

# Periphyton and Water Quality Sampling Report

## *Blue River Integrated Water Management Plan – Phase 3*



Submitted to:



Submitted by:



## TABLE OF CONTENTS

Section 1 – Executive Summary .....	<b>Error! Bookmark not defined.</b>
Section 2 – Project Background .....	<b>Error! Bookmark not defined.</b>
2.1 Periphyton .....	3
2.2 Water Quality .....	4
Section 3 – Sampling Summary .....	<b>Error! Bookmark not defined.</b>
Section 4 – Methods .....	<b>Error! Bookmark not defined.</b>
4.1 Periphyton .....	7
4.2 Water Quality .....	7
Section 5 – Results .....	<b>Error! Bookmark not defined.</b>
5.1 Periphyton .....	11
5.2 Water Quality .....	16
Section 6 – Discussion .....	<b>Error! Bookmark not defined.</b>
Section 7 – Literature Cited .....	<b>Error! Bookmark not defined.</b>

## LIST OF FIGURES

Figure 1. Blue River IWMP Sampling Location .....	6
Figure 2. 2021 Water Quality Sample Results.....	8
Figure 3. Onset Software U24 Mounting Instructions.....	10
Figure 4. Benthic Algae Standing Crop at Select IWMP Sites.....	11
Figure 5. Mean Concentration of Chlorophyll <i>a</i> (chl- <i>a</i> ) at Each IWMP Sample Location.....	13
Figure 6. ALL IWMP Sample Sites Enumerating Chl- <i>a</i> Concentrations for 2020-22 Seasonal Sampling Event.....	14
Figure 7. Mean Concentration of Chlorophyll- <i>a</i> at ALL IWMP Sample Sites for Fall Sampling Seasons.....	15
Figure 8. Compares Mean Chlorophyll- <i>a</i> Concentration from 2012, 2016, 2020, 2021, 2022.....	16
Figure 9. Blue River Periphyton MMI Values Compared to Regional Reference Sites.....	16
Figure 10. Measured Conductivity Values.....	18
Figure 11. A Comparison of Blue River Conductance Measured with a YSI Probe Versus a Laboratory.....	19
Figure 12. A Box and Whisker Plot of Mean Conductivity Values for Each Monthly Sample.....	19
Figure 13. Dissolved Concentrations of Magnesium, Sodium, and Chloride from Monthly Surface Water Samples.....	20
Figure 14. Onset U24 Datalogger Readings from the Blue River above French Gulch (BRaF).....	21
Figure 15. Onset U24 Datalogger Readings from the Upper Blue River (UBR).....	21
Figure 16. Onset U24 Datalogger Readings from the Mainstem 1.....	22
Figure 17. Onset U24 Datalogger Readings from Straight Creek.....	22
Figure 18. Onset U24 Datalogger Readings from Mainstem 2.....	23
Figure 19. Onset U24 Datalogger Readings from Mainstem 3.....	23
Figure 20. Straight Creek Conductivity Values Correlating Chronic Chloride Thresholds.....	24
Figure 21. Straight Creek Conductivity Values Correlating Chronic Chloride Thresholds.....	25

## LIST OF TABLES

Table 1. 2021 Stormwater Sample Results.....	8
Table 2. Phase 3 – Water Quality Instrument Locations.....	9
Table 3. ACZ Labs – Road Deicer Analytical Summary.....	10
Table 4. Mean concentrations on Chl- <i>a</i> at IWMP Sample Site.....	13
Table 5. Seasonal Periphyton MMI Results for Samples Collected from 2020-22.....	15
Table 6. Recorded YSI readings at Each Water Quality Sample Location.....	17
Table 7. A Summary of ACZ Laboratory Data from Monthly Surface Water Samples.....	18

## SECTION 1 – EXECUTIVE SUMMARY

In coordination with the Blue River Integrated Water Management Plan (BRIWMP or IWMP, hereafter) managed by the Blue River Watershed Group (BRWG), Trout Unlimited (TU) completed seasonal benthic algae biomonitoring at nine monitoring sites along the main stem of the Blue River. TU's biomonitoring targeted the Upper and Middle Blue River, reaches upstream and downstream of Dillon Reservoir. The IWMP refers to the Blue River above Dillon Reservoir as the Upper Reach and the Blue River below Dillon Reservoir as the Middle Reach. There are two IWMP monitoring sites in the Upper Blue: one immediately upstream of Swan Mountain Road and the other upstream of the Blue River's confluence with French Gulch. The remaining eight sites span roughly 14 miles of the 17-mile reach of the Middle Blue. Due to the Blue River's lack of winter surface water flow, TU omitted this sample site from the periphyton investigation as it was dry during the spring 2022 sampling event.

A decadal decline of the Blue River fishery led to its Gold Medal delisting in 2016. This action would precipitate a multi-year effort from a group of stakeholders to identify a suite of sampling and watershed-scale inventories for the Blue River to determine the root causes of this decline. Stakeholders identified several key concerns, but the suggested decline in soluble nutrients and how that may affect the ecological function of the Blue River became a central theme. In addition to nutrients and food-web dynamics, quantifying impairment of stream habitat was a primary objective of the Blue River IWMP.

To establish a baseline understanding of the aquatic food web, TU would undertake biomonitoring aspects of the IWMP, to assist in periphyton field sampling. Periphyton or benthic algae can be an indicator of nutrient deficiencies in riverine habitats (Kumar and Sing, 1979), and can therefore be a surrogate to a comprehensive water quality study. The Summit Water Quality Committee (SWQC) initially supported studying benthic algae for a fall 2020 periphyton sampling event at nine study sites. TU continued the periphyton through the 2021 and 2022 field seasons to support ongoing aspects of the Blue River IWMP. Benthic algae samples quantify primary production by investigating periphyton community assemblage and biomass metrics in the 'standing crop' of periphyton. The standing crop refers to colonized benthic algae communities clinging to stream substrate. This report summarizes the results from the 2020, 2021, and 2022 benthic algae field studies.

In addition to benthic algae, TU set out to identify potential water quality impacts that stem from road deicers applied to highways adjacent to the Blue River and its tributaries. Analytical data from grab samples collected during 2021 spring snowmelt events indicate elevated concentrations of major ions. From the parameters analyzed in 2021, sodium ( $\text{Na}^+$ ) and chloride ( $\text{Cl}^-$ ) were measured at the highest concentrations across all sample events at each location. While the grab samples were collected at or near stormwater outfalls, concentrations of sodium exceeded state drinking water standards, and chloride exceeded EPA chronic and acute surface water standards and the EPA aquatic life standard. Because of the elevated levels of these analytes, TU referenced grab sample results with long-term datasets for Straight Creek to verify that observed sodium and chloride concentrations were not random events. According to a Colorado Department of Transportation (CDOT) dataset for Straight Creek from 2000-2019, elevated chloride and dissolved chloride concentrations in nearly all dataset years, with acute exceedances in 2018 and 2019 (CDOT, 2019).

## SECTION 2 – PROJECT BACKGROUND

### 2.1 PERIPHYTON

Periphyton, a complex assemblage of algae, bacteria, and other microorganisms that adhere to submerged surfaces in aquatic ecosystems, exhibit distinct responses to variations in . Cold water temperatures significantly influence periphyton's growth, composition, and metabolic activities, shaping its dynamics in freshwater environments. Studies like Dodds and Welch (2000) have indicated that lower temperatures can lead to reduced metabolic rates and slower periphyton growth in stream ecosystems.

Cold water may impose limitations on the metabolic activities of periphytic organisms, but it can also benefit their community structure. Stevenson et al. (2013) demonstrated that cooler temperatures can suppress the dominance of certain species within periphyton communities, fostering a more diverse assemblage. However, extreme cold conditions can pose challenges, inducing physiological stress in periphyton and affecting their overall performance, including photosynthetic efficiency. The impact of water temperature on periphyton is nuanced, with cold temperatures influencing both the positive and negative aspects of periphyton dynamics. Understanding these responses is crucial for implementing effective conservation and management strategies in freshwater ecosystems.

In addition to temperature, flow dynamics play a pivotal role in shaping periphyton communities in aquatic ecosystems. Water movement influences nutrient availability, substrate stability, and the transport of organisms within the Blue River. Scouring flows can dislodge periphyton from surfaces, limiting their establishment and growth, and channel-forming flows can displace periphyton community structure for a growing season. Conversely, slower flows may facilitate the colonization and development of periphyton communities (Corsi et al., 2009). A study by Biggs and Kilroy (2000) demonstrated that variations in flow regimes significantly impact periphyton biomass and community composition in rivers, highlighting the intricate interplay between hydrodynamics and periphyton dynamics. In streams, for instance, increased flow rates may enhance nutrient delivery to periphyton, promoting their productivity. Conversely, reduced flow can limit nutrient availability, potentially leading to nutrient-limited conditions for periphytic organisms (Kumar and Singh, 1979).

