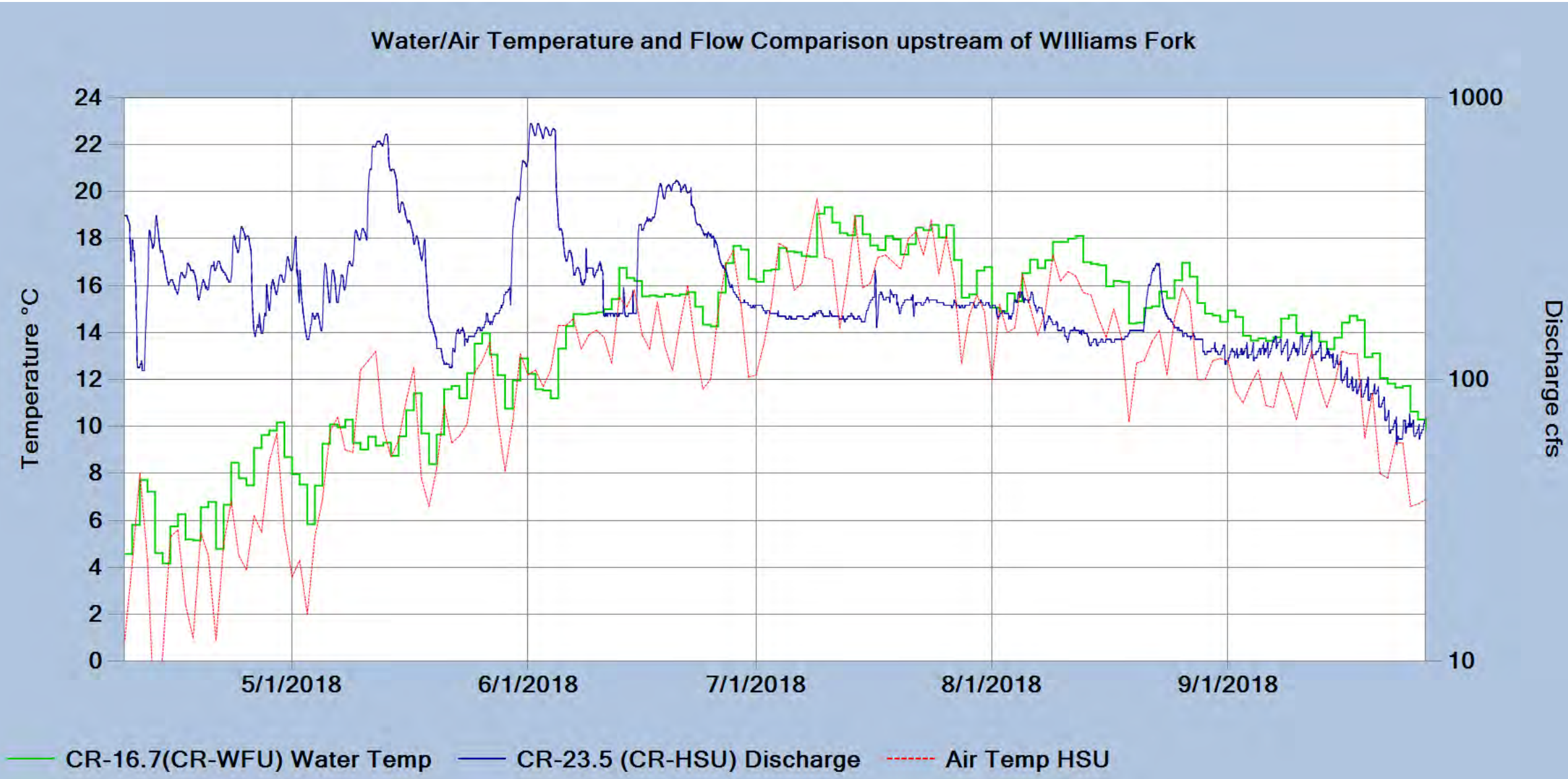


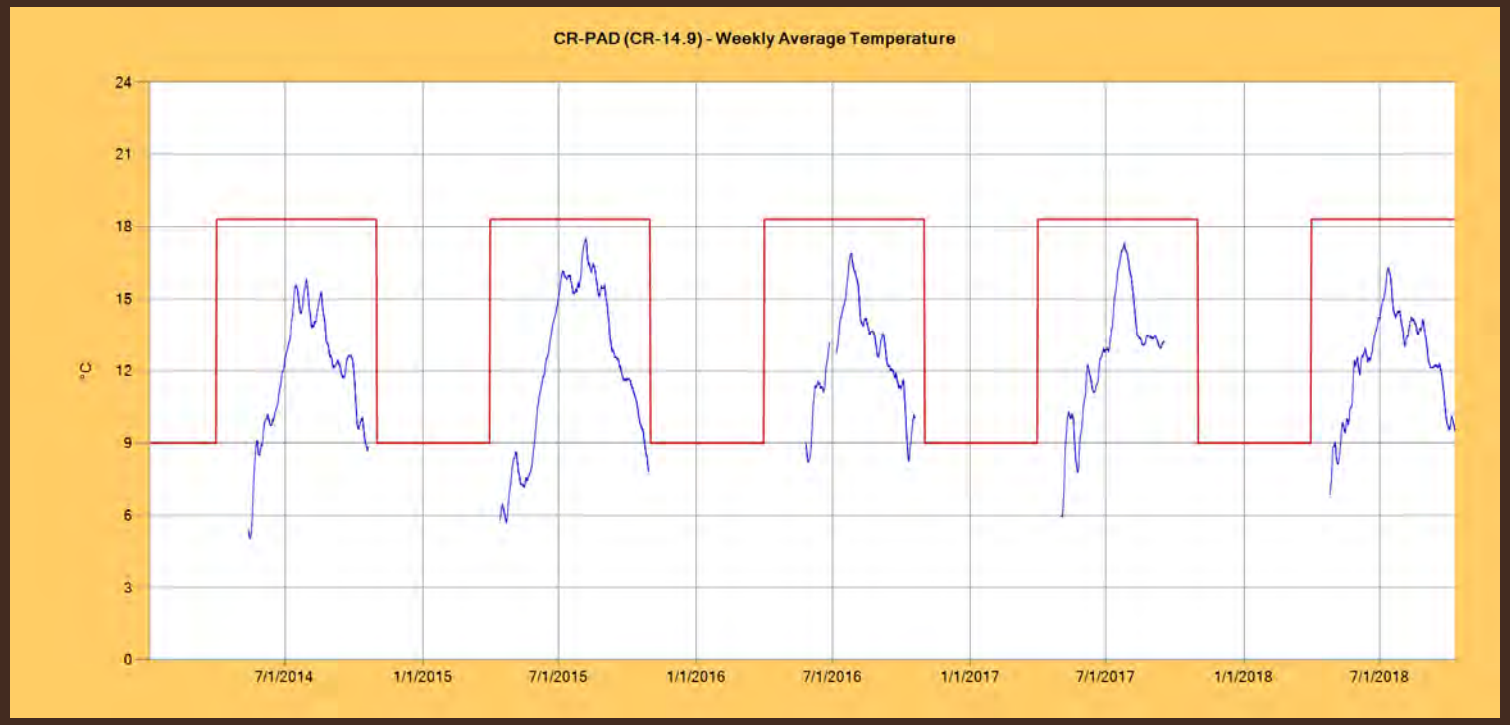
Colorado River upstream Williams Fork – CSII

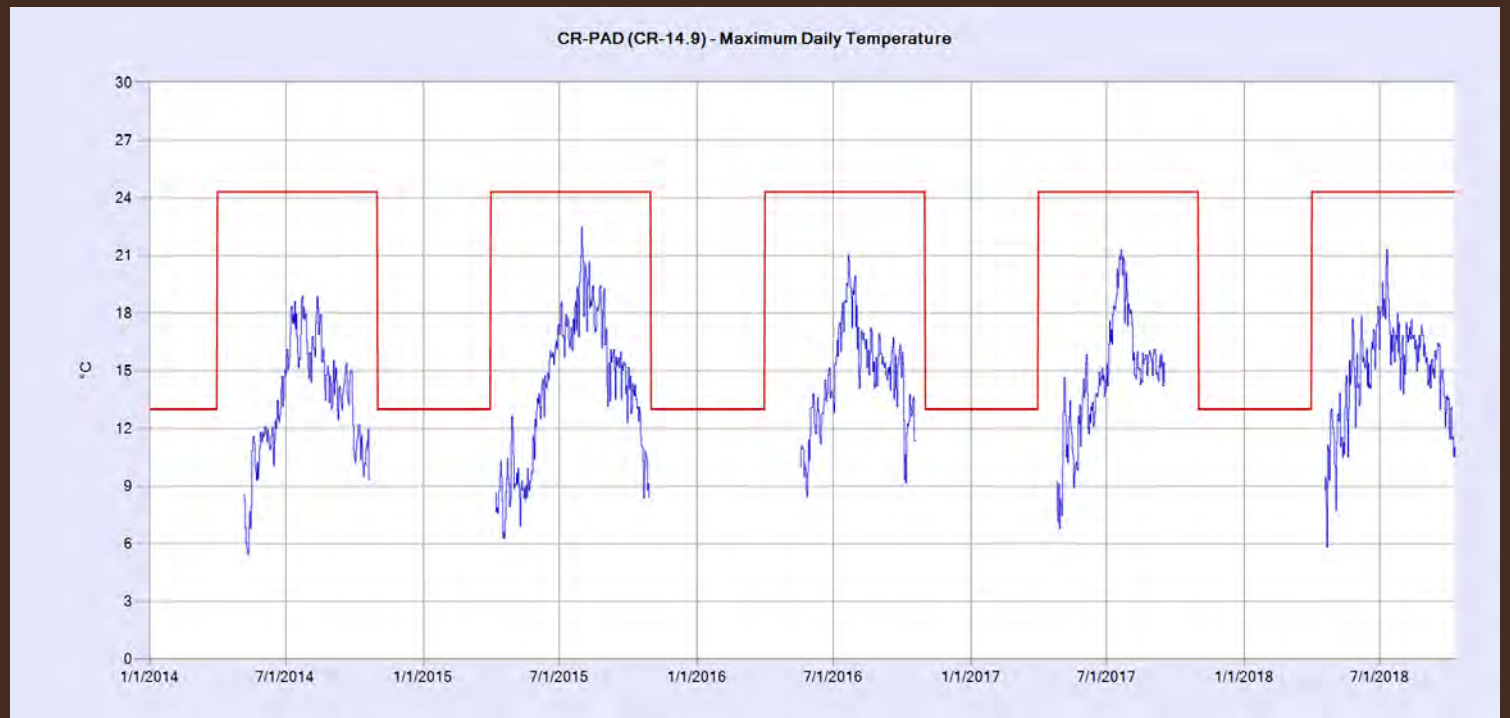


Northern Waters real-time site

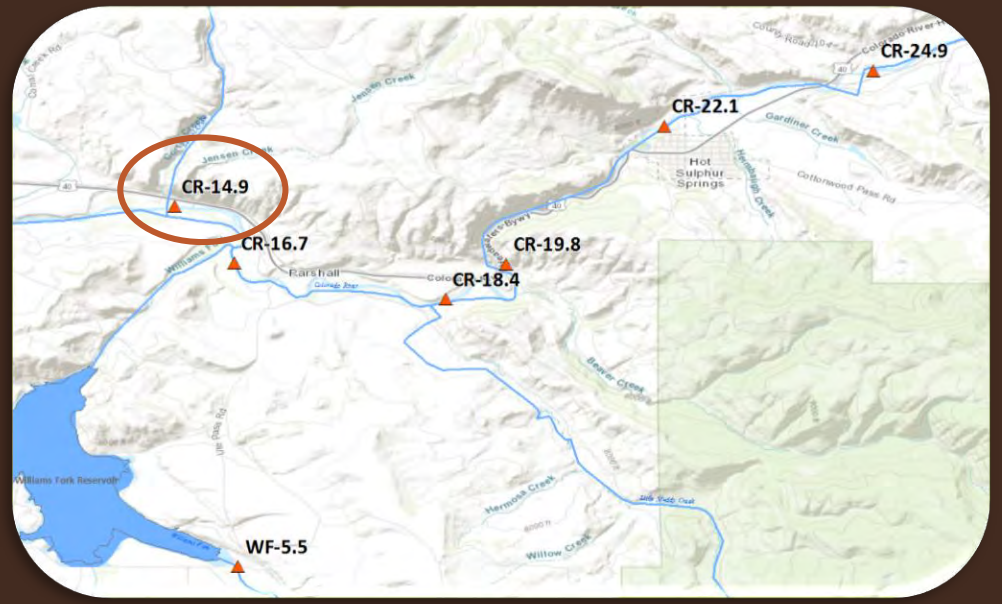

Colorado River Daily Average Temperature Downstream of Windy Gap to Upstream of Williams Fork Confluence
°C
24
22
20
18
16
14
12
10
8
6
4
2
0
5/20/2018
6/3/2018
6/17/2018
7/1/2018
7/15/2018
7/29/2018
8/12/2018
8/26/2018
9/9/2018
9/23/2018
CR-24.9 (CR-SHRF)
CR-19.8 (CR-HSU)
CR-WFU (CR-16.7)

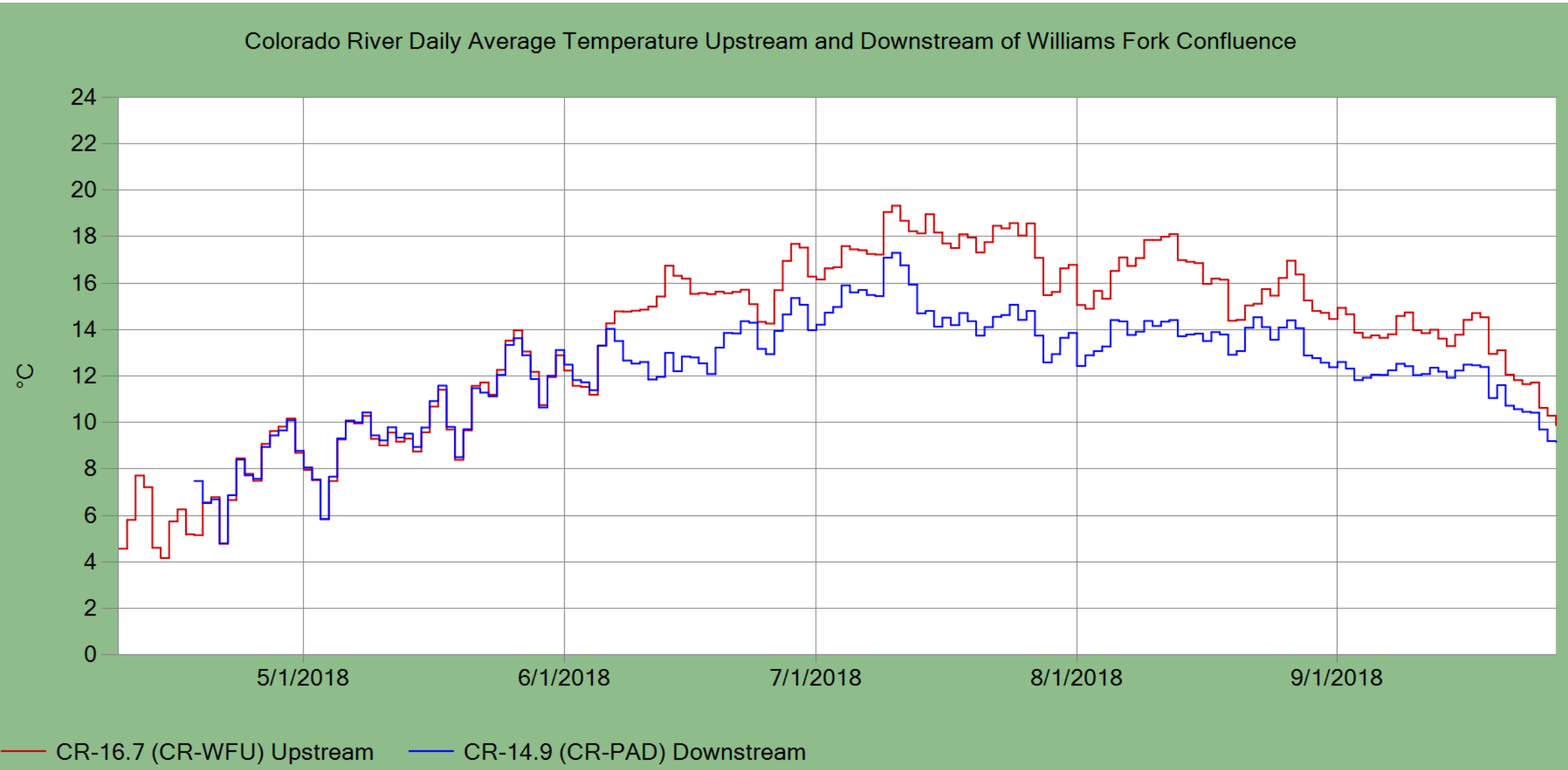

Water/Air Temperature and Flow Comparison upstream of WIlliams Fork
Temperature °C
Discharge cfs
24
22
20
18
16
14
12
10
8
6
4
2
0
1000
100
10
5/1/2018
6/1/2018
7/1/2018
8/1/2018
9/1/2018
CR-16.7(CR-WFU) Water Temp
CR-23.5 (CR-HSU) Discharge
Air Temp HSU

