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LEARNING BY DOING

2019 Aquatic Resource Monitoring Report

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Notable Events

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2019 Notable Events

The following summary of notable events in 2019 is provided to give context to the ongoing monitoring and cooperative Learning By Doing (LBD) effort in Grand County, Colorado. This summary is accompanied by a "Monitoring Year 2019 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 2019 Aquatic Resource Monitoring Report.

In 2019, 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 2019 that may have had a positive impact on water quality.

Climate, Hydrology and Impacts

- Grand County experienced above average snowpack in 2019. The Colorado Basin River Forecast Center (CBRFC) April 1, 2019 Most Probable Runoff Forecast at Kremmling was 113 percent of average. The actual runoff at Kremmling was 129 percent of average. The highest sub-basin runoff forecast within the LBD CEA was in the Willow Creek basin at 125 percent of average, and the lowest was in the Fraser River basin at 102 percent of average. The April 1 Most Probable Runoff Forecast into Granby Reservoir was 107 percent of average.

Coordination Calls

- 2019 was the fifth consecutive year in which LBD conducted weekly water coordination calls from late May to mid September. Calls provide a forum to discuss conditions and weekly projected operations, allow LBD partners to be responsive to low flow and high water temperature conditions through coordination of environmental water releases, and foster communication, relationships, and trust amongst stakeholders.

Operations

- Denver Water Moffat Collection System spill bypasses[1] totaled approximately 42,000 acre-feet (af) during runoff season due to increased available water on the West and East Slopes. This included water diverted from the Williams Fork River basin so that water could be

[1] "Voluntary/environmental bypasses" are releases pursuant to the CRCA; "required bypasses" are releases pursuant to a permit or ROD; "maintenance bypasses" are releases to allow for maintenance; "spill bypasses" are releases as a result of a full reservoir or system constraint (full east-slope reservoirs).

bypassed for environmental benefit into the Fraser River basin on St. Louis and Ranch creeks in early June for environmental benefit. Maintenance bypasses totaled 100 af from the Fraser River Collection System.

- The Grand County Mitigation and Enhancement Coordination Plan (MECP), U.S. Forest Service (USFS) Off-license Agreement, and Section 404 Permit for the Moffat Project all have flushing flow requirements. In 2019, these flows were met or exceeded at all locations.
- Northern Municipal Subdistrict pumped more than 12,000 af from Windy Gap to Granby Reservoir, including 3,000 af for Middle Park Water Conservancy District. Unfortunately, Granby Reservoir spilled in late June and July. This included all Windy Gap water pumped in 2019 and carryover Middle Park water pumped in 2018. Granby Reservoir has spilled in 2011, 2014, 2015, 2016, 2017, and again in 2019.
- Release of 5,412.5 af from the Endangered Fish Pool in Granby Reservoir for the Upper Colorado River Endangered Fish Recovery Program was delayed from its usual August 1st start date due to wet conditions downstream that made additional water unneeded. An exchange of 833 af of the 5412 water into Wolford Mountain Reservoir aided high stream temperatures on the Colorado River above the Williams Fork confluence, while providing temporary storage for later release.

Restoration Projects

- In 2017, volunteers planted approximately 2,400 willows as part of LBD's Fraser Flats River Habitat Project. In 2019, roughly 1,300 willows were observed. Of these, approximately 50 percent were in good to fair condition. While overall survivorship of willows is satisfactory, the revegetated area could be improved with supplemental plantings in future years.
- Volunteers planted more than 2,000 willows along a one mile section of Ranch Creek in 2018. In 2019 approximately 2,000 willows were observed with 75 percent in good or fair condition. The dry year in 2018 did not affect the survivorship of the plantings as much as expected.
- Denver Water completed construction of phase 2 of its Williams Fork River Restoration Project in October 2019. Phase 2 included restoration of 0.34 miles on the Upper Reach of the project, located upstream of the Williams Fork inlet on either side of County Road 3. This compliments habitat connectivity improvements by Grand County's Aquatic Organism Passage culvert project. Phase 2 also included the 0.86-mile restoration at the Kemp Breeze State Wildlife Area. The entire project equals 2.08 miles of restoration on the Williams Fork.

Monitoring Programs

- The LBD Monitoring Subcommittee (Subcommittee) re-evaluated objectives for macroinvertebrate monitoring. During this process, 13 macroinvertebrate metrics were established to provide information to meet program objectives. The Subcommittee issued an RFP for macroinvertebrate monitoring and selected Timberline Aquatics to carry out the bioassessments.
- The Subcommittee issued an RFP for sediment monitoring and selected GEI as the consultant to conduct sediment surveys. The monitoring plan included a change to the

methodology for conducting pebble counts. The new methodology is more robust and adheres to Colorado Division of Water Quality guidelines for collecting sediment data to assess aquatic health.

- The Subcommittee added a new macroinvertebrate and sediment monitoring site on the Fraser River upstream of Union Pacific Railroad's (UPRR) Moffat Tunnel discharge to establish baseline conditions for comparison with a monitoring site located just downstream of the UPRR's discharge. Contingency funds were reserved for emergency macroinvertebrate monitoring at the downstream site in the event of a spill or unauthorized discharge.
- The Subcommittee added weekly temperature data downloads from July–September at site CR-2.3, Colorado River upstream of the confluence with the Blue River. This is the last temperature monitoring location in the CEA and provides important information that will assist the Operations Subcommittee in its decision-making process.
- The Subcommittee developed and executed an extensive Aquatic Resource Monitoring Plan, the result of which is the 2019 Aquatic Resource Monitoring Report.

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Monitoring Year 2019 Snapshot

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LEARNING BY DOING – MONITORING YEAR 2019 SNAPSHOT

For its seventh consecutive year, Learning By Doing (LBD) continued to monitor the health of aquatic resources within the Colorado, Fraser, and Williams Fork River basins in 2019. A snapshot of the 2019 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 2019 there were 65 sites monitored within LBD's Cooperative Effort Area (CEA). This area includes sites on the Colorado and Fraser rivers and 19 tributaries. Temperature data were compared to Colorado temperature standards at 60 monitoring sites. Of the sites monitored, 14 exceeded the state temperature thresholds: 10 sites in the Colorado River basin and 4 in the Fraser River basin. Exceedances generally occurred in late July or early August during the hottest months of the year, or in October and May when the Cold Stream Tier 1 (CSI) standards change from winter to summer. Click here for temperature assessment.	Of the 28 sites where data were compared to temperature standards, 18 sites were in attainment with state temperature standards. Two sites exceeded the state temperature threshold for acute (1-day) exposure: • Colorado River upstream of Granby Reservoir • Arapaho Creek downstream of Monarch Lake Ten sites exceeded the state temperature threshold for chronic (7-day) exposure: • Arapaho Creek downstream of Monarch Lake • Colorado River downstream of Shadow Mountain Reservoir to Granby Reservoir (3 sites) • Colorado River at Sheriff Ranch • Colorado River upstream of Hot Sulphur Springs • Colorado River downstream of Byers Canyon • Colorado River at Lone Buck • Colorado River upstream of Williams Fork • Williams Fork upstream of Williams Fork Reservoir	Of the 32 sites where data were compared to temperature standards, 28 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 at CR 84 • St. Louis Creek Three sites exceeded the state temperature threshold for chronic (7-day) exposure: • Ranch Creek below CR 8315 • Ranch Creek below Meadow Creek • St. Louis Creek
Macro-invertebrates	In 2019, bioassessments were conducted at 18 sites in the CEA. All 18 sites received an attainment for aquatic life use designation through their MMI (v4) scores.[2] Click here for full report.	Of the 10 sites monitored in the Colorado River basin, all were in attainment with state standards in 2019 and appear to support healthy macroinvertebrate populations.	Of the 8 sites monitored in the Fraser basin, all were in attainment with state standards in 2019 and appear to support healthy macroinvertebrate populations.
Fish	CPW conducts electrofishing surveys to estimate trout populations in the Colorado and Fraser river basins. There are 7 total sites for fish surveys along the Fraser River. According to CPW, Mottled Sculpin are the Fraser River's greatest biological asset because they are the main prey source for trout and are a good indicator species of water quality and habitat availability. Sculpin are harder to assess with electrofishing methods, yet the number of sculpin caught each year can still be used to assess trends in the population. [4] Click here for full report.	In 2019 CPW completed a fishery assessment in the Upper Colorado River Basin. However, due to the dynamic situation caused by the COVID-19 pandemic, a report is not available at this time. The data will be included in a future report, most likely combined with the 2020 surveys, which will be made available in 2021.	• Robbers Roost was a new site for 2019 and CPW stocked 10,000 native Colorado River Cutthroat Trout in this stretch above the sedimentation pond. The Safeway site sustains a productive fishery, however, Rainbow Trout are showing declines and stocking of Rainbows is planned for 2020. Lower Behler Creek was sampled for the first time this year and showed good numbers of juvenile fish. Kaibab Park has proven to be a stable fishery for Brown Trout. • LBD's Fraser Flats River Habitat Project showed a second year of slight decline in trout biomass estimations, compared to its peak in 2017 (post restoration) and the estimations from 2018. However, trout biomass estimates post-project continue to be greater than pre-project estimates. The instream habitat, thalweg, and riffle- to-pool ratio has been improved; however, the willow plantings remain immature and have yet to increase canopy cover and ecological function. Sculpin numbers also show a decline, but a greater sampling effort in 2020 will help further the analysis of this trend.
Pebble Counts	A total of 14 sites within the CEA were sampled in 2019. Each location received 400 measurements for the pebble count, utilizing the Modified Wolman Pebble Count Method. Percent embeddedness was also performed at each location with 40 to 50 measurements per site. Click here for full report.	Seven sites were assessed along the Colorado River. It was observed that sites further upstream have lower percentages of fine sediment and lower percentage embeddedness. Downstream sites showed higher values of embeddedness as well as a higher percentage of fine sediment. The proportion of sand and gravel shows a noticeable drop downstream of Windy Gap Reservoir due to the retention of sediment less than 128mm in the reservoir.	Six sites on the Fraser River and 1 site on Ranch Creek were assessed in this basin. Percent embeddedness was mostly consistent through the Fraser River. Notable exceptions were the most upstream site on the Fraser (FR-25.1), and Ranch Creek, which showed percent embeddedness above 50%. Site FR-14 is below the Fraser Flats restoration effort and showed a decrease in embeddedness,and an increase in small gravel. This is likely due to the narrowing of the river and the increased velocities through this section.
Flushing Flows[1]	Spring runoff met Grand County's recommended flushing flows at all 13 sites that were evaluated in the CEA for the 2019 runoff season.	All three sites on the Colorado River (CR3, CR4, CR7) met recommended flushing flows. Individual sites on the Williams Fork, Blue River and Willow Creek also met their recommended flushing flows.[1]	Of the seven sites monitored for flushing flows in the Fraser Basin, three sites are on the Fraser River (F3, F6, F10) and four sites on tributaries to the Fraser (F-VC, F-RC1, F-RC2, F-STL). All seven sites either met or exceeded the flushing flows described in the Grand County Stream Management Plan.[1]

Notes and Citations:

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

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

[4]Colorado Parks and Wildlife, 2020. Fraser River Fishery Management Report. Link here: https://cpw.state.co.us/thingstodo/Fishery%20Survey%20Summaries/FraserRiver.pdf

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Summary Report

Learning by Doing

Benthic Macroinvertebrate Biomonitoring

2019

Prepared for:

Grand County
Learning by Doing Stakeholder Group

Prepared by:

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4 March 2020

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Summary Report

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4 March 2020

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Introduction

In recent years, the biological monitoring (biomonitoring) of benthic macroinvertebrate communities has been identified as a valuable tool for the evaluation of aquatic environments (Plafkin et al. 1989, Barbour et al. 1999, Paul et al. 2005). The monitoring of aquatic life in streams provides opportunities to evaluate aquatic conditions in ways that cannot be achieved through other types of monitoring programs (Ward et al. 2002). Evolution and ecological processes have resulted in benthic macroinvertebrate communities with specific adaptations and sensitivities to their surrounding environment. Aquatic macroinvertebrate communities are considered sensitive to a wide range of environmental disturbances or pollution; thus, community composition reflects the physical and chemical conditions that occur within a stream and associated watershed over time. Consequently, macroinvertebrate assemblages can be monitored in order to measure the ecological integrity of aquatic systems. Biomonitoring programs are often used in conjunction with physical and/or chemical water quality monitoring to evaluate aquatic conditions.

Sustained biological monitoring is essential to understanding the effects of long-term influences such as population growth, urban development, and changes in land-use practices (Likens and Lambert 1998). The unique physical and behavioral attributes of aquatic macroinvertebrates provide an opportunity to monitor past and present influences on aquatic systems at specific locations. Most macroinvertebrate taxa have a relatively long aquatic life-stage and limited mobility. The sensitivity of each taxon in a community often varies with the type of disturbance, and this sensitivity to disturbance can exist at a structural (species/taxon) level and/or functional (trophic) level. These features result in benthic communities that inevitably respond to changes in environmental conditions. The predictability of benthic macroinvertebrates that respond to perturbations provides monitoring opportunities that range from local sources of pollution to watershed scale disturbances (Ward et al. 2002). The results from consistent sampling practices and accurate identifications can provide valuable information regarding anthropogenic influences and impacts on aquatic communities.

Because certain taxa can survive or even thrive in the presence of various contaminants, it becomes necessary to employ the use of several biotic indices (metrics) in the analysis of biological data. The wide range of stressors and potential interaction among disturbances can make identification of the predominant sources of stress difficult (Johnson et al. 2013). However, some insight into the source and spatial distribution of stressors can be obtained through the evaluation of benthic macroinvertebrate community structure and function.

This biomonitoring study was designed to monitor and evaluate the health of aquatic life in a portion of the Upper Colorado River Basin in Grand County, Colorado. The specific study area includes sampling locations on several streams including portions of the Fraser River, Ranch Creek, Williams Fork, and Colorado River (Figure 1). These streams support a variety of aquatic (and terrestrial) life; however, there are several potential sources of anthropogenic stress ranging from impoundments (which may alter the natural temperature and flow regime) to runoff from agricultural and urbanized areas. Results from this biomonitoring study should provide a reliable measurement of the health of benthic macroinvertebrate communities at specific locations within the study area.

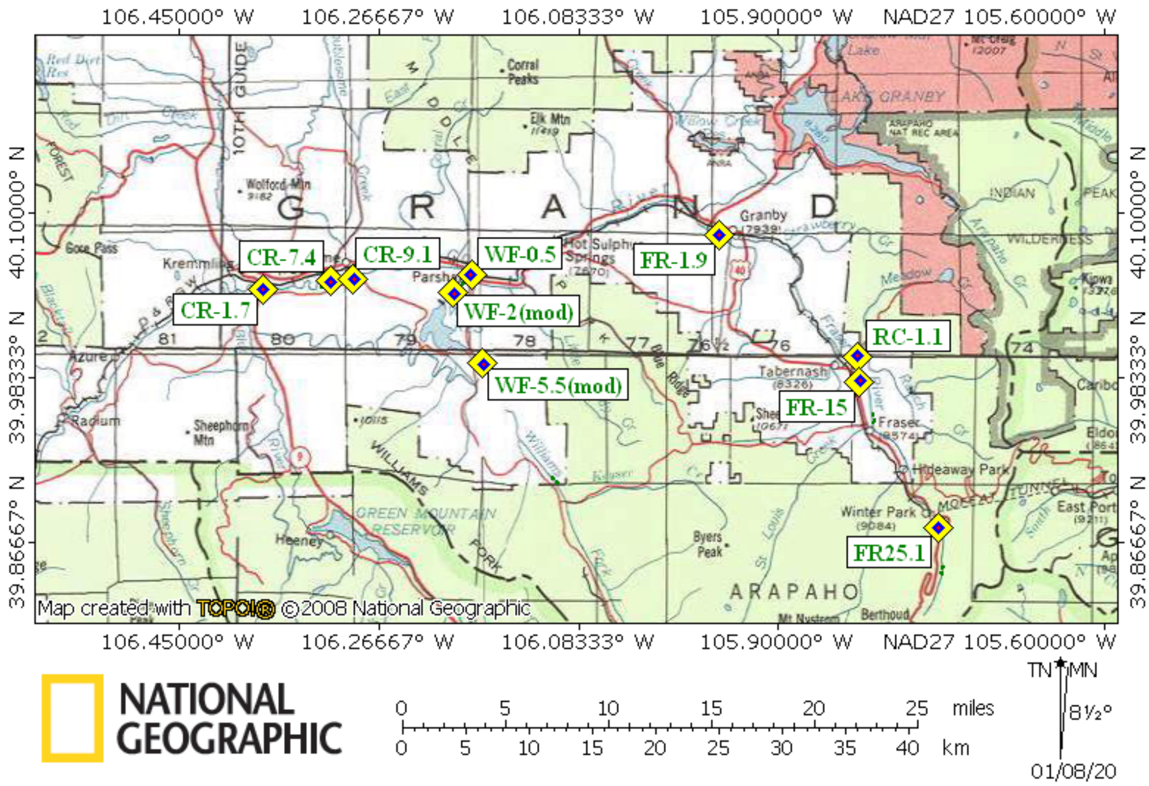

Figure 1. Map of study sites used for the Learning By Doing Biomonitoring study in 2019. This map was created with TOPO! © National Geographic Maps.

Study Area

In the fall of 2019, the Learning By Doing (LBD) study area in Grand County included ten study sites: three on the Fraser River, one on Ranch Creek, three on the Williams Fork, and three on the Colorado River (Table 1, Figure 1). On the Fraser River, the most upstream study site (FR-25.1) was located in riffle habitat upstream of Winter Park and the UP Moffat Tunnel. Farther downstream, site FR-15 was established on the Fraser River above the Fraser Flats Restoration Area and upstream from the confluence with the Ranch Creek. Approximately 23 km downstream, site FR-1.9 was sampled upstream from Windy Gap Reservoir and the Granby Sanitation District. On Ranch Creek, site RC-1.1 was located in riffle habitat upstream of its confluence with the Fraser River, but downstream from Meadow Creek. On the Williams Fork, site WF-5.5 (mod) was established upstream of the Williams Fork Reservoir at a location that could be used to evaluate the influence of a recent habitat improvement project. Approximately 1.5 km downstream of Williams Fork Reservoir, site WF-2 (mod) was sampled to monitor the health of aquatic life as impacts from the reservoir were expected to subside in a downstream direction. Site WF-0.5 was the most downstream site on the Williams Fork, and this site was used to monitor another area of habitat improvement between Williams Fork Reservoir and the confluence with the Colorado River. The two most upstream study sites on the Colorado River included site CR-9.1 (which was located upstream from the CR39 Bridge) and site CR-7.4 (which was established downstream from Troublesome Creek). The remaining sampling location on the Colorado River (site CR-1.7) was established upstream from the confluence with the Blue River near the Town of Kremmling (Figure 1). A comparison of metric values was used to assess macroinvertebrate community health among sampling locations.

Table 1. GPS coordinates and elevations of sample sites in the Learning By Doing study area (Fraser and Colorado Rivers, Ranch Creek, and Williams Fork) sampled in fall of 2019.

	Location	Latitude	Longitude	Elevation (m)
FR-25.1	Fraser River above UP Moffat Tunnel	39.8775	-105.7535	2827
FR-15	Fraser River above Fraser Flats Restoration	39.981338	-105.824946	2580
FR-1.9	Fraser River above Granby Sanitation District	40.08526	-105.95464	2420
RC-1.1	Ranch Creek below Meadow Creek	39.99912	-105.82746	2561
WF-5.5(mod)	Williams Fork above Williams Fork Reservoir	39.994792	-106.17362	2399
WF-2(mod)	Williams Fork below Williams Fork Reservoir	40.04308	-106.19832	2325
WF-0.5	Williams Fork below WF Reservoir	40.0561	-106.1825	2296
CR-9.1	Colorado River at CR39 Bridge - KB Ditch	40.05377	-106.28945	2285
CR-7.4	Colorado River below Troublesome Creek	40.0509	-106.3112	2255
CR-1.7	Colorado River above Blue River	40.0465	-106.373	2246

Objective

The overall objective for the Benthic Macroinvertebrate Bioassessment Study in Grand County, Colorado was to provide an overall evaluation of the health of macroinvertebrate communities at each site in the Learning By Doing study area and to identify areas with potential anthropogenic perturbations.

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Methods

The objective of this particular study required that three (3) replicate, quantitative Hess samples were taken from similar habitat at each study site. The Multi-Metric Index (MMI v4) and several individual biotic indices (metrics) were included in the data analysis to evaluate different aspects of macroinvertebrate community health, and account for different responses to various types of disturbances. The biomonitoring and analysis approach used for this project was intended to provide information describing local aquatic conditions, level of potential disturbances, and densities of various taxa.

Three quantitative, replicate samples were collected from each site on the Fraser River, Ranch Creek, and Colorado River on the 18th of September 2019, and replicate samples were taken from the Williams Fork on the 26th of October 2019. All samples were collected in similar (riffle) habitat at each sampling location using a Hess Sampler to provide quantitative benthic macroinvertebrate data. Substrate within each sample was thoroughly agitated and individual rocks were scrubbed by hand to dislodge benthic organisms. All macroinvertebrates were rinsed into sample jars and preserved in 80% ethanol solution. Each sample jar was labeled (with date, location, and sample ID number) on the outside and inside of each container. Samples were transported to the lab at Timberline Aquatics, Inc. where they were sorted, identified, and enumerated. The sorting and identification process was conducted for each entire sample to avoid potential problems or controversy associated with subsampling.

The sorting and identification process used in this study required that all macroinvertebrates be removed from each sample and placed into vials according to respective major taxonomic groups. As part of the quality control protocols at Timberline Aquatics, Inc., <u>all</u> sorted macroinvertebrate samples were checked by a qualified taxonomist, and approximately 10% of the identifications were checked by Dr. Boris Kondratieff (Professor of Entomology at Colorado State University). As an additional means of QA/QC, Dr. Kondratieff confirmed identifications in all cases where the classification of a species was difficult or questionable.

Macroinvertebrates collected from the Fraser River, Ranch Creek, Williams Fork, and Colorado River were identified to a taxonomic level consistent with the Operational Taxonomic Unit (OTU) established by the CDPHE. Specimens were identified using a variety of taxonomic keys including Ward et al. (2002) and Merritt et al. (2008). This level of identification was typically genus or species for mayflies, stoneflies, caddisflies, and many dipterans. Members of the family Chironomidae were also identified to the genus level. All macroinvertebrate data were analyzed using the MMI v4 and a variety of individual metrics. The following section provides a description of the analysis tools used in this study:

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The Multi-Metric Index (MMI v4)

In 2017, the CDPHE published detailed 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 2017). These guidelines described specific protocols for the evaluation of benthic macroinvertebrate data using a Multi-Metric Index (MMI v4). This most recent version of the MMI provides a single index score based on eight equally weighted metrics. The group of metrics used in MMI v4 calculations depends on the sampling location and corresponding Biotype (Mountains, Transitional, or Plains). In the Learning By Doing study area, site FR-25.1 was located in Biotype 2 (Mountains), while all other sampling locations were located within Biotype 1 (the Transition Zone), which includes lower mountain areas in the State of Colorado. Each of the individual metrics used in the analysis produces a score that is adjusted to a scale from 1 to 100 based on the range of metric scores found at "reference sites". In Biotype 1, these metrics include: EPT Taxa, % Non-Insect Individuals, % EPT Individuals (no Baetidae), % Coleoptera Individuals, % Intolerant Taxa, % Increaser Individuals (Mid-Elevation), Clinger Taxa, and Predator/Shredder Taxa. In Biotype 2, these metrics include: EPT Taxa, % EPT Individuals (no Baetidae), Clinger Taxa, Total Taxa, Intolerant Taxa, % Increasers (Mountains), Predator Taxa, and % Scraper Individuals. A detailed description of these metrics and methods used to calculate MMI v4 scores can be found in the *Aquatic Life Use Attainment: Methodology to Determine Use Attainment for Rivers and Streams, Policy 10-1* and Appendix D in the *Section 303(d) Listing Methodology 2020 Listing Cycle* (WQCD, 2017 and 2019). Thresholds for the MMI v4 in Biotypes 1 and 2 are as follows:

Biotype	Attainment Threshold	Impairment Threshold
Transitional (Biotype 1)	45.2	33.7
Mountains (Biotype 2)	47.5	39.8

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 Biotypes 1 and 2 are listed below, followed by descriptions of each metric:

Biotype	HBI	Diversity
Transitional (Biotype 1)	5.8	2.1
Mountains (Biotype 2)	4.9	3.2

Shannon Diversity (Diversity): Diversity was used as an auxiliary metric for the MMI v4 and as an independent metric in this study to evaluate changes in macroinvertebrate community structure by providing a measure of community balance. 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 (Ward et al. 2002).

Hilsenhoff Biotic Index (HBI): The HBI is another auxiliary metric used for the MMI v4; 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 the value from this metric 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.

Additional metrics used in this study:

In addition to the MMI v4 and associated auxiliary metrics, several other individual metrics were applied in the analysis of macroinvertebrate data from sites in the Learning By Doing study area in order to provide a more thorough evaluation of macroinvertebrate community structure and function. The following section provides a description of each individual metric used in this study:

Density: Macroinvertebrate abundance (Density) was reported as the mean number of macroinvertebrates per m^2 found at each study site. The Density metric provides a means of measuring and comparing standing crop at each site. This metric can be useful when paired with other individual metrics used in this study.

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).

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 sampling location. This number will naturally vary among river systems, but it can be an excellent indicator of disturbances within a specific drainage. The EPT value is expected to decrease in response to a variety of stressors including nutrients (Wang et al. 2007).

Density of *Pteronarcys californica*: This metric measures the abundance of *Pteronarcys californica* from three replicate, quantitative samples to provide a mean number of individuals per square meter. *Pteronarycs californica* is a large species of stonefly that requires specific aquatic conditions to complete its relatively long life-cycle. Therefore, it is known to be sensitive to a variety of anthropogenic disturbances. Additionally, this species is an important part of the aquatic food-web that requires (and processes) leaf material from a healthy riparian corridor as a food source.

Percent EPT (excluding Baetidae): As previously stated, most taxa in the orders Ephemeroptera, Plecoptera, and Trichoptera are expected to be sensitive to environmental perturbations or pollution. However, members of the family Baetidae (Order: Ephemeroptera) tend to be more tolerant to disturbances than other EPT taxa. Therefore, the Percent EPT (excluding Baetidae) metric provides a measure of the percent composition of benthic macroinvertebrates (at each sampling location) that are expected to be highly sensitive to anthropogenic stressors or pollution. A decrease in this metric value suggests that the benthic macroinvertebrate community consists of a higher proportion of tolerant taxa.

Percent Chironomidae: Chironomidae taxa are considered fairly tolerant to environmental disturbances when compared to other aquatic insect families (Plafkin et al. 1989). The Percent Chironomidae metric relies on the assumption that the proportion of Chironomidae will increase with decreasing water quality. Streams that are undisturbed often have a relatively even distribution of Ephemeroptera, Plecoptera, Trichoptera, and Chironomidae (Mandaville 2002); while study sites degraded by metals or other pollutants are often dominated by the Chironomidae family (Barton and Metcalfe-Smith 1992). Most species of Chironomidae tend to have a relatively short life-cycle, which enables them to continually re-colonize unstable or polluted habitats (Lenat 1983).

Percent Hydropsychidae: The Percent Hydropsychidae metric was reported for each study site as the proportion of caddisflies that are in the family Hydropsychidae. Members of this family provide some insight into macroinvertebrate community structure and function because they are almost always collector-filterers and their large body size makes them an important food source for fish. These caddisflies are known to be moderately sensitive to a variety of stressors, particularly ammonia and fine sediment. Five taxa representing the family Hydropsychidae (*Arctopsyche grandis*, *Cheumatopsyche sp.*, *Hydropsyche sp.*, *Hydropsyche cockerelli*, and *Hydropsyche oslari*) were found in this study area during the fall of 2019.

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Percent Tolerant Taxa: Percent Tolerant Taxa is reported as the percentage of taxa that are considered tolerant to a variety of environmental disturbances and stressors. This metric measures the relative abundance of all taxa that have tolerance values of 7 or greater.

Percent Intolerant Taxa: This metric is expressed as the percentage of taxa that are expected to be sensitive to a variety of anthropogenic disturbances and environmental stressors. Intolerant taxa include all taxa with a tolerance value of 3 or lower.

Functional Feeding Groups: Most of the previously described metrics utilize 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 abundance of various groups. Some representation of each group usually indicates healthy aquatic conditions; however, it is common for certain groups (collector-gatherers) to be more abundant than others (Ward et al. 2002).

Results/Discussion

Benthic Macroinvertebrate Sampling – Fall 2019

Benthic macroinvertebrates were collected from study sites on the Fraser River, Ranch Creek, Williams Fork, and Colorado River in the fall of 2019 to evaluate aquatic conditions based on macroinvertebrate community structure and function. After samples were collected using the quantitative (Hess) sampling methodology, they were transported to the lab at Timberline Aquatics, Inc. where specimens were sorted, identified, and enumerated (Appendix A; Tables A1-A10). The previously described metrics and analysis tools (including the MMI v4) were applied to the macroinvertebrate data to provide a comprehensive assessment of macroinvertebrate community health in the study area (Tables 2-4). Results provided by select metrics (MMI v4, Diversity, HBI, EPT, % EPT no Baetidae) were also used to illustrate changes (or similarities) in community parameters among study sites (Figures 2-6). Functional Feeding Group analysis evaluated aquatic communities based on ecological function rather than taxonomic structure (Table 5, Figure 7). In general, results from the fall of 2019 demonstrated considerable variability in the structure, function, and health of benthic macroinvertebrate communities within the study area; however, results from the MMI v4 indicated that all sampling locations were in 'attainment' for aquatic life use.

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Results from the MMI v4

In the fall of 2019, a comprehensive evaluation of benthic macroinvertebrate community health was provided by the MMI v4. All samples were processed according to the guidelines provided in Appendix D of the *Section 303(d) Listing Methodology 2020 Listing Cycle* (WQCD 2019). Despite evidence of variability among individual (component) metric scores, all sites in the study area produced MMI v4 scores that were above the attainment threshold for their respective biotypes (Table 2).

Study sites on the Fraser River were distributed between two Biotypes in the State of Colorado (Biotypes 1 and 2). Site FR-25.1 was located in the mountains (Biotype 2), while the remaining two study sites were in a transitional area (based on State classifications) between the mountains and plains (Biotype 1). On the Fraser River, MMI v4 scores improved in a downstream direction, ranging from 64.5 at site FR-25.1 to 85.4 at site FR-1.9. Site FR-1.9 produced the highest MMI v4 score throughout the study area in the fall of 2019 (Table 2, Figure 2). Much of the improvement detected by the MMI v4 at site FR-1.9 appeared to be associated with an increase in the relative abundance of individuals representing sensitive taxa (EPT Taxa) and specialized taxa (Clinger Taxa). On Ranch Creek (a tributary of the Fraser River), site RC-1.1 produced an MMI v4 score of 79.9, and component metrics indicated that the benthic community was also dominated by sensitive and specialized taxa with low proportions of tolerant individuals (Table 2). Diversity and HBI values were indicative of adequate community balance with relatively low proportions of nutrient-tolerant macroinvertebrates at study sites on the Fraser River and Ranch Creek in the fall of 2019 (Figures 3 and 4).

On the Williams Fork, three study sites were sampled in the fall of 2019 to monitor the influence of Williams Fork Reservoir and recent habitat restoration work that had been conducted both upstream and downstream of this impoundment. The MMI v4 generated scores that were consistently above the attainment threshold, although scores for sites WF-2 (mod) and WF-0.5 were among the lowest in the LBD study area. The most upstream sampling location on the Williams Fork, site WF-5.5 (mod), was established above the reservoir and downstream of a recent habitat enhancement project. This site produced the second highest MMI v4 score (80.0) in study area, and the highest score among sites that were sampled on the Williams Fork. Several of the component metrics for the MMI v4 that performed well at this location included the % EPT Individuals (no Baetidae), % Non-Insect Individuals, % Increasers Mid-Elevation, and Predator/Shredder Taxa metrics (Table 2). These metrics suggested that site WF-5.5 (mod) was able to support a community with high proportions of sensitive individuals and a variety of sensitive and specialized taxa. Farther downstream, the MMI v4 generated scores slightly above the attainment threshold at sites WF-2 (mod) and WF-0.5 (Figure 2). Alterations from the natural flow and temperature regime imposed by reservoir operations were likely responsible for the decline in richness and abundance of sensitive and specialized taxa at these two sampling locations. Several components of the MMI v4 that detected these types of impacts included the EPT Taxa, % EPT Individuals (no Baetidae), Clinger Taxa, % Non-Insect Individuals, and Predator/Shredder Taxa metrics.

It should be noted that habitat restoration work occurred between sites WF-2 (mod) and WF-0.5 prior to sampling in the fall of 2019, and it is unlikely that the habitat and substrate had time to stabilize prior to macroinvertebrate sampling in the fall of 2019. Benefits from these habitat enhancement projects may not be realized until future sampling events. Continued monitoring will provide an opportunity for the long-term assessment of habitat enhancements at study sites on the Williams Fork.

The health of benthic macroinvertebrate communities was assessed using the MMI v4 at three locations on the Colorado River in a reach that spanned approximately 10 river-miles (upstream from the confluence with the Blue River). Scores generated by the MMI v4 ranged from 78.1 (at site CR-7.4) to 66.7 (at site CR-1.7) in the fall of 2019 (Table 2). All sites produced MMI v4 scores that were indicative of relatively healthy aquatic conditions; however, a slight decline in the health of the aquatic community was observed at the most downstream study site (CR-1.7), where habitat improvements had recently been completed. Several component metrics used in the MMI v4 (EPT Taxa, % EPT no Baetidae, Clinger Taxa, and % Non-Insect Individuals) generated scores that remained relatively high at all study sites on the Colorado River (Table 2). These metrics were primarily influenced by high proportions of sensitive and specialized individuals such as *Ephemerella dorothea infrequens* and *Lepidostoma* sp. (Appendix A; Tables A8-A10). Component metrics that detected a slight increase in stress at site CR-1.7 included % Intolerant Taxa and % Increasers Mid Elevation. These two metrics were generally responding to an increase in the richness of tolerant taxa at the downstream study site. A review of values produced by auxiliary metrics showed that there was also a sharp decline in community balance at site CR-1.7 (Figure 3), while the proportion of nutrient-tolerant taxa remained relatively low (Figure 4). Overall, results from the MMI v4 suggested that macroinvertebrate communities were healthy at all three study sites on the Colorado River, with a slight increase in stress at site CR-1.7 that could probably be attributed to limitations in preferred habitat.

In summary, results from the MMI v4 indicated that all sites in the study area were in attainment for aquatic life use during the fall of 2019 (Table 3). These results were generally supported by MMI v4 scores from previous sampling events in this same study area (Appendix B: Tables B1 and B2). In 2019, there was a wide range in MMI v4 scores (from 85.4 at site FR-1.9 to 46.0 at site WF-0.5), and components of the MMI v4 often responded to changes in the richness of specialized taxa and proportions of sensitive individuals (Table 2). Since the % Intolerant Taxa and % Increasers Mid Elevation metrics generated relatively high scores throughout the study area, much of the change in MMI v4 scores could probably be linked to the adequacy of aquatic habitat (including deviations from the natural temperature regime) rather than water quality. Continued biomonitoring efforts will help in the evaluation of potential anthropogenic stressors and the long-term influence of habitat restoration efforts in the Learning By Doing study area.

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Table 2. Individual metrics and MMI scores from benthic macroinvertebrate samples collected in the Learning By Doing study area during fall 2019. All metric scores based on MMI v4 subsampling process.

Metric	Station ID									
	FR-25.1	**FR-15**	**FR-1.9**	**RC-1.1**	**WF-5.5 (mod)**	**WF-2 (mod)**	**WF-0.5**	**CR-9.1**	**CR-7.4**	**CR-1.7**
EPT Taxa	73.5	66.7	100.0	87.5	83.3	41.6	35.6	93.2	100.0	85.3
% EPT, no Baetidae	45.8	45.6	78.9	83.1	81.5	15.1	17.9	68.3	72.9	80.6
Clinger Taxa	70.0	62.5	96.1	76.9	76.9	52.9	35.3	92.6	100.0	84.1
Total Taxa	71.4	--	--	--	--	--	--	--	--	--
Intolerant Taxa	81.0	--	--	--	--	--	--	--	--	--
% Increasers, Mountains	41.3	--	--	--	--	--	--	--	--	--
Predator Taxa	76.9	--	--	--	--	--	--	--	--	--
% Scraper Individuals	56.2	--	--	--	--	--	--	--	--	--
% Non-Insect Individuals	--	88.3	95.8	84.5	90.1	47.0	58.9	78.1	86.0	71.8
% Coleoptera Individuals	--	53.4	58.5	34.8	41.8	1.0	0.0	25.8	33.1	33.1
% Intolerant Taxa	--	74.9	92.4	82.0	77.7	60.7	76.0	75.1	95.2	67.8
% Increasers, Mid-Elev.	--	91.1	97.2	90.5	88.6	93.4	94.5	88.2	80.1	46.7
Predator/Shredder Taxa	--	78.6	64.3	100.0	100.0	71.4	50.0	64.3	57.1	64.3
MMI	**64.5**	**70.1**	**85.4**	**79.9**	**80.0**	**47.9**	**46.0**	**73.2**	**78.1**	**66.7**
	Auxiliary Metrics									
Diversity	4.11	3.69	4.18	4.08	3.73	3.25	2.66	4.30	4.05	2.92
HBI	3.60	3.91	2.85	3.22	3.13	3.74	4.07	3.10	3.40	3.27
Sediment Region	SR1	SR2		SR2						
TIV	4.92	5.69	--	5.20	--	--	--	--	--	--

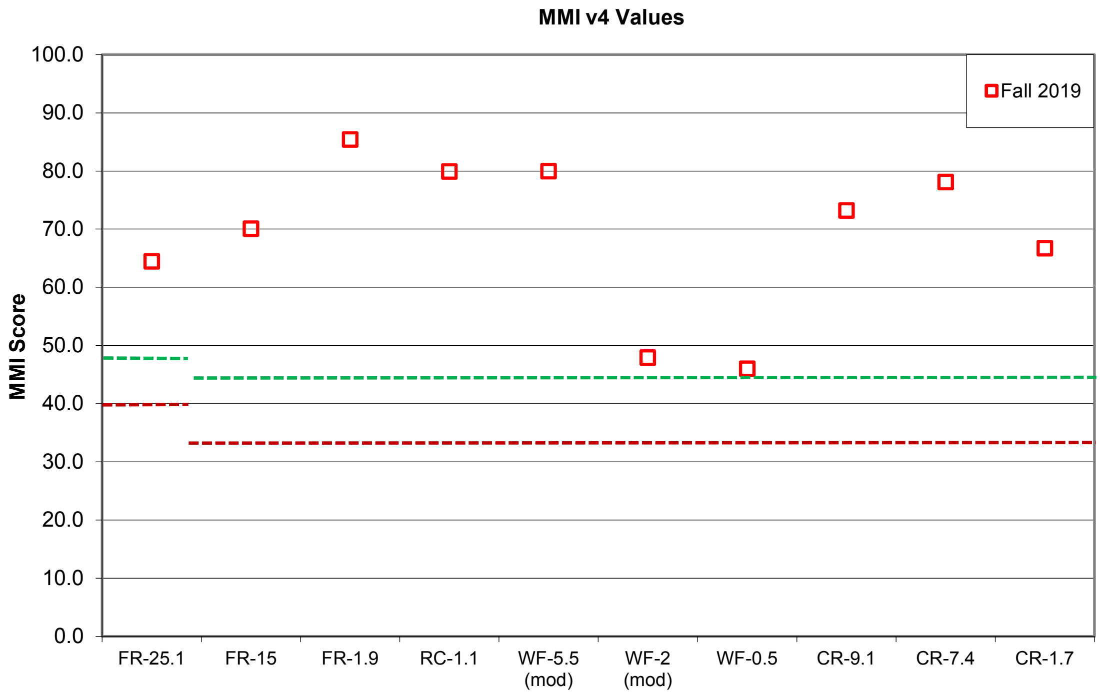

Figure 2. MMI (v4) scores from study sites in the Learning By Doing study area during fall 2019. All scores based on MMI (v4) subsampling process. The green line indicates the attainment threshold and the red line indicates the impairment threshold.

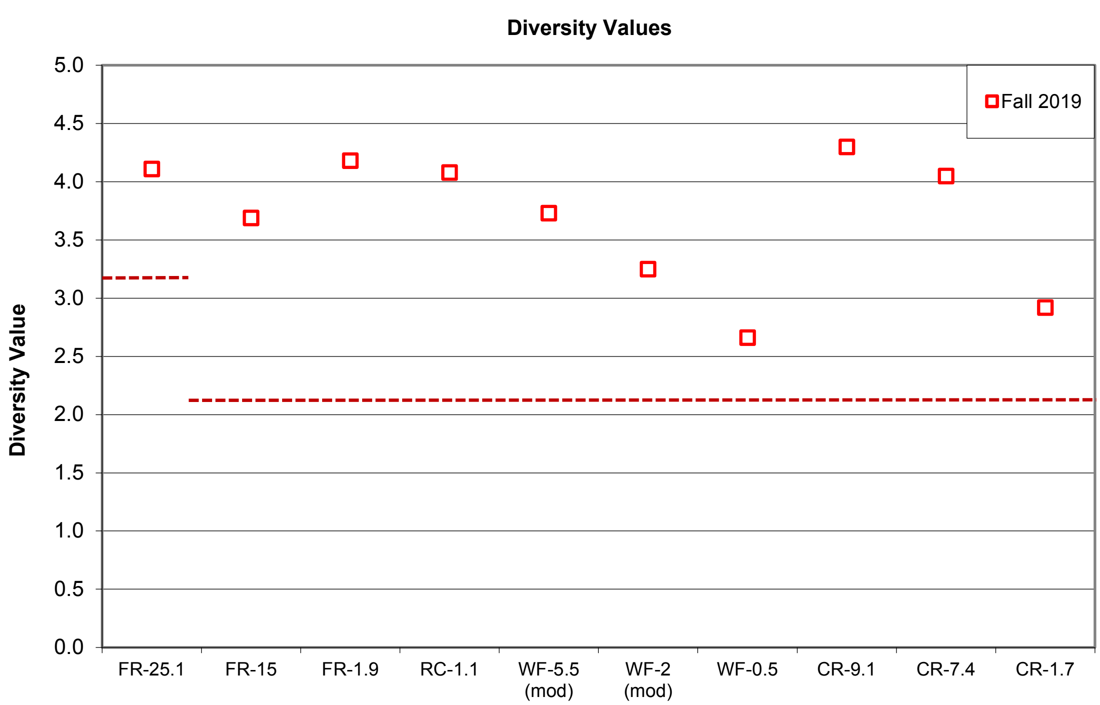

Figure 3. Diversity values from study sites in the Learning By Doing study area during fall 2019. The red line indicates the impairment threshold for Biotypes 2 and 1.

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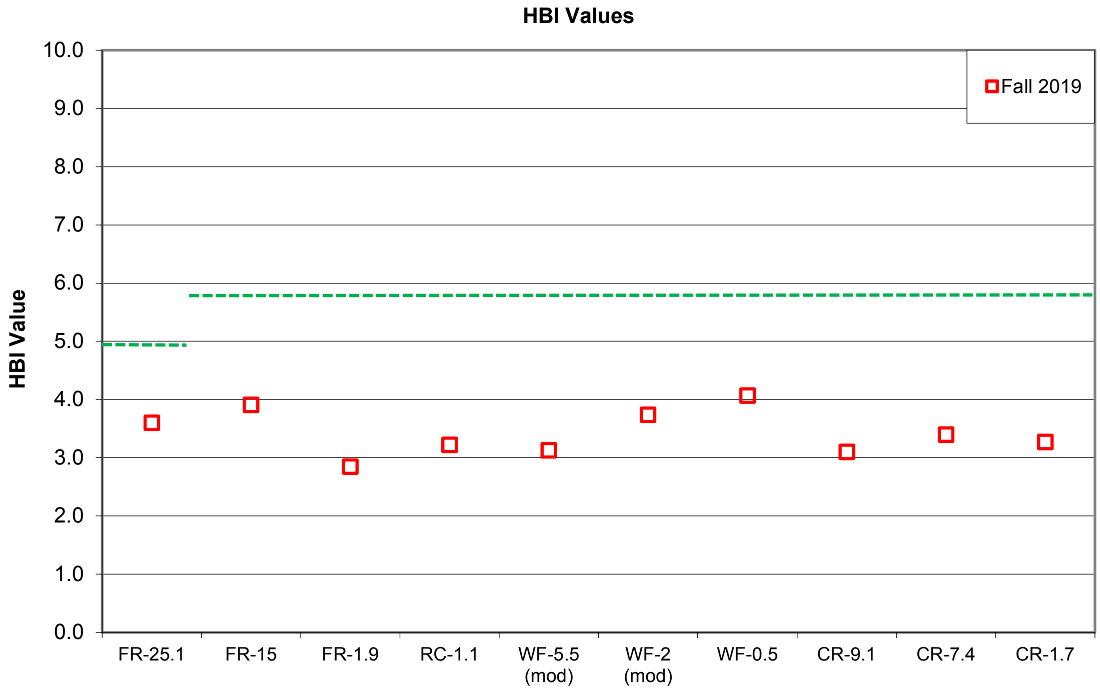

Figure 4. HBI values from study sites in the Learning By Doing study area during fall 2019. Exceeding the green line indicates impairment for Biotypes 2 and 1.

Table 3. Aquatic life designations based on MMI (v4) scores for ten sample sites in the Learning By Doing study area during fall 2019.

Aquatic Life Designations	
Site	Quantitative (Hess) Samples
FR-25.1	Attainment
FR-15	Attainment
FR-1.9	Attainment
RC-1.1	Attainment
WF-5.5(mod)	Attainment
WF-2(mod)	Attainment
WF-0.5	Attainment
CR-9.1	Attainment
CR-7.4	Attainment
CR-1.7	Attainment

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Results from Additional Metrics

In addition to the MMI v4 and associated metrics, nine individual metrics were applied to macroinvertebrate data from the Learning By Doing study area to further evaluate benthic macroinvertebrate community health during the fall of 2019 (Table 4). Although the individual metrics were able to detect changes in macroinvertebrate community structure among sites, the factors influencing these changes were not always easily identifiable. Overall, most study sites could be characterized as supporting a high proportion of sensitive taxa (when compared to tolerant taxa), while the density of benthic macroinvertebrates varied throughout the study area. The stonefly *Pteronarcys californica* was not collected at any study sites during the fall of 2019; however, a variety of other sensitive taxa were present at most sampling locations. The following comparison of individual metric values among study sites provides a more detailed description of macroinvertebrate community health during the fall of 2019.

At sampling locations on the Fraser River and Ranch Creek, the additional metrics used in this study generally supported results from the MMI v4. On the Fraser River, the EPT metric produced values that increased in a downstream direction, from 19 at site FR-25.1 to 25 at site FR-1.9; however, all of these values indicated a healthy representation of sensitive taxa (Figure 5). At site FR-1.9, the % EPT (excluding Baetidae) metric produced a value of 57.78%, suggesting that more than half of the aquatic community was sensitive to general perturbations. The Percent Hydropsychidae metric indicated that this family of net-spinning caddisflies was present at all study sites on the Fraser River and dominated (61.29%) the aquatic community at site FR-15 (Table 4). At site RC-1.1 on Ranch Creek, the Taxa Richness, % EPT (excluding Baetidae), and EPT taxa metrics generated values similar to the Fraser River sites, indicating that site RC-1.1 was able to support a variety of sensitive taxa and a high proportion of sensitive individuals.

A review of results provided by individual metrics for study sites on the Williams Fork demonstrated some of the greatest variability in the study area in 2019 (Table 4). While most metrics were indicative of a healthy macroinvertebrate community at site WF-5.5 (mod), there was evidence of increased stress downstream from Williams Fork Reservoir. At site WF-5.5 (mod), the Taxa Richness and % EPT (excluding Baetidae) metric values were among the highest in the study area, indicating that this site supported a variety of taxa with high proportions of sensitive individuals (Table 4). However, downstream of the reservoir at site WF-2 (mod), several metrics detected increased stress and the Percent EPT (excluding Baetidae) metric indicated that only 8.39% of the community was sensitive to perturbations (Table 4). Farther downstream, continued declines in the Density, Taxa Richness, EPT, and Percent Hydropsychidae values at site WF-0.5 suggested that aquatic habitat had not yet stabilized (following a habitat improvement project) and macroinvertebrates at this location continued to be influenced by the effects of the impoundment. Collectively, these results suggested that macroinvertebrate communities were relatively healthy upstream of the reservoir, but downstream study sites seemed to be influenced by the altered temperature and flow regimes caused by reservoir releases.

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Table 4. Additional metrics and comparative values for macroinvertebrate samples collected from the Learning By Doing study area in fall 2019. All additional metrics are based on full count (quantitative) Hess samples.

Metric	FR-25.1	FR-15	FR-1.9	RC-1.1	WF-5.5 (mod)	WF-2 (mod)	WF-0.5	CR-9.1	CR-7.4	CR-1.7
Density (#/m^2)	1,087	8,521	5,528	7,180	10,328	7,264	1,801	10,060	12,549	8,758
Taxa Richness	31	52	48	49	56	33	20	53	58	49
EPT Taxa	19	24	25	24	23	15	8	27	29	23
Density of *Pteronarcys californica* (#/m^2)	0	0	0	0	0	0	0	0	0	0
% EPT excluding Baetidae	36.33%	34.64%	57.78%	57.68%	57.11%	8.39%	14.90%	49.54%	53.00%	57.36%
% Chironomidae	18.71%	27.71%	7.18%	15.91%	3.46%	17.85%	6.70%	17.49%	6.47%	4.96%
% Hydropsychidae	9.52%	61.29%	21.48%	40.78%	37.60%	22.83%	3.28%	24.09%	14.98%	2.35%
% Tolerant Taxa	12.90%	17.31%	20.83%	26.53%	21.43%	18.18%	20.00%	20.75%	22.41%	30.61%
% Intolerant Taxa	54.84%	40.38%	39.58%	40.82%	39.29%	30.30%	35.00%	37.74%	37.93%	28.57%

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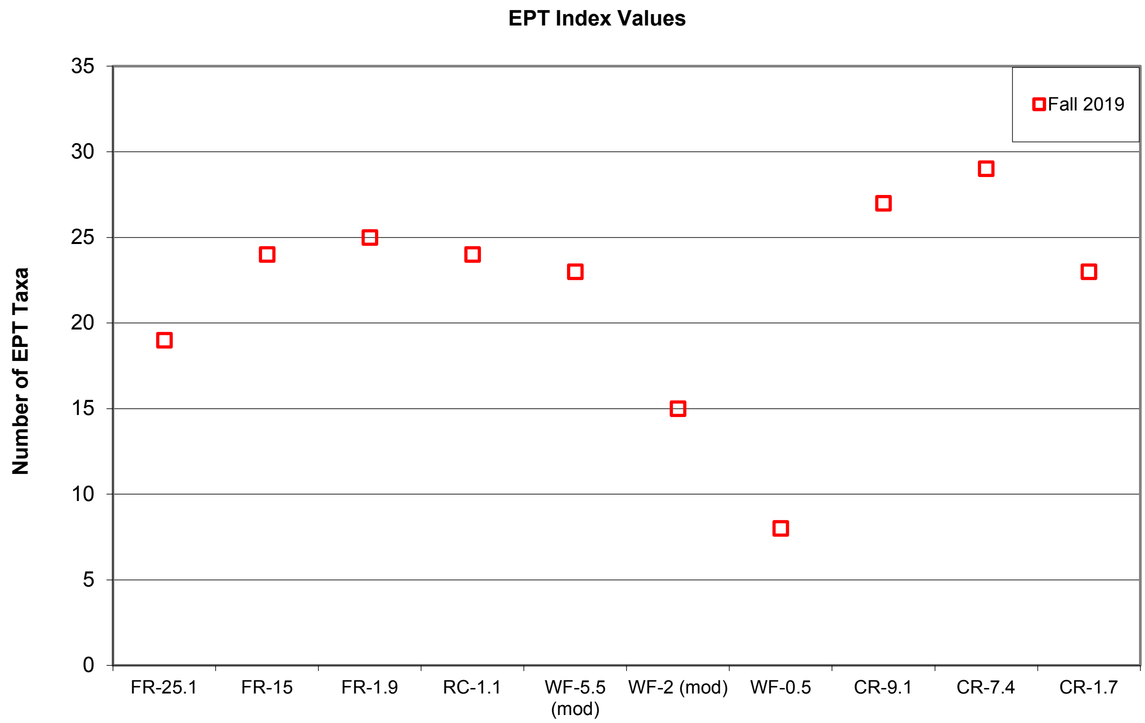

Figure 5. EPT values from study sites in the Learning By Doing study area during fall 2019.

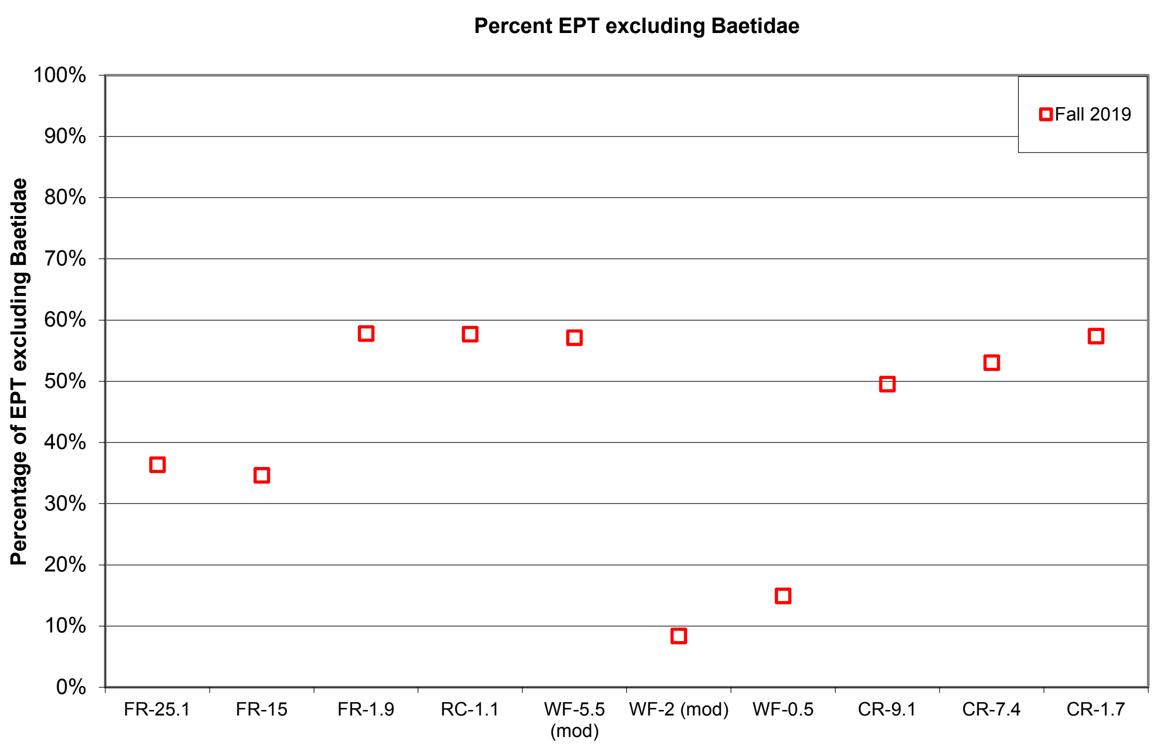

Figure 6. Percent EPT (excluding Baetidae) values from study sites in the Learning By Doing study area during fall 2019.

On the Colorado River, the additional individual metrics continued to detect healthy benthic community parameters while demonstrating some of the highest macroinvertebrate densities in the study area (Table 4). The Taxa Richness, EPT, and % EPT (excluding Baetidae) metrics all performed well relative to other sites in the study area, indicating that sampling locations on the Colorado River were able to support taxa-rich communities with high proportions of sensitive individuals. The most optimal values (in the entire study area) for the Taxa Richness and EPT metric (58 and 29, respectively) were found at site CR-7.4. The abundance (Density) of macroinvertebrates was also higher (12,549 individuals/m^2) at this site than any other sampling location (Table 4). Some of the best evidence of shifts in macroinvertebrate community structure among sites on the Colorado River was provided by the Percent Hydropsychidae metric, which declined in a downstream direction between sites CR-9.1 and CR-1.7 (Table 4). In general, most of the subtle changes in community structure in the Colorado River could probably be attributed to changes in habitat. Although the stonefly *Pteronarcys californica* was not collected during the fall of 2019, all three study sites on the Colorado River were populated with a variety of other sensitive and specialized taxa.

The reorganization of benthic macroinvertebrate taxa according to their method of food acquisition provided an opportunity to evaluate aquatic communities based on ecological function rather than taxonomic structure (Table 5, Figure 7). Healthy aquatic ecosystems typically support adequate representation from most feeding groups; however, it is common for certain groups (such as collector-gatherers) to be proportionally dominant. During the fall of 2019, all sites maintained an adequate distribution among feeding groups, without the dominance of a single trophic guild (Figure 7). While the collector-gatherer group was present at all sampling locations, the relative abundance of this group never exceeded 50.0% (Table 5). Other feeding groups that are considered sensitive and/or specialized (collector-filterers, shredders, and scrapers) were often well-represented or even dominant at certain sampling locations (Figure 7). An evaluation of the Fraser River showed that all study sites maintained good distributions among feeding groups, and although the shredder group was poorly represented upstream (sites FR-25.1 and FR-15), the scraper group maintained relatively high proportions at all sampling locations. Downstream from Williams Fork Reservoir there was a sharp decline in the most sensitive feeding groups (shredders and scrapers) at sites WF-2 (mod) and WF-0.5; however, this was expected due to potential impacts from the altered temperature and flow regime on algal communities and the absence of extensive riparian habitat (a food source for shredders) in the vicinity of the reservoir. On the Colorado River, collector-filterers decreased in a downstream direction, while shredders increased from 9.61% at site CR-9.1, to over half (50.58%) of the benthic macroinvertebrate community at site CR-1.7. This shift among feeding groups may have been caused by an increase in coarse particulate organic material (CPOM) and a decrease in fine particulate organic material (FPOM) in a downstream direction (Table 5, Figure 7). Overall, results from the functional feeding group analysis supported the results from other metrics used in this study by detecting relatively healthy aquatic communities at all study sites despite changes in community composition.

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Table 5. Relative abundance of functional feeding groups during fall 2019 sampling in the Learning By Doing study area.

Site	Functional Feeding Group					
	Collector-Gatherer	Collector-Filterer	Shredder	Scraper	Predator	Omnivore
FR-25.1	48.92%	9.35%	1.80%	18.35%	21.58%	0.00%
FR-15	39.65%	20.10%	0.46%	30.36%	8.71%	0.73%
FR-1.9	28.71%	26.74%	10.56%	28.22%	5.77%	0.00%
RC-1.1	28.68%	27.44%	20.83%	12.99%	10.06%	0.00%
WF-5.5(mod)	30.79%	35.04%	5.34%	21.17%	7.59%	0.08%
WF-2(mod)	49.71%	20.42%	1.71%	0.21%	6.31%	21.65%
WF-0.5	38.01%	30.02%	8.21%	0.00%	3.67%	20.09%
CR-9.1	32.90%	35.68%	9.61%	12.86%	4.05%	4.90%
CR-7.4	30.88%	21.66%	30.20%	14.73%	2.32%	0.22%
CR-1.7	27.35%	6.12%	50.58%	15.12%	0.80%	0.04%

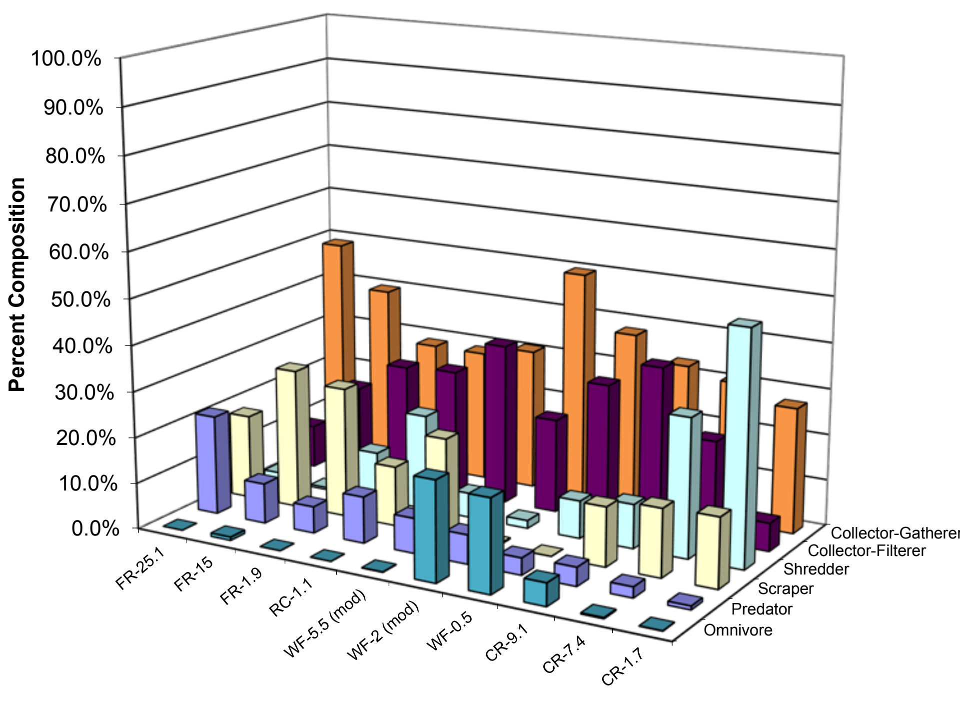

Figure 7. Functional feeding group composition for study sites in the Learning By Doing study area in fall of 2019.

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Conclusions

Overall, benthic macroinvertebrate communities demonstrated minor changes in structure and function while remaining relatively healthy throughout the Learning By Doing study area. Collectively, the MMI v4 and individual metrics indicated that most sampling locations were able to support well-balanced communities with high proportions of sensitive taxa. When the proportion of sensitive to tolerant taxa remains stable and abundance of benthic macroinvertebrates increases or decreases, the observed changes in macroinvertebrate community structure are often responses to changes in habitat adequacy rather than water quality. Functional Feeding Group analysis indicated that all sites maintained adequate ecological balance and proportions of feeding groups likely fluctuated throughout the study area due to variations in the availability of preferred habitat, food resources, competition, predation, etc.

There was some evidence of increased stress detected by the MMI v4 and several individual metrics at study sites downstream of Williams Fork Reservoir. However, the variety of analysis tools used in this study suggested that while these two study sites (WF-2 (mod) and WF-0.5) were apparently stressed, they were not considered 'impaired' for aquatic life use. Habitat restoration work that occurred prior to macroinvertebrate sampling on the Williams Fork had yet to have a discernable positive influence on the applied metrics at site WF-0.5. Future biomonitoring studies would provide an opportunity to assess any changes in influences from anthropogenic activities, and provide a continued assessment of habitat improvement projects that have occurred in this study area.

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Appendix A

Benthic Macroinvertebrate Data – Fall 2019

Table A1. Macroinvertebrate data collected from site FR-25.1 on 18 Sept. 2019.

Fraser River						
FR-25.1		Sample				
18 Sept. 2019	1	2	3		Totals	Total/m
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella sp.	8	18	9		35	136
Baetis flavistriga		1	1		2	8
Baetis (*tricaudatus*)	12	9	4		25	97
Diphetor hageni						
Attenella margarita						
Drunella coloradensis	1				1	4
Drunella doddsii			1		1	4
Drunella grandis						
Ephemerella dorothea infrequens						
Serratella tibialis						
Cinygmula sp.	1				1	4
Epeorus sp.						
Epeorus deceptivus	4	2	1		7	28
Heptagenia sp.						
Rhithrogena sp.	3		2		5	20
Tricorythodes explicatus						
Paraleptophlebia sp.						
Plecoptera (stoneflies)						
Paracapnia angulata	1				1	4
Chloroperlidae						
Sweltsa sp.	1				1	4
Zapada oregonensis group	2	1	1		4	16
Claassenia sabulosa						
Hesperoperla pacifica						
Perlodidae	12	4	5		21	82
Perlodidae (*Cultus* sp.)						
Diura knowltoni						
Isoperla sp.						
Isoperla fulva						
Megarcys signata	2	1	1		4	16
Skwala americana						
Pteronarcella badia						
Taenionema sp.	21	8	5		34	132
Trichoptera (caddisflies)						
Brachycentrus americanus						
Brachycentrus occidentalis						
Micrasema bactro						
Culoptila sp.						
Glossosoma sp.						
Protoptila sp.						
Arctopsyche grandis		1	1		2	8
Cheumatopsyche sp.						
Hydropsyche sp.						
Hydropsyche cockerelli						
Hydropsyche oslari						
Ochrotrichia sp.						
Lepidostoma sp.						
Ceraclea sp.						
Oecetis sp.						
Hesperophylax sp.						
Psychomyia flavida						
Rhyacophila brunnea		2	3		5	20
Rhyacophila coloradensis	3	2	4		9	35
Rhyacophila sibirica group			3		3	12
Oligophlebodes sp.			2		2	8

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Table A1. cont. Macroinvertebrate data collected from site FR-25.1 on 18 Sept. 2019.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola						
Cricotopus/Orthocladius sp.	6	18	2		26	101
Diamesa sp.						
Eukiefferiella sp.	1	9	8		18	70
Limnophyes sp.						
Micropsectra/Tanytarsus sp.						
Microtendipes sp.						
Pagastia sp.	1	2			3	12
Paracladopelma sp.						
Parametriocnemus sp.						
Polypedilum sp.						
Potthastia sp.						
Rheotanytarsus sp.						
Synorthocladius sp.	1	1			2	8
Thienemanniella sp.						
Thienemannimyia group						
Tvetenia sp.	2		1		3	12
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae	3	4			7	28
Chelifera/Neoplasta sp.						
Wiedemannia sp.						
Lispoides aequifrons						
Pericoma sp.						
Simulium sp.	8	1	15		24	93
Antocha sp.						
Dicranota sp.						
Hexatoma sp.						
Tipula sp.						
Coleoptera (beetles)						
Oreodytes sp.						
Heterlimnius sp.	10	3	8		21	82
Optioservus sp.						
Zaitzevia parvula						
Miscellaneous						
Atractides sp.						
Hygrobates sp.						
Lebertia sp.			1		1	4
Protzia sp.						
Sperchon sp.		1			1	4
Torrenticola sp.						
Pisidium sp.						
Caecidotea sp.						
Ferrissia sp.						
Lymnaeidae						
Physa sp.						
Gyraulus sp.						
Polycelis coronata						
Crangonyx sp.						
Erpobdellidae						
Enchytraeidae						
Lumbricidae						
Naididae			1		1	4
Nematoda		8			8	31
Totals	**103**	**96**	**79**		**278**	**1087**

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Table A2. Macroinvertebrate data collected from site FR-15 on 18 Sept. 2019.

Fraser River						
FR-15		Sample				
18 Sept. 2019	1	2	3		Totals	Total/m
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella sp.	3	2			5	20
Baetis flavistriga						
Baetis (*tricaudatus*)	73	49	75		197	764
Diphetor hageni						
Attenella margarita						
Drunella coloradensis						
Drunella doddsii						
Drunella grandis	4	5	17		26	101
Ephemerella dorothea infrequens	20	10	18		48	186
Serratella tibialis		1	2		3	12
Cinygmula sp.			1		1	4
Epeorus sp.		1			1	4
Epeorus deceptivus						
Heptagenia sp.						
Rhithrogena sp.						
Tricorythodes explicatus		1			1	4
Paraleptophlebia sp.	4	2	3		9	35
Plecoptera (stoneflies)						
Paracapnia angulata	4		1		5	20
Chloroperlidae		2	2		4	16
Sweltsa sp.	5				5	20
Zapada oregonensis group			1		1	4
Claassenia sabulosa						
Hesperoperla pacifica						
Perlodidae						
Perlodidae (*Cultus* sp.)	1				1	4
Diura knowltoni						
Isoperla sp.						
Isoperla fulva	12	3	3		18	70
Megarcys signata						
Skwala americana	4	3	10		17	66
Pteronarcella badia						
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	6	3	9		18	70
Brachycentrus occidentalis		3	2		5	20
Micrasema bactro						
Culoptila sp.						
Glossosoma sp.	13	46	136		195	756
Protoptila sp.						
Arctopsyche grandis	13	6	12		31	121
Cheumatopsyche sp.						
Hydropsyche sp.						
Hydropsyche cockerelli	127	45	175		347	1345
Hydropsyche oslari		2			2	8
Ochrotrichia sp.		5	15		20	78
Lepidostoma sp.			2		2	8
Ceraclea sp.						
Oecetis sp.						
Hesperophylax sp.						
Psychomyia flavida						
Rhyacophila brunnea						
Rhyacophila coloradensis						
Rhyacophila sibirica group						
Oligophlebodes sp.						

Table A2. cont. Macroinvertebrate data collected from site FR-15 on 18 Sept. 2019.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.	20	6	6		32	124
Cricotopus nostocicola						
Cricotopus/Orthocladius sp.	147	73	190		410	1590
Diamesa sp.						
Eukiefferiella sp.	33	17	44		94	365
Limnophyes sp.						
Micropsectra/Tanytarsus sp.	3	1	4		8	31
Microtendipes sp.		1	1		2	8
Pagastia sp.	6	5	17		28	109
Paracladopelma sp.						
Parametriocnemus sp.	2	1			3	12
Polypedilum sp.						
Potthastia sp.	1	2	1		4	16
Rheotanytarsus sp.		1			1	4
Synorthocladius sp.	1	1			2	8
Thienemanniella sp.						
Thienemannimyia group			2		2	8
Tvetenia sp.	10	3	9		22	86
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae						
Chelifera/Neoplasta sp.	1	5	3		9	35
Wiedemannia sp.						
Lispoides aequifrons						
Pericoma sp.						
Simulium sp.	10	11	14		35	136
Antocha sp.						
Dicranota sp.	1	1			2	8
Hexatoma sp.		1			1	4
Tipula sp.			2		2	8
Coleoptera (beetles)						
Oreodytes sp.						
Heterlimnius sp.	3				3	12
Optioservus sp.	114	130	199		443	1718
Zaitzevia parvula						
Miscellaneous						
Atractides sp.	1		1		2	8
Hygrobates sp.			1		1	4
Lebertia sp.	7	14	12		33	128
Protzia sp.						
Sperchon sp.	11	17	23		51	198
Torrenticola sp.						
Pisidium sp.						
Caecidotea sp.						
Ferrissia sp.						
Lymnaeidae						
Physa sp.						
Gyraulus sp.						
Polycelis coronata	7	4	5		16	62
Crangonyx sp.						
Erpobdellidae						
Enchytraeidae		1	1		2	8
Lumbricidae	2	4			6	24
Naididae	3	2			5	20
Nematoda		12	1		13	51
Totals	**672**	**502**	**1020**		**2194**	**8521**

Table A3. Macroinvertebrate data collected from site FR-1.9 on 18 Sept. 2019.

Fraser River						
FR-1.9		Sample				
18 Sept. 2019	1	2	3		Totals	Total/m
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella sp.	3	6	9		18	70
Baetis flavistriga						
Baetis (*tricaudatus*)	35	36	63		134	520
Diphetor hageni			1		1	4
Attenella margarita						
Drunella coloradensis						
Drunella doddsii						
Drunella grandis	2	2	3		7	28
Ephemerella dorothea infrequens	9	22	24		55	214
Serratella tibialis						
Cinygmula sp.						
Epeorus sp.	9	10	19		38	148
Epeorus deceptivus						
Heptagenia sp.						
Rhithrogena sp.						
Tricorythodes explicatus		1			1	4
Paraleptophlebia sp.	17	5	26		48	186
Plecoptera (stoneflies)						
Paracapnia angulata	1		4		5	20
Chloroperlidae						
Sweltsa sp.	16		6		22	86
Zapada oregonensis group						
Claassenia sabulosa	1	2	1		4	16
Hesperoperla pacifica						
Perlodidae						
Perlodidae (*Cultus* sp.)	6	2	13		21	82
Diura knowltoni						
Isoperla sp.						
Isoperla fulva	1		6		7	28
Megarcys signata						
Skwala americana		1	2		3	12
Pteronarcella badia						
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	74	71	95		240	931
Brachycentrus occidentalis		2			2	8
Micrasema bactro						
Culoptila sp.	4	8	9		21	82
Glossosoma sp.	16	35	22		73	283
Protoptila sp.	6	4	12		22	86
Arctopsyche grandis		3	1		4	16
Cheumatopsyche sp.		9	5		14	55
Hydropsyche sp.						
Hydropsyche cockerelli	16	5	12		33	128
Hydropsyche oslari	3	36	41		80	311
Ochrotrichia sp.						
Lepidostoma sp.	48	27	44		119	462
Ceraclea sp.						
Oecetis sp.						
Hesperophylax sp.						
Psychomyia flavida	1		1		2	8
Rhyacophila brunnea						
Rhyacophila coloradensis						
Rhyacophila sibirica group						
Oligophlebodes sp.						

Table A3. cont. Macroinvertebrate data collected from site FR-1.9 on 18 Sept. 2019.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.			1		1	4
Cricotopus nostocicola	11	5	8		24	93
Cricotopus/Orthocladius sp.	5	4	1		10	39
Diamesa sp.	1				1	4
Eukiefferiella sp.	7	7	7		21	82
Limnophyes sp.						
Micropsectra/Tanytarsus sp.	1		4		5	20
Microtendipes sp.						
Pagastia sp.	3	6	6		15	59
Paracladopelma sp.			1		1	4
Parametriocnemus sp.						
Polypedilum sp.	1	1			2	8
Potthastia sp.						
Rheotanytarsus sp.						
Synorthocladius sp.						
Thienemanniella sp.						
Thienemannimyia group						
Tvetenia sp.	6	8	8		22	86
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae						
Chelifera/Neoplasta sp.	1		2		3	12
Wiedemannia sp.						
Lispoides aequifrons						
Pericoma sp.						
Simulium sp.	1	1	3		5	20
Antocha sp.						
Dicranota sp.						
Hexatoma sp.	3	1	4		8	31
Tipula sp.						
Coleoptera (beetles)						
Oreodytes sp.						
Heterlimnius sp.	2				2	8
Optioservus sp.	81	44	109		234	907
Zaitzevia parvula	24	12	29		65	252
Miscellaneous						
Atractides sp.						
Hygrobates sp.						
Lebertia sp.						
Protzia sp.			1		1	4
Sperchon sp.	3	1	8		12	47
Torrenticola sp.						
Pisidium sp.	1		1		2	8
Caecidotea sp.						
Ferrissia sp.						
Lymnaeidae						
Physa sp.	3	1	2		6	24
Gyraulus sp.						
Polycelis coronata						
Crangonyx sp.						
Erpobdellidae						
Enchytraeidae	3				3	12
Lumbricidae	3				3	12
Naididae	1				1	4
Nematoda						
Totals	**429**	**378**	**614**		**1421**	**5528**

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Table A4. Macroinvertebrate data collected from site RC-1.1 on 18 Sept. 2019.

Ranch Creek						
RC-1.1		Sample				
18 Sept. 2019	1	2	3		Totals	Total/m
Ephemeroptera (mayflies)						
Ameletus sp.			1		1	4
Acentrella sp.						
Baetis flavistriga						
Baetis (*tricaudatus*)	8	42	17		67	260
Diphetor hageni						
Attenella margarita						
Drunella coloradensis						
Drunella doddsii						
Drunella grandis	7	30	10		47	183
Ephemerella dorothea infrequens	45	107	40		192	745
Serratella tibialis						
Cinygmula sp.	1		2		3	12
Epeorus sp.	1	1	6		8	31
Epeorus deceptivus						
Heptagenia sp.						
Rhithrogena sp.						
Tricorythodes explicatus			1		1	4
Paraleptophlebia sp.	14	9	31		54	210
Plecoptera (stoneflies)						
Paracapnia angulata	3	1	5		9	35
Chloroperlidae						
Sweltsa sp.	3	4	2		9	35
Zapada oregonensis group						
Claassenia sabulosa	1		1		2	8
Hesperoperla pacifica						
Perlodidae						
Perlodidae (*Cultus* sp.)						
Diura knowltoni						
Isoperla sp.						
Isoperla fulva	4	8	2		14	55
Megarcys signata						
Skwala americana	4	3	1		8	31
Pteronarcella badia		2			2	8
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	60	91	57		208	807
Brachycentrus occidentalis						
Micrasema bactro		1	1		2	8
Culoptila sp.						
Glossosoma sp.		2			2	8
Protoptila sp.						
Arctopsyche grandis	1	2	2		5	20
Cheumatopsyche sp.						
Hydropsyche sp.						
Hydropsyche cockerelli	4	6			10	39
Hydropsyche oslari	54	165	58		277	1074
Ochrotrichia sp.	1				1	4
Lepidostoma sp.	67	21	118		206	799
Ceraclea sp.						
Oecetis sp.			2		2	8
Hesperophylax sp.						
Psychomyia flavida						
Rhyacophila brunnea						
Rhyacophila coloradensis		2	1		3	12
Rhyacophila sibirica group						
Oligophlebodes sp.						

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Table A4. cont. Macroinvertebrate data collected from site RC-1.1 on 18 Sept. 2019.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola	66	52	48		166	644
Cricotopus/Orthocladius sp.	3	12	2		17	66
Diamesa sp.						
Eukiefferiella sp.	9	27	7		43	167
Limnophyes sp.						
Micropsectra/Tanytarsus sp.		2			2	8
Microtendipes sp.						
Pagastia sp.	2	17	1		20	78
Paracladopelma sp.						
Parametriocnemus sp.						
Polypedilum sp.						
Potthastia sp.						
Rheotanytarsus sp.	1		1		2	8
Synorthocladius sp.						
Thienemanniella sp.						
Thienemannimyia group						
Tvetenia sp.	4	38	2		44	171
Other Diptera (true flies)						
Atherix pachypus		2			2	8
Ceratopogoninae			2		2	8
Chelifera/Neoplasta sp.	1				1	4
Wiedemannia sp.						
Lispoides aequifrons						
Pericoma sp.	1	2	2		5	20
Simulium sp.		4	1		5	20
Antocha sp.	1	2	1		4	16
Dicranota sp.						
Hexatoma sp.			1		1	4
Tipula sp.						
Coleoptera (beetles)						
Oreodytes sp.						
Heterlimnius sp.						
Optioservus sp.	56	66	54		176	683
Zaitzevia parvula	31	26	19		76	295
Miscellaneous						
Atractides sp.						
Hygrobates sp.			3		3	12
Lebertia sp.	6	18	8		32	124
Protzia sp.	13	11	20		44	171
Sperchon sp.	23	26	13		62	241
Torrenticola sp.			1		1	4
Pisidium sp.						
Caecidotea sp.						
Ferrissia sp.						
Lymnaeidae			1		1	4
Physa sp.			1		1	4
Gyraulus sp.			2		2	8
Polycelis coronata						
Crangonyx sp.						
Erpobdellidae						
Enchytraeidae						
Lumbricidae		3			3	12
Naididae						
Nematoda						
Totals	**495**	**805**	**548**		**1848**	**7180**

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Table A5. Macroinvertebrate data collected from site WF-5.5(mod) on 26 Oct 2019.

Williams Fork						
WF-5.5(mod)		Sample				
26 Oct. 2019	1	2	3		Totals	Total/m
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella sp.						
Baetis flavistriga						
Baetis (*tricaudatus*)	106	242	18		366	1419
Diphetor hageni	1	3	3		7	28
Attenella margarita						
Drunella coloradensis						
Drunella doddsii	2				2	8
Drunella grandis	17	13	11		41	159
Ephemerella dorothea infrequens	87	129	55		271	1051
Serratella tibialis						
Cinygmula sp.	5	5	7		17	66
Epeorus sp.	2		1		3	12
Epeorus deceptivus						
Heptagenia sp.						
Rhithrogena sp.						
Tricorythodes explicatus						
Paraleptophlebia sp.	29	26	24		79	307
Plecoptera (stoneflies)						
Paracapnia angulata		1	1		2	8
Chloroperlidae						
Sweltsa sp.	2				2	8
Zapada oregonensis group						
Claassenia sabulosa		1	1		2	8
Hesperoperla pacifica	3				3	12
Perlodidae						
Perlodidae (*Cultus* sp.)	4	1	3		8	31
Diura knowltoni	1				1	4
Isoperla sp.						
Isoperla fulva	2				2	8
Megarcys signata						
Skwala americana						
Pteronarcella badia		1			1	4
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	164	254	94		512	1985
Brachycentrus occidentalis						
Micrasema bactro						
Culoptila sp.						
Glossosoma sp.						
Protoptila sp.						
Arctopsyche grandis	4	12	3		19	74
Cheumatopsyche sp.						
Hydropsyche sp.						
Hydropsyche cockerelli						
Hydropsyche oslari	132	217	40		389	1508
Ochrotrichia sp.						
Lepidostoma sp.	31	58	46		135	524
Ceraclea sp.						
Oecetis sp.						
Hesperophylax sp.		2			2	8
Psychomyia flavida						
Rhyacophila brunnea	10	9	8		27	105
Rhyacophila coloradensis			1		1	4
Rhyacophila sibirica group						
Oligophlebodes sp.						