## 2.2 WATER QUALITY

The introduction of sodium and chloride from road deicers into freshwater environments has been a subject of scientific investigation, shedding light on the intricate impacts of these elements on lotic ecosystems. A study by Kaushal et al. (2005) investigated the effects of road salt (sodium chloride) on urban freshwater streams, revealing that elevated chloride concentrations were associated with reduced diversity and abundance of aquatic macroinvertebrates. The disruption of osmoregulation in these organisms due to increased salinity levels led to adverse physiological effects, emphasizing the sensitivity of macroinvertebrate communities to road deicer inputs.

The impacts of sodium and chloride on periphyton communities in lotic environments have also been explored in scientific research. Corsi et al. (2010) conducted a study on the effects of road salt runoff on periphyton dynamics in urban streams. The research highlighted that elevated chloride levels were linked to changes in periphyton composition and a reduction in overall biomass. The study provided insights into the specific mechanisms through which road deicers can influence the growth and structure of periphyton communities, with implications for the broader ecological health of freshwater ecosystems.

The scientific evidence suggests that the salinization of water bodies due to road-deicer runoff has pervasive effects on sensitive aquatic organism (Clements and Kotalik, 2016). Moreover, this article points out in the opening statement that, “salinization of streams and rivers is considered one of the most important threats to the ecological integrity of freshwater ecosystems and is recognized as a stressor of concern”. It is important to note that Clements and Kotalik (2016) considered various land use practices leading to salinization of freshwater environments, which included road salts. Increased sodium and chloride concentrations can alter the physical and chemical characteristics of the aquatic environment, influencing the behavior and physiology of aquatic organisms. These studies underscore the importance of considering the long-term ecological consequences of road deicer use and the necessity of adopting sustainable practices to minimize the impact on freshwater environments.

In addition to sodium chloride, the use of magnesium chloride as a road deicer has gained attention for its potential environmental impacts. Magnesium chloride, like sodium chloride, is water-soluble and can be mobilized into freshwater systems during snowmelt and precipitation events. The environmental fate and impact of magnesium chloride have been investigated in studies such as those by Corsi et al. (2010) and Brown and Sturdy (2012). These studies have demonstrated that magnesium chloride runoff can contribute to the salinization of freshwater environments, affecting both macroinvertebrate communities and periphyton.

Magnesium, a component of magnesium chloride, is an essential element for various biological processes, but with the volumes used for various road management practices in the Rocky Mountain West, concerns about potential impacts to riverine ecosystems is growing. However, unlike sodium and chloride, magnesium is subject to complex interactions in the environment, including sorption to soil particles and uptake by vegetation. The fate and transport of magnesium in aquatic ecosystems are influenced by factors such as pH, organic matter content, and the mineral composition of the surrounding environment (Kronvang et al., 1992).

The increase in automobile traffic on roadways is a likely impetus to an exponential increase in road deicer application. This claim is speculative and the annual changes in deicer application rates along segments of I-70 are not readily available to the public. However, according to CDOT traffic counts at the Eisenhower Tunnel, the annual number of vehicles in 1973 (records began) was 2,431,704, compared to the 2019 annual count of 13,114,913 vehicles. Presumably, the topical application of road salts has seen a steady increase over the last two decades to meet the travel demands on Interstate 70. The primary constituents of concern in common road deicing agents are sodium, chloride, and magnesium, but it is not uncommon for deicing agents to include other major ions and heavy metals that can also present hazards to environmental receptors.

It should also be noted that CDOT utilizes liquid anti-icing and deicing agents for roadway management; anti-icing agents are typically applied prior to a storm and deicing agents are applied during and after winter storms. Publicly available resources on this matter can be found in reports prepared by the Colorado Department of Transportation Research Branch, by Principal Investigator, William M. Lewis.

The intricate relationship between flow dynamics, physiological and chemical stressors, riparian function and channel morphology, allochthonous and autochthonous energy inputs, and a litany of other variables can impact periphyton communities, each with the capacity to alter food-web dynamics of freshwater ecosystems. Due to the complexity of potential stressors in the Blue River Watershed, this sampling summary intends to present data and weigh certain variables to establish a biological baseline to indicate ecological function of the Blue River.

### SECTION 3 – SAMPLING SUMMARY

TU adopted sampling methods proposed by Blue Valley Ranch (BVR) and in accordance with the Blue River Nutrient Remediation Project. This step would allow for more comparisons between the three Blue River Reaches identified in the IWMP. Regardless of the long-term fate of the BVR nutrient injections study plan, the data collected by BVR since 2019 provide valuable background information, and BVR's contribution to TU's field sampling events was valuable. BVR contributed time and resources to the periphyton study, which resulted in cohesive methods deployed throughout this study.

Periphyton field sampling utilized the same methods from fall 2020 through fall 2022 and across all sample season. Sampling targeted the standing crop of benthic algae by scraping the exposed margins of stream substrate, delineating surface area using foil, and quantifying mass per unit area with imaging software. Based on the 2021 dataset, TU elected to omit the summer sample as a subset for the 2022: variable summer flow rates present challenges for replicating annual collection parameters. Moreover, algal species are relatively short-lived organisms, and TU believes a Spring and Fall periphyton sampling event represents

the annual standing crop of benthic algae. Genus-level algal taxonomy was completed for all sample years, which allowed for a comparison to the regional diatom MMI being developed by USGS and the Colorado Water Quality Control Division (WQCD).

Ultimately, benthic algae samples will identify differences and similarities between the two Blue River reaches that can be used to inform future management decisions. Data collation in conjunction with the BVR nutrient study will provide quantified data for whether nutrient enhancement could be useful on the Middle Blue (Reach 2) and, if so, whether it would be an effective management tool for restoring ecological function. This periphyton sampling was also intended to serve as continued foundational data to be used in determining root causes for the decline of Blue River's ecological function. TU encourages data overlap and collaboration with BVR and the SWQC to further strengthen an understanding of the potential impacts of water quality and water quantity.