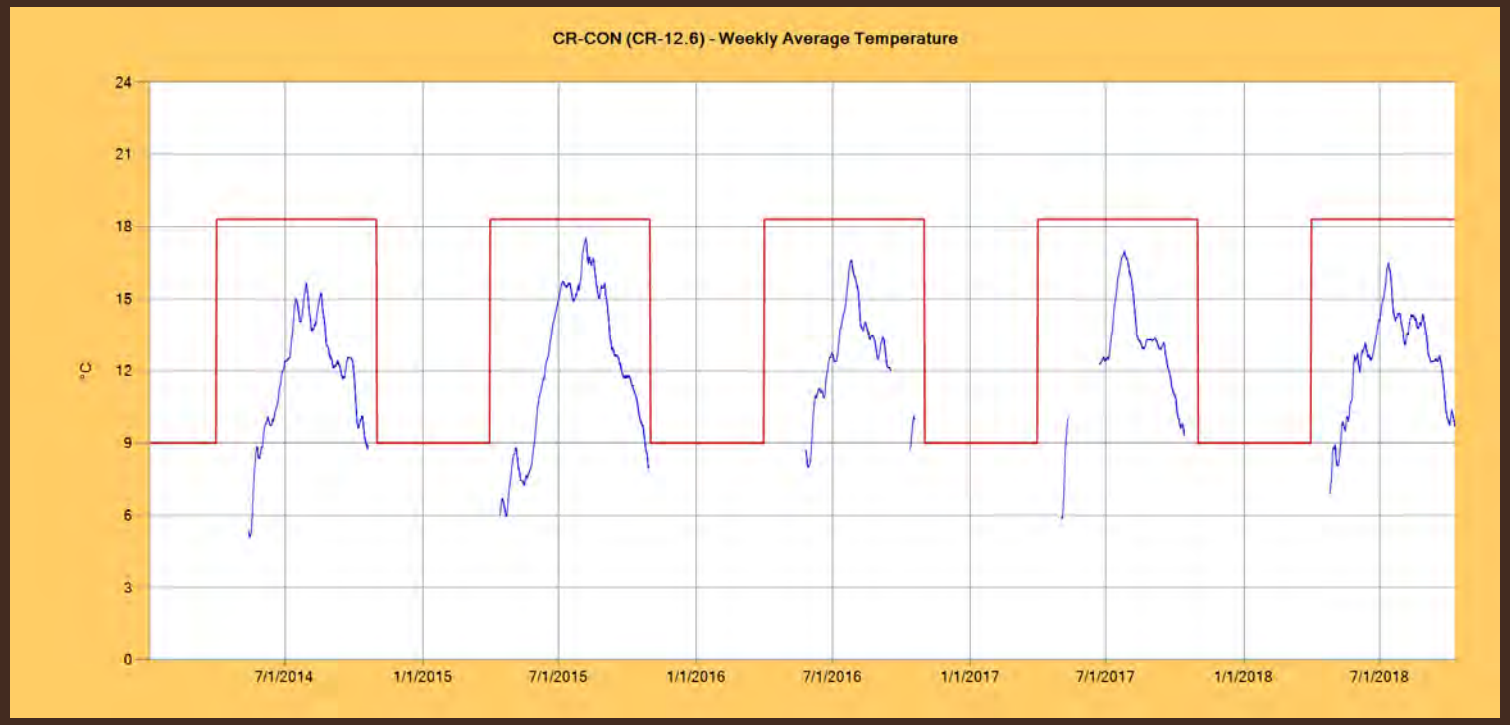


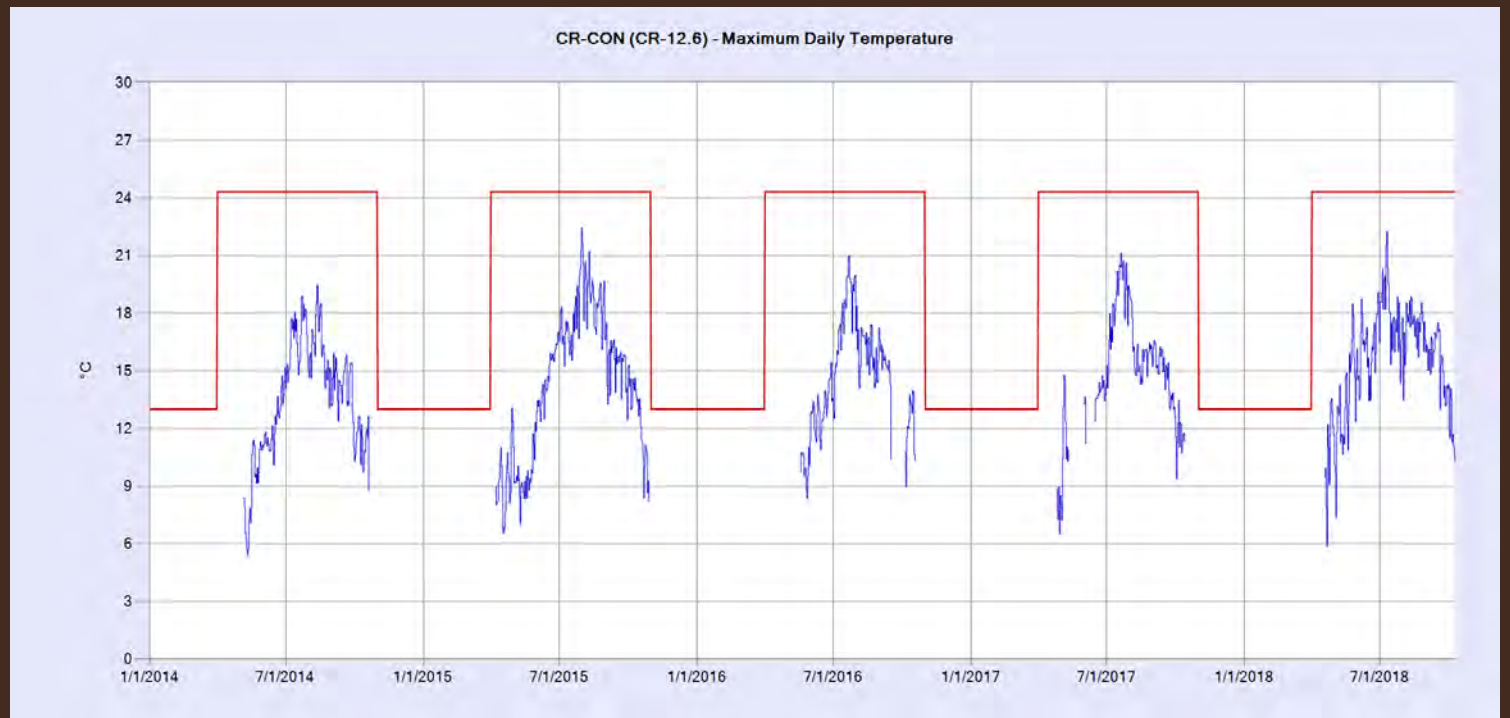


Colorado River downstream Williams Fork – CSII

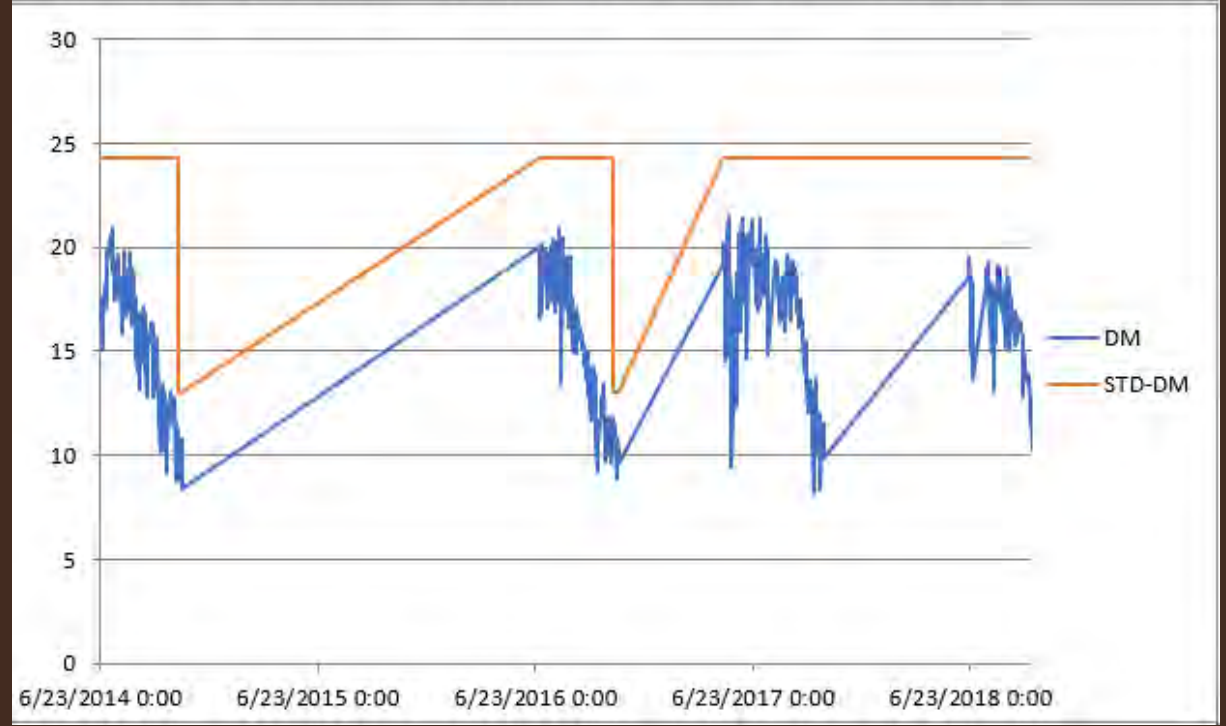



Colorado River Daily Average Temperature Upstream and Downstream of Williams Fork Confluence
°C
24
22
20
18
16
14
12
10
8
6
4
2
0
5/1/2018
6/1/2018
7/1/2018
8/1/2018
9/1/2018
CR-16.7 (CR-WFU) Upstream
CR-14.9 (CR-PAD) Downstream

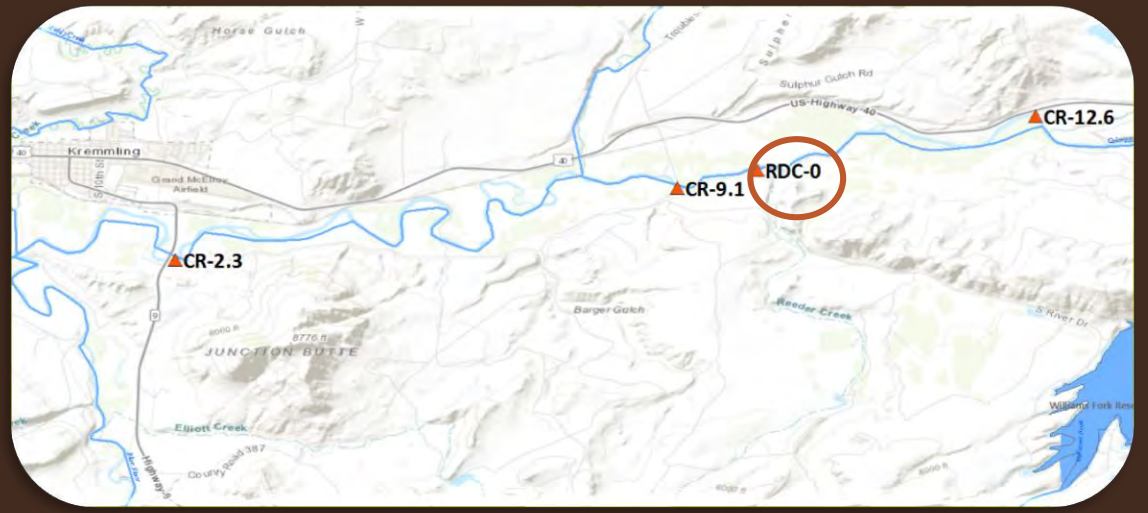


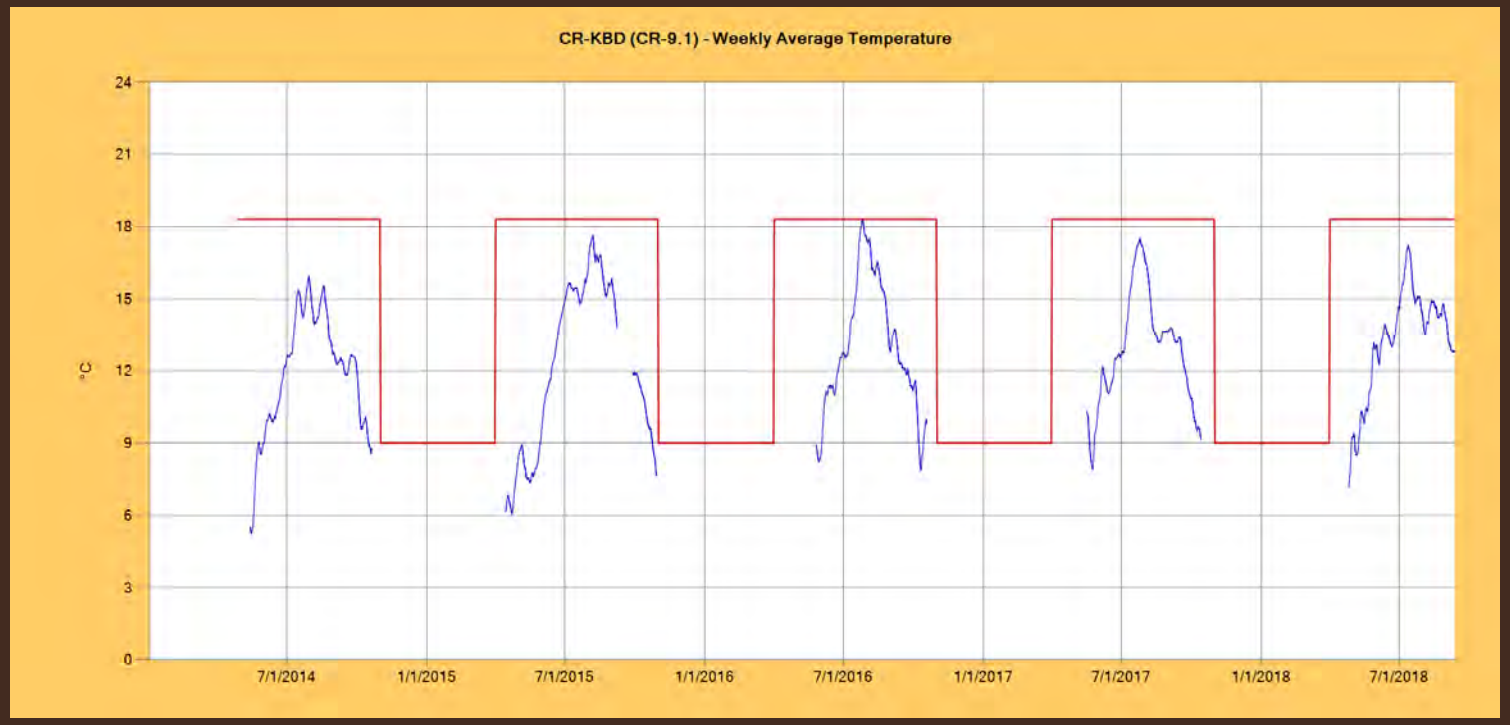


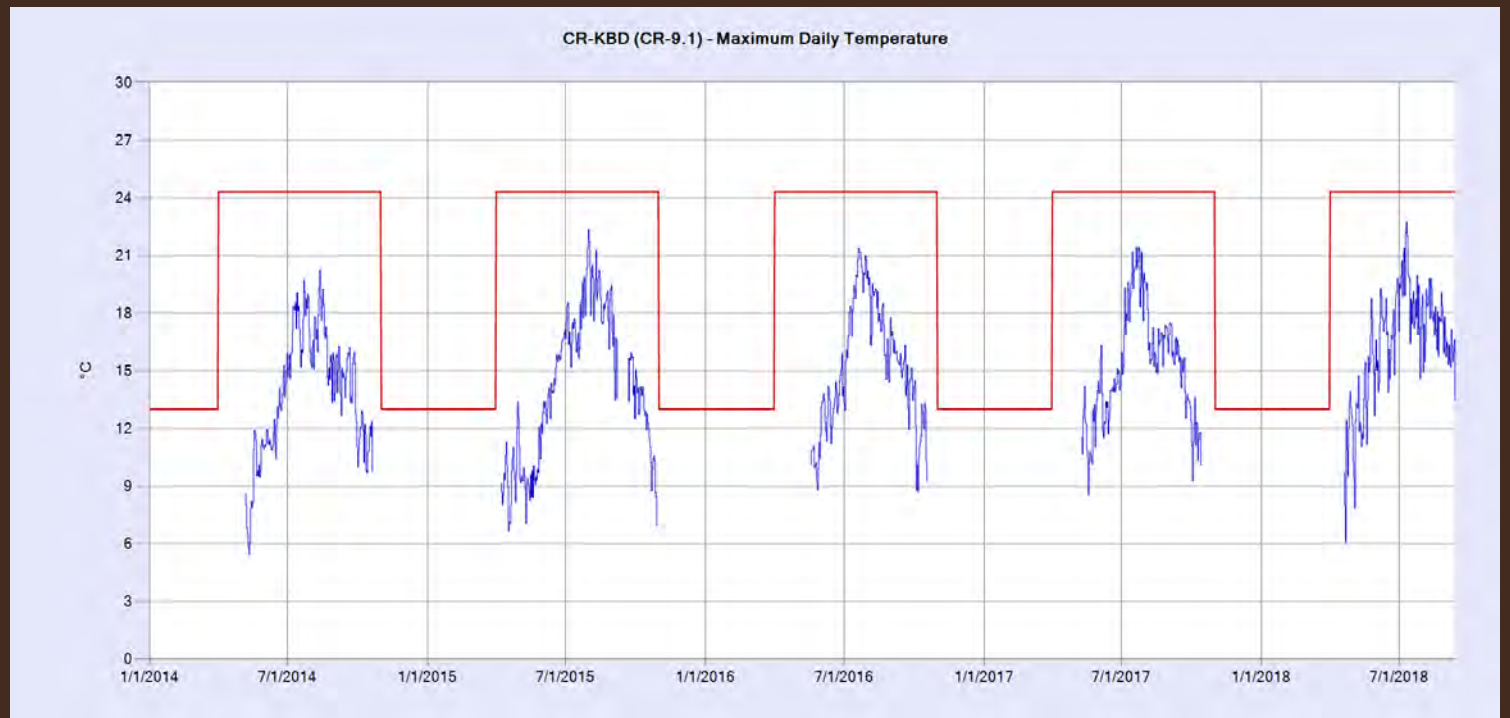
Colorado River downstream Williams Fork – CSII