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Table A5. cont. Macroinvertebrate data collected from site WF-5.5(mod) on 26 Oct 2019.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola						
Cricotopus/Orthocladius sp.		3	1		4	16
Diamesa sp.		2			2	8
Eukiefferiella sp.	4	21			25	97
Limnophyes sp.	1				1	4
Micropsectra/Tanytarsus sp.		1			1	4
Microtendipes sp.						
Pagastia sp.	1	2	1		4	16
Paracladopelma sp.						
Parametriocnemus sp.						
Polypedilum sp.		1			1	4
Potthastia sp.		4	1		5	20
Rheotanytarsus sp.		1			1	4
Synorthocladius sp.						
Thienemanniella sp.						
Thienemannimyia group	7	17	9		33	128
Tvetenia sp.	4	11			15	59
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae						
Chelifera/Neoplasta sp.	2	7	4		13	51
Wiedemannia sp.			1		1	4
Lispoides aequifrons						
Pericoma sp.	7	7	4		18	70
Simulium sp.	3	5	3		11	43
Antocha sp.		2			2	8
Dicranota sp.			1		1	4
Hexatoma sp.		4	4		8	31
Tipula sp.			1		1	4
Coleoptera (beetles)						
Oreodytes sp.						
Heterlimnius sp.	2	1	1		4	16
Optioservus sp.	131	276	87		494	1915
Zaitzevia parvula	2	4			6	24
Miscellaneous						
Atractides sp.						
Hygrobates sp.	3	3	2		8	31
Lebertia sp.	6	20	21		47	183
Protzia sp.	2	2	3		7	28
Sperchon sp.	13	10	13		36	140
Torrenticola sp.	1		1		2	8
Pisidium sp.						
Caecidotea sp.	1	5	2		8	31
Ferrissia sp.						
Lymnaeidae						
Physa sp.			3		3	12
Gyraulus sp.		2			2	8
Polycelis coronata			2		2	8
Crangonyx sp.						
Erpobdellidae						
Enchytraeidae						
Lumbricidae						
Naididae	1				1	4
Nematoda		1			1	4
Totals	**793**	**1386**	**481**		**2660**	**10328**

Table A6. Macroinvertebrate data collected from site WF-2(mod) on 26 Oct 2019.

Williams Fork						
WF-2(mod)		Sample				
26 Oct. 2019	1	2	3		Totals	Total/m
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella sp.						
Baetis flavistriga						
Baetis (*tricaudatus*)	217	117	200		534	2070
Diphetor hageni		1			1	4
Attenella margarita						
Drunella coloradensis						
Drunella doddsii						
Drunella grandis						
Ephemerella dorothea infrequens	22	12	11		45	175
Serratella tibialis						
Cinygmula sp.						
Epeorus sp.						
Epeorus deceptivus						
Heptagenia sp.						
Rhithrogena sp.						
Tricorythodes explicatus		1	1		2	8
Paraleptophlebia sp.			1		1	4
Plecoptera (stoneflies)						
Paracapnia angulata						
Chloroperlidae						
Sweltsa sp.						
Zapada oregonensis group						
Claassenia sabulosa						
Hesperoperla pacifica						
Perlodidae						
Perlodidae (*Cultus* sp.)						
Diura knowltoni						
Isoperla sp.						
Isoperla fulva	8	5	4		17	66
Megarcys signata						
Skwala americana						
Pteronarcella badia						
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	5	6	4		15	59
Brachycentrus occidentalis						
Micrasema bactro						
Culoptila sp.						
Glossosoma sp.						
Protoptila sp.						
Arctopsyche grandis	11	2	5		18	70
Cheumatopsyche sp.	1		1		2	8
Hydropsyche sp.						
Hydropsyche cockerelli						
Hydropsyche oslari			1		1	4
Ochrotrichia sp.			1		1	4
Lepidostoma sp.	9	17	5		31	121
Ceraclea sp.						
Oecetis sp.						
Hesperophylax sp.		1			1	4
Psychomyia flavida						
Rhyacophila brunnea	5	1	12		18	70
Rhyacophila coloradensis	3	1	1		5	20
Rhyacophila sibirica group						
Oligophlebodes sp.						

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Table A6. cont. Macroinvertebrate data collected from site WF-2(mod) on 26 Oct 2019.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola						
Cricotopus/Orthocladius sp.	60	47	48		155	601
Diamesa sp.						
Eukiefferiella sp.	11	7	11		29	113
Limnophyes sp.						
Micropsectra/Tanytarsus sp.	4	4	2		10	39
Microtendipes sp.						
Pagastia sp.	65	28	38		131	508
Paracladopelma sp.						
Parametriocnemus sp.		1			1	4
Polypedilum sp.						
Potthastia sp.	3	1	1		5	20
Rheotanytarsus sp.						
Synorthocladius sp.						
Thienemanniella sp.						
Thienemannimyia group						
Tvetenia sp.	2	1			3	12
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae						
Chelifera/Neoplasta sp.						
Wiedemannia sp.	1				1	4
Lispoides aequifrons		1	1		2	8
Pericoma sp.						
Simulium sp.	197	21	128		346	1342
Antocha sp.	1		5		6	24
Dicranota sp.						
Hexatoma sp.						
Tipula sp.						
Coleoptera (beetles)						
Oreodytes sp.						
Heterlimnius sp.						
Optioservus sp.		1	3		4	16
Zaitzevia parvula						
Miscellaneous						
Atractides sp.						
Hygrobates sp.						
Lebertia sp.	2	8			10	39
Protzia sp.						
Sperchon sp.	9	26	7		42	163
Torrenticola sp.						
Pisidium sp.						
Caecidotea sp.						
Ferrissia sp.						
Lymnaeidae						
Physa sp.						
Gyraulus sp.						
Polycelis coronata	66	221	118		405	1570
Crangonyx sp.						
Erpobdellidae						
Enchytraeidae	1		1		2	8
Lumbricidae						
Naididae	1		3		4	16
Nematoda	5	5	13		23	90
Totals	**709**	**536**	**626**		**1871**	**7264**

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Table A7. Macroinvertebrate data collected from site WF-0.5 on 26 Oct 2019.

Williams Fork						
WF-0.5		Sample				
26 Oct. 2019	1	2	3		Totals	Total/m
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella sp.						
Baetis flavistriga						
Baetis (*tricaudatus*)	22	15	103		140	543
Diphetor hageni						
Attenella margarita						
Drunella coloradensis						
Drunella doddsii						
Drunella grandis						
Ephemerella dorothea infrequens	1		2		3	12
Serratella tibialis						
Cinygmula sp.						
Epeorus sp.						
Epeorus deceptivus						
Heptagenia sp.						
Rhithrogena sp.						
Tricorythodes explicatus						
Paraleptophlebia sp.						
Plecoptera (stoneflies)						
Paracapnia angulata						
Chloroperlidae						
Sweltsa sp.						
Zapada oregonensis group						
Claassenia sabulosa						
Hesperoperla pacifica						
Perlodidae						
Perlodidae (*Cultus* sp.)						
Diura knowltoni						
Isoperla sp.						
Isoperla fulva			5		5	20
Megarcys signata						
Skwala americana						
Pteronarcella badia						
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	2	2	9		13	51
Brachycentrus occidentalis						
Micrasema bactro						
Culoptila sp.						
Glossosoma sp.						
Protoptila sp.						
Arctopsyche grandis						
Cheumatopsyche sp.						
Hydropsyche sp.						
Hydropsyche cockerelli						
Hydropsyche oslari	1		1		2	8
Ochrotrichia sp.						
Lepidostoma sp.	2		35		37	144
Ceraclea sp.						
Oecetis sp.						
Hesperophylax sp.						
Psychomyia flavida						
Rhyacophila brunnea		1	7		8	31
Rhyacophila coloradensis	1				1	4
Rhyacophila sibirica group						
Oligophlebodes sp.						

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Table A7. cont. Macroinvertebrate data collected from site WF-0.5 on 26 Oct 2019.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola						
Cricotopus/Orthocladius sp.	3	2	12		17	66
Diamesa sp.						
Eukiefferiella sp.	3	1	2		6	24
Limnophyes sp.						
Micropsectra/Tanytarsus sp.		1			1	4
Microtendipes sp.						
Pagastia sp.	2		2		4	16
Paracladopelma sp.						
Parametriocnemus sp.						
Polypedilum sp.						
Potthastia sp.			1		1	4
Rheotanytarsus sp.						
Synorthocladius sp.						
Thienemanniella sp.						
Thienemannimyia group						
Tvetenia sp.		1	1		2	8
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae						
Chelifera/Neoplasta sp.						
Wiedemannia sp.						
Lispoides aequifrons						
Pericoma sp.						
Simulium sp.	8	14	102		124	481
Antocha sp.						
Dicranota sp.						
Hexatoma sp.						
Tipula sp.		1			1	4
Coleoptera (beetles)						
Oreodytes sp.						
Heterlimnius sp.						
Optioservus sp.						
Zaitzevia parvula						
Miscellaneous						
Atractides sp.						
Hygrobates sp.						
Lebertia sp.			3		3	12
Protzia sp.						
Sperchon sp.						
Torrenticola sp.						
Pisidium sp.						
Caecidotea sp.						
Ferrissia sp.						
Lymnaeidae						
Physa sp.						
Gyraulus sp.						
Polycelis coronata	2	11	80		93	361
Crangonyx sp.		1			1	4
Erpobdellidae						
Enchytraeidae		1			1	4
Lumbricidae						
Naididae						
Nematoda						
Totals	**47**	**51**	**365**		**463**	**1801**

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Table A8. Macroinvertebrate data collected from site CR-9.1 on 18 Sept. 2019.

Colorado River						
CR-9.1		Sample				
18 Sept. 2019	1	2	3		Totals	Total/m
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella sp.	2	1	1		4	16
Baetis flavistriga						
Baetis (*tricaudatus*)	59	68	83		210	814
Diphetor hageni						
Attenella margarita						
Drunella coloradensis						
Drunella doddsii						
Drunella grandis	1	5	5		11	43
Ephemerella dorothea infrequens	20	35	49		104	404
Serratella tibialis		1			1	4
Cinygmula sp.						
Epeorus sp.	5		3		8	31
Epeorus deceptivus						
Heptagenia sp.						
Rhithrogena sp.	3	2	2		7	28
Tricorythodes explicatus	7	10	2		19	74
Paraleptophlebia sp.	7		4		11	43
Plecoptera (stoneflies)						
Paracapnia angulata						
Chloroperlidae						
Sweltsa sp.	1		4		5	20
Zapada oregonensis group						
Claassenia sabulosa	3	12	7		22	86
Hesperoperla pacifica						
Perlodidae						
Perlodidae (*Cultus* sp.)	9	8	25		42	163
Diura knowltoni						
Isoperla sp.	1		1		2	8
Isoperla fulva		2			2	8
Megarcys signata						
Skwala americana			1		1	4
Pteronarcella badia	1	1			2	8
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	199	143	163		505	1958
Brachycentrus occidentalis						
Micrasema bactro						
Culoptila sp.						
Glossosoma sp.	29	5	18		52	202
Protoptila sp.	20	2	11		33	128
Arctopsyche grandis	1		1		2	8
Cheumatopsyche sp.	3	3			6	24
Hydropsyche sp.	27	32	11		70	272
Hydropsyche cockerelli	15	15	14		44	171
Hydropsyche oslari	40	56	34		130	504
Ochrotrichia sp.			1		1	4
Lepidostoma sp.	135	43	23		201	780
Ceraclea sp.			2		2	8
Oecetis sp.						
Hesperophylax sp.						
Psychomyia flavida						
Rhyacophila brunnea						
Rhyacophila coloradensis						
Rhyacophila sibirica group						
Oligophlebodes sp.						

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Table A8. cont. Macroinvertebrate data collected from site CR-9.1 on 18 Sept. 2019.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.		9			9	35
Cricotopus nostocicola	9	22	11		42	163
Cricotopus/Orthocladius sp.	2	8	14		24	93
Diamesa sp.						
Eukiefferiella sp.	39	78	49		166	644
Limnophyes sp.						
Micropsectra/Tanytarsus sp.	2	1			3	12
Microtendipes sp.						
Pagastia sp.	49	49	68		166	644
Paracladopelma sp.						
Parametriocnemus sp.		2			2	8
Polypedilum sp.		4			4	16
Potthastia sp.						
Rheotanytarsus sp.						
Synorthocladius sp.						
Thienemanniella sp.		1			1	4
Thienemannimyia group			1		1	4
Tvetenia sp.	17	17	1		35	136
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae						
Chelifera/Neoplasta sp.	2	4	1		7	28
Wiedemannia sp.						
Lispoides aequifrons						
Pericoma sp.						
Simulium sp.	27	103	34		164	636
Antocha sp.	1		2		3	12
Dicranota sp.						
Hexatoma sp.						
Tipula sp.						
Coleoptera (beetles)						
Oreodytes sp.						
Heterlimnius sp.						
Optioservus sp.	63	74	72		209	811
Zaitzevia parvula	16	16	14		46	179
Miscellaneous						
Atractides sp.						
Hygrobates sp.						
Lebertia sp.						
Protzia sp.		1			1	4
Sperchon sp.	2	3	6		11	43
Torrenticola sp.						
Pisidium sp.	1	2			3	12
Caecidotea sp.	12	17	4		33	128
Ferrissia sp.						
Lymnaeidae						
Physa sp.	10	2			12	47
Gyraulus sp.		1			1	4
Polycelis coronata	39	44	44		127	493
Crangonyx sp.						
Erpobdellidae						
Enchytraeidae			6		6	24
Lumbricidae		8	7		15	59
Naididae						
Nematoda		1	1		2	8
Totals	**879**	**911**	**800**		**2590**	**10060**

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Table A9. Macroinvertebrate data collected from site CR-7.4 on 18 Sept. 2019.

Colorado River						
CR-7.4		Sample				
18 Sept. 2019	1	2	3		Totals	Total/m
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella sp.	11	14	25		50	194
Baetis flavistriga						
Baetis (*tricaudatus*)	172	77	132		381	1477
Diphetor hageni		2	3		5	20
Attenella margarita	1	2			3	12
Drunella coloradensis						
Drunella doddsii						
Drunella grandis			2		2	8
Ephemerella dorothea infrequens	35	9	22		66	256
Serratella tibialis						
Cinygmula sp.						
Epeorus sp.	2	6	14		22	86
Epeorus deceptivus						
Heptagenia sp.						
Rhithrogena sp.	6	2	6		14	55
Tricorythodes explicatus	37	12	28		77	299
Paraleptophlebia sp.	33	11	8		52	202
Plecoptera (stoneflies)						
Paracapnia angulata	1		1		2	8
Chloroperlidae						
Sweltsa sp.	6	4	1		11	43
Zapada oregonensis group						
Claassenia sabulosa	6	5	1		12	47
Hesperoperla pacifica						
Perlodidae						
Perlodidae (*Cultus* sp.)	10	10	5		25	97
Diura knowltoni						
Isoperla sp.						
Isoperla fulva	4				4	16
Megarcys signata						
Skwala americana	1	1	1		3	12
Pteronarcella badia	3		2		5	20
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	85	37	88		210	814
Brachycentrus occidentalis						
Micrasema bactro						
Culoptila sp.		6			6	24
Glossosoma sp.	13	15			28	109
Protoptila sp.	7	2	2		11	43
Arctopsyche grandis	1				1	4
Cheumatopsyche sp.	2	1			3	12
Hydropsyche sp.	48	16	59		123	477
Hydropsyche cockerelli	12	4	11		27	105
Hydropsyche oslari	24	9	25		58	225
Ochrotrichia sp.						
Lepidostoma sp.	322	208	415		945	3663
Ceraclea sp.			1		1	4
Oecetis sp.						
Hesperophylax sp.						
Psychomyia flavida	2				2	8
Rhyacophila brunnea						
Rhyacophila coloradensis						
Rhyacophila sibirica group						
Oligophlebodes sp.						

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Table A9. cont. Macroinvertebrate data collected from site CR-7.4 on 18 Sept. 2019.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola	7	7	9		23	90
Cricotopus/Orthocladius sp.	2	1	10		13	51
Diamesa sp.						
Eukiefferiella sp.	36	4	33		73	283
Limnophyes sp.						
Micropsectra/Tanytarsus sp.	1		38		39	152
Microtendipes sp.			1		1	4
Pagastia sp.	6		1		7	28
Paracladopelma sp.						
Parametriocnemus sp.	7		4		11	43
Polypedilum sp.			1		1	4
Potthastia sp.	1				1	4
Rheotanytarsus sp.						
Synorthocladius sp.						
Thienemanniella sp.						
Thienemannimyia group	1				1	4
Tvetenia sp.	23	2	14		39	152
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae						
Chelifera/Neoplasta sp.	2				2	8
Wiedemannia sp.						
Lispoides aequifrons						
Pericoma sp.						
Simulium sp.	165	22	90		277	1074
Antocha sp.			1		1	4
Dicranota sp.						
Hexatoma sp.						
Tipula sp.						
Coleoptera (beetles)						
Oreodytes sp.						
Heterlimnius sp.						
Optioservus sp.	195	74	122		391	1516
Zaitzevia parvula	19	3	6		28	109
Miscellaneous						
Atractides sp.	1				1	4
Hygrobates sp.	2				2	8
Lebertia sp.						
Protzia sp.	3				3	12
Sperchon sp.	4	3	3		10	39
Torrenticola sp.						
Pisidium sp.						
Caecidotea sp.	35	19	47		101	392
Ferrissia sp.						
Lymnaeidae						
Physa sp.		1			1	4
Gyraulus sp.		1			1	4
Polycelis coronata	4	3			7	28
Crangonyx sp.	4	3	3		10	39
Erpobdellidae						
Enchytraeidae	4				4	16
Lumbricidae	3	3			6	24
Naididae			28		28	109
Nematoda			1		1	4
Totals	**1369**	**599**	**1264**		**3232**	**12549**

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Table A10. Macroinvertebrate data collected from site CR-1.7 on 18 Sept. 2019.

Colorado River						
CR-1.7		Sample				
18 Sept. 2019	1	2	3		Totals	Total/m
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella sp.	4	2	1		7	28
Baetis flavistriga						
Baetis (*tricaudatus*)	28	30	55		113	438
Diphetor hageni						
Attenella margarita						
Drunella coloradensis						
Drunella doddsii						
Drunella grandis	4	7	11		22	86
Ephemerella dorothea infrequens	9	10	14		33	128
Serratella tibialis						
Cinygmula sp.						
Epeorus sp.			3		3	12
Epeorus deceptivus						
Heptagenia sp.		2			2	8
Rhithrogena sp.			2		2	8
Tricorythodes explicatus		1	9		10	39
Paraleptophlebia sp.		8	15		23	90
Plecoptera (stoneflies)						
Paracapnia angulata						
Chloroperlidae						
Sweltsa sp.						
Zapada oregonensis group						
Claassenia sabulosa			1		1	4
Hesperoperla pacifica						
Perlodidae			1		1	4
Perlodidae (*Cultus* sp.)		1	3		4	16
Diura knowltoni						
Isoperla sp.						
Isoperla fulva						
Megarcys signata						
Skwala americana						
Pteronarcella badia			1		1	4
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	2	2	4		8	31
Brachycentrus occidentalis						
Micrasema bactro						
Culoptila sp.		1			1	4
Glossosoma sp.			1		1	4
Protoptila sp.		1	3		4	16
Arctopsyche grandis						
Cheumatopsyche sp.						
Hydropsyche sp.	2				2	8
Hydropsyche cockerelli			1		1	4
Hydropsyche oslari			25		25	97
Ochrotrichia sp.	5	5	1		11	43
Lepidostoma sp.	407	448	283		1138	4411
Ceraclea sp.			1		1	4
Oecetis sp.						
Hesperophylax sp.						
Psychomyia flavida						
Rhyacophila brunnea						
Rhyacophila coloradensis						
Rhyacophila sibirica group						
Oligophlebodes sp.						

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Table A10. cont. Macroinvertebrate data collected from site CR-1.7 on 18 Sept. 2019.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola	1		1		2	8
Cricotopus/Orthocladius sp.	12	11	11		34	132
Diamesa sp.						
Eukiefferiella sp.	4	2	7		13	51
Limnophyes sp.						
Micropsectra/Tanytarsus sp.	7	26	9		42	163
Microtendipes sp.						
Pagastia sp.						
Paracladopelma sp.						
Parametriocnemus sp.		1			1	4
Polypedilum sp.						
Potthastia sp.						
Rheotanytarsus sp.						
Synorthocladius sp.						
Thienemanniella sp.	1		1		2	8
Thienemannimyia group						
Tvetenia sp.	2	4	12		18	70
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae						
Chelifera/Neoplasta sp.						
Wiedemannia sp.						
Lispoides aequifrons						
Pericoma sp.						
Simulium sp.	3	10	88		101	392
Antocha sp.						
Dicranota sp.						
Hexatoma sp.						
Tipula sp.						
Coleoptera (beetles)						
Oreodytes sp.	1				1	4
Heterlimnius sp.						
Optioservus sp.	60	61	172		293	1136
Zaitzevia parvula	1	2	9		12	47
Miscellaneous						
Atractides sp.						
Hygrobates sp.		2	1		3	12
Lebertia sp.		1	1		2	8
Protzia sp.			1		1	4
Sperchon sp.		2			2	8
Torrenticola sp.						
Pisidium sp.		1			1	4
Caecidotea sp.	31	32	59		122	473
Ferrissia sp.			1		1	4
Lymnaeidae	1				1	4
Physa sp.	1	5	2		8	31
Gyraulus sp.	1	2			3	12
Polycelis coronata	1				1	4
Crangonyx sp.	3		3		6	24
Erpobdellidae			3		3	12
Enchytraeidae	2				2	8
Lumbricidae						
Naididae	101	43	23		167	648
Nematoda						
Totals	**694**	**723**	**839**		**2256**	**8758**

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Appendix B

Historical Metric Results – 2017 & 2018

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Table B1. Individual component metrics and MMI v4 scores from benthic macroinvertebrate samples collected in the Learning By Doing study area during fall 2017. All metric scores based on MMI (v4) subsampling process.

Metric	Station ID							
	FR-23.2	**FR-20**	**FR-15**	**FR-14**	**RC-1.1**	**FR-12.4**	**FR-1.9**	**CR-9.1**
EPT taxa	50.0	45.8	58.3	62.5	66.7	75.0	100.0	93.2
% Non-Insect individuals	70.4	55.6	92.7	94.1	80.6	86.2	94.6	83.1
% EPT individuals, no Baetidae	19.6	15.0	29.1	61.7	53.5	81.3	79.4	68.1
% Coleoptera individuals	16.2	9.5	4.6	31.6	44.8	47.4	54.8	52.3
% Intolerant Taxa	76.5	82.0	71.7	72.3	71.5	72.9	100.0	89.0
% Increasers, Mid-Elevation	70.9	58.9	87.7	95.5	91.2	85.5	95.3	92.9
Clinger taxa	43.3	43.3	72.1	76.9	72.1	62.5	100.0	97.4
Predator/Shredder taxa	85.7	92.9	71.4	100.0	92.9	100.0	100.0	78.6
MMI v4	**54.1**	**50.4**	**61.0**	**74.3**	**71.6**	**76.3**	**90.5**	**81.8**
	Auxiliary Metrics							
Diversity	3.44	3.08	3.49	3.95	3.98	3.49	4.41	4.23
HBI	4.50	3.95	4.66	3.64	3.57	2.68	3.23	3.09
Sediment Region	SR2	SR2	SR2	SR2	SR2			
TIV	6.39	5.88	6.31	5.64	5.56	--	--	--

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Table B2. Individual component metrics and MMI v4 scores from benthic macroinvertebrate samples collected in the Learning By Doing study area during fall 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
Sediment Region	SR1	SR2	SR2	SR2	SR2					
TIV	2.28	6.20	4.79	4.59	4.25	--	--	--	--	--

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Table B3. Additional metrics and comparative values for macroinvertebrate samples collected from the Learning By Doing study area in the fall of 2017. All additional metrics based on full count Hess samples.

Metric	FR-23.2	FR-20	FR-15	FR-14	RC-1.1	FR-12.4	FR-1.9	CR-9.1
Density (#/m^2)	3,866	10,789	8,284	8,908	9,388	11,725	7,934	8,618
Taxa Richness	34	39	42	47	43	53	50	49
EPT	15	14	16	22	19	24	28	25
Density of *Pteronarcys californica* (#/m^2)	0	0	0	0	0	0	4	4
Percent EPT excluding Baetidae	14.49%	10.36%	22.50%	46.51%	40.28%	55.51%	57.79%	48.42%
Percent Chironomidae	48.99%	47.45%	48.57%	25.33%	25.89%	15.01%	11.56%	17.00%
Percent Hydropsychidae	31.91%	9.32%	31.33%	72.59%	19.77%	21.38%	49.66%	17.14%
Percent Tolerant Taxa	17.65%	15.38%	19.05%	14.89%	23.26%	20.75%	18.00%	24.49%
Percent Intolerant Taxa	44.12%	43.59%	33.33%	36.17%	44.19%	37.74%	50.00%	42.86%

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Table B4. Additional metrics and comparative values for macroinvertebrate samples collected from the Learning By Doing study area in the fall of 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%
Percent Hydropsychidae	0.00%	16.42%	86.99%	35.47%	47.22%	26.01%	6.06%	19.45%	19.81%	9.91%
Percent Tolerant Taxa	12.12%	15.22%	19.05%	23.81%	13.51%	31.11%	16.00%	16.36%	23.21%	28.57%
Percent Intolerant Taxa	57.58%	41.30%	35.71%	42.86%	54.05%	28.89%	28.00%	43.64%	39.29%	21.43%

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GRAND COUNTY

LEARNING BY DOING

Sediment Monitoring Results

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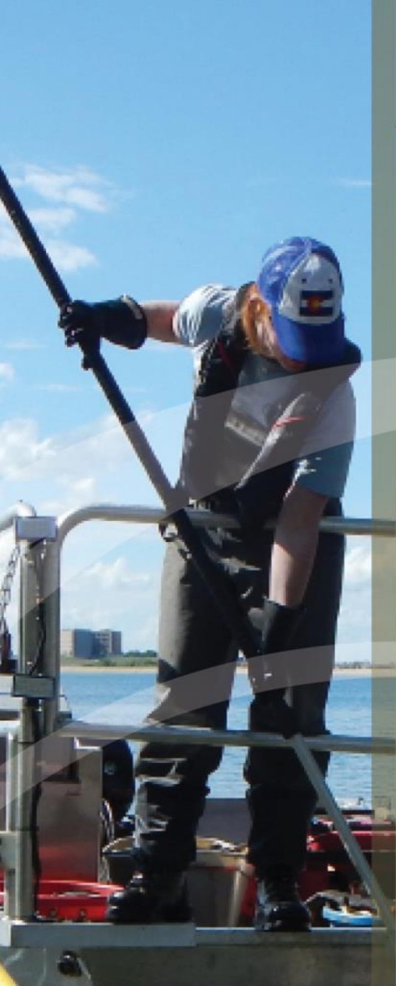
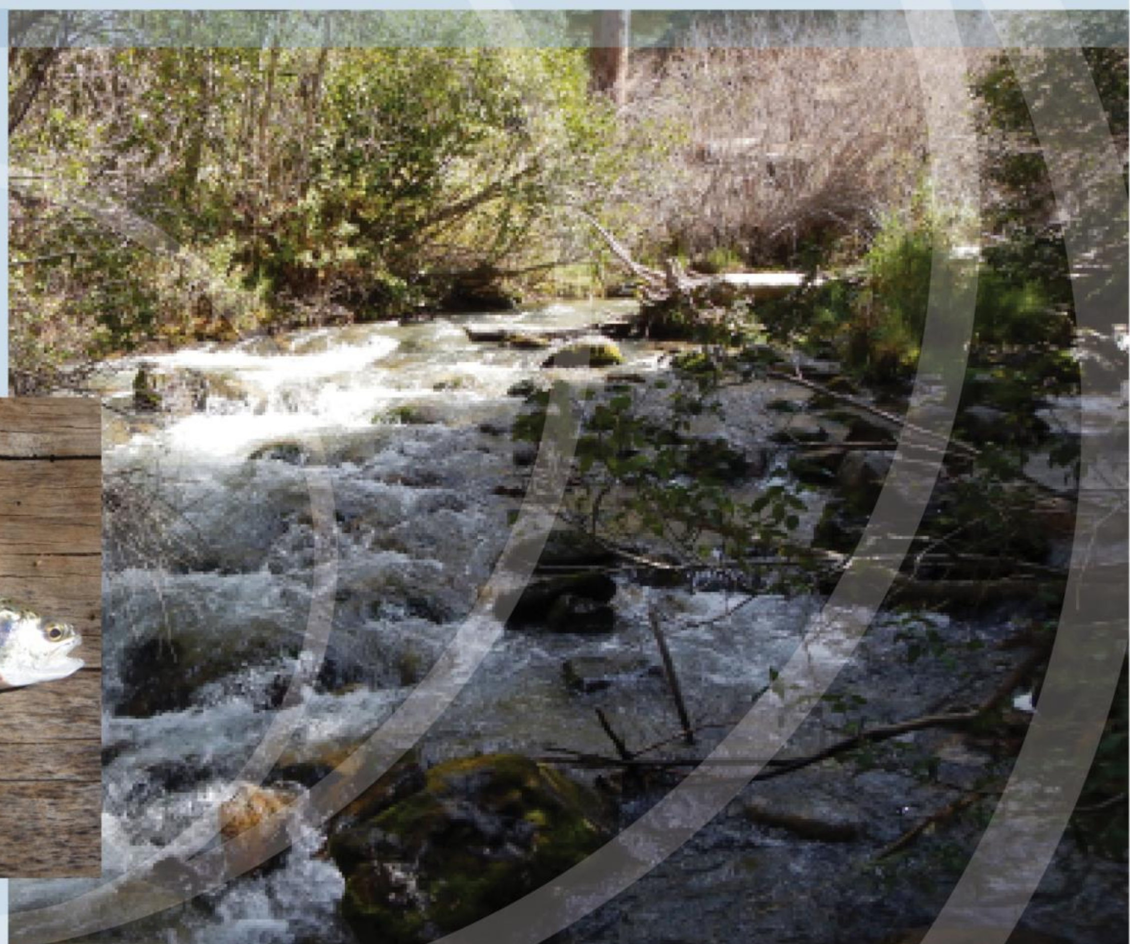
GEI Consultants

Consulting
Engineers and
Scientists



Sediment and Algae Assessment in the Colorado River and Fraser River Basins 2019

DRAFT Report
February 2020



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GEI Consultants

Consulting Engineers and Scientists

Sediment and Algae Assessment in the Colorado River and Fraser River Basins 2019

Submitted to:
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February 2020
Project 1904938

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12/22/2019
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1. Introduction

At the request of Grand County Learning By Doing (LBD), GEI Consultants, Inc. (GEI) conducted assessments of the substrate and algae present at multiple sampling locations in the Colorado River and Fraser River basins in Grand County in the fall of 2019. A total of fourteen sites were sampled from September 24, 2019 through October 1, 2019, with seven sites located on the Colorado River, six sites located on the Fraser River, and one site located on Ranch Creek. The sites sampled by GEI for substrate and algae characteristics were previously established throughout Grand County Learning By Doing's Cooperative Effort Area (CEA).

At each site location, GEI performed pebble counts and measured percent fines, percent embeddedness, riffle stability index, and algal cover. The data collected at each site location may be used to assess potential sediment transport issues in the basin and to address questions related to biological integrity such as the Sediment Tolerance Indicator Value (TIV_{SED}) for macroinvertebrates and a salmonid spawning habitat assessment.

2. Cooperative Effort Area

All sites sampled were located within the Grand County LBD's Cooperative Effort Area (CEA) in Grand County. This area stretches from the town of Winter Park, CO approximately 50 miles downstream to the town of Kremmling, CO (Figure 2-1; Table 2-1). The seven sites on the Colorado River extend from the town of Granby, CO to the town of Kremmling, CO. The six sites on the Fraser River extend from the town of Winter Park, CO to the town of Granby, CO. The one site established on Ranch Creek is located in the town of Tabernash, CO, approximately 0.75 miles (mi) upstream from the confluence with the Fraser River (Figure 2-1).

Figure 2-1: All sediment and algae assessment site locations on the Colorado River, Fraser River, and Ranch Creek.

Table 2-1: Names and locations for all 14 sites sampled in 2019.

Site Name	Station Description	Latitude	Longitude
CR-1.7	Colorado River upstream of Blue River	40.044	-106.374
CR-7.4	Colorado River downstream of Troublesome Creek	40.051	-106.311
CR-9.1	Colorado River at CR39 Bridge at KB Ditch	40.054	-106.289
CR-16.7	Colorado River upstream of Williams Fork	40.050	-106.173
CR-22.9	Colorado River upstream of Hot Sulphur Springs	40.080	-106.099
CR-28.7	Colorado River downstream of Windy Gap	40.108	-106.004
CR-31	Colorado River upstream of Fraser and Windy Gap	40.101	-105.973
FR-1.9	Fraser River upstream of Granby Sanitation District	40.084	-105.954
FR-14	Fraser River upstream of Tabernash	39.992	-105.830
FR-15	Fraser River upstream of Fraser Flats restoration	39.983	-105.826
FR-20	Fraser River at Rendezvous Bridge	39.935	-105.791
FR-23.2	Fraser River upstream of Winter Park Sanitation	39.896	-105.769
FR-25.1	Fraser River upstream of UP Moffat Tunnel discharge	39.878	-105.754
RC-1.1	Ranch Creek downstream of Meadow Creek	39.999	-105.828

3. Methods

3.1 Pebble Counts and Embeddedness

At each site location, pebble counts were performed utilizing the method outlined by Colorado WQCD Policy 98-1 which describes the Modified Wolman Pebble Count Method (CDPHE 2014). A total of ten transects were established at each site, evenly spacing each transect along a length of stream approximately twenty times the average bankfull width. At each of these ten transects, a 60 by 60-centimeter (cm) sampling frame was used to designate 4 substrate particles for measurement at ten evenly spaced points across the transect (Photo 3-1). This accounted for a total of 40 substrate particle measurements per transect, and a total of 400 measurements per sampling location. The 60 by 60 cm sampling frame consisted of 4 aluminum bars connected to form a square, with an inside width of 60 cm, and 4 elastic bands placed forming four cross sections with a width of 50 cm. The intermediate axis of each particle designated by the elastic band cross sections on the sampling frame was measured using a gravelometer or ruler (if the particle was too large to fit through the apertures in the gravelometer). Ocular estimates were used for substrate particles that could not be removed from the bed and measured with a ruler (i.e., due to size).

A subset of the particles measured at each of the transects at each site location were used to determine percent embeddedness, or the extent to which larger particles are surrounded by or buried in fine substrate. A minimum of four or five large gravel or cobble-sized particles at each transect were measured for percent embeddedness, for a total of 40 to 50 embeddedness measurements per sampling location. Embeddedness percentages were determined by measuring the height that each particle was buried and dividing by the total particle height. This method allowed for a quantitative estimate of the total percent embeddedness at each site.

Photo 3-1: Substrate being measured with a gravelometer at Site CR-16.7 on the Colorado River.

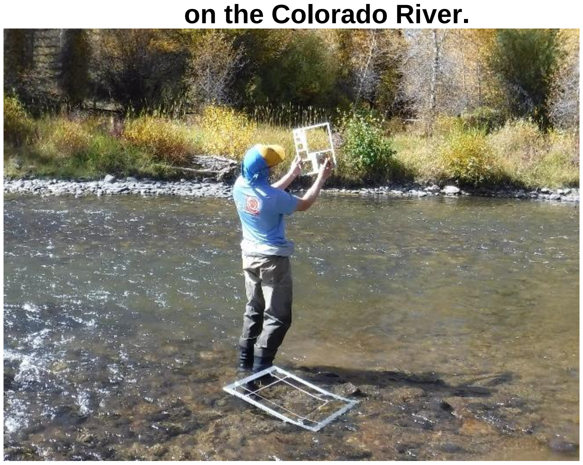
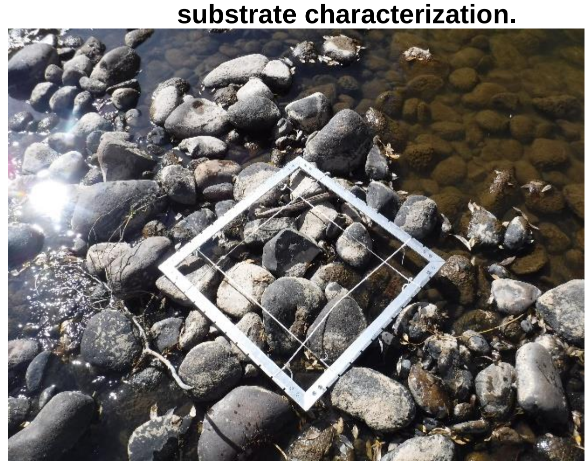


Photo 3-2: Sampling frame with four cross sections for randomized substrate characterization.



3.2 Riffle Stability Index

The Riffle Stability Index (RSI) was determined at each site using the methods outlined by Kappesser (2002). The RSI value indicates the percentage of mobile bed material in the riffle. A point bar, lateral bar, or similar depositional feature at each site location was identified in close proximity to a riffle. A transect was established in a riffle, across its bankfull width, and 200 substrate particles were selected. In smaller streams with insufficient width to allow selection of 200 particles, a second transect was established. The intermediate axis of each particle was measured. On the depositional feature, the intermediate axis of 10 to 30 of the largest recently deposited particles were measured, and the geometric mean of these particles was calculated. The geometric mean was then compared to the cumulative distribution of particle sizes from the 200-riffle pebble count. This determined the percentage of particles in the riffle that were smaller than the representative large mobile particles in the depositional feature at each site. The mobile fraction on the riffle can be estimated by comparing the relative abundance of various particle sizes present on the riffle with the dominant large particles on an adjacent bar (Kappesser 2002).

Photo 3-3: An example of a depositional point bar, from Site FR-23.2 on the Fraser River.

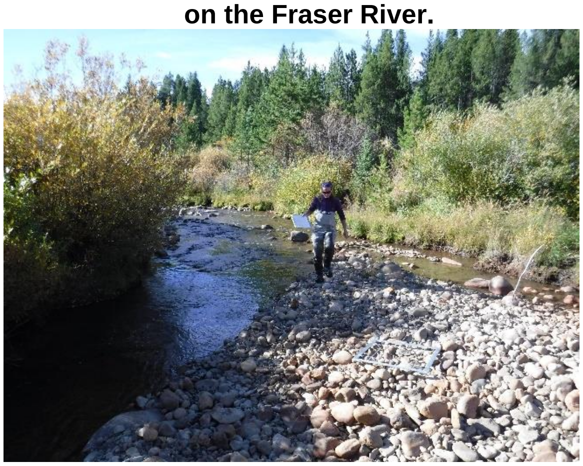
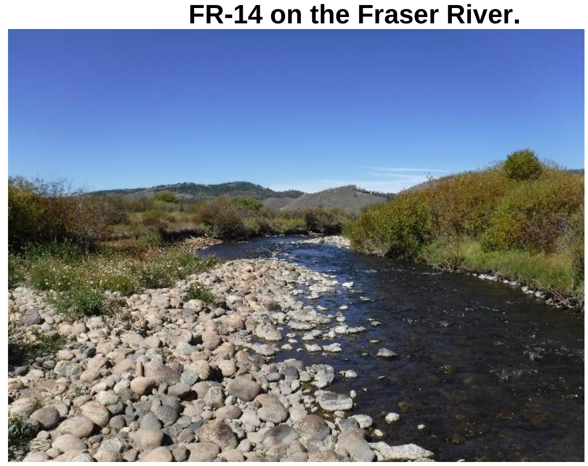


Photo 3-4: An example of a lateral depositional bar, from Site FR-14 on the Fraser River.



3.3 Algae Presence, Percent Cover, and Thickness

Algae presence (filamentous algae and diatoms), the percent filamentous algae cover, and diatom thickness data were recorded using a combined method that included protocols taken from the Colorado Water Quality Control Division Standard Operating Procedures for the Collection of Stream Periphyton Samples (CDPHE, no year) combined with the grid-based pebble count method. Along each transect established for pebble counts, the presence of filamentous algae, the presence of diatoms, the percent filamentous algae cover, and diatom thickness was measured or visually estimated.

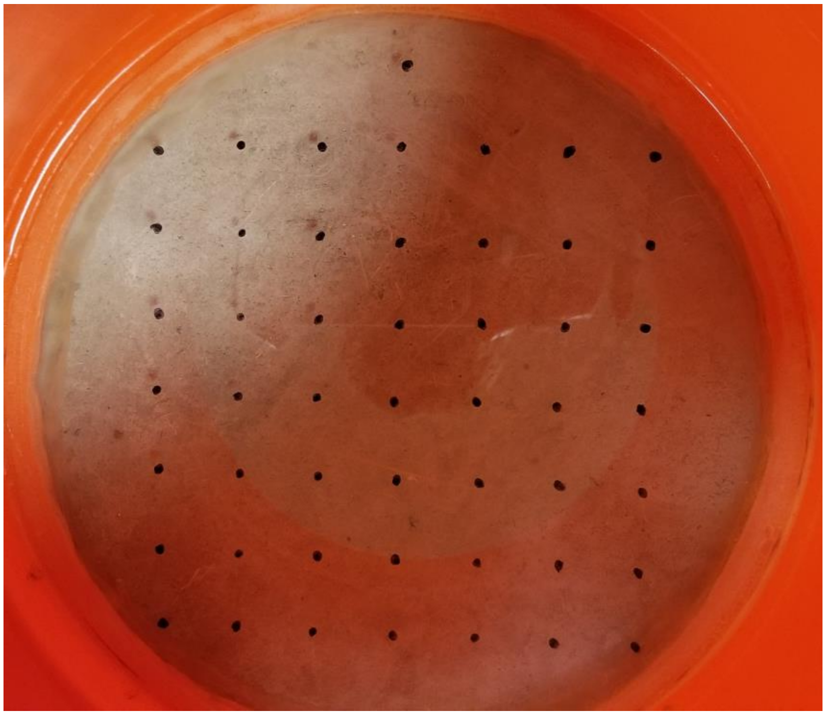
The algal communities were observed at three distances per transect: 25%, 50%, and 75% from the streambank, for a total of 30 points evaluated at each site. The algae viewing bucket consisted of a 5-gallon bucket with its bottom replaced with transparent plexiglass with 50 evenly spaced points marked with permanent marker. At each of the three transect positions, the presence of filamentous algae and/or diatoms was recorded. For filamentous algae cover data, the viewing bucket was used twice at each of the three points along each transect. The total number of points where filamentous algae was growing was divided by 100 to calculate the percent filamentous algae cover at each of the three distances per transect. At each of the three distances the thickness of diatom growth was visually estimated in millimeters (mm) and categorized in accordance to Stevenson and Bahls 1999 (Table 3-1).

Table 3-1: Diatom thickness categories as defined by Stevenson and Bahls 1999.

Category	Categorical Description
0	Substrate rough with no visual evidence of microalgae
0.5	Substrate slimy, but no visual accumulation of microalgae evident
1	A thin layer of microalgae is visually evident
2	Accumulation of microalgal layer from 0.5 to 1 mm thick is evident
3	Accumulation of microalgal layer from 1 to 5 mm thick is evident
4	Accumulation of microalgal layer from 5mm to 2 cm thick is evident
5	Accumulation of microalgal layer greater than 2 cm thick is evident

Photo 3-5: An example of substrate and the algal community present at Site FR-14 on the Fraser River. The piece of cobble substrate pictured below is covered with diatom algal growth, with a thickness between 1 to 5 mm.

Photo 3-6: The 5-gallon algae viewing bucket with transparent bottom and grid. The grid encompasses an area of roughly 100 in^2.



4. Results

4.1 Pebble Counts and Embeddedness

A pebble count was performed at each site location from September 24, 2019 through October 1, 2019. A total of 10 transects were sampled at each site except Site CR-1.7, where four transects were sampled because a majority of the site was not wadeable. At this site, conditions in the riffles, which constituted approximately 20% of the site, were represented by two riffle cross sections. The remainder of the site consisted of deep, monotonous, homogeneous slow-water habitat, which was represented by the other two cross sections. Most sites on the Colorado River and Fraser River were dominated by substrate sizes categorized as small cobble and/or cobble (Table 4-1). The substrate at the Ranch Creek site was dominated by small cobble and gravel-sized substrate. Bedrock was only present in a small proportion at Site CR-16.7. Fine substrate, particles with an intermediate width less than 2 mm, was most common at the two farthest downstream sites on the Colorado River and at the Ranch Creek site (Table 4-1), but Site CR-1.7 was the only site that had a proportion of fine sediment that exceeded the threshold of 29.3% set by CDPHE (CDPHE 2014).

Table 4-1: Percent average substrate size classes at all sites sampled in 2019.

Sites	Substrate Size Categories							
	Fines	Small Gravel	Gravel	Small Cobble	Cobble	Small Boulder	Boulder	Bedrock
	<2 mm	2-8 mm	8-64 mm	64-128 mm	128-256 mm	256-512 mm	>512mm	
CR-1.7	65.8	13.8	6.5	5.8	7.0	1.3	0.0	0.0
CR-7.4	25.7	5.5	33.9	27.7	7.2	0.0	0.0	0.0
CR-9.1	12.0	1.7	17.7	27.2	38.7	2.7	0.0	0.0
CR-16.7	12.3	3.8	23.5	27.0	26.0	4.0	2	1.5
CR-22.9	4.1	2.7	15.2	20.7	46.0	10.6	0.7	0.0
CR-28.7	5.8	3.5	16.1	27.9	36.4	10.3	0.0	0.0
CR-31	5.5	3.3	18.8	32.0	29.0	11.5	0.0	0.0
FR-1.9	8.8	3.8	22.8	35.8	22.3	6.5	0.0	0.0
FR-14	5.9	5.1	23.3	26.2	30.9	8.1	0.5	0.0
FR-15	13.4	2.5	21.3	24.3	22.3	13.6	2.5	0.0
FR-20	15.5	4.0	18.0	28.8	17.3	11.8	4.8	0.0
FR-23.2	4.7	2.5	24.6	35.2	28.3	3.5	1.2	0.0
FR-25.1	8.5	3.0	7.2	8.2	8.0	14.7	50.4	0.0
RC-1.1	21.0	4.5	24.0	27.0	17.5	2.5	3.5	0.0

Average percent embeddedness was equal to or greater than 37.4 at all sites, with the largest average percent embeddedness observed at sites CR-1.7, CR-7.4, FR-25.1, and RC-1.1 (Table 4-2). Average percent embeddedness values were in general lower in the upper portion of the Colorado River, and greatest at the two most downstream sites. These two sites were also observed to have the greatest percentage of fine substrate (<2 mm), with 25.7% fines at Site CR-7.4, and 49.7% fines at Site CR-1.7 (Table 4-1).

The percentage of substrate sizes observed in 2019 at sites on the Colorado River varied between sites. The substrate classes between <2 mm to ≤256 mm were observed at all sites. There was little to no substrate greater than the 256 mm at the two most downstream sites, Site CR-7.4 and Site CR-1.7. These two sites noticeably had a greater percentage of smaller substrate, between <2 mm to ≤64 mm, than all other Colorado River sites (Figure 4-1). The Colorado River sites in general decreased in average substrate size from upstream to downstream (Figure 4-1). In general, channel gradient decreases in a downstream direction with commensurate increases in streamflow and corresponding general decrease in sediment size (Rosgen 1996).

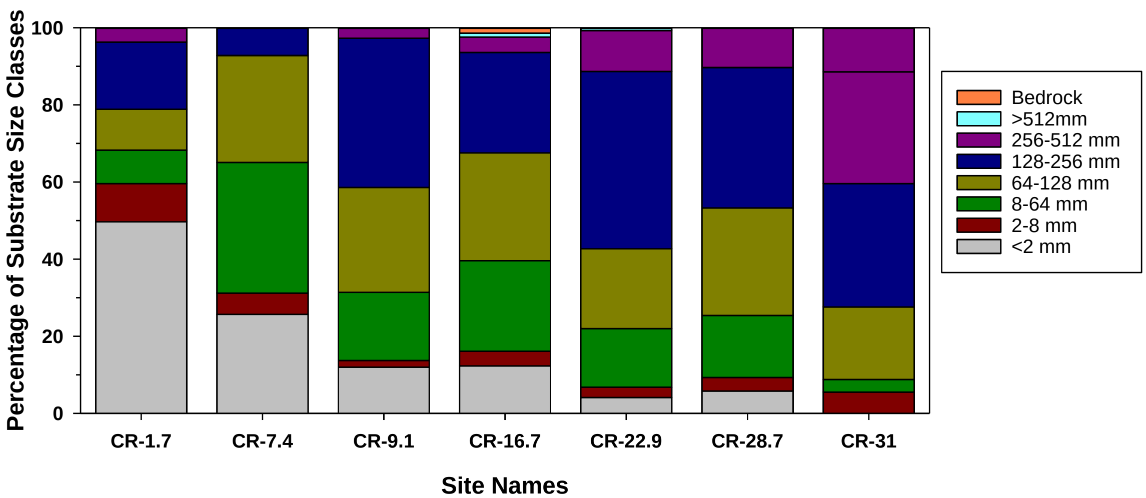


Figure 4-1: Percentage of substrate size classes for all sites on the Colorado River.

Substrate composition varied less between the Fraser River sites than observed on the Colorado River, with the exception of Site FR-25.1 (Figure 4-2). Site FR-25.1 was the most upstream site on the Fraser River, and the hydraulic and geomorphic properties of this site were substantially different from the other sites sampled on the Fraser River in 2019. Site FR-25.1 had a strikingly greater percentage of larger substrate, with the majority of substrate categorized as being greater than 512 mm (Figure 4-2). This site had a higher slope and lower sinuosity than all other Fraser River sites. Site FR-25.1 is mainly composed of step-pool complexes with a limited capacity to store sediment; this site is a “transport reach” that supplies sediment to downstream reaches (Rosgen 1996). Even though sites FR-25.1, FR 23.2, FR-20, and FR-15 had a greater percentage of >512 mm substrate than the most two downstream sites (Figure 4-2), the substrate composition changed less than expected from the upstream-most to downstream-most sampling site. The general homogenous state of the percentages of substrate size across sites on the Fraser River, from site FR-23.2 to FR-1.9, may be attributable a decrease in the natural magnitude of flows that were historically present.

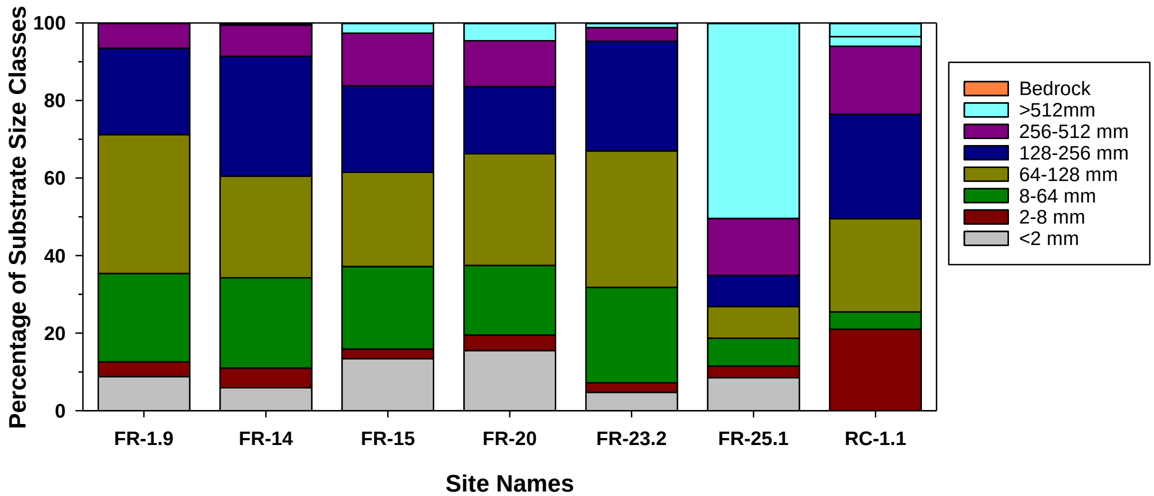


Figure 4-2: **Percentage of substrate size classes for all sites on the Fraser River and Ranch Creek.**

The one site located on Ranch Creek, Site RC-1.1, was approximately 0.75 mi upstream from the confluence of Ranch Creek with the Fraser River, roughly the same distance upstream from the confluence as Site FR-14 on the Fraser River. Site RC-1.1 on Ranch Creek was observed to have similar sinuosity, slope, and habitat types as Site FR-14 on the Fraser River. Additionally, Site RC-1.1 was observed to have comparable values for the types and percentages of substrate sizes observed in the middle portion of the Fraser River that was sampled, sites FR-20, and FR-15 (Figure 4-2).

Average percent embeddedness values on the Fraser River were all comparable between sites, except for at Site FR-25.1, the farthest upstream site location (Table 4-2). Among the Fraser River sites, Site FR-25.1 had the highest average percent embeddedness value observed (Table 4-2). Site FR-25.1 was dissimilar to all other sites on the Fraser River, Colorado River, and Ranch Creek. This site was dominated by very large boulders with a steep grade, and greatly influenced by surrounding human-made alterations to the riverbanks, portions of the river, and nearby roadways.

Table 4-2: **Average embeddedness by site location.**

Sites	Waterbody	Average Percent Embeddedness
CR-1.7	Colorado River	65.5
CR-7.4	Colorado River	55.5
CR-9.1	Colorado River	42.3
CR-16.7	Colorado River	49.0
CR-22.9	Colorado River	43.7
CR-28.7	Colorado River	48.8
CR-31	Colorado River	44.8
FR-1.9	Fraser River	40.0
FR-14	Fraser River	40.5
FR-15	Fraser River	46.9
FR-20	Fraser River	37.4
FR-23.2	Fraser River	39.4
FR-25.1	Fraser River	51.8
RC-1.1	Ranch Creek	51.4

4.2 Riffle Stability Index

A 200-riffle pebble count and a 10 to 30 pebble count on a nearby depositional feature were performed at thirteen of the fourteen sites in 2019. Site FR-25.1, the farthest upstream site on the Fraser River did not have depositional features appropriate for a depositional substrate characterization. Site FR-25.1 was distinctly different than any other site sampled on the Fraser River, Colorado River, or Ranch Creek. This site had very high relief, a slope of approximately 10%, and was dominated by very large substrate. Streams of this type exhibit a high sediment transport potential and a relatively low in-channel sediment storage capacity (Rosgen 1996).

The RSI value indicates the cumulative percentage of riffle particles that are smaller than the dominant large particles on a depositional bar (Kappesser 2002). A higher RSI indicates that sand and small gravel loading is occurring in riffles. The minimum RSI value observed occurred at Site FR-15 on the Fraser River and the maximum observed value was observed at Site CR-22.9 on the Colorado River. In general, the RSI values were relatively high, with an average RSI of 81 on the Colorado River, 78 on the Fraser River, and 71 at Ranch Creek.

Table 4-3: Average Riffle Stability Index (RSI) by site location.

Sites	Waterbody	Riffle Stability Index
CR-1.7	Colorado River	77
CR-7.4	Colorado River	77
CR-9.1	Colorado River	85
CR-16.7	Colorado River	73
CR-22.9	Colorado River	93
CR-28.7	Colorado River	79
CR-31	Colorado River	85
FR-1.9	Fraser River	89
FR-14	Fraser River	90
FR-15	Fraser River	65
FR-20	Fraser River	74
FR-23.2	Fraser River	73
FR-25.1	Fraser River	--
RC-1.1	Ranch Creek	71

4.3 Algae Presence, Percent Cover, and Thickness

The algae community at a total of 30 points within each site reach was assessed in conjunction with pebble count surveys from September 24, 2019 through October 1, 2019. The percent average presence of filamentous algae varied considerably across all sampling locations. Values ranged from 0 percent filamentous algae presence at Site FR-20 on the Fraser River, to a maximum of 100 percent presence at Site CR-22.9 on the Colorado River. The percent filamentous algae cover at each site also varied widely, and was generally low, with the exception of sites CR-1.7 and CR-22.9 on the Colorado River, and at sites FR-14 and FR-15 on the Fraser River (Table 4-4).

Table 4-4: Filamentous algae and diatom data by site location.

Sites	Waterbody	Percent Average Filamentous Presence	Percent Average Filamentous Algae Cover	Percent Average Diatom Presence	Average Categorical Diatom Thickness
CR-1.7	Colorado River	58.3	40.2	50.0	3.9
CR-7.4	Colorado River	13.3	2.1	93.3	1.5
CR-9.1	Colorado River	30.0	5.2	96.7	1.5
CR-16.7	Colorado River	66.7	8.2	96.7	2.8
CR-22.9	Colorado River	100	82.6	86.7	1.3
CR-28.7	Colorado River	13.3	1.4	100.0	1.8
CR-31	Colorado River	26.7	2.8	100.0	1.8
FR-1.9	Fraser River	63.6	11.9	100.0	0.7
FR-14	Fraser River	86.7	39.0	100.0	0.7
FR-15	Fraser River	73.3	30.9	90.0	2.6
FR-20	Fraser River	0.0	0.0	100.0	0.5
FR-23.2	Fraser River	6.7	3.7	96.7	0.6
FR-25.1	Fraser River	6.7	1.1	100.0	0.6
RC-1.1	Ranch Creek	50.0	7.6	93.3	1.1

Diatom algae was present at every site in 2019, and with the exception of a relatively low percentage of presence at Site CR-1.7 on the Colorado River, the percentage of diatom presence at each site was high, ranging from a minimum of 86.7 percent to 100 percent (Table 4-4). The diatom species *Didymosphenia geminata* (Didymo) is a stalked diatom that can form nuisance blooms in rivers in the western United States (Spaulding and Elwell 2007). This species was present at almost all sites sampled and prevalent at sites CR-28.7, CR-22.9, and CR-16.7. Didymo accounted for almost all of the diatoms observed with a thickness greater than 1-2 mm, except at sites FR-14 and FR-15. Diatom thickness was categorized as less than 1 mm at sites FR-1.9, FR-20, FR-23.2, and FR-25.1 on the Fraser River. All other sites sampled had thickness categories that exceeded a thickness of 1 mm (Table 4-4; Table 3-1).

5. Discussion

The substrate and algae community data gathered in the fall of 2019 at multiple sites along representative stretches of both the Colorado River and Fraser River, and one site on Ranch Creek have enabled a basin-wide assessment of substrate size, substrate mobility, substrate deposition, and algae population data. This in turn allows inference about the effects of current substrate conditions on fish and macroinvertebrate habitat quality.

5.1 Pebble Counts and Embeddedness

5.1.1 Colorado River

Based on observed changes between sites, sediment composition in the CEA is likely affected by large-scale factors such as reservoirs, and tributary inputs and by local-scale factors such as hillslope erosion and stream diversion infrastructure.

Near the upstream end of the CEA on the Colorado River, just below the Colorado River and Fraser River confluence between Site CR-31 and Site CR-28.7 is the Windy Gap Reservoir. This reservoir is a relatively small flow-through system that extends about 0.4 miles from the inlet to the outlet. A large proportion of the sediment transported into the reservoir is retained, inhibiting the natural sediment transport historically observed in the upper portion of the Colorado River. This is evident from the decrease in material smaller than 128 mm (i.e., gravel and sand) between Site CR-31, which is upstream of Windy Gap Reservoir, and sites CR-28.7 and CR-22.9, the next two downstream sites from Windy Gap Reservoir. The proportion of sand and gravel decreases from 59.6% at Site CR-31 to 53.3% at Site CR-28.7 to 42.7% at Site CR-22.9, indicating a lack of smaller substrate availability and transport. As expected, the percentages of these smaller substrate classes decreased below the reservoir, until the river passed through areas that receive sediment input. Diagonal cobble bars and mid-channel cobble bars, both of which indicate a lack of sediment mobility (Rosgen 2006), were observed downstream of Windy Gap Reservoir. Substantial additions of new substrate material into the Colorado River likely do not occur until the river reaches Byers Canyon, downstream of the town of Hot Sulphur Springs, below Site CR-22.9.

Byers Canyon and Muddy Creek are both located between Site CR-22.9 and Site CR-16.7 on the Colorado River. Byers Canyon is characterized by escarpments adjacent to the stream along with a steep stream corridor composed of mainly large boulder substrate. This section of the river extends approximately 1.9 miles just downstream of Hot Sulphur Springs. The river in the canyon is narrow and has a higher slope than adjacent reaches, resulting in greater water velocities than the sections of river just upstream and just downstream of the canyon. This creates a higher potential for sediment transport and a lower potential for sediment storage. The steep canyon walls also provide material ranging from silt to boulders to the river, largely through natural processes. Muddy Creek is downstream of Byers

Canyon; this small, unregulated system likely also serves as a source of new material to the Colorado River. Because of these new sources of sediment, sand and gravel (i.e., substrate <128 mm in size) increases from 42.7% to 66.4% between Site CR-22.9 and Site CR-16.7, the first study site located below Byers Canyon.

There are two relatively large tributaries to the Colorado River in the downstream portion of the study reach that likely influence substrate characteristics in the river. The Williams Fork of the Colorado River (Williams Fork) flows into the Colorado River just downstream of Site CR-16.7 in the town of Parshall, CO, and Troublesome Creek flows into the Colorado River between Site CR-9.1 and Site CR-7.4. The Williams Fork downstream of Williams Fork Reservoir is a short section of river about 2.0 miles in length before the confluence. This reservoir disrupts the continuity of sediment transport in the Williams Fork and likely diminishes the amount of substrate provided to the Colorado River. The Williams Fork adds a relatively large amount of volume to the flow in the Colorado River, which assists with transporting sediment downstream. Substrate at Site CR-9.1, the first sampling site downstream of the Williams Fork confluence, had smaller proportions of substrate material smaller than 128 mm than observed at the next upstream site, Site CR-16.7. The additional river flow (and therefore, increased water velocity) from the Williams Fork River, combined with its low sediment input, increases the capacity of the Colorado River to move the existing substrate in the vicinity of Site CR-9.1. As expected, the proportion of sediment less than 128 mm in diameter decreases from 66.4% to 58.6% between sites CR-16.7 and CR-9.1. The KB Ditch Diversion also appears to affect sediment dynamics at Site CR-9.1. The KB Ditch is located approximately 0.4 miles upstream of Site CR-9.1 on the Colorado River and diverts flow from the Colorado River for agricultural use. The diversion runs the width of the river at the ditch inlet, with the exception of a small bypass on river right (looking in a downstream direction). This structure also has the potential to trap sediment. The KB Ditch and Williams Fork confluence with the Colorado River are both upstream of Site CR-9.1; without a monitoring site between these two potentially influencing factors. An additional site located between Williams Fork and KB Ditch might determine their relative influences on the sediment characteristics at Site CR-9.1.

Photo 5-1: Aerial image of the KB Ditch diversion and inlet (Google Earth, earth.google.com/web/). The Colorado River flows towards the left of the photo.

Troublesome Creek is a moderately sized tributary to the Colorado River, and the confluence is located between Site CR-9.1 and CR-7.4, approximately 0.4 miles upstream from Site CR-7.4. This creek is low-gradient, sinuous (i.e., meandering), and runs adjacent to agricultural fields for much of its length. The confluence of Troublesome Creek and the Colorado River is located just upstream of where the sinuosity of the Colorado River increases dramatically, the slope decreases, and the water velocity decreases in comparison to the upstream reaches. The highly sinuous section of the Colorado River extends approximately 9 miles through the most downstream site CR-1.7 before entering Gore Canyon just downstream of the town of Kremmling.

Due to higher sinuosity, lower slope, reduced water velocity, and the addition of sediment from Troublesome Creek, the Colorado River transitions from being dominated by small cobble and cobble substrate to being dominated by smaller substrate size classes. Site CR-7.4 was dominated by gravel substrate with a large proportion of fine substrate, and Site CR-1.7 was dominated by fine substrate.

Based on observed changes between sites, sediment composition throughout the CEA is likely affected by a combination of natural and man-made factors. Troublesome Creek, Muddy Creek, and Byers Canyon likely act as sources of sand and gravel in an otherwise sediment-limited system. While the Williams Fork provides additional flow, it is also sediment-limited and probably does not provide substantial amounts of gravel to the system. The predominance of fine substrate at Kremmling is likely due to transport capacity being limited by low gradient and high sinuosity. Low-gradient, sinuous systems have low water velocity and allow for small substrate particles to fall out of the water column and become deposited, and the low velocity inhibits larger particles from being transported. Based on observations at sites downstream of Windy Gap and KB Ditch, with a lower amount of gravel substrate compared to their adjacent upstream sites, much of the gravel in the CEA remains trapped behind dams or diversions instead of being moved downstream, as is typical in managed systems.

5.1.2 Fraser River and Ranch Creek

As with the Colorado River, sediment composition on the Fraser River is affected by large-scale and local-scale factors. The primary large-scale factor is flow management, but local features such as unpaved roads, erodible hillslopes, beaver ponds and man-made ponds appear to have a larger effect on the proportion of fine sediment in the watershed, as opposed to the cumulative proportion of sediment less than 128 mm in diameter.

The percentage of substrate <2 mm was greater at Site RC-1.1 than all sites on the Fraser River (21% versus an average of 9.5 for the six Fraser River sites). The higher proportion of fine sediment may be due to a combination of low flows from multiple diversions in the Ranch Creek Watershed and the high availability of sediment from unpaved roads and hillslopes in the watershed.

The Fraser River in the CEA has four relatively large tributaries: Vasquez Creek, which enters the Fraser River between sites FR-23.2 and FR-20, Elk Creek and St. Louis Creek, both of which enter the Fraser River between sites FR-20 and FR-15, and Ranch Creek, which enters the Fraser River downstream of Site FR-14. Surprisingly, despite these tributary inputs, the proportion of sediment from 2 – 128 mm in size is remarkably consistent between sites FR-23.2 and FR-14. The individual influences of tributaries like Vasquez Creek and St. Louis Creek on Fraser River sediment dynamics were not pronounced in 2019, perhaps because the tributaries are highly regulated by diversions.

The local factors in the Fraser River Drainage include stream diversions, beaver dams, and unpaved roads. The proportion of fine sediment decreased by almost 50% between sites FR-25.1 and FR-23.2, perhaps because there is a municipal diversion and a large beaver pond between the two sites. Beaver dams affect streams in similar but less pronounced ways than dams and larger diversions; while they slow the water velocity, allowing for substrate particles to be deposited and stored on their upstream side instead of being moved downstream, they tend not to last as long as larger, engineered structures and likely have a lesser effect on sediment dynamics. It is possible that there are multiple beaver dams within the CEA that were not observed but could affect sediment dynamics in the drainage.

The proportion of substrate <2 mm at Site FR-20 was the highest among all Fraser River sites at 15.5%. This could be due to the high density of unpaved roads and cleared areas under construction in the valley between sites FR-23.2 and FR-20. Both unpaved roads and construction sites could cause elevated rates of fine sediment in the river, particularly on a localized scale of tens to hundreds of meters.

Mid-channel and diagonal bars were also observed in the Fraser River drainage and are evidence of its highly managed status. These depositional bars form when powerful, rapid flows recede and leave behind sediment deposits that cannot be moved by subsequent, lower flows; additional high flow events are required to move these features. These bars were likely created during the last significant flow event on the river. Almost all of the mid-channel and diagonal bars observed on the Fraser River did not show signs of recent formation and are likely not a result of recent flows.

Embeddedness values were in general comparable between sites on the Fraser River with the exception of Site FR-25.1 and Site FR-15. Site FR-25.1 is a “transport reach” that receives fine sediment directly from the valley walls, because it is a confined reach with a very limited floodplain. However, historic and actively used/maintained roads in close vicinity to this site have also probably contributed a disproportionate amount of fine sediment to this reach. Site FR-15 had the second highest average percent embeddedness observed in 2019, noticeably greater than values observed at all sites other than Site FR-25.1. The relatively high amount of embeddedness at Site FR-15 is likely attributable to a widening of the river downstream of the town of Fraser, just upstream of Site FR-15, that results in a decrease in water velocity that inhibits the transport of smaller substrate material downstream. There was an observed decrease in the embeddedness and substrate <2 mm at Site FR-14, the next site downstream from Site FR-15, and an increase in the percentage of small gravel at Site FR-14. This is an indication that the stretch of river between these two sites is likely enabling the transport of smaller substrate material, and likely has a greater average water velocity than the portion of the river upstream of Site FR-15. The section of river between Site FR-15 and Site FR-14 was the focus of restoration efforts, and the narrowing of the river coupled with an increase in stream velocity has allowed this section of river to transport sediment more successfully than the other sections of the Fraser River below Site FR-25.1.

5.2 Riffle Stability Index

The mobile percentile of particles in a riffle, or RSI, is a useful estimate of the degree of increased sediment supply to riffles in mountain streams (Kappesser 2002). A stable stream reach in dynamic equilibrium has similar sediment size and sediment transport rates at the beginning of a reach compared to the end of a reach, so that there is no net gain or loss of sediment (Kappesser 2002).

In the Kappesser 2002 study in north Idaho, reference streams had a median RSI value of 58 and managed watersheds had a median RSI value of 80. The median RSI value for the sites on the Colorado and Fraser drainages was 78. A higher RSI value shows that a higher proportion of the material in a riffle is smaller than the larger materials on depositional features. This indicates that a riffle is storing a higher proportion of fine materials such as sand. The RSI values from the 2019 sampling sites suggest that stream flows in these drainages have a limited capacity to flush sand and gravel from riffles, which is typical of managed streams. The RSI decreased noticeably from a relatively high value at Site FR-15 to the lowest value observed in the CEA at Site FR-14. This decrease is likely attributable to the increased velocity in the restored reach between these two sites transporting substrate material more readily than in the remainder of the CEA. Riffles with a lower RSI value (i.e., those with a lower proportion of fine material) provide more clean substrate with interstitial spaces, or small spaces between clean substrate particles. These interstitial spaces provide high-quality habitat for macroinvertebrates, some species of juvenile fishes, and benthic, or bottom-dwelling, fishes.

Compaction of the substrate, or the packing of embedded substrate such that it is difficult to remove from the streambed was common in the Fraser River and in Ranch Creek, but not in the Colorado River. Compaction occurs when interstitial spaces become filled with too much fine substrate, which is transported as suspended load in the water column, as opposed to an unconsolidated mix of fines and gravels that move along the streambed (Babbitt and Bidelspach, personal communication, 10/29/2019). The gravels that move as bedload tend to become trapped behind diversions in highly managed streams systems such as the Fraser and Colorado rivers. Substrate compaction negatively affects aquatic organisms by clogging interstitial spaces, as discussed above, and it limits spawning habitat by preventing fish from moving substrate to make nests or redds.

5.3 Algae Presence, Percent Cover, and Thickness

Diatoms were present at all sites unless the substrate was occluded by green algae. Didymo was the reason for thick diatom cover at all sites except CR 1.7, FR-14, and FR-15 and was most common in the CEA between Windy Gap and the mouth of the Williams Fork. This species tends to create blooms in stable, low velocity flow regimes (Kirkwood et al. 2007; Miller at al. 2009), and it is possible that flow variation outside of this reach is sufficient to discourage its proliferation. Although Didymo was present at most sites, it did not occur at nuisance levels; it is possible that relatively high flows in 2019 flushed much of the Didymo from the CEA.

Green filamentous algae coverage was only extensive upstream of Hot Sulphur Springs at Site CR-22.9 and in Kremmling at Site CR-1.7 on the Colorado River. The abundance of filamentous algae at Site CR-22.9 is likely partially due to excessive nutrient inputs from agricultural run-off. This site is also relatively wide and low-sloped, creating shallow and low-velocity conditions preferable to filamentous algae. At Site CR-1.7, nutrients for algae production would be available due to the presence of extensive agricultural fields upstream of the site. The filamentous algae at Site CR-1.7 persists in the two short riffles that have a relatively high gradient compared to the remainder of the site. These riffles are the only locations at the site with hard substrate that algae can colonize. It was also apparent in 2019 that flow conditions had been low for an extended period and were insufficient to scour away algae growth at these two sites. However, the high spring flows in 2019 could have flushed much of the green algae from the system, with the exception of Sites CR-22.9 and CR-1.7.

On the Fraser River, green filamentous algae were only present in relatively high concentrations at Site FR-14 and site FR-15. A large percentage of the river extending upstream from Site FR-15 all the way to Site FR-1.9, just upstream of the town of Fraser, runs adjacent to agricultural fields. The addition of run-off from these agricultural areas likely provide ample nutrients to allow for robust algae growth. Additionally, the lack of natural scouring flows in the Fraser River allow the algae to persist.

6. Conclusion

The sediment conditions in the CEA in the Colorado and Fraser River drainages are typical of managed systems, and a combination of natural and man-made features influence the river's sediment dynamics. The 2019 annual daily flows observed in Grand County, CO during spring run-off and during the remainder of the year in the Colorado River, Fraser River, and Ranch Creek were greater than in 2018, and comparable to observed values in 2017 (Appendix B). These flows probably flushed a large amount of accumulated fine sediment and Didymo from the CEA. On a more local scale, ditches/dams and beaver ponds trap gravels, and unpaved roads, unregulated tributaries, and erodible hillslopes provide sources of sand and gravel. Although the proportion of sand and silt at all sites except Site CR-1.7 was typical for rivers in this region, gravel was limited at most sampling sites. Embeddedness was over 35% at all sites, and the sediment was compacted at most of the sampling locations. Didymo was present at several sites, and green filamentous algae blooms were present at a small number of sites, but nuisance blooms were generally absent in 2019. The sediment and algae conditions in the CEA have some implications for aquatic habitat quality, as discussed briefly below.

A low proportion of gravels and embeddedness of cobbles limit habitat for macroinvertebrates and small fishes (Waters 1995). Furthermore, the compaction of the substrate also limits spawning habitat, as trout cannot move the particles in the substrate to create redds. Dense blooms of Didymo have the potential to affect macroinvertebrates (Kilroy et al. 2009) and small benthic fish by limiting their habitat quality and availability. A limited number of studies indicate that the effects of Didymo on macroinvertebrate communities is variable (Spaulding and Elwell 2007), but reduction of sensitive taxa like mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera) have been documented in some studies (Kilroy et al. 2009). Historic flows in the CEA were substantially greater in magnitude and duration during spring run-off than they are in modern times, multiple instream structures disrupt sediment transport, and human land use has altered the nutrient dynamics of the Colorado and Fraser rivers. Aquatic habitat conditions are somewhat limited within the CEA. However, this is unsurprising, given that the Colorado and the Fraser are both working rivers.

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Appendix A 2019 Sediment and Algae Data

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Site: CR-1.7
Date: 9/27/2019
Notes: Transects 1 and 4 were in riffles, the only 2 riffles present in site reach. Transects 2 and 3 likely represent the rest of the reach (80%). Remainder of transects were non-wadeable.

Transect Substrate Count

	Fines	**Sm. Gravel**	**Gravel**	**Sm. Cobble**	**Cobble**	**Sm. Boulder**	**Boulder**	**Bedrock**
Transect	**<2mm**	**2-8mm**	**8-64mm**	**64-128mm**	**128-256mm**	**256-512mm**	**>512mm**	**Bedrock**
1 (riffle)	12	1	7	7	10	3		
2	33	5		2				
3	28	8	4					
4 (riffle)	7	2	3	8	18	2		
5								
6								
7								
8								
9								
10								
total	80	16	14	17	28	5	0	0
% of total	50	10	8.8	10.6	17.5	3.1	0	0

	Fines	**Sm. Gravel**	**Gravel**	**Sm. Cobble**	**Cobble**	**Sm. Boulder**	**Boulder**	**Bedrock**
	<2mm	**2-8mm**	**8-64mm**	**64-128mm**	**128-256mm**	**256-512mm**	**>512mm**	**Bedrock**
Point Bar Deposition					12	3		
% of total	0	0	0	0	80	20	0	0
200 Riffle Count	14	14	33	38	76	15	9	0
% of total	7	7	16.6	19.1	38.2	7.5	4.5	0
cumulative percent	7	14	30.6	49.7	87.9	95.4	99.9	99.9

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Embeddedness						
Transect	**Emb. 1**	**Emb. 2**	**Emb. 3**	**Emb. 4**	**Emb. 5**	Avg.
1	20	30	50	30	30	32.0
2	100	100	100	100	100	100.0
3	100	100	100	80	50	86.0
4	20	20	60	50	70	44.0
5						
6						
7						
8						
9						
10						
					Total Avg.	**65.5**

Algae Data								
Transect	**25% Fil. Cover**	**25% Diatom Presence**	**25% Filamentous Presence**	**25% Diatom Thickness (categorical)**	**50% Fil. Cover**	**50% Diatom Presence**	**50% Filamentous Presence**	**50% Diatom Thickness (categorical)**
1	12	x	x	3	0	x		4
2	100		x	5	0			
3	100		x	5	0			
4	72	x	x	3	0	x		3
5								
6								
7								
8								
9								
10								
average/count	71	2	4	4	0	2	0	3.5

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Transect	75% Fil. Cover	75% Diatom Presence	75% Filamentous Presence	75% Diatom Thickness (categorical)
1	70	x	x	4
2	0			
3	100		x	5
4	28	x	x	3
5				
6				
7				
8				
9				
10				
average/count	49.5	2	3	4

Total avg. Fil. Cover	40.2
Total avg. Diatom Presence	50.0
Total avg. Fil. Presence	58.3
Mean Diatom Thickness	3.9

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Site: CR-7.4
Date: 9/27/2019
Notes:

Transect Substrate Count								
	Fines	Sm. Gravel	Gravel	Sm. Cobble	Cobble	Sm. Boulder	Boulder	Bedrock
Transect	**<2mm**	**2-8mm**	**8-64mm**	**64-128mm**	**128-256mm**	**256-512mm**	**>512mm**	**Bedrock**
1	2	3	17	15	3			
2	8	3	12	8	9			
3	5		19	11	5			
4	5	3	24	7	1			
5	5	1	16	18				
6	1	2	16	20	2			
7	12	3	16	8	1			
8	26	3	3	8				
9	19		4	10	7			
10	20	4	9	6	1			
total	103	22	136	111	29	0	0	0
% of total	25.7	5.5	33.9	27.7	7.2	0	0	0

	Fines	Sm. Gravel	Gravel	Sm. Cobble	Cobble	Sm. Boulder	Boulder	Bedrock
	<2mm	**2-8mm**	**8-64mm**	**64-128mm**	**128-256mm**	**256-512mm**	**>512mm**	**Bedrock**
Point Bar Deposition			1	16	3			
% of total	0	0	5	80	15	0	0	0
200 Riffle Count	38	10	73	71	20			
% of total	17.9	4.7	34.4	33.5	9.4	0	0	0
cumulative percent	17.9	22.6	57	90.5	99.9	99.9	99.9	99.9

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Embeddedness						
Transect	**Emb. 1**	**Emb. 2**	**Emb. 3**	**Emb. 4**	**Emb. 5**	Avg.
1	40	40	60	50	50	48.0
2	30	70	50	50	40	48.0
3	50	50	70	50	30	50.0
4	50	60	60	50	40	52.0
5	40	50	50	50	60	50.0
6	30	50	30	30	50	38.0
7	40	40	50	60		47.5
8	100	60	60	60	70	70.0
9	100	60	60	50	40	62.0
10	70	70	100	100	100	88.0
					Total Avg.	**55.5**

Algae Data								
Transect	**25% Fil. Cover**	**25% Diatom Presence**	**25% Filamentous Presence**	**25% Diatom Thickness (categorical)**	**50% Fil. Cover**	**50% Diatom Presence**	**50% Filamentous Presence**	**50% Diatom Thickness (categorical)**
1	0	x		0.5	16	x	x	1
2	8	x		2	25	x	x	2
3	0	x		1	0	x		1
4	0	x		2	0	x		2
5	0	x		3	0	x		3
6	25	x	x	2	0	x		2
7	0	x		3	4	x	x	2
8	0	x		0.5	0	x		0
9	0	x		0.5	0	x		0.5
10	0			0	0	x		0.5
average/count	3.3	9	1	1.5	4.5	10	3	1.4

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Transect	75% Fil. Cover	75% Diatom Presence	75% Filamentous Presence	75% Diatom Thickness (categorical)
1	0	x		2
2	0	x		2
3	0	x		2
4	0	x		2
5	0	x		3
6	0	x		2
7	0	x		0.5
8	0	x		1
9	0	x		1
10	0			0
average/count	0	9	0	1.6

Total avg. Fil. Cover	2.6
Total avg. Diatom Presence	93.3
Total avg. Fil. Presence	13.3
Mean Diatom Thickness	1.47

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Site: CR-9.1
Date: 9/27/2019
Notes:

Transect Substrate Count								
	Fines	Sm. Gravel	Gravel	Sm. Cobble	Cobble	Sm. Boulder	Boulder	Bedrock
Transect	<2mm	2-8mm	8-64mm	64-128mm	128-256mm	256-512mm	>512mm	Bedrock
1	5		9	11	16			
2	12	1	9	10	7	1		
3	4	1	5	11	18	1		
4	1		5	9	21	4		
5		1	7	9	21	2		
6	9	2	6	8	15			
7	7		7	10	16			
8	3	2	6	16	13			
9			5	12	21	2		
10	7		12	13	7	1		
total	48	7	71	109	155	11	0	0
% of total	12	1.7	17.7	27.2	38.7	2.7	0	0

	Fines	Sm. Gravel	Gravel	Sm. Cobble	Cobble	Sm. Boulder	Boulder	Bedrock
	<2mm	2-8mm	8-64mm	64-128mm	128-256mm	256-512mm	>512mm	Bedrock
Point Bar Deposition				1	24	5		
% of total	0	0	0	3.3	80	16.7	0	0
200 Riffle Count	2	1	29	82	88			
% of total	1	0.5	14.4	40.6	43.6	0	0	0
cumulative percent	1	1.5	15.9	56.5	100.1	100.1	100.1	100.1

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Embeddedness						
Transect	**Emb. 1**	**Emb. 2**	**Emb. 3**	**Emb. 4**	**Emb. 5**	Avg.
1	40	60	60	30	40	46.0
2	50	70	40	40	15	43.0
3	30	50	50	40	30	40.0
4	30	60	30	40	40	40.0
5	10	50	60	40	40	40.0
6	60	50	30	30	20	38.0
7	20	30	60	50	50	42.0
8	30	50	60	40	40	44.0
9	10	40	50	40	50	38.0
10	50	60	60	50	40	52.0
					Total Avg.	**42.3**

Algae Data								
Transect	**25% Fil. Cover**	**25% Diatom Presence**	**25% Filamentous Presence**	**25% Diatom Thickness (categorical)**	**50% Fil. Cover**	**50% Diatom Presence**	**50% Filamentous Presence**	**50% Diatom Thickness (categorical)**
1	4	x	x	3	8	x	x	3
2	100		x		0	x		0.5
3	4	x	x	2	4	x	x	2
4	0	x		2	4	x	x	1
5	0	x		3	0	x		3
6	0	x		0.5	0	x		0.5
7	0	x		1	4	x	x	1
8	0	x		0.5	0	x		0.5
9	0	x		1	0	x		1
10	0	x		2	0	x		2
average/count	10.8	9	3	1.7	2	10	4	1.5

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Algae Data				
Transect	**75% Fil. Cover**	**75% Diatom Presence**	**75% Filamentous Presence**	**75% Diatom Thickness (categorical)**
1	8	x	x	3
2	0	x		0.5
3	12	x	x	2
4	0	x		0.5
5	0	x		3
6	0	x		1
7	0	x		0.5
8	0	x		1
9	0	x		1
10	8	x		2
average/count	2.8	10	2	1.5

Total avg. Fil. Cover	5.2
Total avg. Diatom Presence	96.7
Total avg. Fil. Presence	30.0
Mean Diatom Thickness	1.52

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Site: CR-16.7
Date: 10/1/2019
Notes:

Transect Substrate Count								
	Fines	**Sm. Gravel**	**Gravel**	**Sm. Cobble**	**Cobble**	**Sm. Boulder**	**Boulder**	**Bedrock**
Transect	**<2mm**	**2-8mm**	**8-64mm**	**64-128mm**	**128-256mm**	**256-512mm**	**>512mm**	**Bedrock**
1	4	2	13	12	6		3	
2		3	11	17	9			
3	3	2	21	9	5			
4	12		11	11	6			
5	13		2	6	11	2	6	
6	2		4	12	17	2		3
7	7		8	10	10	2		3
8		3	7	10	13	7		
9	5	5	4	13	10	3		
10	3		13	7	17			
total	49	15	94	107	104	16	9	6
% of total	12.3	3.8	23.5	26.8	26	4	2.3	1.5

	Fines	**Sm. Gravel**	**Gravel**	**Sm. Cobble**	**Cobble**	**Sm. Boulder**	**Boulder**	**Bedrock**
	<2mm	**2-8mm**	**8-64mm**	**64-128mm**	**128-256mm**	**256-512mm**	**>512mm**	**Bedrock**
Point Bar Deposition				22	8			
% of total	0	0	0	73.3	26.7	0	0	0
200 Riffle Count	10	12	76	59	41	2		
% of total	5	6	38	29.5	20.5	1	0	0
cumulative percent	5	11	49	78.5	99	100	100	100

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Embeddedness						
Transect	**Emb. 1**	**Emb. 2**	**Emb. 3**	**Emb. 4**	**Emb. 5**	Avg.
1	80	70	50	60	70	66.0
2	50	30	60	50	50	48.0
3	40	50	30	40	50	42.0
4	60	40	60	60	40	52.0
5	45	40	50	40	70	49.0
6	30	35	40	50	40	39.0
7	100	100	60	40	30	66.0
8	50	60	30	30	60	46.0
9	60	40	40	50	30	44.0
10	50	20	30	50	40	38.0
					Total Avg.	**49.0**

Algae Data								
Transect	**25% Fil. Cover**	**25% Diatom Presence**	**25% Filamentous Presence**	**25% Diatom Thickness (categorical)**	**50% Fil. Cover**	**50% Diatom Presence**	**50% Filamentous Presence**	**50% Diatom Thickness (categorical)**
1	0	x		2	68	x	x	3
2	7	x	x	3	6	x	x	3
3	0	x		4	0	x		3
4	15	x	x	3	3	x	x	2
5	0	x		1	0	x		2
6	0	x		3	0	x		3
7	0	x		2	0	x		3
8	0	x		3	0	x		3
9	10	x	x	2	0	x		3
10	8	x	x	3	0	x		3
average/count	4	10	4	2.6	7.7	10	10	2.8

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Algae Data				
Transect	75% Fil. Cover	75% Diatom Presence	75% Filamentous Presence	75% Diatom Thickness (categorical)
1	75	x	x	3
2	6	x	x	4
3	0	x		2
4	25	x	x	3
5	0			0
6	2	x	x	3
7	5	x	x	3
8	7	x	x	4
9	8	x		1
10	0	x		3
average/count	12.8	9	6	2.6

*Transect located on macrophyte bed.