### SECTION 4 – METHODS

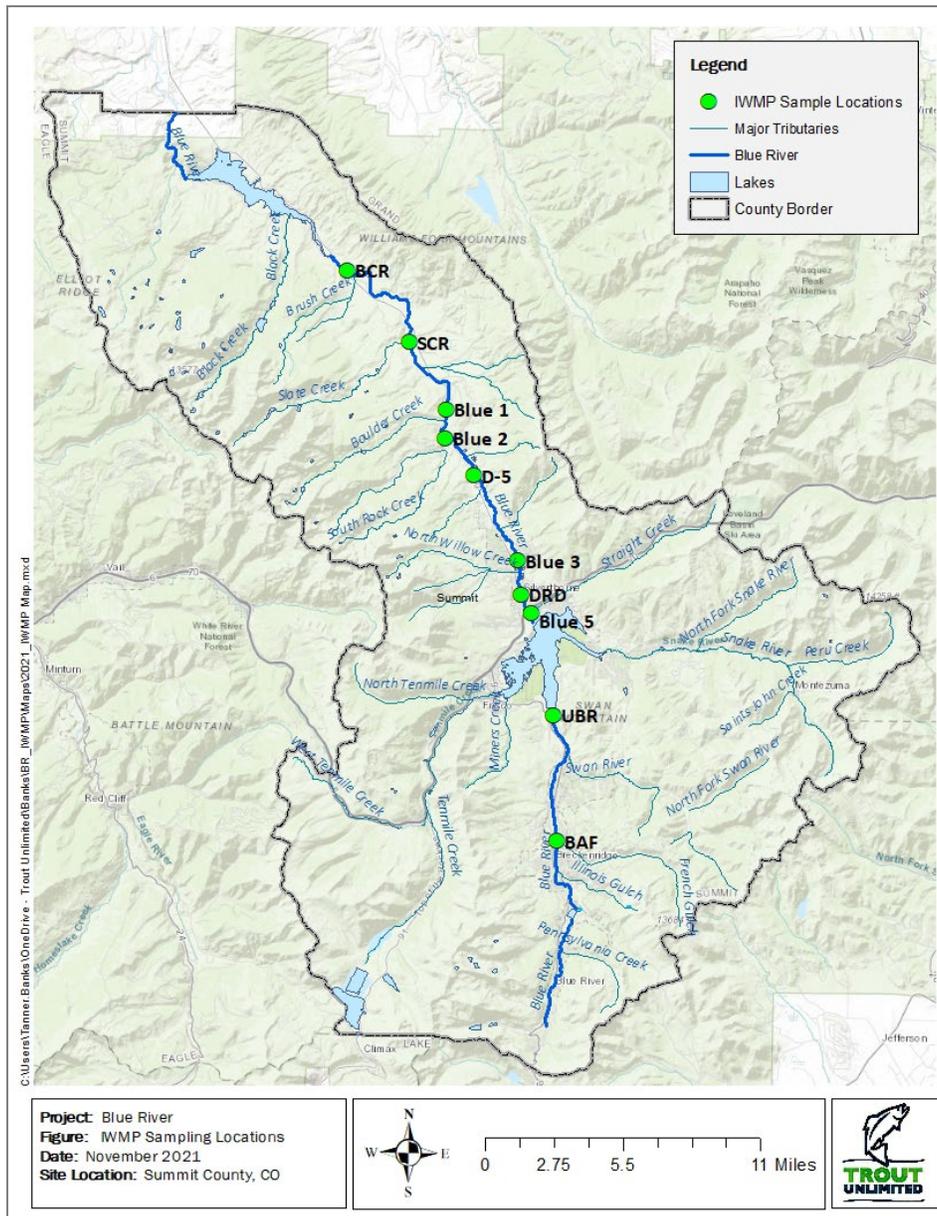


FIGURE 1. BLUE RIVER IWMP SAMPLE LOCATIONS. \*Blue River above French Gulch (BAF) was not a benthic algae sample site due to infrequent winter/spring surface flow

#### 4.1 PERIPHYTON

At each Site, a total of eight small to large cobbles with an estimated range of 60 - 180 mm are collected from a single riffle/run segment. Each specimen is collected from a targeted depth of less than 1-foot downstream to upstream orientation until four substrate samples are collected. Sub-sample rocks are placed in a site-specific bin to ensure transect specimens are not mixed during later stages of sample collections.

Based on the low number of replicates per Site, top rock scrapes from a relatively uniform depth decrease some variability of exposure to increased flows and seasonal scour. This method promotes particle collections in a downstream to upstream orientation in riffle habitat where flows are relatively consistent throughout the year. Selected riffle segments remain in the wetted perimeter year-round and account for baseflow operations of Dillon Reservoir.

Once all top rock samples are collected, TU and BVR staff expanded a streamside sampling station with various smaller bins, rinse bottles, and scrub brushes. The top margin of the rock is then scraped and delineated to decipher the scraped surface area. The standing crop is collected over a small plastic tub, and the standing crop margin is scraped and brushed to dislodge benthic algae and organic matter. Algae-laden water is then funneled into a 16-ounce/500 mL lab-quality polypropylene Nalgene bottle and labeled for lab analysis. Following the scrapes, aluminum foil was placed over the top of each rock and cut to fit the total area scraped; the foil is used to determine the surface area to quantify the mass per unit area of each subsample. Following the delineation of scraped surface area from the four samples that comprise a transect, instruments are scrubbed and rinsed with river water to reduce pollution of the next set of samples. Foil areas are scanned, and the image is traced on Photoshop to compute the total surface area for each transect. The mass per unit area is based on surface area scraped by the total biomass of benthic algae.

Each sample and respective sub-sample corresponds with a Chain of Custody (CoC) form completed and shipped overnight in a sealed cooler. Coolers contain ice packs placed on the bottom and top of sample bottles to keep specimens cool; the internal target temperature of the cooler is 43°F. The benthic algae samples are then sent to EnviroScience, Inc., a biological lab based in Stow, Ohio, since 1989. EnviroScience was chosen to process algae samples due to affordability and willingness to provide expertise to the project. EnviroScience processes samples and preserves each composite sample on the receipt date.

For 2020 through 2022, lab analysis focused on three main parameters: Chlorophyll *a* (Chl-*a*), Ash free dry weight (AFDW), and genus-level algal taxonomy. The concentration of Chl-*a* is the measure of pigment-producing plant matter, identified using spectrophotometry. AFDW is a general quantification of the total organic mass using oxidation methods for the total organic mass of a sample; AFDW does not differentiate the type of organics (Steinman et al. 2006). The advantage of a pigment analysis compared to AFDW is its ability to differentiate algal biomass from organics such as detritus or fungi (Steinman et al. 2006). Genus-level taxonomy was accomplished by identifying major algae groups (i.e., diatoms, green algae, blue-green algae, and cryophytes) from each IWMP monitoring site.

#### 4.2 WATER QUALITY

Data from grab samples collected during 2021 spring snowmelt events indicate elevated concentrations of major ions. From the parameters analyzed, sodium and chloride were measured at the highest concentrations at each sample location across all sample events. While the grab samples were collected at or near stormwater outfalls, concentrations of sodium exceeded state drinking water standards, and chloride exceeded EPA chronic and acute surface water standards and the EPA aquatic life standard. TU referenced the 2021 grab samples with long-term datasets for Straight Creek to verify that observed sodium and chloride concentrations were not random events. The Colorado Department of Transportation (CDOT 2019) annual report presented Straight Creek data from 2000-2019, indicating elevated chloride and dissolved chloride concentrations in nearly all dataset years, with acute exceedances in 2018 and 2019.

Based on publicly available data from various local and regional sources, TU set out to measure select water quality parameters to initiate targeted data on the issue regarding the Blue River. The sampling and analysis of common constituents found in road deicers is highly controversial given the intersection between human and environmental health concerns. The fact that Colorado's WQCD has not established surface water standards for sodium and chloride presents additional challenges for interpretation of the data. Moreover, chemical insult of sodium and chloride to wetland and riverine habitat that derive from current roadway management practices are not currently enforceable. The intention of this study was to identify the potential need for a comprehensive long-term study to understand the impacts road-deicers may have on riverine function in the Blue River Watershed.

TABLE 1. GRAB SAMPLES TAKEN FROM VARIOUS TRIBUTARY LOCATIONS THAT HAVE HIGH POTENTIAL STORMWATER INFLUENCE ON THE BLUE RIVER. MEASURED VALUES OF CONDUCTIVITY, TOTAL DISSOLVED SOLIDS (TDS), MAGNESIUM, CHLORIDE, AND SODIUM ARE PRESENTED, WITH AQUATIC LIFE STANDARDS COLORED AND BOLDED (BLUE=CHRONIC AQUATIC LIFE THRESHOLD, RED=ACUTE AQUATIC LIFE THRESHOLD).

Site	Date	Conductivity (uS/cm)	Measured TDS (mg/L)	Measured Value Magnesium (mg/L)	Measured Value Chloride (mg/L)	Measured Value Sodium (mg/L)
TOS - BR1	4/27/2021	362	242	6.1	9.64	6.96
	1/7/2022	265	168	4.81	7.96	5.94
Straight Cr	3/5/2021	4200	2380	49.2	<b>1290</b>	<b>681</b>
	4/27/2021	1110	616	16.5	<b>298</b>	<b>138</b>
	1/7/2022	5040	2850	60.2	<b>1710</b>	<b>825</b>
Salt Lick	3/5/2021	1710	904	17.1	<b>496</b>	<b>257</b>
	4/27/2021	474	300	7.68	122	51.1
	1/7/2022	381	224	7.22	87.9	32.6
13th St	3/5/2021	1920	1050	32.3	<b>569</b>	<b>286</b>
	4/27/2021	95	94	2.46	8.44	7