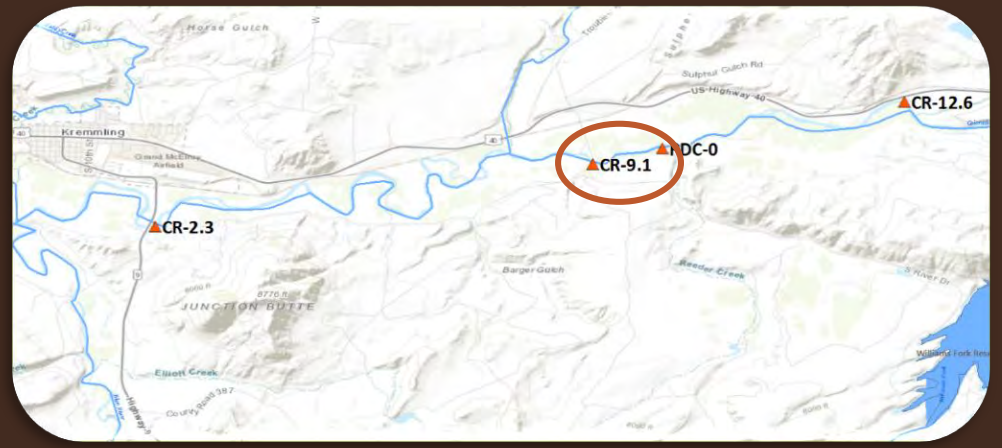
Reeder Creek upstream Colorado River – CSII

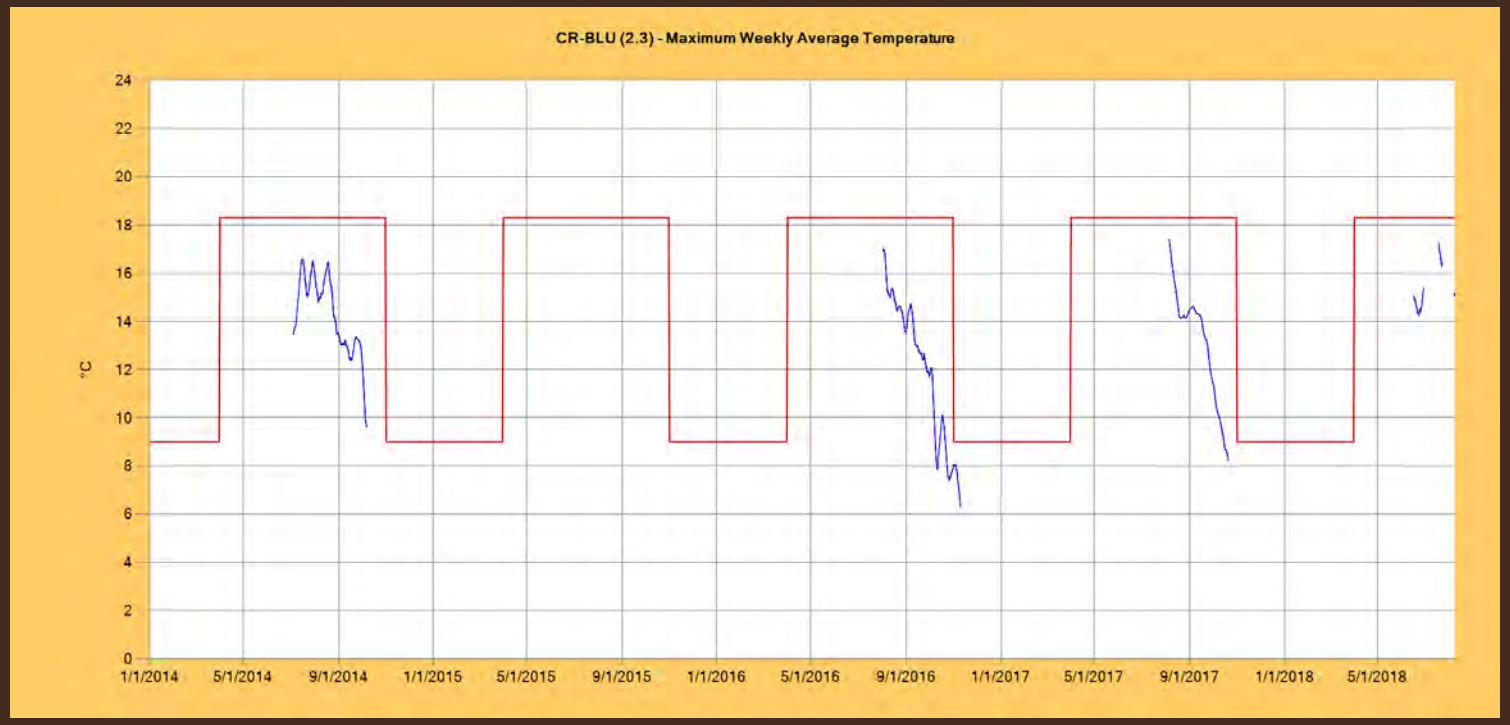




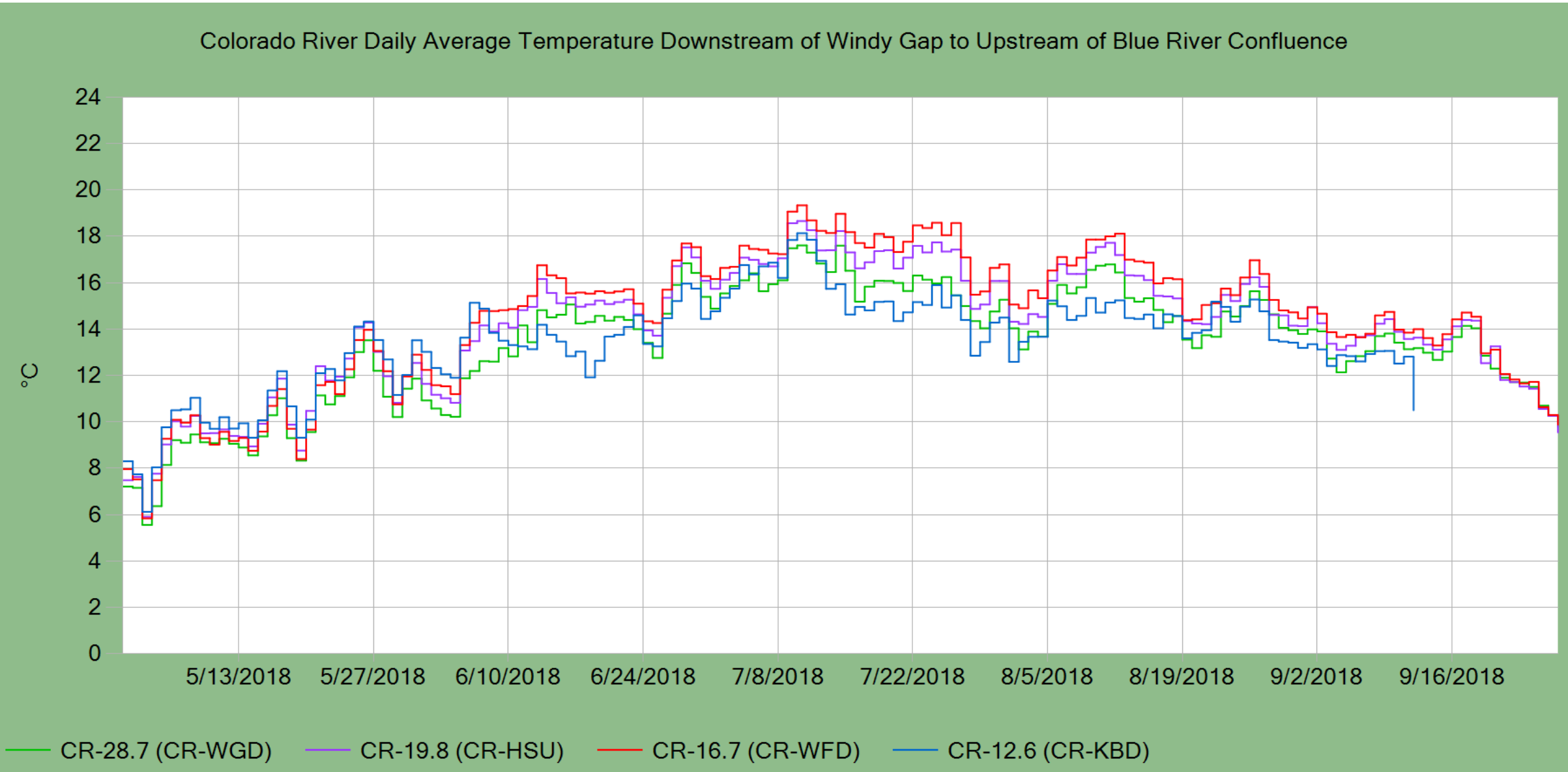


Colorado River downstream KB Ditch – CSII

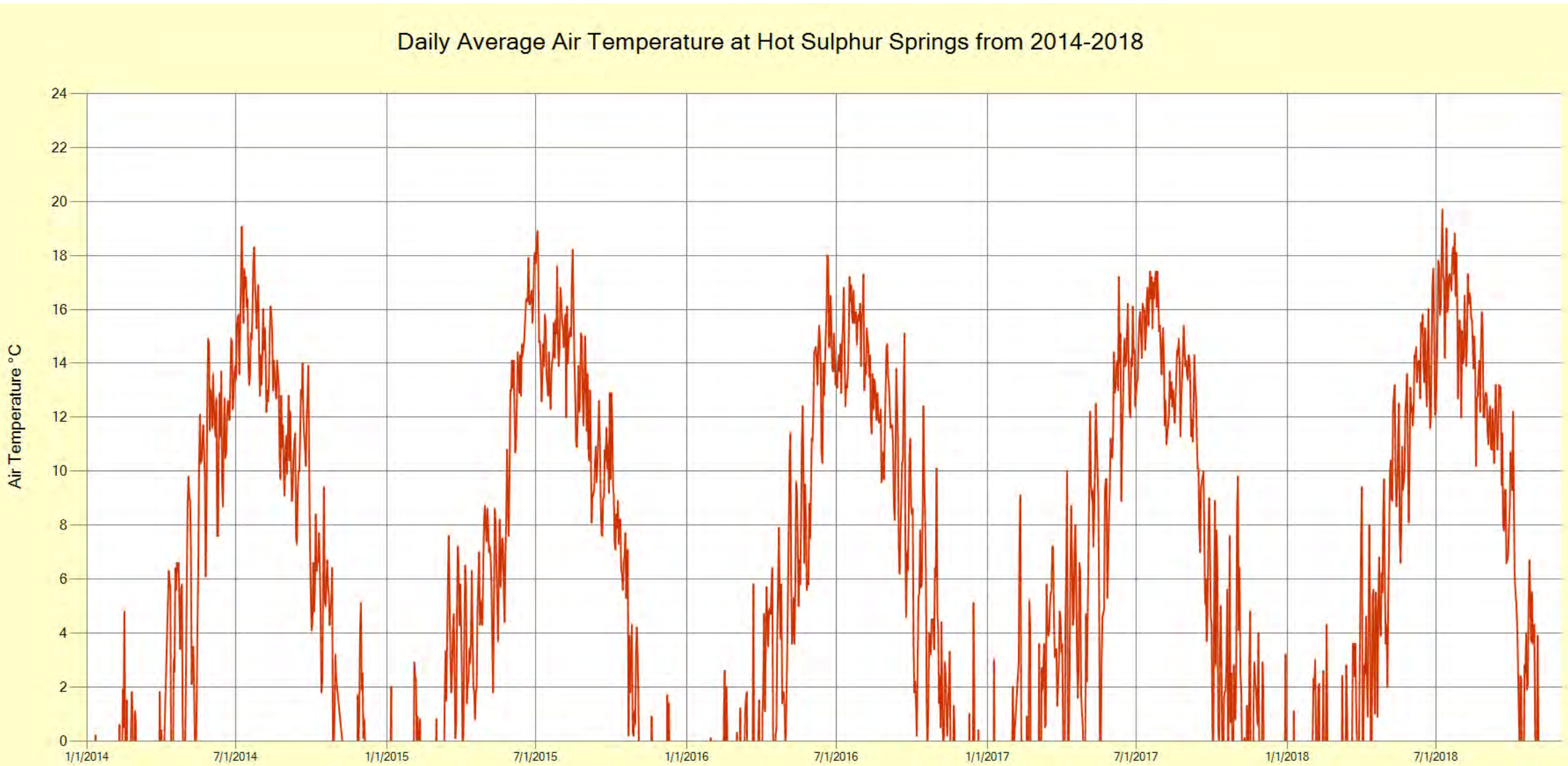


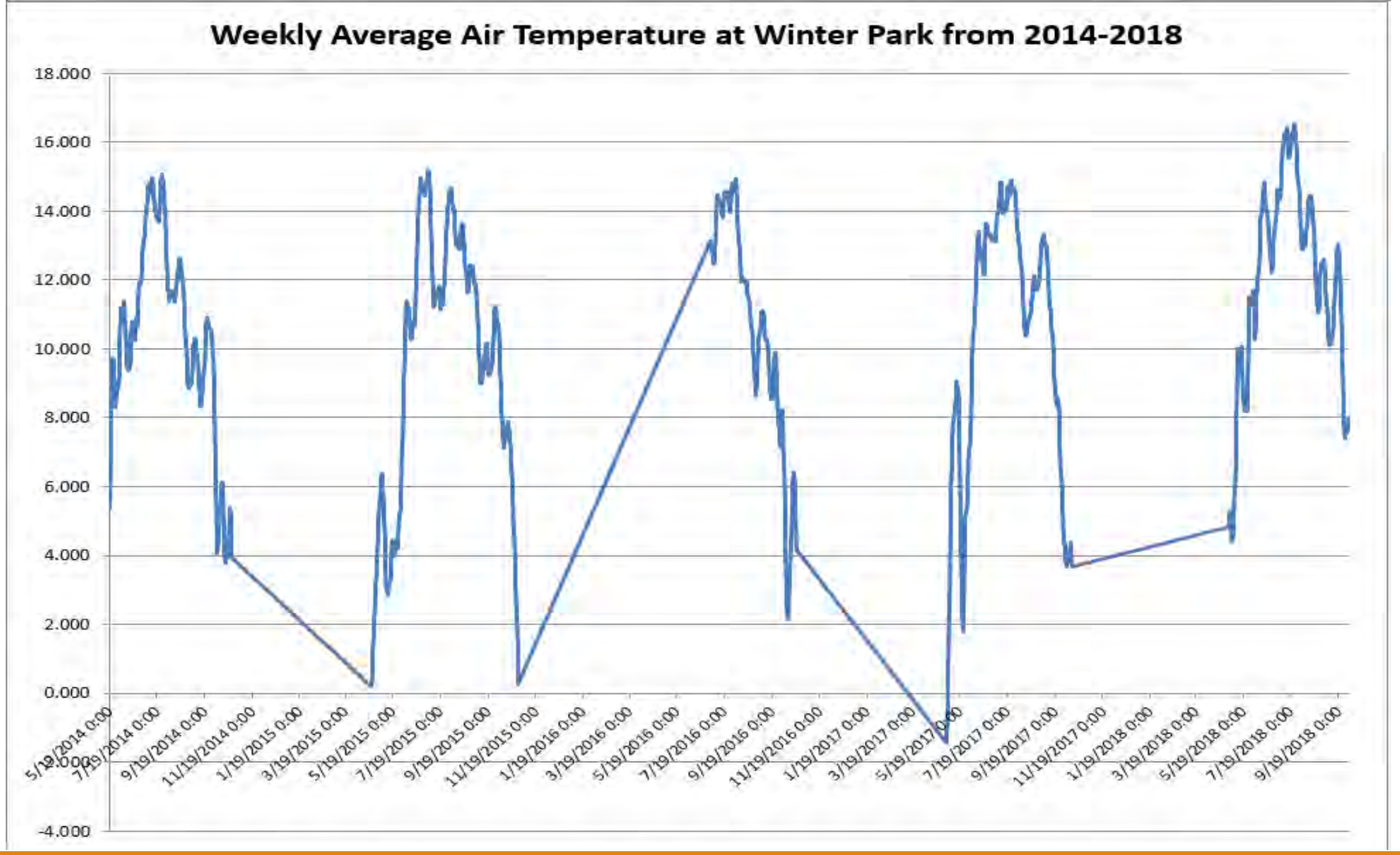


Colorado River upstream Blue River – CSII


Colorado River Daily Average Temperature Downstream of Windy Gap to Upstream of Blue River Confluence
°C
24
22
20
18
16
14
12
10
8
6
4
2
0
5/13/2018
5/27/2018
6/10/2018
6/24/2018
7/8/2018
7/22/2018
8/5/2018
8/19/2018
9/2/2018
9/16/2018
CR-28.7 (CR-WGD)
CR-19.8 (CR-HSU)
CR-16.7 (CR-WFD)
CR-12.6 (CR-KBD)

Questions & Comments


Daily Average Air Temperature at Hot Sulphur Springs from 2014-2018
Air Temperature °C
24
22
20
18
16
14
12
10
8
6
4
2
0
1/1/2014
7/1/2014
1/1/2015
7/1/2015
1/1/2016
7/1/2016
1/1/2017
7/1/2017
1/1/2018
7/1/2018


Weekly Average Air Temperature at Winter Park from 2014-2018
18.000
16.000
14.000
12.000
10.000
8.000
6.000
4.000
2.000
0.000
-2.000
-4.000
5/19/2014 0:00
7/19/2014 0:00
9/19/2014 0:00
11/19/2014 0:00
1/19/2015 0:00
3/19/2015 0:00
5/19/2015 0:00
7/19/2015 0:00
9/19/2015 0:00
11/19/2015 0:00
1/19/2016 0:00
3/19/2016 0:00
5/19/2016 0:00
7/19/2016 0:00
9/19/2016 0:00
11/19/2016 0:00
1/19/2017 0:00
3/19/2017 0:00
5/19/2017 0:00
7/19/2017 0:00
9/19/2017 0:00
11/19/2017 0:00
1/19/2018 0:00
3/19/2018 0:00
5/19/2018 0:00
7/19/2018 0:00
9/19/2018 0:00