Total avg. Fil. Cover	8.2
Total avg. Diatom Presence	96.7
Total avg. Fil. Presence	66.7
Mean Diatom Thickness	2.67

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Site: CR-22.9
Date: 10/1/2019
Notes: Bar Lazy J, upstream from bridge

Transect Substrate Count								
	Fines	**Sm. Gravel**	**Gravel**	**Sm. Cobble**	**Cobble**	**Sm. Boulder**	**Boulder**	**Bedrock**
Transect	**<2mm**	**2-8mm**	**8-64mm**	**64-128mm**	**128-256mm**	**256-512mm**	**>512mm**	**Bedrock**
1	1	3	11	8	14	3		
2		1	5	9	21	8		
3	2		8	15	26			
4		2	7	5	21	5		
5	6		5	9	18	2		
6		1	9	12	16	2		
7	2	2	5	7	18	3	3	
8	3	1	7	7	18	4		
9	2	1		8	22	7		
10	1		6	6	17	10		
total	17	11	63	86	191	44	3	0
% of total	4.1	2.7	15.2	20.7	46	10.6	0.7	0

	Fines	**Sm. Gravel**	**Gravel**	**Sm. Cobble**	**Cobble**	**Sm. Boulder**	**Boulder**	**Bedrock**
	<2mm	**2-8mm**	**8-64mm**	**64-128mm**	**128-256mm**	**256-512mm**	**>512mm**	**Bedrock**
Point Bar Deposition					5	15		
% of total	0	0	0	0	25	75	0	0
200 Riffle Count		3	36	46	116	22		
% of total	0	1.3	16.1	20.6	52	9.9	0	0
cumulative percent	0	1.3	17.4	38	90	99.9	99.9	99.9

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Embeddedness						
Transect	**Emb. 1**	**Emb. 2**	**Emb. 3**	**Emb. 4**	**Emb. 5**	Avg.
1	10	50	40	40	40	36.0
2	50	50	50	60	40	50.0
3	50	60	60	60	60	58.0
4	40	50	60	30	30	42.0
5	50	60	40	20	50	44.0
6	70	60	40	40	40	50.0
7	60	50	30	50	30	44.0
8	40	30	30	30	25	31.0
9	60	40	30	30	30	38.0
10	50	60	50	20	40	44.0
					Total Avg.	**43.7**

Algae Data								
Transect	**25% Fil. Cover**	**25% Diatom Presence**	**25% Filamentous Presence**	**25% Diatom Thickness (categorical)**	**50% Fil. Cover**	**50% Diatom Presence**	**50% Filamentous Presence**	**50% Diatom Thickness (categorical)**
1	80	x	x	0.5	76	x	x	3
2	86	x	x	3	84	x	x	3
3	92	x	x	0.5	54	x	x	0.5
4	100		x	0	100		x	0
5	100	x	x	1	100	x	x	1
6	100	x	x	1	100	x	x	1
7	4	x	x	1	94	x	x	1
8	76	x	x	0.5	76	x	x	2
9	74	x	x	2	72	x	x	2
10	80	x	x	0.5	78	x	x	0.5
average/count	79.2	9	10	1	83.4	9	10	1.4

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Algae Data				
Transect	**75% Fil. Cover**	**75% Diatom Presence**	**75% Filamentous Presence**	**75% Diatom Thickness (categorical)**
1	90	x	x	3
2	80	x	x	3
3	100		x	0
4	96		x	0
5	100	x	x	1
6	100	x	x	1
7	86	x	x	1
8	70	x	x	3
9	74	x	x	1
10	56	x	x	2
average/count	85.2	8	10	1.5

Total avg. Fil. Cover	82.6
Total avg. Diatom Presence	86.7
Total avg. Fil. Presence	100.0
Mean Diatom Thickness	1.3

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Site: CR-28.7
Date: 9/24/2019
Notes: No point bars at site. Used small gravel bar at channel margin.

Transect Substrate Count								
	Fines	**Sm. Gravel**	**Gravel**	**Sm. Cobble**	**Cobble**	**Sm. Boulder**	**Boulder**	**Bedrock**
Transect	**<2mm**	**2-8mm**	**8-64mm**	**64-128mm**	**128-256mm**	**256-512mm**	**>512mm**	**Bedrock**
1			3	19	15	3		
2	4	4	4	15	13			
3	8	3	6	10	10	3		
4	2		11	15	9	2		
5	1	1	13	11	13	1		
6	2	1	4	7	16	9		
7	2	1	8	6	15	8		
8	2	1	3	9	19	6		
9		1	5	13	15	6		
10	2	2	7	6	20	3		
total	23	14	64	111	145	41	0	0
% of total	5.8	3.5	16.1	27.9	36.4	10.3	0	0

	Fines	**Sm. Gravel**	**Gravel**	**Sm. Cobble**	**Cobble**	**Sm. Boulder**	**Boulder**	**Bedrock**
	<2mm	**2-8mm**	**8-64mm**	**64-128mm**	**128-256mm**	**256-512mm**	**>512mm**	**Bedrock**
Point Bar Deposition				3	7	5		
% of total	0	0	0	20	46.7	33.3	0	0
200 Riffle Count		3	40	54	102	5		
% of total	0	1.5	19.6	26.5	50	2.5	0	0
cumulative percent	0	1.5	21.1	47.6	97.6	100.1	100.1	100.1

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Embeddedness						
Transect	**Emb. 1**	**Emb. 2**	**Emb. 3**	**Emb. 4**	**Emb. 5**	Avg.
1	40	40	40	50	30	40.0
2	40	60	20	20	50	38.0
3	50	50	50	50	30	46.0
4	40	50	40	40	50	44.0
5	60	50	60	30	30	46.0
6	70	60	60	60	50	60.0
7	40	50	50	50	60	50.0
8	70	40	60	60	50	56.0
9	60	40	60	70	50	56.0
10	70	50	50	60	30	52.0
					Total Avg.	**48.8**

Algae Data								
Transect	**25% Fil. Cover**	**25% Diatom Presence**	**25% Filamentous Presence**	**25% Diatom Thickness (categorical)**	**50% Fil. Cover**	**50% Diatom Presence**	**50% Filamentous Presence**	**50% Diatom Thickness (categorical)**
1	9	x	x	1	0	x		2
2	0	x		2	0	x		2
3	4	x	x	2	0	x		2
4	0	x		3	0	x		3
5	0	x		2	25	x	x	2
6	0	x		1	0	x		2
7	0	x		2	0	x		2
8	0	x		1	0	x		2
9	0	x		1	0	x		2
10	0	x		1	0	x		2
average/count	1.3	10	2	1.6	2.5	10	1	2.1

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Algae Data				
Transect	75% Fil. Cover	75% Diatom Presence	75% Filamentous Presence	75% Diatom Thickness (categorical)
1	0	x		2
2	0	x		2
3	0	x		2
4	0	x		2
5	4	x	x	1
6	0	x		1
7	0	x		2
8	0	x		2
9	0	x		1
10	0	x		1
average/count	0.4	10	1	1.6

Total avg. Fil. Cover	1.4
Total avg. Diatom Presence	100.0
Total avg. Fil. Presence	13.3
Mean Diatom Thickness	1.77

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Site: CR-31
Date: 9/26/2019
Notes:

Transect Substrate Count								
	Fines	Sm. Gravel	Gravel	Sm. Cobble	Cobble	Sm. Boulder	Boulder	Bedrock
Transect	**<2mm**	**2-8mm**	**8-64mm**	**64-128mm**	**128-256mm**	**256-512mm**	**>512mm**	**Bedrock**
1	3	2	8	13	13	1		
2	1	3	8	19	6	3		
3		1	12	18	6	3		
4			7	11	17	5		
5		1	7	11	13	8		
6	4	3	1	12	12	8		
7	2	1	9	11	12	5		
8	1	2	3	13	17	4		
9	3		7	12	13	5		
10	8		13	8	7	4		
total	22	13	75	128	116	46	0	0
% of total	5.5	3.3	18.8	32	29	11.5	0	0

	Fines	Sm. Gravel	Gravel	Sm. Cobble	Cobble	Sm. Boulder	Boulder	Bedrock
	<2mm	**2-8mm**	**8-64mm**	**64-128mm**	**128-256mm**	**256-512mm**	**>512mm**	**Bedrock**
Point Bar Deposition				6	10	8		
% of total	0	0	0	25	41.7	33.3	0	0
200 Riffle Count	3	5	44	58	81	13	1	
% of total	1.5	2.4	21.5	28.3	39.5	6.3	0.5	0
cumulative percent	1.5	3.9	25.4	53.7	93.2	99.5	100	100

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Embeddedness						
Transect	**Emb. 1**	**Emb. 2**	**Emb. 3**	**Emb. 4**	**Emb. 5**	Avg.
1	40	50	50	60	40	48.0
2	50	50	50	50	60	52.0
3	60	50	50	50	40	50.0
4	50	60	50	60	40	52.0
5	50	50	50	20	40	42.0
6	30	50	40	50	40	42.0
7	50	20	30	50	40	38.0
8	40	30	50	30	30	36.0
9	40	30	40	40	40	38.0
10	100	30	40	50	30	50.0
					Total Avg.	**44.8**

Algae Data								
Transect	**25% Fil. Cover**	**25% Diatom Presence**	**25% Filamentous Presence**	**25% Diatom Thickness (categorical)**	**50% Fil. Cover**	**50% Diatom Presence**	**50% Filamentous Presence**	**50% Diatom Thickness (categorical)**
1	4	x	x	0.5	12	x	x	1
2	0	x		4	0	x		0.5
3	8	x	x	1	12	x	x	3
4	0	x		3	0	x		3
5	0	x		1	0	x		1
6	0	x		3	0	x		3
7	0	x		3	0	x		2
8	0	x		0.5	0	x		2
9	0	x		2	0	x		1
10	0	x		1	0	x		1
average/count	1.2	10	2	1.9	2.4	10	2	1.8

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Algae Data				
Transect	**75% Fil. Cover**	**75% Diatom Presence**	**75% Filamentous Presence**	**75% Diatom Thickness (categorical)**
1	12	x	x	1
2	16	x	x	3
3	0	x		3
4	0	x		2
5	0	x		3
6	16	x	x	1
7	4	x	x	0.5
8	0	x		2
9	0	x		1
10	0	x		1
average/count	4.8	10	4	1.8

Total avg. Fil. Cover	2.8
Total avg. Diatom Presence	100.0
Total avg. Fil. Presence	26.7
Mean Diatom Thickness	1.8

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Site: FR-1.9
Date: 9/25/2019
Notes:

Transect Substrate Count								
	Fines	**Sm. Gravel**	**Gravel**	**Sm. Cobble**	**Cobble**	**Sm. Boulder**	**Boulder**	**Bedrock**
Transect	**<2mm**	**2-8mm**	**8-64mm**	**64-128mm**	**128-256mm**	**256-512mm**	**>512mm**	**Bedrock**
1	3		7	5	15	9		
2	1		11	21	5	2		
3	6	2	2	18	9	3		
4	6	1	2	14	15	2		
5	6	2	11	9	10	2		
6	2	2	10	16	9	1		
7	8	2	10	11	8	1		
8	1	4	17	13	4	1		
9	1	1	10	18	8	2		
10	1	1	11	18	6	3		
total	35	15	91	143	89	26	0	0
% of total	8.8	3.8	22.8	35.8	22.3	6.5	0	0

	Fines	**Sm. Gravel**	**Gravel**	**Sm. Cobble**	**Cobble**	**Sm. Boulder**	**Boulder**	**Bedrock**
	<2mm	**2-8mm**	**8-64mm**	**64-128mm**	**128-256mm**	**256-512mm**	**>512mm**	**Bedrock**
Point Bar Deposition				4	15	10		
% of total	0	0	0	13.8	51.7	34.5	0	0
200 Riffle Count	1	3	42	101	42	11		
% of total	0.5	1.5	21	50.5	21	5.5	0	0
cumulative percent	0.5	2	23	73.5	94.5	100	100	100

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Embeddedness						
Transect	**Emb. 1**	**Emb. 2**	**Emb. 3**	**Emb. 4**	**Emb. 5**	Avg.
1	30	15	40	20	10	23.0
2	30	15	50	50		36.3
3	40	50	50			46.7
4	30	50	50	40		42.5
5	55	40	30	30		38.8
6	55	65	50	50		55.0
7	35	90	60	55		60.0
8	30	15	20	40		26.3
9	40	40	35	50		41.3
10	50	35	30	30		36.3
					Total Avg.	**40**

Algae Data								
Transect	**25% Fil. Cover**	**25% Diatom Presence**	**25% Filamentous Presence**	**25% Diatom Thickness (categorical)**	**50% Fil. Cover**	**50% Diatom Presence**	**50% Filamentous Presence**	**50% Diatom Thickness (categorical)**
1	80	x	x	0.5	8	x	x	0.5
2	4	x		0.5	16	x	x	0.5
3	0	x		0.5	0	x		0.5
4	8	x	x	2	24	x	x	1
5	9	x	x	0.5	2	x	x	0.5
6	0	x		0.5	6	x	x	0.5
7	24	x	x	2	0	x		0.5
8	0	x		0.5	69	x	x	0.5
9	0	x		0.5	16	x	x	2
10	4	x	x	0.5	8	x	x	0.5
average/count	12.9	10	5	0.8	14.9	10	8	0.7

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Algae Data				
Transect	75% Fil. Cover	75% Diatom Presence	75% Filamentous Presence	75% Diatom Thickness (categorical)
1	0	x		0.5
2	4	x	x	0.5
3	20	x	x	0.5
4	20	x	x	0.5
5	0	x		0.5
6	12	x	x	0.5
7	0	x		0.5
8	8	x	x	0.5
9	0	x		0.5
10	16	x	x	2
average/count	8	10	6	0.7

Total avg. Fil. Cover	11.9
Total avg. Diatom Presence	100.0
Total avg. Fil. Presence	63.3
Mean Diatom Thickness	0.72

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Site: FR-14
Date: 9/25/2019
Notes: Worked US to DS, so transects are backwards

Transect Substrate Count								
	Fines	**Sm. Gravel**	**Gravel**	**Sm. Cobble**	**Cobble**	**Sm. Boulder**	**Boulder**	**Bedrock**
Transect	**<2mm**	**2-8mm**	**8-64mm**	**64-128mm**	**128-256mm**	**256-512mm**	**>512mm**	**Bedrock**
10	1		15	12	5	9		
9	5	2	6	6	17	3		
8	4	3	7	9	13	3	1	
7		2	8	12	14	4		
6	1	1	6	17	16	4	1	
5	4	2	7	10	16	2		
4	2	1	10	12	12	3		
3	1	7	12	10	8	2		
2	1	1	14	10	12	2		
1	5	2	10	9	13	1		
total	24	21	95	107	126	33	2	0
% of total	5.9	5.1	23.3	26.2	30.9	8.1	0.5	0

	Fines	**Sm. Gravel**	**Gravel**	**Sm. Cobble**	**Cobble**	**Sm. Boulder**	**Boulder**	**Bedrock**
	<2mm	**2-8mm**	**8-64mm**	**64-128mm**	**128-256mm**	**256-512mm**	**>512mm**	**Bedrock**
Point Bar Deposition					16	4		
% of total	0	0	0	0	80	20	0	0
200 Riffle Count	1	3	35	97	67	1		
% of total	0.5	1.5	17.2	47.5	32.8	0.5	0	0
cumulative percent	0.5	2	19.2	66.7	99.5	100	100	100

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Embeddedness						
Transect	**Emb. 1**	**Emb. 2**	**Emb. 3**	**Emb. 4**	**Emb. 5**	Avg.
10	30	30	40	20	20	28.0
9	55	40	40	40	50	45.0
8	40	30	40	50	20	36.0
7	15	40	30	20	20	25.0
6	20	20	65	40	20	33.0
5	40	40	60	60	60	52.0
4	40	40	50	40	50	44.0
3	70	75	40	50	30	53.0
2	60	50	30	40	40	44.0
1	40	45	50	40	50	45.0
					Total Avg.	**40.5**

Algae Data								
Transect	**25% Fil. Cover**	**25% Diatom Presence**	**25% Filamentous Presence**	**25% Diatom Thickness (categorical)**	**50% Fil. Cover**	**50% Diatom Presence**	**50% Filamentous Presence**	**50% Diatom Thickness (categorical)**
10	8	x	x	1	0	x		0.5
9	0	x		3	8	x	x	0.5
8	40	x	x	0.5	12	x	x	0.5
7	40	x		0.5	50	x	x	0.5
6	52	x	x	0.5	60	x	x	0.5
5	56	x	x	0.5	52	x	x	0.5
4	6	x	x	0.5	24	x	x	0.5
3	0	x		3	28	x	x	0.5
2	44	x	x	0.5	64	x	x	0.5
1	24	x	x	2	11	x	x	0.5
average/count	27	10	7	1.2	30.9	10	9	0.5

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Algae Data				
Transect	75% Fil. Cover	75% Diatom Presence	75% Filamentous Presence	75% Diatom Thickness (categorical)
10	25	x	x	0.5
9	25	x	x	0.5
8	50	x	x	0.5
7	68	x	x	0.5
6	52	x	x	0.5
5	80	x	x	0.5
4	100	x	x	0.5
3	56	x	x	0.5
2	48	x	x	0.5
1	88	x	x	0.5
average/count	59.2	10	10	0.5

Total avg. Fil. Cover	39
Total avg. Diatom Presence	100.0
Total avg. Fil. Presence	86.7
Mean Diatom Thickness	0.73

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Site: FR-15
Date: 9/26/2019
Notes: Started above split channel

Transect Substrate Count								
	Fines	Sm. Gravel	Gravel	Sm. Cobble	Cobble	Sm. Boulder	Boulder	Bedrock
Transect	**<2mm**	**2-8mm**	**8-64mm**	**64-128mm**	**128-256mm**	**256-512mm**	**>512mm**	**Bedrock**
1	4		9	10	3	8	6	
2	3	2	7	10	11	11		
3	1	1	5	15	12	6		
4	2	1	5	3	21	8		
5	6	2	9	12	7	4		
6			5	9	16	7	2	
7	4	1	19	15	1			
8	8	2	12	7	6	3	2	
9	2	1	12	12	8	5		
10	24		3	5	5	3		
total	54	10	86	98	90	55	10	0
% of total	13.4	2.5	21.3	24.3	22.3	13.6	2.5	0

	Fines	Sm. Gravel	Gravel	Sm. Cobble	Cobble	Sm. Boulder	Boulder	Bedrock
	<2mm	**2-8mm**	**8-64mm**	**64-128mm**	**128-256mm**	**256-512mm**	**>512mm**	**Bedrock**
Point Bar Deposition				12	3			
% of total	0	0	0	80	20	0	0	0
200 Riffle Count	4	1	62	85	36	10	2	
% of total	2	0.5	31	42.5	18	5	1	0
cumulative percent	2	2.5	33.5	76	94	99	100	100

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Embeddedness						
Transect	**Emb. 1**	**Emb. 2**	**Emb. 3**	**Emb. 4**	**Emb. 5**	Avg.
1	30	40	40	60	30	40.0
2	30	50	30	50	30	38.0
3	40	60	30	30	60	44.0
4	25	30	50	80	40	45.0
5	40	60	50	60	50	52.0
6	50	50	30	60	40	46.0
7	40	30	60	50	70	50.0
8	20	50	50	70	70	52.0
9	50	40	50	40	40	44.0
10	30	30	80	80	70	58.0
					Total Avg.	**46.9**

Algae Data								
Transect	**25% Fil. Cover**	**25% Diatom Presence**	**25% Filamentous Presence**	**25% Diatom Thickness (categorical)**	**50% Fil. Cover**	**50% Diatom Presence**	**50% Filamentous Presence**	**50% Diatom Thickness (categorical)**
1	52	x	x	2	40	x	x	2
2	56	x	x	2	8	x	x	2
3	68	x	x	2	58	x	x	2
4	8	x	x	2	32	x	x	2
5	36	x	x	2	0	x		3
6	24	x	x	1	48	x	x	1
7	0	x		3	0	x		3
8	84	x	x	4	96	x	x	4
9	16	x	x	5	56	x	x	3
10	0			0	0			0
average/count	34.4	9	8	2.3	33.8	9	7	2.2

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Algae Data				
Transect	**75% Fil. Cover**	**75% Diatom Presence**	**75% Filamentous Presence**	**75% Diatom Thickness (categorical)**
1	56	x	x	2
2	16	x	x	2
3	46	x	x	2
4	0	x		3
5	8	x	x	4
6	8	x	x	1
7	0	x		4
8	96	x	x	4
9	16	x	x	2
10	0			0
average/count	24.6	9	7	2.4

Total avg. Fil. Cover	30.9
Total avg. Diatom Presence	90.0
Total avg. Fil. Presence	73.3
Mean Diatom Thickness	2.3

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Site: FR-20
Date: 9/25/2019
Notes:

Transect Substrate Count								
	Fines	Sm. Gravel	Gravel	Sm. Cobble	Cobble	Sm. Boulder	Boulder	Bedrock
Transect	**<2mm**	**2-8mm**	**8-64mm**	**64-128mm**	**128-256mm**	**256-512mm**	**>512mm**	**Bedrock**
1	7	2	11	11	5	3	1	
2	7		8	13	4	6	2	
3	7	2	8	11	6	5	1	
4	17		2	10	9		2	
5	3	4	6	8	10	5	4	
6	4	1	10	8	9	5	3	
7	2	4	10	16	3	5		
8		1	5	10	10	8	6	
9	8	2	7	17	5	1		
10	7		5	11	8	9		
total	62	16	72	115	69	47	19	0
% of total	15.5	4	18	28.8	17.3	11.8	4.8	0

	Fines	Sm. Gravel	Gravel	Sm. Cobble	Cobble	Sm. Boulder	Boulder	Bedrock
	<2mm	**2-8mm**	**8-64mm**	**64-128mm**	**128-256mm**	**256-512mm**	**>512mm**	**Bedrock**
Point Bar Deposition				9	5	1		
% of total	0	0	0	60	33.3	6.7	0	0
200 Riffle Count	12	16	33	85	27	14	13	
% of total	6	8	16.5	42.5	13.5	7	6.5	0
cumulative percent	6	14	30.5	73	86.5	93.5	100	100

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Embeddedness						
Transect	**Emb. 1**	**Emb. 2**	**Emb. 3**	**Emb. 4**	**Emb. 5**	Avg.
1	35	45	70	40	30	44.0
2	50	60	40	50	65	53.0
3	40	15	50	40	40	37.0
4	50	60	50	70	50	56.0
5	25	30	40	20	30	29.0
6	55	40	5	50	40	38.0
7	25	50	20	50	30	35.0
8	30	40	20	20	30	28.0
9	50	10	10	15	20	21.0
10	40	35	20	30	40	33.0
					Total Avg.	**37.4**

Algae Data								
Transect	**25% Fil. Cover**	**25% Diatom Presence**	**25% Filamentous Presence**	**25% Diatom Thickness (categorical)**	**50% Fil. Cover**	**50% Diatom Presence**	**50% Filamentous Presence**	**50% Diatom Thickness (categorical)**
1	0	x		0.5	0	x		0.5
2	0	x		0.5	0	x		0.5
3	0	x		0.5	0	x		0.5
4	0	x		0.5	0	x		0.5
5	0	x		0.5	0	x		0.5
6	0	x		0.5	0	x		0.5
7	0	x		0.5	0	x		0.5
8	0	x		0.5	0	x		0.5
9	0	x		0.5	0	x		0.5
10	0	x		0.5	0	x		0.5
average/count	0	10	0	0.5	0	10	0	0.5

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Algae Data				
Transect	**75% Fil. Cover**	**75% Diatom Presence**	**75% Filamentous Presence**	**75% Diatom Thickness (categorical)**
1	0	x		0.5
2	0	x		0.5
3	0	x		1
4	0	x		0.5
5	0	x		0.5
6	0	x		0.5
7	0	x		0.5
8	0	x		0.5
9	0	x		0.5
10	0	x		0.5
average/count	0	10	0	0.6

Total avg. Fil. Cover	0
Total avg. Diatom Presence	100.0
Total avg. Fil. Presence	0.0
Mean Diatom Thickness	0.52

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Site: FR-23.2
Date: 9/25/2019
Notes:

Transect Substrate Count								
	Fines	Sm. Gravel	Gravel	Sm. Cobble	Cobble	Sm. Boulder	Boulder	Bedrock
Transect	**<2mm**	**2-8mm**	**8-64mm**	**64-128mm**	**128-256mm**	**256-512mm**	**>512mm**	**Bedrock**
1			20	17	3	1		
2			8	14	16	2		
3	8	4	13	5	8	2		
4	4		8	11	16		1	
5	2	2	11	8	18			
6	2	1	2	14	18	2	1	
7		1	10	15	11	2	1	
8	1	1	13	18	6	1		
9	1	1	9	13	13	2	1	
10	1		5	27	5	2	1	
total	19	10	99	142	114	14	5	0
% of total	4.7	2.5	24.6	35.2	28.3	3.5	1.2	0

	Fines	Sm. Gravel	Gravel	Sm. Cobble	Cobble	Sm. Boulder	Boulder	Bedrock
	<2mm	**2-8mm**	**8-64mm**	**64-128mm**	**128-256mm**	**256-512mm**	**>512mm**	**Bedrock**
Point Bar Deposition				8	8			
% of total	0	0	0	50	50	0	0	0
200 Riffle Count	2	2	44	95	55	1	1	
% of total	1	1	22	47.5	27.5	0.5	0.5	0
cumulative percent	1	2	24	71.5	99	99.5	100	100

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Embeddedness						
Transect	**Emb. 1**	**Emb. 2**	**Emb. 3**	**Emb. 4**	**Emb. 5**	Avg.
1	30	30	25	30	40	31.0
2	30	60	20	30	20	32.0
3	50	90	15	20	30	41.0
4	30	20	50	50	70	44.0
5	50	40	50	30	50	44.0
6	50	50	20	30	30	36.0
7	50	40	40	50	30	42.0
8	30	20	30	40	50	34.0
9	50	40	50	60	20	44.0
10	40	50	40	50	50	46.0
					Total Avg.	**39.4**

Algae Data								
Transect	**25% Fil. Cover**	**25% Diatom Presence**	**25% Filamentous Presence**	**25% Diatom Thickness (categorical)**	**50% Fil. Cover**	**50% Diatom Presence**	**50% Filamentous Presence**	**50% Diatom Thickness (categorical)**
1	0	x		1	0	x		1
2	0	x		0.5	0	x		0.5
3	0	x		1	0	x		1
4	0	x		0.5	0	x		0.5
5	0	x		0.5	0	x		0.5
6	0	x		1	0	x		1
7	12	x	x	0.5	0	x		1
8	0	x		0	0	x		0
9	0	x		0.5	0	x		1
10	0	x		0.5	0	x		0.5
average/count	1.2	10	1	0.6	0	10	0	0.7

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Algae Data				
Transect	**75% Fil. Cover**	**75% Diatom Presence**	**75% Filamentous Presence**	**75% Diatom Thickness (categorical)**
1	0	x		1
2	0	x		0.5
3	0	x		1
4	0	x		0.5
5	0	x		0.5
6	0	x		1
7	0	x		0.5
8	0	x		0
9	0	x		1
10	100		x	0
average/count	10	9	1	0.6

Total avg. Fil. Cover	3.7
Total avg. Diatom Presence	96.7
Total avg. Fil. Presence	6.7
Mean Diatom Thickness	0.63

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Site: FR-25.1
Date: 9/25/2019
Notes: very high gradient

Transect Substrate Count								
	Fines	**Sm. Gravel**	**Gravel**	**Sm. Cobble**	**Cobble**	**Sm. Boulder**	**Boulder**	**Bedrock**
Transect	**<2mm**	**2-8mm**	**8-64mm**	**64-128mm**	**128-256mm**	**256-512mm**	**>512mm**	**Bedrock**
1	5	1	1	2	2	8	21	
2	2	1	3	1		4	29	
3	2	1	1	6	3	8	19	
4	14	2	2	5	7	2	8	
5	3	1	2	5	1	3	25	
6	5		5	3	2	3	22	
7		1	4		2	6	28	
8		1	5	4	5	8	17	
9	3	4	3	5	7	5	13	
10			3	2	3	12	20	
total	34	12	29	33	32	59	202	0
% of total	8.5	3	7.2	8.2	8	14.7	50.4	0

	Fines	**Sm. Gravel**	**Gravel**	**Sm. Cobble**	**Cobble**	**Sm. Boulder**	**Boulder**	**Bedrock**
	<2mm	**2-8mm**	**8-64mm**	**64-128mm**	**128-256mm**	**256-512mm**	**>512mm**	**Bedrock**
Point Bar Deposition	none, very high gradient							
% of total	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
200 Riffle Count	none, very high gradient							
% of total	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

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Embeddedness						
Transect	**Emb. 1**	**Emb. 2**	**Emb. 3**	**Emb. 4**	**Emb. 5**	Avg.
1	70	30	50	60	60	54.0
2	20	50	80	50	60	52.0
3	70	50	5	30	25	36.0
4	80	50	50	50	30	52.0
5	50	40	20	70	50	46.0
6	50	60	30	40	50	46.0
7	80	70	60	60	50	64.0
8	10	50	60	60	65	49.0
9	65	60	70	60	70	65.0
10	50	60	70	50	40	54.0
					Total Avg.	**51.8**

Algae Data								
Transect	**25% Fil. Cover**	**25% Diatom Presence**	**25% Filamentous Presence**	**25% Diatom Thickness (categorical)**	**50% Fil. Cover**	**50% Diatom Presence**	**50% Filamentous Presence**	**50% Diatom Thickness (categorical)**
1	0	x		0.5	0	x		0.5
2	0	x		0.5	0	x		0.5
3	0	x		0.5	0	x		0.5
4	0	x		0.5	0	x		0.5
5	0	x		0.5	0	x		0.5
6	0	x		0.5	0	x		0.5
7	0	x		0.5	0	x		0.5
8	24	x	x	2	0	x		0.5
9	0	x		0.5	8	x	x	1
10	0	x		0.5	0	x		0.5
average/count	2.4	10	1	0.7	0.8	10	1	0.6

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Algae Data				
Transect	**75% Fil. Cover**	**75% Diatom Presence**	**75% Filamentous Presence**	**75% Diatom Thickness (categorical)**
1	0	x		0.5
2	0	x		0.5
3	0	x		0.5
4	0	x		0.5
5	0	x		0.5
6	0	x		0.5
7	0	x		0.5
8	0	x		0.5
9	0	x		0.5
10	0	x		0.5
average/count	0	10	0	0.5

Total avg. Fil. Cover	1.1
Total avg. Diatom Presence	100.0
Total avg. Fil. Presence	6.7
Mean Diatom Thickness	0.57

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Site: RC-1.1
Date: 9/26/2019
Notes:

Transect Substrate Count								
	Fines	**Sm. Gravel**	**Gravel**	**Sm. Cobble**	**Cobble**	**Sm. Boulder**	**Boulder**	**Bedrock**
Transect	**<2mm**	**2-8mm**	**8-64mm**	**64-128mm**	**128-256mm**	**256-512mm**	**>512mm**	**Bedrock**
1	7		5	9	8	6	5	
2	3	1	14	12	8		2	
3	3	2	10	16	6	3		
4	13	3	10	9	3		2	
5	18	2	2	10	8			
6		1	8	18	13			
7	18	2		9	6	1	4	
8	3	4	9	13	10		1	
9	13	2	18	6	1			
10	6	1	20	6	7			
total	84	18	96	108	70	10	14	0
% of total	21	4.5	24	27	17.5	2.5	3.5	0

	Fines	**Sm. Gravel**	**Gravel**	**Sm. Cobble**	**Cobble**	**Sm. Boulder**	**Boulder**	**Bedrock**
	<2mm	**2-8mm**	**8-64mm**	**64-128mm**	**128-256mm**	**256-512mm**	**>512mm**	**Bedrock**
Point Bar Deposition			2	6	2			
% of total	0	0	20	60	20	0	0	0
200 Riffle Count	14	15	59	70	46			
% of total	6.9	7.4	28.9	34.3	22.5	0	0	0
cumulative percent	6.9	14.3	43.2	77.5	100	100	100	100

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Embeddedness						
Transect	**Emb. 1**	**Emb. 2**	**Emb. 3**	**Emb. 4**	**Emb. 5**	Avg.
1	40	30	40	50	30	38.0
2	60	30	60	50	40	48.0
3	40	50	30	40	30	38.0
4	60	50	70	70	60	62.0
5	70	30	50	60	90	60.0
6	40	40	50	30	30	38.0
7	70	50	100	100	80	80.0
8	30	40	20	60	30	36.0
9	70	40	80	60	50	60.0
10	50	70	50	40	60	54.0
					Total Avg.	**51.4**

Algae Data								
Transect	**25% Fil. Cover**	**25% Diatom Presence**	**25% Filamentous Presence**	**25% Diatom Thickness (categorical)**	**50% Fil. Cover**	**50% Diatom Presence**	**50% Filamentous Presence**	**50% Diatom Thickness (categorical)**
1	12	x	x	3	60	x	x	4
2	12	x	x	3	12	x	x	3
3	0	x		0.5	8	x	x	0.5
4	0	x		0.5	0	x		0.5
5	0	x		0.5	0	x		1
6	4	x	x	1	32	x	x	5
7	12		x	0	0			0
8	0	x		0.5	0	x		0.5
9	0	x		0.5	0	x		0.5
10	0	x		0.5	0	x		0.5
average/count	4	9	4	1	11.2	9	4	1.6

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Algae Data				
Transect	75% Fil. Cover	75% Diatom Presence	75% Filamentous Presence	75% Diatom Thickness (categorical)
1	24	x	x	3
2	0	x	x	0.5
3	16	x	x	0.5
4	12	x	x	0.5
5	12	x	x	0.5
6	4	x	x	0.5
7	0	x		0.5
8	4	x	x	0.5
9	4	x	x	0.5
10	0	x		0.5
average/count	7.6	10	8	0.8

Total avg. Fil. Cover	7.6
Total avg. Diatom Presence	93.3
Total avg. Fil. Presence	53.3
Mean Diatom Thickness	1.1

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Appendix B Long-term Flow Data

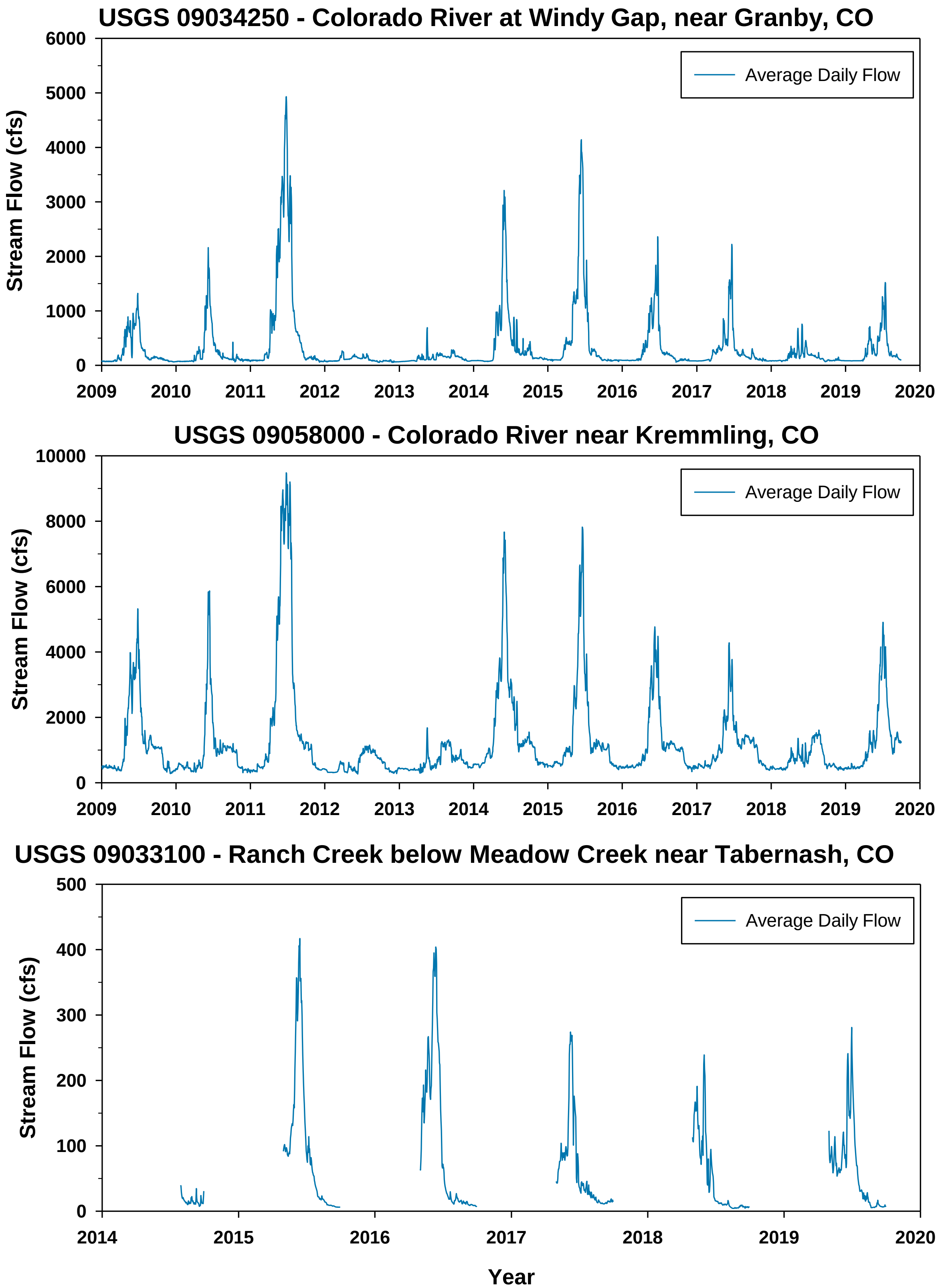

Figure 7-1: Average daily flow data for USGS stream gages on the Colorado River and Ranch Creek in Grand County, CO.

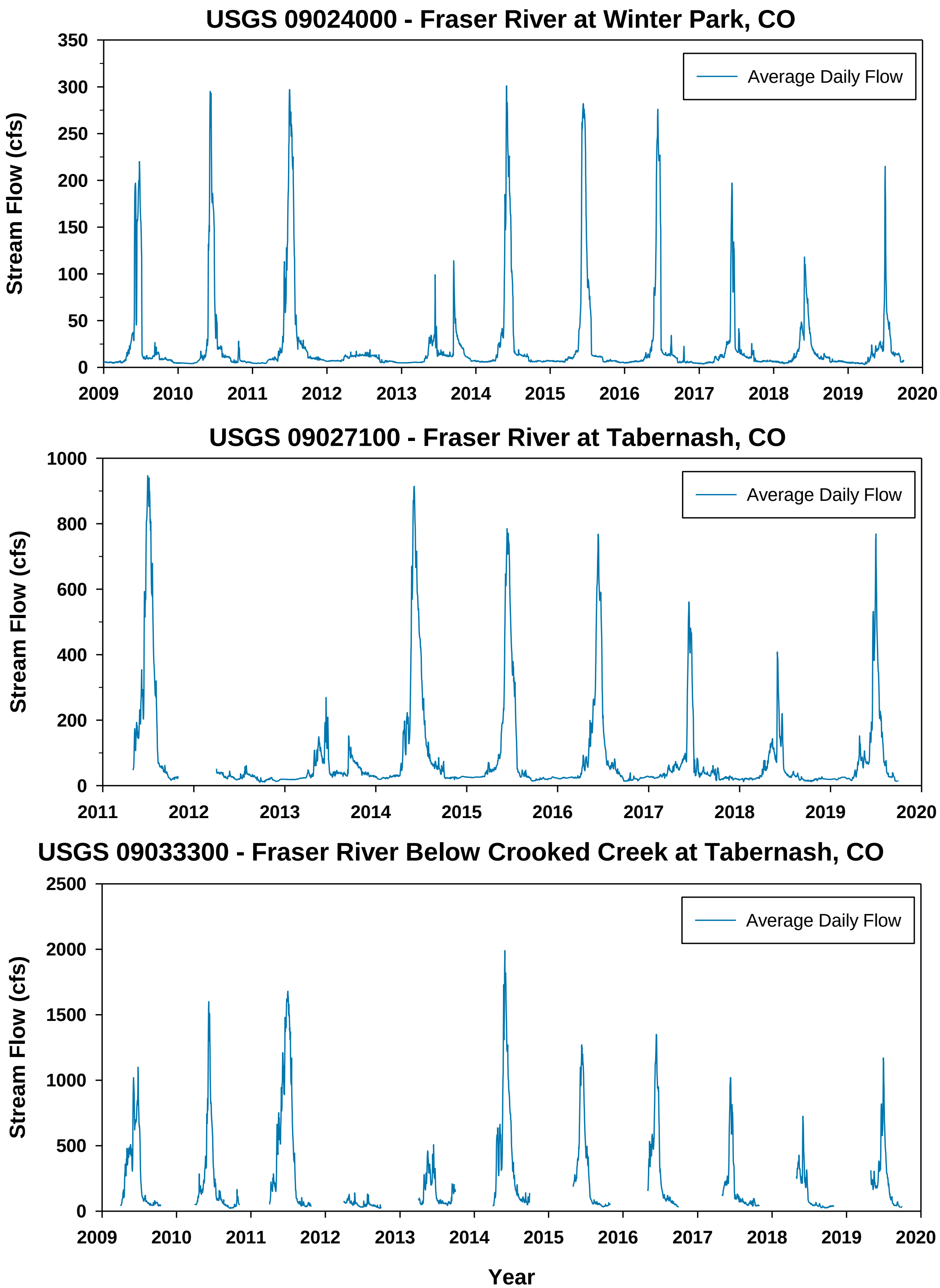

Figure 7-2: Average daily flow data for USGS stream gages on the Fraser River in Grand County, CO.

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GRAND COUNTY

LEARNING BY DOING

Stream Temperature Monitoring Results

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Temperature in the LBD Cooperative Effort Area

2015 – 2019 WEEKLY AVERAGE AND DAILY MAXIMUM DATA COMPILATION

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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

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Overview - Temperature Monitoring in CEA

- 65 sites in the CEA
- Sites maintained by GCWIN, Northern Water, USGS, BLM
- Financial support from many stakeholders
- LBD program supplemental to existing monitoring

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Colorado Temperature Standards

All temperature standards in ºC

Chronic Standard	Acute 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)
	• 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

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New sites

- No new sites in 2019
- Monitored same sites as 2018

Frequency

In 2019, data at six sites were downloaded and/or reviewed 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- 28.7 (Colorado River downstream of Windy Gap)*
- CR-22.1 (Colorado River upstream of Hot Sulphur Water Treatment Plant)*
- CR-16.7 (Colorado River upstream of confluence with Williams Fork)*
- CR-2.3 (Colorado River, HWY 9 Bridge upstream of confluence with Blue River)
- **NEW** - weekly downloads in 2019 in cooperation with BLM

•**Northern Water's real-time temperature monitoring sites.*

2019 LBD Program

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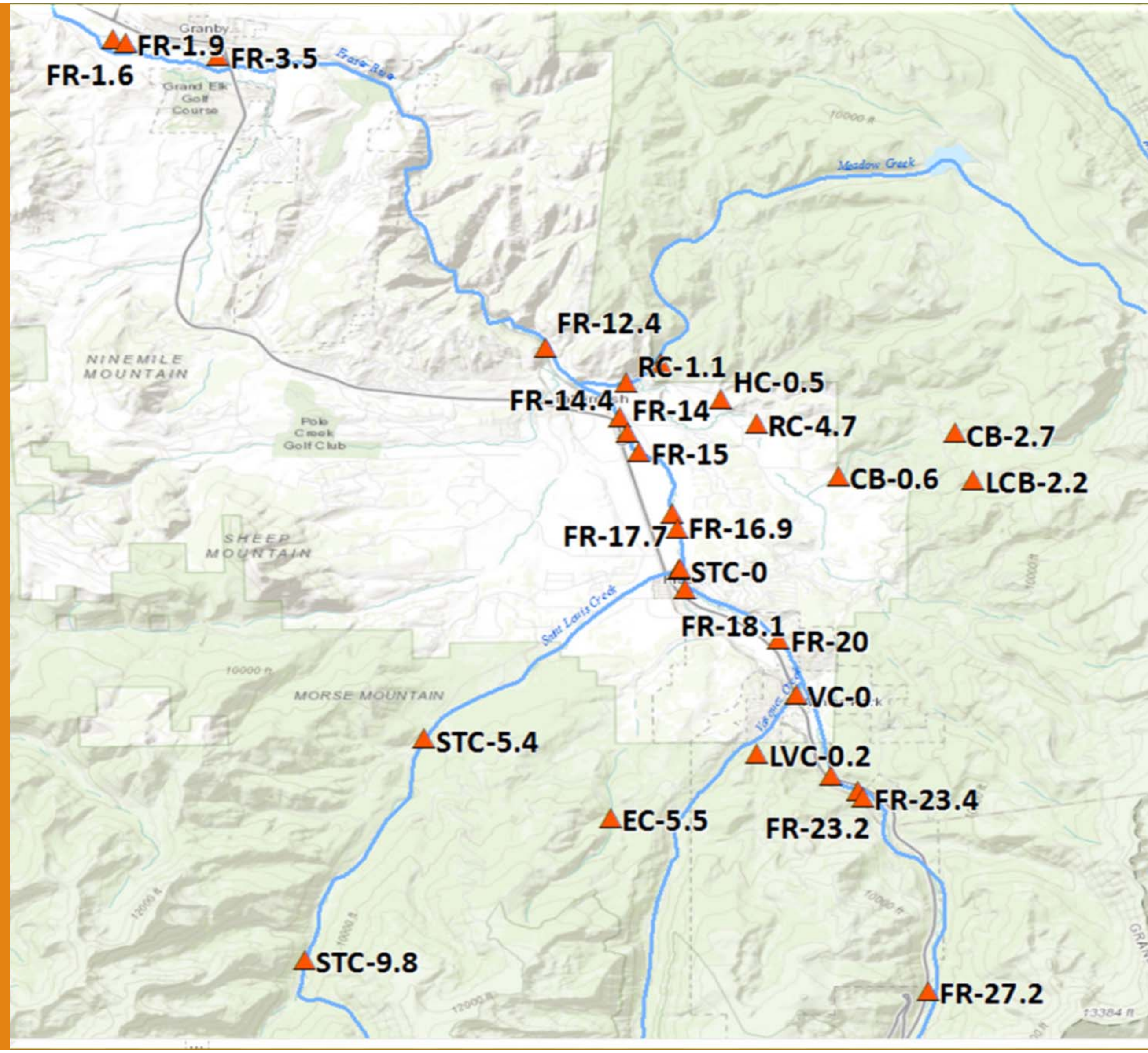
Fraser River and Tributaries



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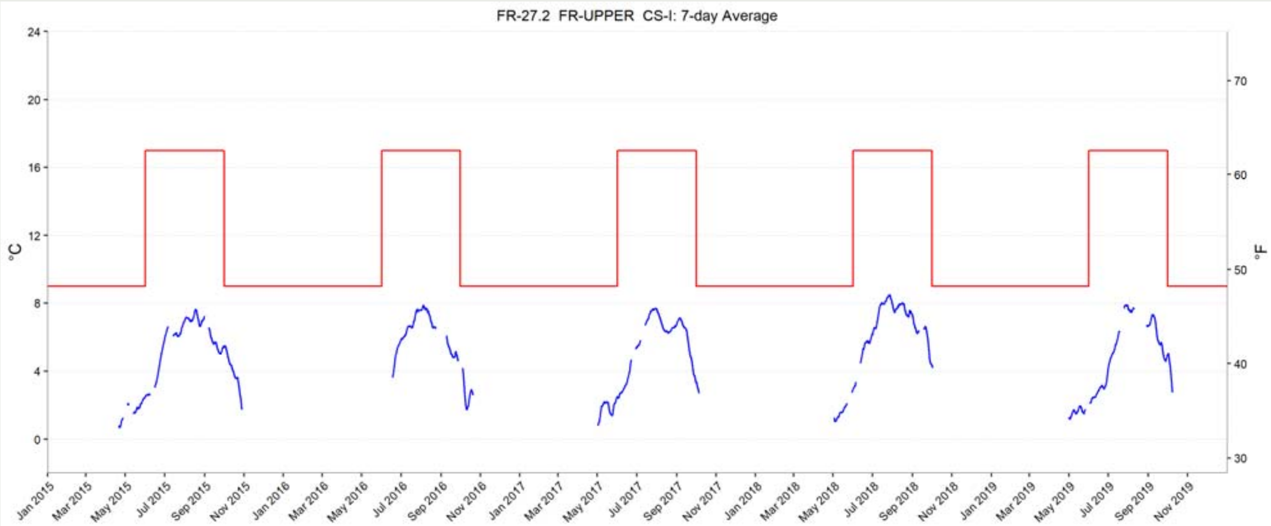
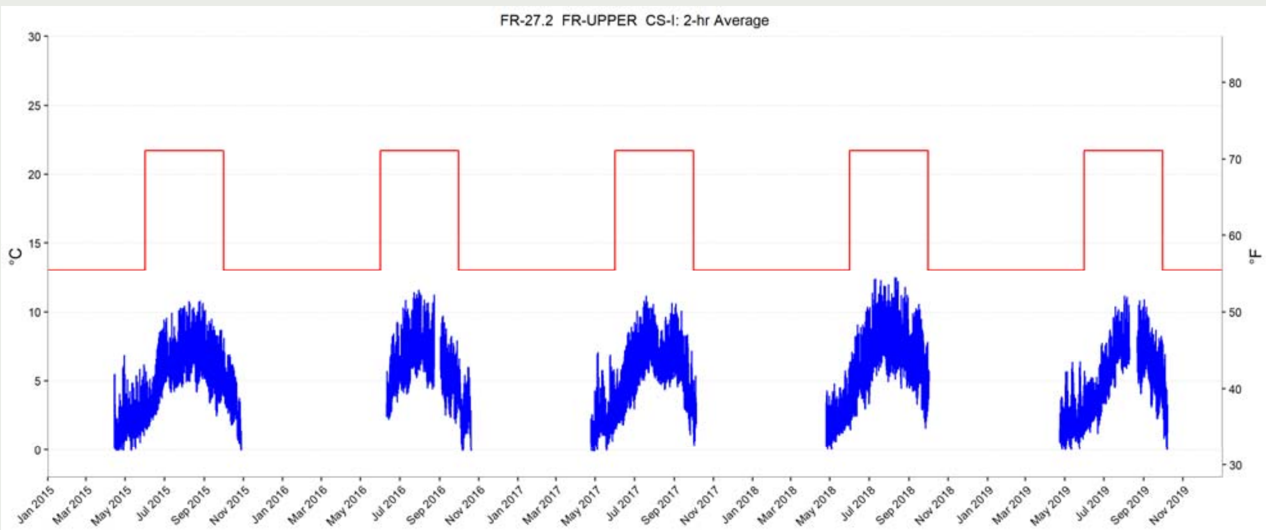
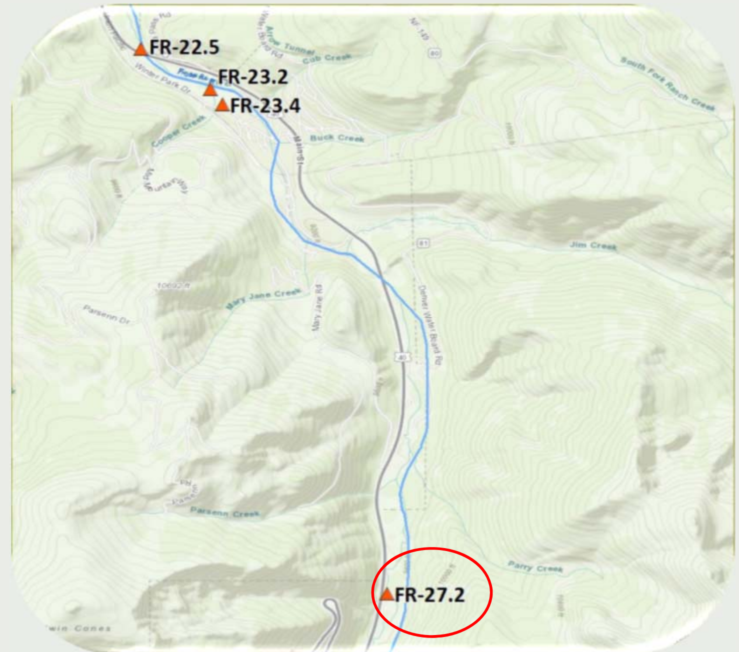
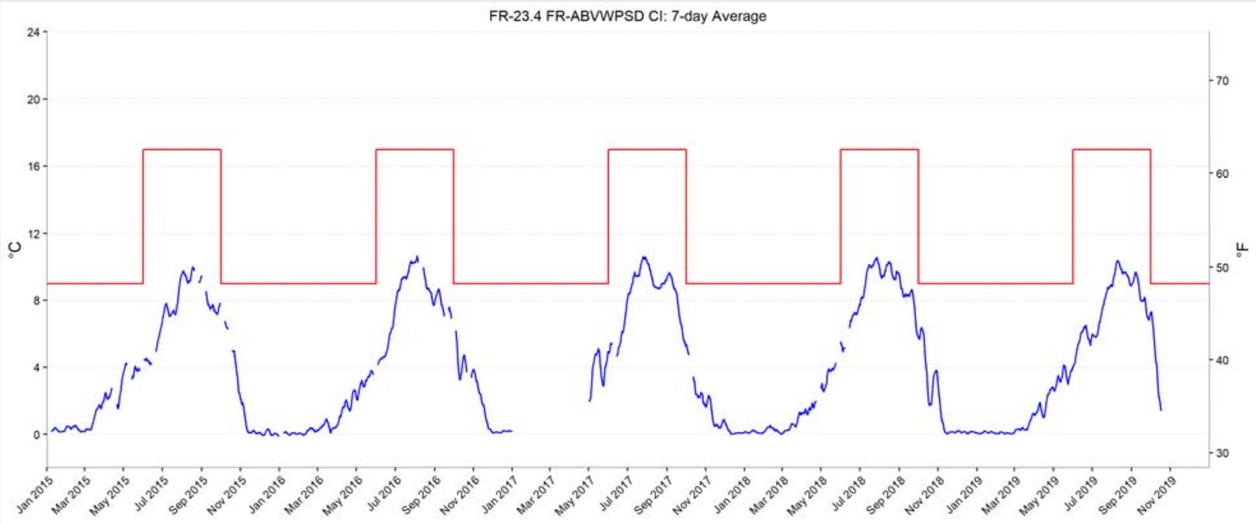


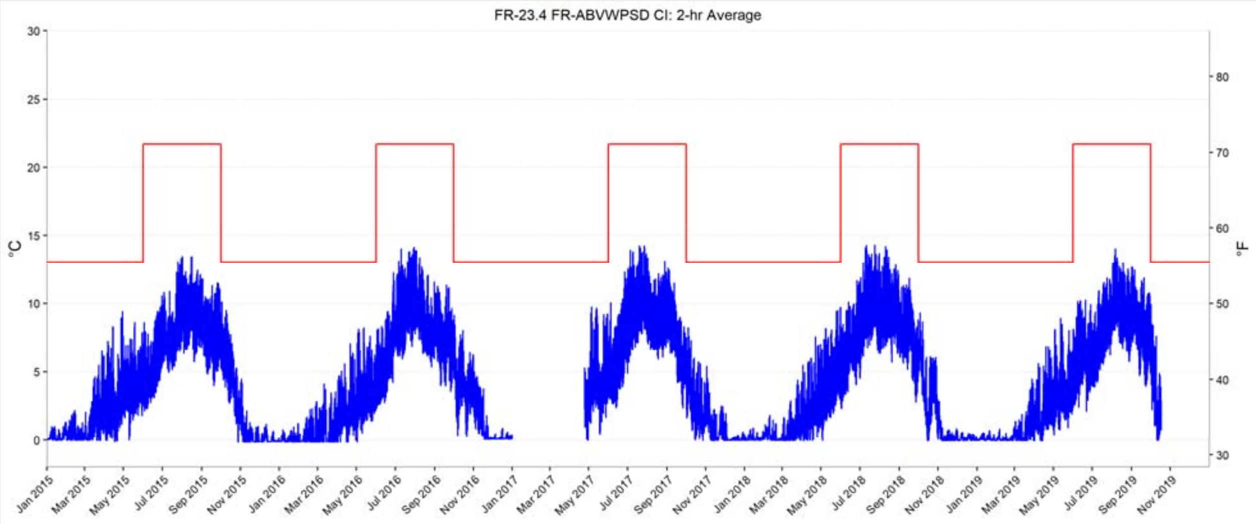


CSI
FR-Upper
FR-27.2

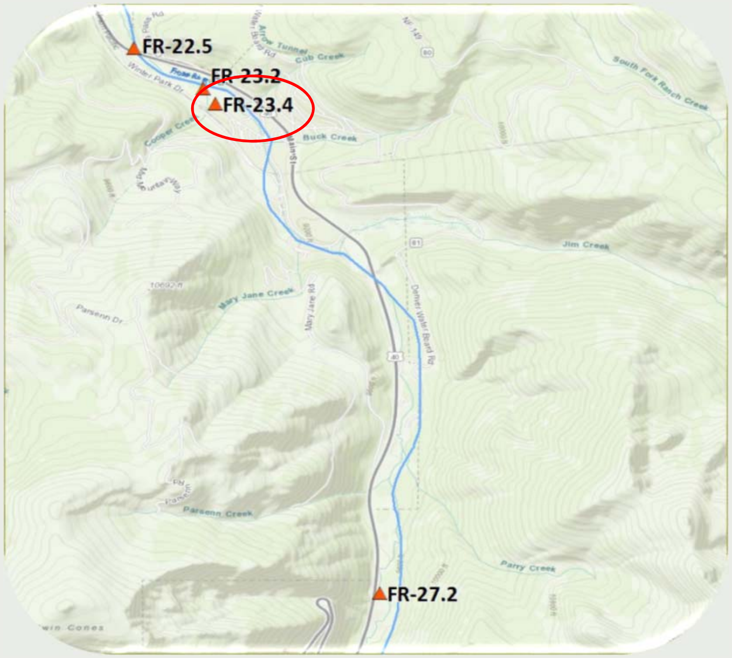


Note: Data gap in 2019 – Sensor found out of water.





CSI
FR-abvWPSD
FR-23.4



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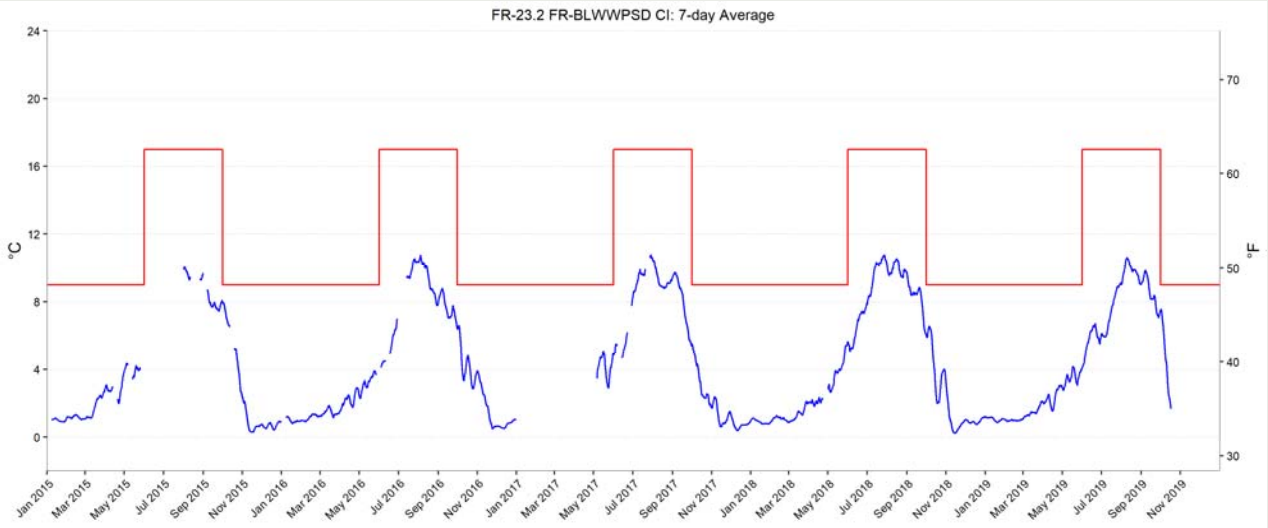
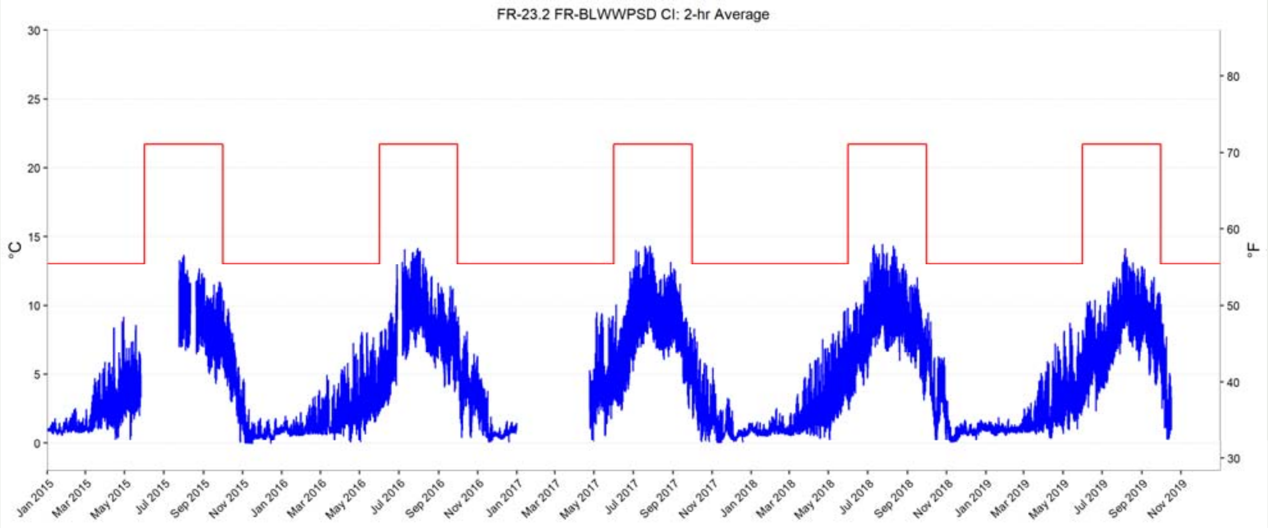
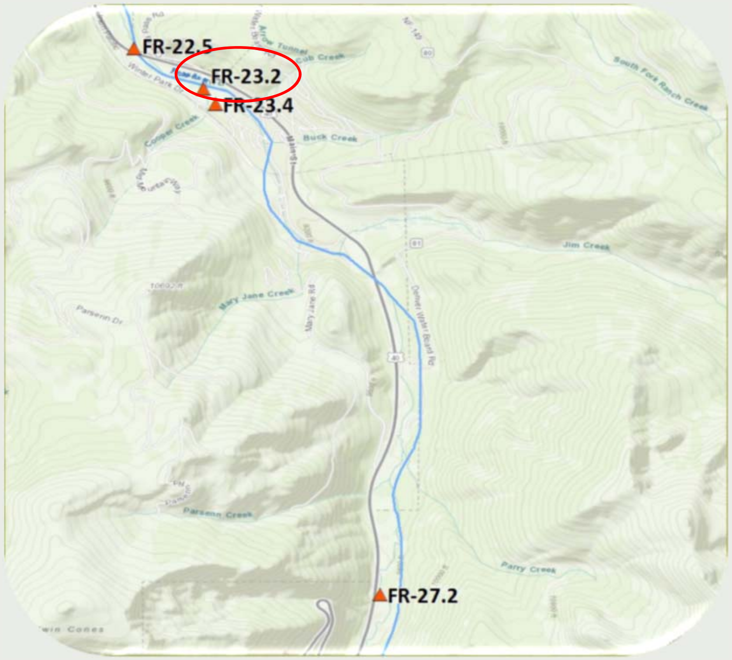




CSI
FR-blwWPSD
FR-23.2



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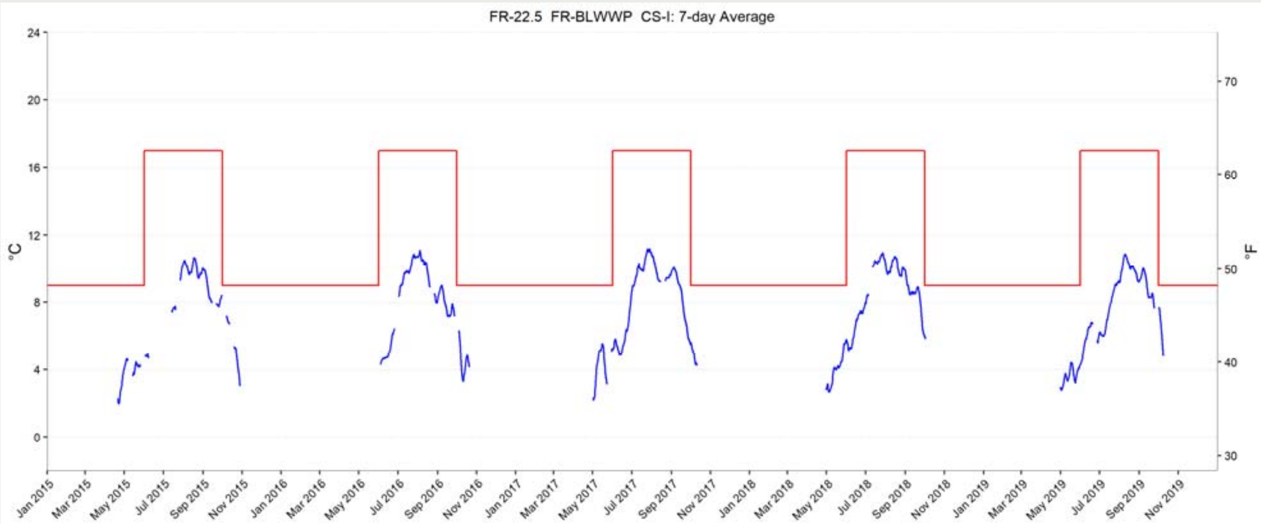
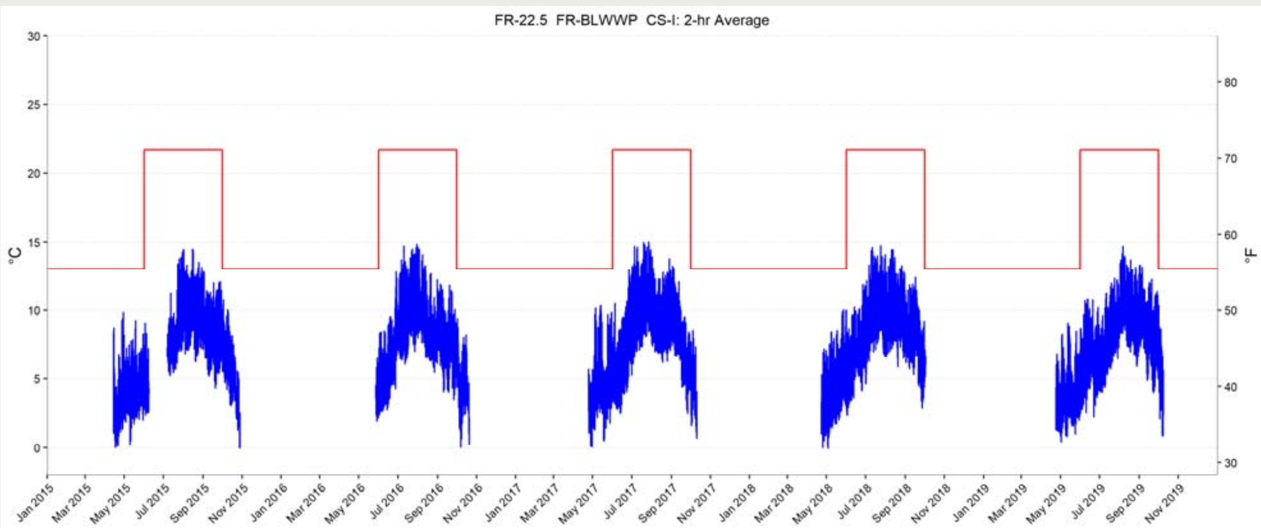
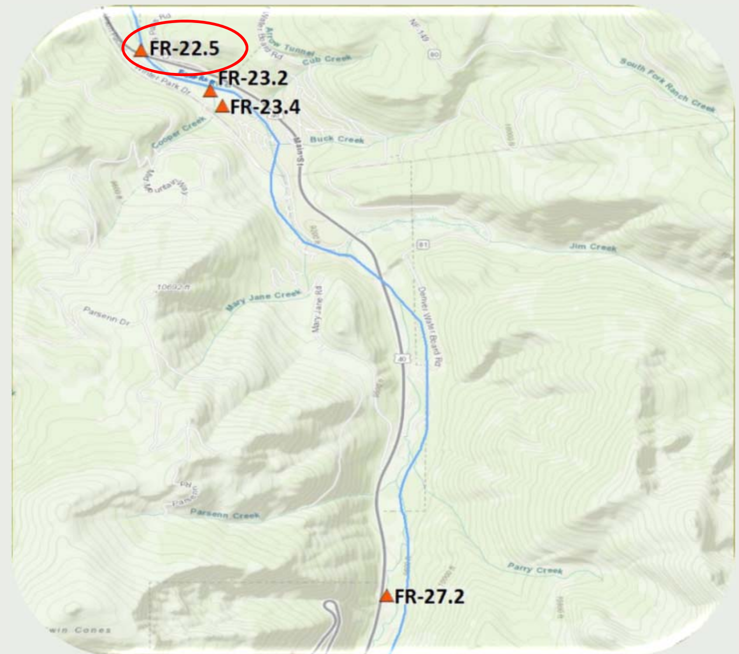




CSI
FR-blwWP
FR-22.5



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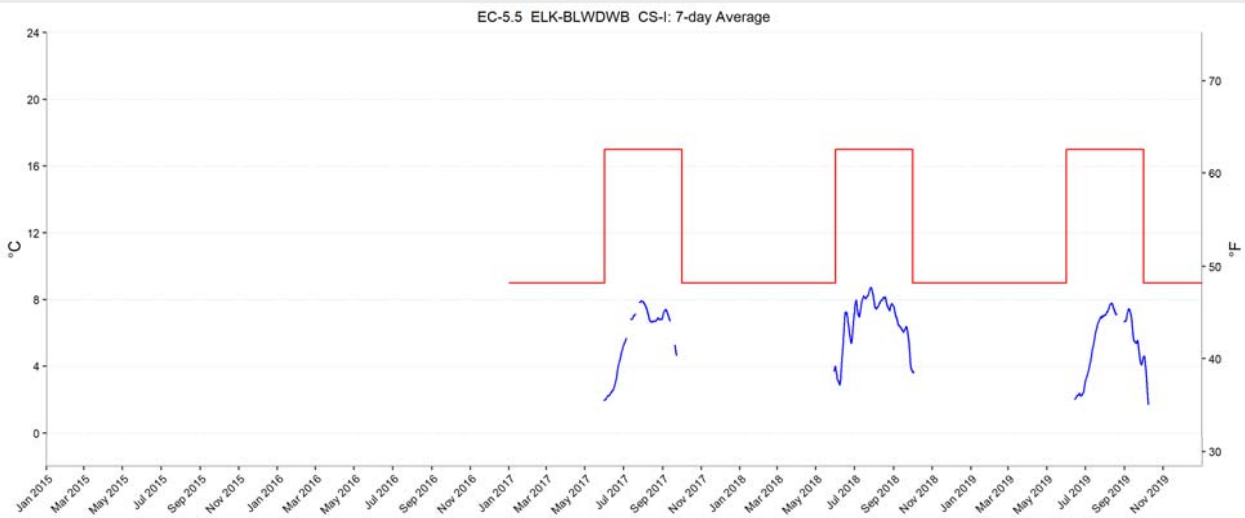
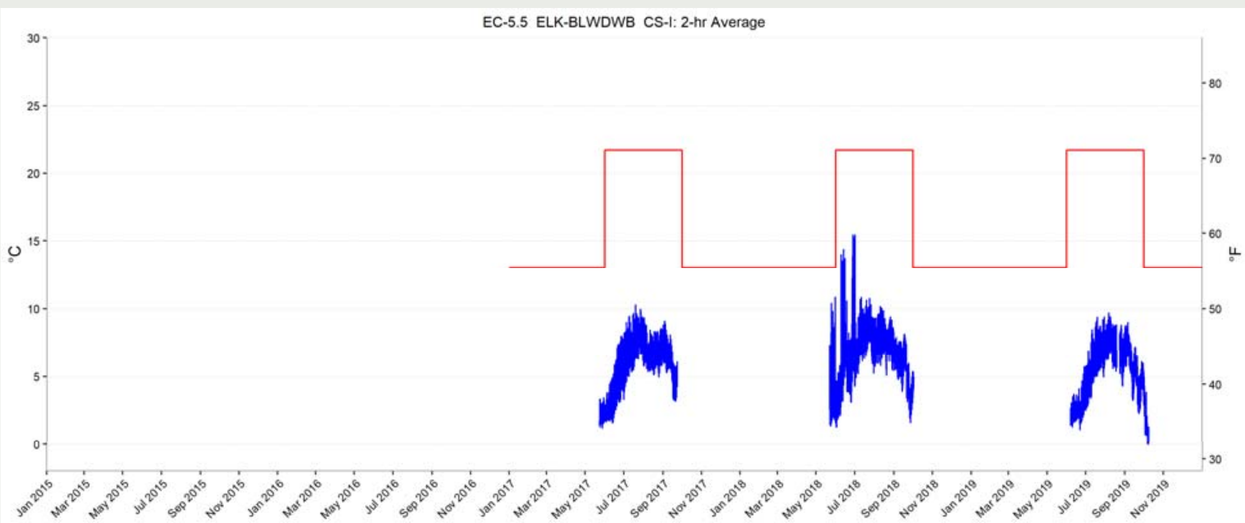
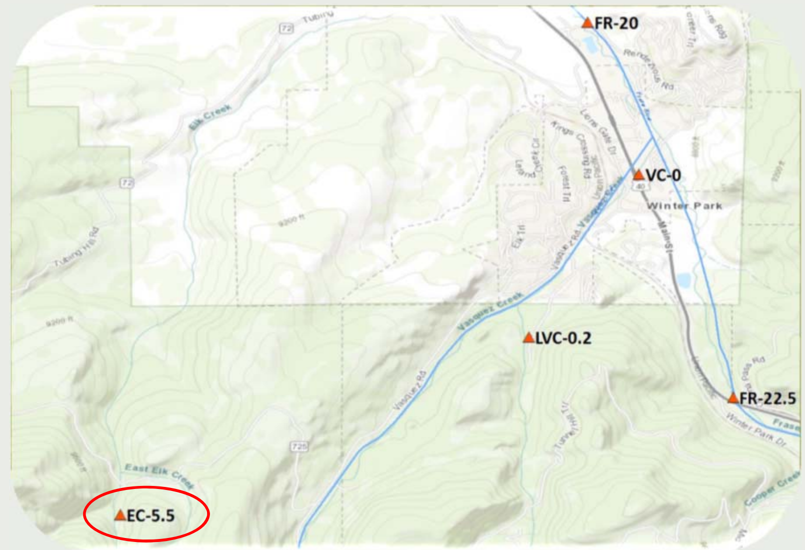
CSI
Elk-blwDWB
EC-5.5







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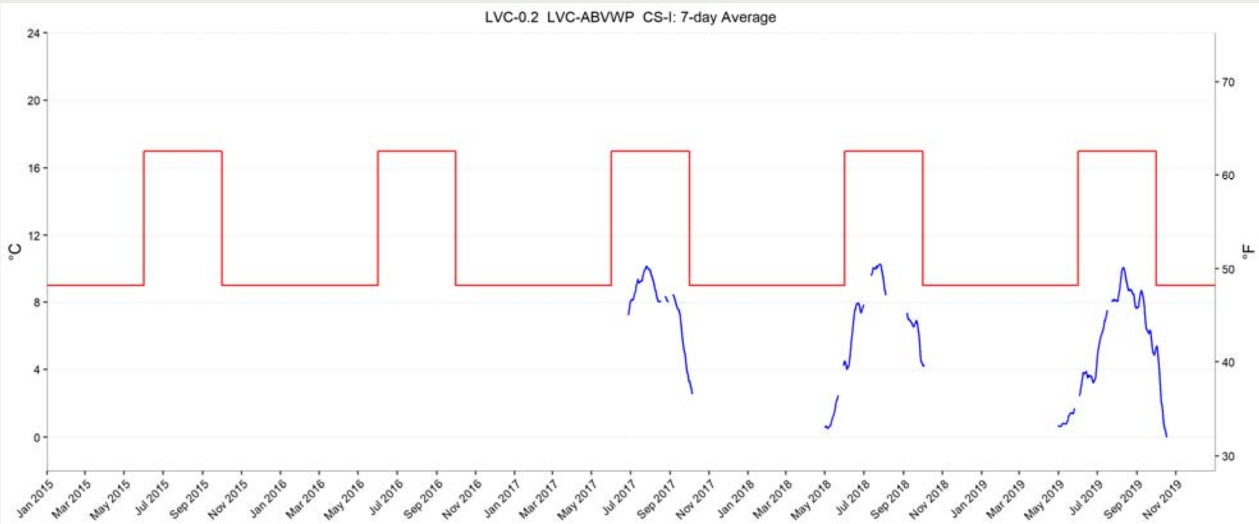
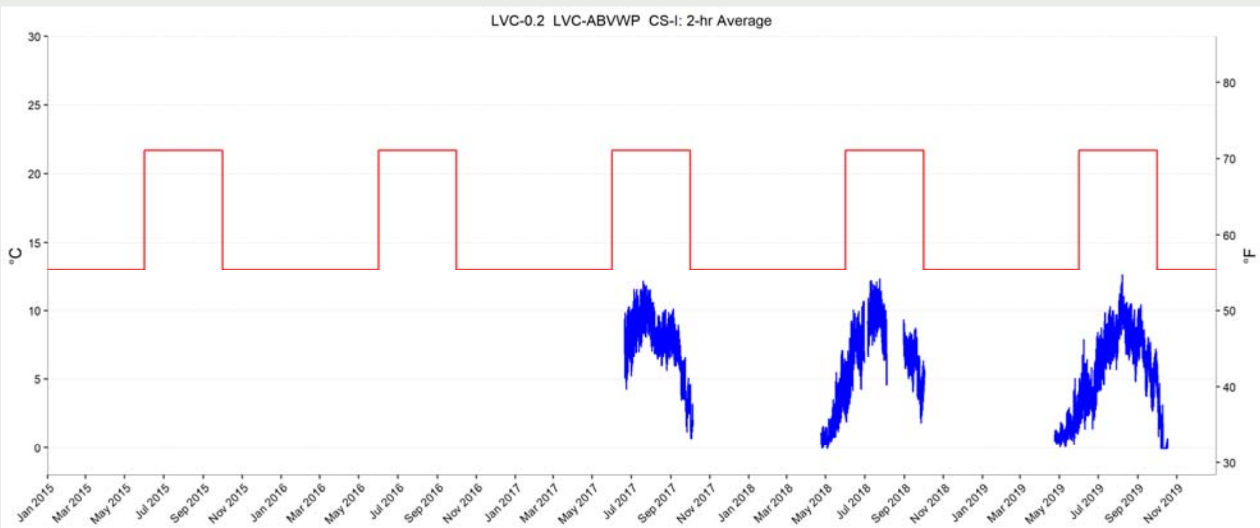
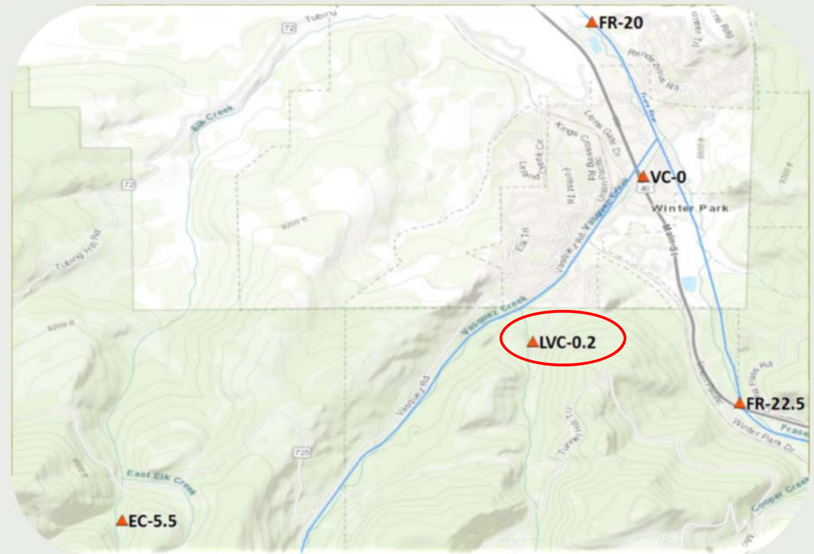




CSI
LVC-abvWP
LVC-0.2



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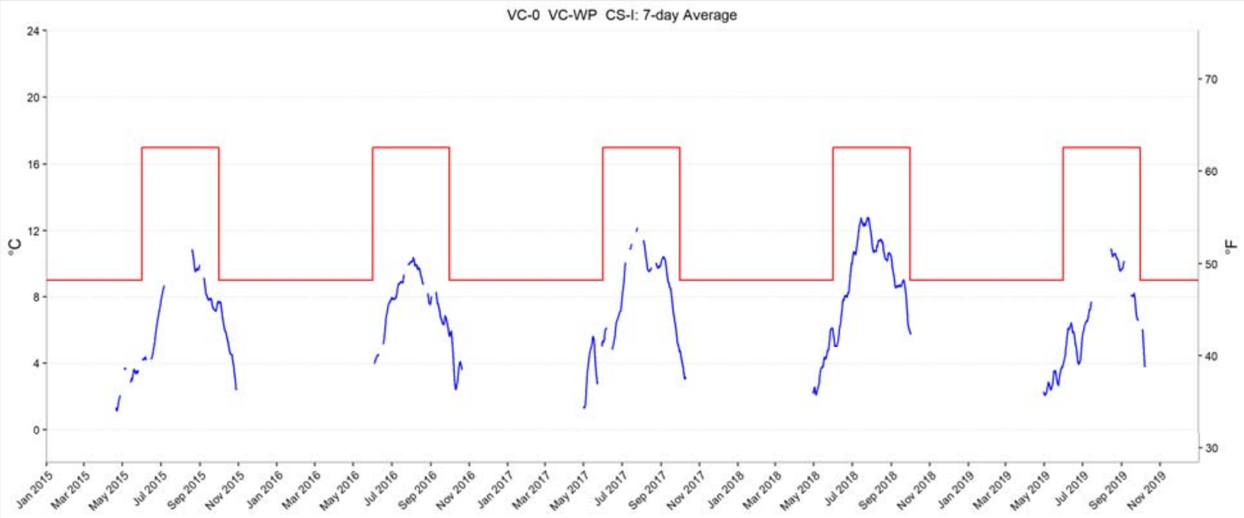
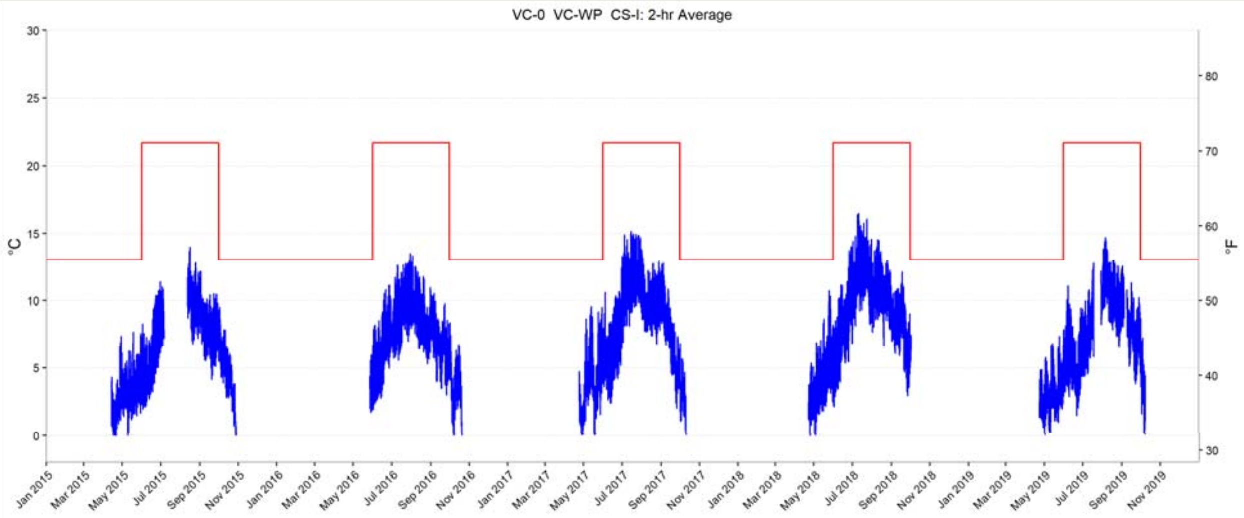
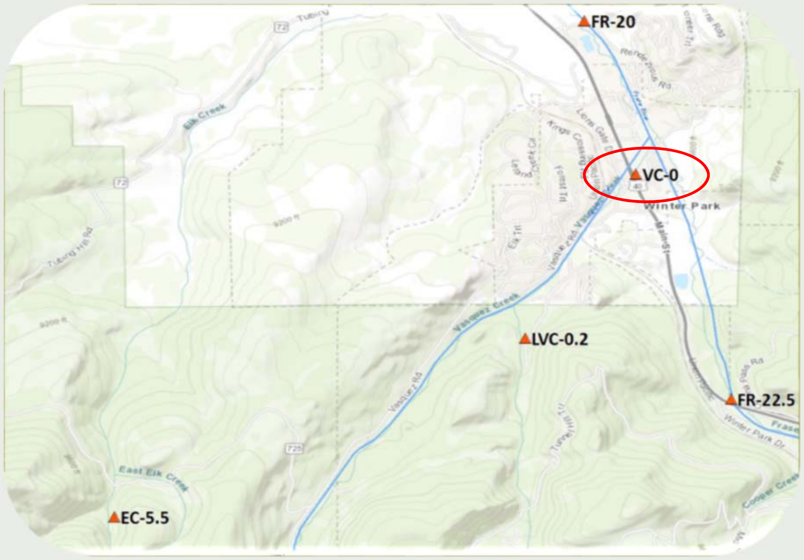




CSI
VC-WP
VC-0



Note: Data gap in 2019 – Sensor found out of water. This site is in a highly trafficked area beside a town park.