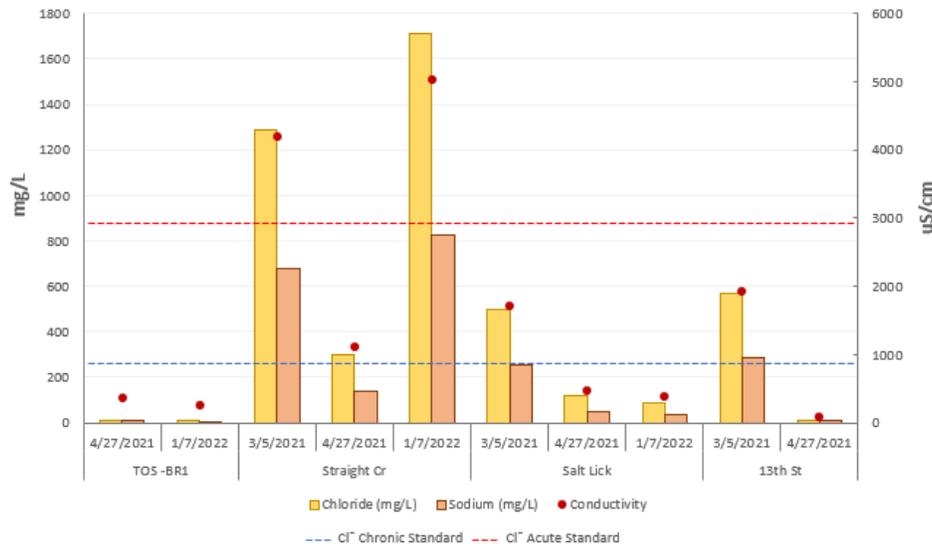


FIGURE 2. ILLUSTRATES WATER QUALITY RESULTS FROM SERIES OF GRAB SAMPLES INTERMITTENTLY COLLECTED FOLLOWING SNOMELT EVENTS DURING THE 2021-22 WINTER SEASON. THE GRAB SAMPLES SERVED AS A GENERALIZED INVESTIGATION TO IDENTIFY WHETHER STORMWATER DISCHARGE TO THE BLUE RIVER HAS POTENTIAL TO AFFECT AQUATIC BIOLOGICAL COMMUNITIES. \*CHRONIC AND ACTURE THRESHOLDS DEPICTED IN FIGURE 2 DENOTE AQUATIC LIFE STANDARDS; COLORADO DOES NOT HAVE A ESTABLISHED SURFACE WATER THRESHOLDS FOR SODIUM OR CHLORIDE.

TU elected the *Onset HOBO U24 Freshwater Conductivity/Temperature Datalogger* to monitor surface water conductivity through the 2022 winter season. Data loggers were deployed on February 17, 2022.

Each instrument was programmed to record conductivity and temperature at 15-minute intervals at six stormwater monitoring sites (Table 3). The Straight Creek logger resides upstream of the creek's confluence with the Blue River and will identify additional loading from the CDOT datalogger at Laskey Gulch (upstream of Dillon Valley). Three mainstem loggers will be deployed in the Blue River below Dillon Reservoir, two bracketing Straight Creek and the third downstream of 13<sup>th</sup> Street in the Town of Silverthorne to capture inputs from various outfalls.

Onset U24 Conductivity loggers were deployed using Onset's recommended Calibration Method 1 in the manufacturer's user manual. Method 1 calibration includes taking readings directly in water at the site where each instrument was deployed. A portable YSI Professional Series Pro30 Conductivity Probe was used at the time of instrument deployment to acquire three consecutive readings from the U24 logger while monitoring the YSI readings to compare and stabilize the data readings. The values from both the YSI and U24 instruments are recorded and later referenced in data analysis phases. The YSI probe is calibrated prior to field use by cleaning and drying the sensor, followed by immersion into lab-grade calibration solution and a pH 7.0 buffer solution (YSI ProDSS Calibration Guide).

During the deployment 2022 deployment dates, monthly surface water samples were collected to provide a secondary reference for instrument readings. Water quality samples were entirely focused on common chemical constituents found in road deicers. For this ongoing water quality pilot study, ACZ Labs was contracted to complete lab analyses according to parameters in Table 2. TU elected to reduce the total number of analytes to be analyzed in each sample to reduce sampling costs, which would allow for more frequent collection of water quality samples. Water quality samples were obtained using best management field practices and samples were shipped overnight from Silverthorne, CO to Steamboat Springs, CO. Appended Chain of Custody forms were completed for each water quality sampling event.

TABLE 2. PHASE 3 – WATER QUALITY INSTRUMENT LOCATIONS

<i>U24 Onset Datalogger Locations</i>		
<b>Site Name</b>	<b>GPS Coordinates</b>	<b>Notes</b>
Blue at French Gulch (BAF)	39.49329, -106.04605	Optional - Flow Upstream Seasonally Intermittent
Upper Blue River (UBR)	39.56693, -106.04959	Downstream of UBR/Swan Mtn Rd
Mainstem 1 (MNST 1)	39.62545, -106.06653	Upstream of Blue 5
Straight Creek @ Outlets	39.62768, -106.06656	Downstream of Stevens Way Bridge
Mainstem 2 (MNST 2)	39.62630, -106.07037	Upstream of I-70 Bridge/Influence
Mainstem 3 (MNST 3)	39.56693, -106.04959	Downstream of 13th Street Outfall

TU initiated this study based on measured exceedances of sodium (Na<sup>+</sup>) and chloride (Cl<sup>-</sup>) from the 2021-22 grab samples collected downstream of major stormwater inputs that stem from the Town of Dillon or Town of Town of Silverthorne stormwater infrastructure. TU also referred to recent public-facing documents from the Colorado Department of Transportation (2019), a report that concludes through decade-long field collections, that increasing concentrations of sodium and chloride in Straight Creek are significant enough to qualify concern. Based on these factors, IWMP partners elected to initiate a field study to better quantify the potential impacts to the Blue River.

Study sites (Table 3) were selected based on surface waters known or believed to have the potential to impact the Blue River through the Town of Silverthorne. Additional sites in the Upper Reach (upstream of Dillon Reservoir) were used to reference concentration and conductivity on the Middle Reach. U24 dataloggers were not deployed in Ten Mile Creek or the Swan River due to cost and capacity concerns. Any ongoing water quality studies should include each of these major tributaries.

Of note, surface water samples and presented lab results have an increased Standard error or Standard deviation when the dilution factor increases. The dilution factor simply means the amount (to a factor of 10) the sample needs to be diluted to arrive at an empirical value according to extraction methods outlined in Table 2. For instance, ACZ labs reported that the highest dilution factor for sodium was 2, and for chloride, the dilution factor was 50.

TABLE 3. ACZ LABS – ROAD DEICER ANALYTICAL SUMMARY (T=TOTAL CONCENTRATION, D=DISSOLVED CONCENTRATION)

<i>Water Chemistry Lab Analysis</i>			
Parameter	Method	Detection Limit	
Calcium (t)	M200.7 ICP	0.1 mg/L	
Calcium (d)	M200.7 ICP	0.1 mg/L	
Magnesium (t)	M200.7 ICP	0.1 mg/L	
Magnesium (d)	M200.7 ICP	0.1 mg/L	
Sodium (t)	M200.7 ICP	0.1 mg/L	
Sodium (d)	M200.7 ICP	0.2 mg/L	
<i>Wet Chemistry</i>			
Alkalinity (CaCO3)	SM2320B	2 mg/L	
Chloride	SM4500CI-E	0.5 mg/L	
Conductivity @ 25°C	SM2510B	1 umhos/cm	
Hardness as CaCO3 (total)	SM2340B - Calc	Calculation	
pH	SM4500H+ B	0.1 C	
Residue, Filterable (TDS) @ 180C	SM2540C	20 mg/L	
Sulfate	D516-02/-07/-11 Turbidimetric	1 mg/L	

An additional challenge of the Onset U24 dataloggers is they need to mount upright for the sensor to properly function. The logger must also be housed in a way that reduces impacts to the instrument. TU constructed very similar instrument stilling wells for field instruments, which included a threaded top for monitoring the instrument and a ported 1.5" PVC housing to allow sufficient water infiltration rates.

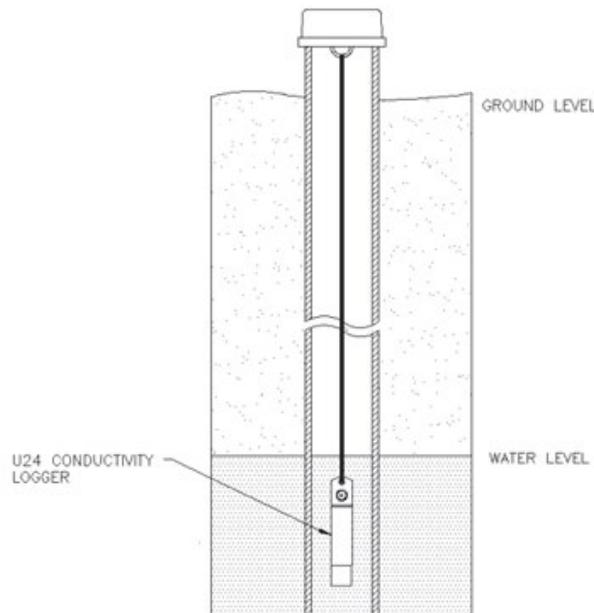


FIGURE 3. ONSET SOFTWARE U24 MOUNTING INSTRUCTIONS (ILLUSTRATION OBTAINED FROM ONSET'S U24 USER'S MANUAL)

## SECTION 5 -- RESULTS

This section describes the results from the multi-year periphyton study, which TU and BRWG intend to continue as part of ongoing steps to understand the ecological function and principal factors that may influence the Blue River. The results from the water quality are also considered ongoing—TU initially set out to understand the impacts of road deicers through the 2022 field season. A comprehensive water quality study at six newly established monitoring sites makes way for time-intensive field collections, instrument maintenance, data management and data interpretation.