Fraser River and Tributaries

River Mile ID	Description	River	Sampling Entity	Entity Station ID	Tier
FR-27.2	Fraser River above Mary Jane entrance to Winter Park	Fraser River	GCWIN	FR-Upper	CS-I
FR-23.4	Fraser River above Winter Park Sanitation District	Fraser River	GCWIN	FR-abvWPSD	CS-I
FR-23.2	Fraser River below Winter Park Sanitation	Fraser River	GCWIN	FR-blwWPSD	CS-I
FR-22.5	Fraser River below Winter Park Resort at Idlewild Campground	Fraser River	GCWIN	FR-blwWP	CS-I
LVC-0.2	Little Vasquez above Winter Park on Arapaho Road	Little Vasquez	GCWIN	LVC-abvWP	CS-I
VC-0	Vasquez Creek at the town of Winter Park	Vasquez Creek	GCWIN	VC-WP	CS-I
FR-20	Fraser River at Rendezvous Bridge	Fraser River	GCWIN	FR-Rendezvous	CS-II
EC-5.5	Elk Creek below Denver Water diversion	Elk Creek	GCWIN	Elk-blwDWB	CS-I
FR-18.1	Fraser River below County Rd 804	Fraser River	GCWIN	FR-CR804	CS-II
STC-9.8	Saint Louis Creek upstream of Denver Water Board diversion	St. Louis Creek	GCWIN	STC-blwDWB	CS-I
STC-5.4	Saint Louis Creek at Fraser Experimental Forest	St. Louis Creek	GCWIN	STC-Mid	CS-I
STC-0	Saint Louis Creek above confluence with Fraser River	St. Louis Creek	GCWIN	ST-LC	CS-I
FR-17.7	Fraser River below County Rd 8 at Hammond Ditch	Fraser River	GCWIN	FR-blwCR8HD	CS-II
FR-16.9	Fraser River above Fraser Sanitation	Fraser River	GCWIN	FR-abvFSD	CS-II
FR-16.6	Fraser River below Fraser Sanitation	Fraser River	GCWIN	FR-blwFSD	CS-II
FR-15	Fraser River LBD Restoration Project, Upstream end	Fraser River	GCWIN	FR-SpProjU	CS-II
FR-14.4	Fraser River LBD Restoration Project, Downstream end	Fraser River	GCWIN	FR-SpProjD	CS-II

Fraser River and Tributaries

River Mile ID	Description	River	Sampling Entity	Entity Station ID	Tier
FR-14	Fraser River At Tabernash Co.	Fraser River	USGS	09027100	CS-II
LCB-2.2	Little Cabin Creek below Denver Water diversion	Little Cabin	GCWIN	LCAB-blwDWB	CS-I
CB-2.7	Cabin Creek below Denver Water diversion	Cabin Creek	GCWIN	CAB-blwDWB	CS-I
CB-0.6	Cabin Creek upstream of North and South Channels	Cabin Creek	GCWIN	CAB-abvChan	CS-I
RC-4.7	Ranch Creek below County Rd 8315	Ranch Creek	GCWIN	RC-blwCR8315	CS-I
HC-0.5	Herd Creek on County Road 843	Herd Creek	GCWIN	HRD-atCR843	CS-I
MC-0.5	Meadow Creek on County Road 84/USFS 129	Meadow Creek	GCWIN	MEA-atCR84	CS-I
RC-1.1	Ranch Creek below Meadow Creek near Tabernash CO	Ranch Creek	USGS	09033100	CS-I
RC-1.1	Ranch Creek below Meadow Creek	Ranch Creek	GCWIN	RC-blwMC	CS-I
FR-12.4	Fraser River above Fraser Canyon below Tabernash	Fraser River	GCWIN	FR-abvFrCan	CS-II
FR-4.5	Fraser River below Fraser Canyon at Granby Ranch	Fraser River	GCWIN	FR-blwFrCan	CS-II
FR-3.5	Fraser River below Highway 40 in Granby	Fraser River	GCWIN	FR-Hwy40Gr	CS-II
FR-1.9	Fraser River above Granby Sanitation District	Fraser River	GCWIN	FR-abvGSD	CS-II
FR-1.6	Fraser River below Granby Sanitation District	Fraser River	GCWIN	FR-blwGSD	CS-II

Colorado River- Headwaters to Windy Gap

River Mile ID	Description	River	Sampling Entity	Entity Station ID	Tier
EI-0.1	East Inlet upstream of Grand Lake	East Inlet	Northern	EI-GLU	CS-I
NI-0.1	North Inlet upstream Grand Lake	North Inlet	Northern	NI-GLU	CS-I
NF-0.1	North Fork of Colorado River upstream Shadow Mountain Reservoir	North Fork	Northern	CR-SMU	CS-I
CR-44.6	Colorado River downstream of Shadow Mountain Reservoir	Colorado River	Northern	CR-SMD	CS-I
CR-43.5	Colorado River upstream of Lake Granby	Colorado River	Northern	CR-GRU	CS-I
ST-0	Stillwater Creek upstream Lake Granby	Stillwater Creek	Northern	ST-GRU	CS-I
RF-0	Roaring Fork upstream Lake Granby	Roaring Fork	Northern	RF-GRU	CS-I
AC-0.6	Arapaho Creek upstream Lake Granby	Arapaho Creek	Northern	AC-GRU	CS-I
CR-38.3	Colorado River downstream of Lake Granby	Colorado River	Northern	CR-GRD	CS-II
CR-35.6	Colorado River downstream of Lake Granby at flow gage	Colorado River	Northern	CR-YGAGE	CS-II
WC-3.8	Willow Creek downstream of Willow Creek Reservoir	Willow Creek	Northern	WC-WCRD	CS-I
WC-2.3	Willow Creek upstream of Bunte Highline Ditch	Willow Creek	GCWIN	WC-abvBHD	CS-I
WC-0.5	Willow Creek upstream of confluence with Colorado River	Willow Creek	GCWIN	WC-abvCOR	CS-I

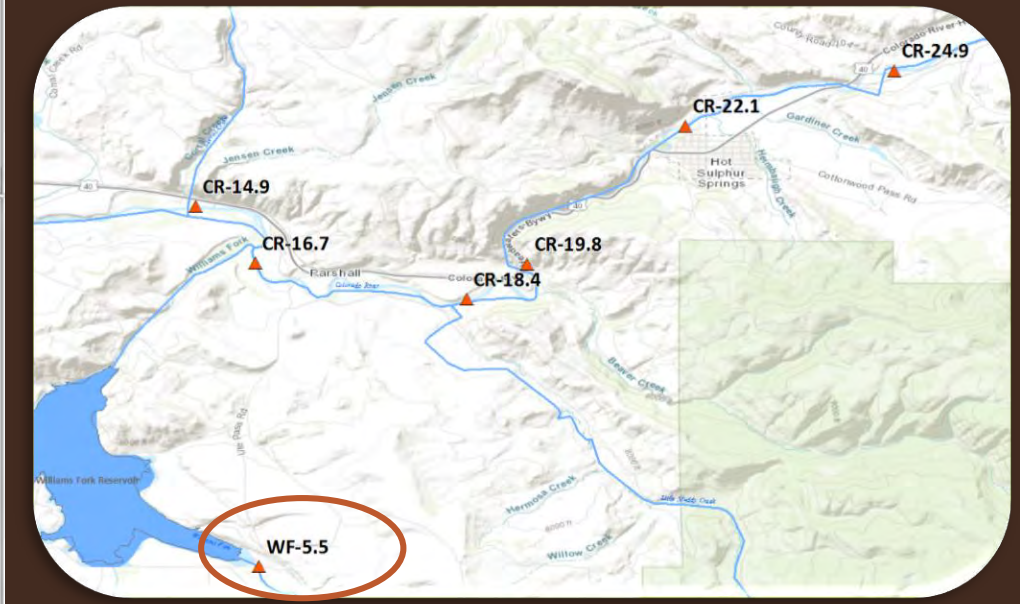
Colorado and Fraser River at Windy Gap

River Mile ID	Description	River	Sampling Entity	Entity Station ID	Tier
CR-31	Colorado River upstream of Windy Gap and Fraser River confluence	Colorado River	Northern	CR-WGU	CS-II
FR-0.1	Fraser River upstream of confluence with Colorado River	Fraser River	Northern	FR-WGU	CS-II
CR-30	Colorado River at Windy Gap Bypass	Colorado River	Northern	CR-WGB	CS-II
CR-29.8	Colorado River at confluence of Windy Gap spillway and bypass	Colorado River	Northern	CR-WGC	CS-II
CR-28.7	Colorado River downstream of Windy Gap Reservoir	Colorado River	Northern	CR-WGD	CS-II

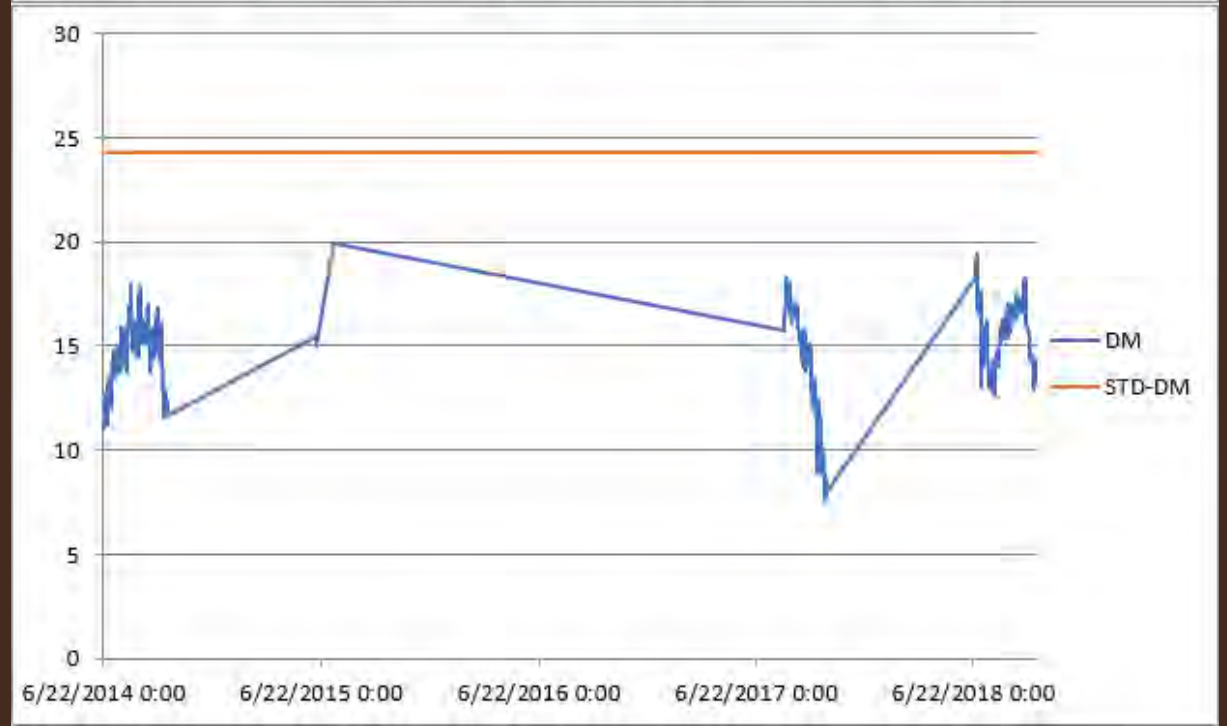
Colorado River- Downstream Windy Gap to Blue River

River Mile ID	Description	River	Sampling Entity	Entity Station ID	Tier
CR-24.9	Colorado River at Sheriff Ranch	Colorado River	GCWIN	COR-SHRF	CS-II
CR-22.1	Colorado River upstream Hot Sulphur Springs	Colorado River	Northern	CR-HSU	CS-II
CR-19.8	Colorado River downstream of Byers Canyon	Colorado River	GCWIN	COR-blwByers	CS-II
CR-18.4	Colorado River at Lone Buck	Colorado River	GCWIN	COR-LoneBuck	CS-II
CR-16.7	Colorado River upstream of Williams Fork	Colorado River	Northern	CR-WFU	CS-II
WF-5.5	Williams Fork upstream of Williams Fork Reservoir	Williams Fork	GCWIN	WF-abvWFR	CS-I
CR-14.9	Colorado River above Kid Fishing Pond	Colorado River	GCWIN	COR-KidPond	CS-II
CR-12.6	Colorado River at ConRitschard	Colorado River	GCWIN	COR-ConRitschard	CS-II
RDC-0	Reeder Creek upstream of Colorado River confluence	Reeder Creek	BLM	REE-Upper	CS-II
CR-9.1	Colorado River downstream of KB Ditch	Colorado River	GCWIN	COR-KBDitch	CS-II
CR-2.3	Colorado River upstream Hwy 9 Bridge at Kremmling	Colorado River	BLM	COR-Hwy9	CS-II
MC-2.1	Muddy Creek below Hwy 40 in Kremmling	Muddy Creek	BLM	MC-blwHwy40	CS-II

Williams Fork upstream of Williams Fork Reservoir – CSI



Tier II
MC-blwHwy40
MC-2.1



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Fraser River

Fishery Management Report

Jon Ewert - Aquatic Biologist (Hot Sulphur Springs)

General Information: The Fraser River is a highly diverse river offering many transitions in habitat type through the course of its length. Public access is somewhat limited in some sections and care should be taken to avoid trespass problems. Please consult with local agencies regarding access locations. Guided fishing is available on some privately held reaches. During dry summers such as 2018, some sections of the Fraser experience dangerously high water temperatures for trout and voluntary angling closures are enacted. Please check current local information and do not fish if water temperatures exceed 65 degrees.

Location: Eastern Grand County—towns of Winter Park, Fraser, and Granby.

Recreational Management: US Forest Service, towns of Winter Park, Fraser and Granby, Grand County, and BLM.

Amenities and General Info.

- The Fraser River flows through multiple towns which offer general amenities in close proximity to the river.
- Guide services available through several area outfitters.

Regulations

Fraser River - Grand County

a. From the headwaters downstream to the confluence with St. Louis Creek:

1. Fishing is by artificial flies and lures only.
2. All rainbow trout must be returned to the water immediately upon catch.

b. From the confluence with St. Louis Creek downstream to the Colorado River:

1. The bag and possession limit for trout is two fish.

Previous Stocking

Whirling Disease-resistant Rainbow trout were stocked at various sizes from 2010-2013 with the goal of establishing a wild, self-sustaining rainbow fishery. Due to the success of this stocking, beginning in 2014 rainbow trout stocking ceased in order to give the rainbows a chance to sustain themselves. See discussion on following pages.

Sportfishing Notes

The Fraser offers an enjoyable mix of fishing for brook, rainbow and brown trout. The composition of these three species depends on the location in the river one fishes. It is home to the highest densities of mottled sculpin in the area. Streamer fishing for large browns beneath undercut banks is always an option. The most prolific insect hatch is caddis, which takes place after runoff. Golden stoneflies and various mayflies are also abundant. Terrestrial fishing can be productive in late summer as well.

This 5” sculpin had recently consumed a 3” dace. This is the only time we have documented sculpin piscivory in this area.

This brown trout, captured in the same reach, had recently eaten a sculpin.

Fraser River at Kaibab Park

Population Estimates								
	2009	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2017**
Date of survey	9/1	9/2	9/1	9/6	9/3	9/4	9/3	9/6
Brown trout: pounds per acre	76	62	60	56	87	73	71	114
>14" per acre	18	23	14	4	16	22	16	19
>6" per mile	857	607	578	1,409	845	715	729	1,464
mottled sculpin captured	256	466	533	1,279	521	262	469	249

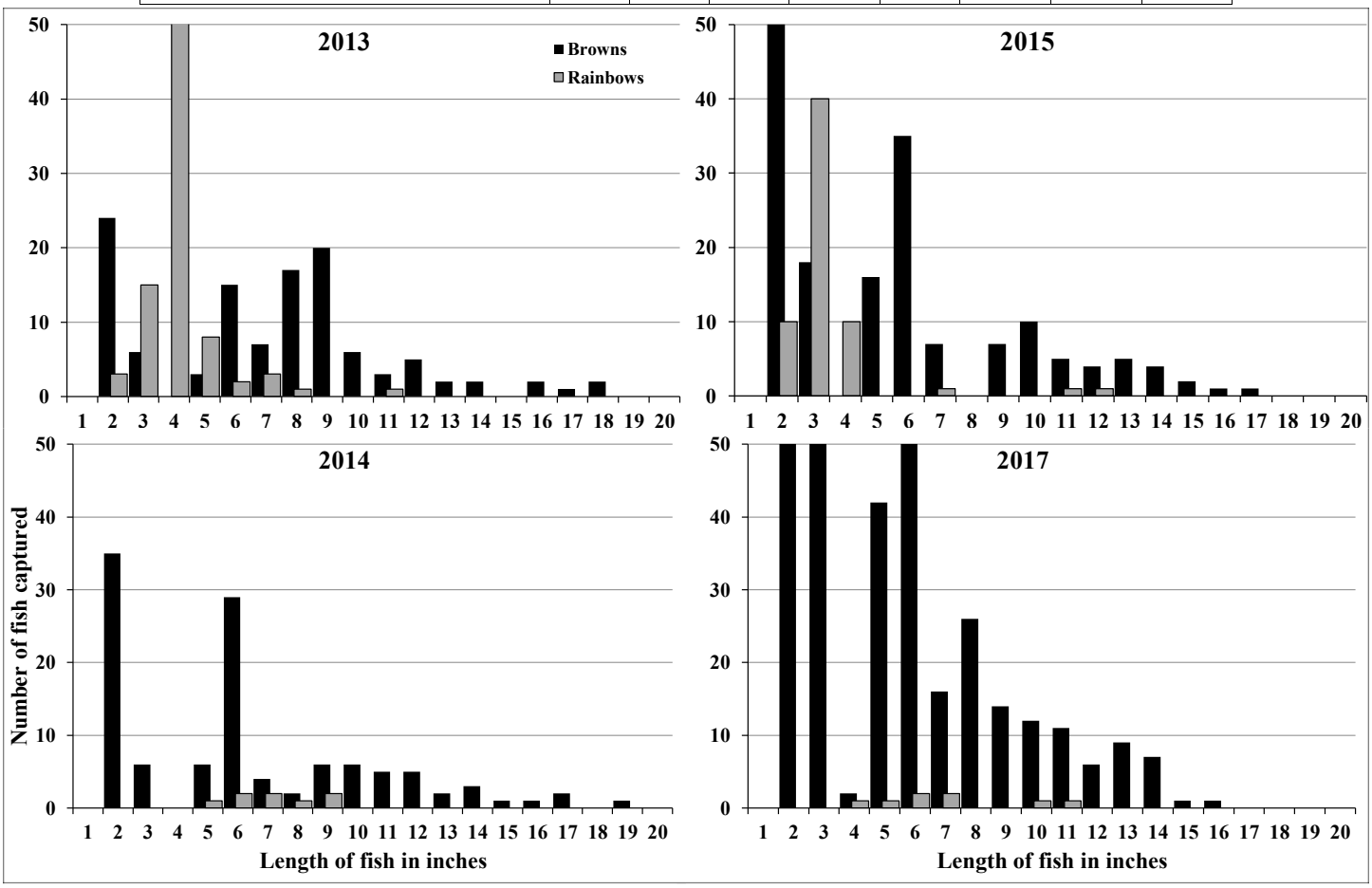


Figure 1. Size distribution of trout captured in Kaibab Park reach

The Kaibab Park station is located in the town of Granby where the river flows between the park and the fire station, immediately downstream of the Highway 40 crossing. This is the farthest downstream site on the Fraser that we survey regularly. This site was not surveyed in 2018. Population estimates are shown in the table above and Figure 1 displays the size distribution of brown and rainbow trout. Only brown trout population estimates appear in the table because rainbow trout have not constituted a significant portion of the fish population, despite the fact that rainbows have been stocked here on the same occasions that have been successful farther upstream.