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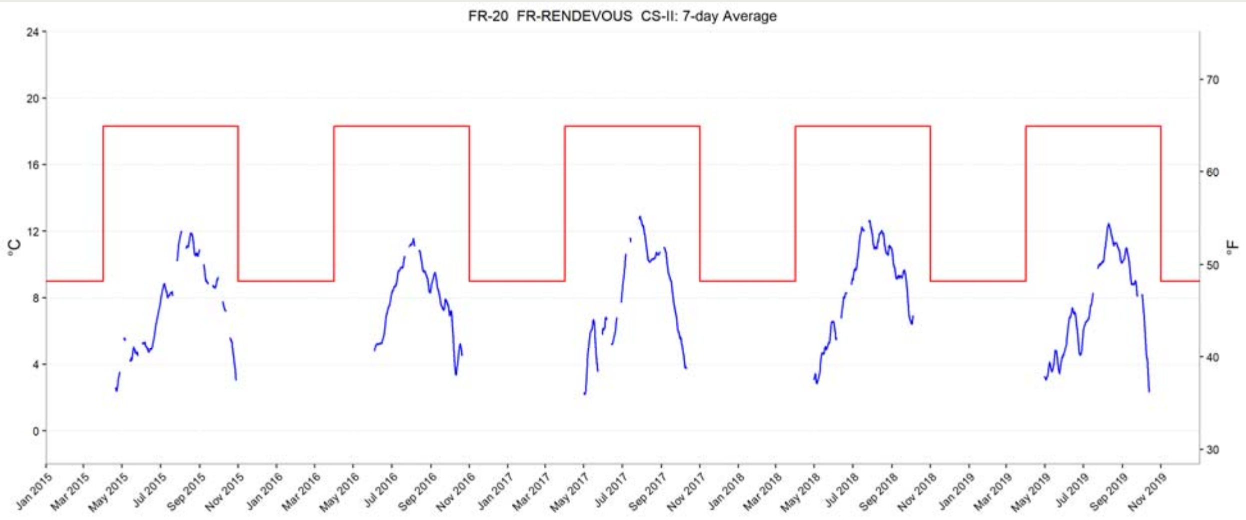
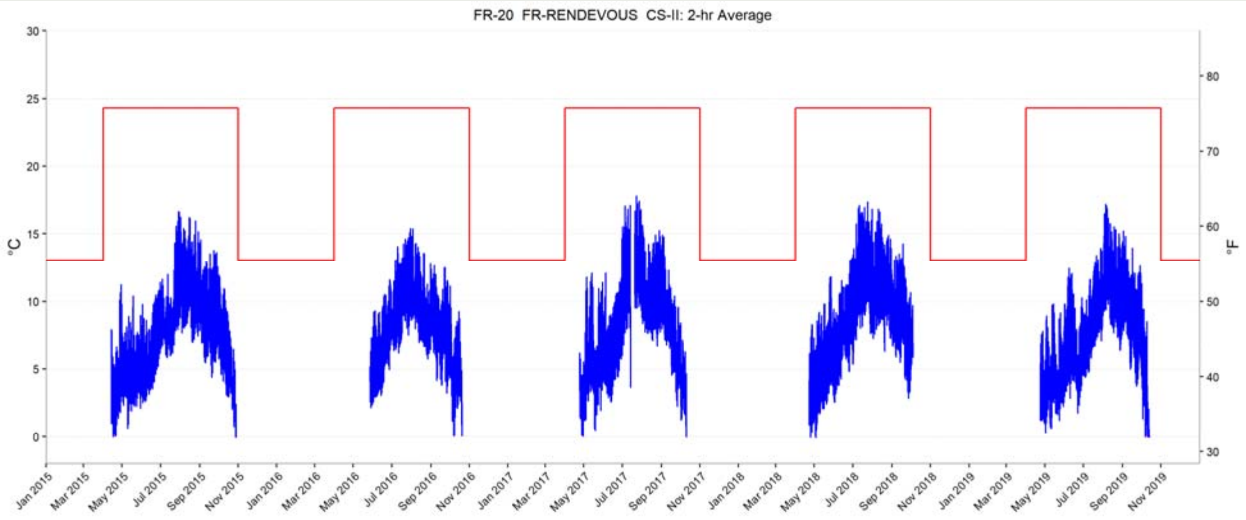
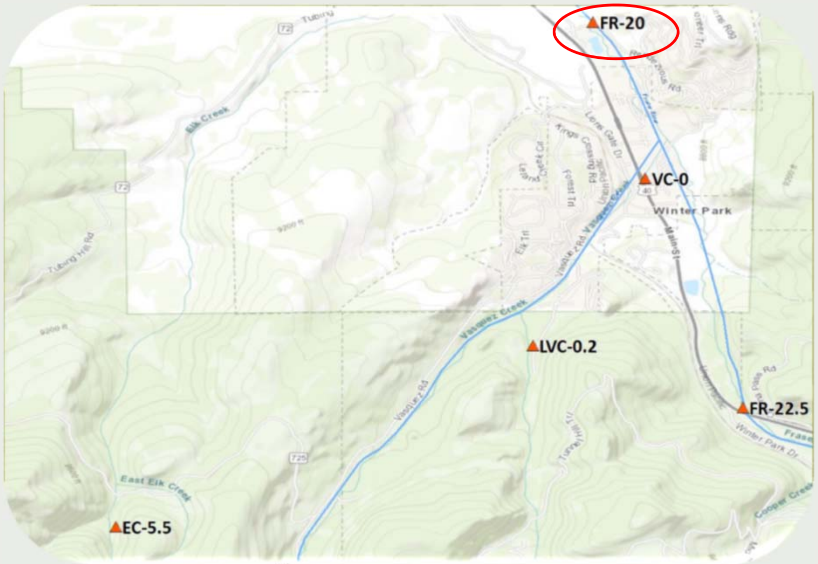




CSII
FR-Rendezvous
FR-20



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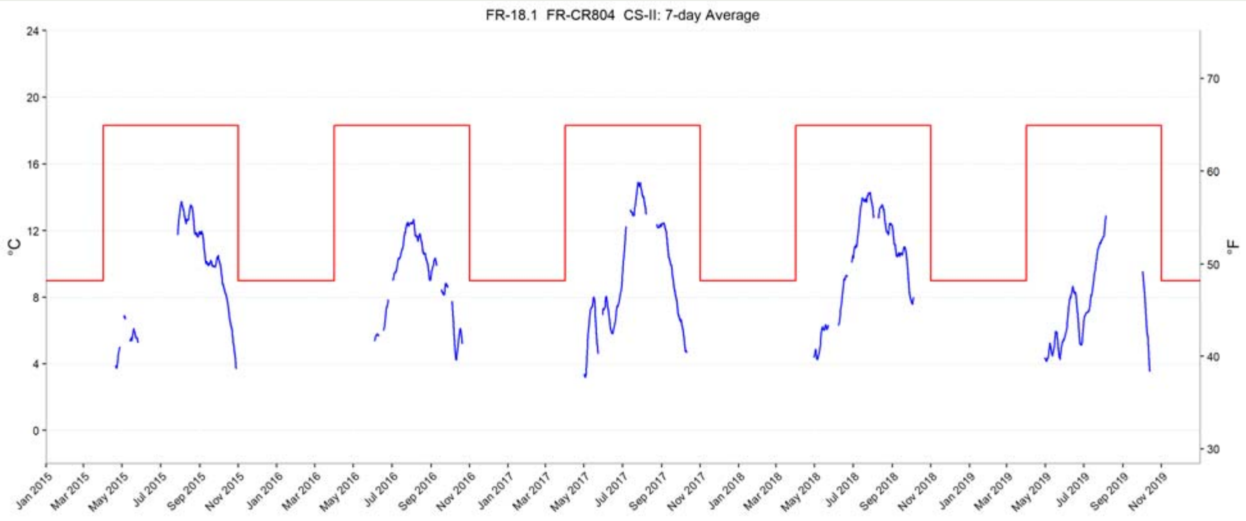
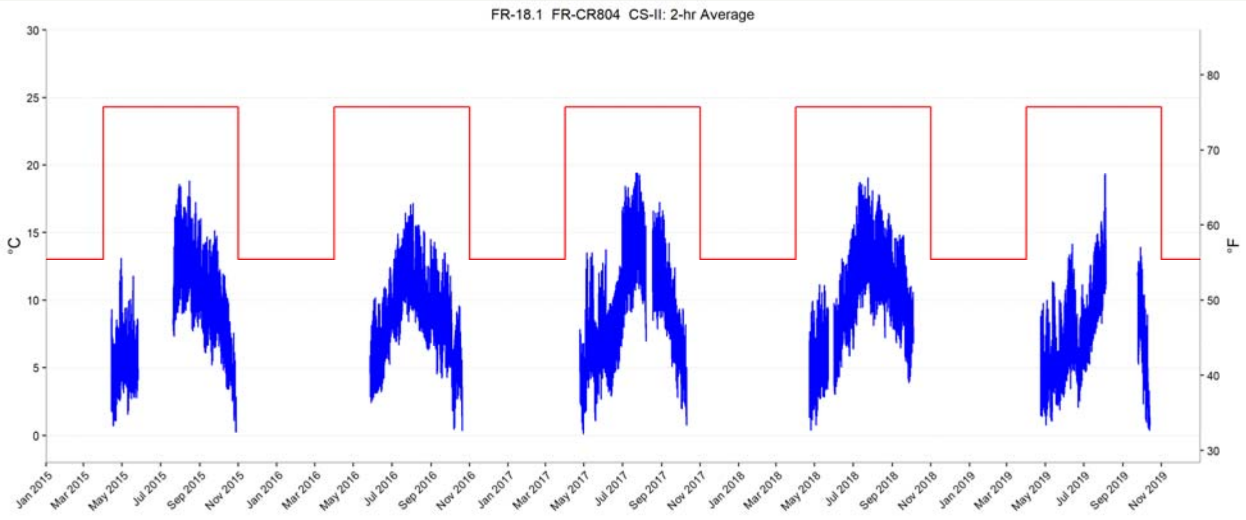
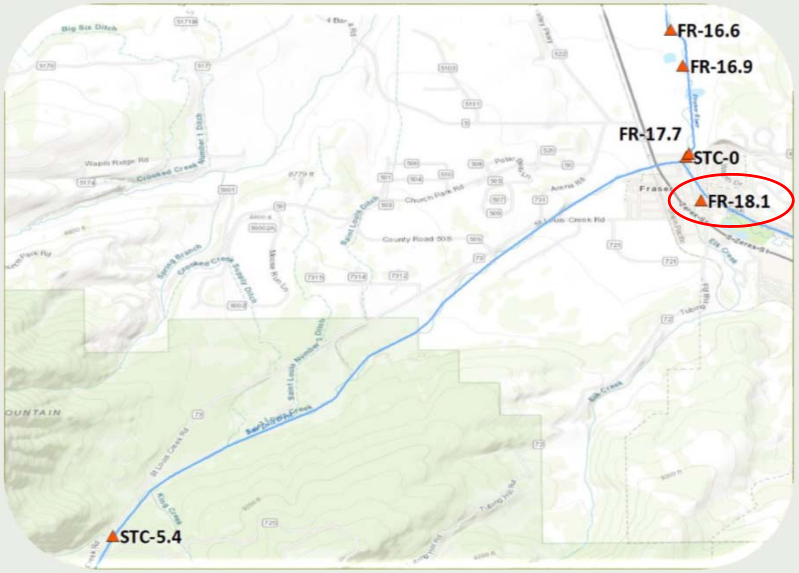
CSII
FR-CR804
FR-18.1







Note: Data gap in 2019 – Sensor found out of water. This site is located at a popular fishing spot.

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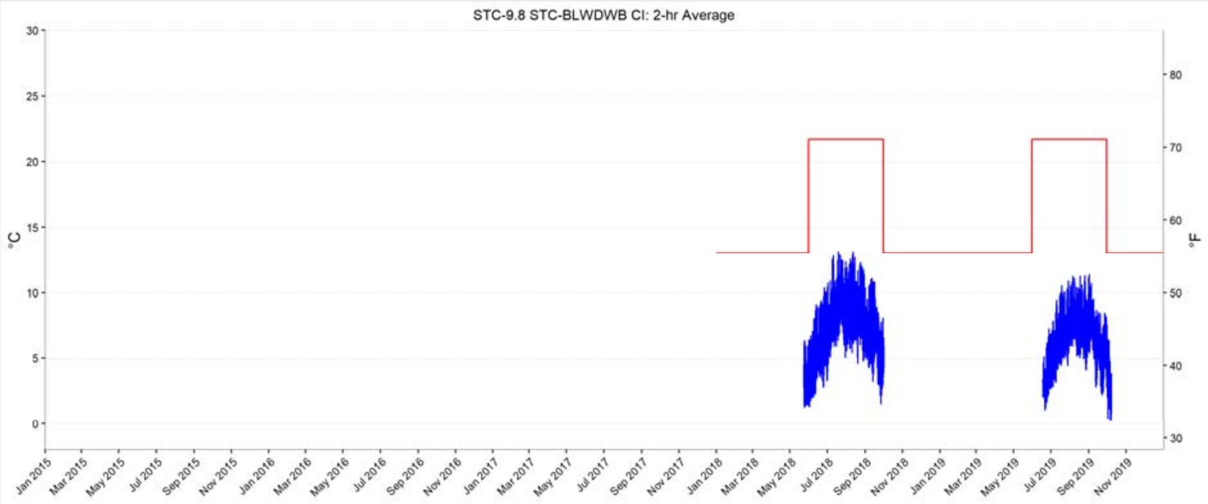
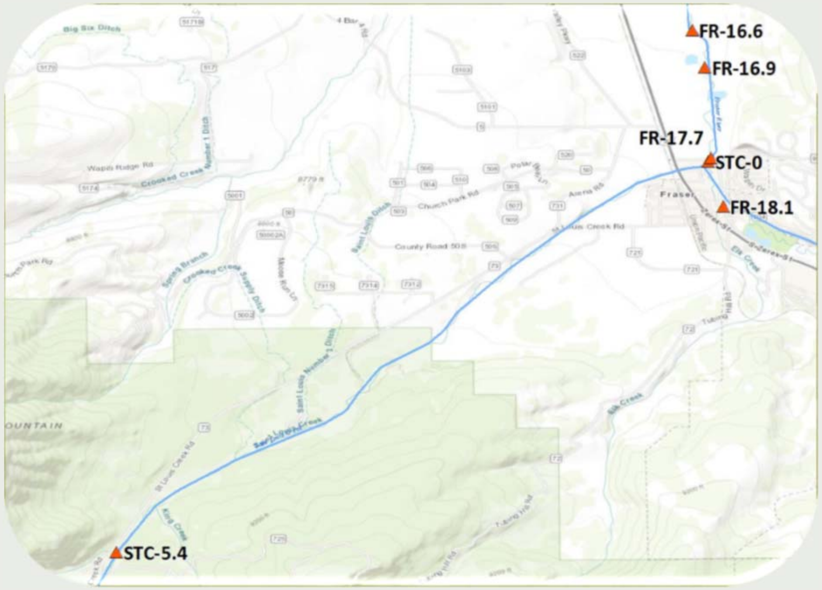


CSI
STC-blwDWB
STC-9.8



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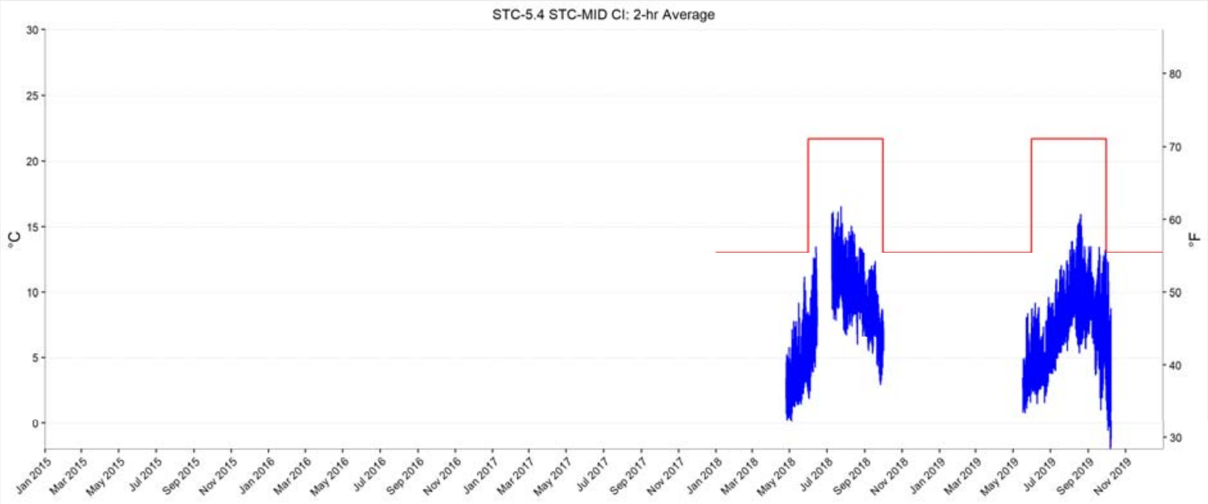
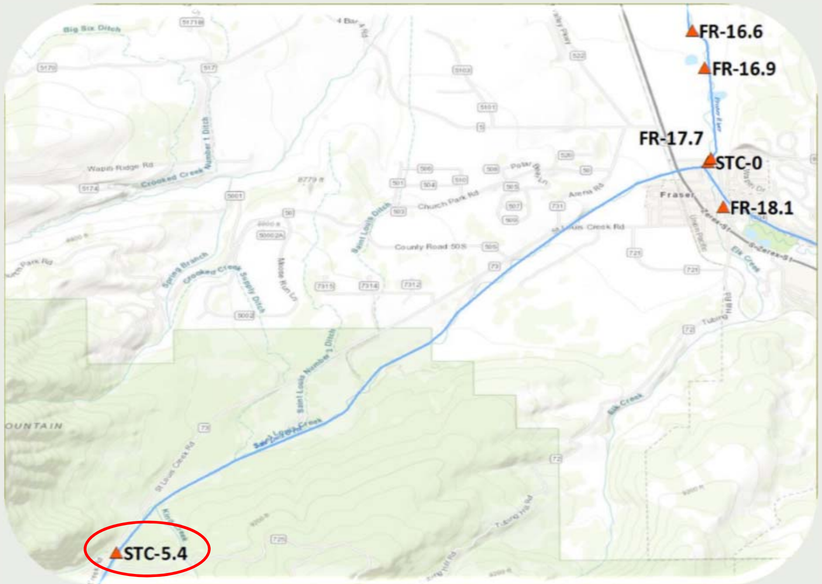


CSI
STC-Mid
STC-5.4



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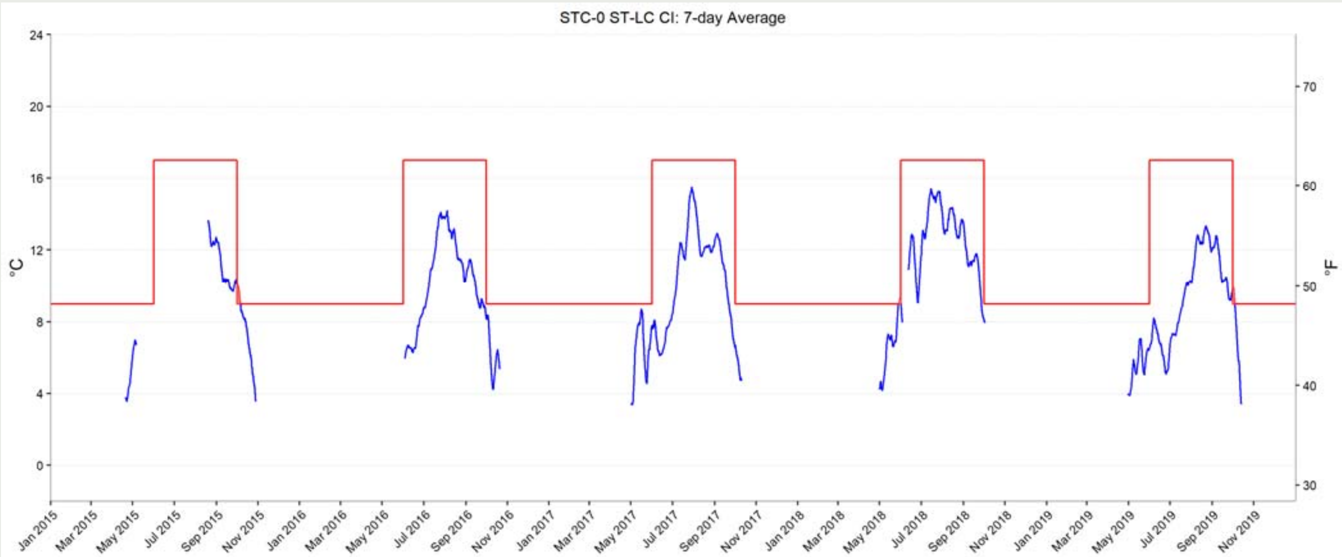
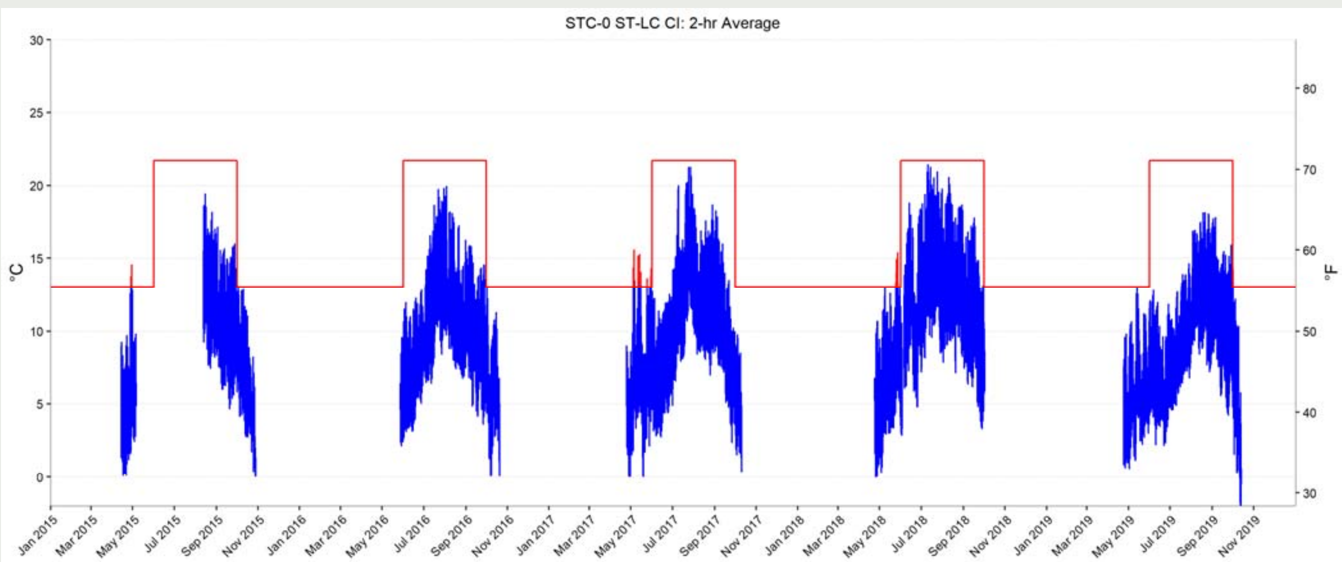
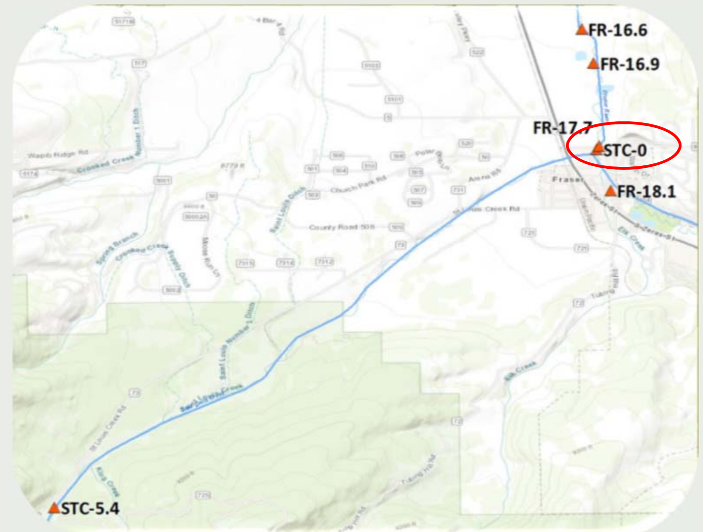




CSI
ST-LC
STC-0



Above WAT standard
- 10/1/2019 – 10/4/2019
- Max: 14.38 deg C

Above DM standard
- 5/13/19 & 10/1/19
- Max: 14.2 deg C

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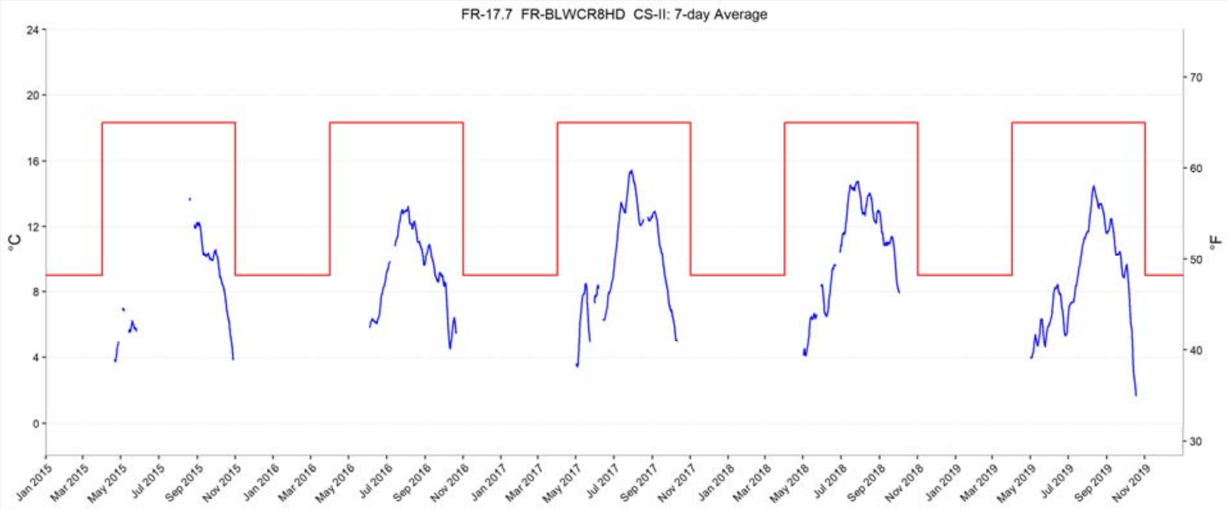
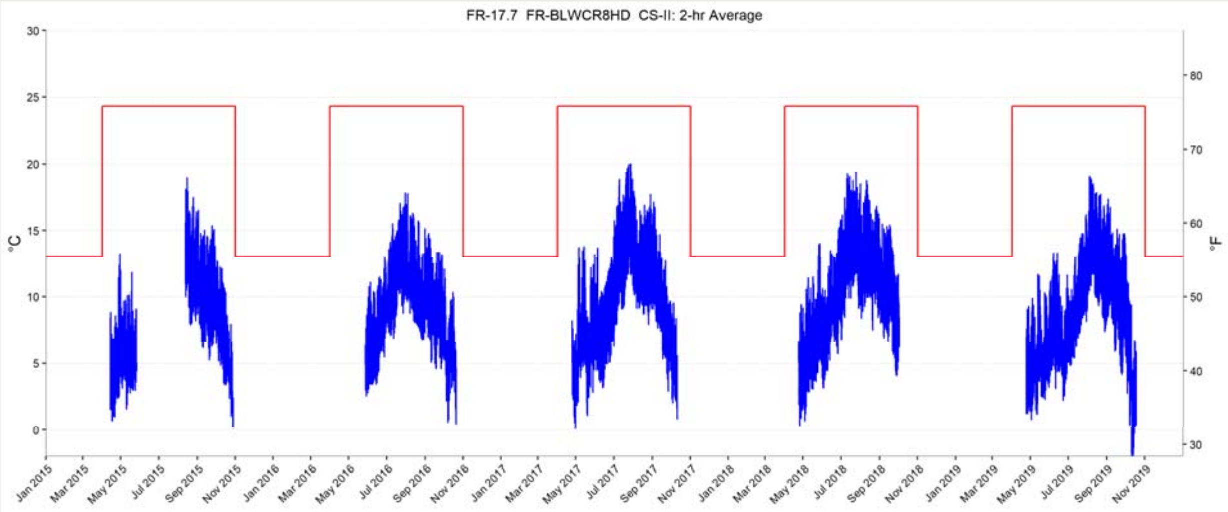
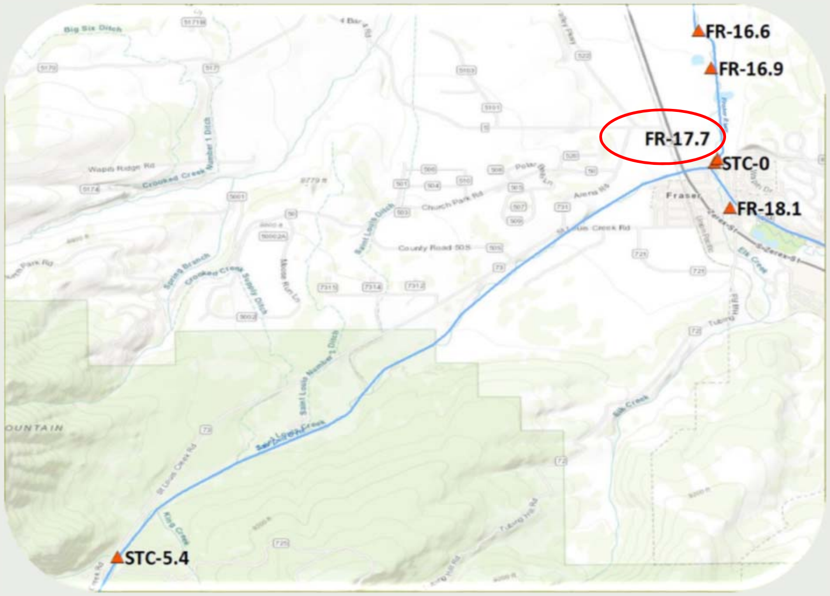
CSII
FR-blwCR8HD
FR-17.7







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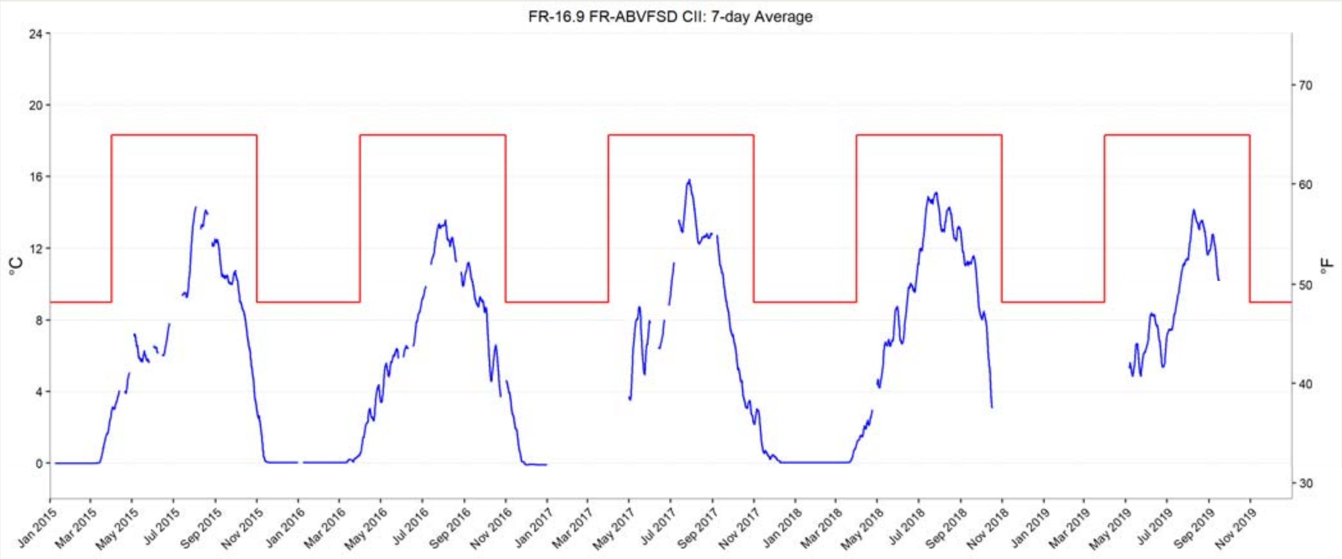
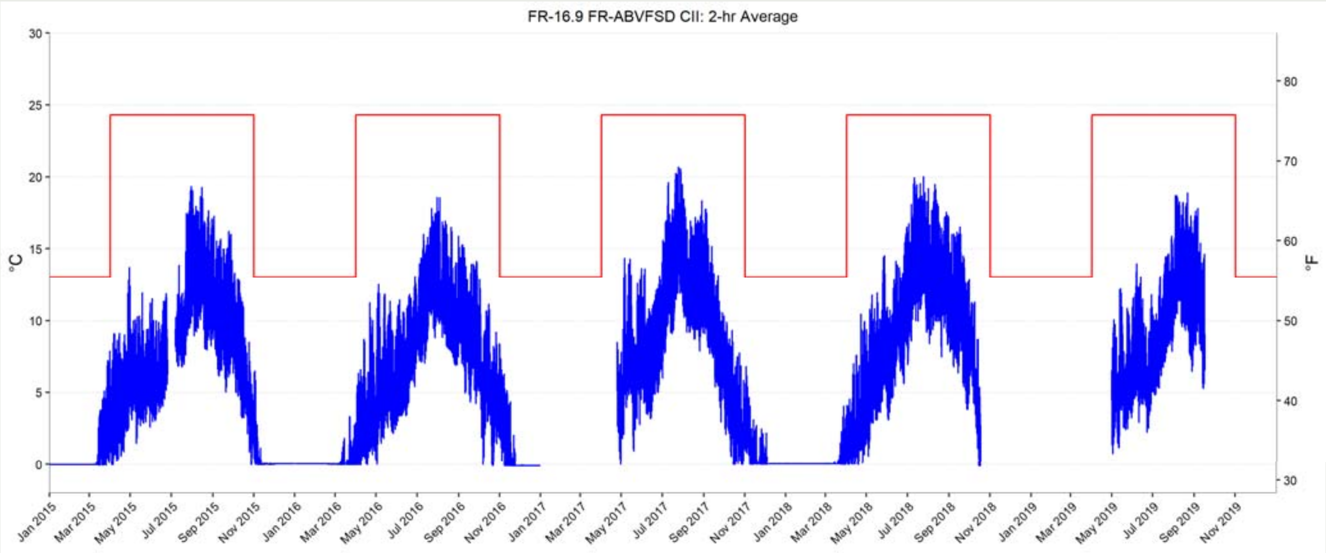
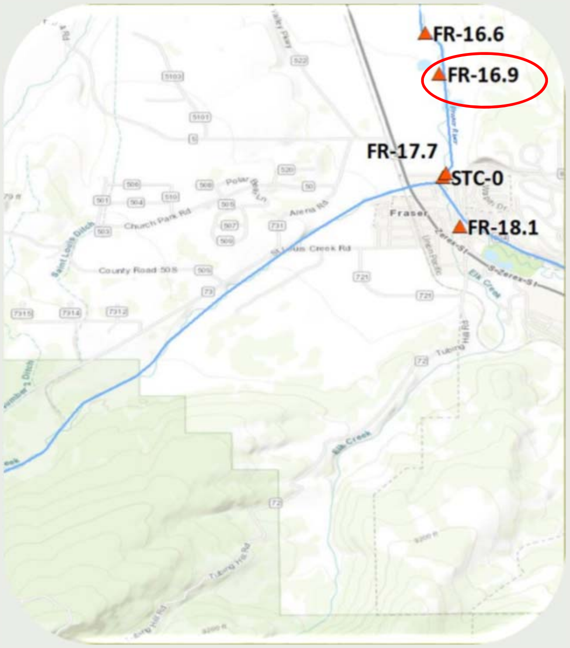




CSII
FR-abvFSD
FR-16.9



Note: Data gap in 2019 – Sensor found out of water. Popular location for fishing.

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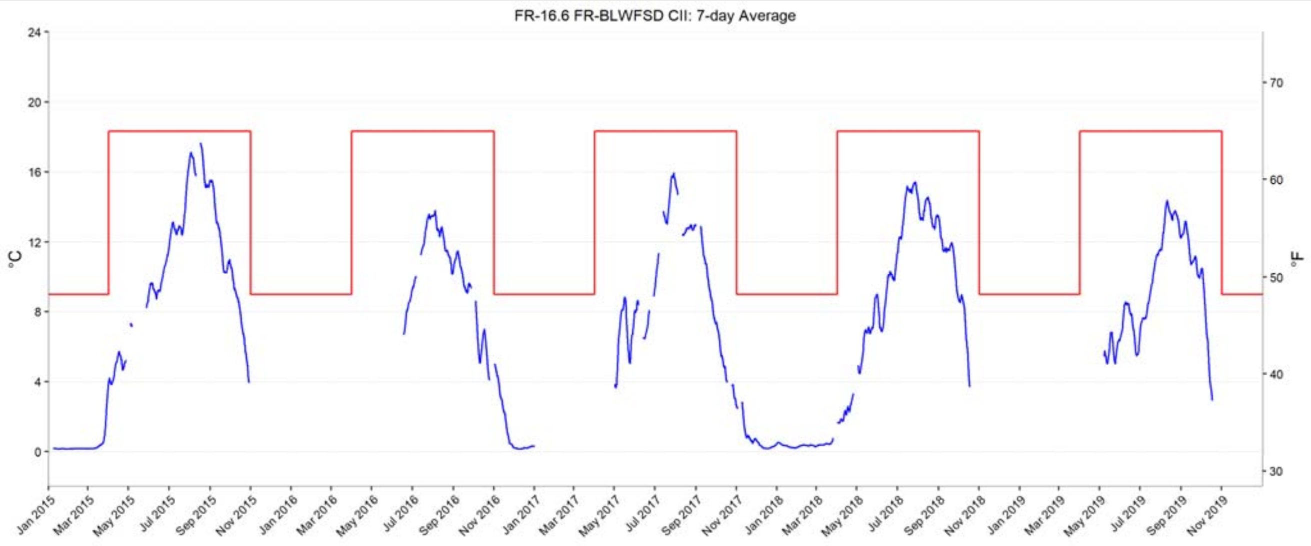
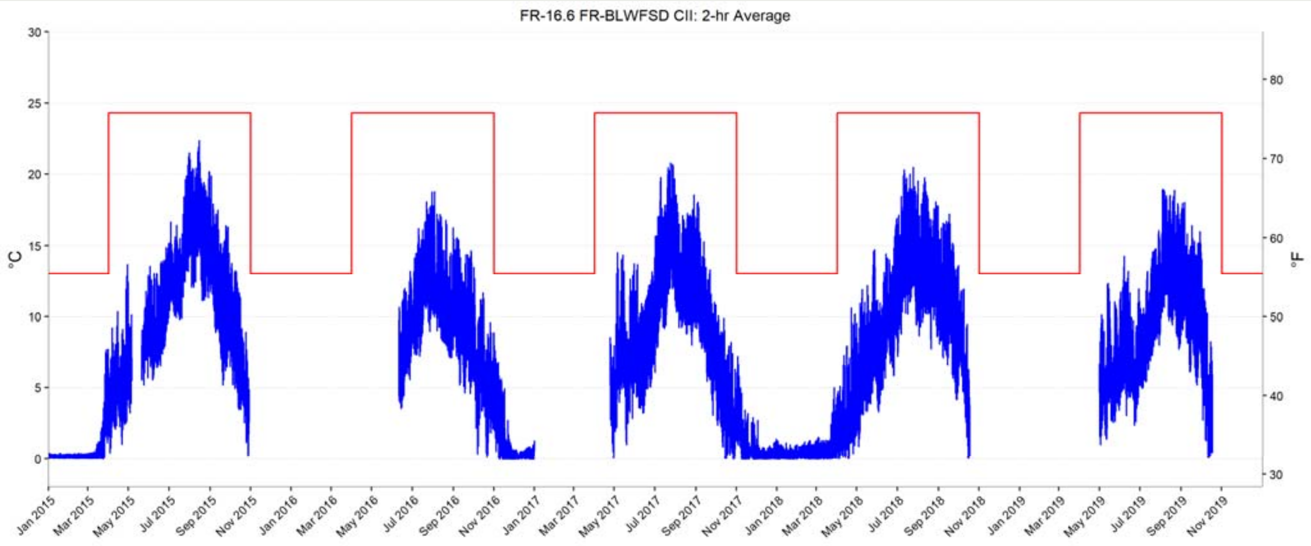
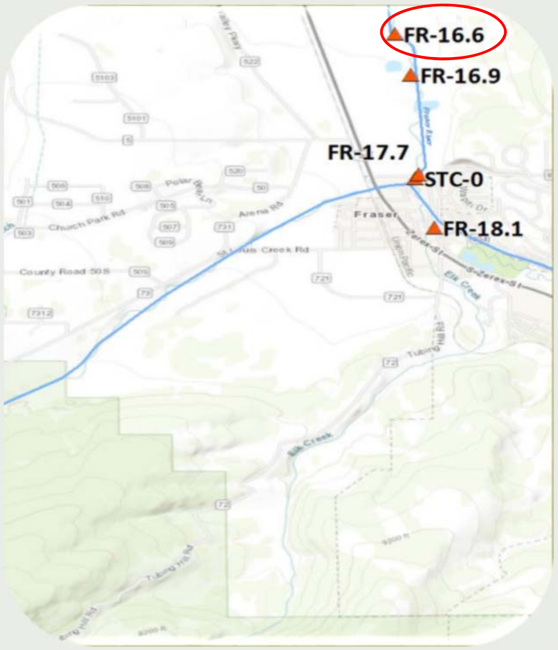
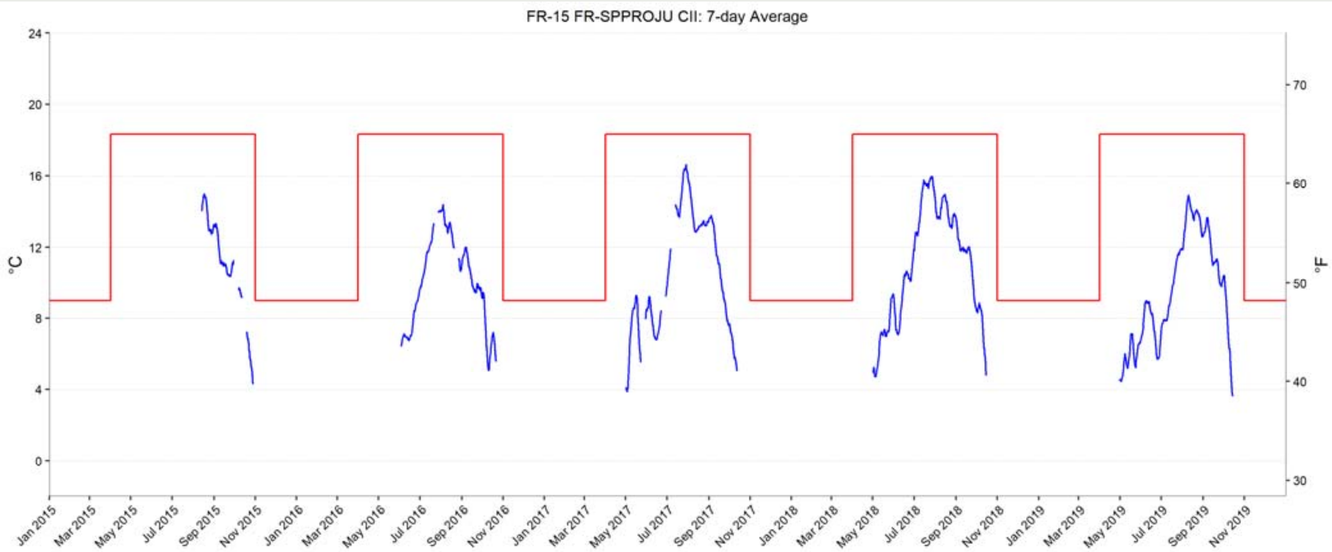
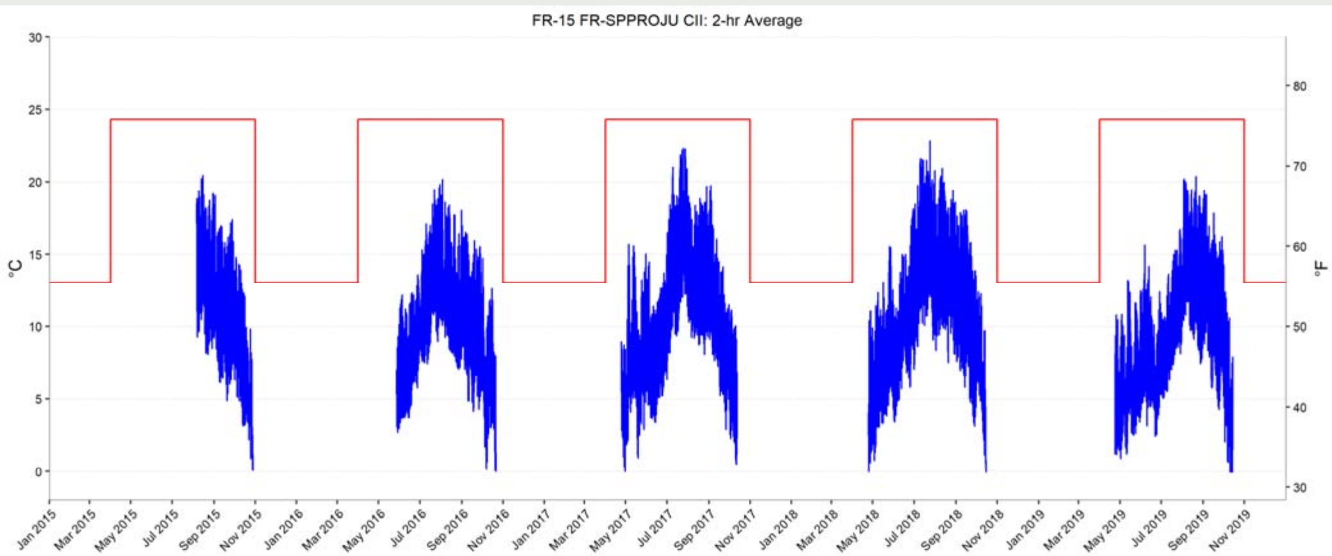




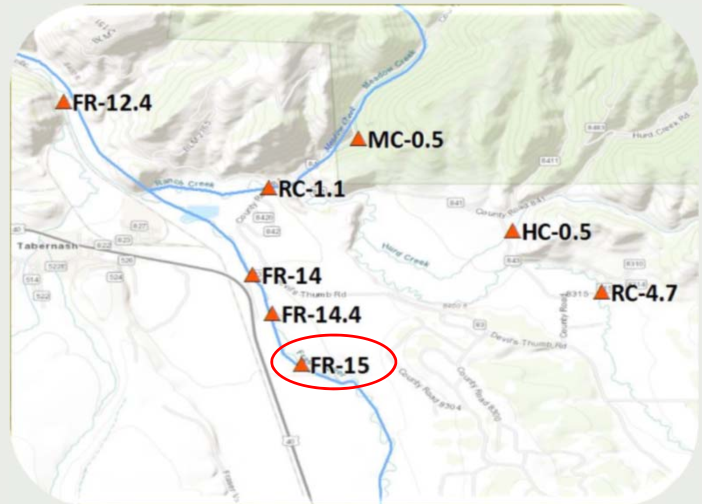
CSII
FR-blwFSD
FR-16.6







CSII
FR-SpProjU
FR-15



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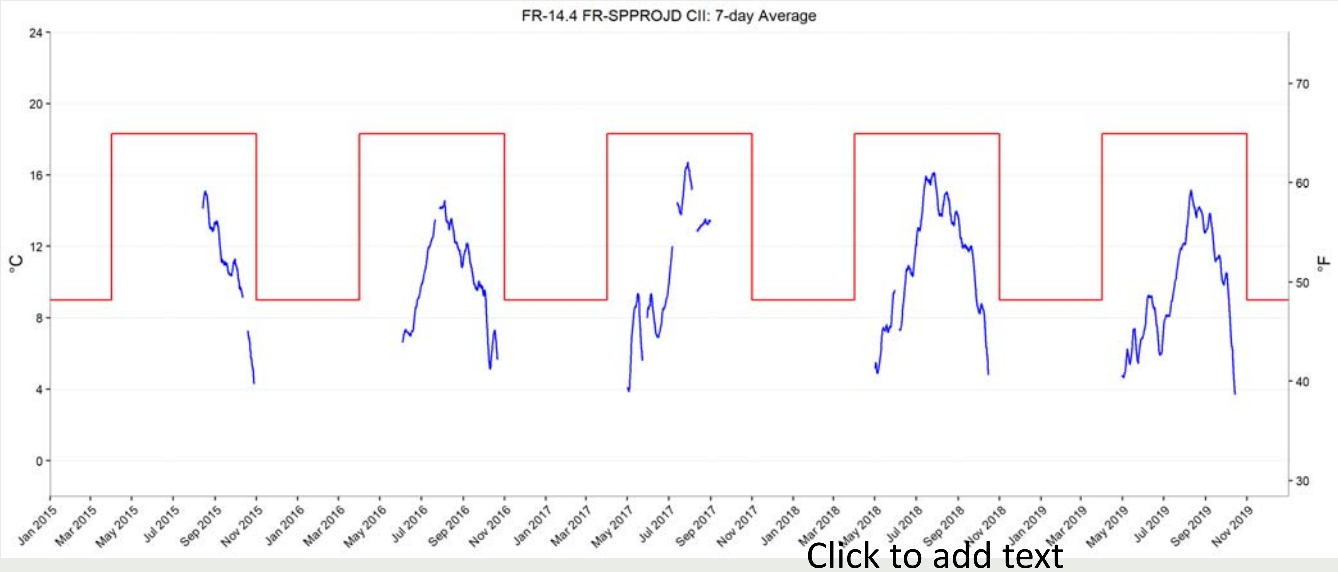
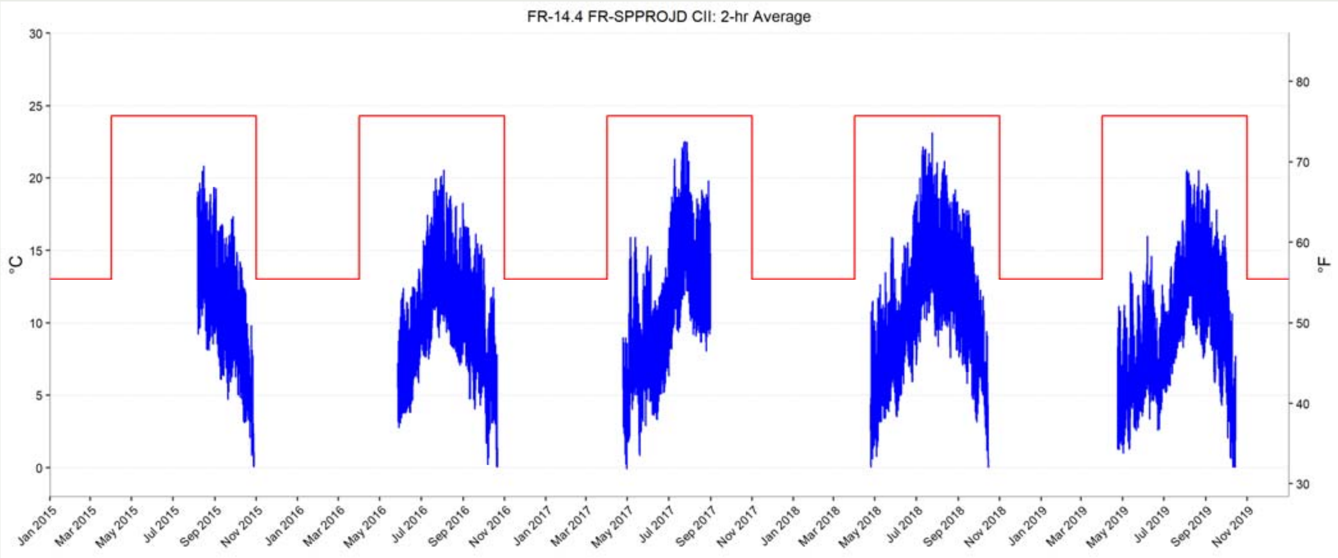
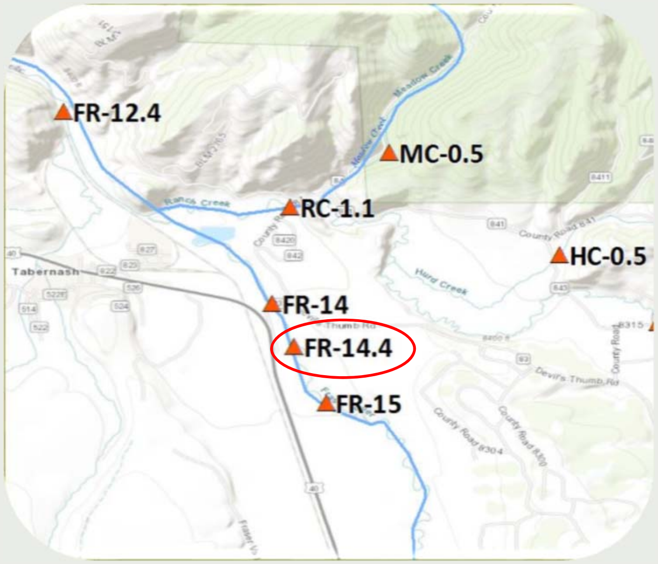
CSII
FR-SpProjD
FR-14.4



Click to add text





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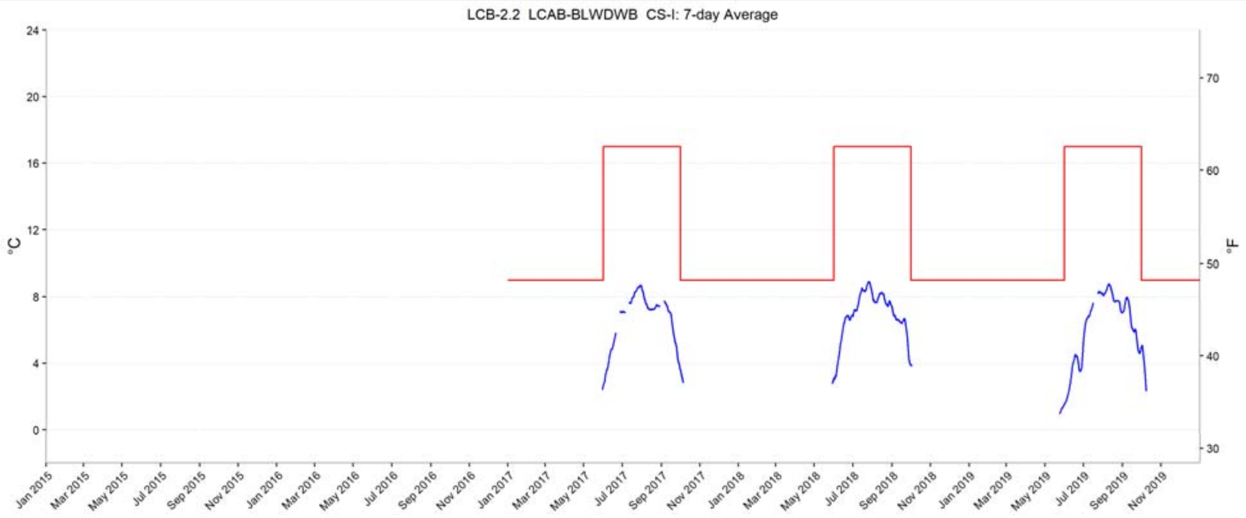
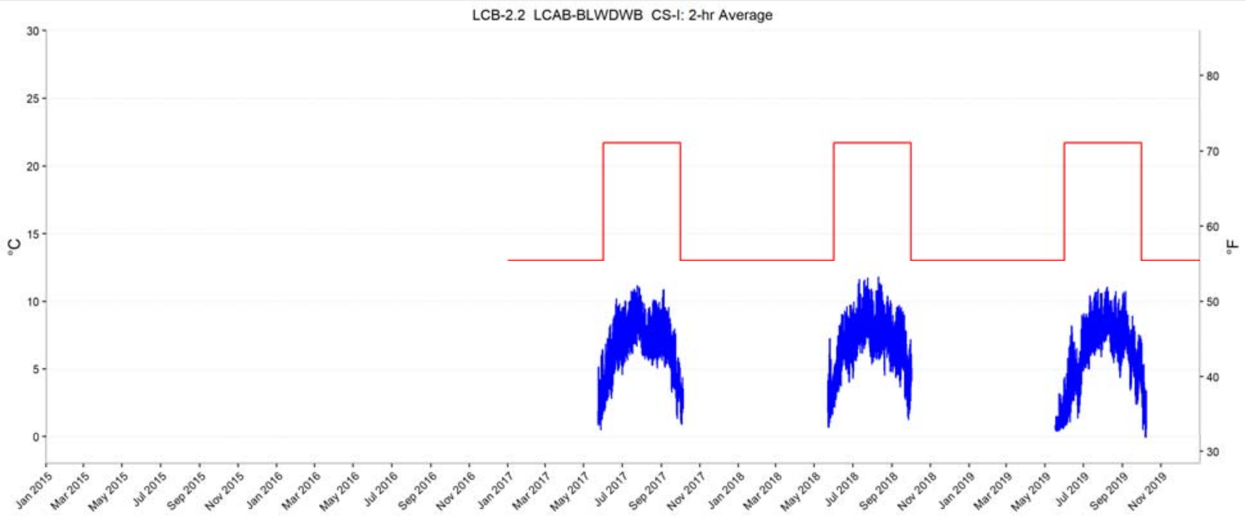
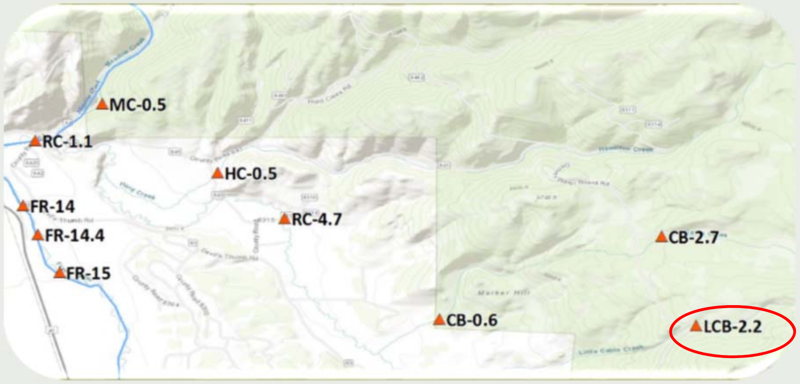




CSI
LCAB-blwDWB
LCB-2.2



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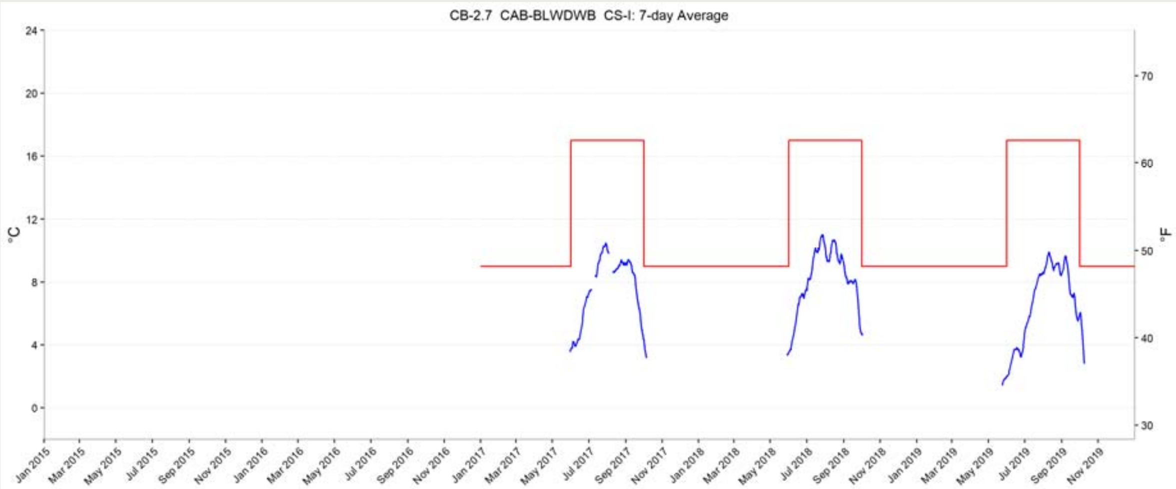
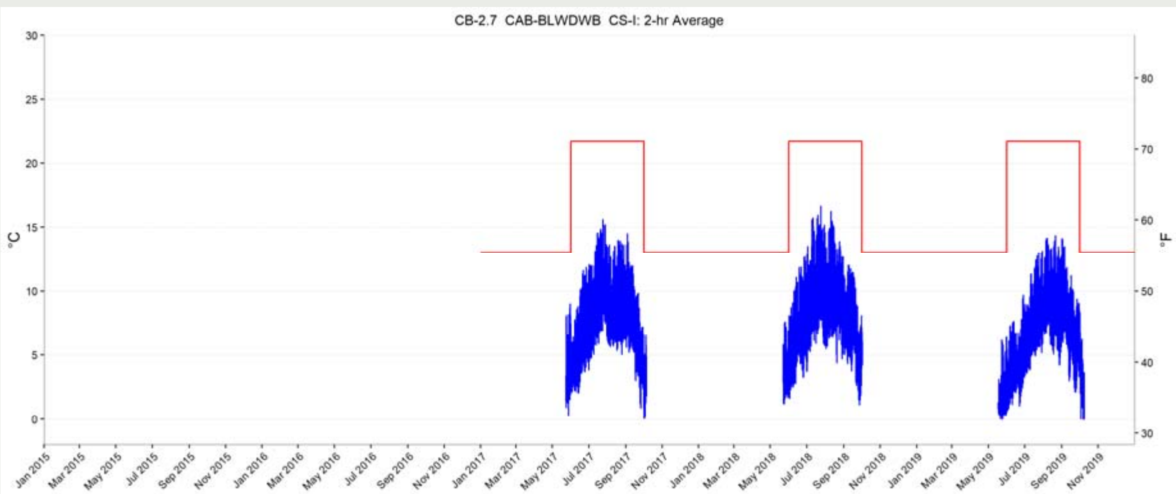
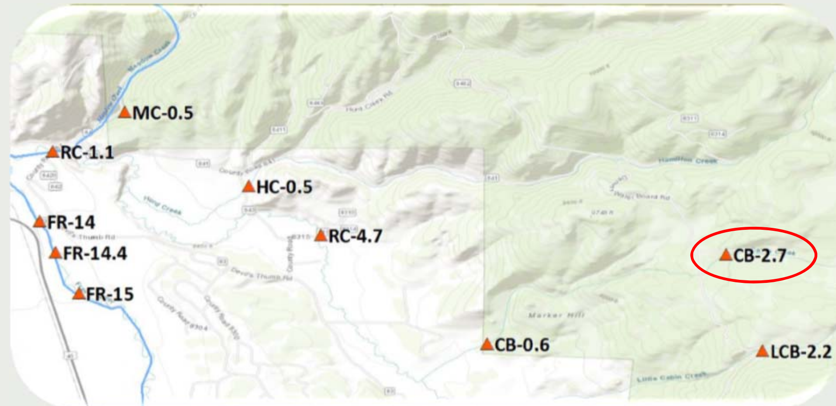




CSI
CAB-blwDWB
CB-2.7



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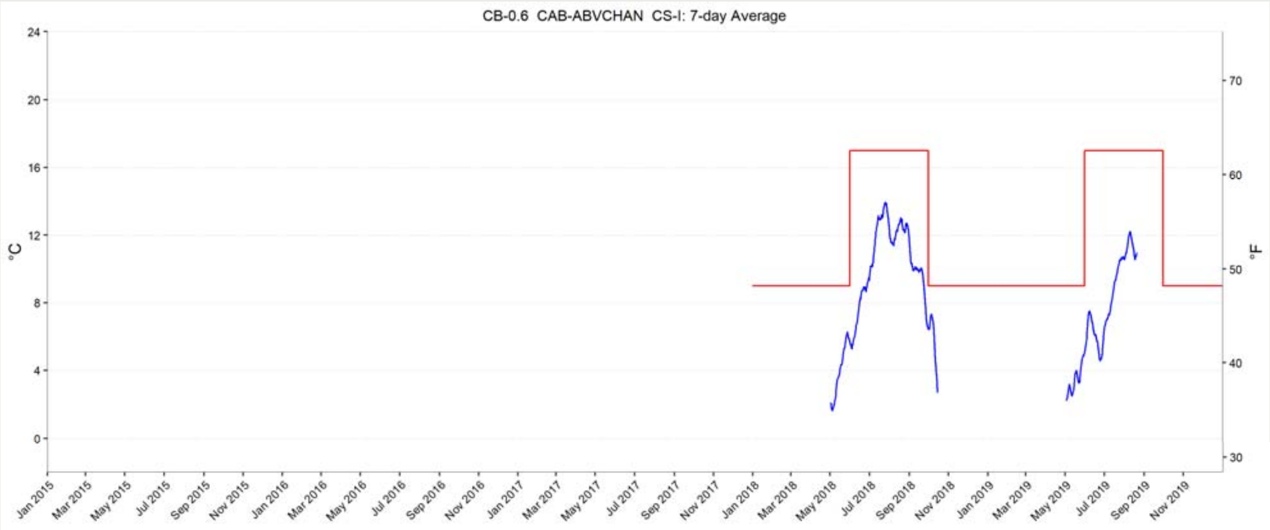
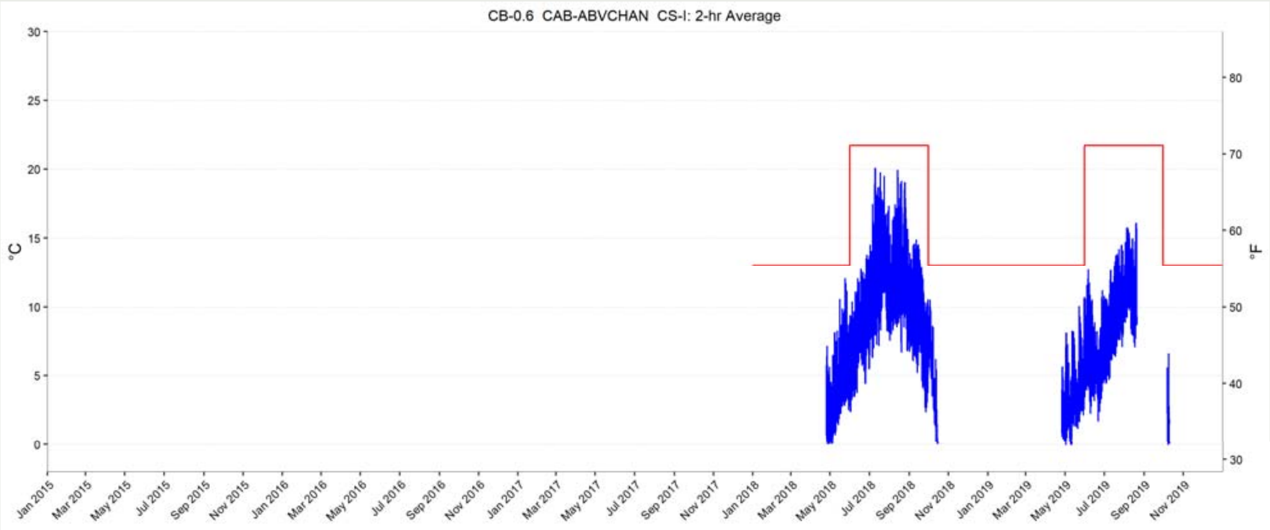
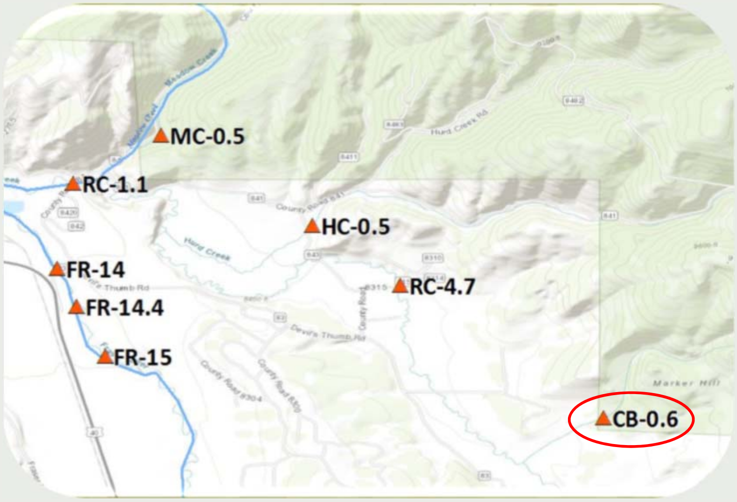
CSI
CAB-abvChan
CB-0.6







Note: Data gap in 2019 – Sensor found out of water. This site is located approximately 30 feet down stream of a Devils Thumb head gate. During this data gap, the water level dipped very low, exposing the rig and sensor.