TU, in partnership with BRWG and the various IWMP stakeholders strongly support the notion that ongoing standardized data collection of physical, biological, and chemical parameters of the Upper and Middle reaches of the Blue River that assist in management and maintenance of the ecological function of the Blue River. Despite the numerous anthropogenic influences that may impact long-term ecological function, a multi-year standardized study is strongly recommended. State regulated segments and respective assessments should be undertaken by the Colorado Department of Public Health and the Environment.

### 5.1 PERIPHYTON

Periphyton biomass is closely linked to the overall productivity of aquatic systems, influencing the availability of nutrients and energy for higher trophic levels. Stevenson et al. (2013), demonstrated the importance of periphyton as a primary food source, supporting invertebrates and small fish and forming the foundation of the aquatic food web. Additionally, periphyton contributes to the structural complexity of habitats, providing essential refuge and breeding sites for various aquatic organisms.

Periphyton (benthic algae) is a complex assemblage of algae, bacteria, and other microorganisms adhering to submerged surfaces in aquatic ecosystems, and often exhibits distinct responses to variations to physical conditions. For example, cold water temperatures can significantly influence the growth, composition, and metabolic activities of periphyton, shaping its dynamics in freshwater environments. Studies, such as Dodds and Welch (2000), have indicated that lower temperatures can lead to reduced metabolic rates and slower growth of periphyton in stream ecosystems.

Moreover, flow patterns influence nutrient availability for periphyton. Changes in water velocity can alter nutrient concentrations, affecting the nutrient fluxes that sustain periphytic growth. In streams, for instance, increased flow rates may enhance nutrient delivery to periphyton, promoting their productivity. Conversely, reduced flow can limit nutrient availability, potentially leading to nutrient-limited conditions for periphytic organisms. Francoeur et al. (2015) described the importance of considering flow-mediated nutrient dynamics to assess periphyton communities' responses to changes in biotic and abiotic conditions.



FIGURES 4, A—D. BENTHIC ALGAE STANDING CROP AT IWMP SITES UPPER BLUE RIVER (UBR), BLUE 5 (BELOW DILLON RESERVOIR), SLATE CREEK RANCH (SCR), AND BELOW BRUSH CREEK (BCR) TAKEN DURING THE 2022 FALL SAMPLING EVENT. THE PHOTOS ILLUSTRATE DIFFERENCES IN THE ABUNDANCE OF THE STANDING CROP BETWEEN SITES AND FROM PARTICLE TO PARTICLE.

TABLE 4. MEAN CONCENTRATIONS ON CHL-A AT EACH IWMP SAMPLE SITE FOR EACH RESPECTIVE SAMPLE SEASON. CHLOROPHYLL-A CONCENTRATIONS ARE REPORTED AS MILLIGRAMS PER SQUARE METER (MG/M<sup>2</sup>).

Site	Site Notes	Fall 2020		Spring 2021		Summer 2021		Fall 2021		Spring 2022		Fall 2022	
		Chl-a (mg/m <sup>2</sup> )	Mean	Chl-a (mg/m <sup>2</sup> )	Mean	Chl-a (mg/m <sup>2</sup> )	Mean						
UBR	Historic FS Site - Above Swm Mtn Rd	6.792	9.146	12.317	8.490	32.337	28.113	8.497	5.272	19.491	25.274	9.146	14.522
		11.501		4.663		23.888		2.046		31.057		19.898	
Blue 5	Historic FS Site - Above Straight Cr	109.130	81.766	28.355	38.519	64.047	64.796	63.294	121.681	39.051	25.765	43.924	27.950
		54.403		48.683		65.544		180.068		12.478		11.977	
DRD	Dillon Ranger Station	0.940	1.041	2.437	3.988	5.818	3.644	8.707	5.022	4.074	2.868	1.777	1.397
		1.142		5.539		1.470		1.337		1.662		1.018	
Blue 3	Historic FS Site - Below Willow Cr	1.942	5.583	10.239	15.456	10.901	13.480	6.425	10.652	0.840	5.283	0.835	3.545
		9.225		20.673		16.059		14.879		9.726		6.254	
D 5	Historic FS Site - Pioneer Cr	8.801	33.989	101.061	88.772	8.019	6.860	49.426	69.611	13.108	11.471	7.950	7.429
		59.177		76.483		5.700		89.795		9.834		6.907	
Blue 2	Historic FS Site - Campground	43.662	29.029	27.375	39.542	10.059	8.602	48.113	45.304	24.054	17.038	10.481	10.548
		14.397		51.708		7.145		42.495		10.021		10.615	
Blue 1	Historic FS Site - Below Boulder Cr	22.260	16.977	40.114	30.309	9.010	7.497	72.139	59.489	12.808	11.906	9.652	7.301
		11.694		20.505		5.983		46.839		11.004		4.951	
SCR	Above Slate Cr	23.400	15.763	17.958	21.322	6.195	8.763	25.555	17.760	12.824	8.546	8.399	4.895
		8.127		24.685		11.332		9.965		4.268		1.391	
BRC	Below Brush Cr	0.653	0.975	5.787	6.284	3.894	2.370	0.425	0.721	10.432	8.861	4.110	3.740
		1.296		6.781		0.846		1.016		7.291		3.369	

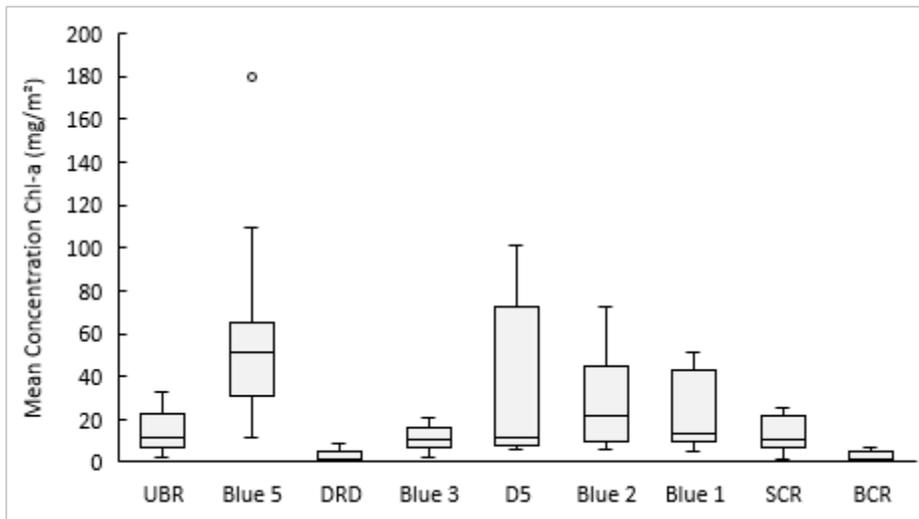


FIGURE 5. ILLUSTRATES THE MEAN CONCENTRATION OF CHLOROPHYLL A (CHL-A) AT EACH IWMP SAMPLE LOCATION ACROSS ALL SAMPLE SEASONS (FALL 2020 THROUGH FALL 2022).

Measuring the mean concentration of chl-a in the benthic algae standing crop (Figure 6), identified a great deal of variability between sites. The figure does not isolate seasons and instead, presents on the mean (central bar of each box plot/site). Chl-a concentrations and variability between sites that form the measured range for each site (box plot surrounding the mean) can be interpreted as the percentage of algae concentrations surrounding the mean (i.e., D5, the mean is 13 mg/m<sup>2</sup>). The maximum and minimum measured values for each site are represented by the whiskers; the outlier at site Blue 5 was isolated for the figure but is weighted in calculation of the mean.