2017 saw the highest biomass and fish-per-mile estimates to date for brown trout in this reach. Extreme high-water years such as 2014 likely have a flushing effect on juvenile brown trout here, while drought years such as 2012 see decreases in large fish density estimates, likely due to lack of habitat during low flows. 2017 conditions probably represent a "happy medium" situation in which the river has benefitted from the flush of recent high water years, yet the 2017 runoff wasn't high enough to displace juveniles. At the same time, flows did not become so low that adult fish vacated the section.

The rainbow trout appearing in the 2015 sample were fingerlings stocked that year. This is the only location on the Fraser that rainbow fingerlings have been stocked since 2013. The 2014 and 2017 samples found that recruitment from rainbow fingerling stocking in this reach was poor.

Peak flows at Granby	
Date	**Flow (cfs)**
6/4/09	991
6/8/10	1767
7/1/11	1519
4/27/12	157
5/18/13	651
5/31/14	2256
6/12/15	1425
6/13/16	1351
6/11/17	1027
6/1/18	781

Fraser River on Grand County Water and Sanitation Property

Fraser River GCW&S Population Estimates				
Year	**2007**	**2016**	**2017**	**2018**
Date of survey	9/3	10/5	10/5	10/5
Brown trout				
Biomass (pounds per surface acre)	33	26	111	60
Fish >14" per acre	3	6	33	24
Fish > 6" per mile	752	430	923	528
Rainbow trout				
Biomass	9	6	16	19
Fish >14" per acre	3	2	8	12
Fish > 6" /mile	53	35	70	70
Brook trout				
Biomass	2	1	0	0
Fish > 6" /mile	44	9	0	0
Total trout biomass	44	33	127	79
Total sculpin captured	726	971	264	377

Table 1.Population estimates.

This reach is on property owned by Grand County Water and Sanitation District 1 immediately outside of Tabernash. In 2017 an in-stream physical habitat improvement project was constructed on the site, a cooperative effort by the Learning By Doing stakeholder group (for more information visit https://co.grand.co.us/737/Learning-by-Doing) and was opened to public access for the first time in 2018. Prior to the habitat project, this reach had relatively poor trout habitat, characterized by a high width-to-depth ratio, poor thalweg definition, sparse and shallow pools, and excessive riffles. All of these deficiencies were addressed in the habitat improvement project.

Table 1 (above) contains the trout population estimates obtained on the four occasions that we have surveyed the site. Prior to the habitat project (2007 and 2016), this site yielded the poorest estimates of any location discussed in this report, and among the lowest population estimates ever obtained in any location on the Fraser. We observed an immediate benefit after completion of the project, with greatly increased numbers of adult fish and a nearly four-fold increase in total trout biomass from 2016 to 2017. The total biomass estimate declined in 2018 by 38%. This decline is most likely attributable to the high level of public fishing pressure that this section experienced in 2018, discussed below. If public use of this reach becomes increasingly heavy in the future, some form of access management may be advisable in order to maintain the quality of the fishery.

Rainbow and brown trout size distribution is displayed in Figure 1 (right). Prior to the habitat project, we found high numbers of juvenile trout in their first two years of life, but by age 3 the fish had mostly vacated the reach in

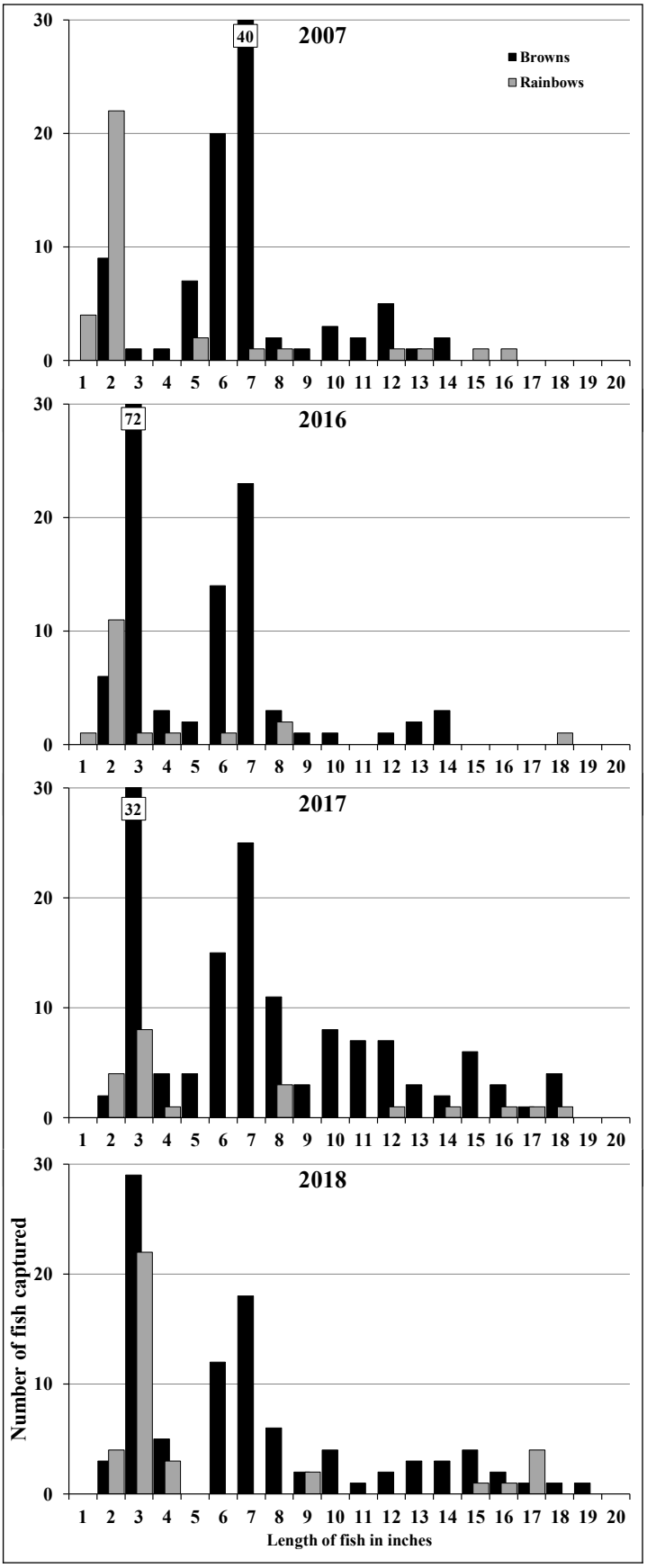


Figure 1. Size distribution of trout captured on GCW & S site.

search of more suitable habitat. This did not appear to be the case any more after completion of the project. Interestingly, on all occasions we collected a number of age-0 rainbow fry, with especially good numbers collected in 2018. These fish were not stocked, and are the product of wild reproduction. However, at this site and at Safeway (see pages 5-6), there appears to be a lack of recruitment of rainbows from Age-0 (2-4" in this survey) to Age-1 (6-10"). If wild rainbows are to persist into the future without stocking, the formation of strong Age-1 year classes is critical. At this site and at Safeway, the 2018 year class represents the best opportunity yet for this to happen, due to its strong numbers (see additional discussion on this topic in the Safeway report, pages 5-6).

The sharp decline in sculpin numbers captured in 2017 is most likely due to the fact that the elecrofishing survey took place approximately two weeks after the habitat work was completed, which is a short amount of time for sculpin to recolonize after a high level of disturbance to the stream bed. We collected an increased number of sculpin in 2018, suggesting a recovery from the disturbance. If adult trout densities remain relatively high in this reach, it may not be reasonable to expect sculpin densities to return to the levels we saw prior to the project, due to predation pressure.

Angler survey	
# surveys completed	40
# anglers represented	58
Total hours fished	123.25
Avg. time of trip	2.1 hrs
Brown trout caught	51
Rainbow trout caught	24
Brook trout caught	2
Avg. catch per hour	0.62
Residence - Grand County	19
CO Front Range	14
Out of state	4
Other (Grand Junction)	1

Table 2. Angler survey results

Angler survey

In August, September and October of 2018 we conducted a simple angler survey on this reach to obtain information about use rates and success. The survey consisted of a voluntary paper questionnaire for anglers to complete at the end of their trip. Results are presented in Tables 2 and 3.

2018 survey crew. Photo by Dave Showalter.

Location of survey reach. Downstream terminus is at top, indicated by arrow, and upstream terminus is at bottom. CR 83 intersection is visible at left. Note that this photo was taken prior to construction of the habitat project.

Angler survey qualitative questions							
Why did you fish here today?		How often do you fish here?		Will you fish here again?		How would you rate this fishery?	
Not crowded	15	First time	22	Yes	38	Excellent (4)	13
Small stream type	15	Once a month	7	No	1	Good (3)	15
Wild fishery	8	Once a week	4			Fair (2)	9
Fish size	4	Once a year	4			Poor (1)	2
Easy access	2	More than once/week	2			Avg. response	3.0
Number of fish	1						

Table 3. Qualitative results

Fraser River at Safeway

The Safeway station is located immediately behind the Safeway store in the town of Fraser (Figure 1, below). This station has the longest and most consistent history of fish population surveys. The Town of Fraser, in partnership with other entities including Trout Unlimited and the Colorado Division of Wildlife (now CPW), completed a habitat improvement project in this area in 2005. These surveys show that the habitat project has proven to be overwhelmingly successful.

Figure 1. Safeway Station location. Arrows indicate downstream and upstream terminus of survey reach.

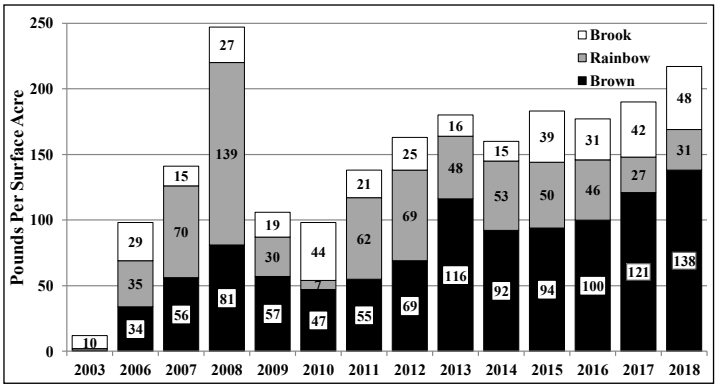


Figure 2. Safeway station trout biomass estimates.

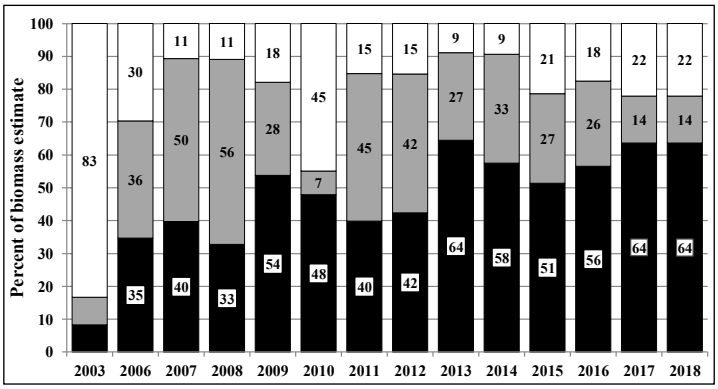


Figure 3. Biomass estimate percent contribution by species

Figure 2 (below, left) contains biomass estimates of trout in pounds per surface acre by species. Figure 3 contains the percent contribution to these estimates by species. 2003 was the only year that this station was surveyed prior to the habitat project construction. The survey that year yielded population estimates that were quite poor in all parameters of the trout population. All subsequent sampling occasions have produced estimates that are many times greater than the 2003 values.

Many of the changes in the rainbow population can be directly attributed to stocking patterns. Soon after the habitat project was completed, we stocked rainbows in this reach at high densities in order to quickly occupy habitat and possibly gain a competitive advantage over the brown trout. In 2007 and 2008, we stocked several hundred large brood fish, averaging 14-15", which produced the elevated rainbow biomass and quality fish density estimates in those years. The intention of stocking those fish was to "kick start" the rainbow population in the newly-improved habitat. These fish occupied the stream for a couple of seasons but did not accomplish natural reproduction. From 2010-13, we stocked an average of 49,215 whirling-disease resistant rainbow fingerlings from 1-4" in length, for a total of 196,861 fish stocked over the four-year period. The fish were stocked in various locations from the U.S. Highway 40 crossing upstream of Idlewild Campground downstream to the County Road 804 crossing near this station. These plants had good success, and rainbow fingerling stocking ceased after 2013 due to the success of the program. We were concerned about overstocking, and we also wanted to observe whether or not the rainbows would begin sustaining themselves through natural reproduction. The contribution of rainbows to the overall trout population has slowly dwindled since these fish first became established in 2011. 2017 yielded the lowest biomass estimate for rainbows since fingerling stocking ceased. The 2018 estimate revealed a slight rebound but the increase was not statistically significant. These trends may indicate that more stocking in the future is warranted.

Figure 4 contains density estimates of quality-sized (>14") trout. No brook trout larger than 14" have ever been captured in this reach. In 2018 we saw a possible reversal in a developing downward trend that we observed from 2013-2017.

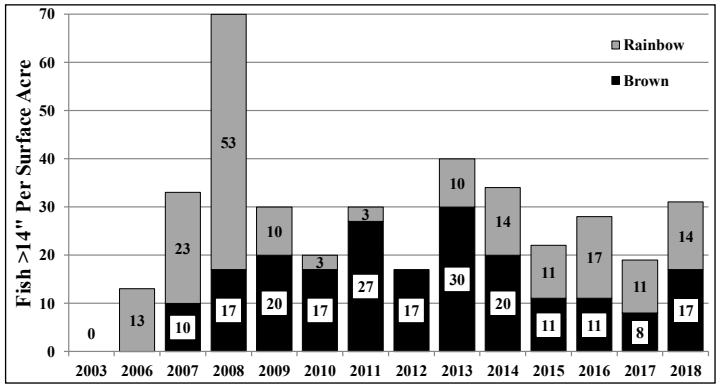


Figure 4. Safeway station quality trout density estimates.

Fraser River at Safeway, continued

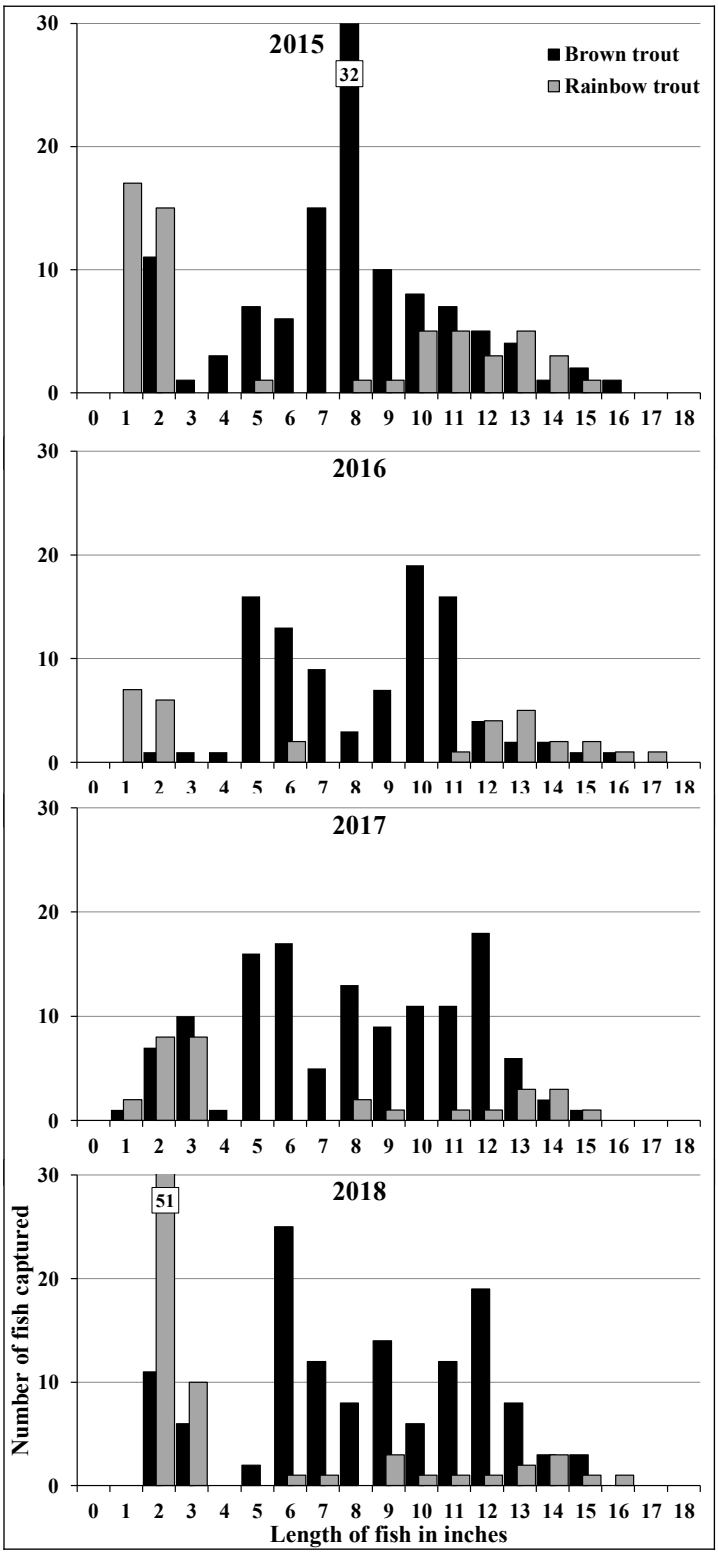


Figure 5. Size distribution of brown and rainbow trout captured in the Safeway reach.