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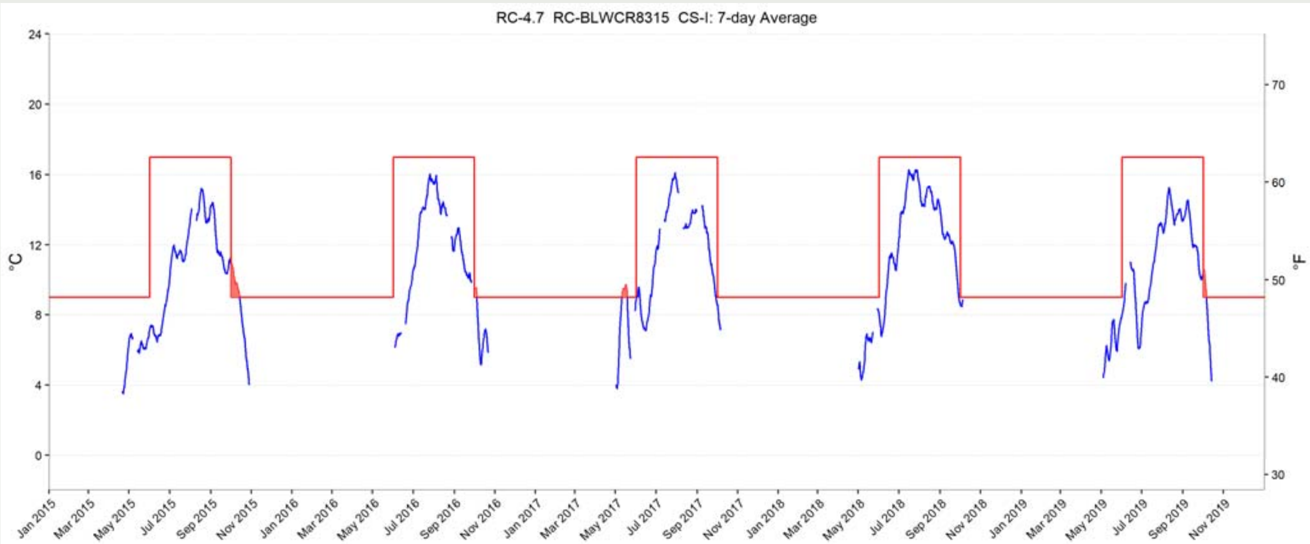
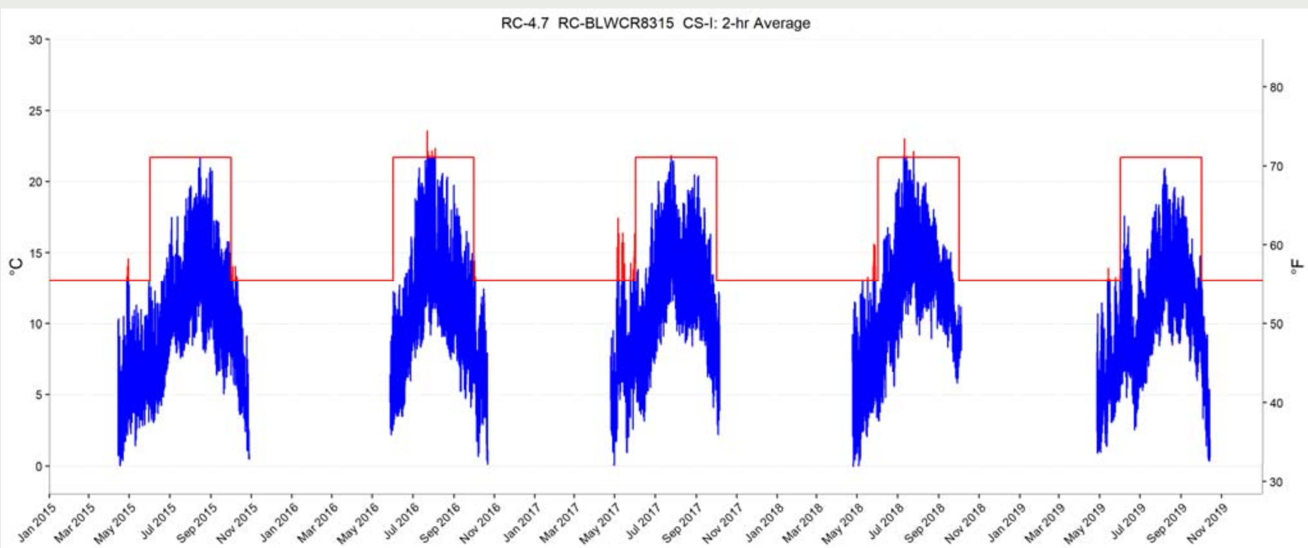
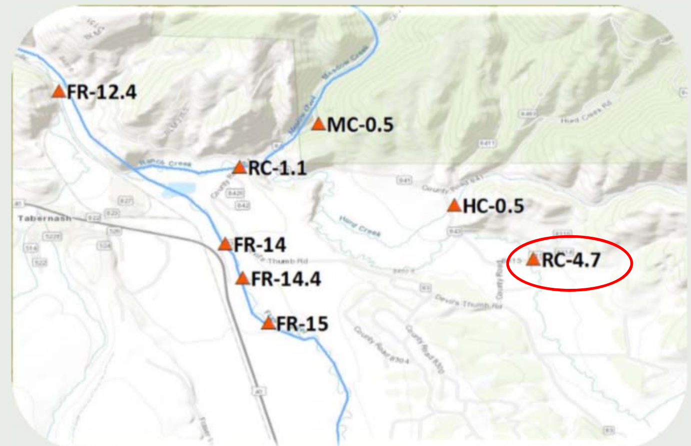




CSI
RC-blwCR8315
RC-4.7



Above WAT standard
- 10/1/19-10/5/19
- Max: 10.6 deg C

Above DM standard
- 5/12, 5/13, 5/14, 5/15, 5/24 & 5/31/2019
- Max: 14.4 deg C

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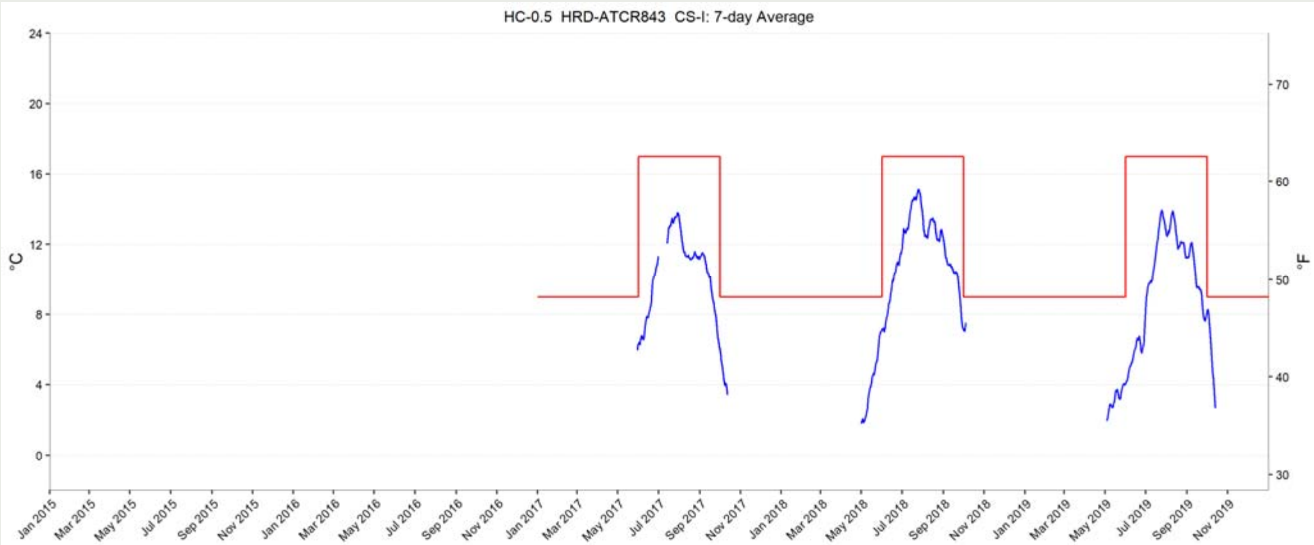
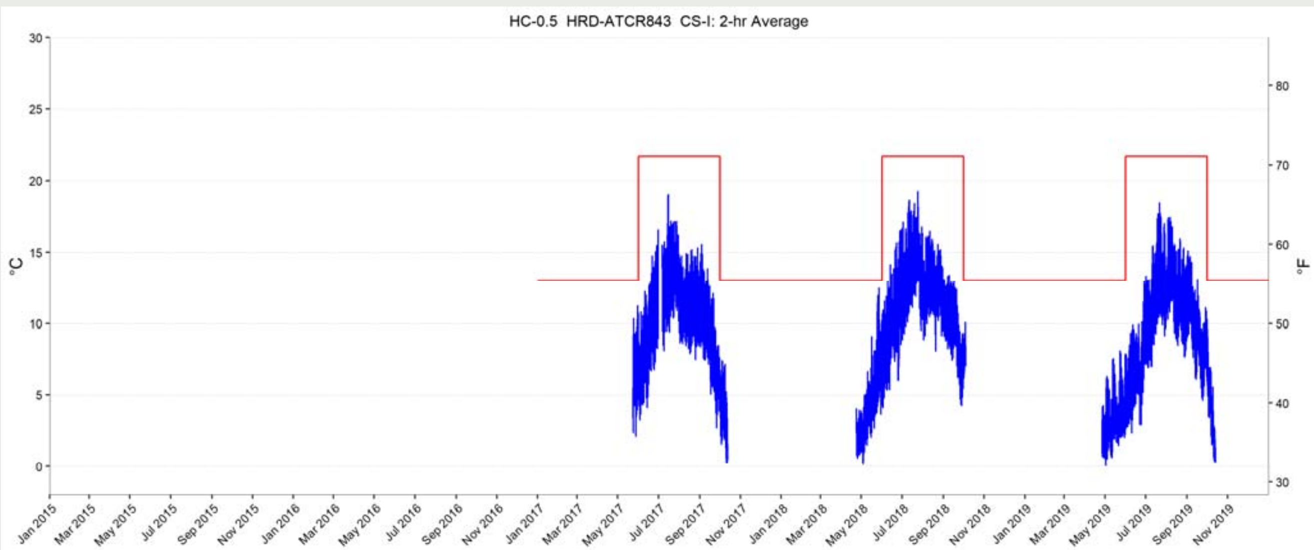
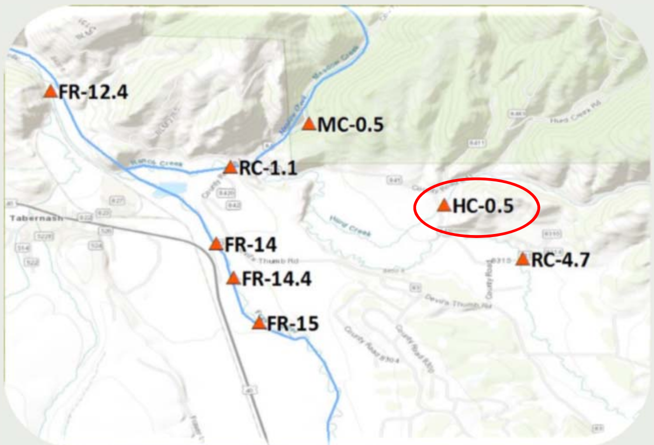




CSI
HRD-atCR843
HC-0.5



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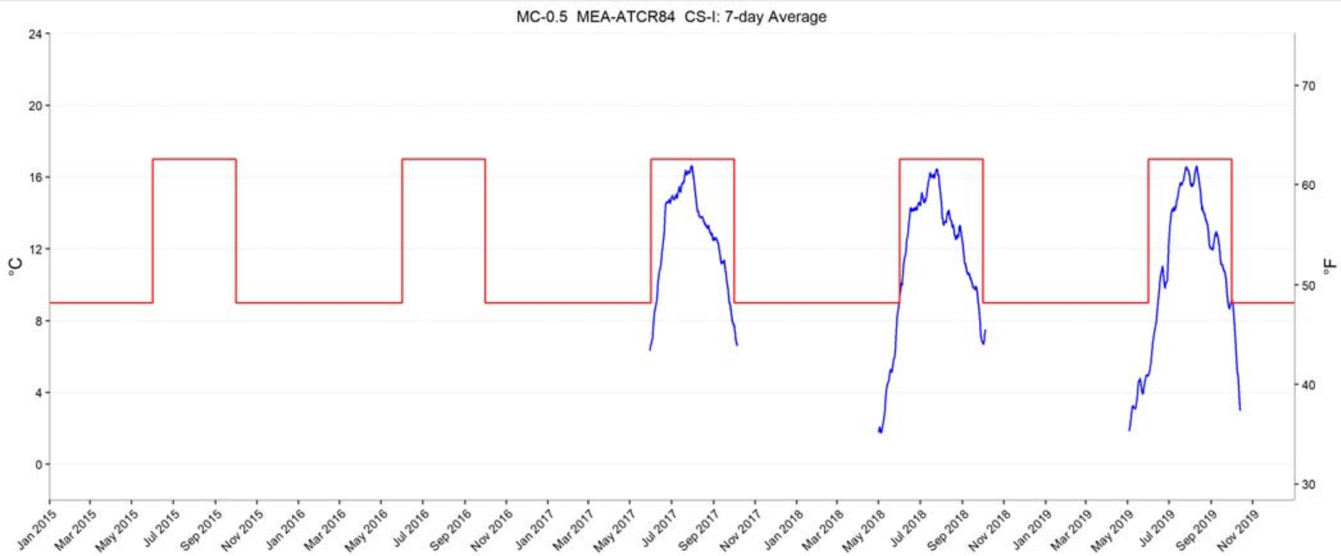
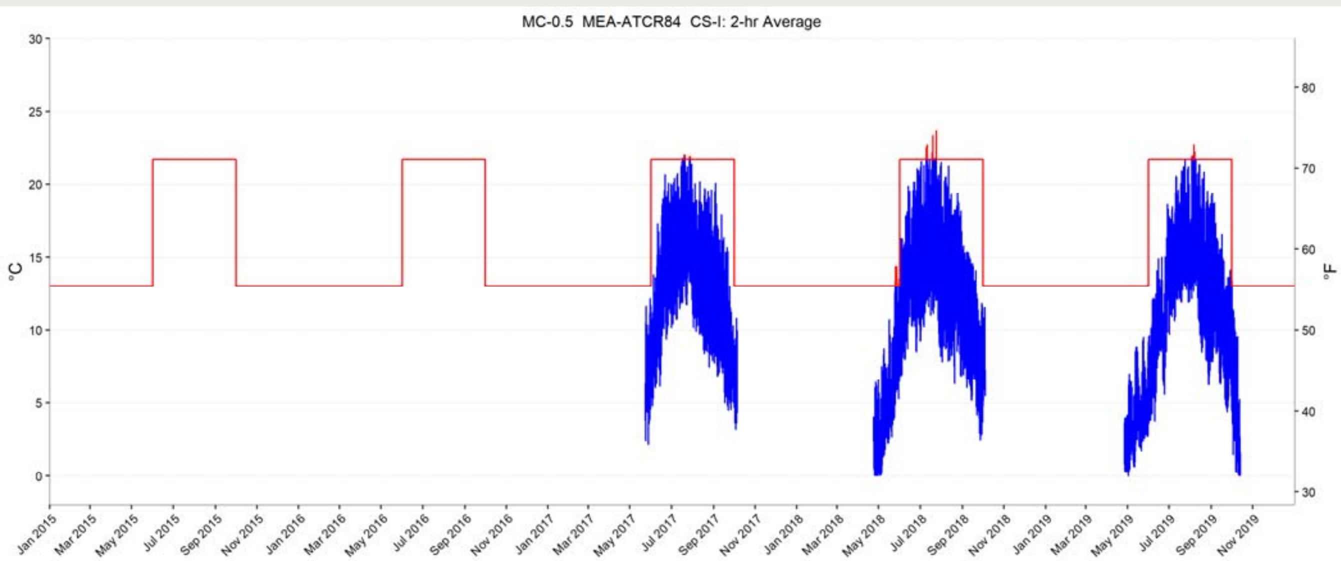
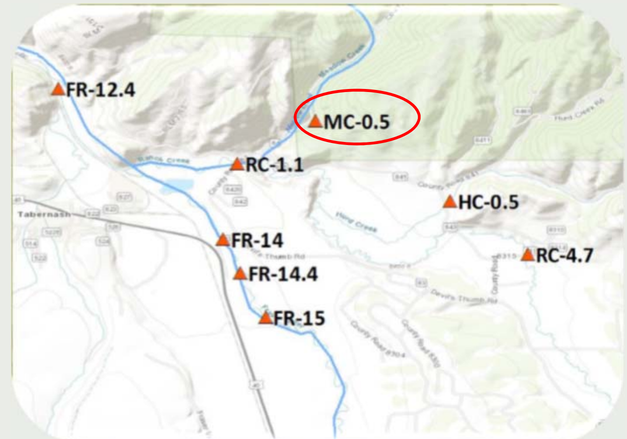




CSI
MEA-atCR84
MC-0.5



Above DM standard

- 7/17, 7/19, 7/20, & 7/27/2019
- Max: 22 deg C

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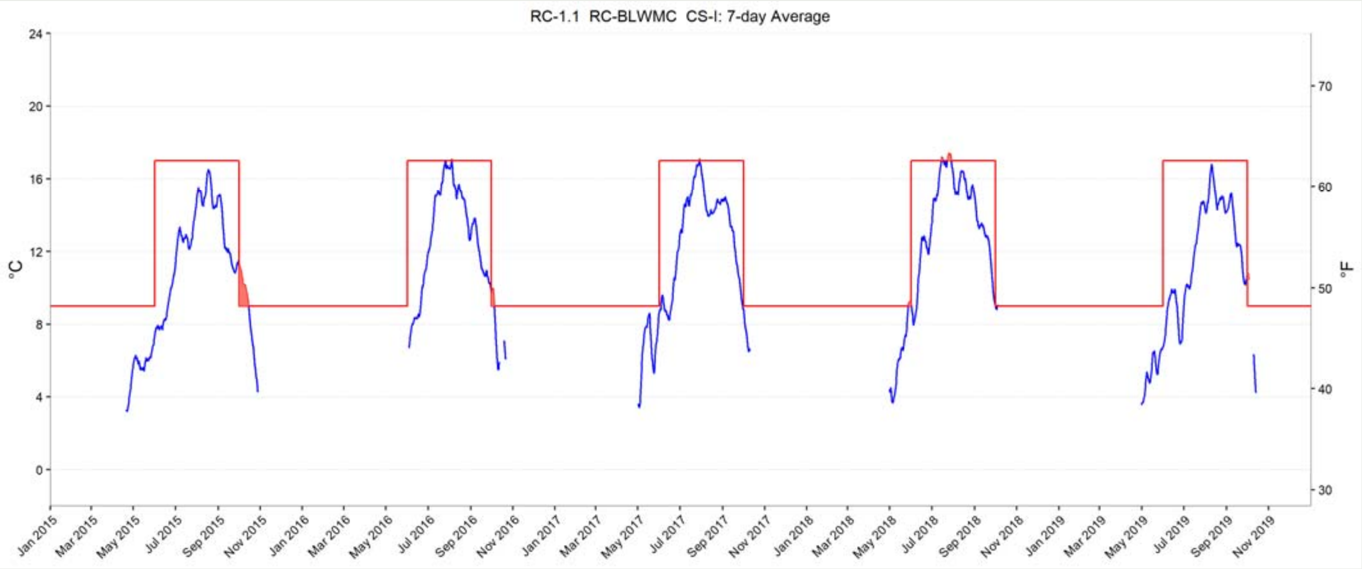
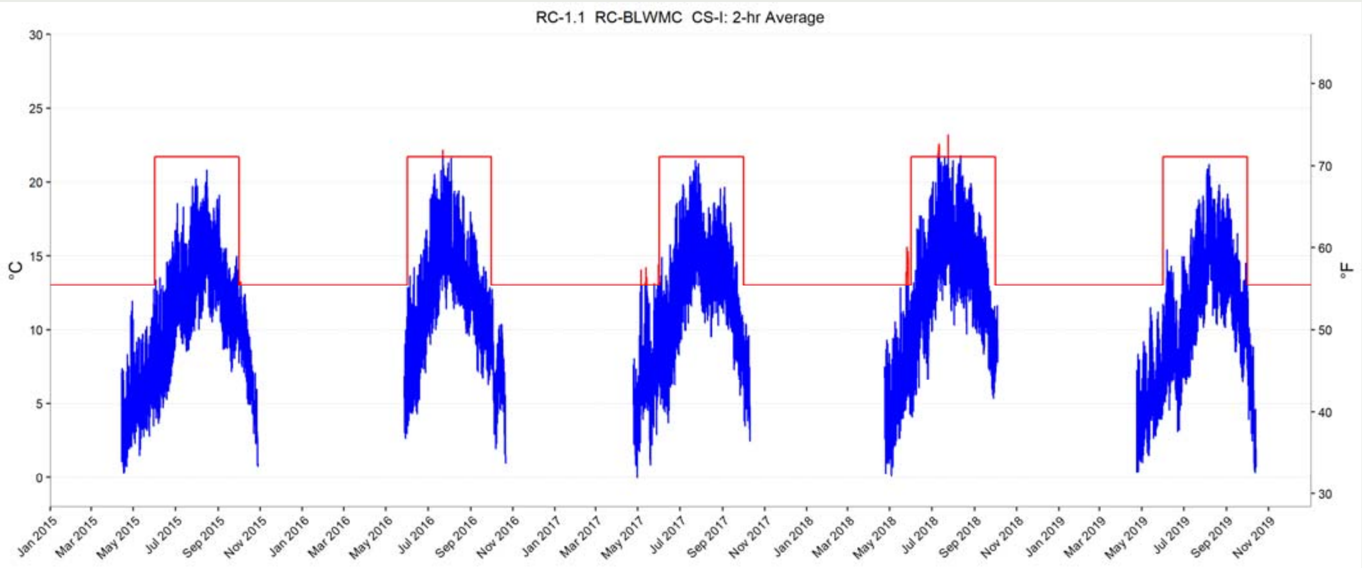
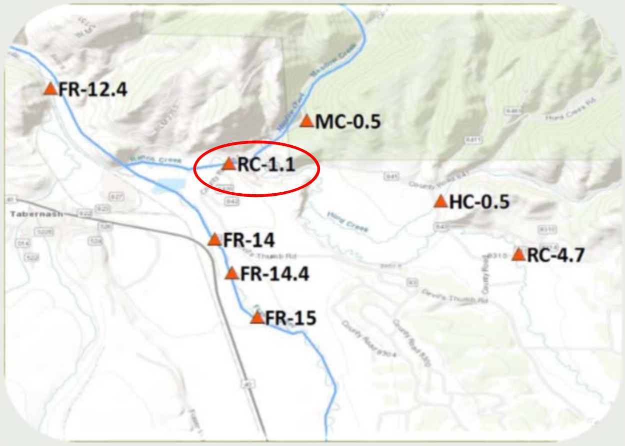




CSI
RC-blwMC
RC-1.1



Above WAT standard

- 10/1/19-10/3/19
- Max: 10.8 deg C

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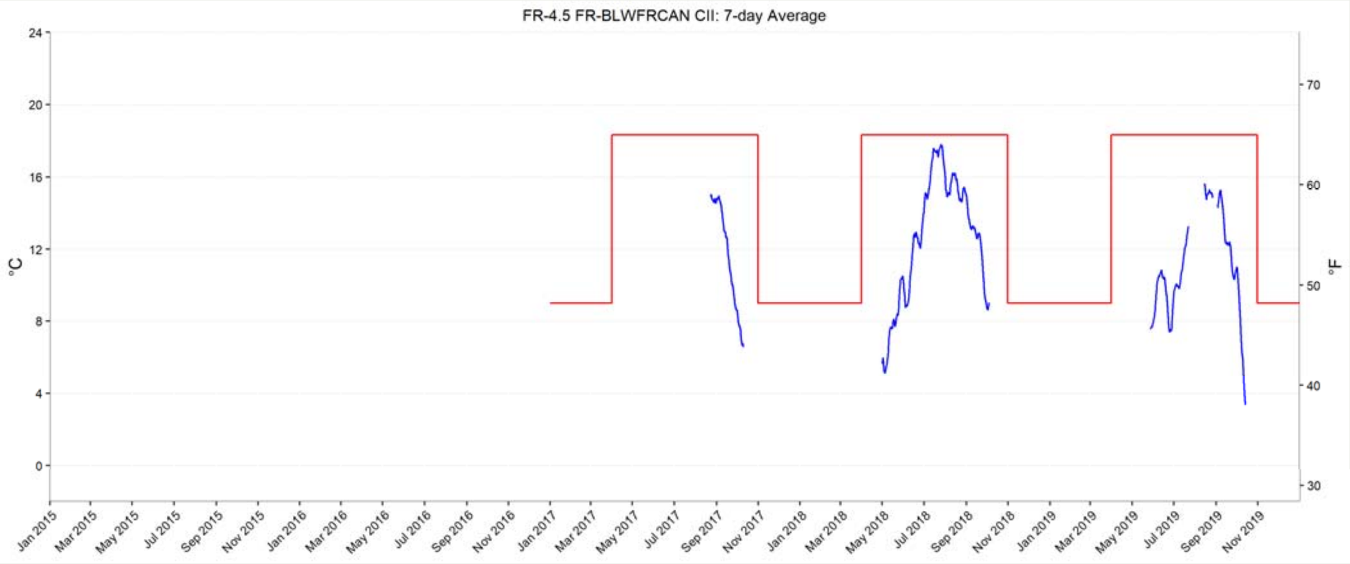
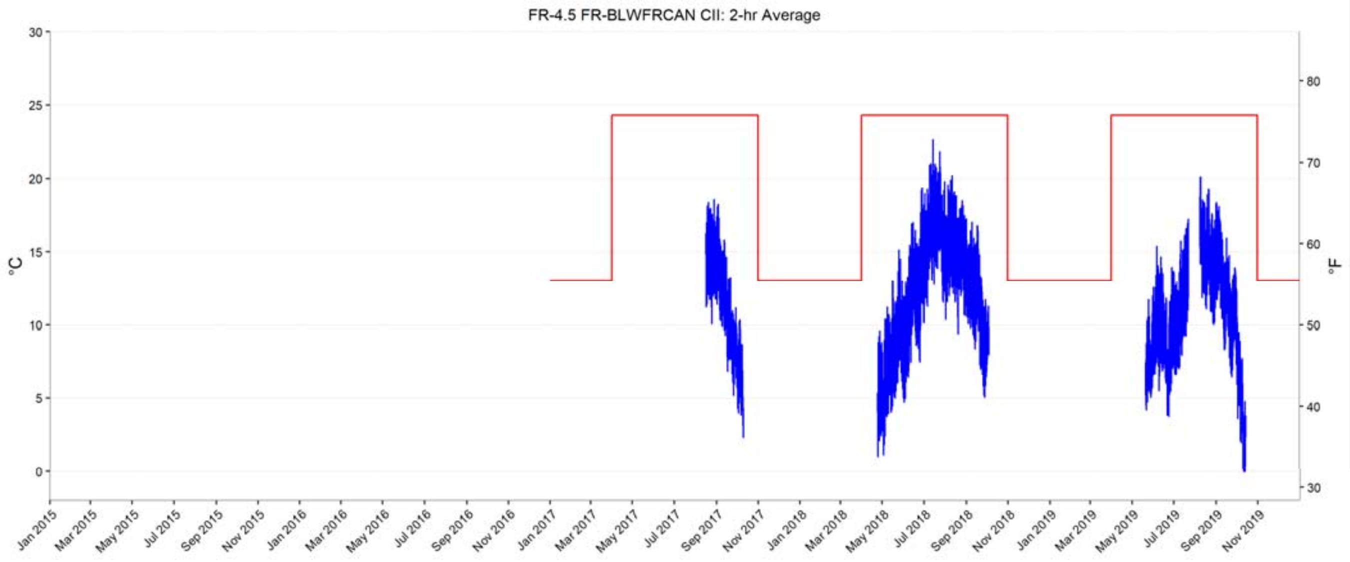
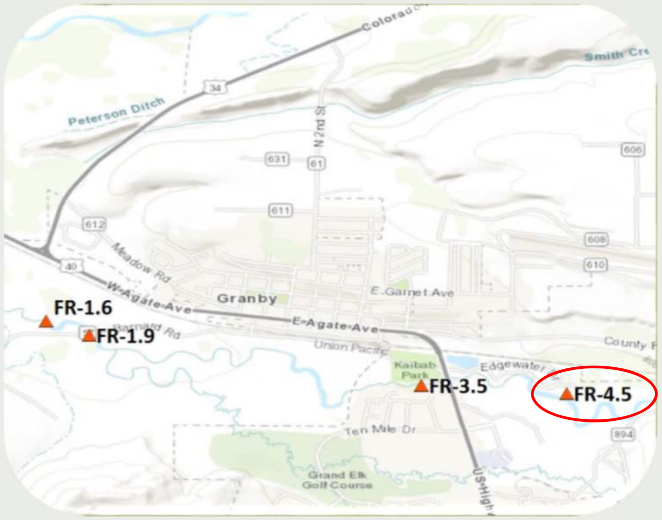




CSII
FR-blwFrCan
FR-4.5



Note: Data gap in 2019 – Sensor found out of water.

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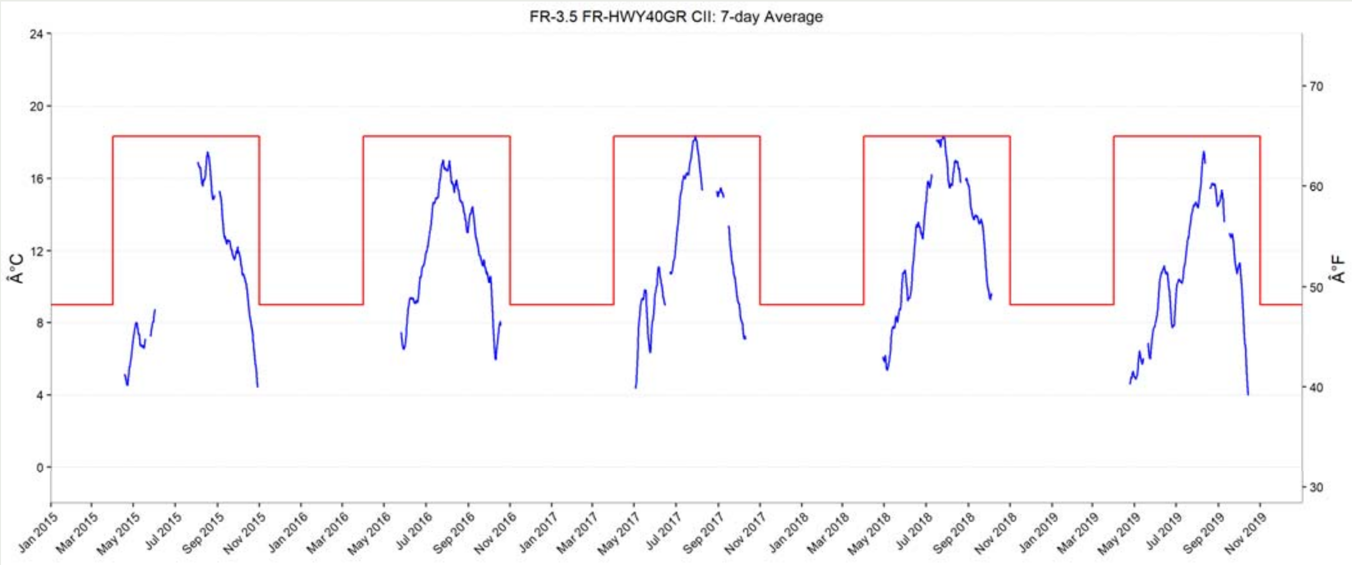
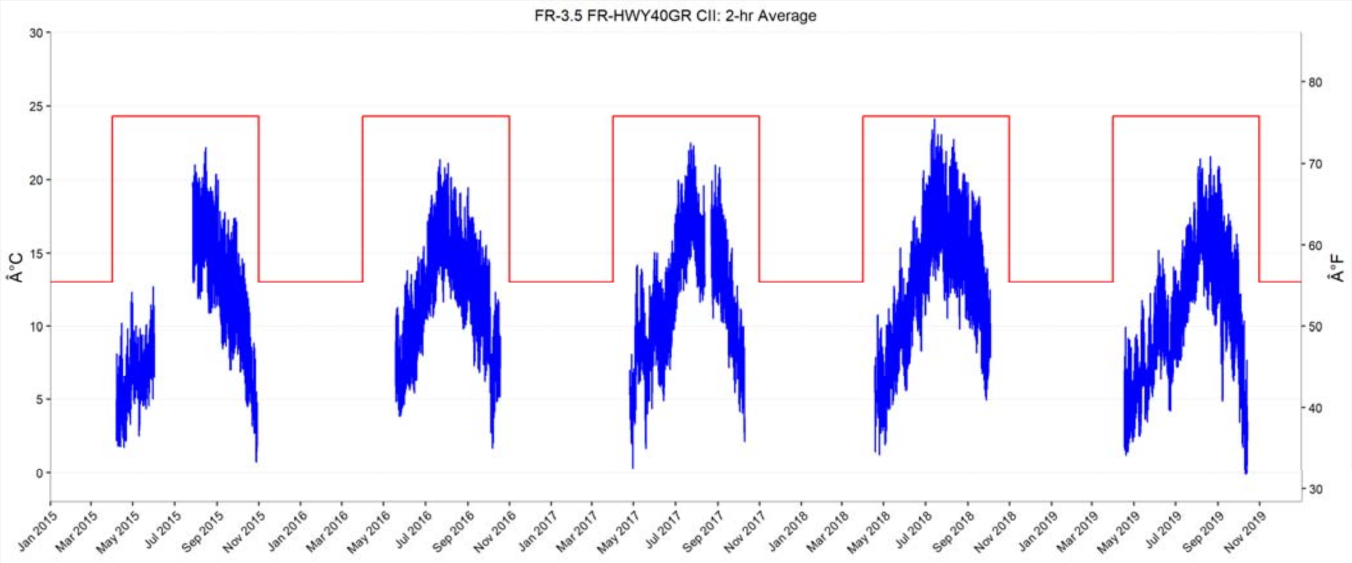
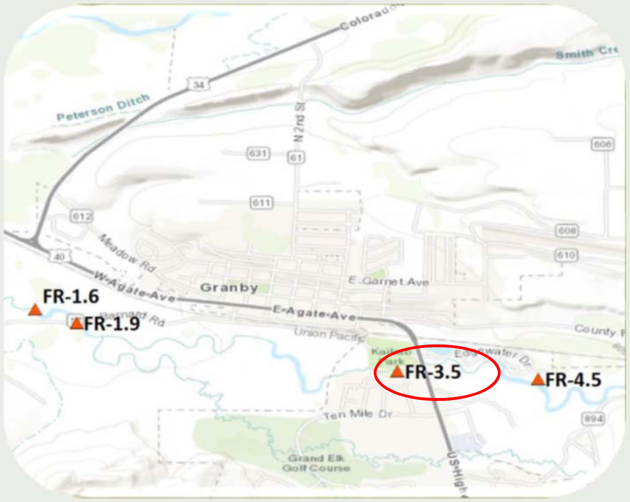




CSII
FR-HWY40GR
FR-3.5



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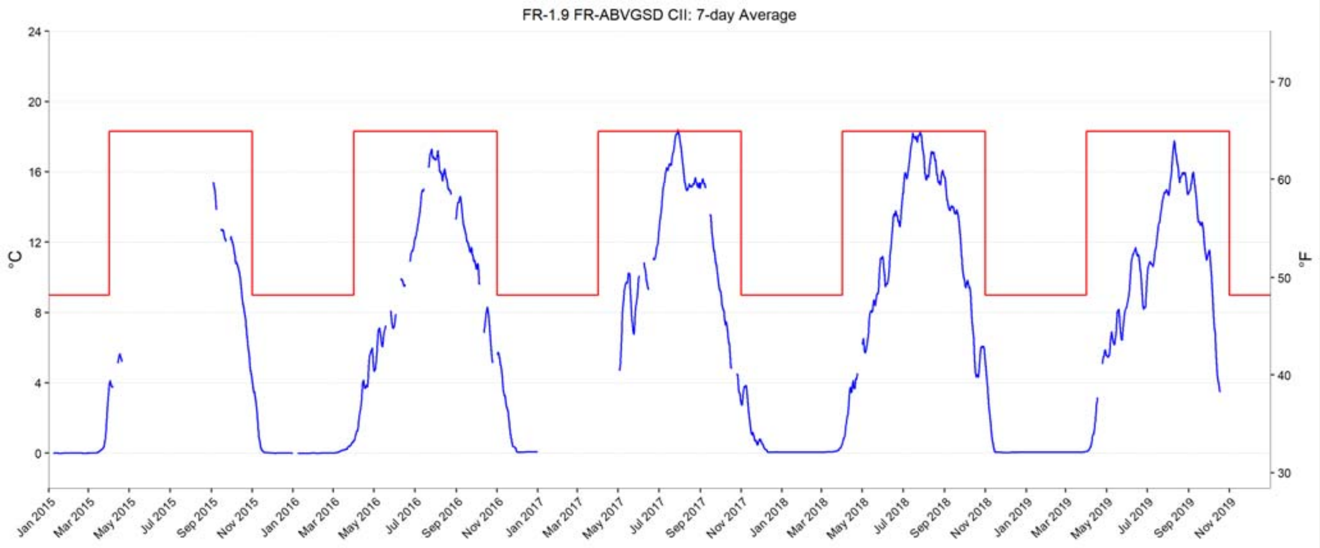
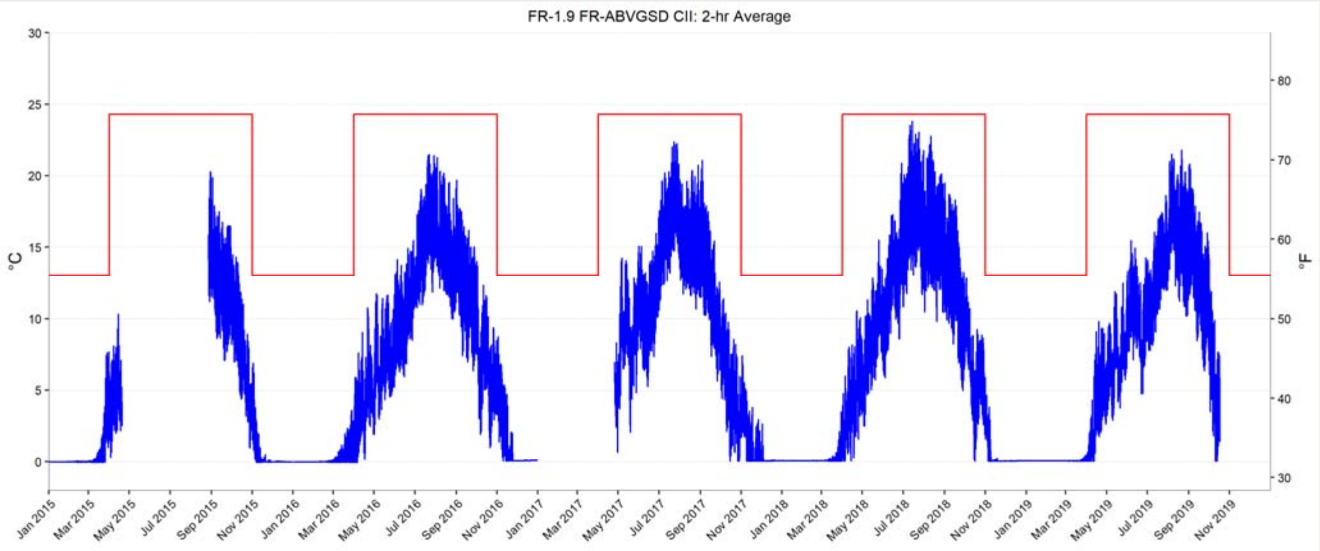
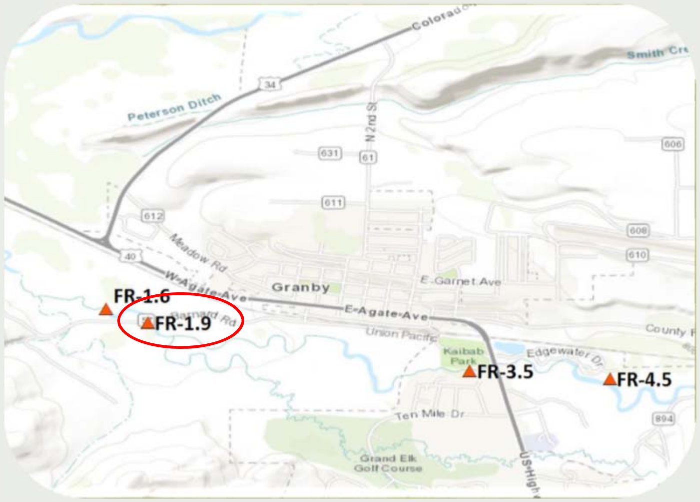




CSII
FR-abvGSD
FR-1.9



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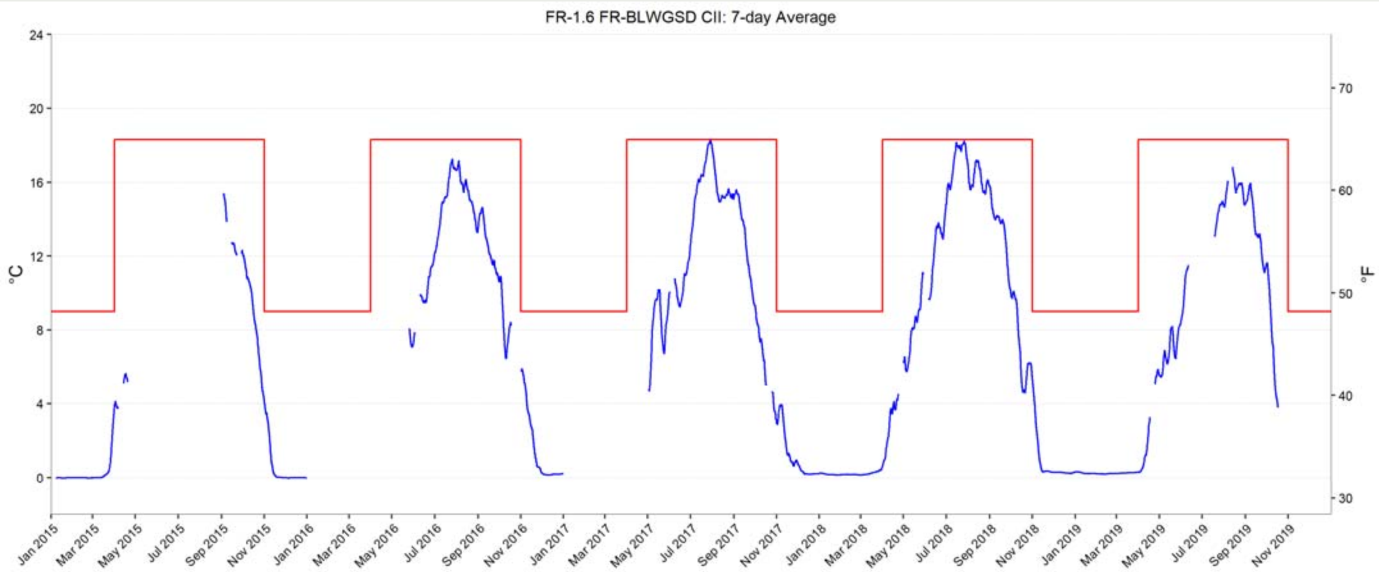
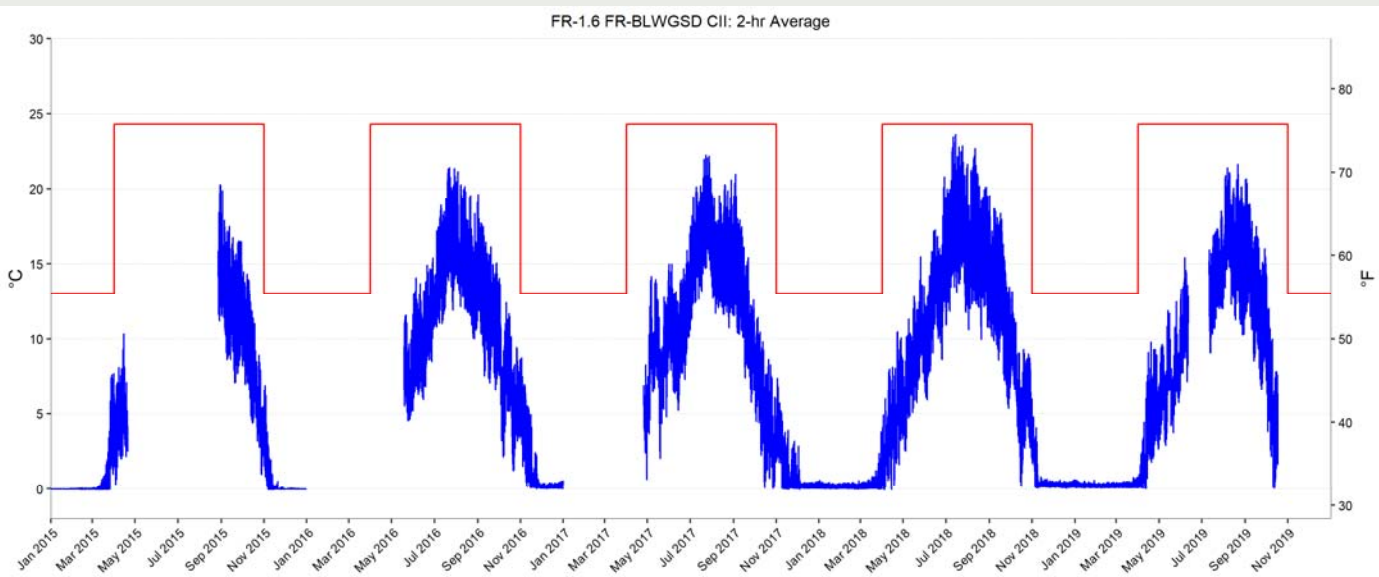
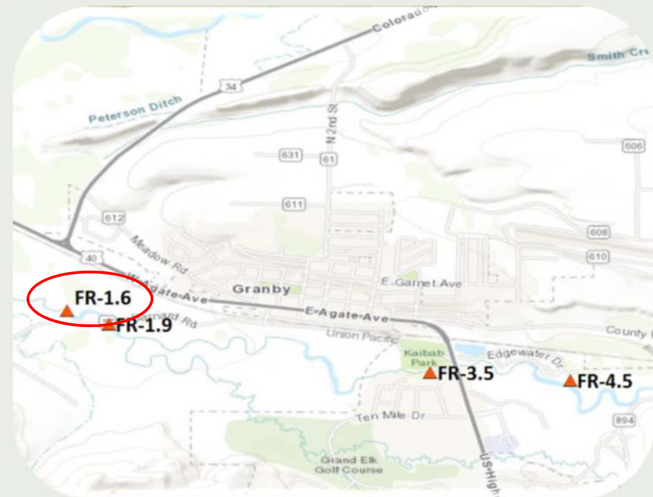




CSII
FR-blwGSD
FR-1.6



Note: Data gap in 2019 – Lost rig during high water.

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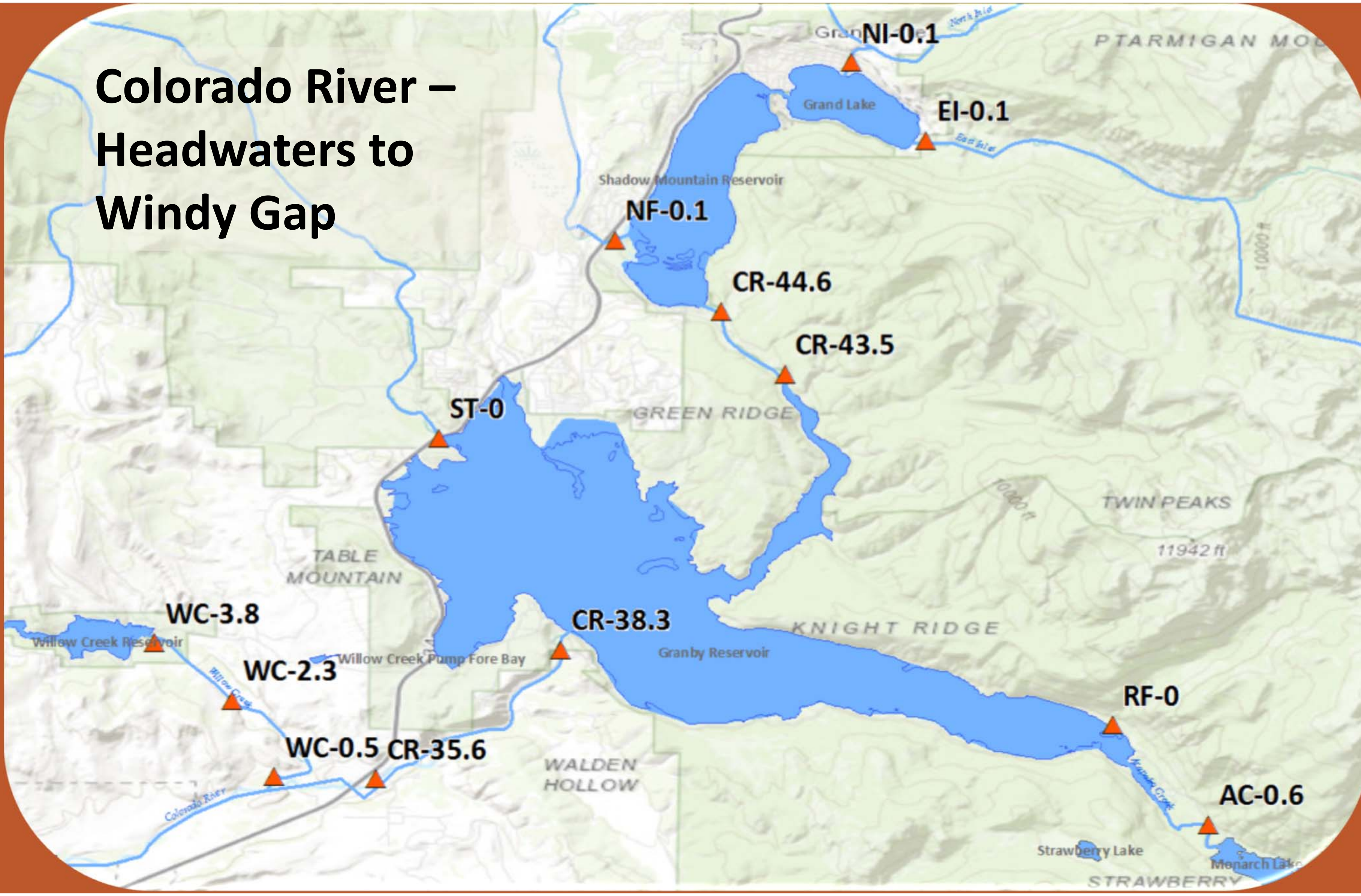

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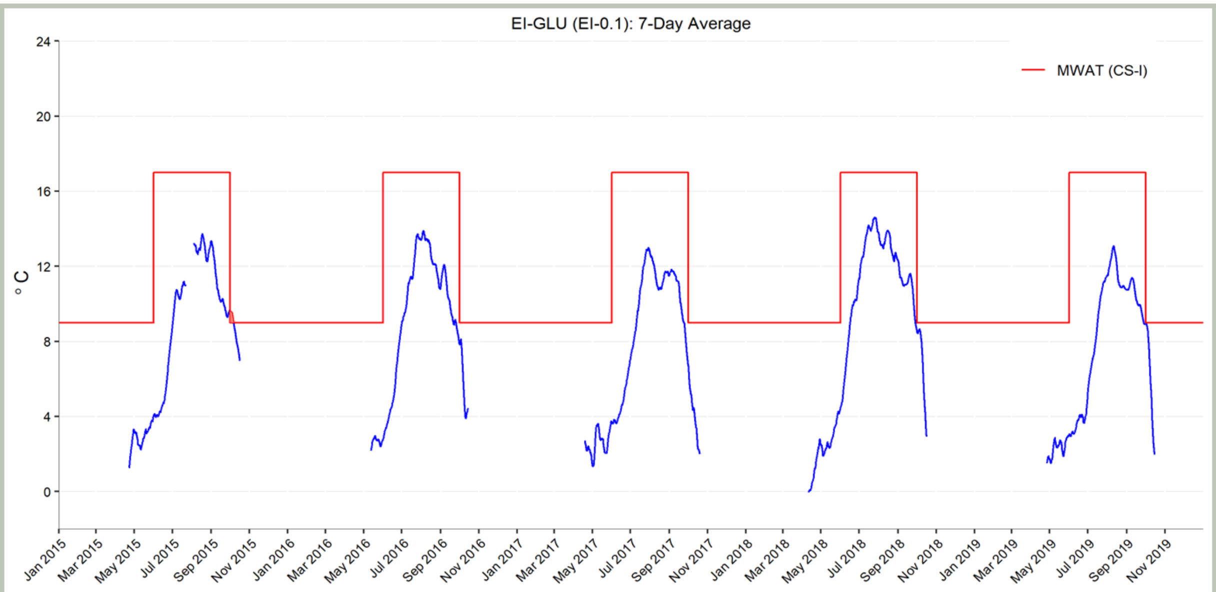
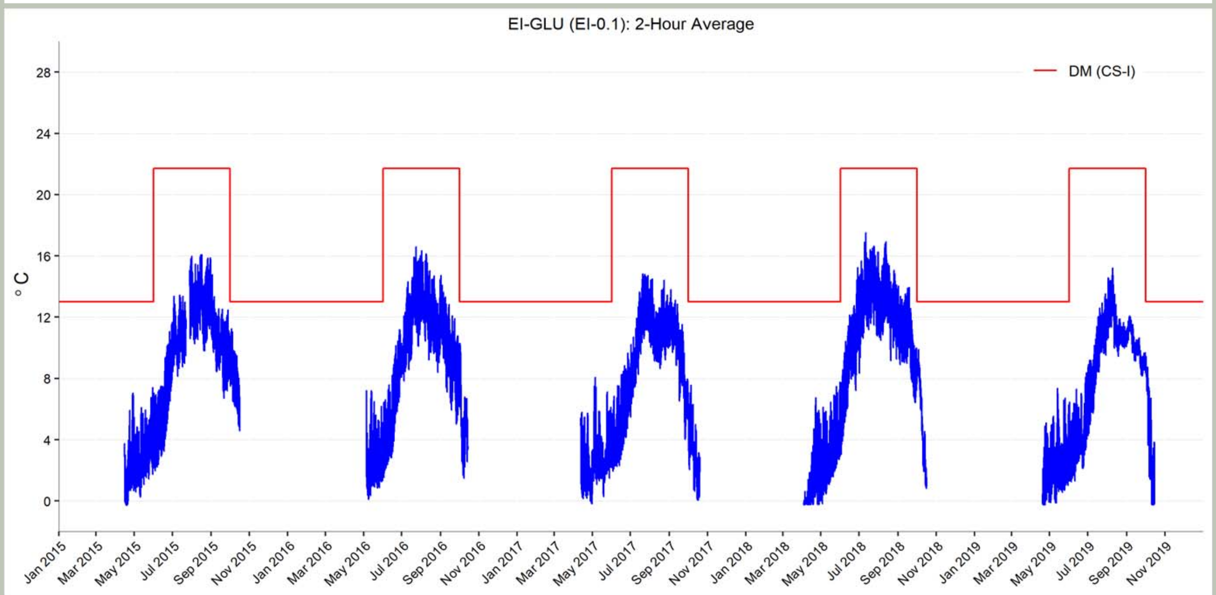
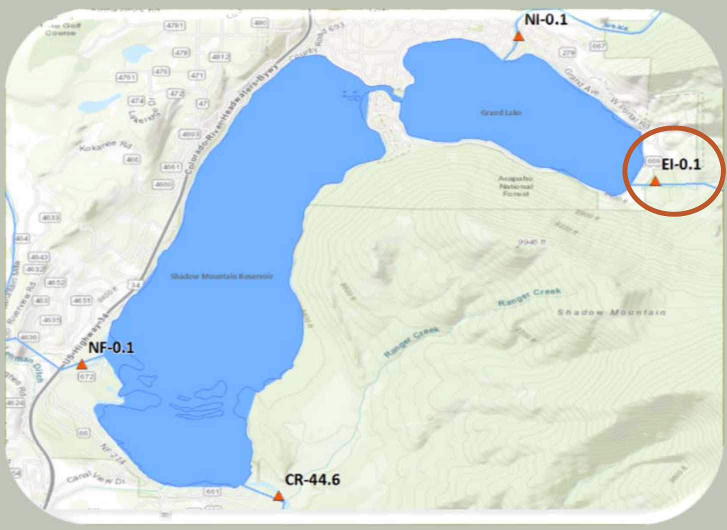




East Inlet - CSI



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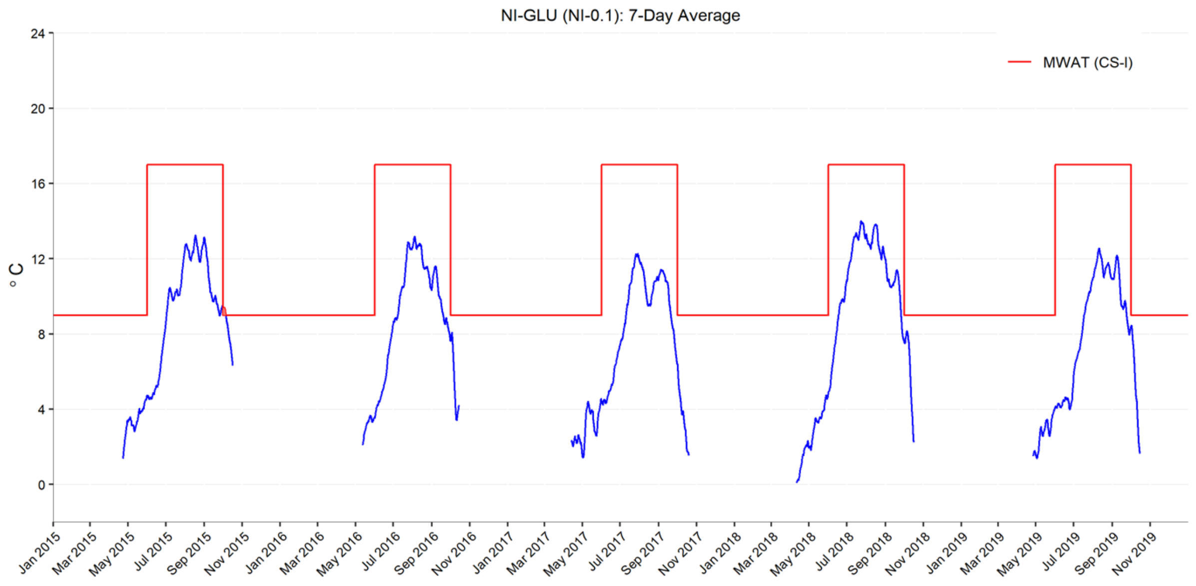
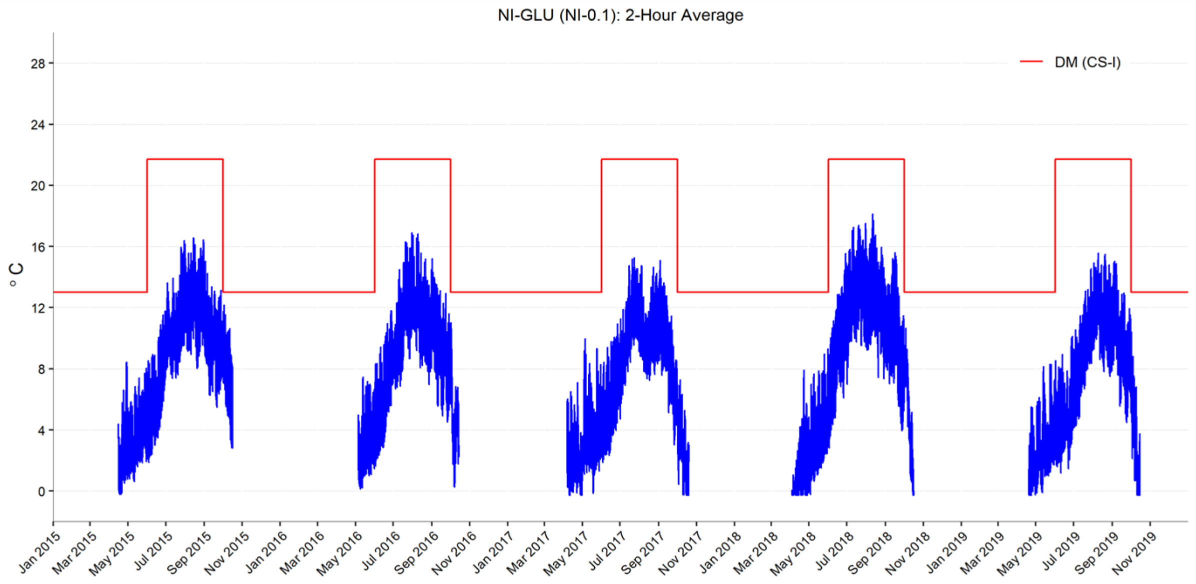
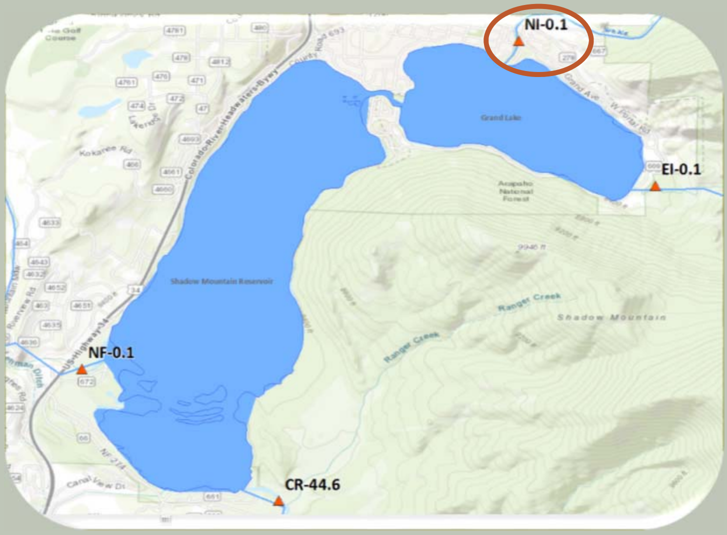




North Inlet - CSI



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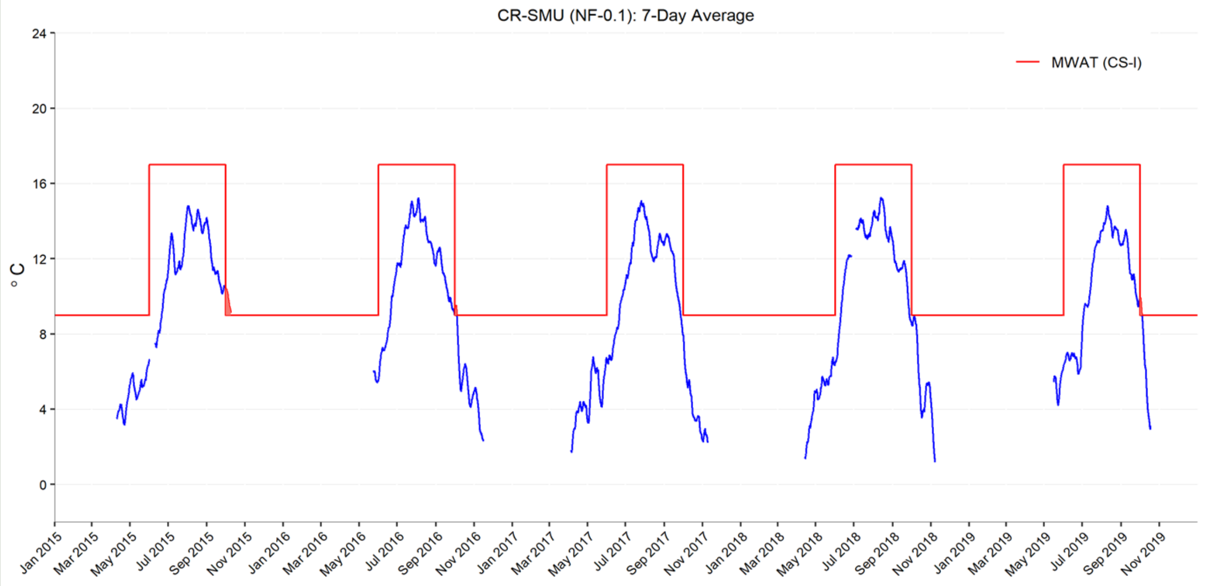
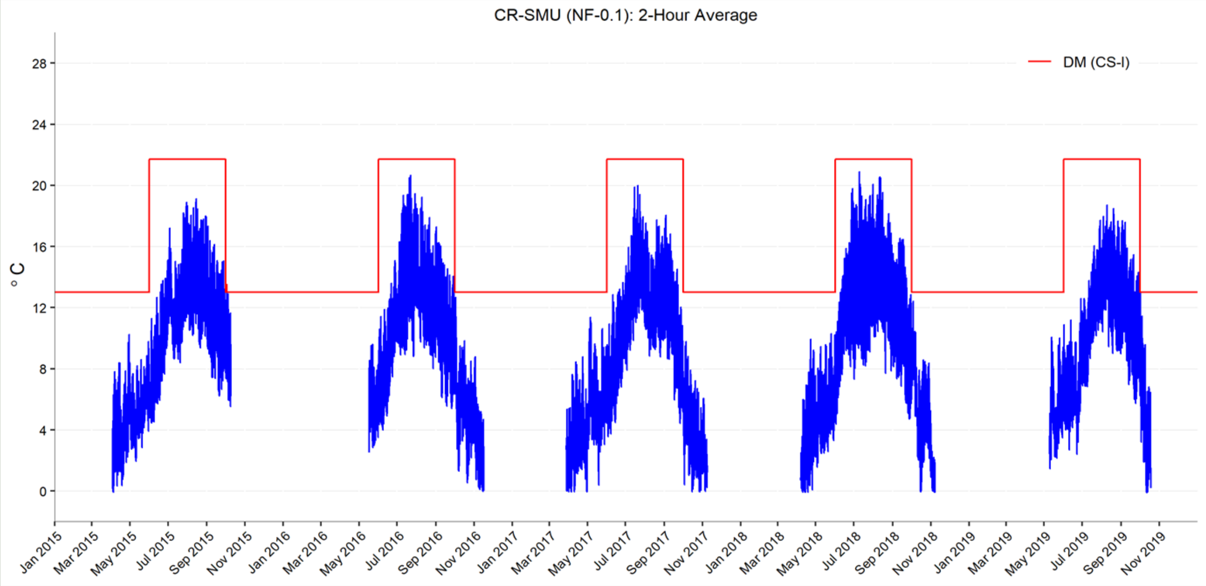
North Fork Colorado - CSI





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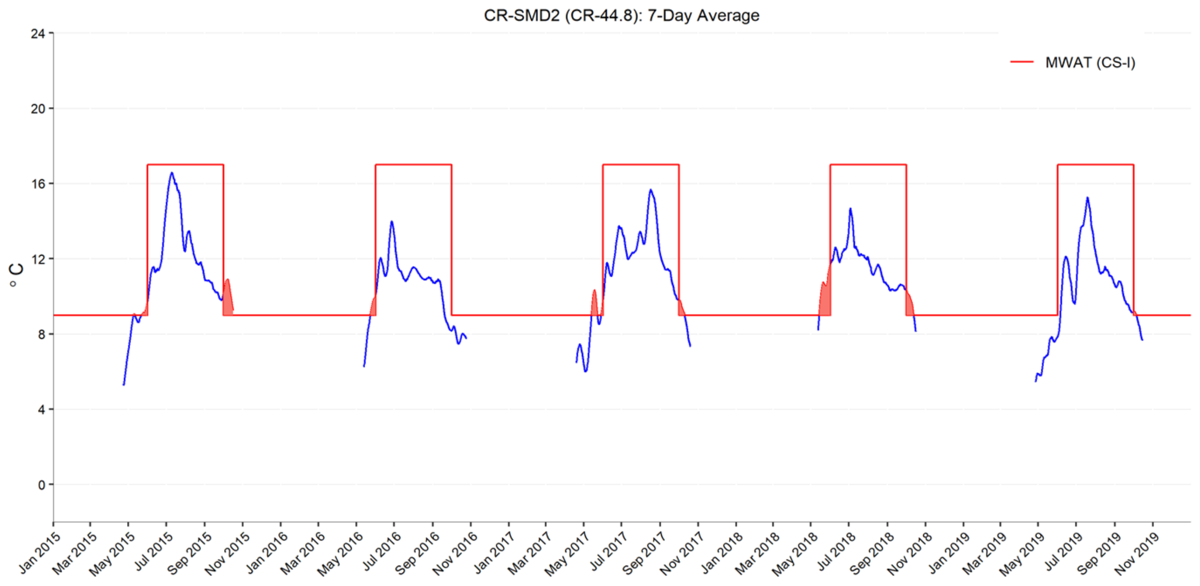
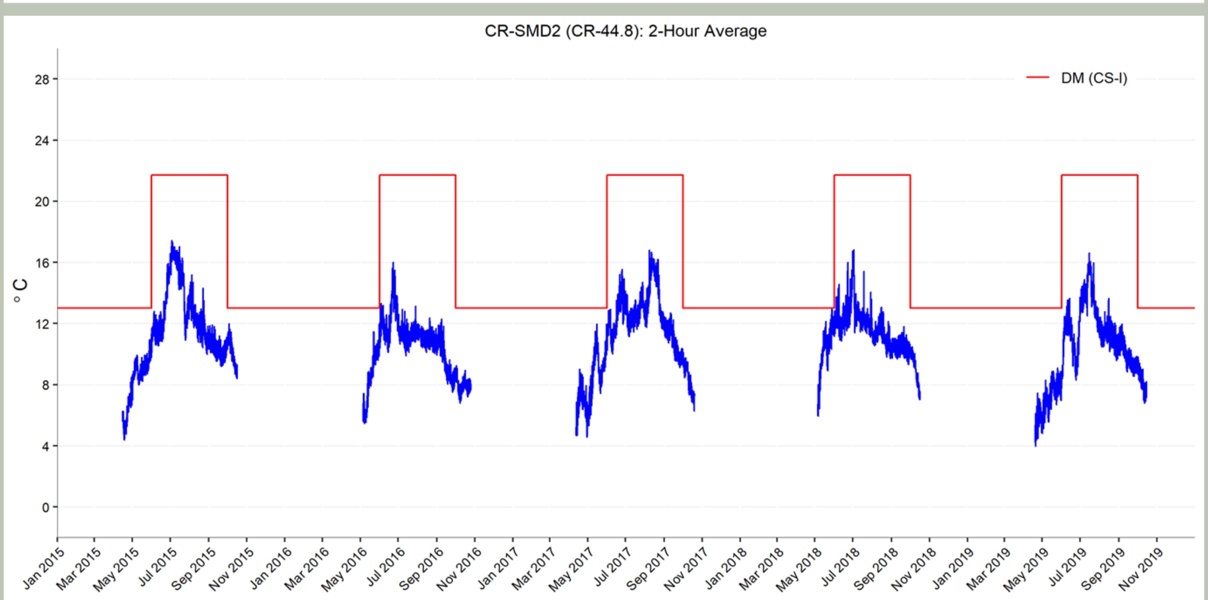
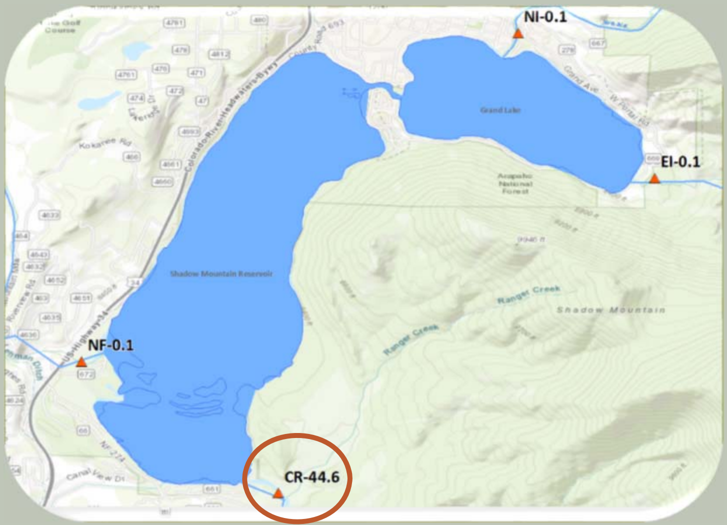




GCWIN/NW Site Colorado downstream Shadow Mountain - CSI



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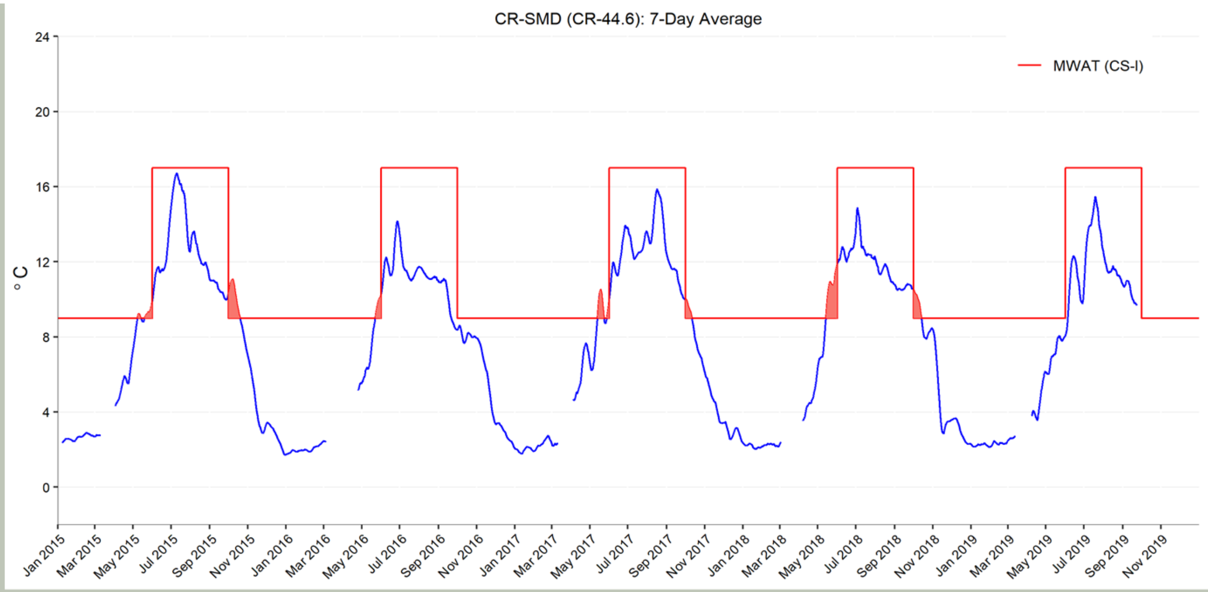
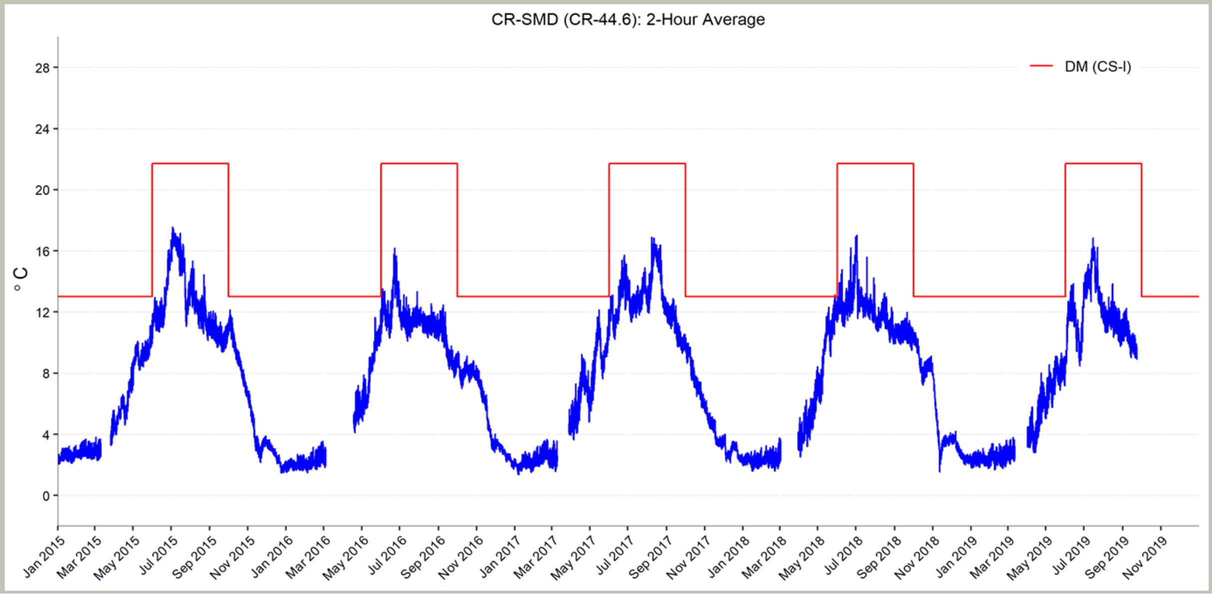
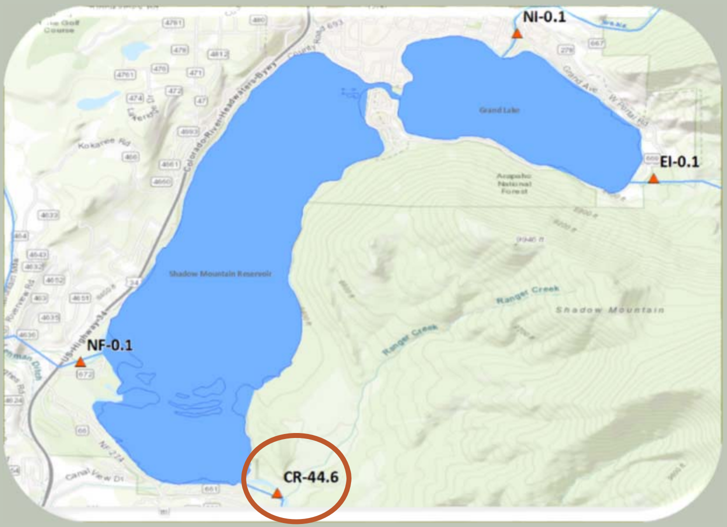
Northern Water Site Colorado downstream Shadow Mountain - CSI







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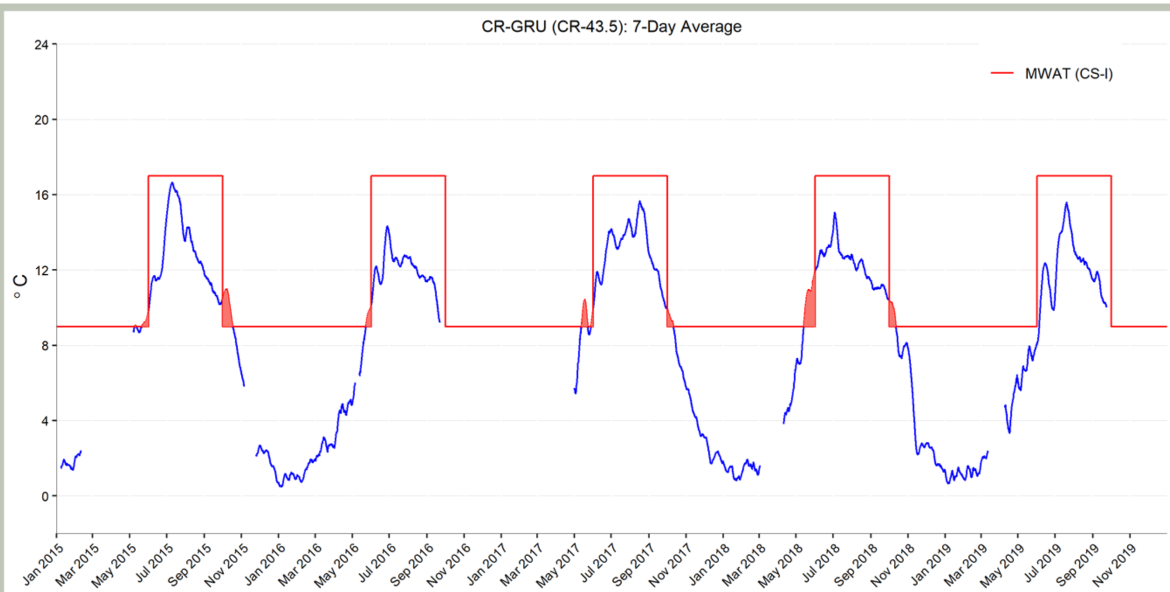
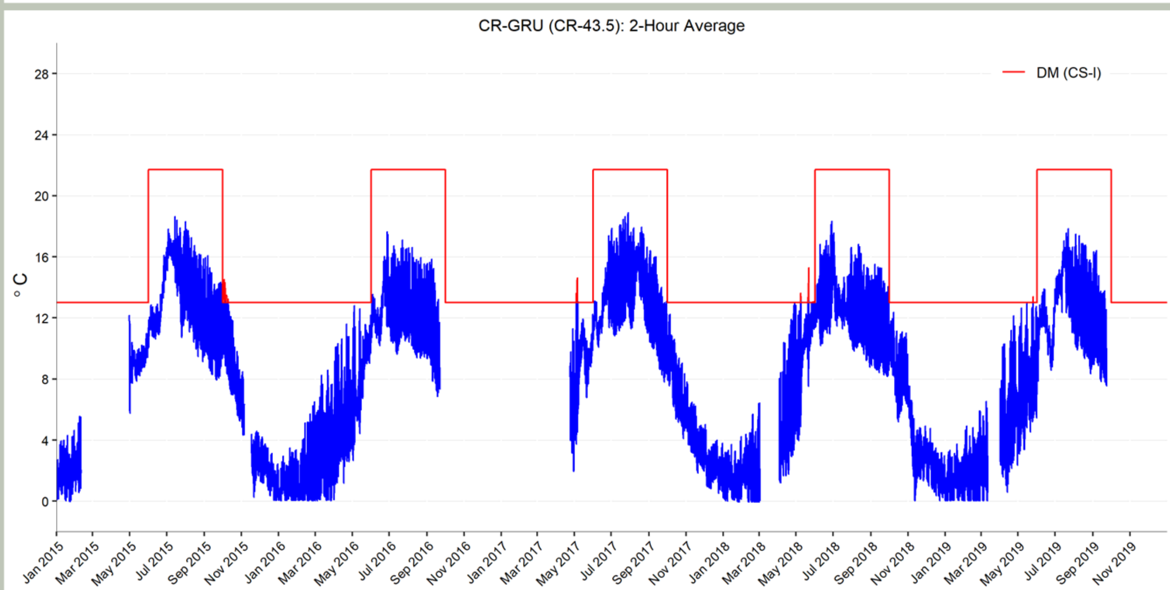
Colorado upstream Granby Reservoir - CSI





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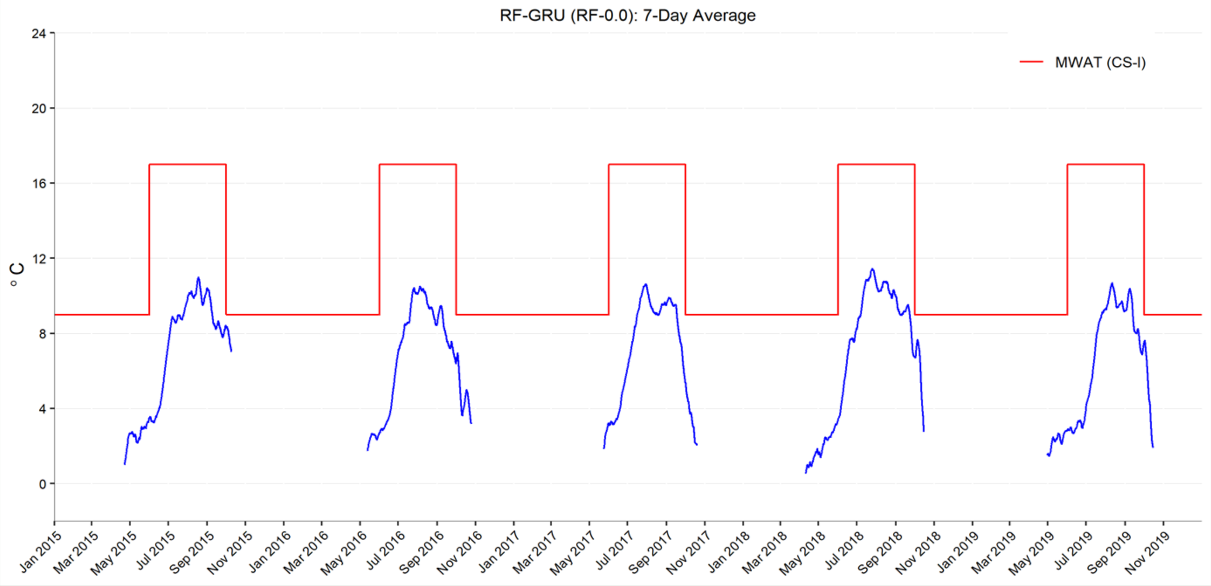