As stated in previous Blue River IWMP benthic algae sampling reports, there are limited relevant studies on periphyton abundance in high elevation streams. And due to the spatial variability of periphyton within the same stream, direct comparison of sites and ‘reference streams’ may be misleading. However, Lewis and McCutchan (2010) explain that benthic algae production in alpine environments is driven more by temperature and length of the growing season than nutrient availability. The 2010 study by Lewis and McCutchan explains that based on their 74-site study, the growing season decreases with increased elevation, which leads to diminishing primary productivity, measured in mg/m<sup>2</sup> of Chlorophyll a. The IWMP monitoring sites range from 9250 feet (2819 m) to 8105 feet (2470 m) in elevation above mean sea level (AMSL). According to the 2010 study, sites with the elevation ranges of the BRWIMP sample sites, mean

Chl-*a* concentrations roughly range from 20 to 100 mg/m<sup>2</sup>. Therefore, comparing Chl-*a* concentrations discovered through IWMP sampling to those presented by Lewis and McCutchan (2010), site UBR, DRD, Blue 3, and BCR may not attain the mean suggested in the case study. However, the data range presented by Lewis and McCutchan (2010) is highly variable, with observed concentrations as low as 4 mg/m<sup>2</sup> and as high as 300 mg/m<sup>2</sup>.

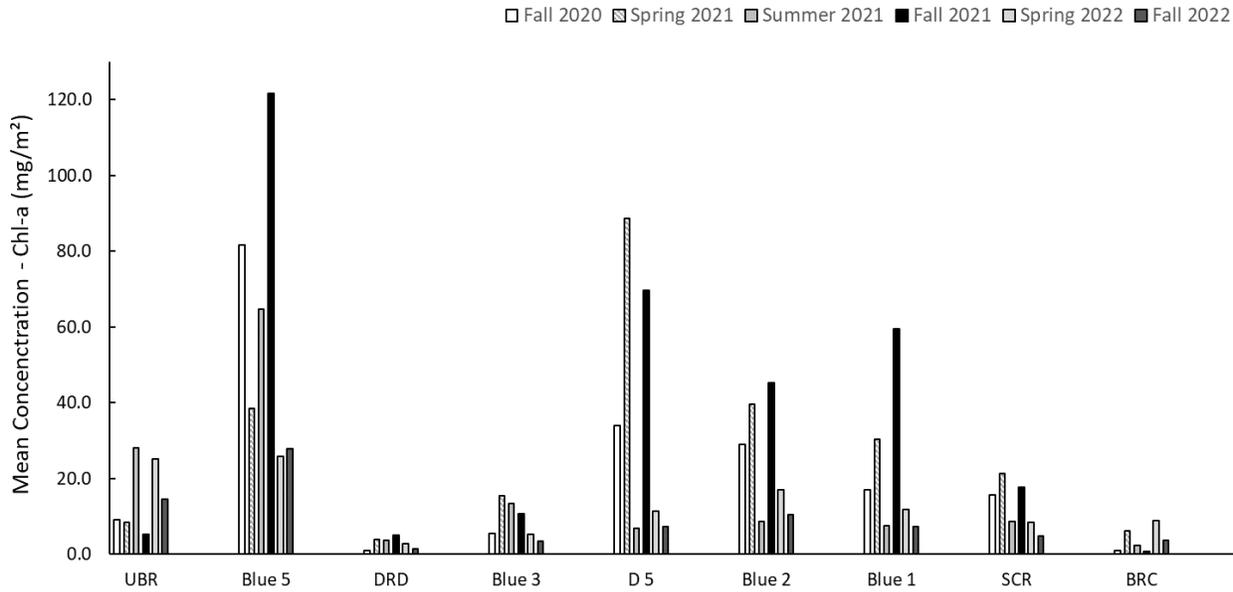


FIGURE 6. REPRESENTS THE SAME VALUES PRESENTED IN FIGURE 2 (MEAN CONCENTRATION CHLOROPHYLL A (CHL-A)) AT ALL IWMP SAMPLE SITES AND ENUMERATING CHL-A CONCENTRATIONS THROUGH EACH SEASONAL SAMPLING EVENT.

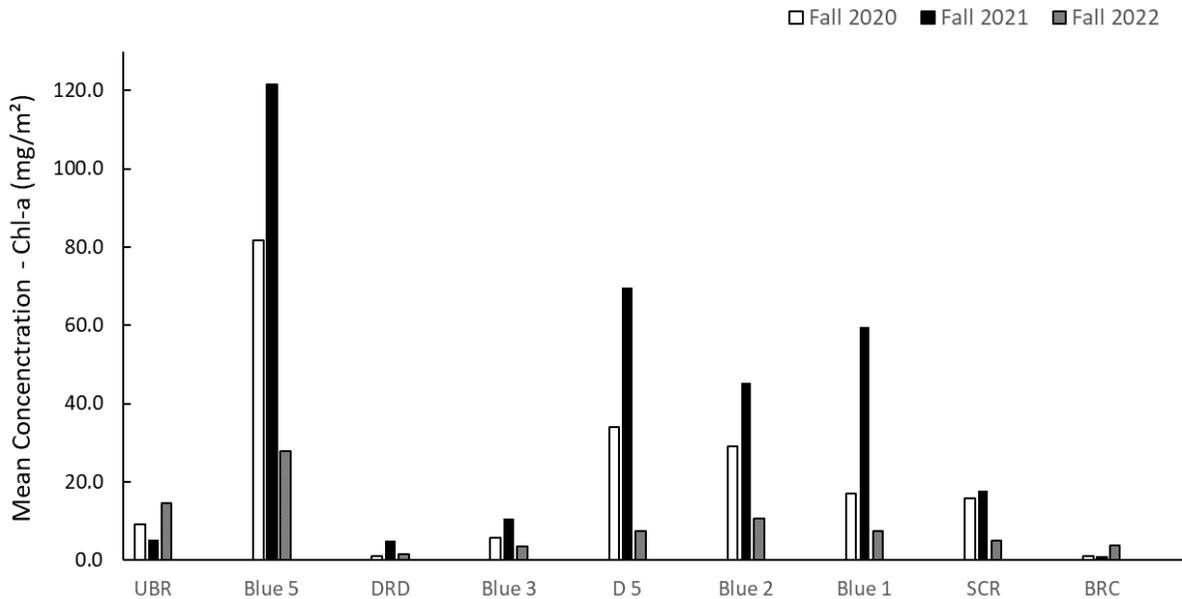


FIGURE 7. MEAN CONCENTRATION OF CHLOROPHYLL-A (CHL-A) AT ALL IWMP SAMPLES SITES FOR ALL FALL SAMPLING SEASONS. COLORADO WQCD RECOGNIZES THE STANDING CROP TO BE MOST REPRESENTATIVE IN FOR THE ROCKY MOUNTAIN REGIONS FROM SEPTEMBER THROUGH OCTOBER.

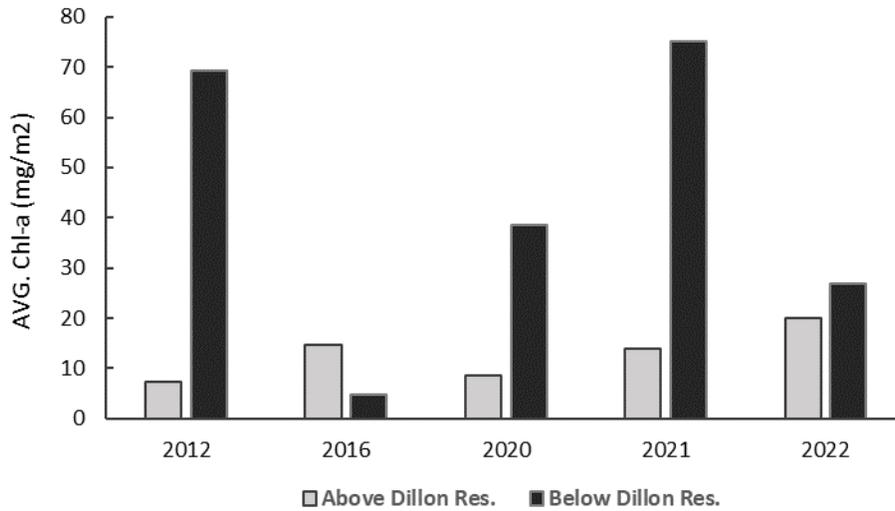


FIGURE 8. COMPARES MEAN CHLOROPHYLL A CONCENTRATION FROM 2012 AND 2016, COLLECTED BY LEWIS AND MCCUTCHAN, AS WELL AS EMPIRICAL DATA COLLECTED BY IN 2020, 2021, 2022.

For the Blue River, flow and temperature regimes are highly altered due to reservoir operations, and increasingly shifting climatic patterns that directly impact reservoir operation. For the Blue River, TU and partners set out to understand community abundance and diversity of the seasonal standing crop of benthic algae. Field samples collected from IWMP monitoring sites were then analyzed by site and season. For 2022, TU worked with EnviroScience to compare Blue River periphyton community abundance to multi-metric indices (MMI) for the Western Ecoregion. Figure 9 depicts how Blue River samples from fall of 2020 through fall of 2022 scored according to this MMI.