Figure 5 (left) displays the size distribution of rainbow and brown trout captured at the Safeway station over the past four years.

2013 was the last year that rainbow fingerlings were stocked. They were stocked on August 1, averaging 3.75" in length. In 2013 we also caught a large number of 2" rainbows, which were not explained by stocked fish and were likely the result of wild reproduction. Because of this, and the success of these plants that we have observed here and at Confluence Park, after 2013 we ceased the stocking of rainbows in order to observe whether or not they will sustain themselves through natural reproduction. The group of rainbows visible in 2015 at 8-12" in length represent the last of these stocked fish.

For three of the past four years, age-0 rainbows (1-3" in length) produced by natural reproduction have outnumbered age-0 brown trout. We found roughly equal numbers of age-0 fish of the two species in 2017. In 2018 we found the strongest year class of Age-0 rainbows to date in the post-stocking period, far outnumbering brown trout. However, recruitment of rainbows from age-0 to age-1 to date has been poor, which is evident in the scarcity of rainbow trout in the 5-10" range from 2015 onward. If wild rainbows are going to persist in this reach, better survival to Age-1 is imperative. Because of their numbers, the 2018 year class represents the best chance to date to form a strong Age-1 year class in 2019. If this year class survives at better rates, they could finally recruit into the elusive intermediate-size range which will in turn produce mature adult wild rainbows in 2020 and beyond.

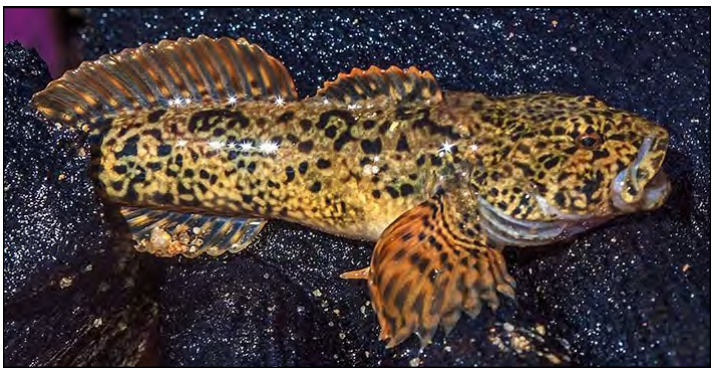


Figure 6. A sculpin from the Fraser River.
Photo by Kevin Birznieks

Dates of Safeway Station surveys	
9/30/2003	9/6/2012
10/21/2006	9/4/2013
8/23/2007	9/3/2014
10/03/2008	9/2/2015
9/3/2009	8/31/2016
9/7/2010	9/5/2017
9/1/2011	9/4/2018

# sculpin captured	
2011	292
2012	550
2013	355
2014	122
2015	249
2016	148
2017	235
2018	233

Fraser River at Confluence Park

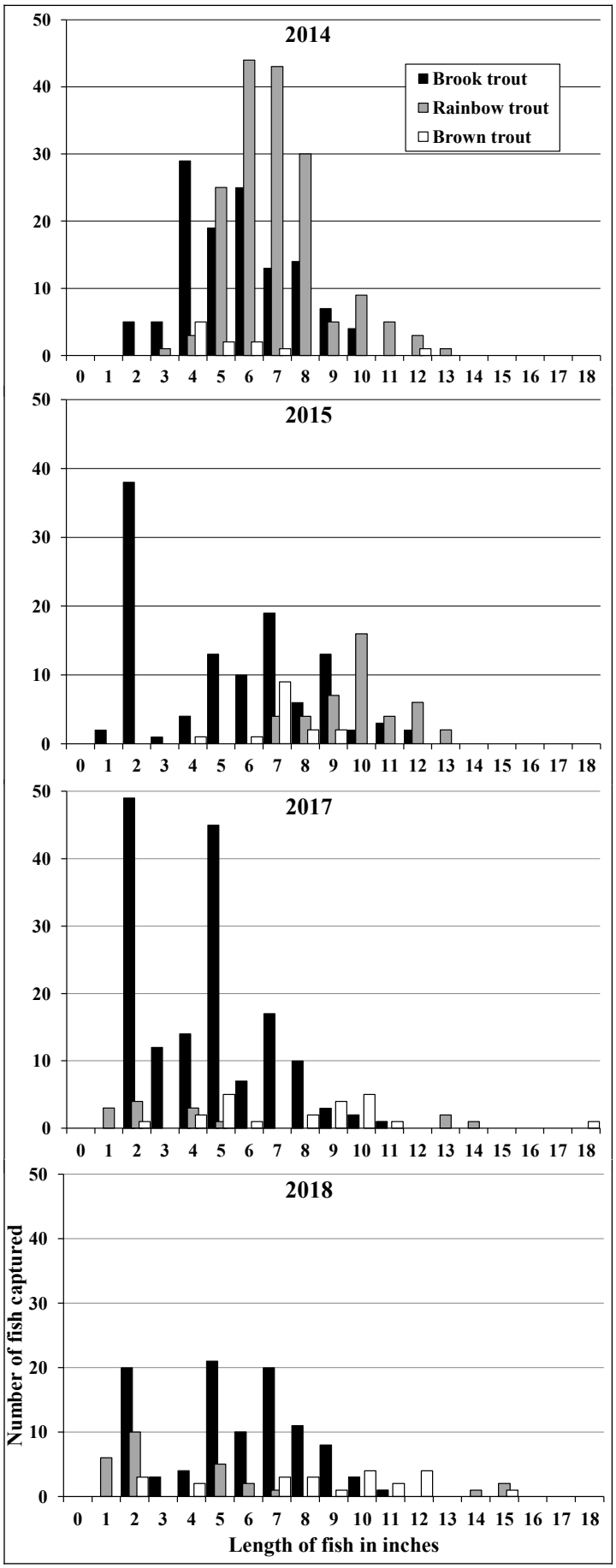


Figure 1. Size distribution of trout at Confluence Park

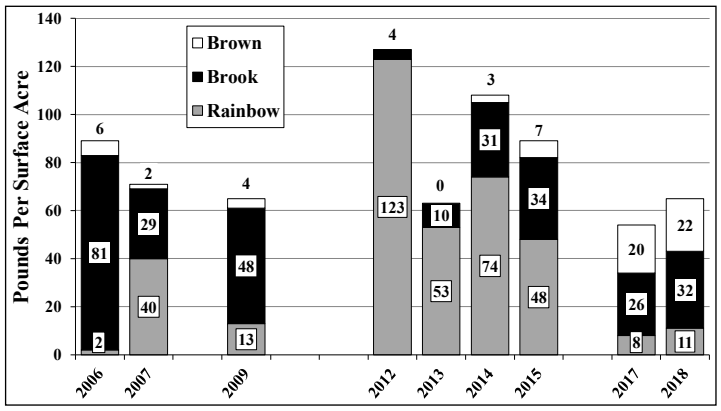


Figure 2. Biomass estimates at Confluence Park.

The Confluence Park station is located in the town of Winter Park. The upstream end of the station is the pool where Vasquez Creek joins the Fraser. Figure 2 (above) contains biomass estimates in pounds per surface acre. This reach was not sampled in the years with no data. This is a higher-gradient, forested reach with a colder temperature regime, which explains the relative scarcity of brown trout. Trout populations here have been highly dynamic, with 2017 and 2018 revealing an unprecedented influx of brown trout, but also (in 2017) the lowest total trout biomass estimates to date. These recent low total biomass estimates can be mostly attributed to the cessation of rainbow trout stocking.

Fingerling rainbow trout stocking in 2010-2013 was very successful at this site. By 2012 the data suggested that our rainbow stocking may be overpopulating the reach, which was one of the factors that led to the decision to cease rainbow stocking as discussed previously. The 2017 and 2018 data suggests that rainbow trout biomass has declined more rapidly here than at Safeway after the cessation of stocking and that rainbows will apparently not sustain themselves here without resumption of stocking.

Figure 1 (left) displays the size distribution of the trout captured in the last four surveys. These data reflect a dynamic situation with regard to competition between brook trout and stocked rainbows. During the period of 2012-2014, the high density of rainbows in the 5-12" range appeared to be suppressing the adult brook trout population, resulting in suppressed biomass estimates for brook trout in 2012 and 2013. By 2015, brook trout began regaining the upper hand, with multiple age classes in the smaller sizes outnumbering juvenile rainbows, which were nonexistent in that survey. Two distinct size-groups of brown trout appeared for the first time in 2017, as well as an 18" brown, the largest ever captured here. It is unlikely that the influx of brown trout was due solely to spawning movements, because the survey has occurred close to the same date on every occasion and the presence of multiple size-groups of browns, not only sexually mature ones. At this site, Safeway and Idlewild, there appears to be a current trend of increasing brown trout biomass and possibly expanding their range upstream in the Fraser.

Fraser River at Idlewild Campground

This site is located adjacent to the Forest Service campground just upstream of the town of Winter Park. This station is 675 feet in length and averages 20.2 feet in width. Table 1 contains population estimates collected on the three occasions we have surveyed this reach. Unlike our other monitoring sites, this reach is dominated by small brook trout which rarely exceed 10" in length.

Every parameter of the trout population in Table 1 experienced significant declines from 2014 to 2016, and the estimate of total trout biomass declined by 49.6%. The decline in brook trout biomass can likely be attributed to the absence of a 2014 year class (which would have appeared at the 2" mark), which by 2016 had resulted in a suppressed adult population. Brook trout in high-elevation mountain streams such as this are relatively short-lived (4-5 years), and therefore a missing year class can have a strong short-term effect on the adult population in the future. Sculpin capture declined only slightly, and this was not by a significant margin. 2018 estimates improved somewhat but not to the level seen in 2014. Sculpin capture declined again. Continued declines in sculpin capture at this site could be cause for concern, as they are strong indicators of water and habitat quality.

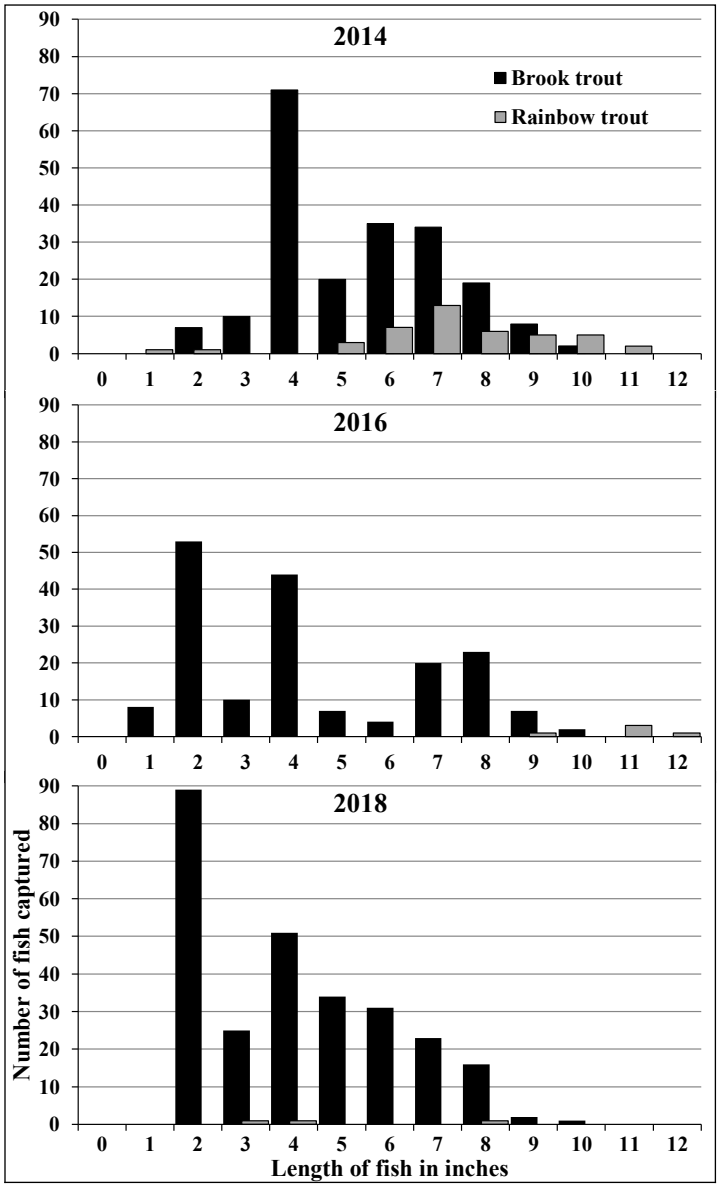


Figure 1. Size distribution of trout at Idlewild Campground.

Figure 1 displays the size structure of brook and rainbow trout captured at this station over the three surveys to date. As discussed previously, 2013 was the last year that we stocked rainbow trout fingerlings in the Fraser. The decline in the rainbow trout population can likely be attributed to this change. The rainbows in the 5-10" range in 2014 are the result of past stocking. The two small rainbows we captured in 2014, 1-2" in length, are evidence of successful natural reproduction that year. Like Confluence Park, by 2018 it has become apparent that despite some successful reproduction, rainbow trout will not sustain themselves on this reach without additional stocking.

We were surprised to capture two brown trout larger than 18" in 2018 at this site, which contributed a large portion of the increased brown trout biomass estimate. These were far larger than any fish we had captured here before, and were obviously not resident fish, but rather migrants from downstream that were preparing to spawn. This is further evidence of the apparent trend this year of upstream expansion of brown trout.


Figure 2. Brook trout from the Idlewild reach.
Photo by Kevin Birznieks

Fraser River Idlewild Fish Population Estimates			
Year	**2014**	**2016**	**2018**
Date of survey	9/3	8/31	9/6
Brown trout			
Biomass (pounds per surface acre)	40 lbs/acre	11	28
Fish > 6" per mile	150/mile	55	39
Rainbow trout			
Biomass	33	16	1
Fish > 6" /mile	297	55	8
Brook trout			
Biomass	58	39	43
Fish > 6" /mile	794	443	671
Total trout biomass	131 lbs/acre	66	72
Total sculpin captured	69	60	52

Table 1. Population estimates.

Colorado River at Parshall

Fishery management report
Jon Ewert, Aquatic Biologist, Colorado Parks and Wildlife
March 2019

Introduction

Located approximately 10 miles east of Kremmling, CO on US highway 40, this section of the Colorado River offers approximately 4 miles of public access on the Kemp-Breeze, Lone Buck, and Paul Gilbert State Wildlife Areas (SWA), managed by Colorado Parks and Wildlife (CPW), and the Bureau of Land Management's (BLM) Sunset property unit. This is one of the most well-known and heavily fished trout rivers in the state. Despite heavy angling pressure, trout populations here are generally excellent and this is a designated Gold Medal fishery.

Regulations

This section is under special regulations, restricted to fishing with flies and lures only, and all trout must be returned to the water immediately.

Stocking

Whirling disease-resistant strains of rainbow trout were stocked at various sizes through 2015 with the goal of reestablishing a wild, self-sustaining rainbow trout population. Results of these efforts are discussed in more detail on pages 5-6.

Fishery surveys

The information in this report reflects trout population data collected on the two-mile reach of river beginning just upstream of the "Parshall Hole" and extending downstream through the Kemp-Breeze SWA to the irrigation diversion on the BLM Sunset property. This survey is conducted in the third or fourth week of September annually. Population estimates are obtained by raft electrofishing using standard mark-recapture methodology .

Figure 1 displays estimates for trout biomass in pounds per surface acre over the 2-mile reach. From 2007-2011, this estimate declined annually, and from 2011-2018 the estimate has steadily increased. In all years this estimate has generously exceeded the minimum Gold Medal criteria of at least 60 lbs./acre. During this period brown trout have contributed an average of 95% of this estimate while rainbows have contributed 5%.

Figure 2 displays trout population estimates in fish per mile 6" or larger. The high brown trout estimate in 2007 is the result of multiple large year classes of young brown trout recruiting during the relatively low-water years leading up to that year (see Figure 5). It is common to see high recruitment of juvenile brown trout during drought periods, simultaneous with declining numbers of large fish. The increase in rainbow trout estimates beginning in 2012 reflects the introduction of Whirling Disease resistant rainbows to this section of river (see discussion on page 5-6). During this time, brown trout have contributed an average of 97% of these estimates and rainbows have contributed 3%.