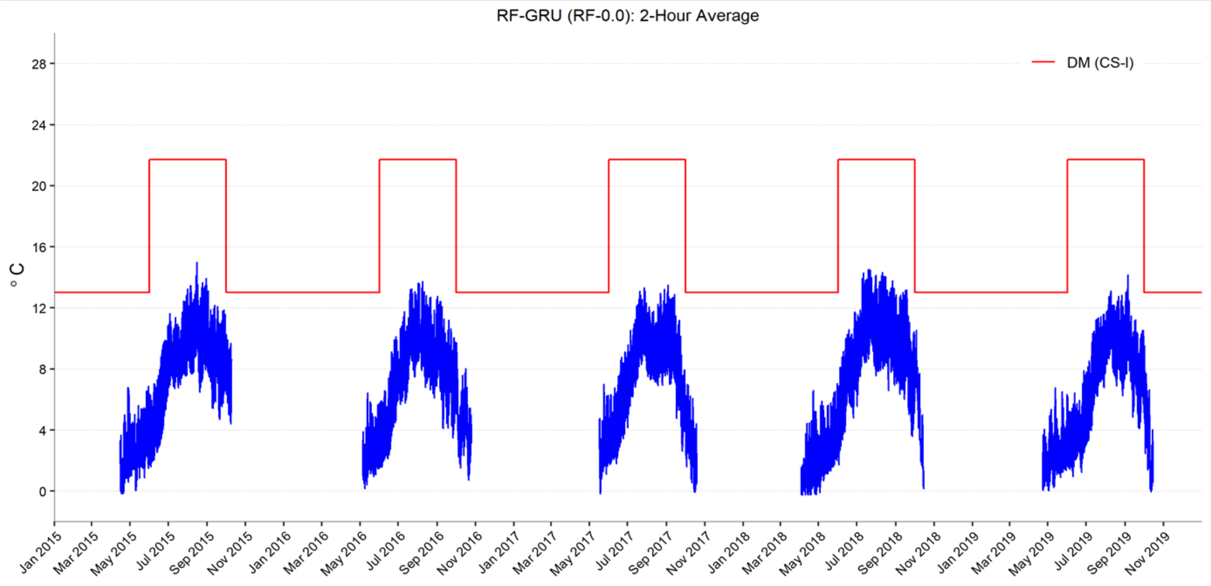

Roaring Fork - CSI

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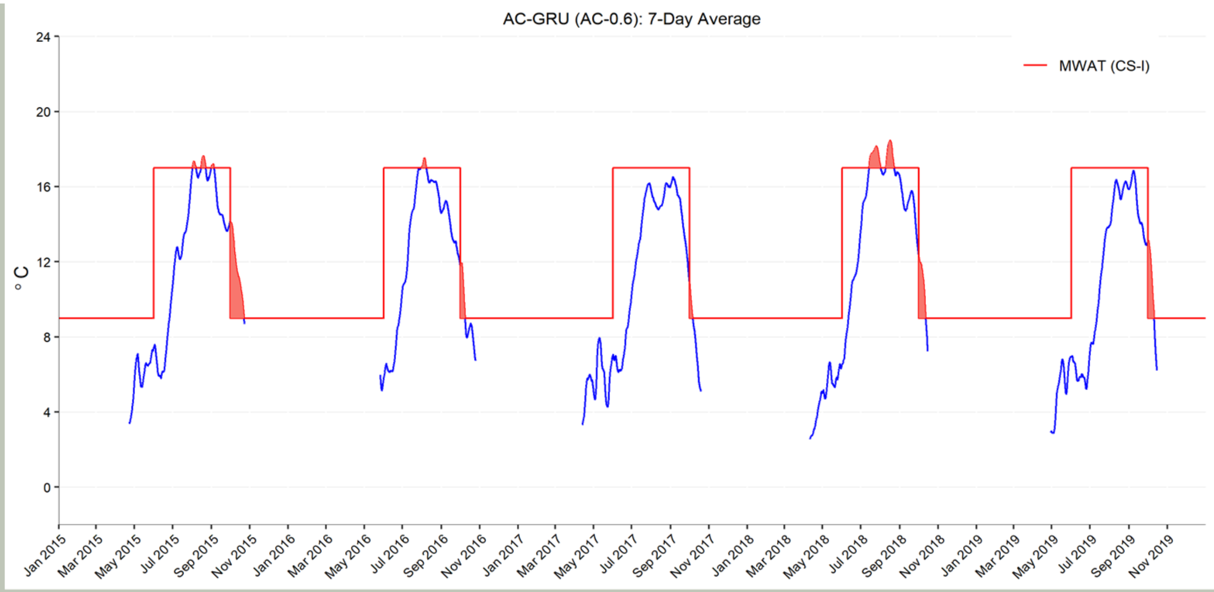

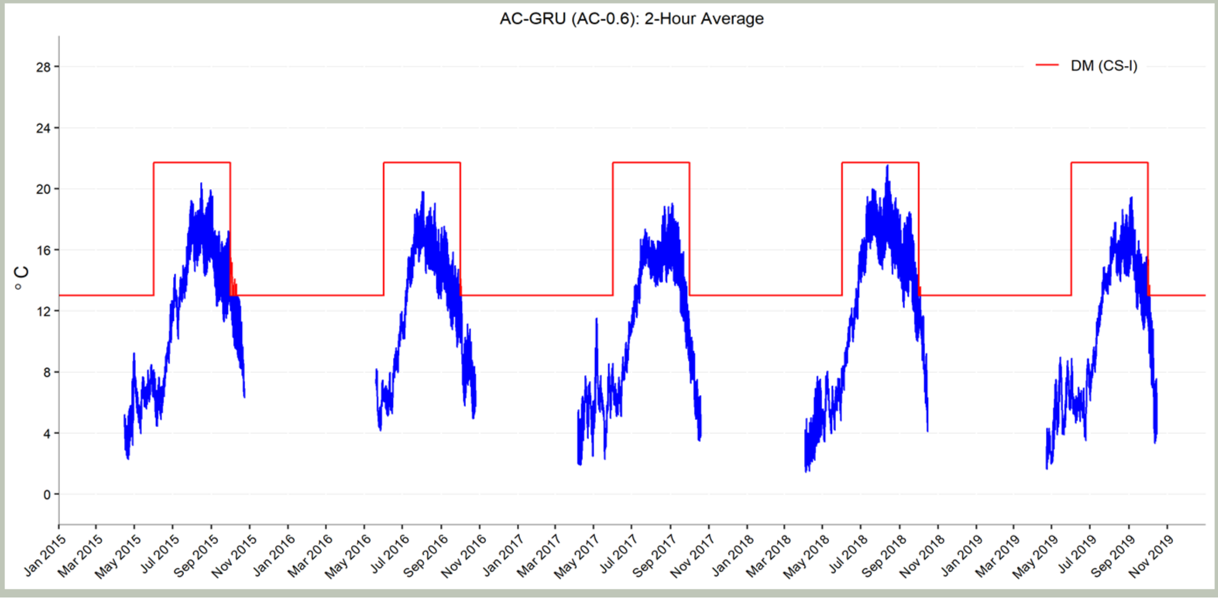

Arapaho Creek - CSI

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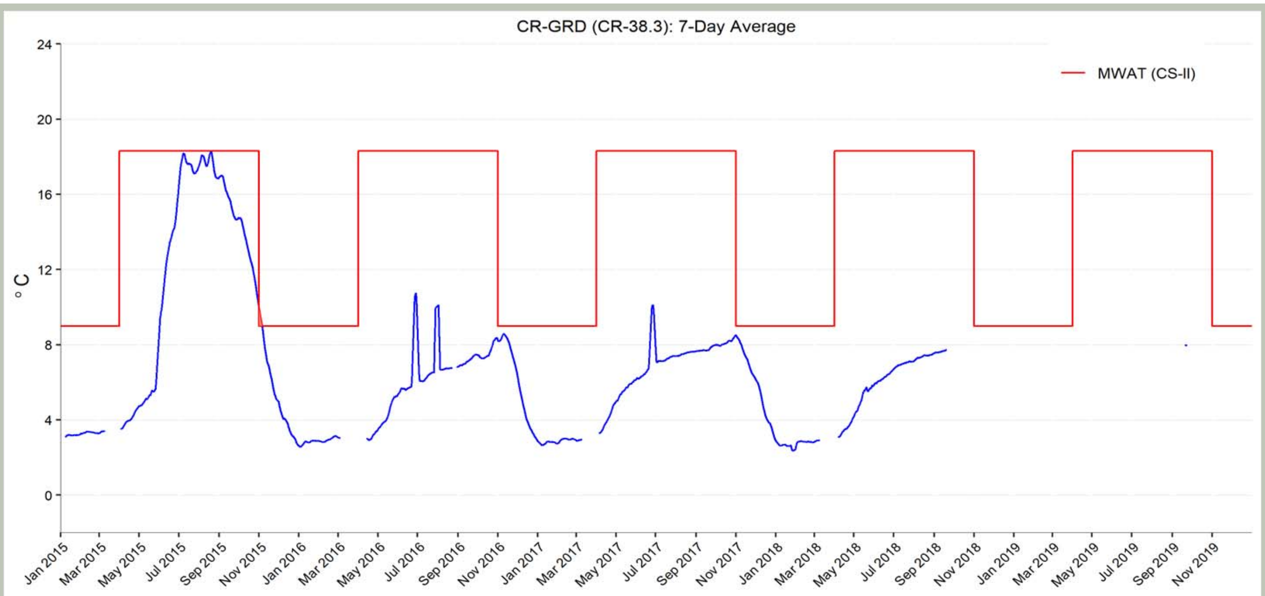

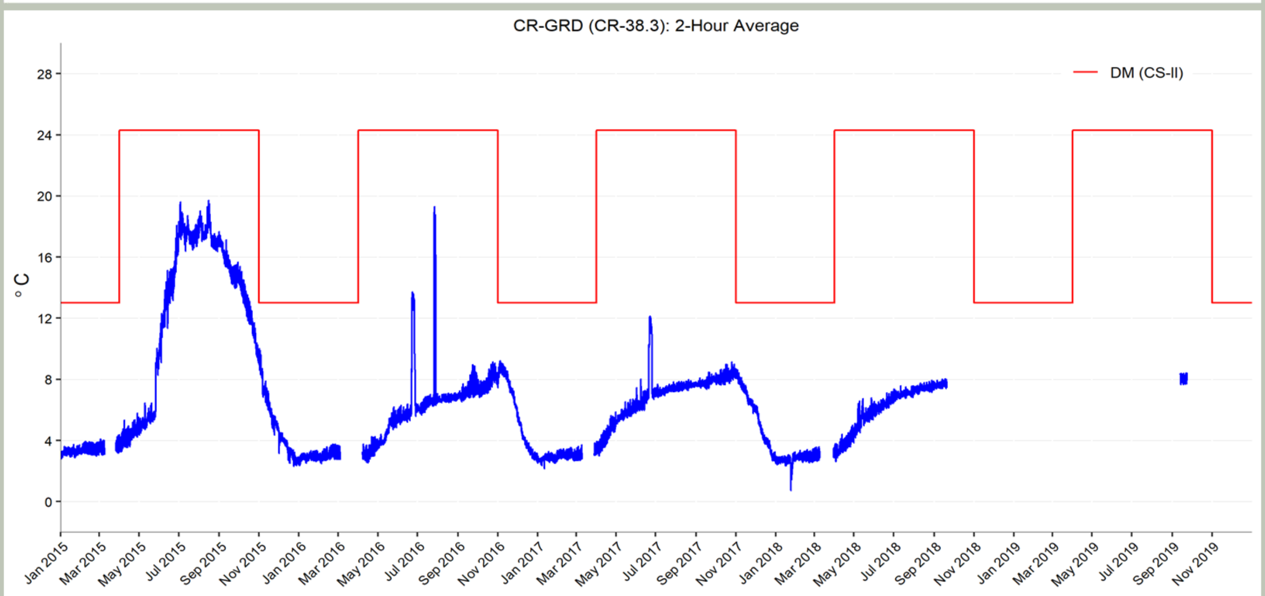

Colorado River downstream of Granby Reservoir- CSII

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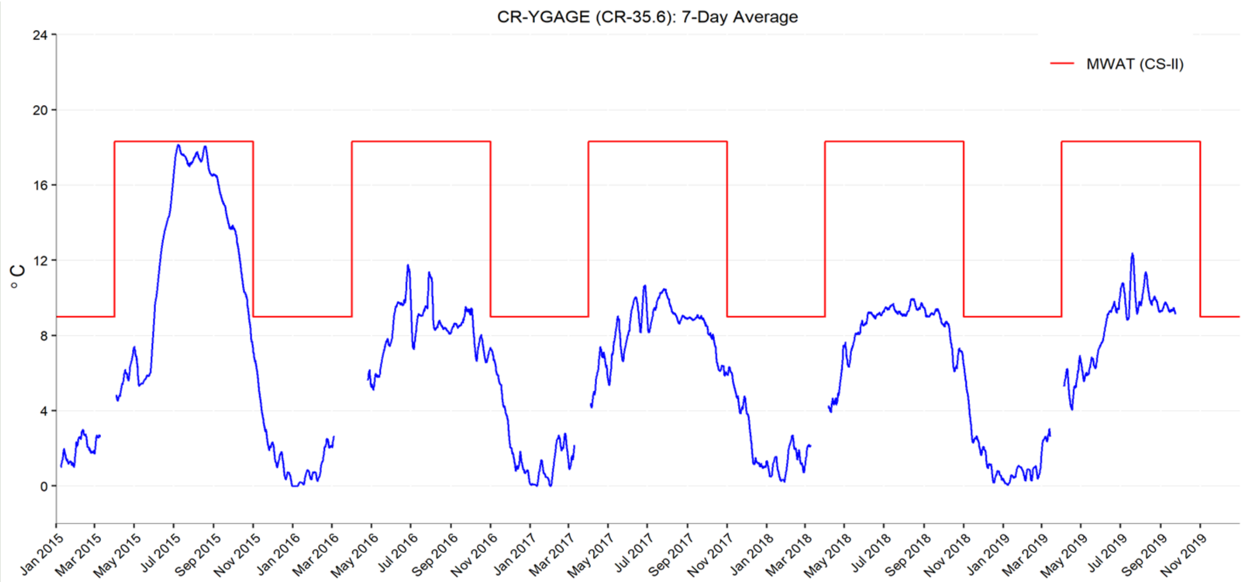
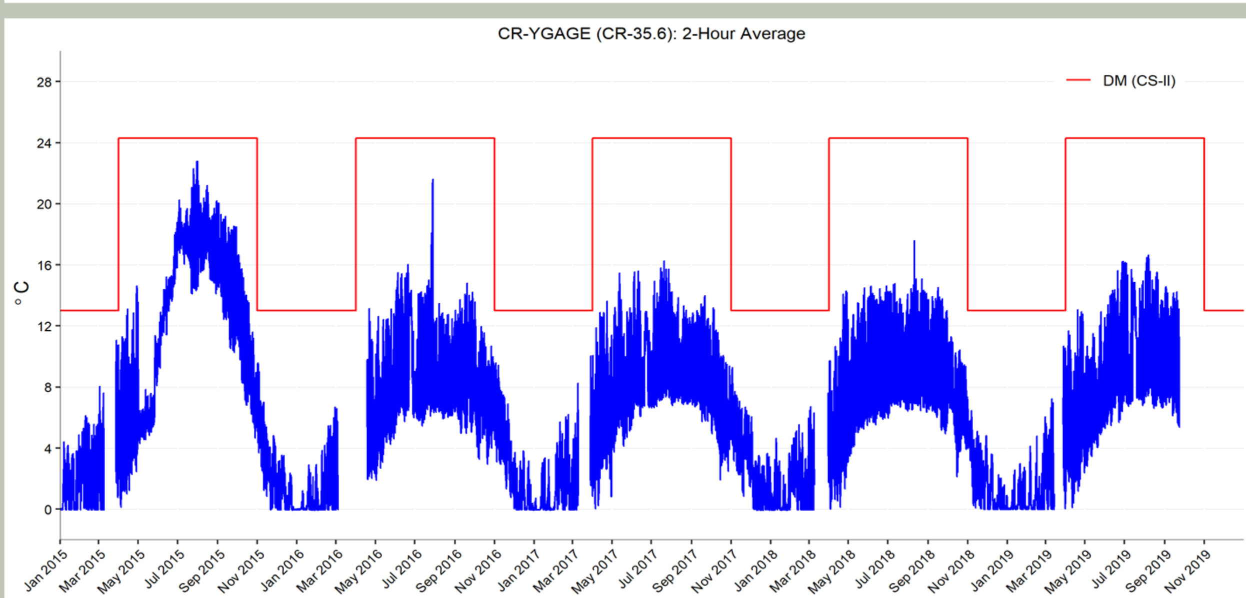
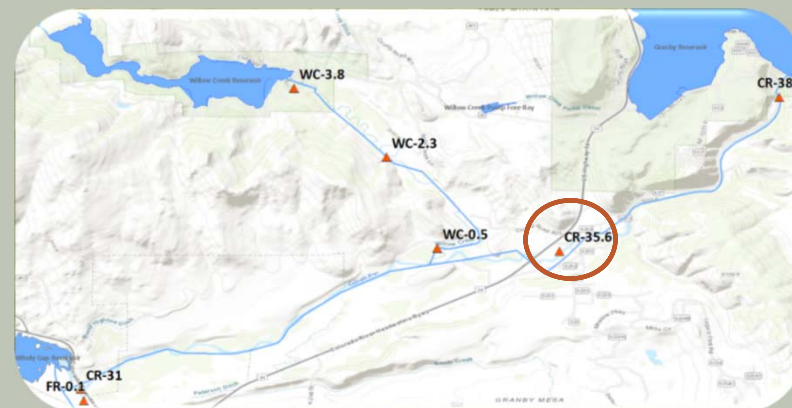
Colorado River at Y-Gage - CSII







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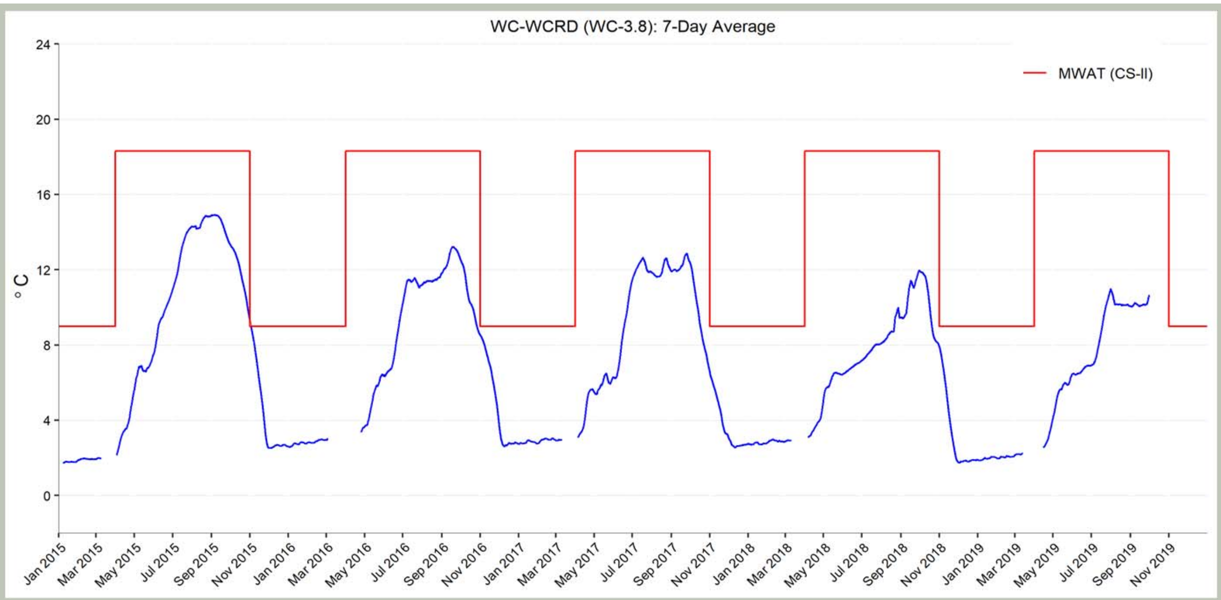
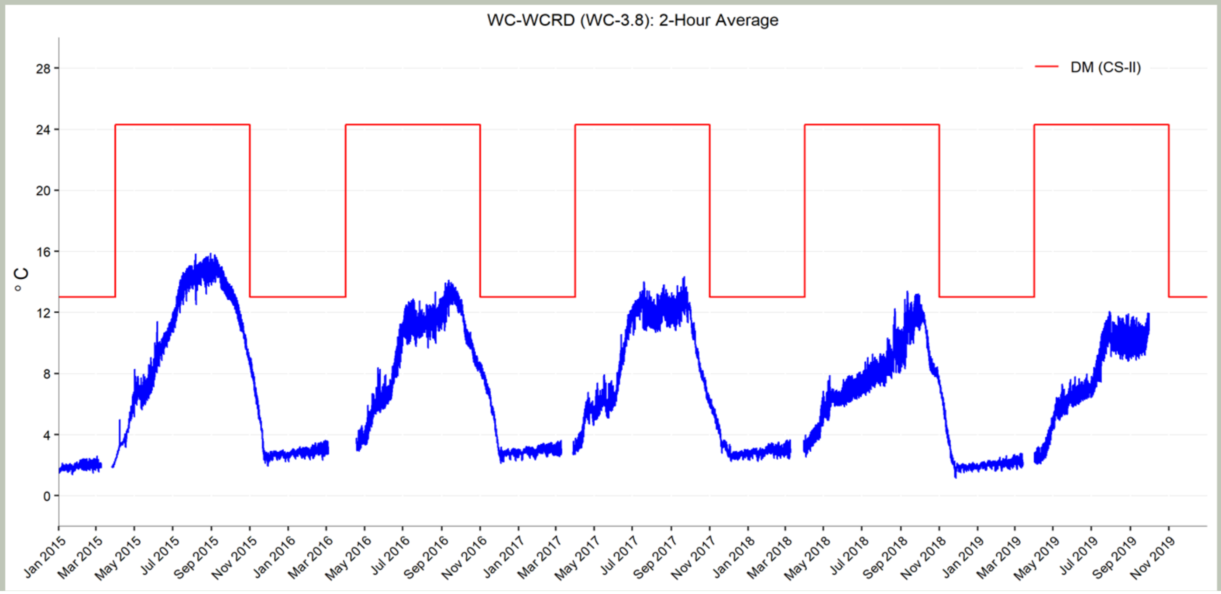
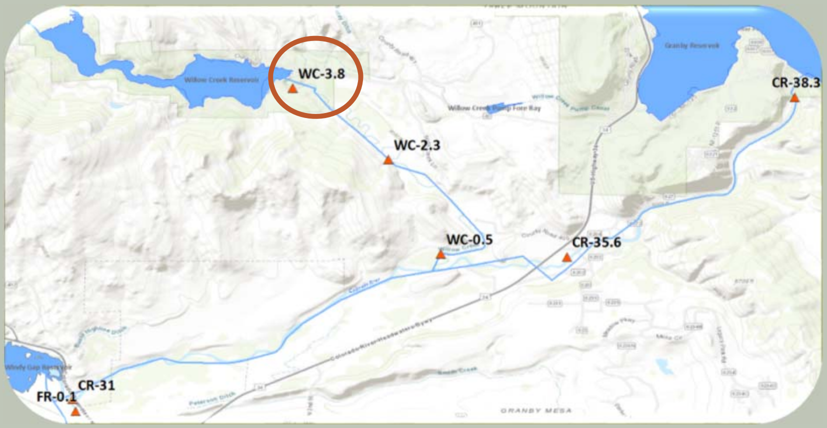




Willow Creek downstream of Reservoir – CS-II



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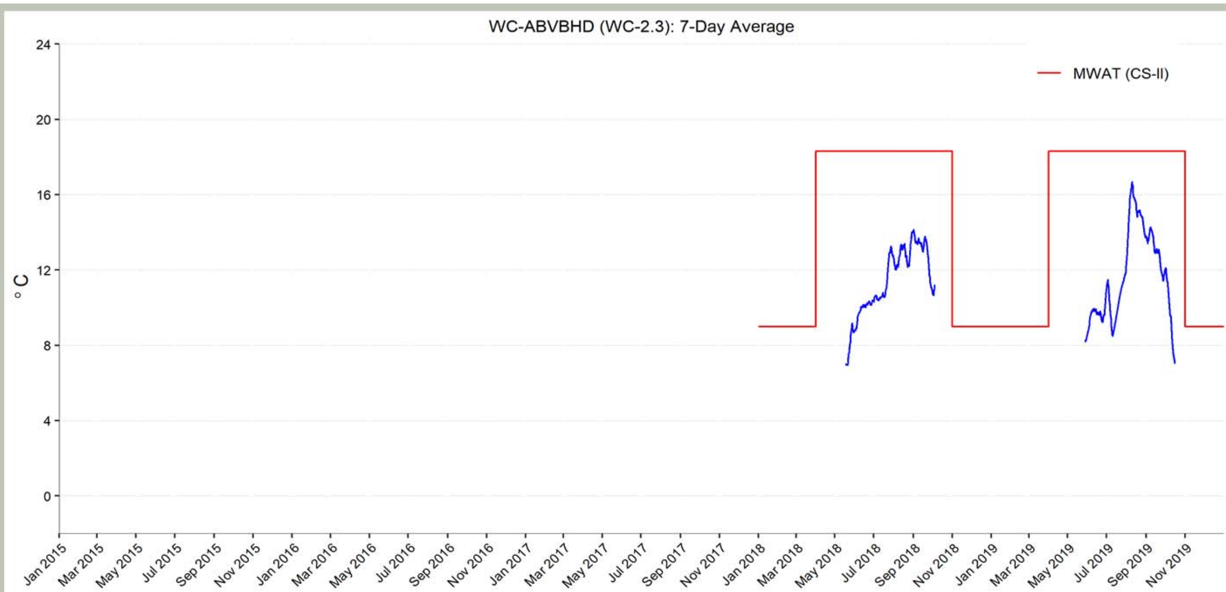
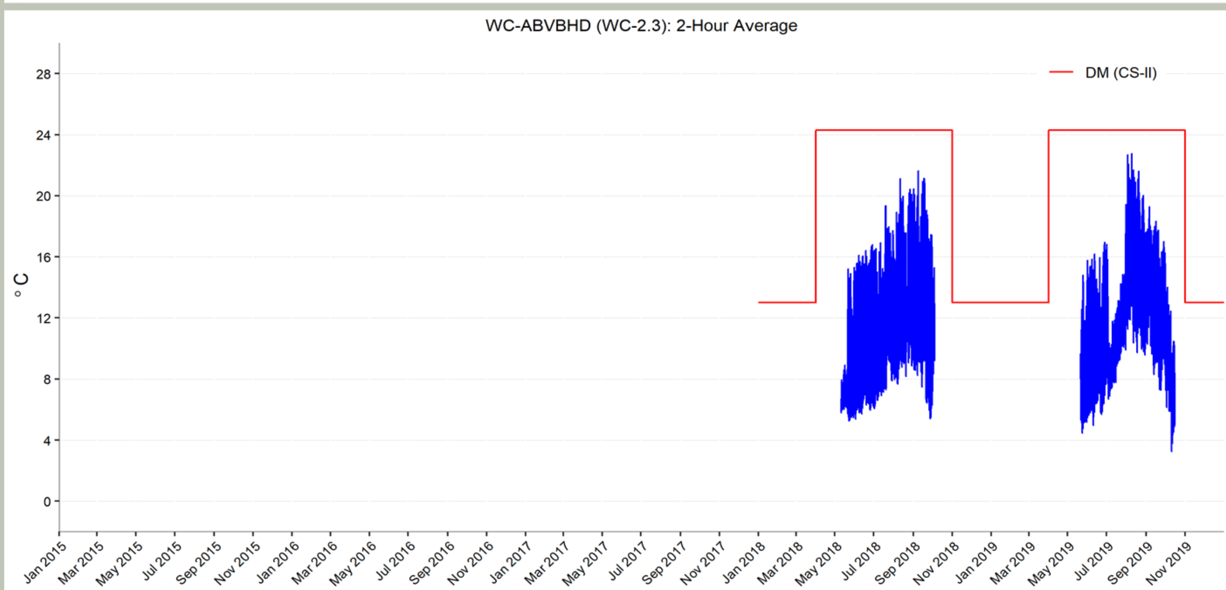
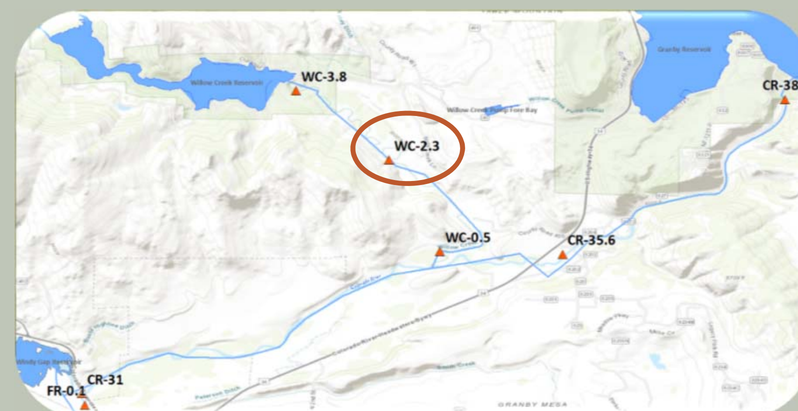




Willow Creek upstream Bunte Highline – CS-II



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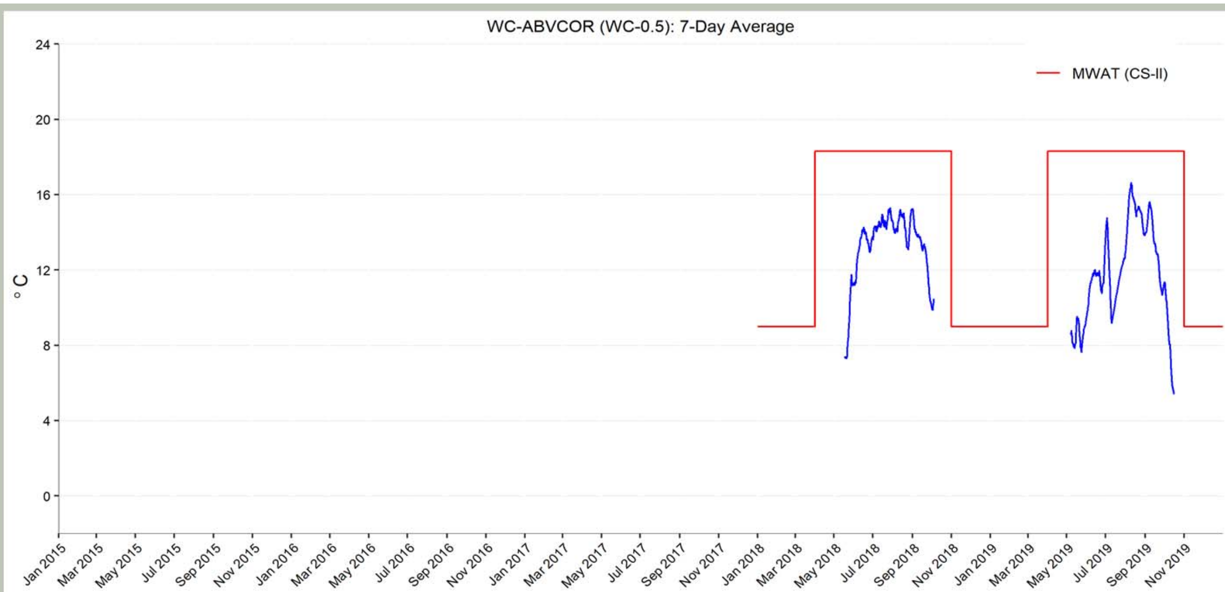
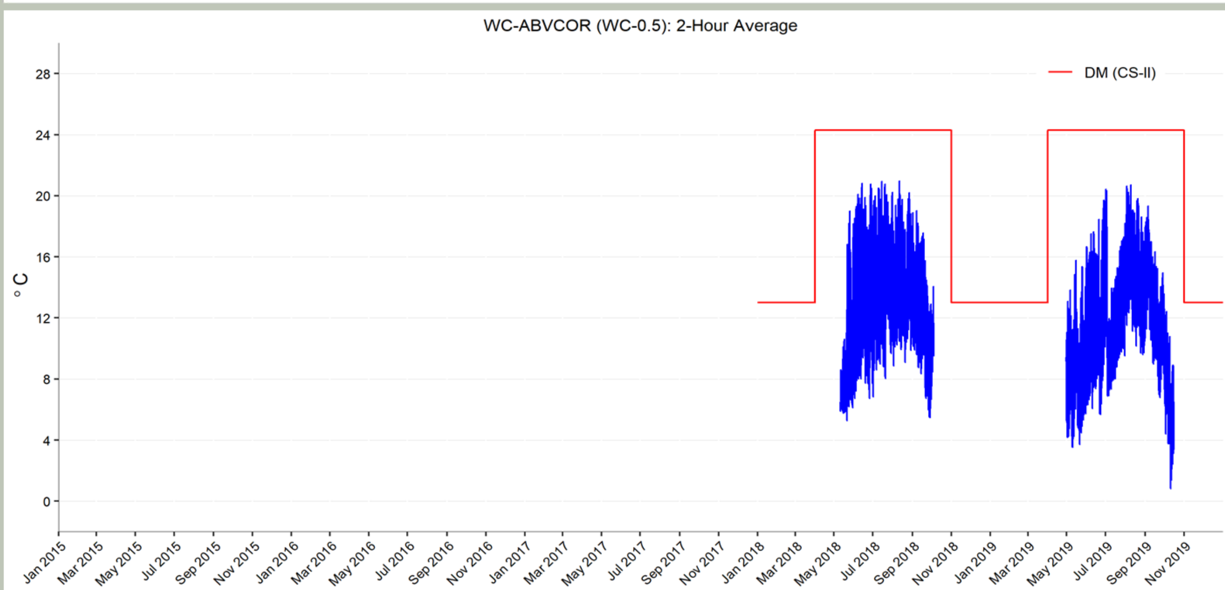
Willow Creek upstream Colorado River – CS-II





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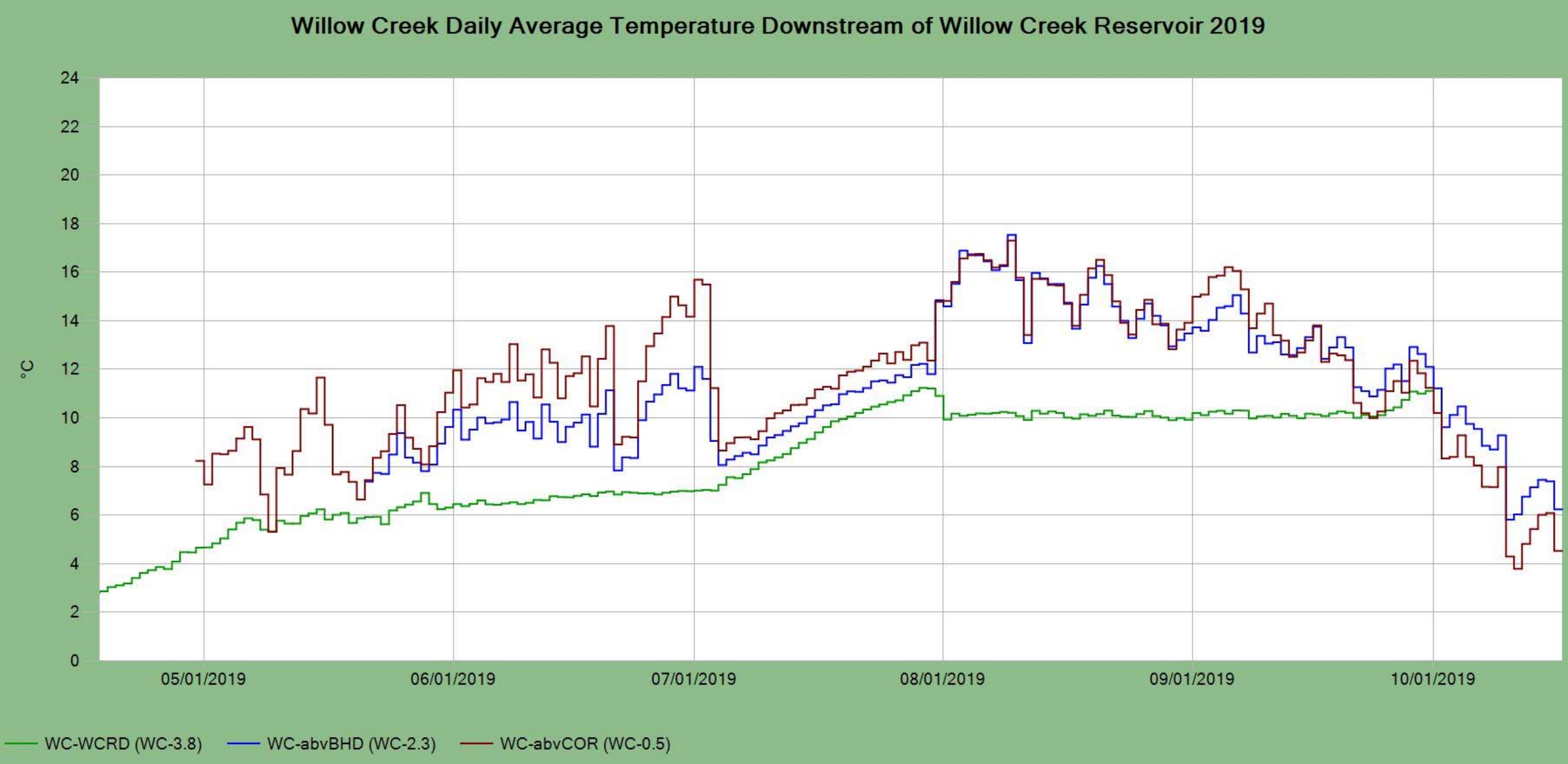

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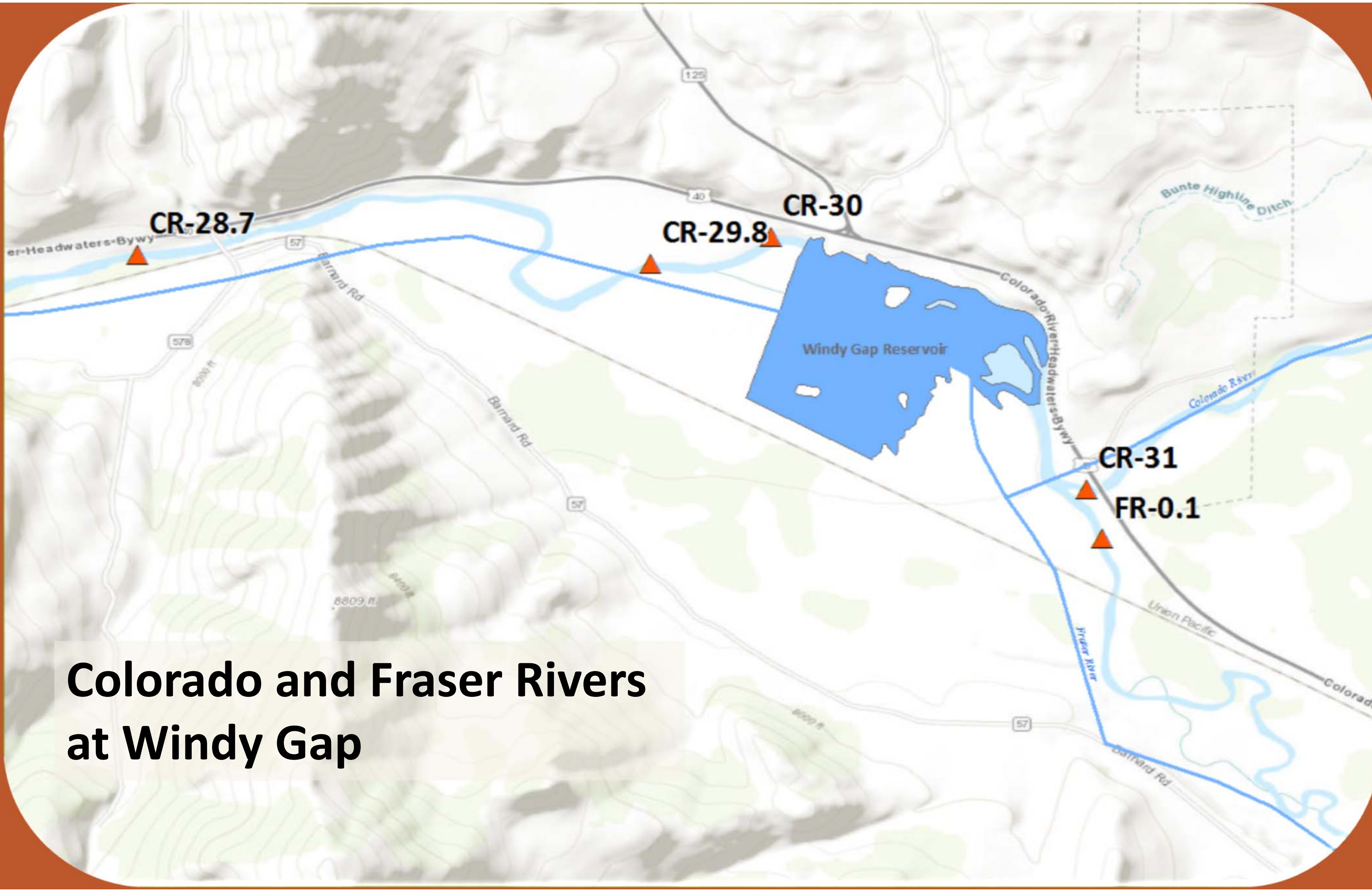

Colorado and Fraser Rivers at Windy Gap

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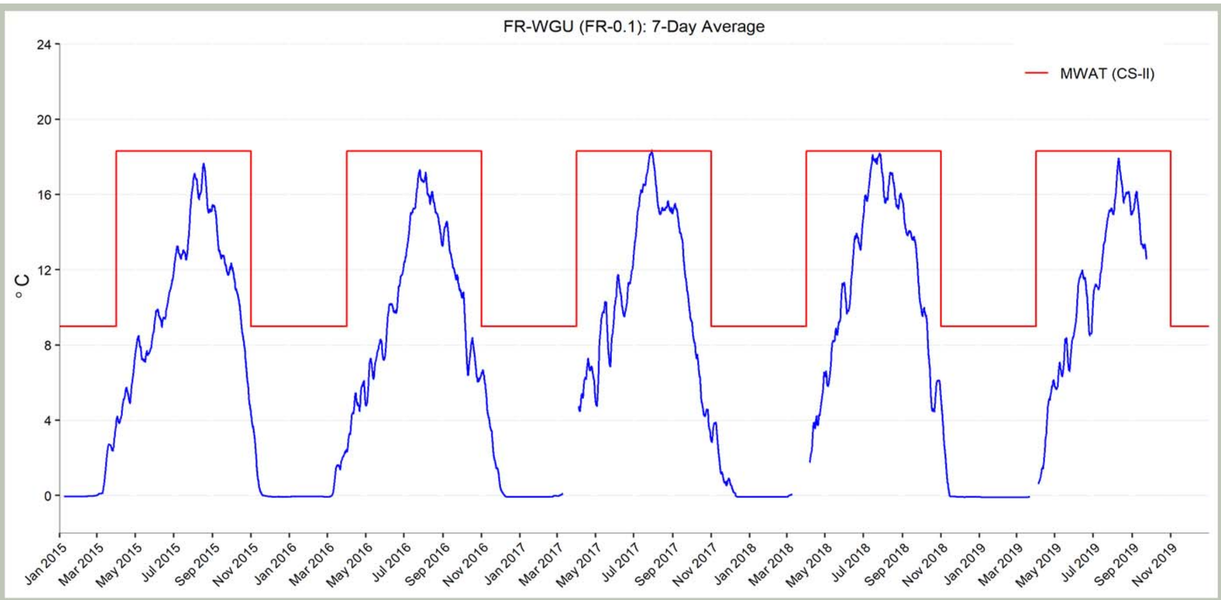
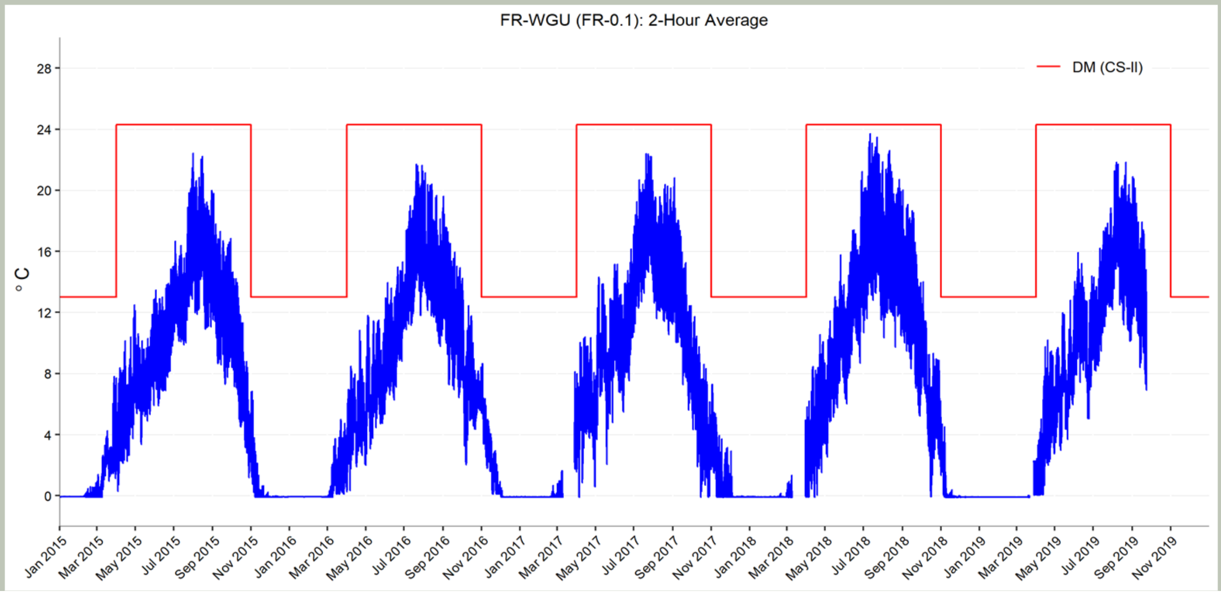
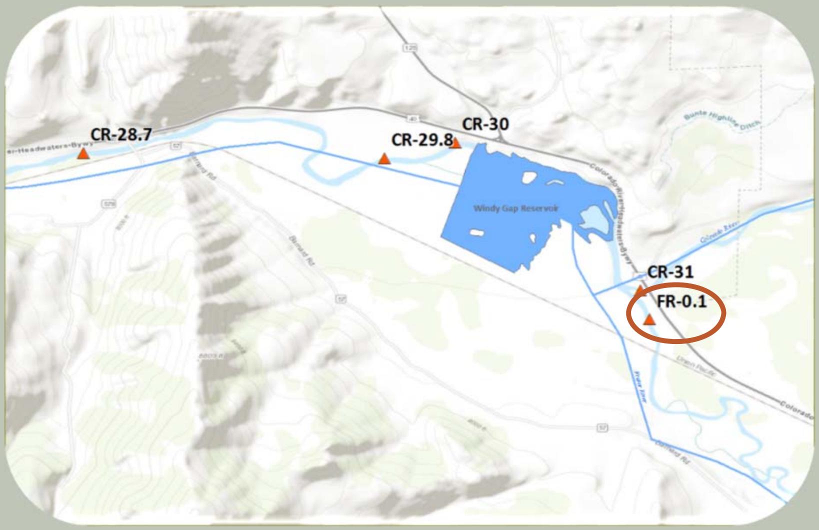




Fraser River upstream of Windy Gap – CSII



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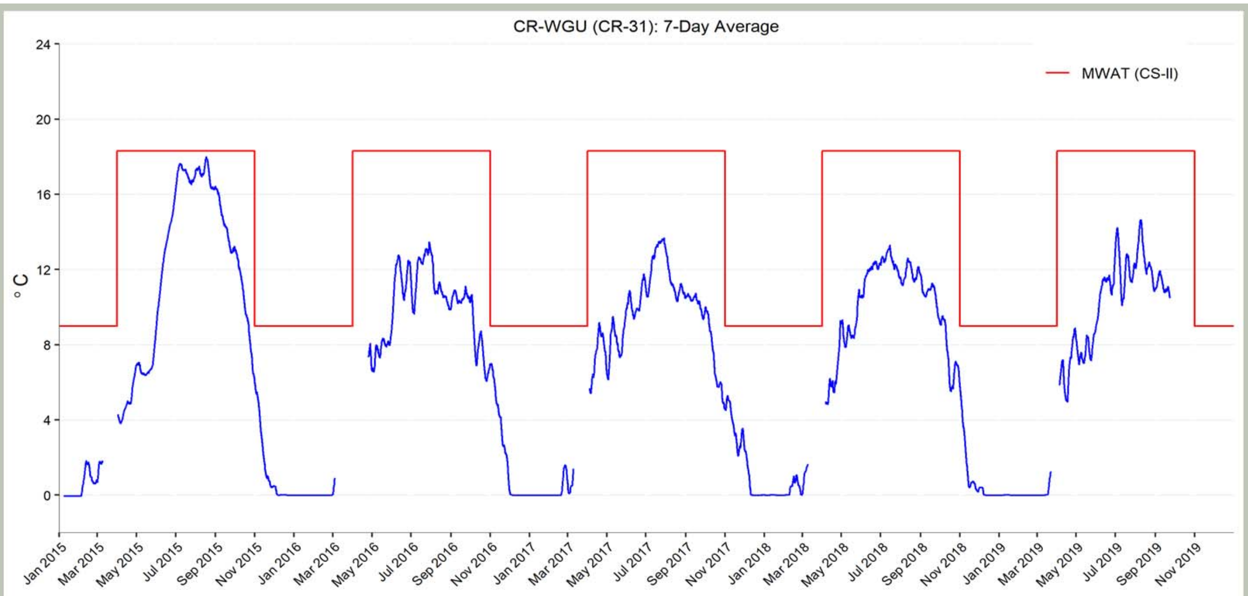
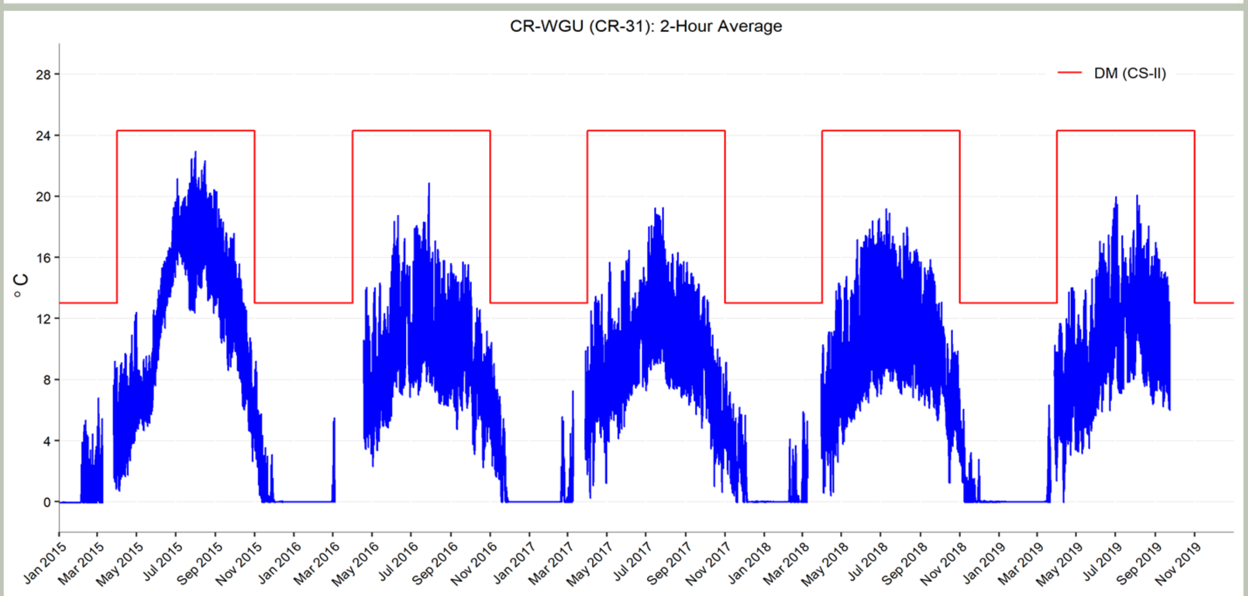
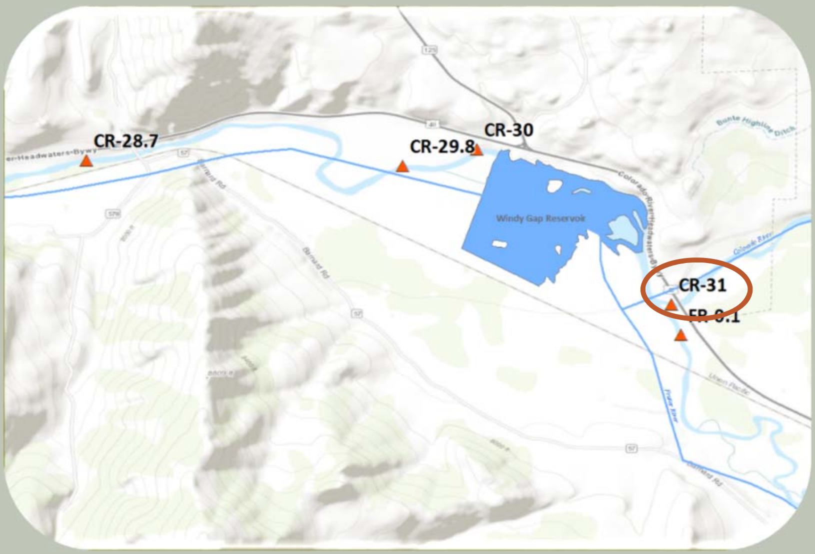
Colorado River upstream of Windy Gap – CSII







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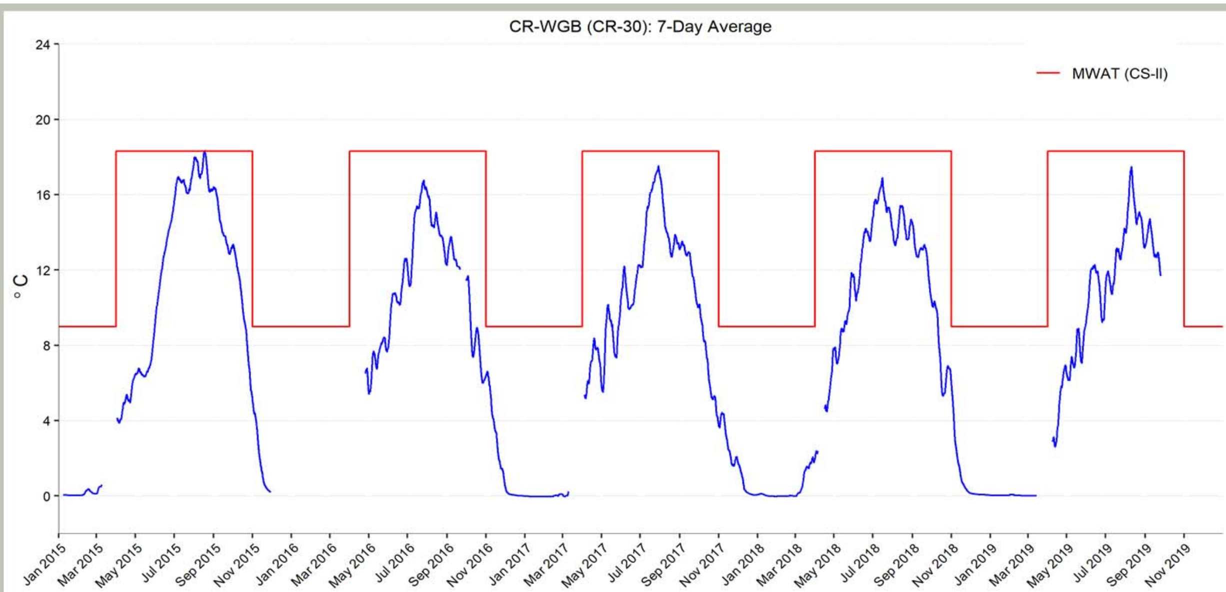
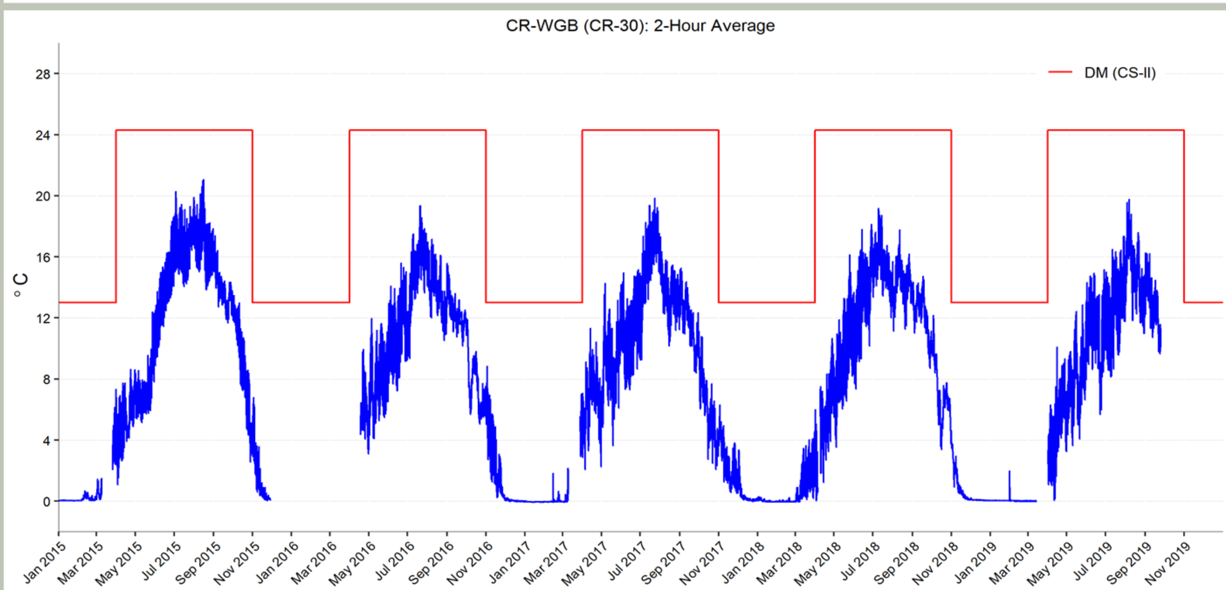
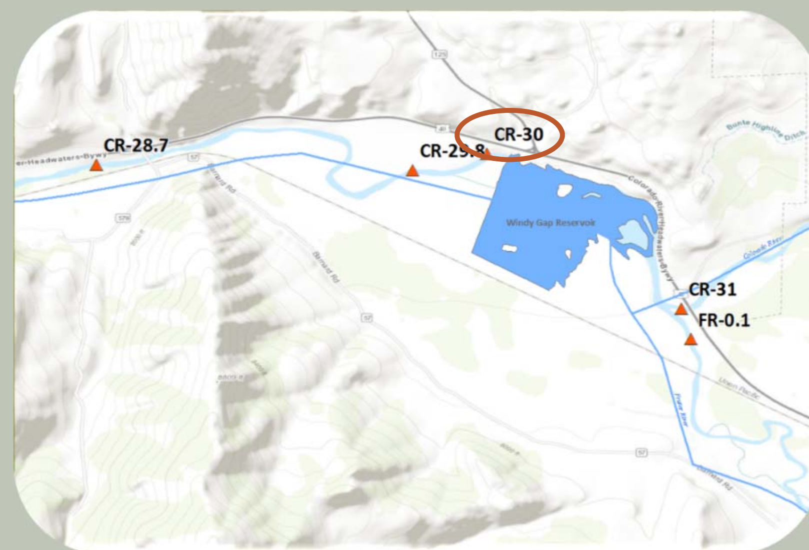
Windy Gap Bypass – CSII







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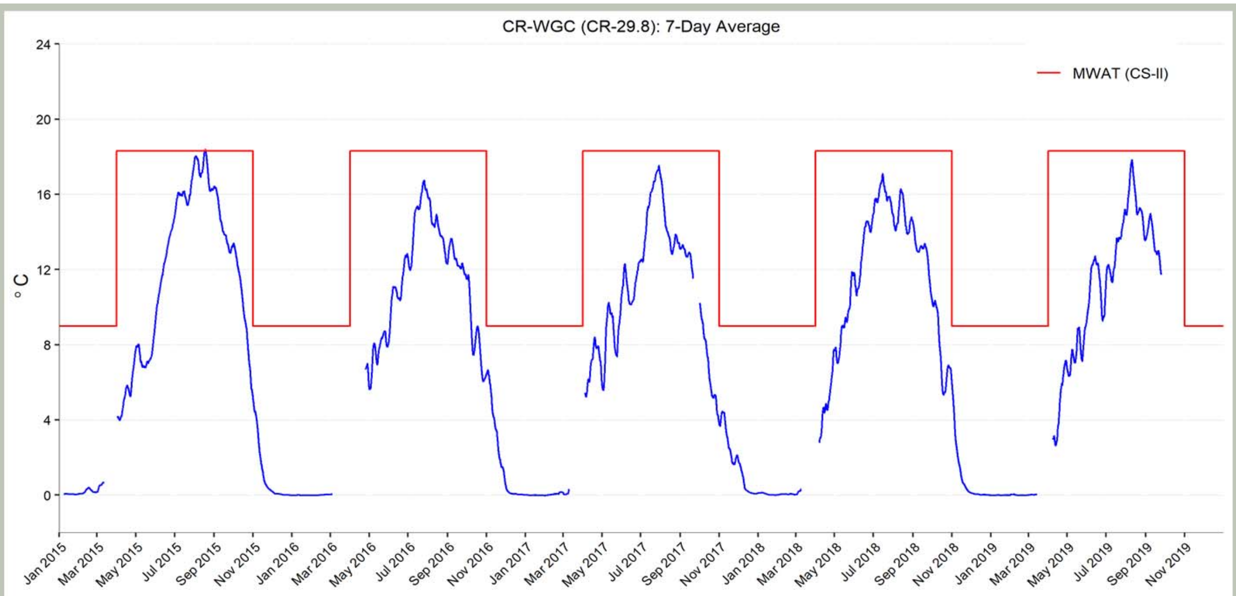
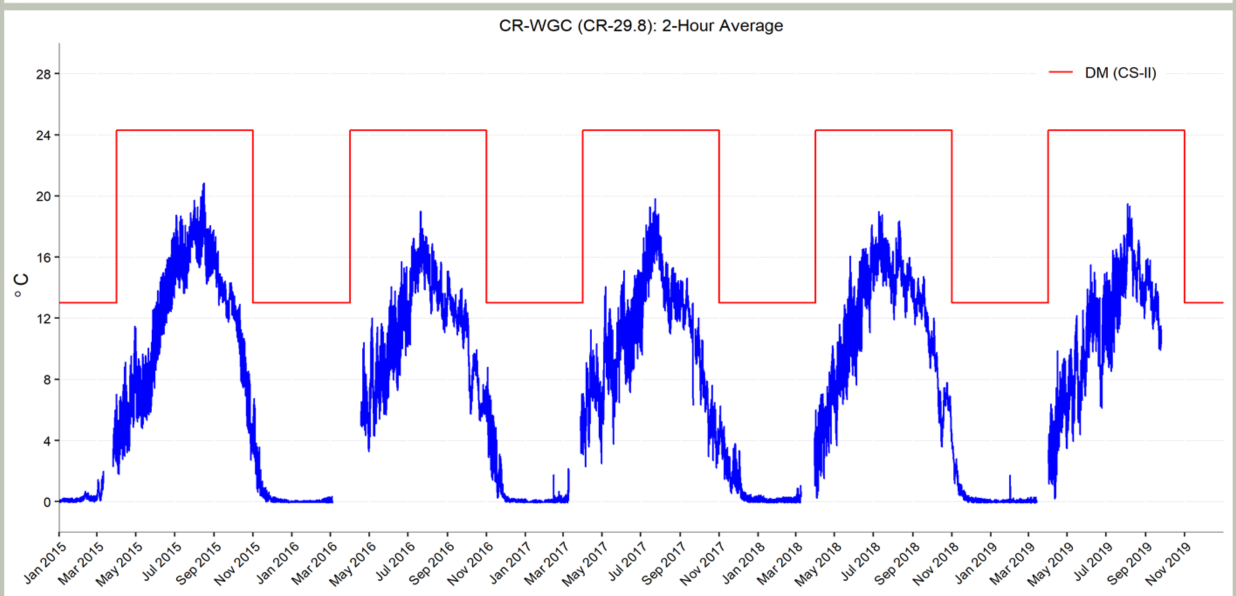
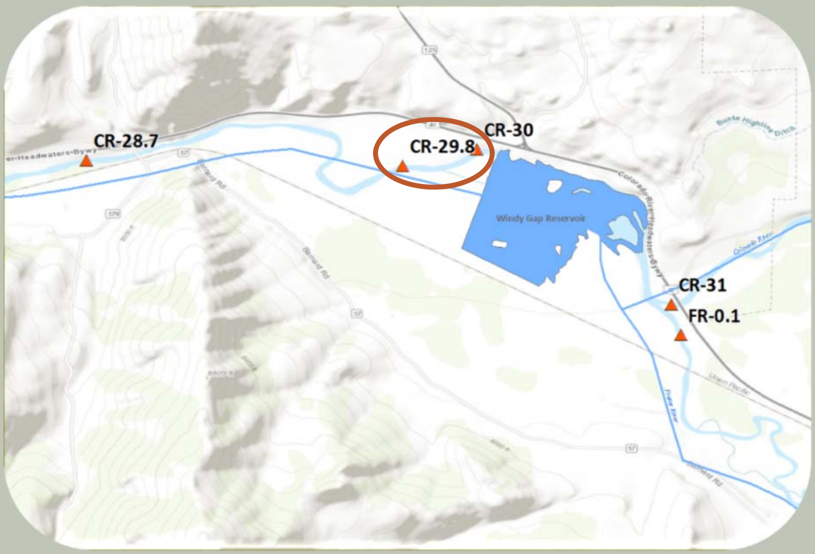




Windy Gap confluence of Bypass and Spillway – CSII



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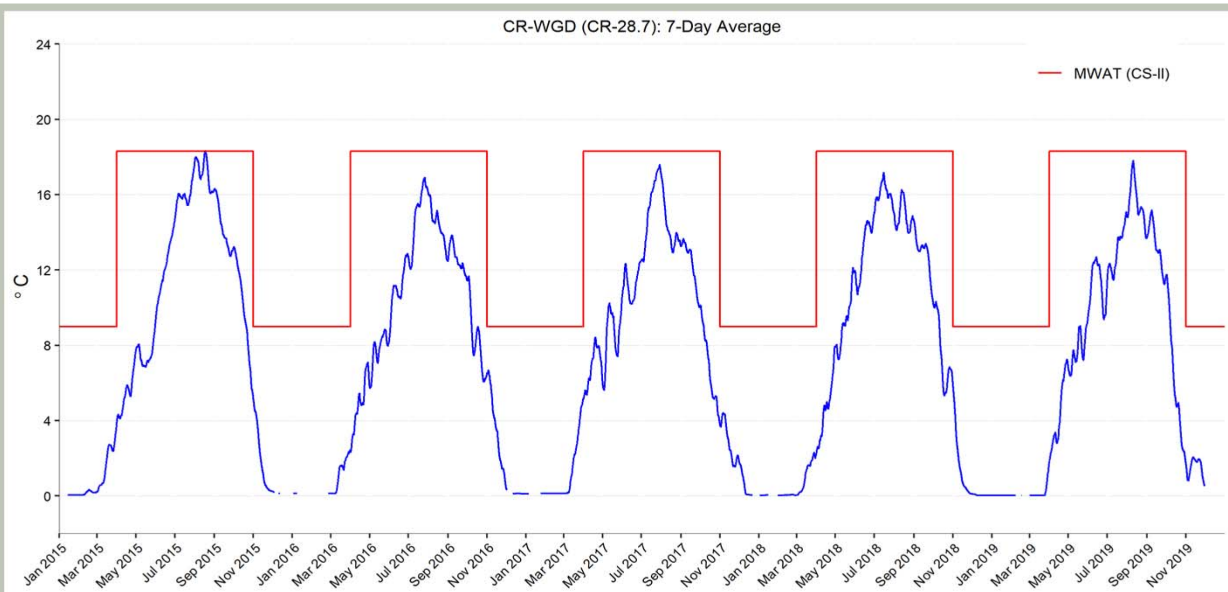
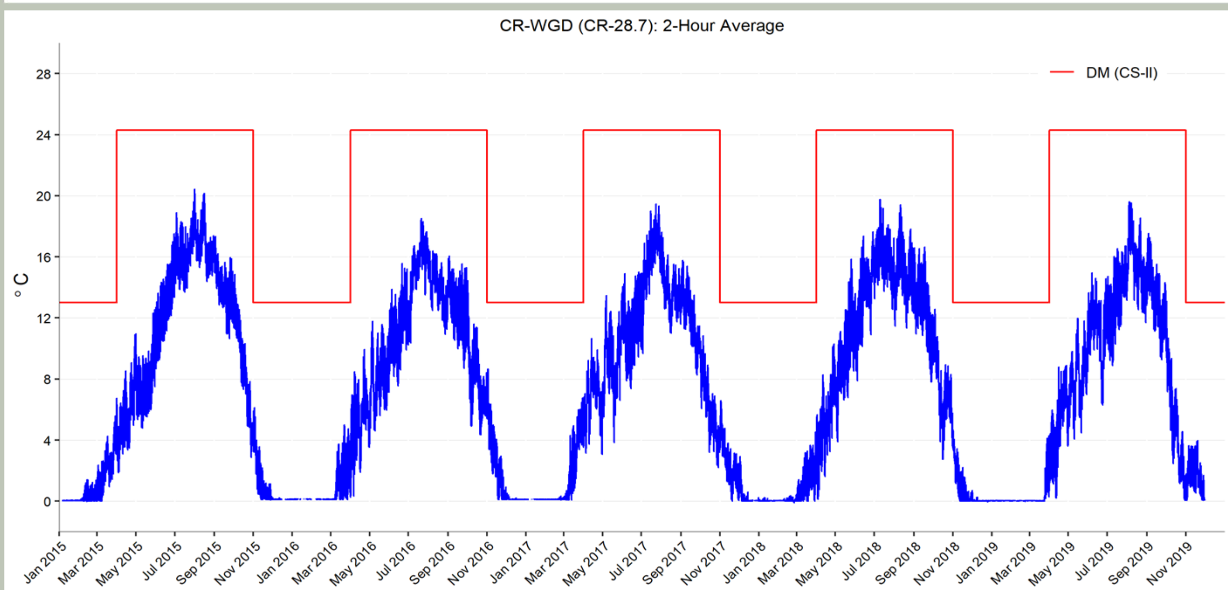
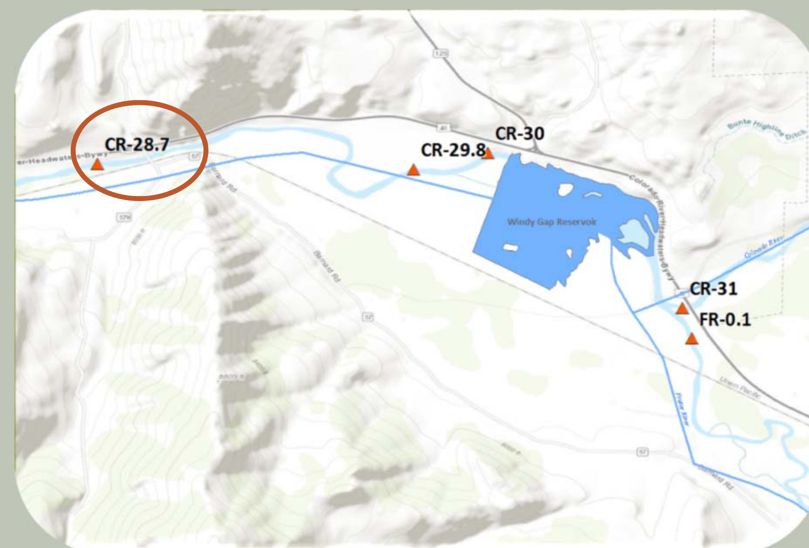
Colorado River downstream of Windy Gap – CSII







Northern Waters real-time site

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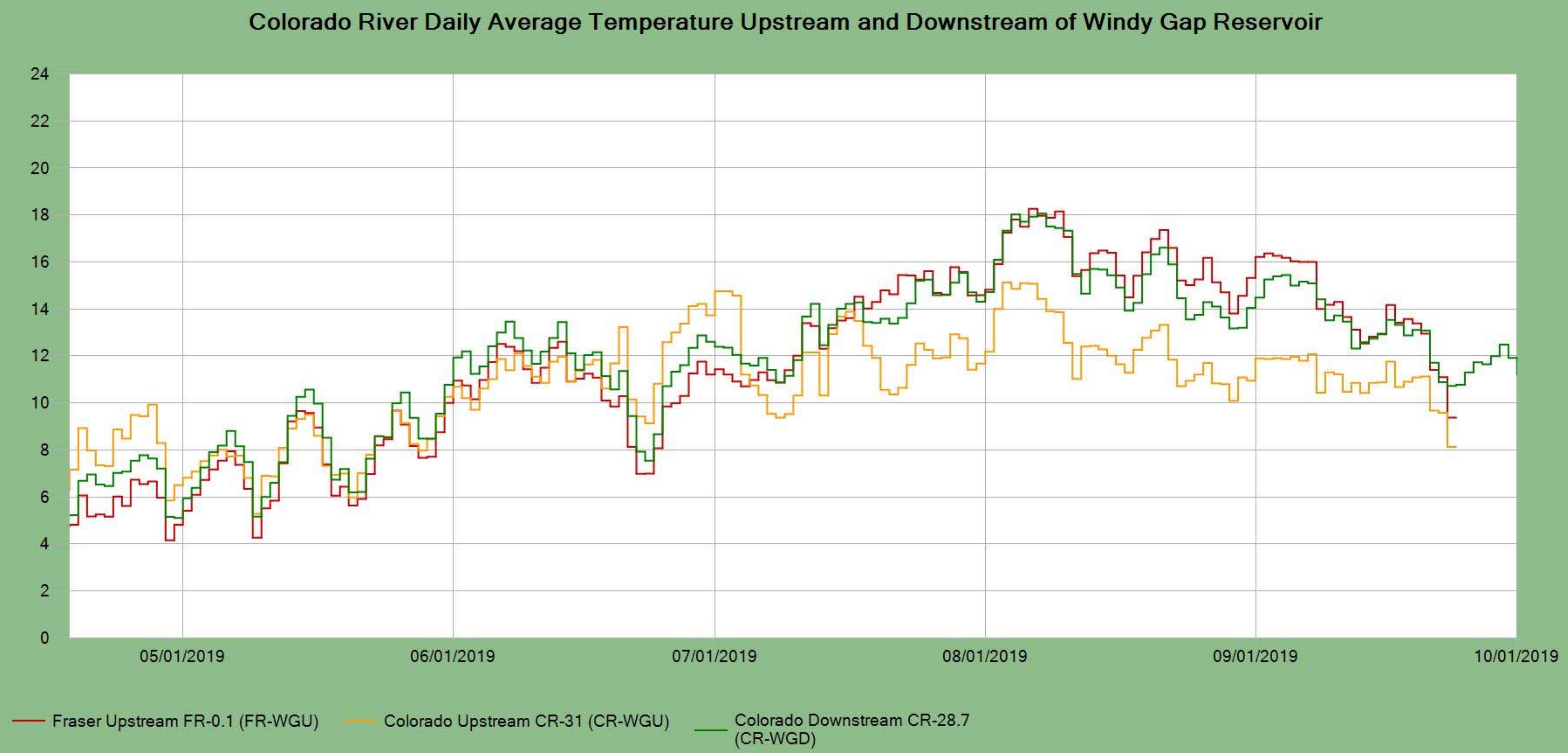

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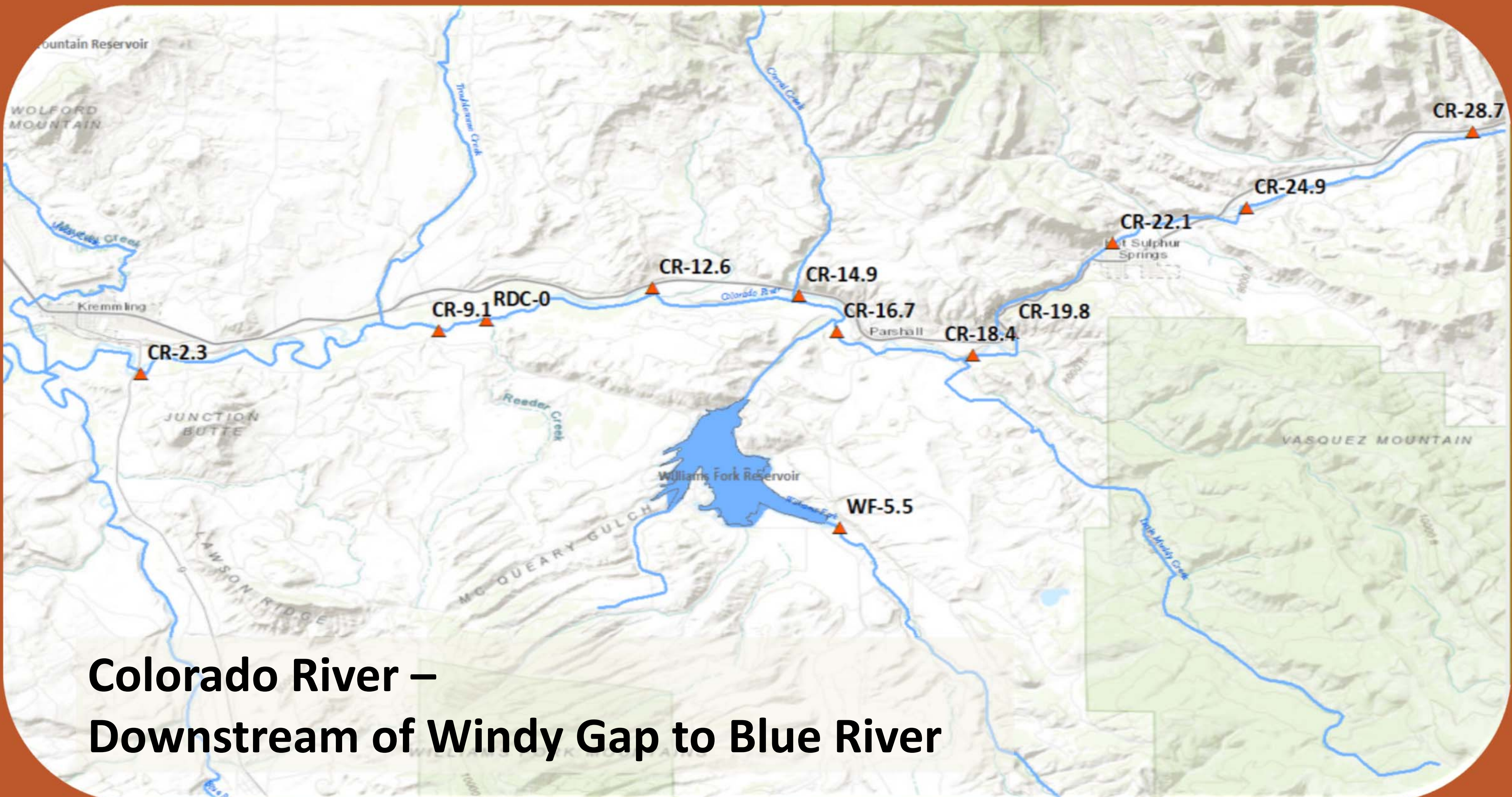