TABLE 5. SEASONAL MMI SCORES AS A PERCENTILE FOR PERIPHYTON SAMPLES COLLECTED FROM 2020-22 ACCORDING TO THE IWMP SAMPLE SITE. MMI SCORES WERE COMPUTED ACCORDING TO EVALUATION STANDARDS ESTABLISHED BY USGS AND CARLISLE ET AL. 2022. \*RED VALUES DENOTE A FAILING MMI (≤ THE 56<sup>TH</sup> PERCENTILE; ALL VALUES ABOVE THE 56<sup>TH</sup> PERCENTILE RECEIVE A PASSING MMI SCORE.

IWMP Site	Fall 2020	Fall 2021	Fall 2022
UBR	60.857	56.797	<b>55.155</b>
Blue 5	59.143	67.002	61.924
DRD	59.075	65.088	<b>55.776</b>
Blue 3	61.732	58.700	59.875
D5	66.612	61.732	<b>53.576</b>
Blue 2	<b>55.797</b>	62.554	67.512
Blue 1	64.443	64.027	63.142
SCR	56.278	<b>54.497</b>	63.011
BCR	<b>51.067</b>	58.961	64.002

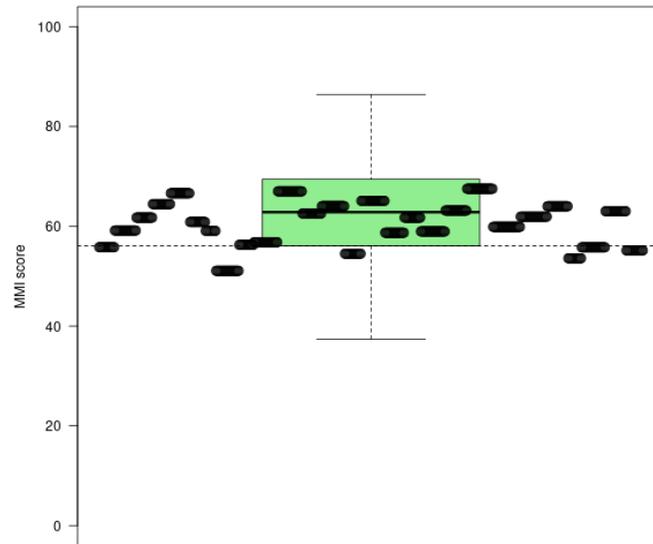


FIGURE 9. MMI VALUES OF REGIONAL REFERENCE SITES ARE DISPLAYED IN THE GREEN BOXPLOT. MMI VALUES OF SITES ARE ALSO SHOWN; NOTE THAT THE POSITION ON THE X-AXIS IS ARBITRARY. MMI VALUES LESS THAN THE 25TH PERCENTILE (HORIZONTAL DASHED LINE, 56) OF THE REFERENCE SITES MAY BE BIOLOGICALLY IMPAIRED. \*THE FIGURE IS A DIRECT OUTPUT FROM THE USGS WEB-BASED TOOL FOR BENTHIC DIATOM ASSEMBLAGES.

The Blue River diatom MMI presented in Figure 9 illustrates that while Blue River periphyton community abundance is not high, samples attain normal-expected MMI scores compared to various high-elevation streams in Western Ecoregions. TU has determined that while Blue 5 (immediately downstream of Dillon Reservoir) consistently supports more biomass in the standing crop, it is likely attributed to consistent annual water temperature, infrequent scour events during high flows, and rapid uptake of nutrients that stem from Dillon Reservoir hypolimnetic releases. Figure 4 illustrates no significant observable differences between primary production spring and fall. Still, there are failing MMI scores (Table 5) at in Fall samples at UBR, DRD, D5, Blue 2, SCR, and BCR.

Species diversity within periphyton communities is a key aspect of their ecological significance. Stevenson et al. (1996) highlighted the importance of considering periphyton community composition, as diverse assemblages contribute to ecosystem resilience and stability. Species diversity of periphyton communities enhances the functional platform of ecosystem services, the biological foundation of lotic ecological function (Biggs and Kilroy, 2000). Understanding the roles of periphyton biomass and species diversity is crucial for comprehensive ecosystem management, a key reason why it was included in the Blue River IWMP and notable because of the decline in the health of the fishery.

## 5.2 WATER QUALITY

Road deicers, including sodium chloride ( $\text{NaCl}^-$ ) and magnesium chloride ( $\text{MgCl}^-$ ), directly impact biological communities in freshwater environments, primarily during snowmelt and precipitation events. Particular events can lead to increased dissolved sodium, magnesium, and chloride concentrations. Local and regional studies identify acute and chronic inputs of each analyte of concern, resulting in a long-term upward trend of dissolved elements in freshwater streams. Data recovered to defend this concern is commonly collected in our region along the I-70 corridor and impacts streams like Clear Creek, Straight Creek, and Gore Creek, but impacts are not limited to these areas.

TABLE 6. RECORDED YSI READINGS FROM EACH WATER QUALITY SAMPLE LOCATION TO VERIFY INSTRUMENT CALIBRATION. READINGS WERE TAKEN IN CONCERT WITH LIVE U24 INSTRUMENT READOUTS (15-SECOND INTERVALS).

<i>Field Calibration Readings</i>						
Parameter	BRaF	UBR	Mainstem 1	Straight Creek	Mainstem 2	Mainstem 3
<b>April 20 - YSI Reading Range (11:24 am - 4:52 pm)</b>						
pH	7.84	8.26	7.25	7.91	7.23	7.86
Conductivity (uS/cm)	200.5	142.7	226.6	757	252.3	274.9
Spec Conduct. (uS/cm)	309.9	205.1	382.8	1068	419.1	440.1
Temp (°C)	6.5	9.1	3.6	9.7	4.2	5.4
<b>May 18 - YSI Reading Range (11:01 am - 12:30 pm)</b>						
pH	<i>YSI Malfunction</i>		7.28	7.44	7.34	7.52
Conductivity (uS/cm)			250.8	155.8	188.1	210.1
Spec Conduct. (uS/cm)			411.2	241.6	299.4	324.7
Temp (°C)			4.6	6.4	5.4	6.5
<b>June 30 - YSI Reading Range (9:30 am - 12:15 pm)</b>						
pH	8.04	7.73	7.29	7.65	7.32	7.55
Conductivity (uS/cm)	114.5	108.1	200.8	168.7	199.7	167.6
Spec Conduct. (uS/cm)	162.7	155.2	327.8	248.7	321.9	262.8
Temp (°C)	9.7	9.1	4.7	8.2	5.2	6.1
<b>July 20 - YSI Reading Range (17:30 am - 10:16 am)</b>						
pH	7.7	7.8	7.2	7.67	7.35	7.76
Conductivity (uS/cm)	132.9	126.2	196.1	139.1	197.4	196.6
Spec Conduct. (uS/cm)	184.3	175.5	316.3	197.4	317.7	309.7
Temp (°C)	10.4	10.3	5.1	9.5	5.2	5.9

The elevated chloride ions in water bodies can adversely affect aquatic organisms (Clements and Kotalik, 2017). The study by Kaushal et al. (2005) emphasized that increased salinity disrupts macroinvertebrate life cycle and community assemblages in response to increased seasonal physiological stressors, which can lead to reduced survival rates and long-term shifts in community composition (Kaushal et al., 2005, Kotalik et al., 2017, Corsi et al., 2010). The adverse effects on these key components of aquatic ecosystems can trigger shifts in community structure, impacting biodiversity and the overall health of lotic environments.

Introducing sodium and chloride from road deicers into freshwater environments has been a subject of scientific investigation, shedding light on the intricate impacts of these elements on lotic ecosystems. A study by Kaushal et al. (2005) investigated the effects of road salt (sodium chloride) on urban freshwater streams, revealing that elevated chloride concentrations were associated with reduced diversity and abundance of aquatic macroinvertebrates. The disruption of osmoregulation in these organisms due to increased salinity levels led to adverse physiological effects, emphasizing the sensitivity of macroinvertebrate communities to road-deicer inputs.

TABLE 7. A SUMMARY OF ACZ LABORATORY DATA FROM MONTHLY SURFACE WATER SAMPLES.