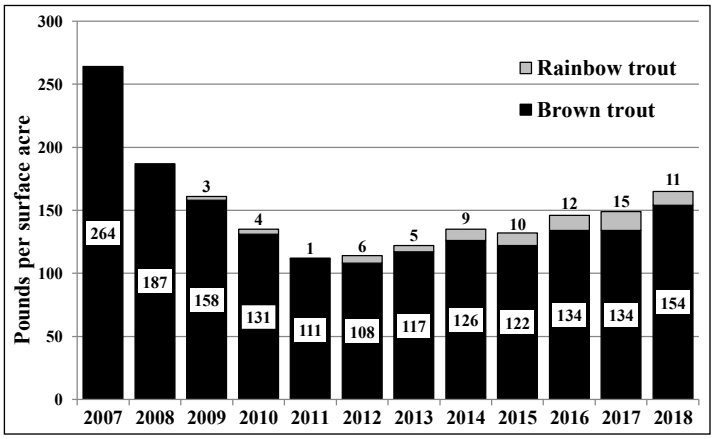


Figure 1. Brown and rainbow trout biomass estimates, Parshall-Sunset, 2007-2018.

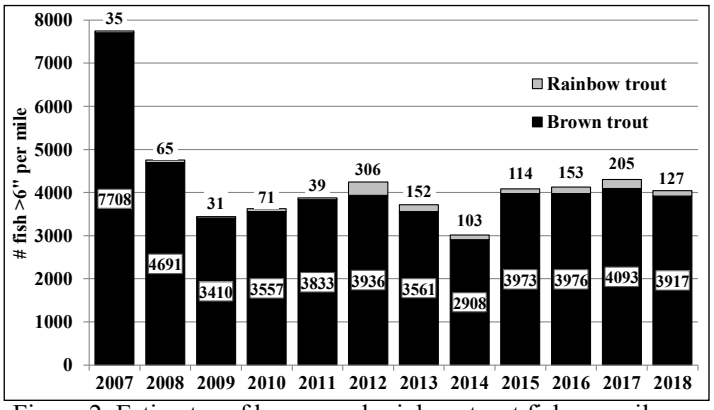


Figure 2. Estimates of brown and rainbow trout fish per mile larger than 6", Parshall-Sunset, 2007-2018.

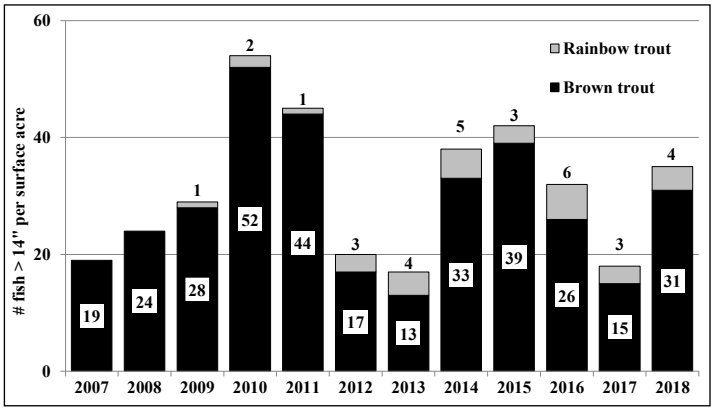


Figure 3. Density estimates of quality-sized (>14") brown and rainbow trout per surface acre, Parshall-Sunset, 2007-2018.

Figure 3 displays density estimates of trout greater than 14" per surface acre, which is the second biological criteria for Gold Medal designation, requiring a minimum of 12 trout per acre 14" or larger. In years such as 2013 and 2017, these estimates have come close to slipping below that standard.

Historic density estimates of quality trout from the years 1981-2004, collected by Colorado Division of Wild-

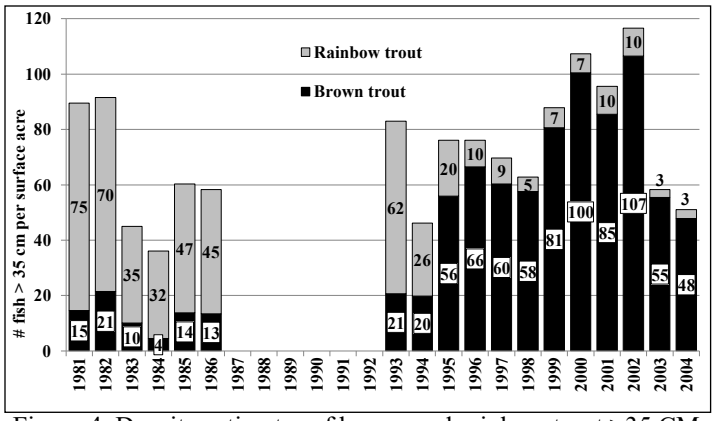


Figure 4. Density estimates of brown and rainbow trout >35 CM per surface acre, Parshall-Sunset, 1981-2004.

life research biologist Barry Nehring and colleagues, are displayed in Figure 4. The parasite which causes whirling disease was first introduced to the Colorado River during this time, and its effects are evident in the decline of the rainbow fishery and subsequent expansion of brown trout densities. Regardless, in 15 of the 18 sampling occasions during this period, quality trout estimates exceeded 50 fish per acre, while this has occurred only once in the most recent decade (Figure 3). This information suggests that this fishery has undergone a long-term decline. All the reasons for this are not known, but two of the most likely culprits are a long-term degradation in the quality of invertebrate forage, long-term degradation in the quality of physical habitat (particularly overwinter habitat), some combination of those two factors, or an issue not yet known.

Figures 5 and 6 (following page) display the size distributions for all brown trout captured in the Parshall-Sunset reach in September from 2007-2018. The vertical axis on all graphs is the same, enabling comparisons among years. The vertical bars represent the number of fish that were captured in each size class by centimeter (15 cm = 6”). Viewing the data in this way reveals a wealth of useful information including rough estimates of annual growth and survival rates. Fish less than 15 cm are not effectively captured during these surveys, so it is difficult to assess the abundance of the age-0 year class (fish that were born the year of the survey) from this data. However, the age-1 year class (born the year prior to the sample), in the 12-20 cm range, is represented more accurately.

When studying this survey data, a question sometimes arises regarding movement of trout. The question is whether or not the data represents the “true” resident population of fish, or whether the fish move so much that it is more of a single snapshot in time of the trout that happen to be occupying the reach on that day. There are a few aspects of this data which at least partially answer that question. First, the survey is conducted as close to the same date as possible every year. If the results are heavily influenced by fish movements, those movements should at least be similar among years as long as the dates of the survey are consistent. Anecdotally, many fish are collected each year that have small scars in the tail where they were marked in previous years’ surveys, proving that those fish occupy the same reach across multiple years.

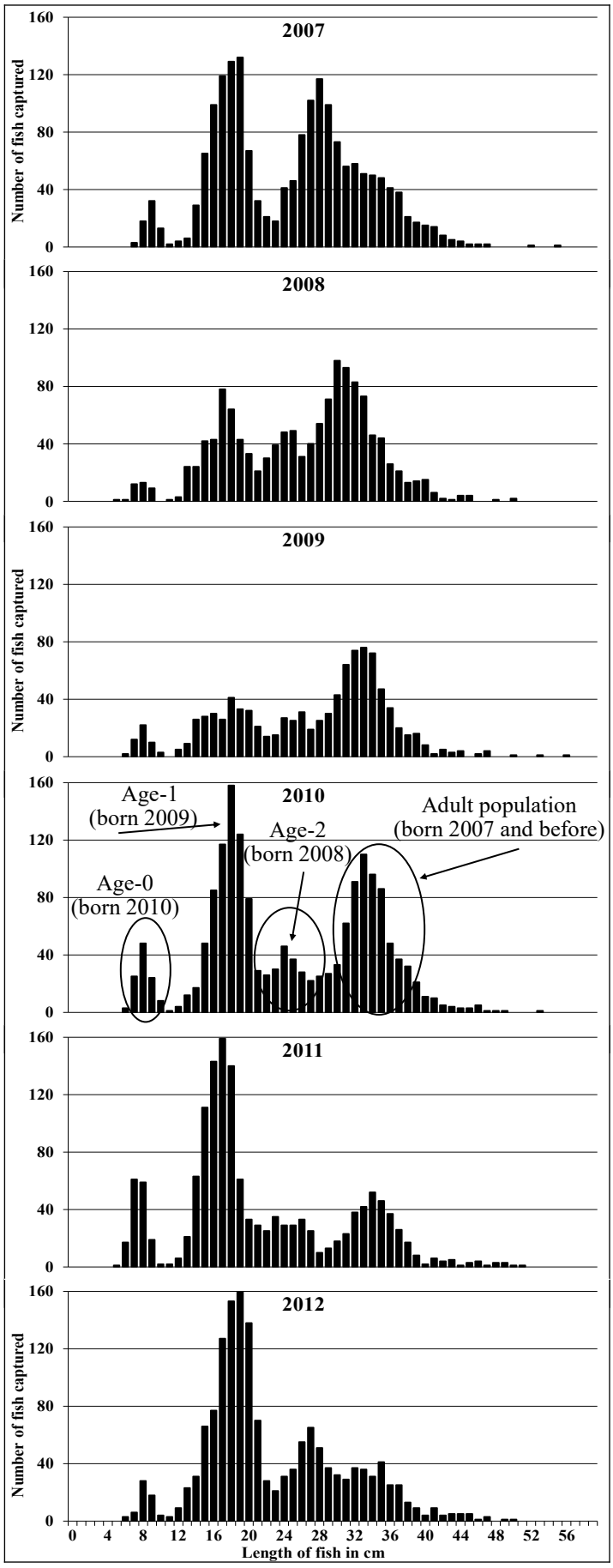


Figure 5. Brown trout size distribution, 2007-2012.

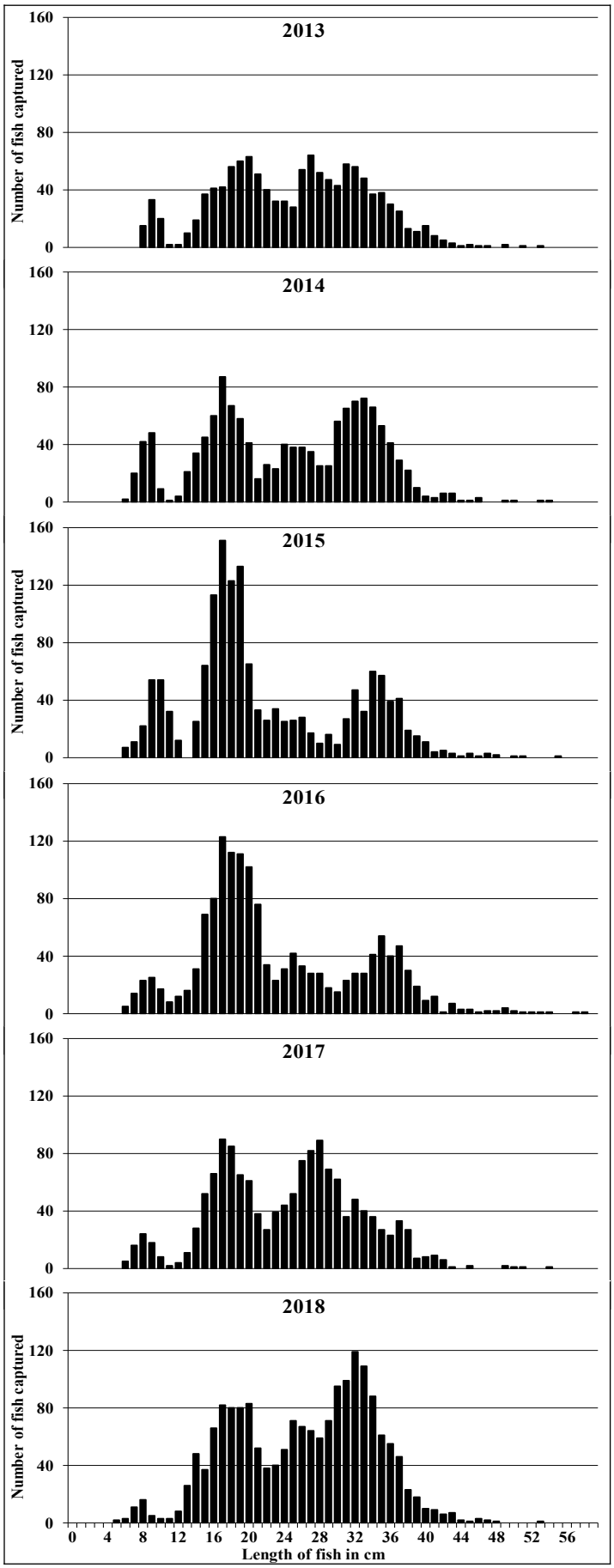


Figure 6. Brown trout size distribution, 2013-2018.

Also, the analysis below demonstrates that year class strength is a strong predictor of the future adult population. If the population was heavily influenced by emigration or immigration, this would not necessarily be the case. There are examples of other reaches of the Colorado (such as the Radium survey reach) where the number of juvenile fish has never explained the high density of adult fish present, meaning that the reach "gains" fish from elsewhere.

The strength of the age-1 year class in any given year is of great interest because of its ability to predict trends in the adult population in future years. Due to high mortality rates in small fish, strong age-1 year classes are necessary in order to maintain the adult population. We have seen an oscillation in the abundance of age-1 fish that appears to occur over 2– or 3-year cycles (Figure 7).

The result of weak age-1 recruitment in 2008 and 2009 can be seen in the weakening adult population in 2011 and 2012. That weakening of the adult population is evident on page 2 in the biomass and quality trout estimates for those years.

In 2012 the age-2 fish were poised to bolster the adult population, which took place in 2013 and 2014. This also appears in Figure 1 in the improving biomass estimates in those years and the increase in quality trout in 2014.

2013 revealed another strong age-2 year class; however the age-1 group was weak in both 2013 and 2014. The adult population in 2014 reflects the benefit of the strong age-1 groups of 2011 and 2012. This is also evident in the increased number of quality trout that we observed in 2014. However, the weak recruitment years of 2013 and 2014 resulted in moderate decreases in the adult population in 2015 and 2016, which was ultimately manifested in the lower quality fish estimate in 2016. Age-1 recruitment in 2015 and 2016 returned to strong levels, which again bolstered the adult population in 2017 and 2018. Age-0 capture in 2016 was low, resembling that of 2012 and 2013, which predicted a weak Age-1 year class in 2017.

Quality trout density estimates in 2017 were among the lowest ever (Figure 3). However, the 2017 sample revealed a large, overlapping group of Age-2 and 3 fish (peaking at 28 cm) resulting from the strong age-1 groups in 2015 and 2016. These fish advanced in size in 2018, which resulted in an improved quality trout estimate in 2018 and we anticipate this to continue with another increase in 2019. 2018 saw another weak age-1 group, and Age-0 capture in 2018 was exceptionally weak. If this manifests as a weak Age-1 group in 2019, this will be the first time since 2007 that we have observed three consecutive weak Age-1 groups, which predicts poor estimates of quality fish (>14") in 2020, 2021, and 2022.

We have observed an oscillation in both the strength of Age-1 year classes and density of quality trout (Figure 7). We do not have a strong understanding of factors that produce strong or weak year classes in any given year on this reach of the Colorado. In some rivers, above-average runoff results in high mortality of brown trout, thus forming poor year classes, while drought years see high survival of age-0 fish due to the lack of intense flows. However, we have seen counterexamples of that dynamic in the Col-

orado River in recent years. 2011 produced a peak runoff period that was far above average, yet a strong year class survived. Conversely, 2012 was a drought year that produced a weak age-1 group the following year. Intensity of runoff probably plays a role in some years, but does not appear to be the chief factor determining year class strength on this reach.

Spawning habitat quality could act as a limiting factor in the formation of year classes. However, if there was a general lack of spawning habitat, there would be no reason for the variability in year class strength that we have observed. All year classes would be equally poor.

In some winters, anchor ice, frazil ice, and various formations of ice damming are common on this reach of the Colorado. It is possible that harsh winter conditions exacerbated by low flows lead to high mortality rates of brown trout eggs that are incubating in the gravel, which would result in poor year class formation. We do not currently have a way to quantify those conditions, and the degree to which they vary among winters. However, in-channel habitat improvements would address this issue by enhancing the quality of spawning riffles as well as overwintering habitat, making these areas less vulnerable to the harsh winter conditions that can take place during periods of cold weather and low flows.

It is difficult to determine exactly how the two patterns of oscillation in Figure 7 are related. Under a recruitment-driven hypothesis, strong juvenile year classes would predict peaks in large fish density by approximately two years, as described above. However, a predation-driven dynamic could also be at play, in which a higher density of large fish actually limits the strength of juvenile year-classes through predation pressure. The true determination of these trajectories is most likely driven my a more complex interaction among these two factors as well as others, such as water year type.

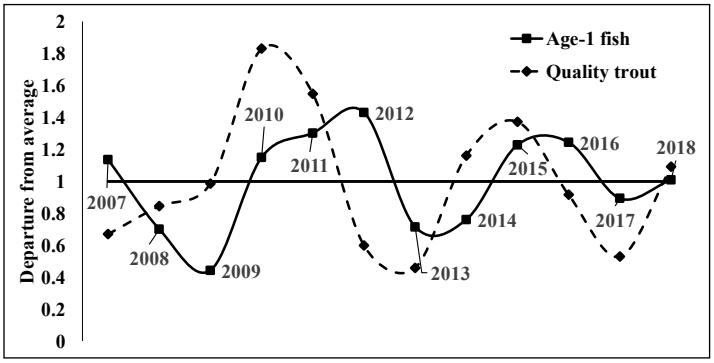
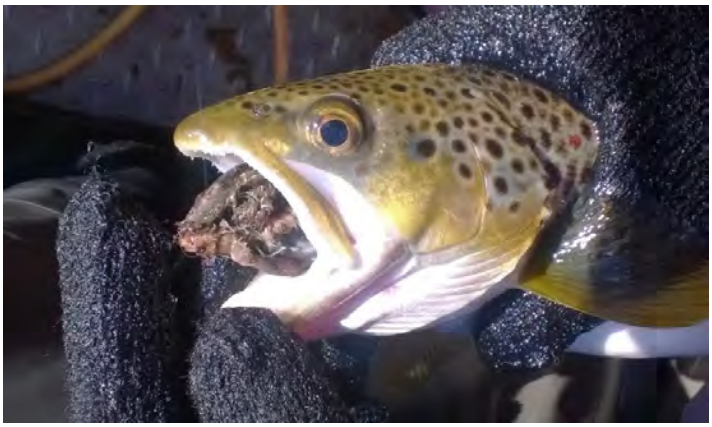


Figure 7. Oscillation in quality trout estimates (dashed line) and number of juvenile (12-23 cm) brown trout handled annually. Values for both parameters were standardized to the average for the period, represented by the flat line.