Colorado River – Downstream of Windy Gap to Blue River

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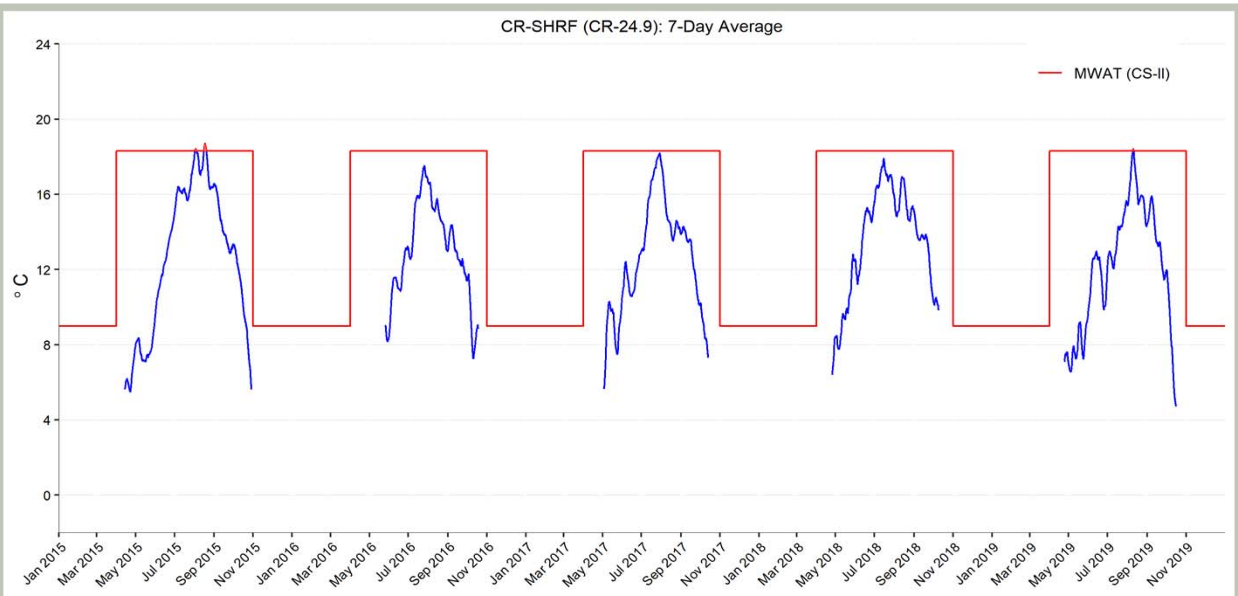
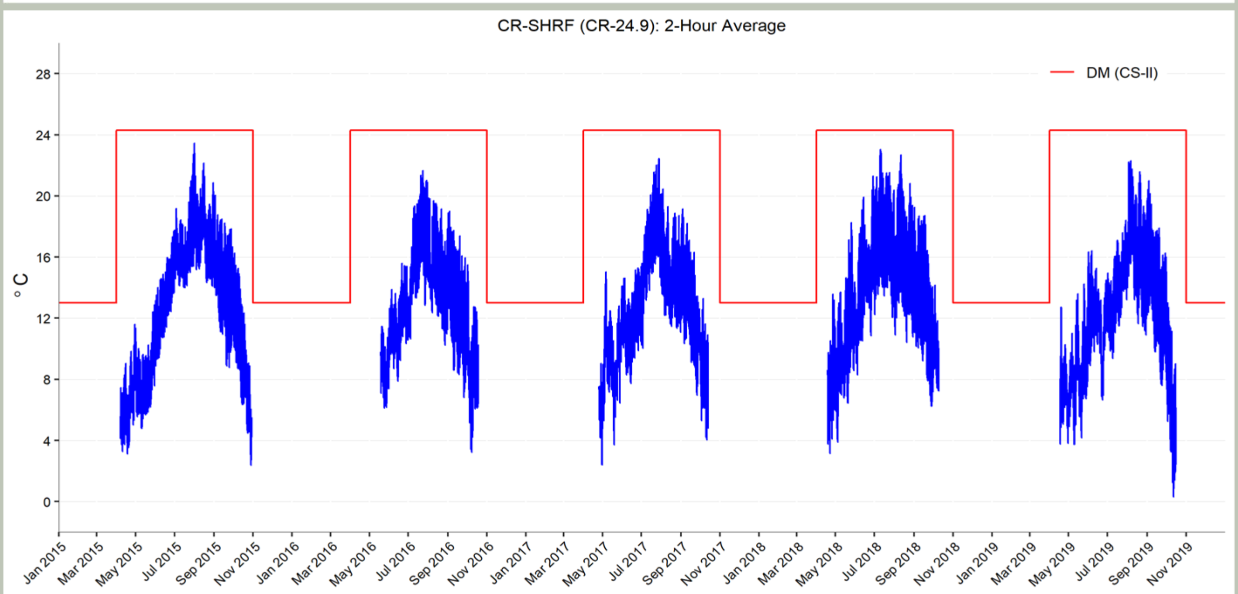
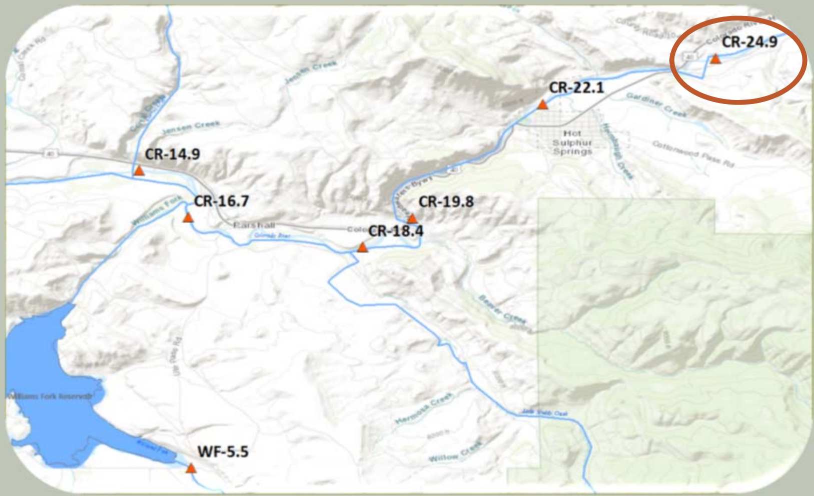




Colorado River at Sheriff Ranch – CSII



Above WAT standard

- 8/9/19-8/10/19
- Max - 18.4 deg C

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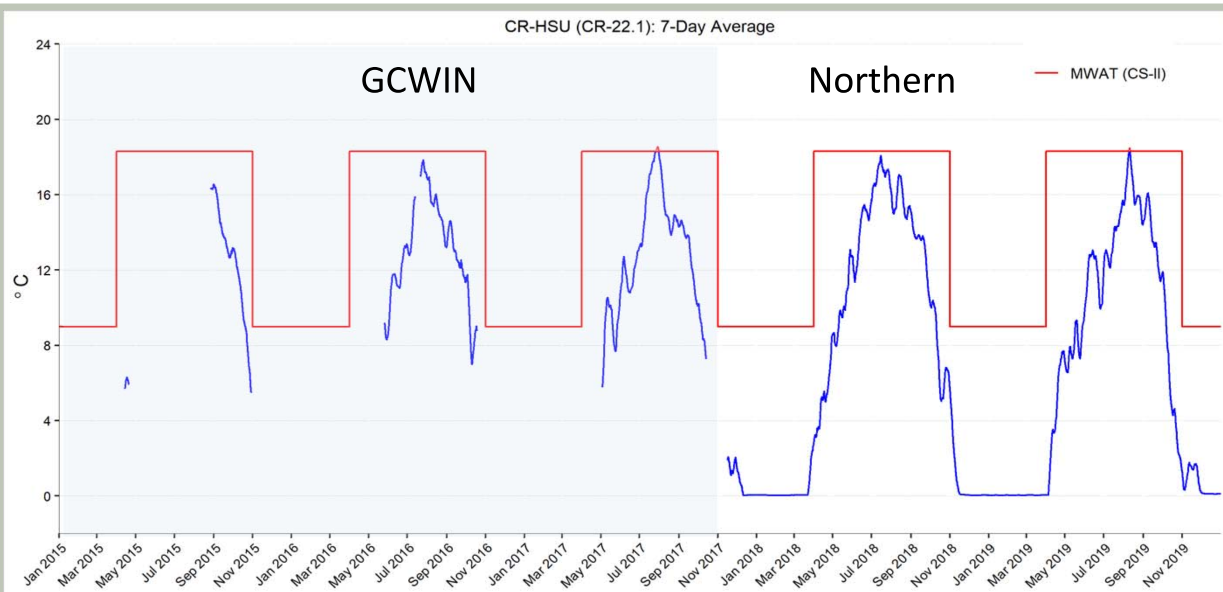
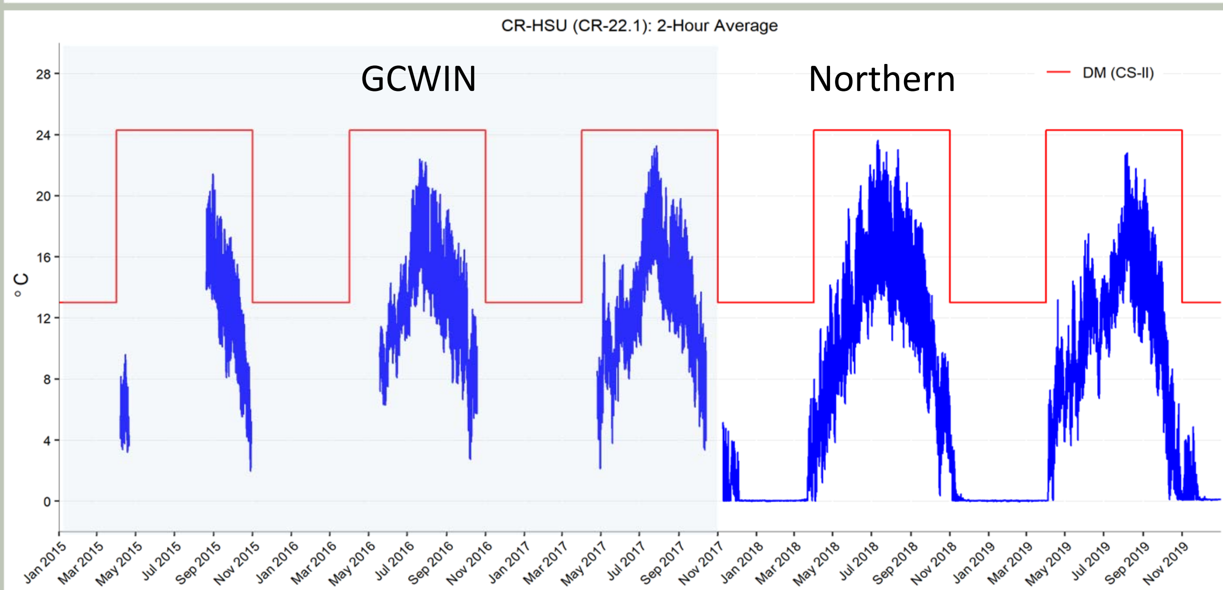
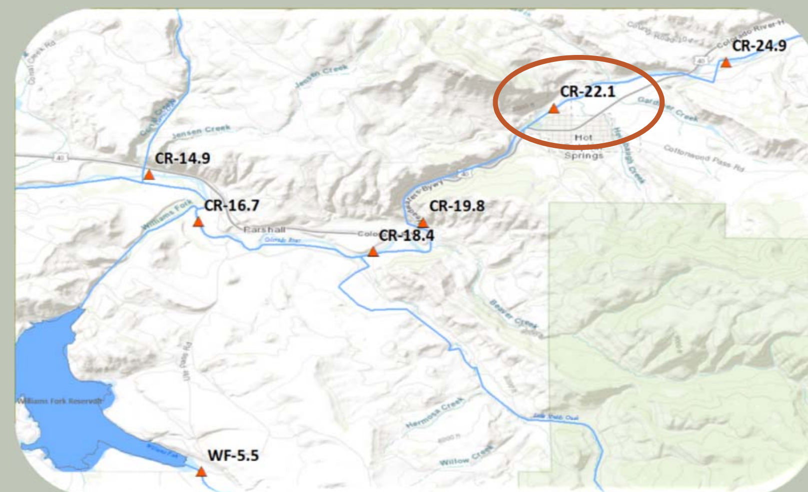
Colorado River upstream Hot Sulphur Springs – CSII







Northern Waters real-time site

Above WAT standard

- 8/9/19-8/11/19
- Max - 18.5 deg C

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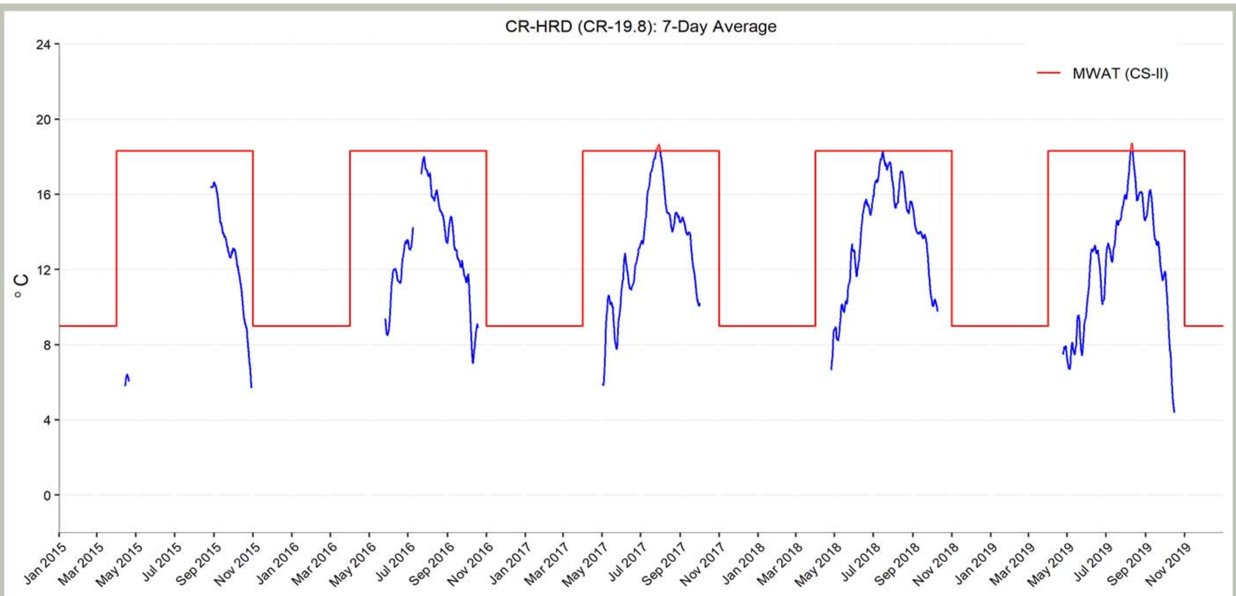
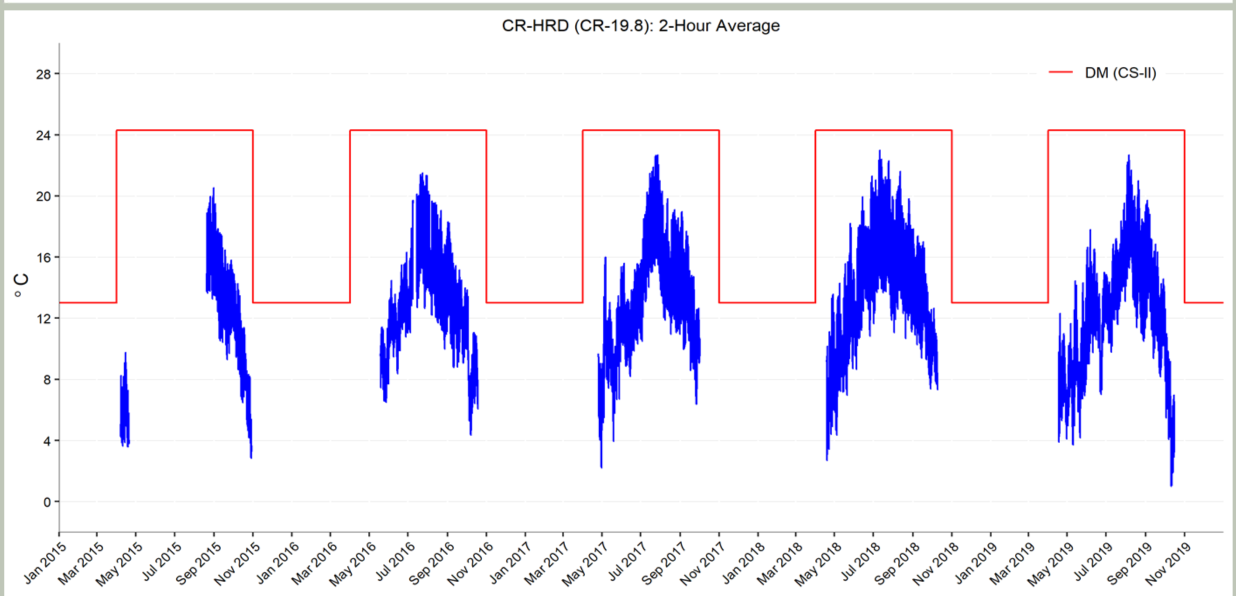
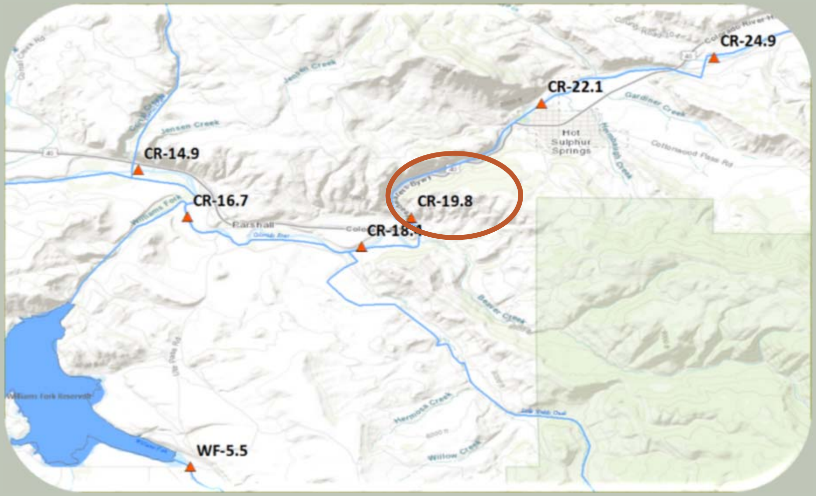
Colorado River downstream Byers Canyon– CSII







Above WAT standard

- 8/8/19-8/11/19
- Max - 18.7 deg C

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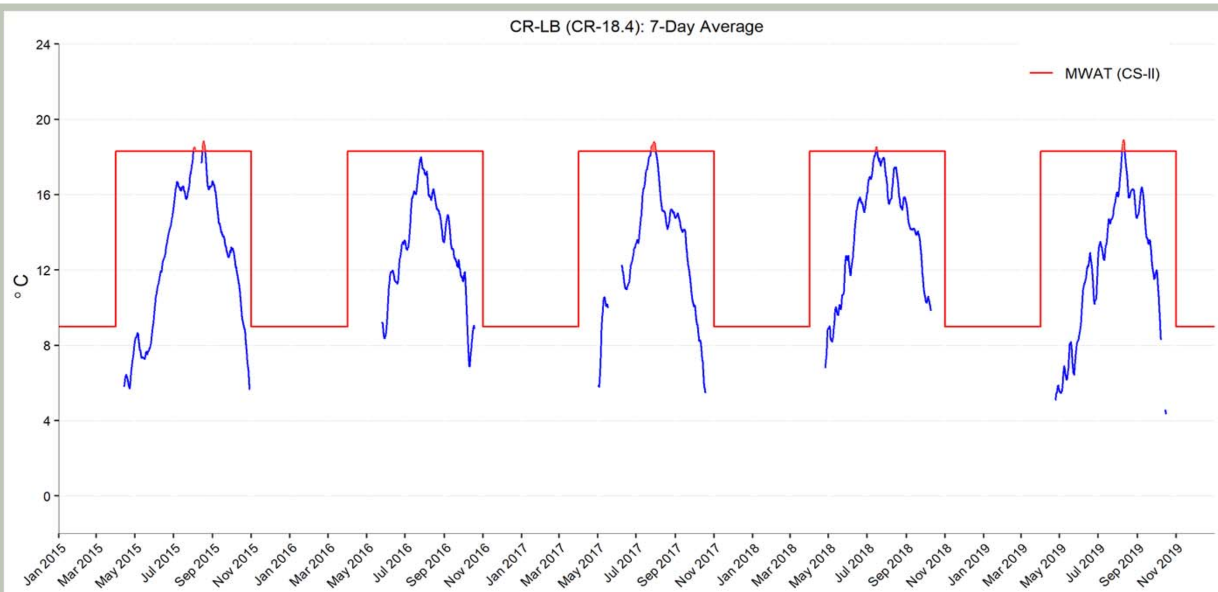
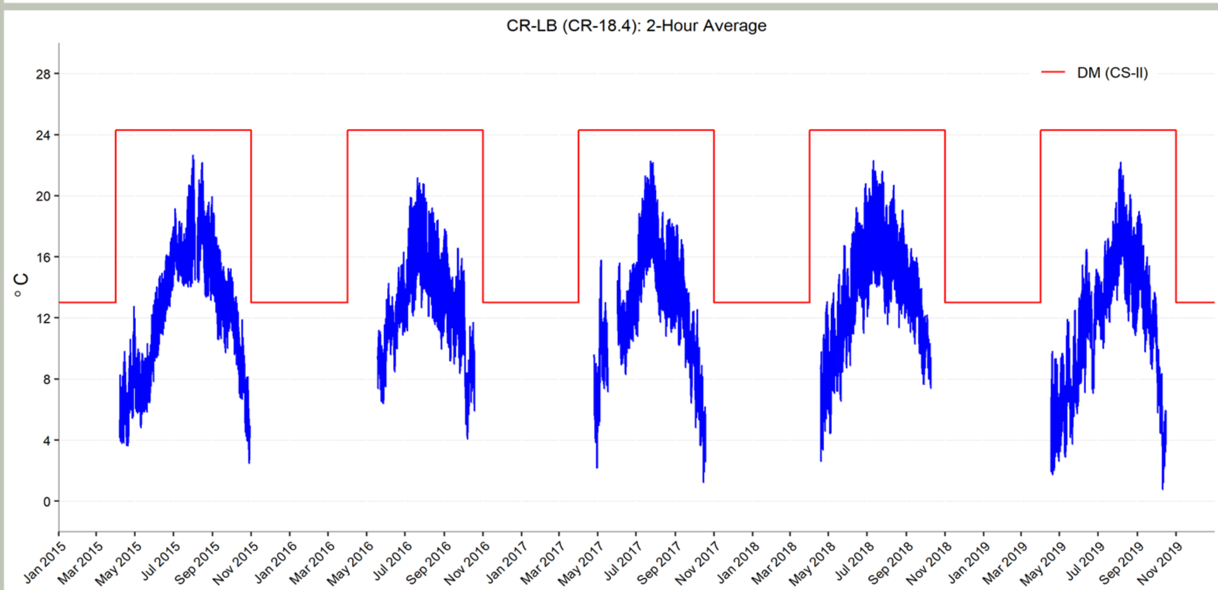
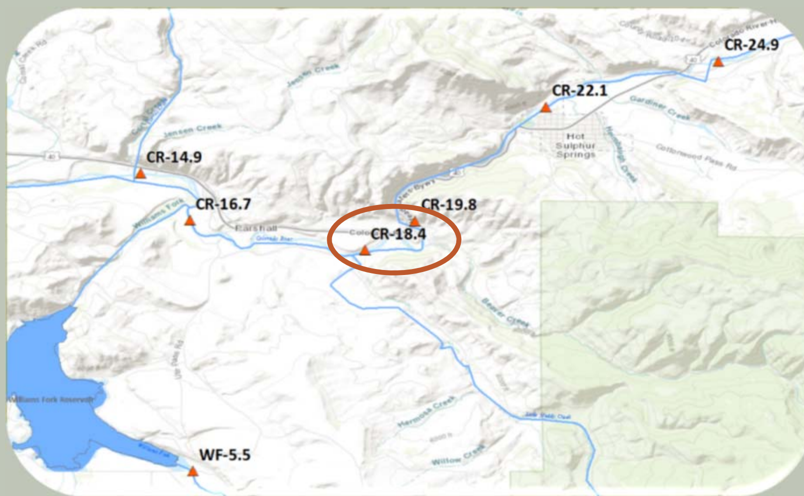
Colorado River at Lone Buck – CSII







Above WAT standard

- 8/7/19-8/12/19
- Max - 18.9 deg C

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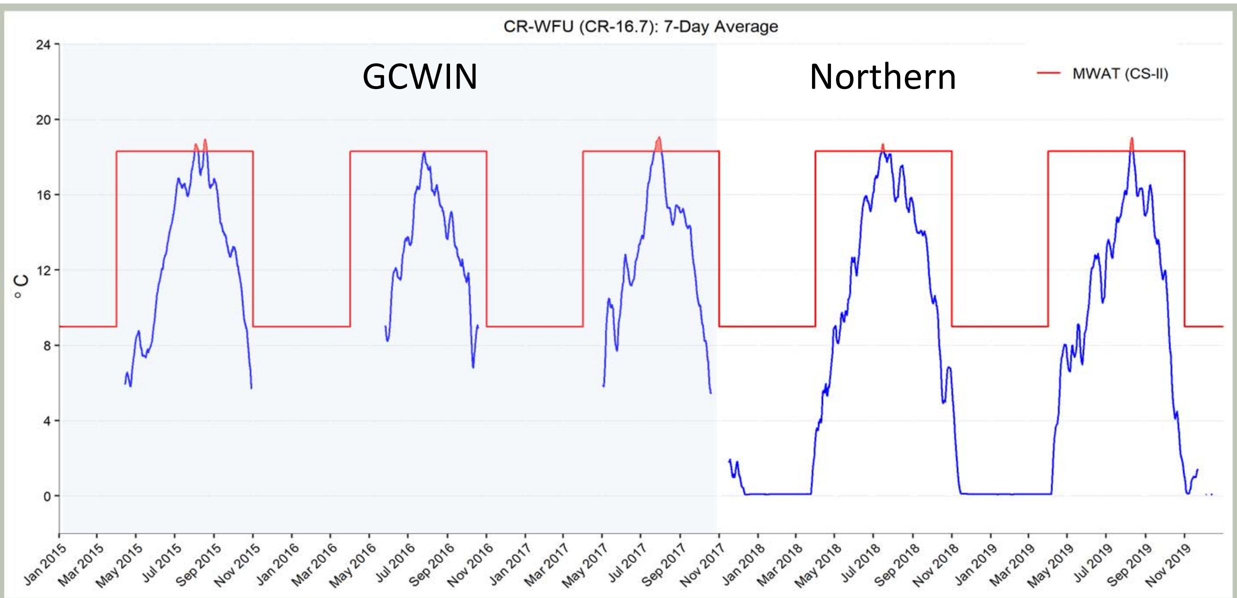
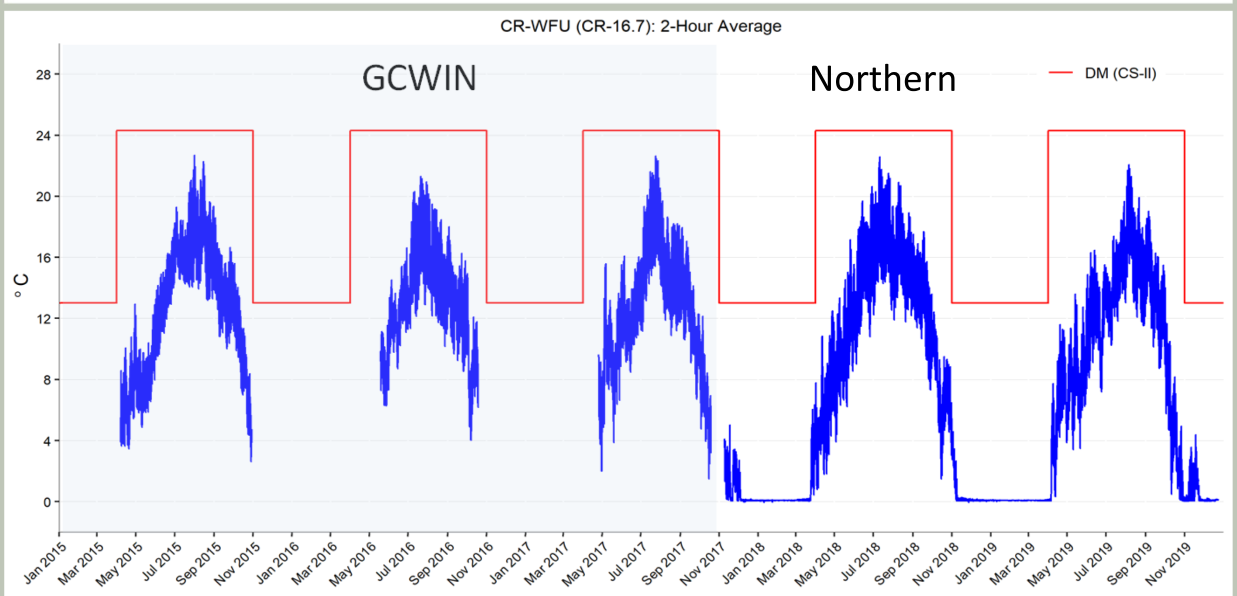
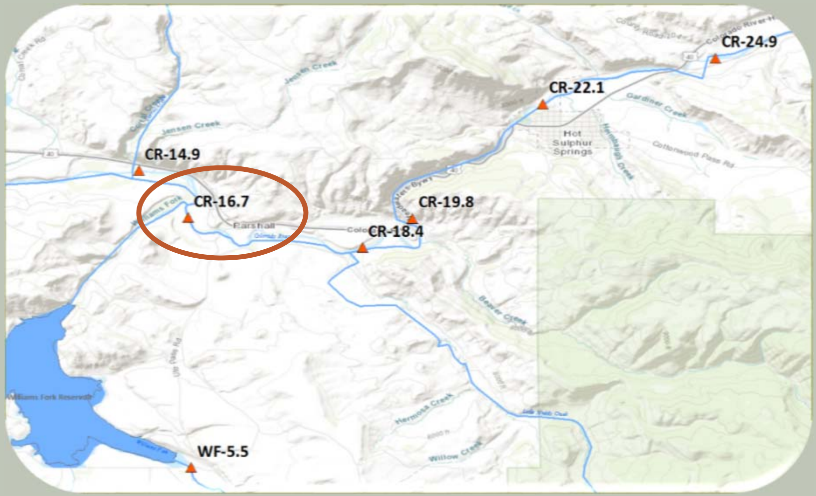
Colorado River upstream Williams Fork – CSII







Northern Waters real-time site

Above WAT standard

- 8/7/19-8/12/19
- Max - 19.0 deg C

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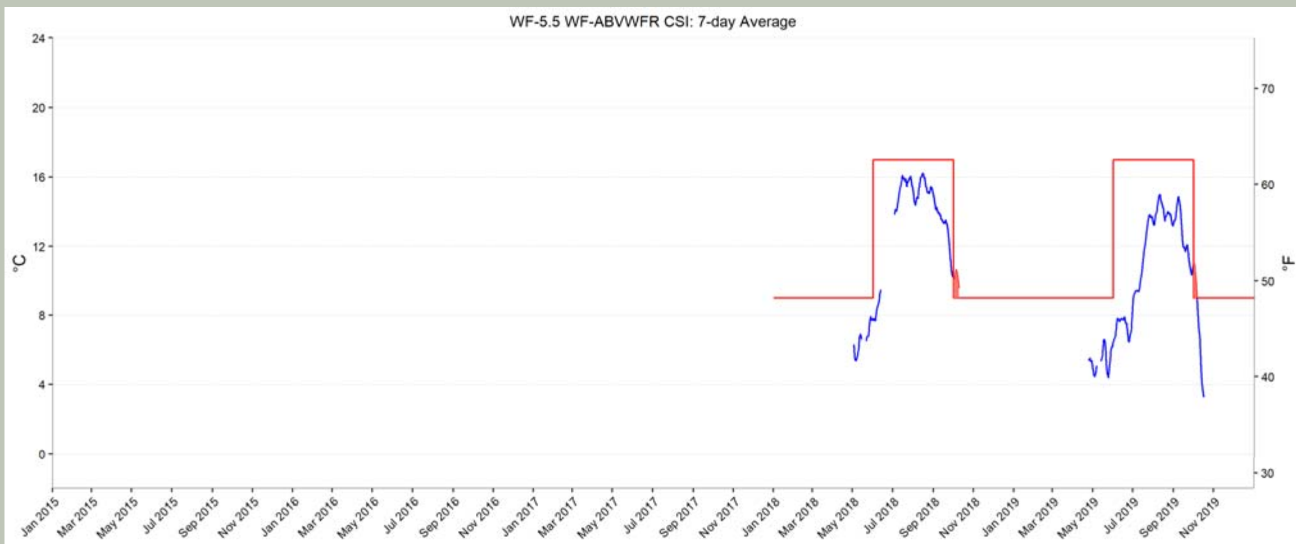
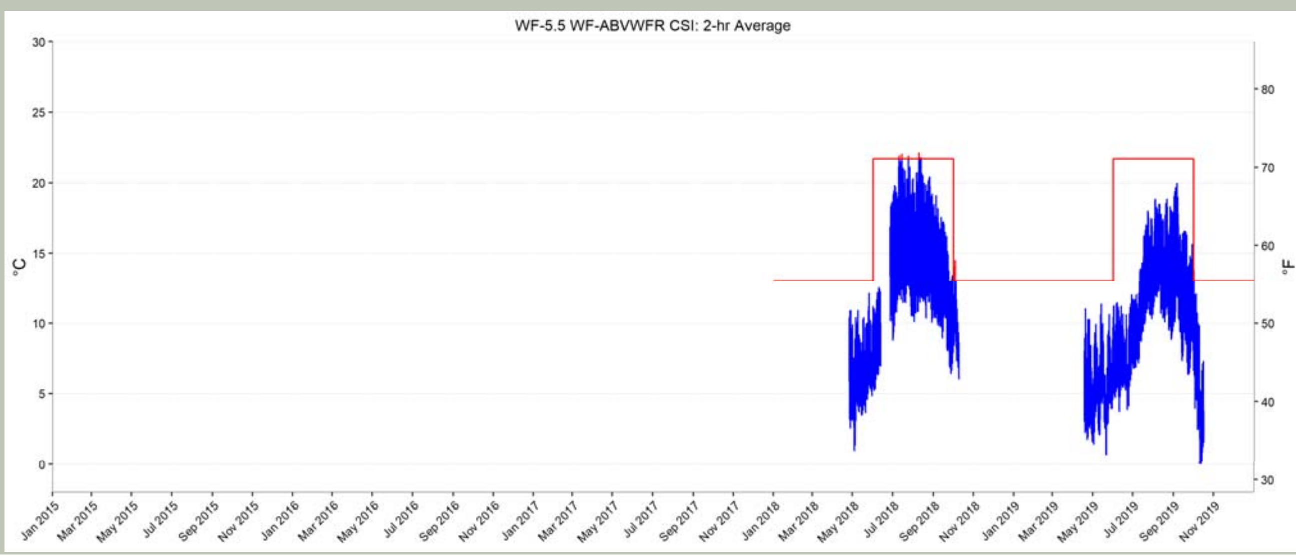
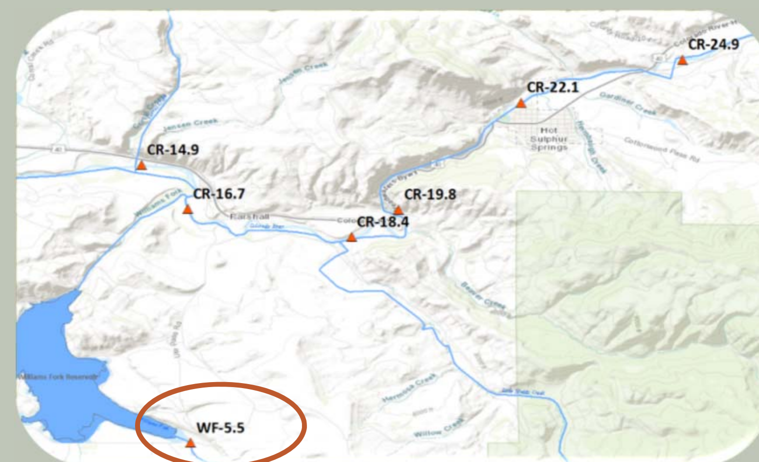
Williams Fork upstream of Williams Fork Reservoir – CSI







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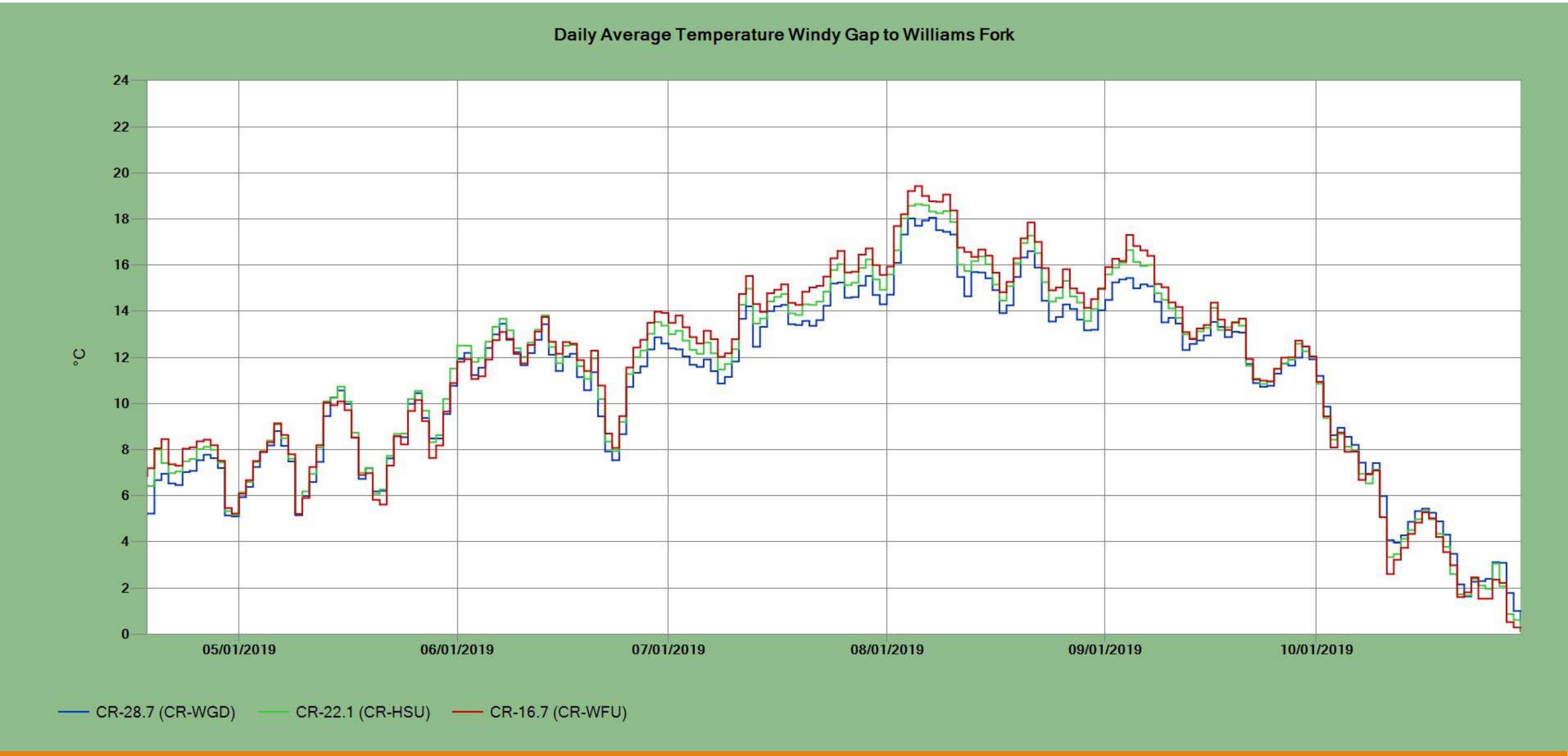

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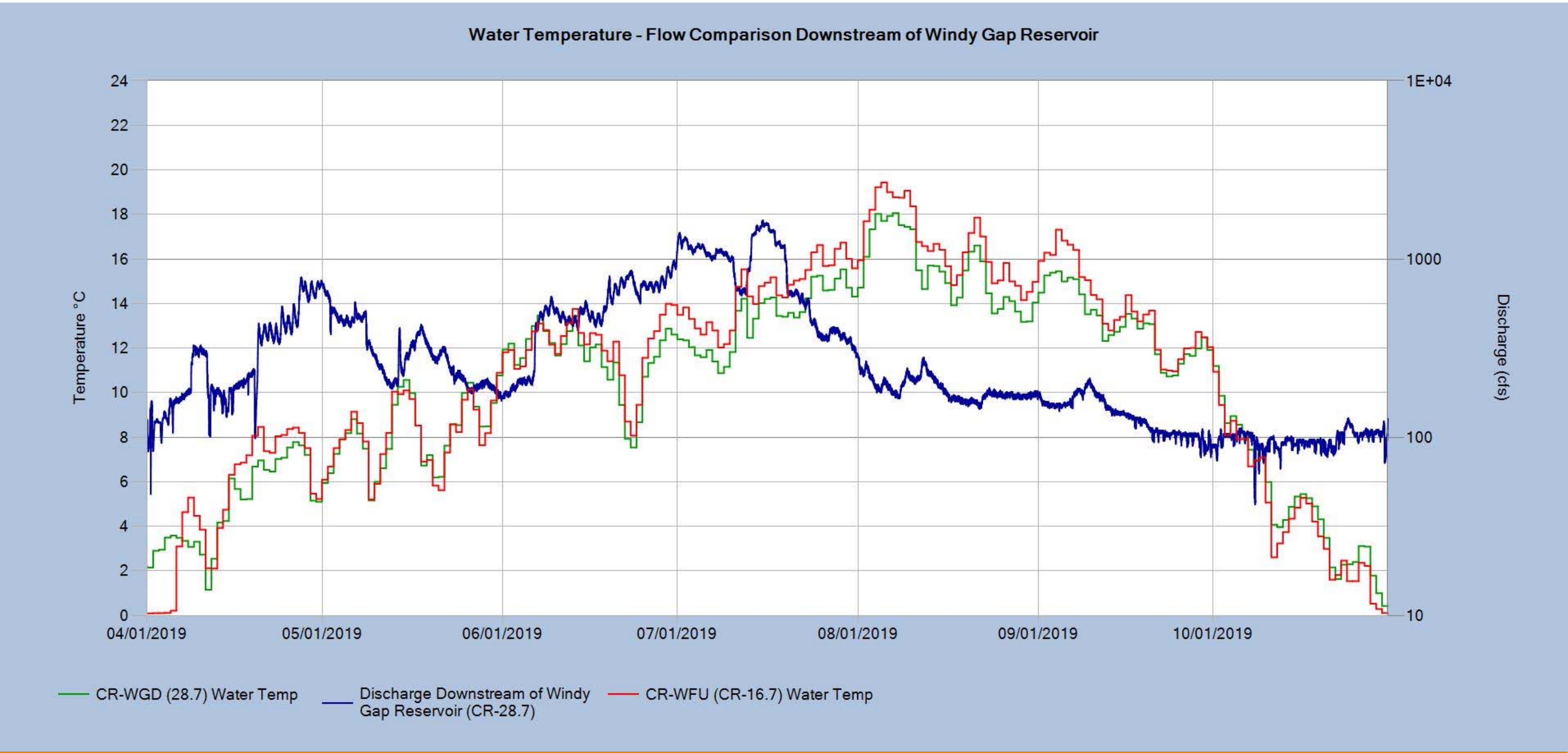

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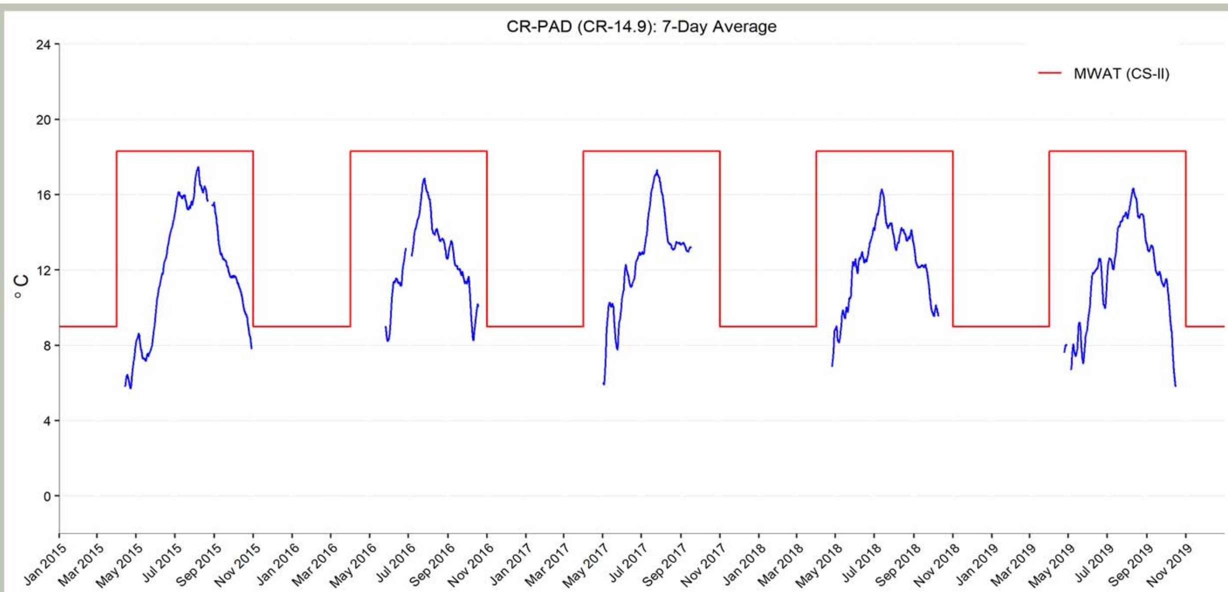
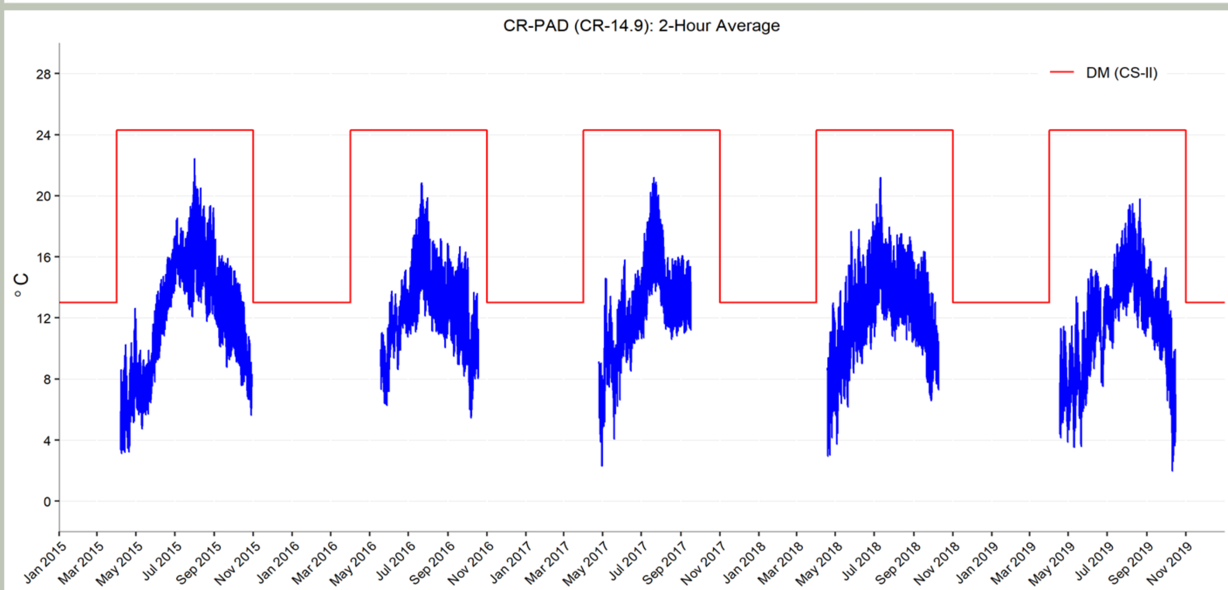
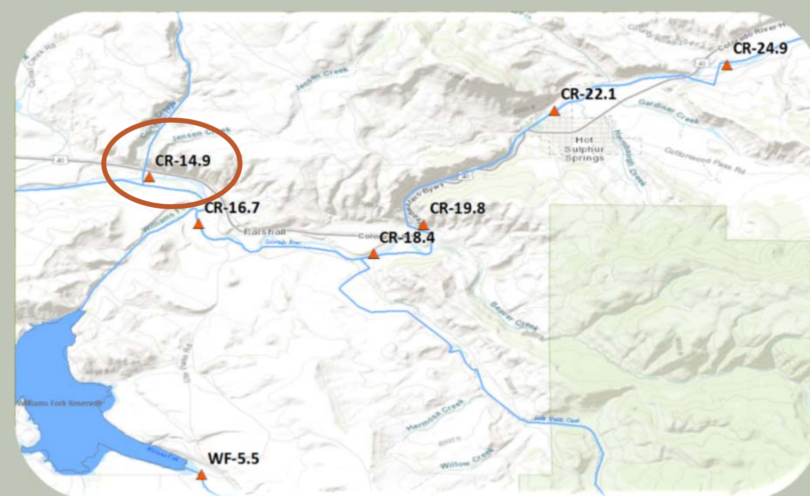




Colorado River downstream Williams Fork – CSII



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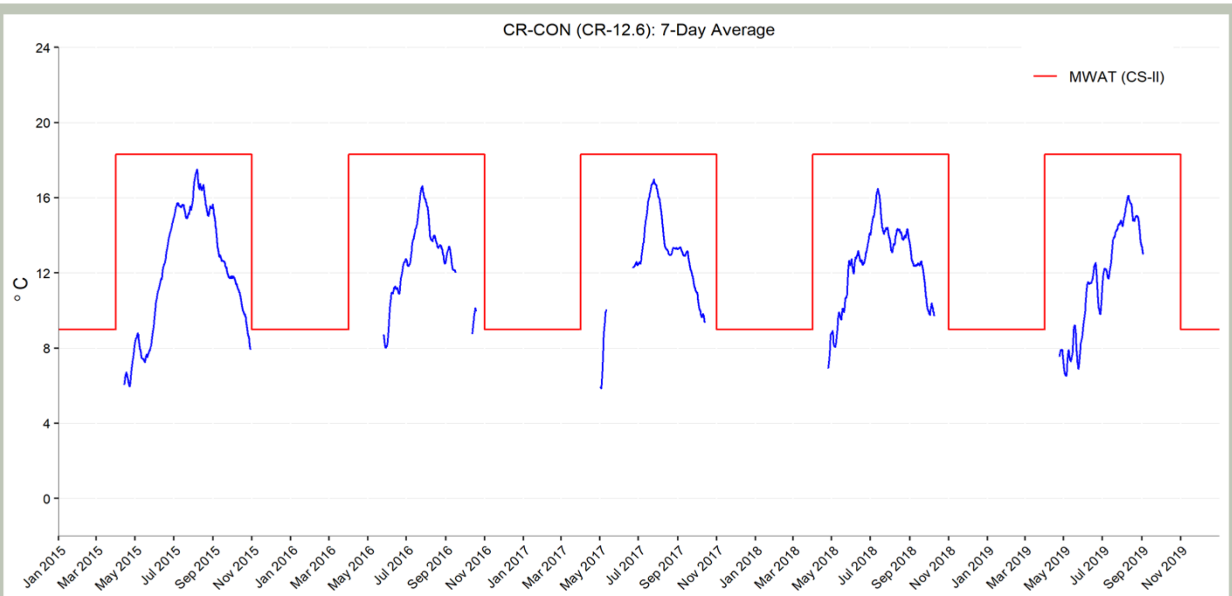

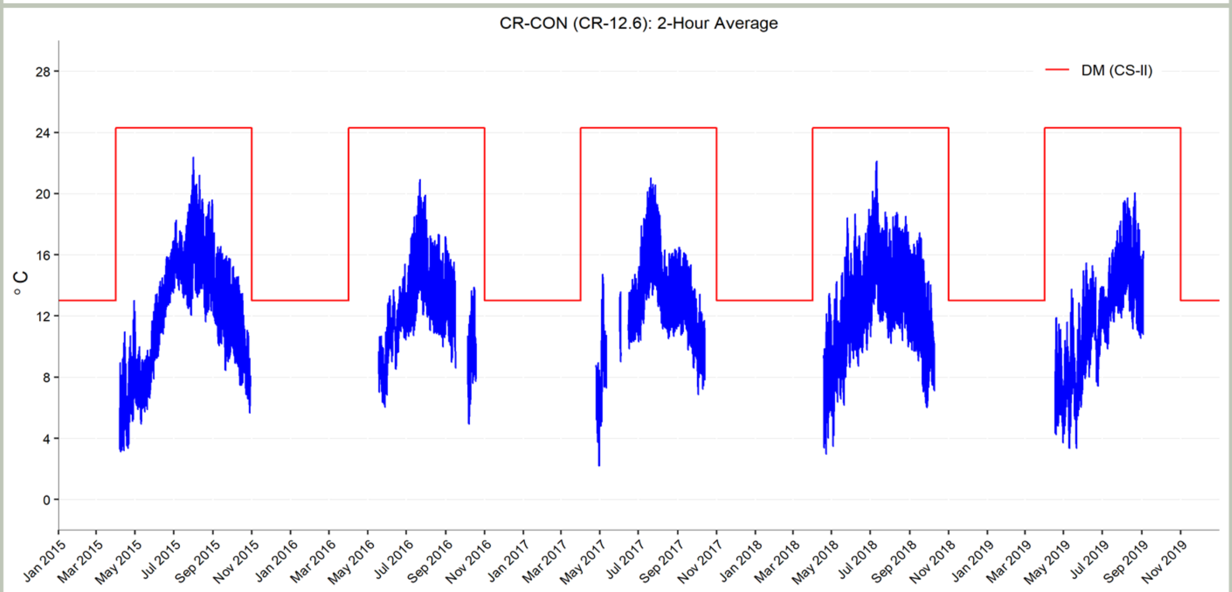

Colorado River at Con Ritschard – CSII

Note: Data gap in 2019 – Sensor found out of water. This is a popular fishing location.

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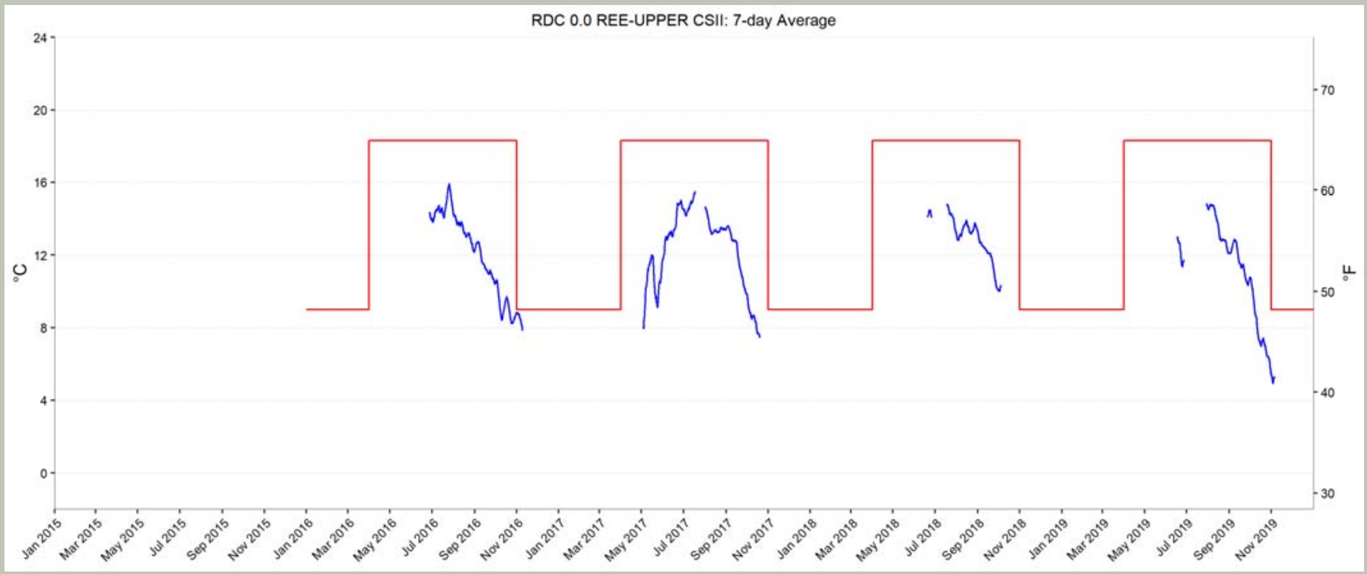
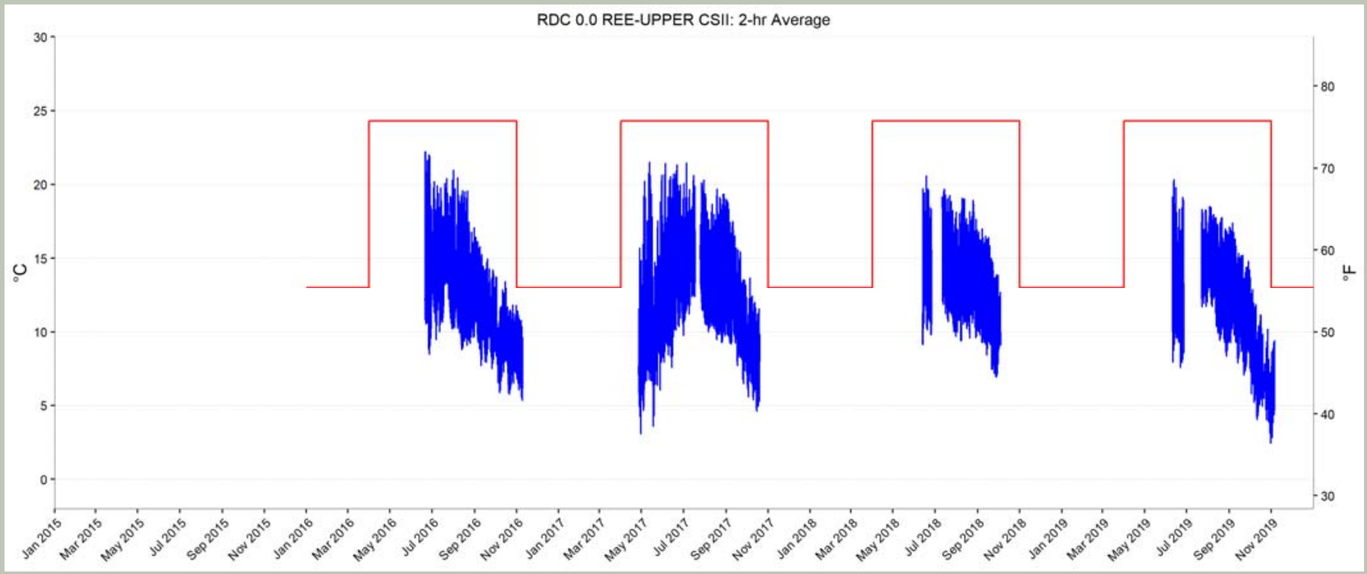
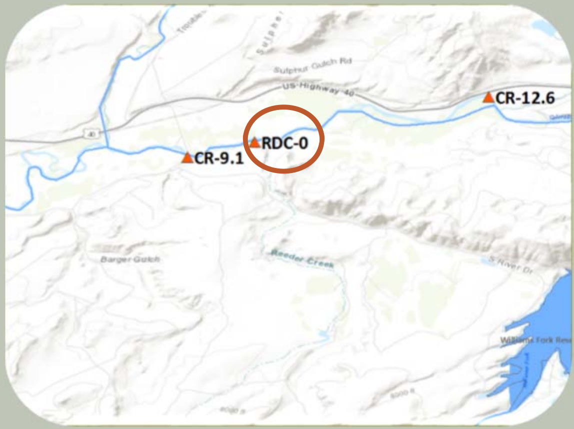
RDC 0.0 - Reeder Creek upstream Colorado River – CSII







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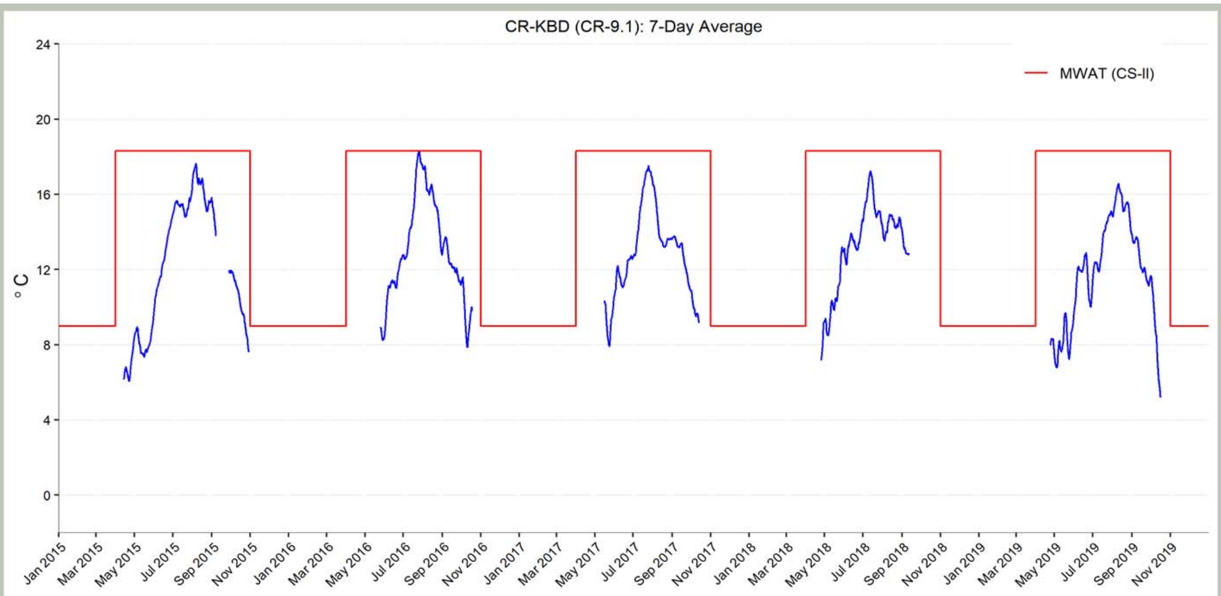
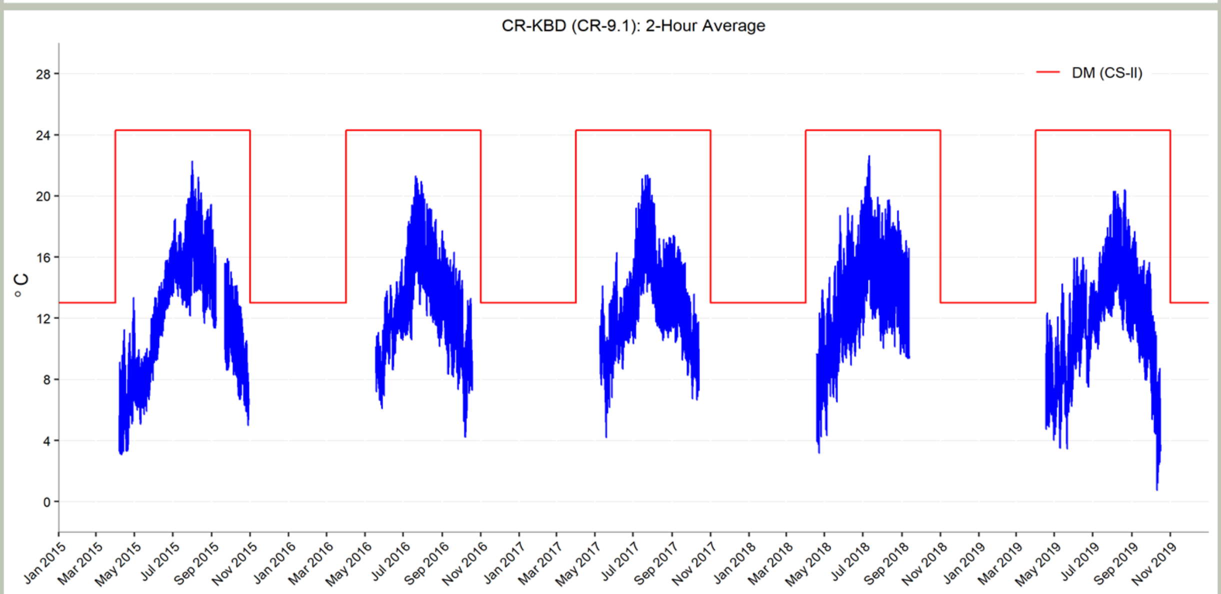
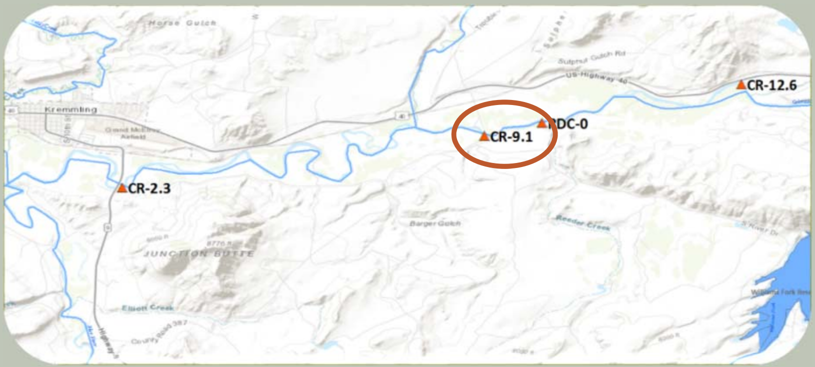




Colorado River downstream KB Ditch – CSII



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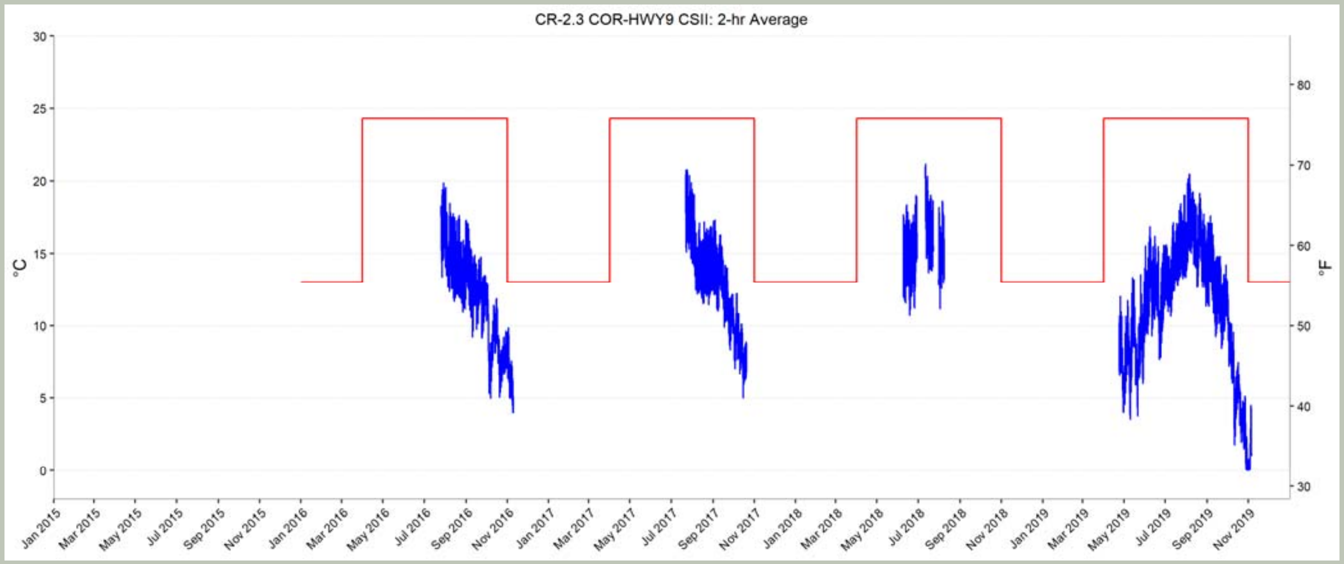
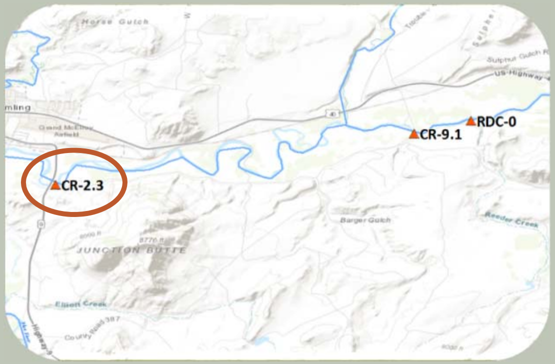


CR 2.3 - Colorado River upstream Hwy 9 Bridge at Kremmling– CSII



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Fraser River Basin, including tributaries 2019 Summary

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Fraser River Basin, including tributaries

- 32 sites assessed
- 28 sites in attainment with state temperature standards

3 sites exceeded the state temperature threshold for acute (1-day) exposure:

- Ranch Creek below CR 8315
- Meadow Creek at CR 84
- St. Louis Creek

3 sites exceeded the state temperature threshold for chronic (7-day) exposure:

- Ranch Creek below CR 8315
- Ranch Creek below Meadow Creek
- St. Louis Creek

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Colorado River Basin, including Williams Fork 2019 Summary

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Colorado River/ Williams Fork

- **28 sites assessed**
- **17 sites in attainment with state temperature standards**

2 sites exceeded the state temperature threshold for acute (1-day) exposure:

- Colorado River upstream of Granby Reservoir
- Arapaho Creek downstream of Monarch Lake

10 sites exceeded the state temperature threshold for chronic (7-day) exposure:

- Arapaho Creek downstream of Monarch Lake
- Colorado River downstream of Shadow Mountain Reservoir to Granby Reservoir (3 sites)
- Colorado River at Sheriff Ranch
- Colorado River upstream of Hot Sulphur Springs
- Colorado River downstream of Hot Sulphur Springs
- Colorado River at Lone Buck
- Colorado River upstream of Williams Fork
- Williams Fork upstream of Williams Fork Reservoir

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Questions & Comments

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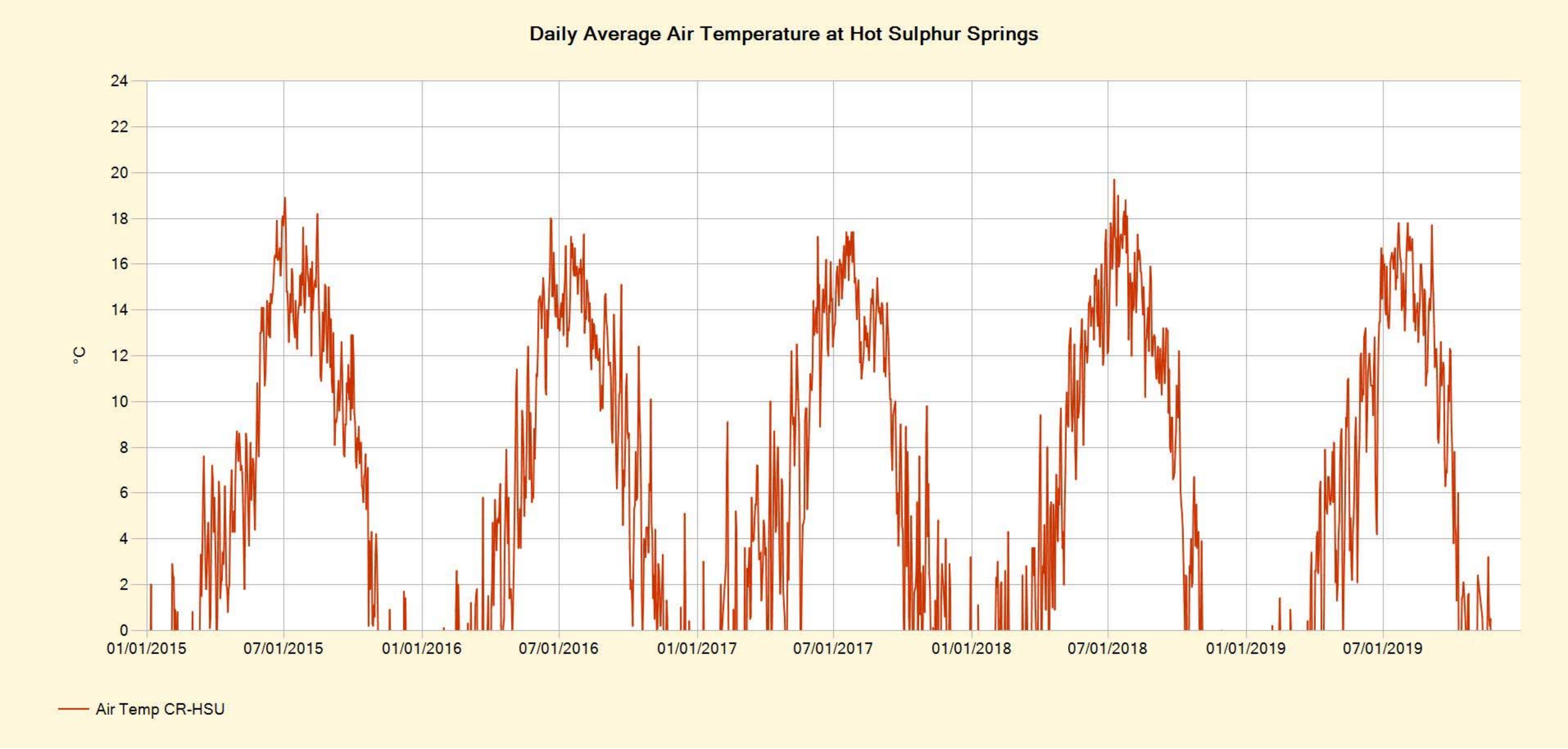

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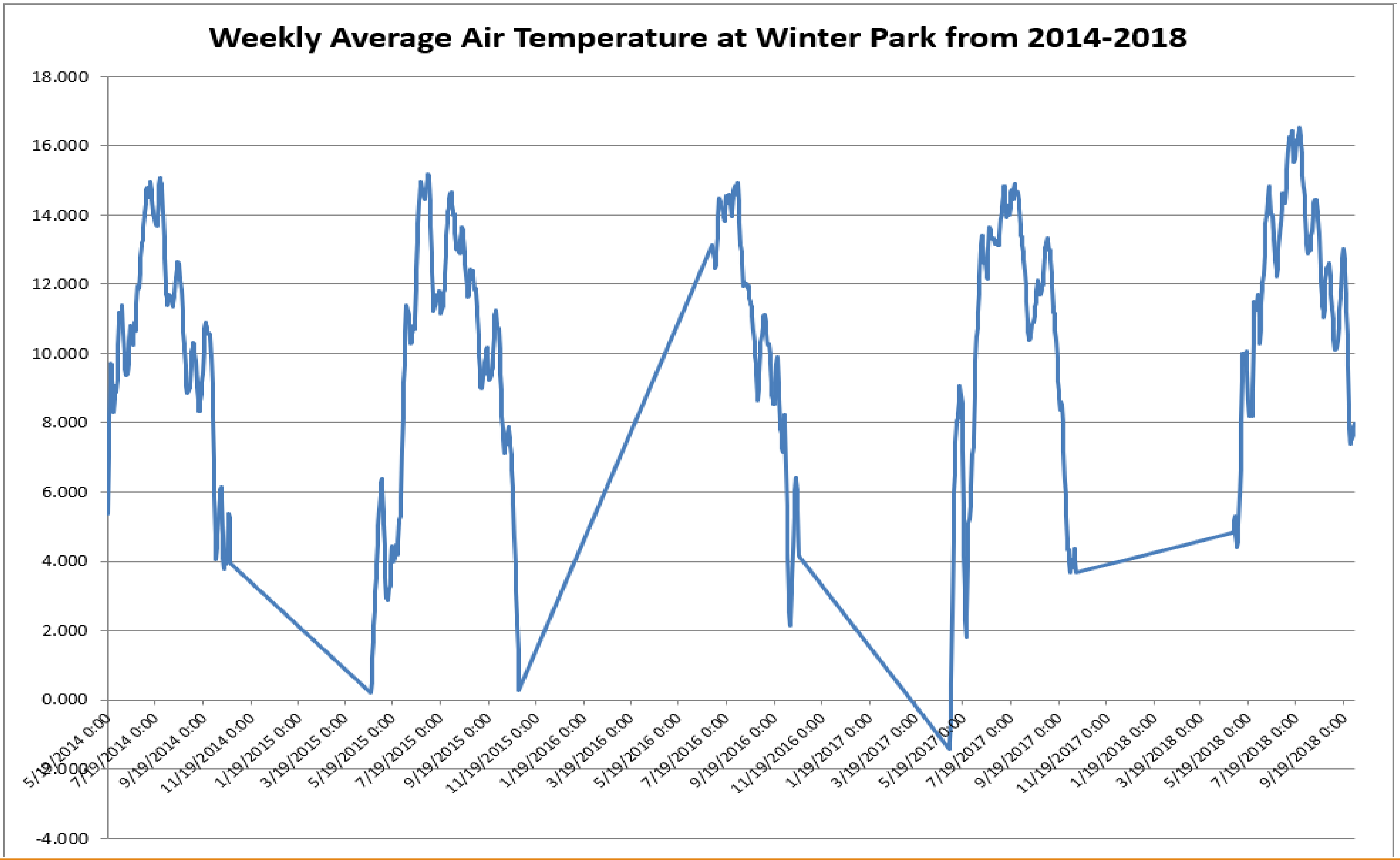

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Fraser River and Tributaries

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
EC-5.5	Elk Creek below Denver Water diversion	Elk Creek	GCWIN	Elk-blwDWB	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
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

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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	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

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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

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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

ka2

ka2 Doesn't Northern have a site near CR3? We discontinued this site in 2018.

kayli.foulk@gcwin.org, 2/14/2019

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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

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GRAND COUNTY

LEARNING BY DOING

Colorado Parks and Wildlife
Fraser River Fishery Management Report
March 2020

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Fraser River

Fishery Management Report

Jon Ewert, Aquatic Biologist, Colorado Parks and Wildlife

March 2020

Introduction

This report summarizes fish population surveys and fisheries management activities undertaken over the past decade by Colorado Parks and Wildlife (CPW) on the Fraser River in Grand County, Colorado.

From its headwaters at Berthoud Pass to its confluence with the Colorado River near the town of Granby, the Fraser is a highly diverse, small high-elevation river that passes through many transitions in habitat type through the course of its relatively short length. There are multiple environmental stressors that occur along the course of the Fraser, nevertheless most reaches of it harbor a productive trout fishery. Mottled Sculpin, a small native fish species, are prolific throughout nearly the entire river. This species is critically important to the ecology of the Fraser, both as a highly valuable prey source for trout populations as well as an indicator of habitat and water quality. These fish are the Fraser's greatest biological asset.

CPW, along with several other East and West Slope water stakeholders, is a partner in Grand County Learning By Doing (LBD), a cooperative effort in part designed to address environmental stressors on the Fraser and other Grand County waterways and improve river health. LBD has implemented multiple successful projects. For more information, see www.grandcountylearningbydoing.org.

Property ownership along the Fraser is highly fragmented. Public access for fishing is available on U.S. Forest Service (USFS), Bureau of Land Management (BLM), Grand County, and various municipal properties. Care should be taken by anglers to avoid trespass problems as not all private reaches are marked. Guided fishing is available on some privately held reaches.

Stocking

CPW stocked Whirling Disease-resistant strains of Rainbow Trout for 6 years in the Fraser River (Table 1, following page). Generally, stocking took place from the Highway 40 crossing upstream of Idlewild Campground downstream to the County Road 8 bridge in the Town of Fraser, and at Kaibab Park in Granby. Stocking was ceased after 2015 because these strains established themselves successfully and appeared poised to sustain themselves through natural reproduction. However, by 2019 it became evident that Rainbow Trout numbers were dwindling and additional stocking would be required. CPW plans to stock 50,000 2" Whirling Disease-resistant Rainbow Trout again in 2020. This is discussed in more detail later in this report.

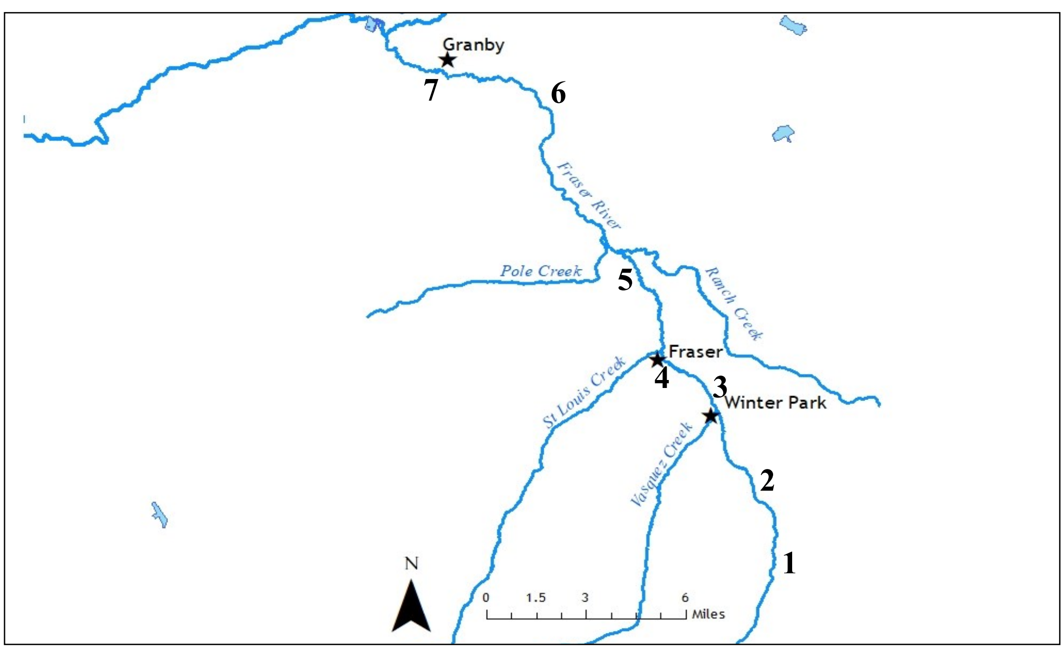

Figure 1. Fraser River, Grand County, Colorado. Survey stations discussed in this report are listed by number as follows: 1. Robber's Roost, 2. Idlewild Campground, 3. Confluence Park, 4. Safeway, 5. Fraser Flats, 6. Behler Creek Upper & Lower, 7. Kaibab Park.

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Date	# stocked	Avg. size (inches)
10/29/08	10,000	4.9
9/13/10	50,000	3.6
8/4/11	44,251	1.1
7/17/12	55,000	0.9
8/1/13	47,610	3.7
7/14/15*	68,715	1.9

Table 1. Stocking history of whirling-disease resistant Rainbow Trout in the Fraser River. *The 2015 plant was made entirely at Kaibab Park in Granby.

In 2019 CPW also stocked 10,000 native Colorado River Cutthroat Trout averaging 2.7" in the area of the Robbers' Roost survey reach, discussed on page 3.

Fishing Regulations

From the headwaters of the Fraser to the confluence with Saint Louis Creek, fishing is by artificial flies and lures only and all Rainbow Trout must be returned to the water. From Saint Louis Creek downstream to the confluence with the Colorado River, 2 trout may be kept and standard statewide regulations on method of take apply.

Methods

For all fish population surveys discussed in this report, standard electrofishing methods were used to generate depletion estimates of the trout populations. Mottled Sculpin are especially difficult to capture and we typically do not achieve enough of a depletion to generate a population estimate. Therefore, the total number of sculpin captured is reported as an index of population status and trend.

We have established standard locations ("stations," Figure 1) that we believe to be representative of that area of the river, and we return to these reaches annually, biennially, or less frequently depending on the circumstances. When we observe trends occurring in these reaches, it is reasonable to assume these trends are occurring over a larger reach of river. Stations are generally approximately 600 feet in length and encompass multiple pool-riffle-run complexes.

In all cases except for the Robber's Roost station, a bank rig electrofisher with five electrodes was used. At Robber's Roost, the river is much smaller and two backpack electrofishers were used. Sampling has generally taken place during the first ten days of September unless otherwise noted. Every effort is made to survey these stations as close to the same date as possible in order to control for seasonal movements of fish.

These electrofishing surveys typically require a crew of 10 or more, the majority of whom are dedicated local volunteers and members of various stakeholder groups (Figure 2, below). Without their willing assistance, the collection of the information appearing in this report would not be possible. CPW extends its sincerest thanks to these volunteers.

The remainder of this report consists of a discussion of each station surveyed, in order from upstream to downstream.

Figure 2. Electrofishing crew consisting mostly of local volunteers at Confluence Park station.

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Robber's Roost

We surveyed this station for the first time on September 6, 2019, to address a lack of current information on this farthest upstream portion of the Fraser. The station is actually not immediately adjacent to the Robber's Roost USFS campground, but is approximately 0.75 mile downstream of the campground, adjacent to an unnamed dispersed camping area (Figure 3, right). The station measured 611 feet in stream length and 15.4 feet in average wetted width and the downstream terminus is at approximately 9,550 feet in elevation.

The site is on USFS land approximately 1.25 miles upstream of the sediment retention pond that was constructed by a partnership of stakeholders to collect highway sand and enable its removal from the river. Due to its location upstream of that structure, this station provides an example of a portion of the Fraser near its headwaters that undergoes the stresses of excess bedload in the form of highway sand input. The highway sand is obvious in this reach in small gullies across the forest floor leading to the river and in the pool tails and other slow-water depositional features of the station. Aside from the highway sand, the physical habitat on this reach was in good condition for a forested reach of this type, featuring drop pools formed by large wood recruited into the stream channel, among other typical features.

We captured 46 Brook Trout in this reach, averaging 5.7" in length and a maximum length of 10" (Figure 4, right). No other species of fish were captured. This yielded relatively sparse population estimates of 26 pounds of trout biomass per surface acre and 191 fish >6" per mile. It appears likely that this population is suppressed by the condition of the substrate in this reach. Annual recruitment of fry may be lower than would otherwise be expected. Brook Trout are fall spawners, and their eggs overwinter in the gravel before hatching in the spring. It is possible that each year's input of highway sand with the first melt-out periods of early spring may cause some smothering of Brook Trout eggs that have not yet hatched.

22 of the fish we captured were large enough to weigh, and their body condition was actually quite good, averaging 123 on the relative weight (plumpness) scale. High average relative weight is an indicator that food availability is not a limiting factor. This is not surprising in a sparse population, as competition for available food is minimized even if invertebrate production is relatively poor.

Figure 3. Location of Robber's Roost electrofishing survey station. DS = downstream terminus; US = upstream terminus.

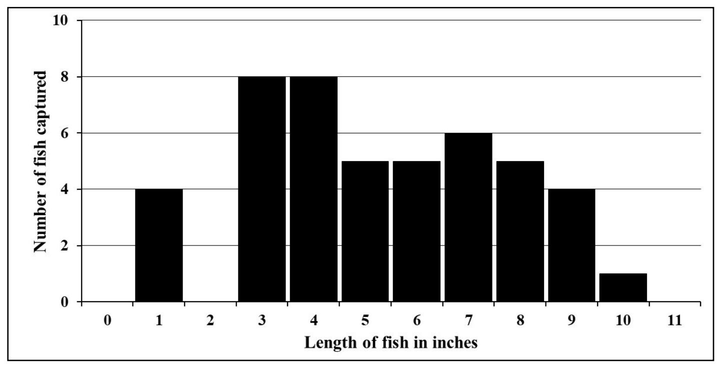

Figure 4. Size distribution of Brook Trout captured at Robber's Roost electrofishing station, 9-6-2019

Partially in response to the results of this survey, on September 26, 2019, we stocked 10,000 native Colorado River Cutthroat Trout averaging 2.7" in length. This was an opportunistic stocking occasion as these were excess fish available from our hatchery system. It is possible that spring-spawning Cutthroat may have a competitive advantage over Brook Trout in this reach. When mature, the Cutthroats will deposit their eggs after the peak of runoff and after the bulk of the highway sand for the year has entered the stream. Therefore, potential smothering of developing eggs may be reduced. We will revisit this site again in the coming years to ascertain whether the Cutthroats appear to have such a competitive advantage in recruitment. We will also likely continue stocking Cutthroat fingerlings here in the short term as they are available.

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Idlewild Campground

This site is located adjacent to the Forest Service campground just upstream of the town of Winter Park at an elevation of approximately 8,895 feet. This station is 675 feet in length and averages 20.2 feet in width. Table 2 (below) contains population estimates collected on the three occasions we have surveyed this reach. The fish population here is dominated by small Brook Trout which rarely exceed 10" in length (Figure 5, below and Figure 6, right). This is the farthest-upstream of our established Fraser River stations where Mottled Sculpin are present.

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.

2013 was the last year that we stocked Rainbow Trout fingerlings in this portion of the Fraser. The decline in their population here can 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. By 2018 it was 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 evidence an apparent recent trend of upstream expansion of Brown Trout.

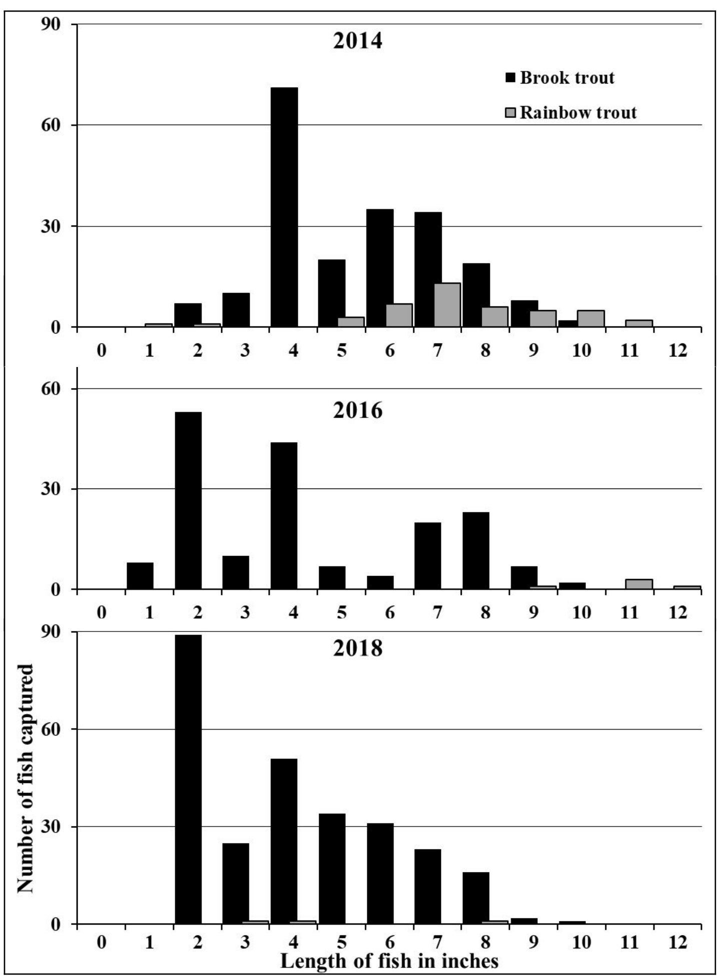

Figure 5. Size distribution of trout at Idlewild Campground.


Figure 6. Brook Trout from the Idlewild reach. Photo by Kevin Birznieks.

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 2. Population estimates, Idlewild Station.

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Confluence Park

The Confluence Park station is located in the town of Winter Park at an approximate elevation of 8,725 feet. The surveyed reach measures 640 feet in stream length with an average width of 28.0 feet. The upstream end of the station is the pool where Vasquez Creek joins the Fraser. We have surveyed this reach on nine occasions since 2006. 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 (Figure 7, right). These recent low total biomass estimates can be mostly attributed to the cessation of Rainbow Trout stocking. This is a higher-gradient, forested reach with a cooler temperature regime, which explains the relative scarcity of Brown Trout to date.

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 stocking as discussed previously. The 2017 and 2018 data suggests that Rainbow Trout biomass has declined rapidly here after the cessation of stocking and that Rainbows will apparently not sustain themselves here without resumption of stocking.

Figure 8 (right) 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 after stocking ceased, 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 multiple size-groups of Browns have been collected, not only sexually mature fish. At this site there appears to be a current trend of increasing Brown Trout biomass and possible expansion of their range upstream in the Fraser. The 2018 survey also found weak groups of Age-0 (2" avg.) and Age-1 (5" avg.) Brook Trout, which will likely result in lower biomass estimates in coming years.

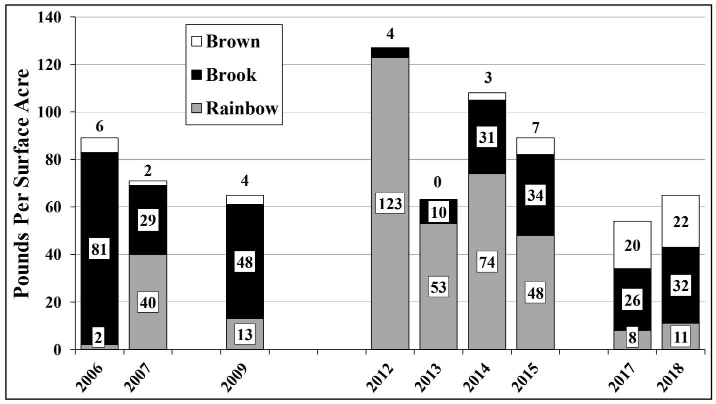

Figure 7. Biomass estimates at Confluence Park.

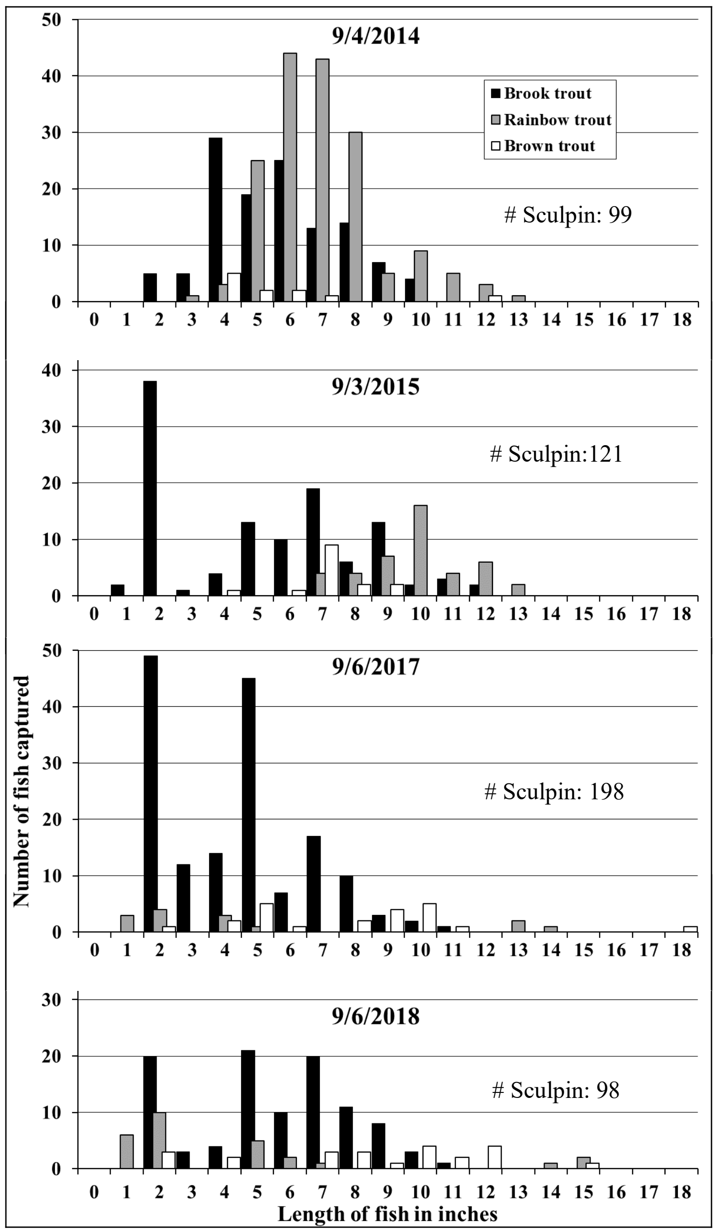

Figure 8. Size distribution of trout and number of Mottled Sculpin captured at Confluence Park

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Safeway

The Safeway station is located immediately behind the Safeway store in the town of Fraser (Figure 9, right). 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. This station measures 621 feet in length and 25.0 feet in average wetted width.

2003 was the only year that this station was surveyed prior to 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. Biomass estimates for all trout combined (Figure 10, below) have been following a general upward trend over the past decade.

Despite its location in relatively heavily urbanized surroundings, We have consistently found this to be one of the most productive reaches on the Fraser. This section lies on the downstream end of the Cozens Ranch Open Space, owned by the Town of Fraser. The property extends upstream to the Rendezvous Road bridge. We believe this station to be representative of conditions throughout the property. The great foresight of the planners who were involved in protecting this reach has resulted in this highly robust fishery. It is impossible to over-

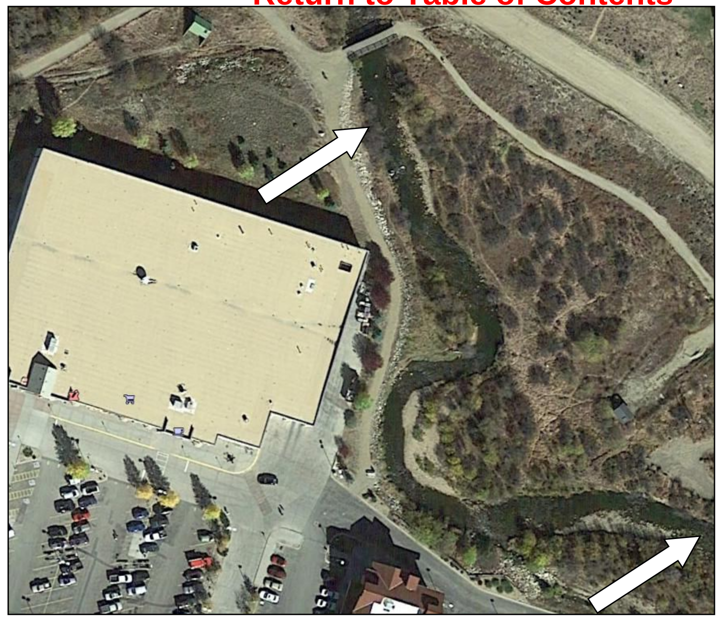

Figure 9. Safeway Station location. Arrows indicate downstream and upstream terminus of survey reach.

state the importance of the mature willow riparian community and its contributions to the ecological processes that maintain this fishery. While physical habitat improvement projects in the channel have proven to be highly beneficial, it is the combination of such projects with a healthy and functioning riparian zone that produces excellent results.

Most 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

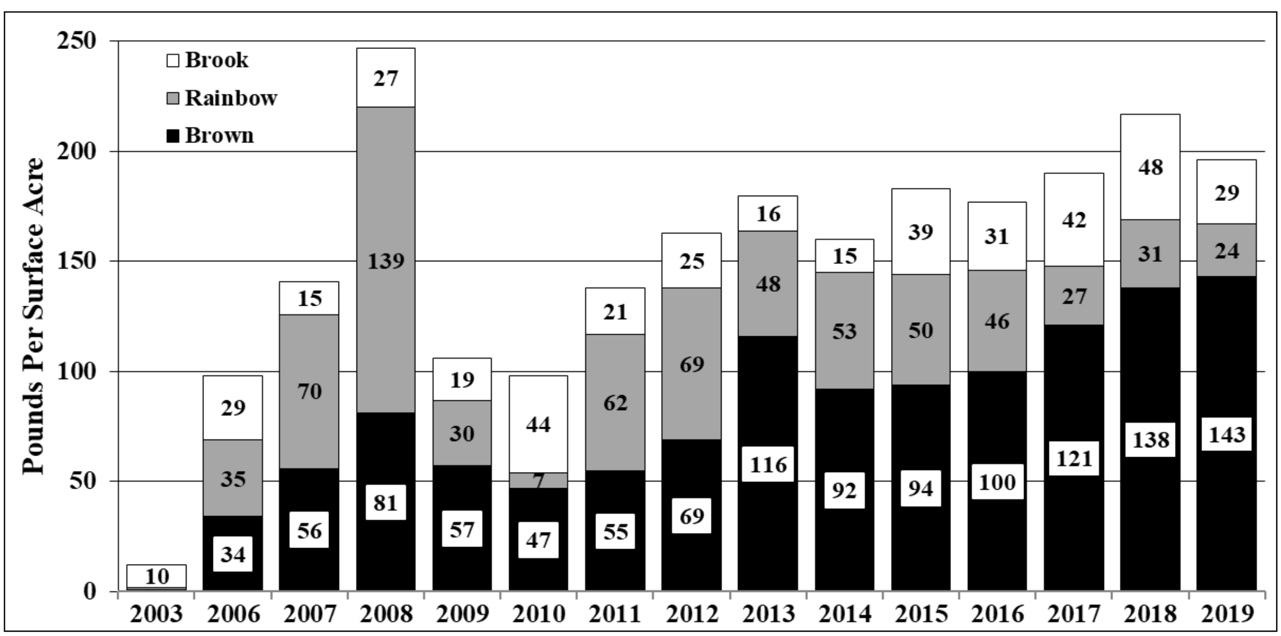

Figure 10. Biomass estimates in pounds per surface acre of Brook, Rainbow, and Brown Trout, Safeway.

Dates of surveys
9/30/2003
10/21/2006
8/23/2007
10/03/2008
9/3/2009
9/7/2010
9/6/2012
9/4/2013
9/3/2014
9/2/2015
8/31/2016
9/5/2017
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9/5/2019

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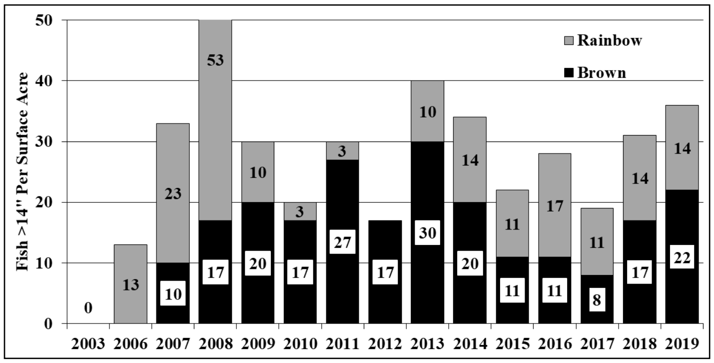

Figure 11. Quality trout (>14”) density estimates, Safeway. We have never collected a Brook Trout >14” at this site.

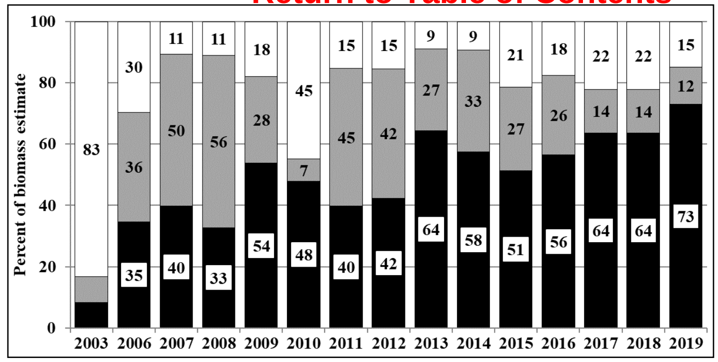

Figure 12. Percent contribution of each trout species to the biomass estimates appearing in Figure 10 (previous page). Bar colors are as follows: Brook—white; Rainbow–gray; Brown—black.

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 artificially 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, and at Kaibab Park in Granby. These stocked fish had good success, leading to the cessation of Rainbow fingerling stocking after 2013. 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 in recent years (Figure 12, above). 2019 produced the lowest biomass estimate for Rainbows since fingerling stocking ceased. These trends indicate that a resumption of Rainbow fingerling stocking is warranted, and we plan to stock again in 2020.

Densities of trout >14” increased in 2018 and ’19, reversing an apparent downward trend from 2013-’17 (Figure 11, above). These changes have been driven primarily by variation in numbers of larger Brown Trout, as Rainbows have remained more consistent during this time.

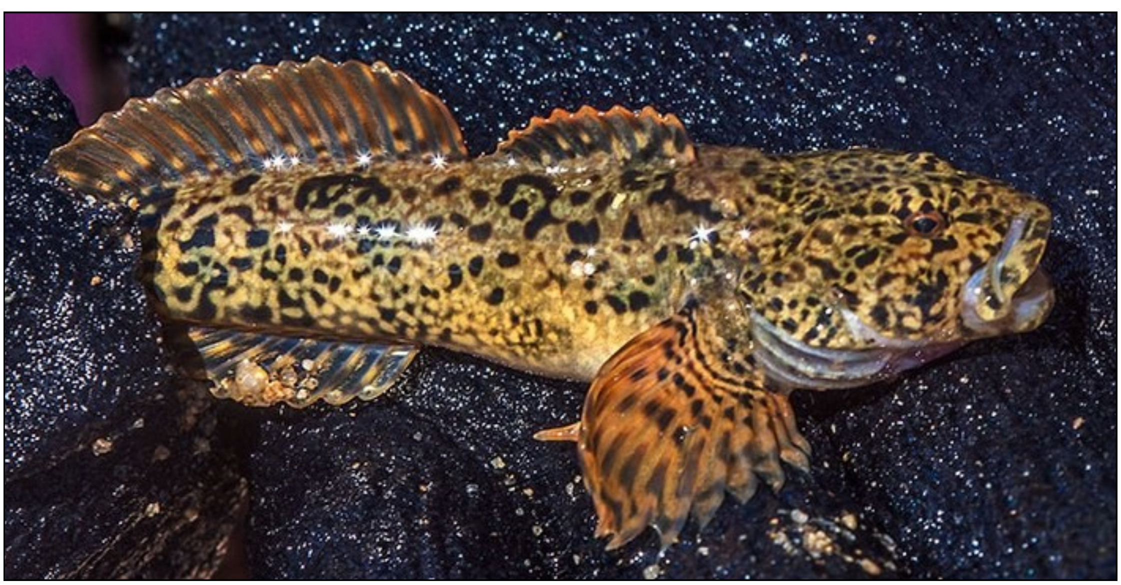

Figure 13. A sculpin from the Fraser River. Photo by Kevin Birznieks

2003	159
2006	178
2007	260
2008	191
2009	176
2010	431
2011	292
2012	550
2013	355
2014	122
2015	249
2016	148
2017	235
2018	233
2019	176

Table 3. Number of Mottled Sculpin captured by year.

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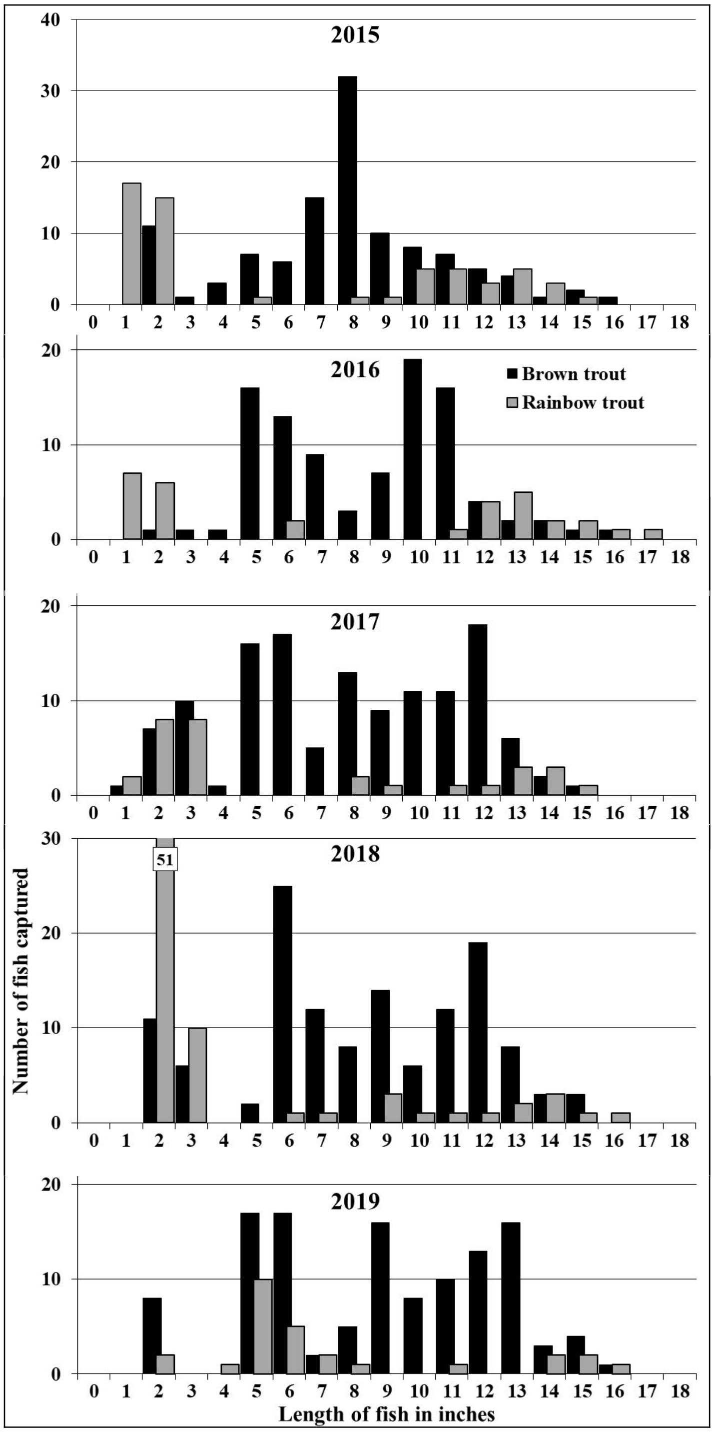

Figure 14. Size distribution of Brown and Rainbow Trout captured in the Safeway reach.

All Rainbows >14” appearing in the surveys from 2013 onward were produced from the stocked fingerlings, demonstrating the success of these stocked fish here.

Sculpin capture in 2019 was lower than average but not the lowest that we have observed here (Table 3, previous page). However, this provides another piece of evidence that Mottled Sculpin numbers in 2019 were generally down.

The size distribution of all Brown and Rainbow Trout captured in recent surveys is presented in Figure 14 (left). In 2013 we 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 stocked fish 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 most of the recent 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. The 2018 year class represented the best chance to date to form a strong Age-1 year class in 2019. We did find the strongest Age-1 year class to date, yet even with such a strong 2018 cohort, they were outnumbered by Brown Trout in the same size range in 2019. We plan to stock Rainbow fingerlings again in 2020.

Figure 15. A wild Rainbow Trout from the Safeway site.

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Fraser Flats

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 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 design of the project. This location is also the site of a large willow planting effort undertaken by LBD stakeholders and local volunteers in an effort to restore the willow riparian community. This effort appears to have been initially successful, and the results will develop over the coming decade as the planted willows mature. The fishery surveys discussed here were obtained on a reach measuring 600 feet in length and 35.9 feet in average wetted width (Figure 18).

Prior to the habitat project (2007 and 2016), this site produced poor population estimates, among the lowest ever obtained in any location on the Fraser (Figures 16 & 17, below). 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. However, this was followed in

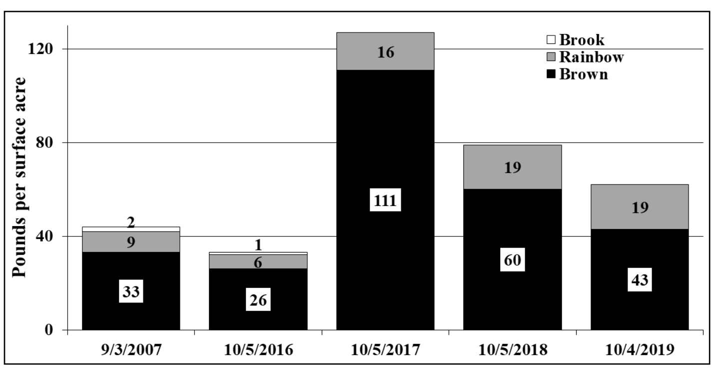

Figure 16. Biomass estimates in pounds per surface acre, Fraser Flats site.

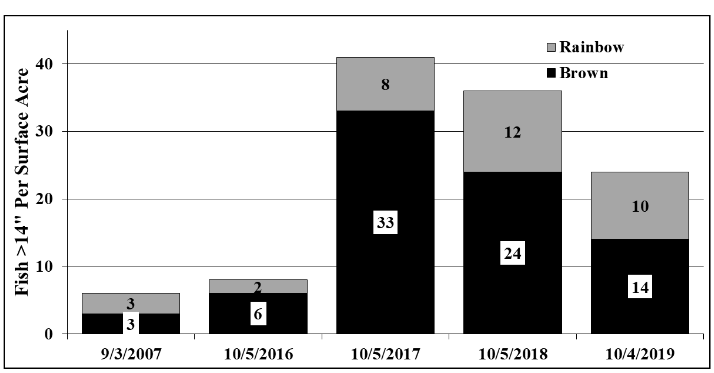

Figure 17. Quality trout (>14") density estimates, Fraser Flats site.

Figure 18. Two views of the Fraser Flats site. The intersection of US Highway 40 and Grand County Road 83 is visible at left in both photos. The upper photo was taken on 9/7/2016 prior to construction of the Fraser Flats Habitat Improvement Project. The flow on that date was approximately 35 CFS. The lower photo was taken on 9/13/19 after construction of the project. Flow was approximately 26 CFS. Channel narrowing with point bar enhancements, thalweg definition and channel-within-a-channel design is clearly visible. The arrows in the lower photo indicate the downstream (top) and upstream (bottom) ends of the fish population survey reach. The red lines indicate the approximate location of the two surveyed cross-sections discussed on page 11.

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2018 by a 38% decline in total biomass, and a further decline of 12% in 2019, or a total decline of 51% from the 2017 estimate. The 2019 estimate still represented an 88% increase over the pre-project biomass estimate in 2016. We believe that this decline is most likely attributable to the high level of public fishing pressure that this section has experienced since opening to the public. The public river reach measures approximately 1,500 feet in length. It is bounded on both ends by private land and there are no natural impediments to fish movement on either end. It is possible that heavy pressure on this limited reach is causing fish to vacate the area in favor of more lightly fished waters in either direction. In 2019, the LBD partners agreed to institute a voluntary fishing closure of this reach on Tuesdays and Thursdays in order to "rest" the fishery. Results of this approach are not yet known.

Prior to the habitat project, we found high numbers of juvenile trout in their first two years of life, but by age 3 (10" and larger) the fish appeared to have mostly vacated the reach in search of more suitable habitat (Figure 19, right). This no longer appeared to be the case 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, which corresponds with the strong age-0 group that we also observed at Safeway that year. These fish were not stocked and are the product of wild reproduction. However, as at the Safeway site (see discussion on pages 6-8), we have seen a lack of recruitment of Rainbows from age-0 (2-4" in this survey) to age-1 (6-10"). The Rainbows that we most recently stocked in the Fraser were resistant to whirling disease, however these fish may be losing resistance over successive wild generations. Therefore, we plan to stock 50,000 whirling-disease resistant Rainbow fingerlings again in 2020.

The sharp decline in Mottled Sculpin numbers captured in 2017 (Table 4, following page) is most likely due to the fact that our 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. However, in 2019 we collected the lowest number of sculpin to date. There is no immediately apparent reason for this decline. It is worth noting that Mottled Sculpin capture was low in three of our long-term monitoring reaches (Safeway, Fraser Flats, and Kaibab Park) in 2019. This is a difficult species to reliably capture, so it is currently unknown whether the reduced catch in 2019 is a reflection of a trend in actual

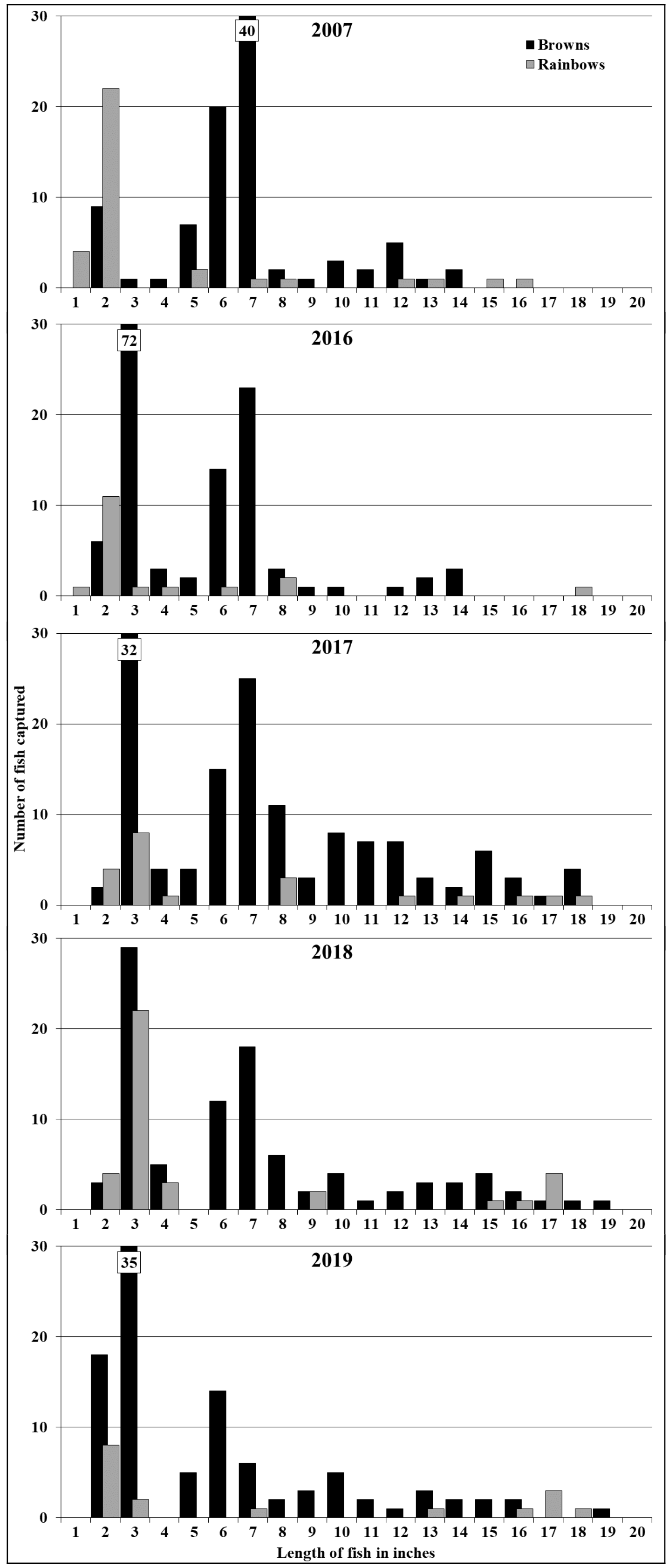

Figure 19. Size distribution of Brown and Rainbow Trout captured in the Fraser Flats reach.

numbers or a reflection of the ability of our crews to efficiently capture them. We will expend extra effort in our 2020 surveys to attempt to answer this question. If this negative trend continues, it may be cause for concern.

One explanation for the decline in trout population that we have observed since construction of the habitat project here could be that the project was not successful in creating and sustaining an increase in physical habitat for adult trout. In order to attempt to answer this question, we conducted simple cross-section surveys with a laser level, tape and stadia rod in 2016 prior to construction and in 2019 after the project had been in place through two runoff cycles. Results of two of these cross-section surveys are displayed in Figure 20 (below). These surveys appear to demonstrate that the project has performed as intended using the width:depth (W:D) ratio as an indicator. Both surveys documented a high W:D ratio before construction, which is an indicator of poor trout habitat. The 2019 surveys found that the W:D ratios in these two locations remains at less than half of the pre-project ratios. This lends additional support to the hypothesis of angling pressure being the determining factor in reduced trout numbers.

An interesting comparison can be drawn between this site and Safeway. Both sites have had habitat work projects and see heavy angling pressure. However the Safeway site has a far more robust riparian vegetation community. This illustrates how important the riparian community is to a small river such as the Fraser. The highly complex overhead cover, undercut bank habitats, and organic inputs to the stream that are provided by mature willows cannot be replicated by construction of in-channel features, and are likely the most important element in maintaining a fishery of this type that is resilient to angling pressure as well as other types of disturbances.

2007	726
2016	971
2017	264
2018	377
2019	204

Table 4. Number of Mottled Sculpin captured in each survey by year at Fraser Flats site.

Figure 21. 2018 survey crew, Fraser Flats station. Photo by Dave Showalter.

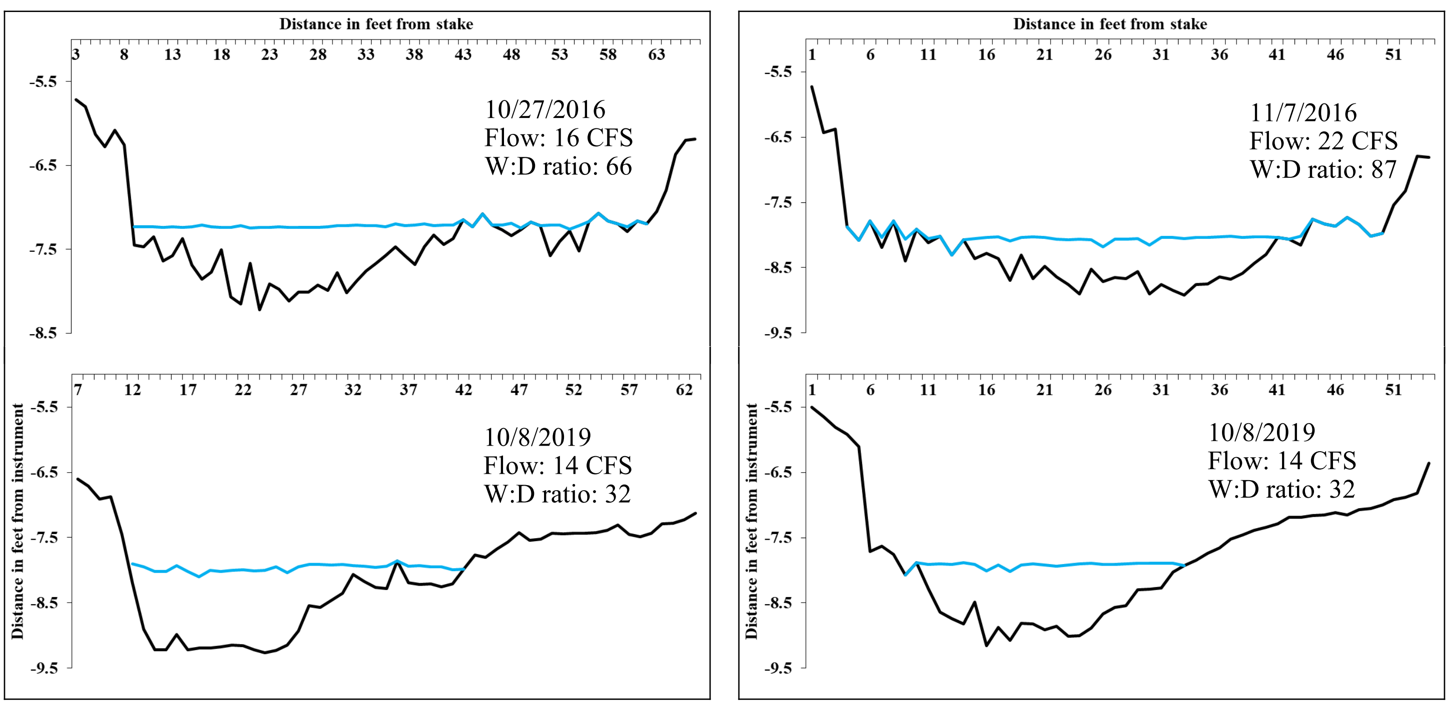

Figure 20. Simple cross-section surveys collected at two sites within the Fraser Flats Habitat Improvement Project reach (for locations, see Figure 18 on Page 9). Blue lines indicate water surface elevation at the time of the survey, and black lines indicate ground elevation. Cross-section #1 before (top) and after (bottom) habitat work is at left, and Cross-section #2 is at right.

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Angler survey

In 2018 and 2019 we conducted a simple angler survey here 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 5 (right) and 6 (below). The proportion that each species contributed to the reported catch is similar to the proportions that these species contributed to our population estimates. There were minimal differences in the results between the two years. Minor declines in catch rates and anglers' subjective rating of the fishery are likely reflections of the declines in trout populations that we observed.

	2018	2019
# surveys completed	40	36
# anglers represented	58	59
Total hours fished	123.25	114.25
Avg. time of trip	2.1 hrs.	2.0 hrs.
Brown trout caught	51	46
Rainbow trout caught	24	19
Brook trout caught	2	2
Avg. catch per hour	0.62	0.59
Residence - Grand County	19	10
CO Front Range	14	17
Out of state	4	3
Other Colorado	1	2

Table 5. Angler survey results, Fraser Flats.

Why did you fish here today?	2018	2019	How often do you fish here?	2018	2019	Will you fish here again?	2018	2019	How would you rate this fishery?	2018	2019
Not crowded	15	14	First time	22	19	Yes	38	31	Excellent (4)	13	8
Small stream type	15	10	Once a month	7	8	No	1	4	Good (3)	15	17
Wild fishery	8	16	Once a week	4	2				Fair (2)	9	7
Fish size	4	3	Once a year	4	4				Poor (1)	2	2
Easy access	2	0	More than once/week	2	1				Avg. response	3.0	2.9
Number of fish	1	1									

Table 6. Angler survey results, Fraser Flats.

Figure 21. A large Brown Trout from the Fraser Flats reach.

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Upper and Lower Behler Creek

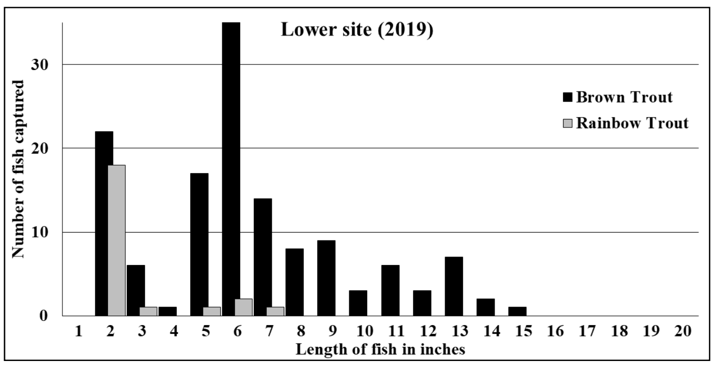
At the downstream end of the Fraser River canyon between Tabernash and Granby, over 1 mile of the river flows across public land held by the BLM. However, due to its landlocked position surrounded by private parcels, there is currently no public access to this section. Our two sampling sites are located on BLM property immediately upstream of Granby Ranch and downstream of the confluence with Behler Creek, which joins the Fraser from the east (Figure 23, below). We have surveyed these two sites on one occasion each — the upper site in 2015 and the lower site in 2019.

Physical habitat conditions in the upper site are far more ideal than the lower site, which is reflected in the survey results. The lower site is part of an approximately 1,200-foot section at the downstream end of BLM property that has been identified by stakeholders as a candidate for habitat improvement, if public access to this reach were ever to be secured.

Similar to the Fraser Flats site prior to the habitat project, the lower Behler Creek site held large numbers of juvenile trout but fish larger than 8” were rare, due to a lack of quality adult trout habitat (Figure 22, below) .

	Upper Behler Creek (2015)	Lower Behler Creek (2019)
Site length	530 feet	574 feet
Site average width	46.6 feet	64.7 feet
Brown Trout: pounds per acre	148	34
> 14” per acre	39	4
> 6” per mile	1,529	895
Rainbow Trout: pounds per acre	9	—
>14” per acre	4	—
>6” per mile	50	27
Total trout biomass	157	34
Total sculpin captured	452	101

Table 7. Population estimates for Brown and Rainbow Trout, Behler Creek Upper and Lower sites.



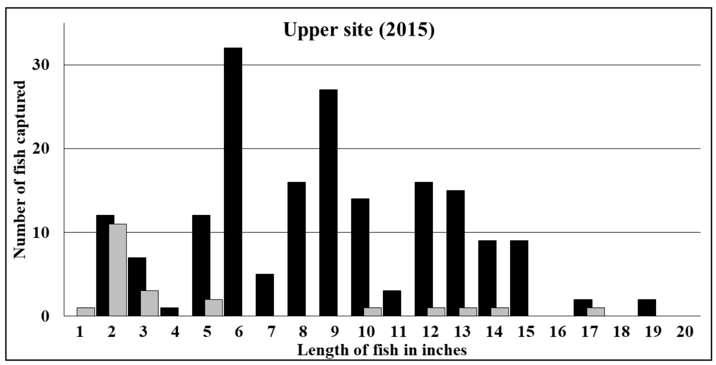


Figure 22. Size distribution of Brown and Rainbow Trout, Behler Creek Upper (right) and Lower (left)stations, Fraser River.

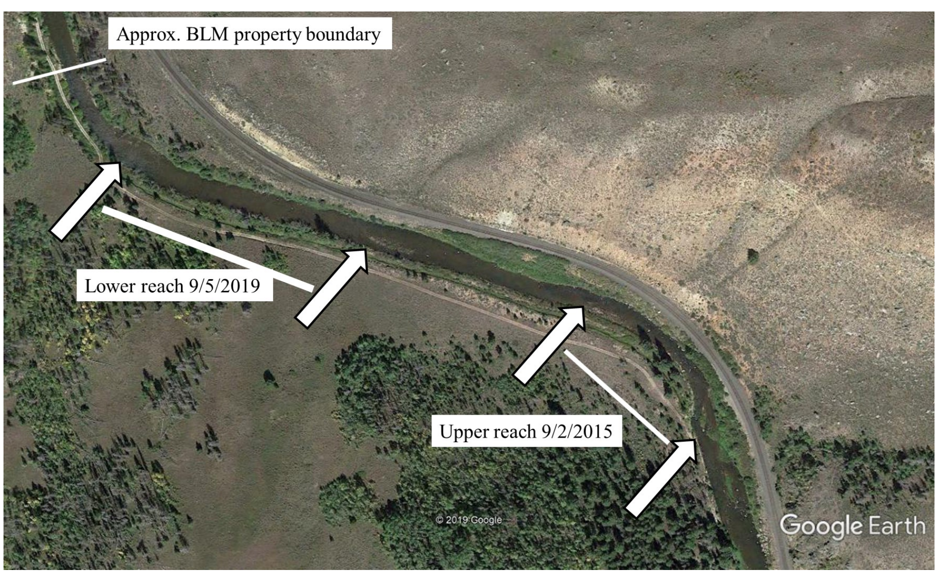


Figure 23. Location of Behler Creek Upstream and Behler Creek Downstream stations, Fraser River.

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Kaibab Park

The Kaibab Park station is located in the town of Granby where the Fraser flows between the park and the fire station, immediately downstream of the Highway 40 crossing (Figure 26, below). The site measures 650 long by 33.4 feet in average width. This is the farthest downstream site on the Fraser that we survey regularly. Only Brown Trout population estimates are presented (Figures 24 & 25, right) 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 were successful farther upstream.

Biomass estimates for Brown Trout in this reach have remained relatively stable over time, with 2017 and 2012 producing the highest and lowest estimates, respectively. Extreme high-water years such as 2014 (Table 8) likely have a flushing effect on juvenile Brown Trout here, while drought years such as 2012 see decreases in adult fish density estimates, likely due to lack of habitat during low flows. 2017 conditions probably represented a “happy medium” situation in which the river benefitted from the flush of recent high water years, yet the 2017 runoff was not high enough to displace juveniles. At the same time, flows did not become so low that adult fish vacated the section.

The 2019 survey produced the second-lowest density estimates of fish >14” (Figure 25), which was a surprise because 2019 flows were generous. Reasons for this drop are not obvious, aside from the observation that other than the plunge pool at the base of the diversion structure, this reach is generally lacking in habitat for larger fish.

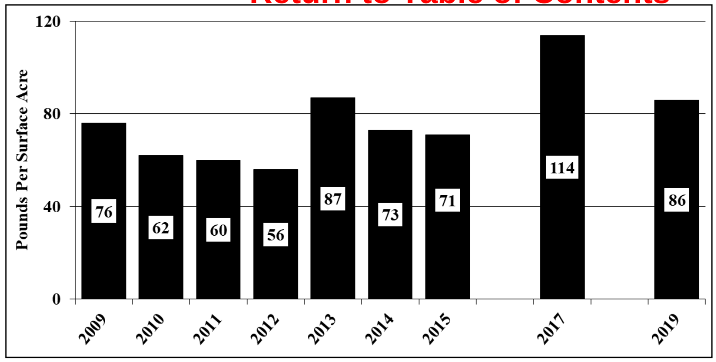

Figure 24. Biomass estimates in pounds per surface acre, Kaibab Park site.

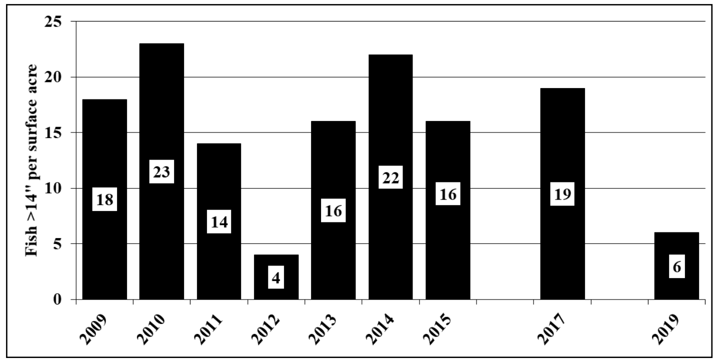

Figure 25. Quality trout (>14”) density estimates, Kaibab Park site.

Date	Flow (cfs)	Date	Flow (cfs)
6/4/09	991	6/12/15	1425
6/8/10	1767	6/13/16	1351
7/1/11	1519	6/11/17	1027
4/27/12	157	6/1/18	781
5/18/13	651	7/1/19	1142
5/31/14	2256		

Table 8. Annual peak flows in the Fraser River at Granby.

Figure 26. Location of Fraser River Kaibab Park survey station. US Hwy 40 bridge is visible at right.

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This was the only location on the Fraser that we stocked Rainbow Trout fingerlings in 2015. The Rainbow Trout appearing in the 2015 sample (Figure 27, right) were the result of the stocking that year. The 2017 and 2019 samples revealed that similar to our past experiences here, the Rainbows stocked in 2015 did not recruit into the population in any significant number. This is the warmest reach of the Fraser in late summer and early fall, and it is possible that this section of the river simply becomes too warm on an annual basis for wild Rainbow Trout to flourish here. Due to this lack of past stocking success, when we stock the Fraser in 2020 we do not plan to stock the Kaibab Park reach.

As discussed previously, we captured low numbers of Mottled Sculpin here in 2019, and in fact this was the lowest number we have ever captured here (Table 9, right). We plan to pay particularly close attention to Mottled Sculpin numbers in future surveys to determine whether or not this is a consistent trend.

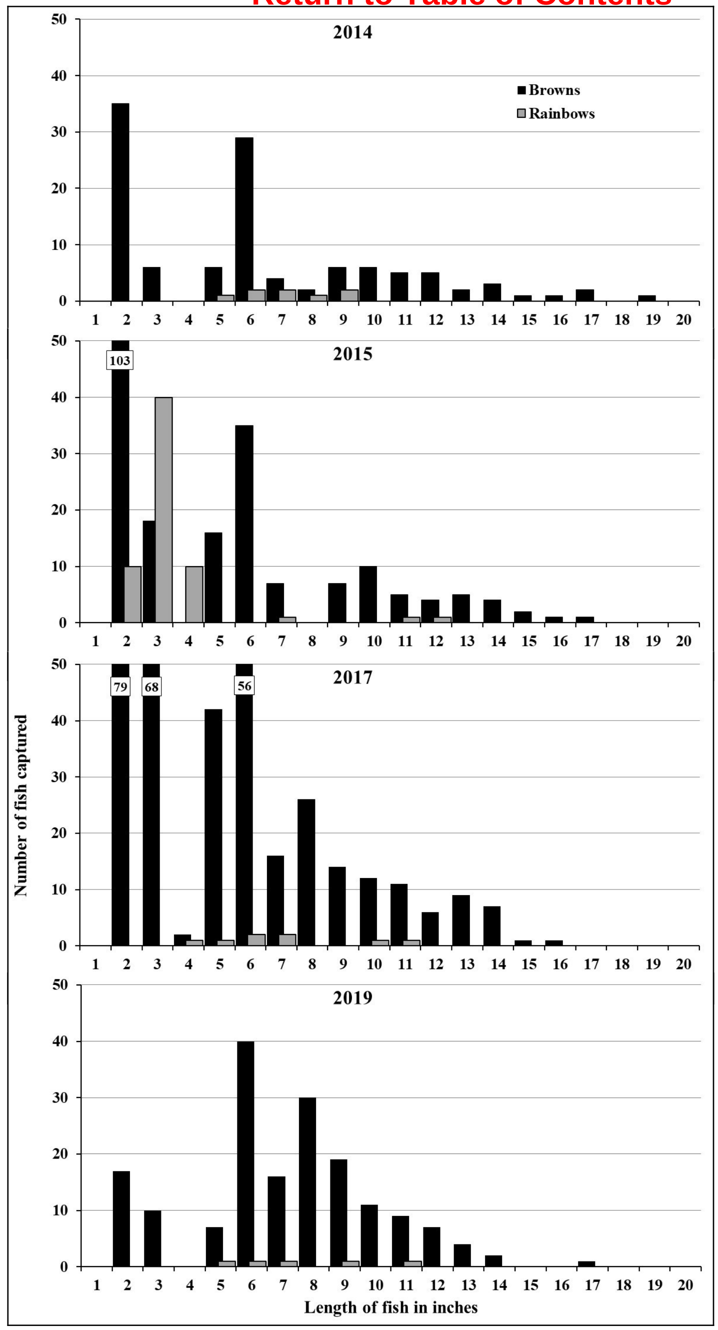

Figure 27. Size distribution of trout captured in Kaibab Park reach.

Figure 28. In 2014 we examined a 5” Mottled Sculpin that had recently consumed a 3” dace, another native small fish species common in the Fraser. This is the only time we have documented sculpin piscivory in this area.

Figure 29. In the same 2014 survey we examined this Brown Trout that had recently eaten a Mottled Sculpin.

2009	256
2010	466
2011	533
2012	1,279
2013	521
2014	262
2015	469
2017	249
2019	98

Table 9. Number of Mottled Sculpin captured by year, Kaibab Park site.

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GRAND COUNTY

LEARNING BY DOING

Colorado Parks and Wildlife
Colorado River, ILVK Reach Fishery Monitoring Report
January 2020

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Colorado River, ILVK Reach

Fishery Monitoring Report

Jon Ewert, Aquatic Biologist, Colorado Parks and Wildlife

January 2020

Introduction

Since 2016, Colorado Parks and Wildlife (CPW) aquatics crews, local landowners, and U.S. Bureau of Land Management (BLM) personnel have surveyed the fish population on a 2.8-mile reach of the Colorado River east of Kremmling (Figure 1). Surveys have occurred annually in the spring. The purpose of these surveys was to establish baseline estimates of the resident fish populations prior to large-scale habitat improvement and stabilization work being constructed by the Irrigators of the Lands in the Vicinity of Kremmling (ILVK); and then to monitor any changes in fish populations following construction of ILVK projects. The construction work is being funded in part by the Colorado Water Conservation Board and Colorado Basin Roundtable. ILVK is a partner in the Colorado River Headwaters Project, which is a Regional Conservation Partnership Program administered by the Natural Resources Conservation Service. CPW is an active participant in the program in multiple capacities, one of which is monitoring fish populations. Land ownership along this reach consists of a succession of private ranches as well as a small amount of BLM property.

This reach covers a transitional area in the river and thus habitat conditions follow a continuum from top to bottom. The substrate is dominated by cobble in approximately the upper 1/3 of the reach, which transitions to sand and fine sediment by the bottom. Functioning point bars occur in this upper portion, but are absent in the lower portion. Habitat conditions become poor by the downstream end of the reach, where the river channel is overwhelmed with sediment input from wasting banks and other sources, very little to no functioning riparian vegetation zone, and overwide channel with no thalweg definition and little bedform diversity. These are all issues that the ILVK cooperative effort aims to address.

Methods

We conducted mark-recapture population estimates using a raft-mounted electrofishing unit. Recapture days were separated from mark days by at least a full day to allow for marked fish to redistribute. Because this reach had not been surveyed previously, we were uncertain of ideal flow rates to conduct the work. In 2016, flows of 1,200 CFS (measured at the KB Ditch gauge) proved to be too high to be effective and we did not conduct a recapture pass. In 2017, 2018, and 2019, flows were more manageable and allowed us to generate valid estimates.

Results & Discussion

We captured seven species of fish in these surveys: brown, rainbow, cutthroat and golden trout, mountain whitefish, white sucker, and bluehead sucker (a native species, 2 individuals captured in 2017). Brown trout are the dominant species and the only one with capture rates high enough to generate population estimates (Table 1). Rainbow trout have been captured in small numbers, always less than 10% of the total trout catch. The origin of the cutthroat and golden trout (1 of each species captured in 2019) is unknown.

Figure 1. Location of ILVK reach on the Colorado River east of Kremmling. The Troublesome Creek confluence is visible at upper right.

	2017	2018	2019
Dates of survey	5/5 & 8	4/20 & 25	4/16 & 19
Flow at KB gauge	569	358	315
Brown trout: lbs. per acre	15	32	25
>14” per acre	6	11	11
>6” per mile	230	497	416
Avg. relative weight	84.4	86.1	85.9
Capture probability	0.16	0.16	0.22
# Whitefish captured	33	67	84

Table 1. Population estimates for ILVK reach, 2017-2019

Brown trout population estimates in 2018 and 2019 were very similar, but the 2017 estimates were significantly lower — roughly half of the following two years. Capture probabilities (a statistical estimate derived from the recapture rate, Table 1) were the same for 2017 and 2018, which suggests that the survey in those years was equally efficient at generating the population estimate. It is possible that flows rising above their late winter/early spring base levels trigger emigration of brown trout out of this reach. If this is the case, the 2017 survey may have occurred after this movement had begun. In the future, we will target the flow window of 300-500 CFS prior to May 1 to repeat this survey.

The size distribution of brown trout and mountain whitefish are displayed in Figures 3 and 4, respectively (following page). The average size of brown trout has been

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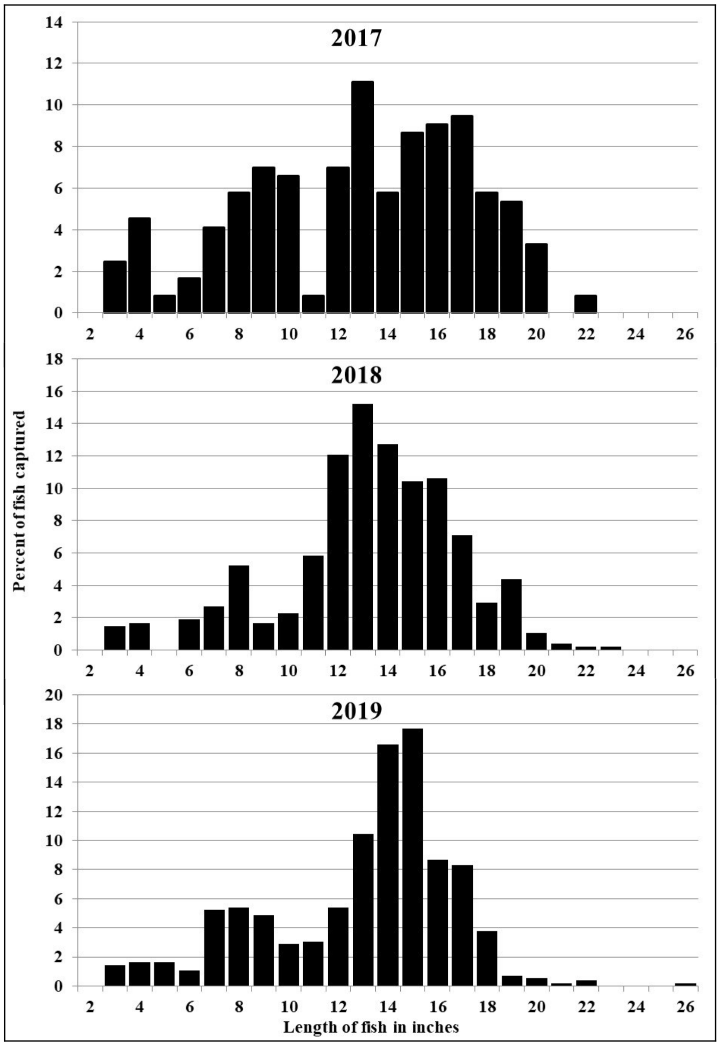

Figure 2. Size distribution of brown trout captured on the ILVK reach, 2017-2019.

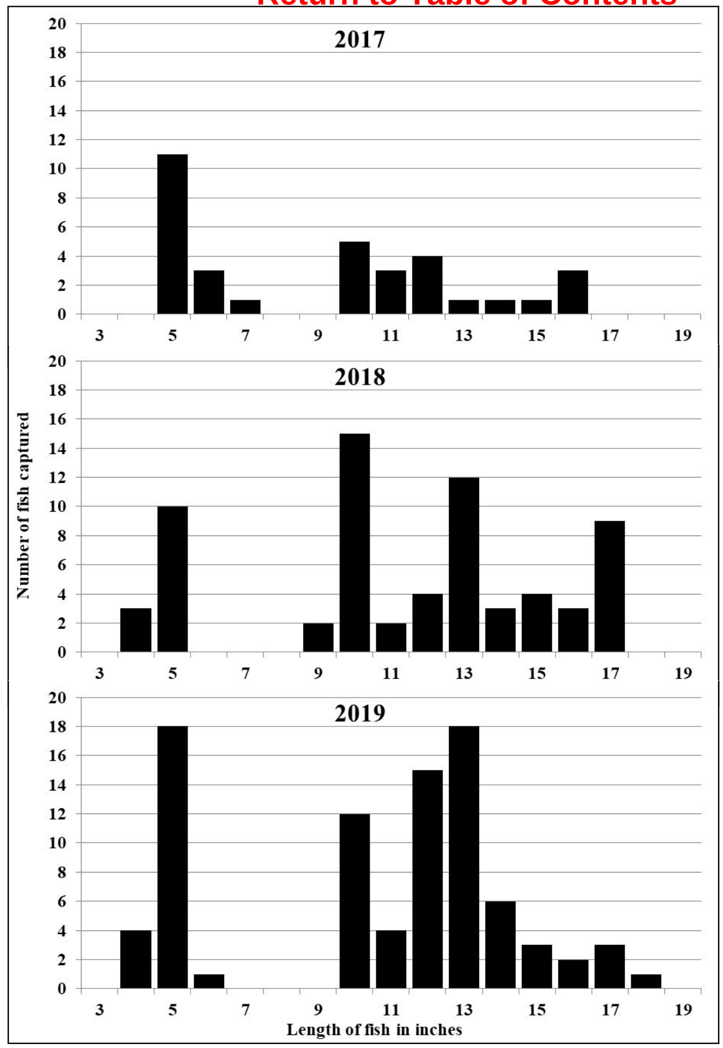

Figure 3. Size distribution of mountain whitefish captured on the ILVK reach, 2017-2019.

relatively stable over the three years, although in 2017 adult fish (>10") made up a smaller portion of the total sample. This supports the emigration hypothesis, because we would expect juvenile fish to be slower to move away from their natal habitat, thus comprising a higher percentage of the total if our sample did in fact take place after an emigration of adults had occurred.

Relative weight is a measure of body condition on a scale of 100. It can be seen as an indirect measure of prey availability in the reach. We surveyed two other nearby sites on the Colorado in spring of 2019, one in Radium downstream of Gore Canyon, and one on the Paul Gilbert State Wildlife Area (SWA) near Parshall. Average relative weight in brown trout in the Radium reach was 94.9, and on the SWA was 84.1. The ILVK biomass estimate was 15% that of the Radium reach and 22% of the SWA reach. This evidence suggests that prey availability in the ILVK reach is particularly poor, which is in all likelihood a reflection of substrate condition. Habitat projects that are planned and underway as part of the ILVK effort will hopefully result in improvements in these parameters.

The mountain whitefish population has been more dynamic than the brown trout over this study period. This species has only recently appeared in Middle Park, first appearing in CPW surveys in 2013 (See CPW report on

Figure 4. The largest brown trout captured to date in our surveys on the ILVK reach, 26.6", 3.6 lbs.

the Colorado River near Parshall). The number of whitefish do not constitute a large percentage of total fish captured, but they have steadily increased over the three years of this study (Table 1). This corresponds with the trend in whitefish numbers that we have seen near Parshall. The size distribution (Figure 3) generally reflects four year classes present, at roughly 5, 10, 13, and 17 inches. The habitat within the ILVK reach is highly suitable for this species, and the data suggest an expanding population.

CPW plans to continue monitoring this reach in coming years.

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GRAND COUNTY

LEARNING BY DOING

303(d) and Monitoring and Evaluation List 2020

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303(d) and Monitoring and Evaluation List 2020 (Rulemaking Hearing held December 2019)

Learning By Doing (LBD) evaluates impairments identified in Regulation #93 – Colorado's Section 303(d) List of Impaired Waters and Monitoring and Evaluation (M&E) List (Colorado Department of Public Health and Environment, Water Quality Control Commission. Regulation #93., 2020[i]) within the LBD Cooperative Effort Area (CEA) to ensure that adequate monitoring is being done in segments where there are impairments.

Regulation #93 consists of 3 components:

1. The list of Water-Quality-Limited Segments Requiring total maximum daily loads (TMDLs) fulfills requirements of section 303(d) of the federal Clean Water Act, which requires that states submit to the U.S. Environmental Protection Agency a list of those waters for which technology-based effluent limitations and other required controls are not stringent enough to implement water quality standards.
2. Colorado's Monitoring and Evaluation List identifies water bodies where there is reason to suspect water quality problems, but there is also uncertainty regarding one or more factors, such as the representative nature of the data. Water bodies that are impaired, but where it is unclear whether the cause of impairment is attributable to pollutants as opposed to pollution, are also placed on the Monitoring and Evaluation List. This Monitoring and Evaluation list is a state-only document that is not subject to EPA approval.
3. The list of Water-Quality-Limited Segments Not Requiring a TMDL identifies segments where data is available that indicates that at least one classified use is not being supported, but a TMDL is not needed.

The objectives of the 303(d) Monitoring Program are to:

- Evaluate the current 303(d) and M&E listed water bodies within the CEA;
- Evaluate current water quality sampling programs being conducted by various agencies to determine if 303(d) listed waters are being monitored appropriately;
- Develop monitoring plan for segments that are determined to need additional sampling.

2020 Review of Impaired Segments

In January 2020 the Water Quality Control Commission adopted the most recent version of Regulation #93, which became effective on March 3, 2020. The most current 303(d) and M&E list showed that 15 stream segments are currently listed as impaired within Grand County; 7 of these segments, **COUCUC01, COUCUC02, COUCUC03, COUCUC08, COUCUC09, COUCUC10a, COUCUC10c and four water bodies (COUCUC12)** are located within the LBD CEA as shown in Figure 1. Of the 7 listed segments within the LBD CEA, the

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impaired uses are for Recreation, Water Supply, and Aquatic Life Use. The primary analytes of concern are arsenic (total), E. coli, copper (dissolved), silver, zinc, pH, stream temperature, and macroinvertebrates. There are seventeen new listings within the CEA for arsenic, pH, copper, silver, zinc, and E. coli. Eleven segments were delisted for macroinvertberates, copper, dissolved oxygen, manganese, and iron. These changes are detailed below.

In regards to arsenic, it is worth noting arsenic is a national/statewide water quality issue. Arsenic is a naturally occurring, toxic element found in soil, bedrock, and water. Arsenic is colorless and odorless as well as a known carinogen. Arsenic is regulated at the federal level under mutlitple agencies and 7 different acts, including two associated with the Colorado Department of Public Health and Environment.[ii] In 2013, Colorado implemented a major update to the arsenic water quality standards. Because fish consumption and bioaccumulation in fish is a consideration, Colorado's arsenic standard is extremely low. These standards have led to some interesting and costly regulatory compliance needs in Colorado. At this time there are no feasible treatment processes available to meet current arsenic standards for many stream segments.[iii] Please see the State of Colorado Arsenic Fact Sheet, attached here as Exhibit A, for more information.

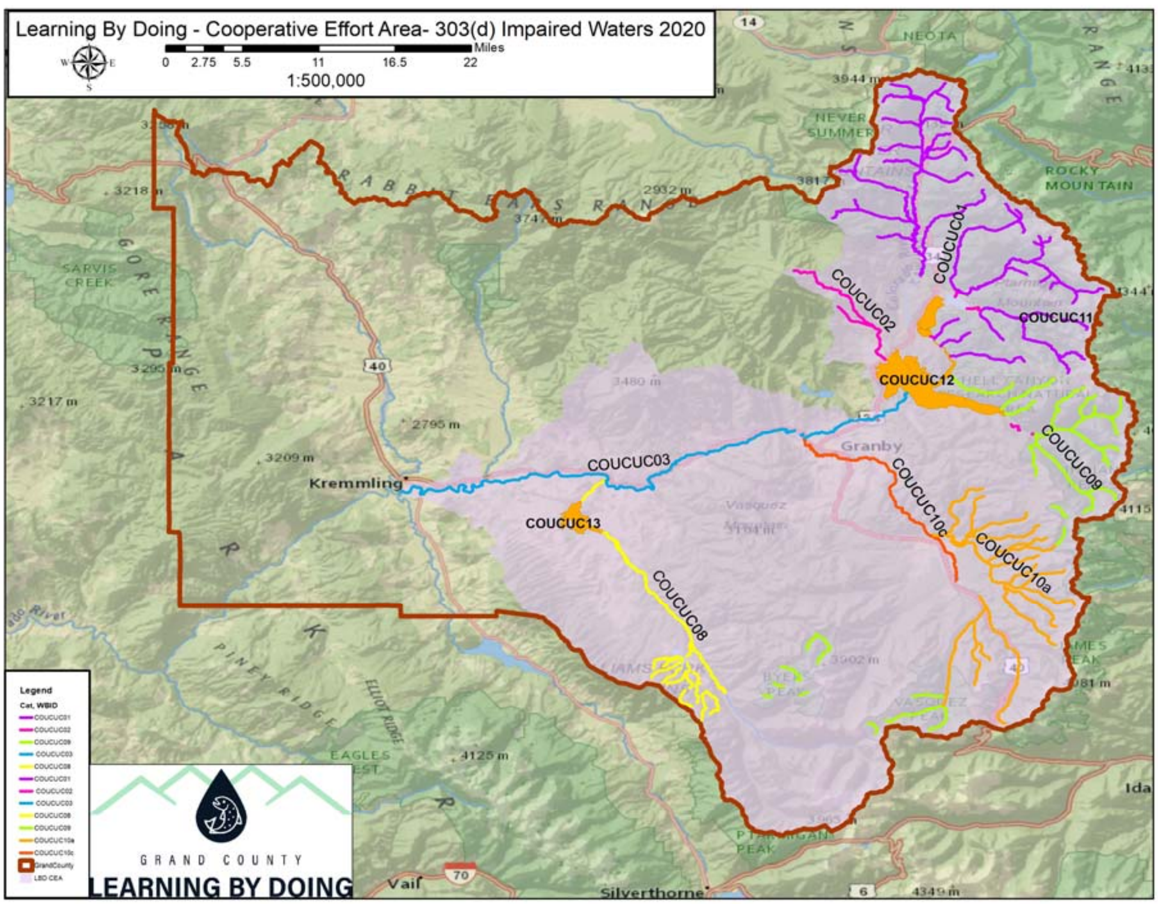

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Figure 1. Grand County Impaired Waters.

Below is a detailed breakdown of the listed segment portions, analytes, and listing classifications:

1. **<u>COUCUC01</u> Mainstem of the Colorado River, including all tributaries and wetlands, within Rocky Mountain National Park, or which flow into Rocky Mountain National Park.**
   - COUCUC01-A: Mainstem of the Colorado River, including all tributaries and wetlands, within or flowing into Rocky Mountain National Park
     Aquatic Life Use – Zinc (Dissolved) – 303(d) * *New listing 2020*

2. **<u>COUCUC02</u> Mainstem of the Colorado River, including all tributaries and wetlands within, or flowing into Arapahoe National Recreation Area.**
   - COUCUC02_B: Willow Creek, Stillwater Creek, and Arapaho Creek
   - COUCUC02_C Colorado River from Shadow Mountain Reservoir to Granby Reservoir

     Aquatic Life Use – Temperature – 303(d)

   - COUCUC02_D: Mainstem of Colorado River from North Inlet to Grand Lake
     Aquatic Life Use – Zinc (Dissolved) – M&E List* *New listing 2020*
     Aquatic Life Use – Silver (Dissolved) – M&E List* *New listing 2020*
     Aquatic Life Use – Copper (Dissolved) – 303(d)

   - COUCUC02_E: Mainstem of East Inlet
     Aquatic Life Use – Zinc (Dissolved) – M&E List* *New listing 2020*
     Aquatic Life Use – Silver (Dissolved) – M&E List* *New listing 2020*
     Aquatic Life Use – Copper (Dissolved) – 303(d) * *New listing 2020*

   - COUCUC02_I: Arapaho Creek downstream of Monarch Lake
     Aquatic Life Use – Silver (Dissolved) – M&E List* *New listing 2020*
     Aquatic Life Use – Temperature – 303(d) * *New listing 2020*

   - COUCUC02_L: Stillwater Creek, including tributaries and wetlands, within or flowing into Arapaho Recreation Area
     Water Supply Use – Arsenic (Total) – 303(d) * *New listing 2020*
     Water Supply Use – Silver (Dissolved) – 303(d) * *New listing 2020*
     Aquatic Life Use – Temperature – 303(d) * *New listing 2020*

3. **<u>COUCUC03</u> - Mainstem of the Colorado River from the outlet of Lake Granby to the confluence with Roaring Fork River.**
   - COUCUC03_A: Colorado River from outlet of Lake Granby to Windy Gap Reservoir

     Water Supply use – Arsenic – M&E List

   - COUCUC03_B: Colorado River from Windy Gap Reservoir to 578 Road Bridge.

     Water Supply use – Arsenic – M&E List

   - COUCUC03_C: Colorado River from 578 Road Bridge to Gore Canyon.

     Water Supply use – Arsenic – M&E List
     Aquatic Life Use – Temperature – 303(d)

4. **<u>COUCUC08</u> - Mainstem of the Williams Fork River, including all tributaries and wetlands from the source to the confluence with the Colorado River, except for those tributaries listed in Segment 9.**
   - COUCUC08_B: Mainstem of Williams Fork River below Kinney Creek.

     Water Supply use – Arsenic – M&E List* *New listing 2020*

5. **<u>COUCUC09</u> – All tributaries to the Colorado and Fraser Rivers, including of all wetlands, within the Never Summer, Indian Peaks, Byers, Vasquez, Eagles Nest and Flat Top Wilderness Areas.**
   - COUCUC09_B: Roaring Fork Arapaho Creek and its tributaries.

     Aquatic Life Use – Macroinvertebrates – 303(d) * *New listing 2020*

6. **<u>COUCUC10a</u> - Mainstem of the Fraser River from the source to a point immediately below the Rendezvous Bridge. All tributaries to the Fraser River, including wetlands, from the source to the confluence with the Colorado River, except for those tributaries included in Segment 9.**
   - COUCUC10a_B: Ranch Creek and its tributaries.

     Aquatic Life Use – Temperature – 303(d)

   - COUCUC10a_D: Vasquez Creek and its tributaries.

     Aquatic Life Use – Macroinvertebrates (provisional) – 303(d)
     Aquatic Life Use – Copper – 303(d)

   - COUCUC10a_E: Mainstem of Fraser River from source to Leland Creek

     Aquatic Life Use – Copper – 303(d) **new listing in 2020.*

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7. **<u>COUCUC10c</u> - Mainstem of the Fraser River from a point immediately below the Hammond Ditch to the confluence with the Colorado River.**
    - COUCUC10c_A: Fraser River from below the Hammond Ditch in Town of Fraser to Fraser Canyon near Tabernash.
      Aquatic Life Use – pH – M&E List **new listing in 2020*
      Water Supply Use – Arsenic (total) – 303(d)
    - COUCUC10c_B: Fraser River from Fraser Canyon near Tabernash to the Town of Granby.
      Water Supply Use – Arsenic (total) – 303(d)
    - COUCUC10c_C: From the Town of Granby to confluence with the Colorado River.
      Recreation – E. coli – 303(d) **new listing in 2020*
      Water Supply Use – Arsenic (total) – 303(d)

8. **<u>COUCUC12</u> – Lakes and reservoirs within Arapaho National Recreation Area, including Grand Lake, Shadow Mountain Lake and Lake Granby.**
    - COUCUC12_B: Shadow Mountain Reservoir
      Water Supply Use – Arsenic (total) – 303(d)
    - COUCUC12_C: Lake Granby
      Water Supply Use – Arsenic (total) – 303(d)
    - COUCUC12D: Willow Creek Reservoir
      Water Supply Use – Arsenic (total) – 303(d)

9. **<u>COUCUC13</u> – All lakes and reservoirs tributary to the Colorado River from the boundary of Rocky Mountain National Park and Arapaho National Recreation Area to a point below the confluence of the Roaring Fork River, except for specific listings in Upper Colorado Segments 11 and 12 and the Blue and Eagle Rivers.**
    - COUCUC13_D: Williams Fork Reservoir
      Water Supply Use – Arsenic (total) – M&E List**new listing in 2020*

2020 LBD Monitoring to Support 303(d) Listings

The Listing Methodology sets forth criteria that will be utilized to decide which waters will be included on the Section 303(d) List and the Monitoring and Evaluation List under Regulation #93. The water quality assessment process depends on analysis of sufficient

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reliable data. Generally, only data from the previous five years is assessed.[1] In order for a 303(d) listing there has to be a representative data set, which is defined in the Section 303(d) Listing Methodology 2020 Listing Cycle. The impairments listed in these segments were evaluated against the 2020 Monitoring Summary (Appendix B). This evaluation showed that there is sufficient monitoring being conducted by various entities throughout the CEA. The 4 impaired segments within the CEA were evaluated against known water quality monitoring.

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[i] Colorado Department of Public Health. Water Quality Control Division. Section 303(d) Listing Methodology 2020 Listing Cycle. January 2020.

[ii] Environmental Protection Agency. Arsenic Fact Sheet 2013. https://www.epa.gov/sites/production/files/2014-03/documents/arsenic_factsheet_cdc_2013.pdf

[iii] Rocky Mountain Water – Updates to Colorado's Arsenic Regulations – Dan Delaughter, PE. Pages 12 -15.
https://www.apogeepublications.com/emags/RMW_March2020/

STATE OF COLORADO

John W. Hickenlooper, Governor
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Executive Director and Chief Medical Officer

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Colorado Department of Public Health and Environment

ARSENIC FACT SHEET

What is Arsenic?
Arsenic is a naturally occurring, toxic element that is found in soil, bedrock, and water. It is used in a variety of industrial settings such as making metals, glass, electronic components and wood preserving. High arsenic levels can also be found as a contaminant in certain fertilizers and animal feeding operations. Arsenic is odorless and tasteless.

What are arsenic's health effects?
Arsenic is a known human carcinogen that causes skin, lung, liver, bladder and kidney cancer if given low doses over a long period of time. It can also cause skin lesions and organ failure at high doses.

How is arsenic regulated?
Arsenic levels are set to protect people who are exposed to arsenic by drinking the water and/or eating fish that live in the water (arsenic can accumulate in fish).

Arsenic is regulated at the federal level under multiple agencies and 7 different acts including two associated with the Colorado Department of Public Health and Environment:

Safe Drinking Water Act
Arsenic is regulated under the Safe Drinking Water Act, by the Environmental Protection Agency (EPA). EPA is supposed to set the standard to reflect a level at which no adverse health effects are expected. This is called the maximum contaminant level *goal* (MCLG). The MCLG for arsenic is 0 parts per billion. However, the enforceable level is set as close to the goal as possible, considering cost, benefits, and the ability of public water systems to detect and remove contaminants. EPA set the maximum contaminant *level* at 10 parts per billion, in recognition that while the goal is 0, the treatment difficulties make zero unattainable . This maximum contaminant level has been required since 2006. (It used to be 50 ppb before that).

Clean Water Act
The federal Clean Water Act (CWA) establishes the basic structure for regulating discharges of pollutants into the waters of the United States. The CWA defines a list of priority pollutants for which EPA must establish water-quality criteria for the protection of aquatic life and human health in surface water. The initial list of priority pollutants was based on a 1977 consent decree that settled a legal challenge to EPA's program for controlling hazardous pollutants.

EPA established human health criteria for arsenic for two cases – one: where exposure is through drinking water (DW); the other, where exposure is through drinking water and eating fish that bioaccumulate arsenic (water + fish). EPA's criteria are calculated based on the cancer slope factor (derived through toxicological studies), an assumed water intake of 2 liters per day, 70-years of exposure and an acceptable cancer risk of 1 in 1,000,000. Calculation of the water + fish criterion also incorporates factors that account for the degree of bioaccumulation that can be expected for arsenic and the portion of arsenic that is actually toxic (for arsenic, the inorganic portion is the toxic, which is about 30% of the arsenic in fish flesh) with a 17.5 grams/ day intake level. There is no accommodation in the CWA system for relaxation of the criteria based on treatment difficulties. Colorado's W+F criterion is 0.02 ug/L.

The CWA directs states to develop water quality criteria at least as stringent as EPA's guidelines. Many states are currently struggling with setting appropriate and protective arsenic standards. Colorado's procedures are very similar to the national model except that we have a third use category. This category is 'fish ingestion" (or FI), which protects human health where the exposure is only through eating fish. The FI criterion uses the same fish factors as the W+F calculation. Colorado's FI criterion is 7.6 ug/L.

CWA criteria are met with state water quality standards and effluent limitations for specific industrial sources.