Figure 8. The largest brown captured in 2014. 21", 4.6 lbs.



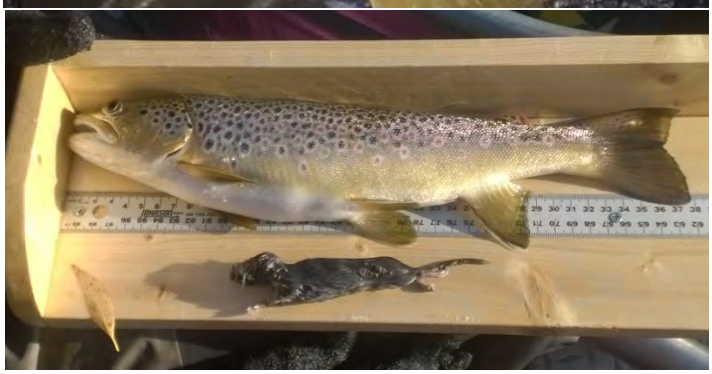


Figure 9. This 15" brown trout had recently eaten a rodent.

Status of wild rainbow trout

The Colorado River in Grand County historically supported one of the most productive wild rainbow trout fisheries in the world. In 1981, there were estimated to be 75 rainbow trout per acre over 14" (Figure 4). These fish were all the product of wild reproduction and unsupported by stocking. Brown trout comprised 25% of the trout population in the river that year. Whirling disease appeared in the river in 1987 and the proliferation of this parasite ended virtually all successful reproduction of rainbow trout. In the following years, the brown trout population exploded to fill the habitat that was vacated due to lack of reproduction in the rainbow population. It has always been the goal of CPW to restore some level of a wild rainbow trout fishery to this reach of the Colorado. Beginning in 1994, CPW began stocking fingerling rainbow trout to attempt to compensate for the lost natural reproduction. Research has shown that rainbow trout mortality from whirling disease drops dramatically when the fish have reached a length of 5". Based on this information, that is the size of fish that was stocked throughout the 2000's. Due to the timing of rainbow spawn in CPW hatcheries, fish of that size were not available until the fall, usually October. 40,000 5" fish per year were stocked annually in October in this reach of river.

Figure 10 demonstrates the failure of the stocking strategy described above. Even though 5" fish should be able to survive in the presence of whirling disease, recruitment rates from stocking these fingerlings was abysmal, and rainbow trout continued to constitute a tiny fraction of the total trout population of this reach.

In more recent years, CPW has developed strains of rainbow trout that are highly resistant to whirling disease. We first stocked this fish in this reach in 2008. In 2008 and 2009, the fish were stocked at 5" in October. We did not observe any evidence that this strain was successful at recruiting into the population when stocked at that size.

In 2010, we adopted a different stocking strategy based on the hypothesis that the limitation on recruitment in the 5" plants was timing rather than WD infection. If this was not the case we should have seen a positive response with the introduction of the WD-resistant strain in 2008. We stocked a larger number (60,000) of smaller (1.6 inches average) fish during the third week of July. We stocked these small fish out of a raft, only in the most ideal fry habitat. At this small size the fish are not habituated to

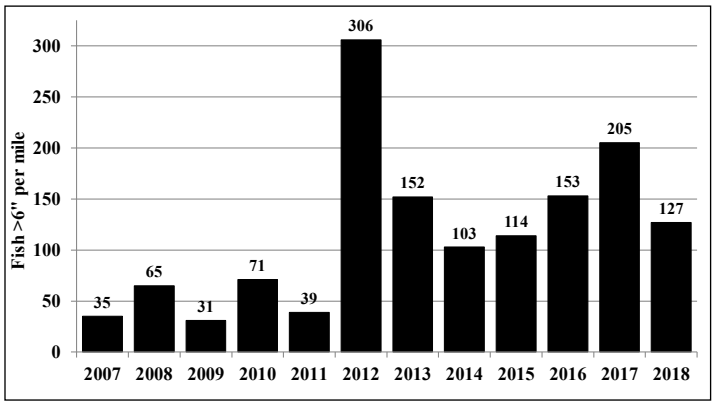


Figure 10. Estimates of rainbow trout >6" per mile, Parshall-Sunset 2007-2018.

Figure 11. This Parshall Hole rainbow had recently eaten a 10" brown trout.

Figure 12. The largest rainbow we captured in 2018, measuring 22".

being fed yet, and hopefully develop wild behaviors that are likely already lost in fish that have been raised to 5” in a hatchery environment. After encouraging results in 2010, in 2011 and 2012 we continued this stocking strategy and increased the number of fry stocked to 100,000.

Our 2012 survey detected the recruitment of these fish into the adult rainbow population for the first time (Figure 10). Subsequent surveys have not yielded estimates as high as 2012, but they have remained above pre-2012 levels. We have documented successful natural reproduction but it remains to be seen if it will be enough for the percentage of rainbows in the trout population to increase.

Figure 14 displays the size distribution of all the rainbow trout captured over the past six years in this reach. In 2010 we captured rainbow trout smaller than 6” for the first time. These were the 2” fry that had been stocked two months previously. By 2013 we observed the development of a more robust adult population in the 12-16” range as a result of the fry stocking.

In 2014 we found the most fully developed adult rainbow population to date. The density estimate for rainbows larger than 14” was 5 fish per acre, which was the highest estimate in the post-WD era, until 2016 yielded an estimate of 6 per acre. We also did not detect an age-1 year class in 2014 for the first time since fry stocking began, for unknown reasons. However, we did collect some age-0 (fry stocked in 2014) fish. 2015 and 2016 saw the return of moderate age-1 groups.

Due to a disease issue in our hatchery system, 2015 was the last year that we stocked rainbow trout fry. This was also an opportune time to cease stocking and evaluate whether or not natural reproduction would sustain and/or increase rainbow numbers. The 8” age-1 year class seen in 2016, the 12” Age-2 group in 2017, and the 13”-17” adult group in 2018 represent the last stocked rainbow fry. The 7-9” group in 2017 and 2018 are wild fish, and through fry monitoring we have observed some successful natural reproduction. We are hopeful that this trend will continue, although the numbers of juvenile fish we have observed in the past two years do not appear to be adequate to sustain the rainbow fishery. We will consider stocking rainbow fry again, possibly beginning in 2020.

Figure 13. Rainbow trout fry on the raft ready to be stocked.

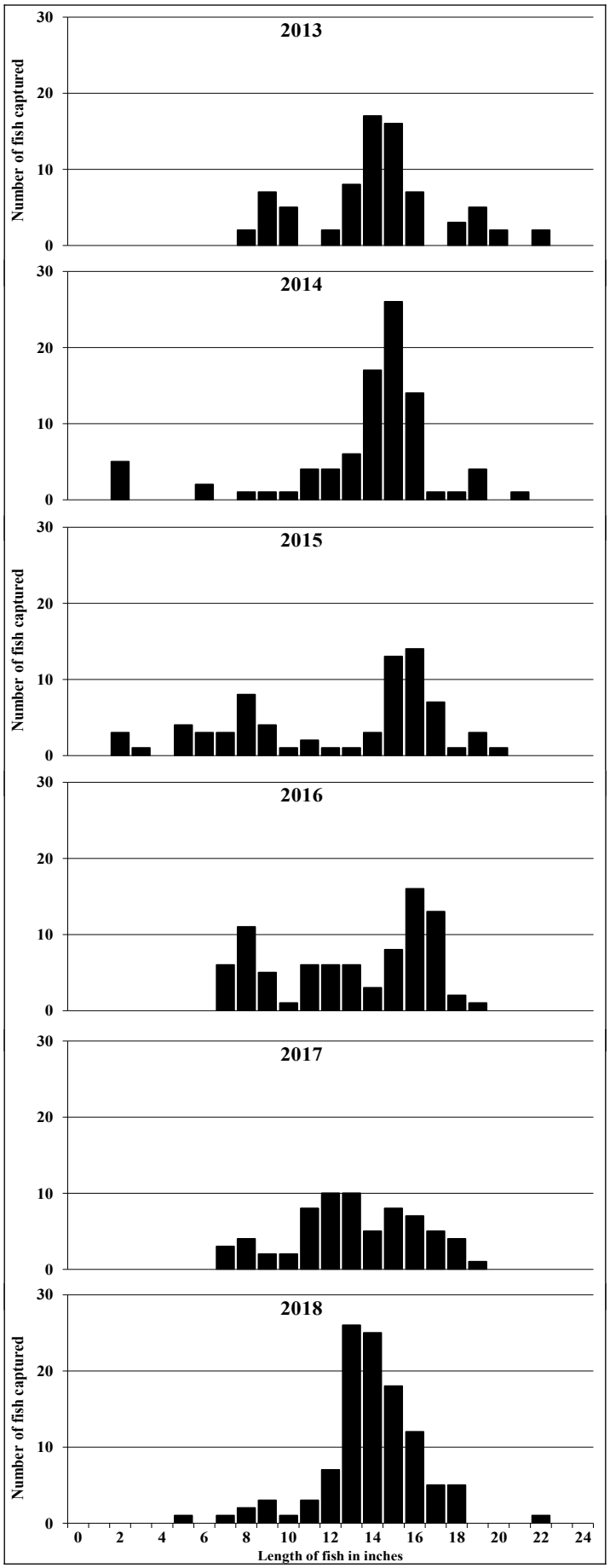


Figure 14. Size distribution of rainbow trout captured on the Parshall-Sunset reach 2013-2018.

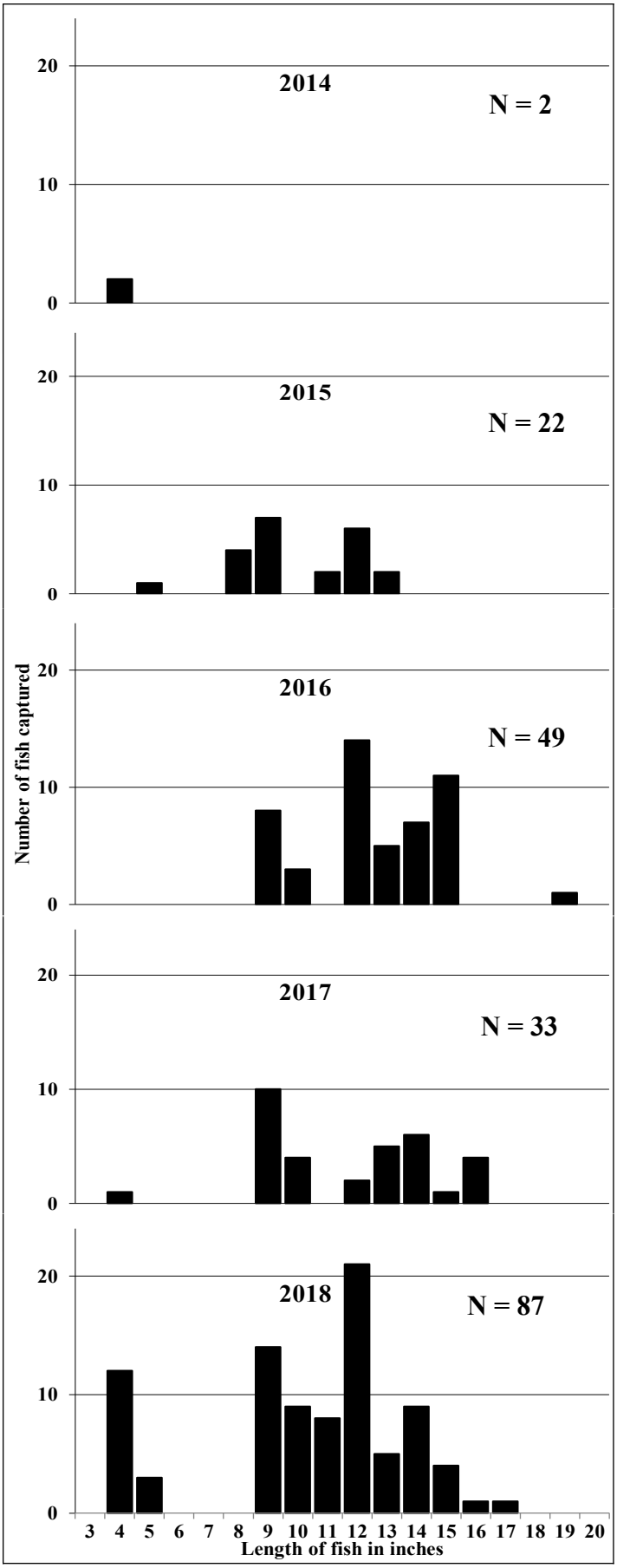


Figure 15. Size distribution of mountain whitefish captured in Parshall-Sunset reach, 2014-2018.

Mountain whitefish invasion

In 2013, we collected four juvenile mountain whitefish on this reach for the first time. This species had never been captured on this reach of river in a history of biological survey work that extends back to 1981. There are no known historical records of mountain whitefish occurring anywhere in Middle Park upstream of Gore Canyon. This species is native to the White and Yampa river drainages but not to the Colorado. There is an established population in the Colorado downstream of Gore Canyon.

Figure 15 displays the size distribution of whitefish that we have captured since 2014. That year, we captured two juvenile whitefish. A year later we captured 22 whitefish representing three age-classes, which corresponded to the juveniles we had caught the two previous years. In 2016 our catch increased to 49 mountain whitefish representing four year-classes and ranging up to 19" in length. We captured fewer in 2017, but still found at least three year-classes. 2018 saw a large jump in the number that we captured, including the highest number of Age-0 (4-5") fish yet found.

In other surveys, we have also captured whitefish as far upstream as Windy Gap dam. These findings suggest that we are witnessing the beginning of a significant invasion of the species into the upper Colorado. The reasons that this is occurring now are unknown. 2011 saw the highest flows on the Colorado River since the early 1980's, and our current theory is that the prolonged high flows during that summer allowed adult whitefish to find their way through Gore Canyon for the first time.

Impacts of mountain whitefish on the trout fishery are unknown at this time. There are ways in which they might benefit the fishery (for example, providing an additional prey source for large, predatory brown trout), but they may also present new competition with trout for food and habitat. Catch-and-release regulations on this reach apply to trout only, so these fish are available for angler harvest. We will closely monitor this invasion over the coming years and continually assess whether or not any management changes are warranted.

Figure 16. Mountain whitefish captured in the Parshall Hole.

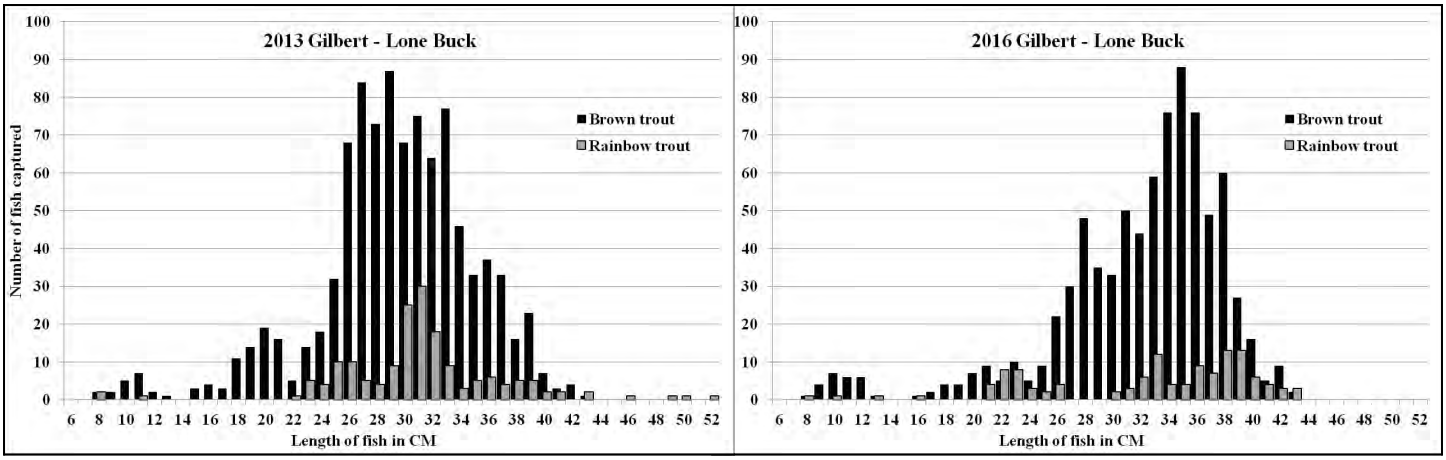
Spring 2013 & 2016 surveys of Paul Gilbert—Lone Buck reach

In spring of 2013 & 2016, we conducted a raft electrofishing survey of the Colorado River beginning just downstream of the Byers Canyon bridge and extending to the downstream border of the Lone Buck State Wildlife Area. This encompassed a river reach of approximately 7,000 feet in length. The main reason for this survey was to determine the number of spawning rainbow trout in this reach, which contains locations where rainbows regularly spawned historically. This was the first time since 2013 that we had surveyed this section. These are the only two occasions in recent history that the reach has been surveyed in the spring.

Results of the 2013 and 2016 surveys are contained in the table at right. Rainbow estimates remained essentially the same across the two occasions, while the number of large brown trout increased dramatically. This resulted in a greatly increased estimate of brown trout biomass. The size distribution of both species is shown in the graphs below.

Colorado River, Paul Gilbert—Lone Buck		
	2013	**2016**
Date of survey	5/6 & 8	4/19 & 21
Rainbows: #> 6”/mile	214	182
#>14”/surface acre	5	6
Biomass (lbs./acre)	13	13
Browns: #> 6”/mile	1,537	1,178
#>14”/acre	11	28
Biomass (lbs./acre)	74	132

In the 2016 survey, we also captured one mountain whitefish measuring 16”. At that time this was the farthest-upstream location that we had captured a whitefish; however, the following month we captured two more whitefish upstream of the town of Hot Sulphur Springs, indicating that they are present in the river up to Windy Gap dam.



A Whirling Disease-resistant rainbow from the Lone Buck reach.

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