2022 ACZ Labs Surface Water Sample Results											
Site Name	Surface Water Sample Date	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Chloride (mg/L)	Conductivity (umhos/cm)	Alkalinity (CaCO3, mg/L)	Hardness (Total CaCO3, mg/L)	Residue (TDS)	Sulfate (mg/L)	pH
BRaF	20-Apr	37.7	6.23	8.97	8.7	307	50.8	130	190	86.0	8.0
	19-May	22.9	4.1	3.2	5.26	170	55.0	80	110	21.6	8.2
	30-Jun	21.6	4.01	3.01	3.62	161	48.4	70	92	22.6	7.7
	20-Jul	23.6	4.02	3.38	3.02	182	48.5	77	112	34.2	7.5
UBR	20-Apr	24.4	4.82	5.45	11.6	205	61.8	87	116	24.4	8.2
	19-May	20.3	3.63	3.64	7.69	159	50.4	75	104	19.2	8.2
	30-Jun	19.4	3.74	3.59	5.04	153	45.9	64	90	19.4	7.6
	20-Jul	21.3	4.14	4.24	6.66	173	52.0	72	112	20.4	7.6
MNST 1	20-Apr	53.9	6.69	8.11	11.2	408	46.7	174	258	136.0	8.0
	19-May	56.1	6.45	8.40	12.3	404	44.0	175	264	131	8.0
	30-Jun	42.6	5.83	7.2	10.7	322	41.1	133	192	91.5	7.5
	20-Jul	39.8	5.5	7.05	10.6	310	44.0	127	204	83.5	7.3
Straight Creek	20-Apr	44.0	14	125	326	1070	46.5	179	584	14.4	8.0
	19-May	15.5	3.53	22.6	57.1	240	27.8	56	142	5.3	7.9
	30-Jun	17	4.22	20.8	50.3	245	31.9	60	142	6.0	7.4
	20-Jul	21.5	5.54	24.9	70.8	317	38.8	80	196	7.6	7.3
MNST 2	20-Apr	55.6	6.89	10.2	15.5	420	46.8	177	262	135	8.0
	19-May	30.3	4.62	16.5	40.8	305	33.6	101	186	44.5	7.9
	30-Jun	41.4	5.75	7.92	12.1	316	40.5	125	190	87.0	7.5
	20-Jul	38.7	5.38	7.24	11.7	309	41.0	125	202	82.6	7.9
MNST 3	20-Apr	52.8	7.31	21.1	47.0	460	44.4	166	270	108.0	8.0
	19-May	36.1	4.94	13.8	28.8	319	35.1	118	204	70.3	8.0
	30-Jun	37	5.41	9.6	20.2	306	39.6	117	182	73.7	7.9
	20-Jul	35.7	5.44	10.3	22.0	315	36	117	192	66.0	7.1

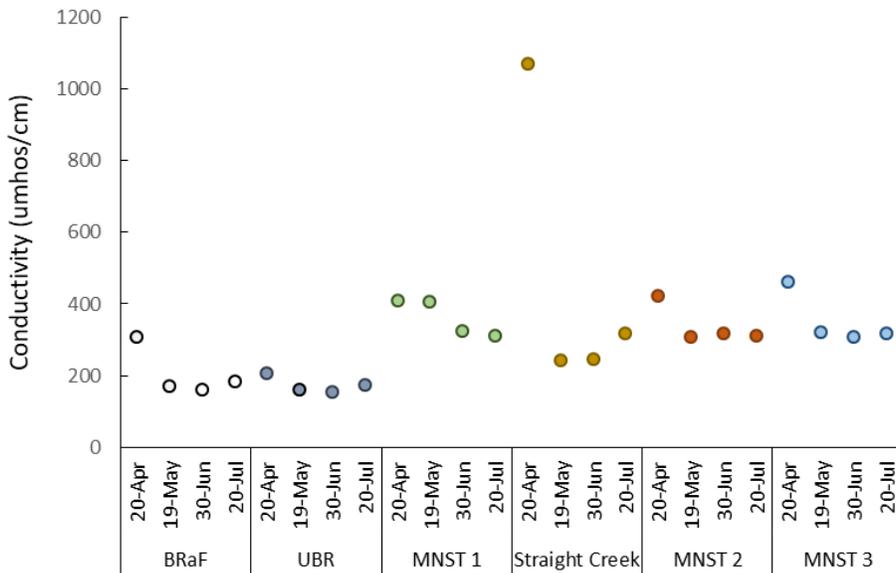


FIGURE 10. MEASURED CONDUCTIVITY VALUES ARE PRESENTED IN TABLE 7, BROKEN DOWN BY SITE AND IN CORRELATION WITH THE MONTHLY SURFACE WATER SAMPLES COLLECTED.

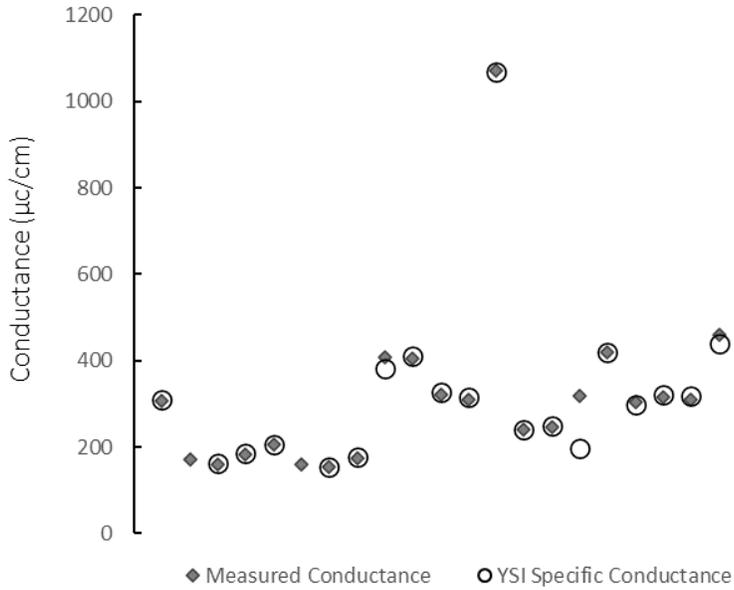


FIGURE 11. A COMPARISON OF CONDUCTANCE MEASURED IN THE FIELD WITH A YSI PROBE (WHITE CIRCLES) VERSUS IN A LABORATORY SETTING BY ACZ LABS (GREY DIAMONDS). THE SIGNIFICANCE OF THIS FIGURE IS TO DEMONSTRATE THE RELATIVELY LOW DEVIATION OF PROBE MEETINGS TAKEN IN THE FIELD TO CALIBRATE U24 HOBO CONDUCTIVITY LOGGERS.

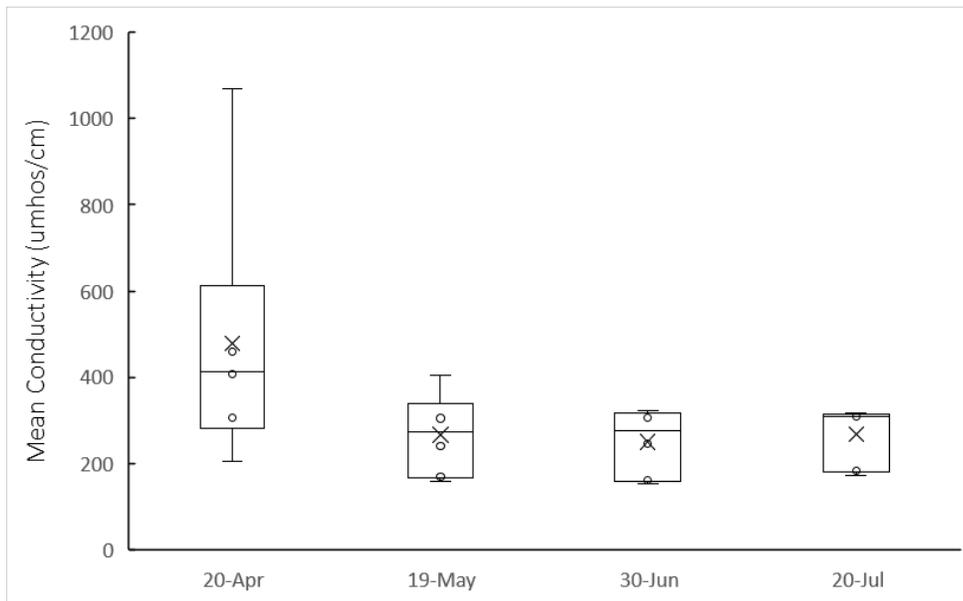


FIGURE 12. A BOX AND WHISKER PLOT OF MEAN CONDUCTIVITY VALUES (LABORATORY) FOR EACH MONTHLY SAMPLE.

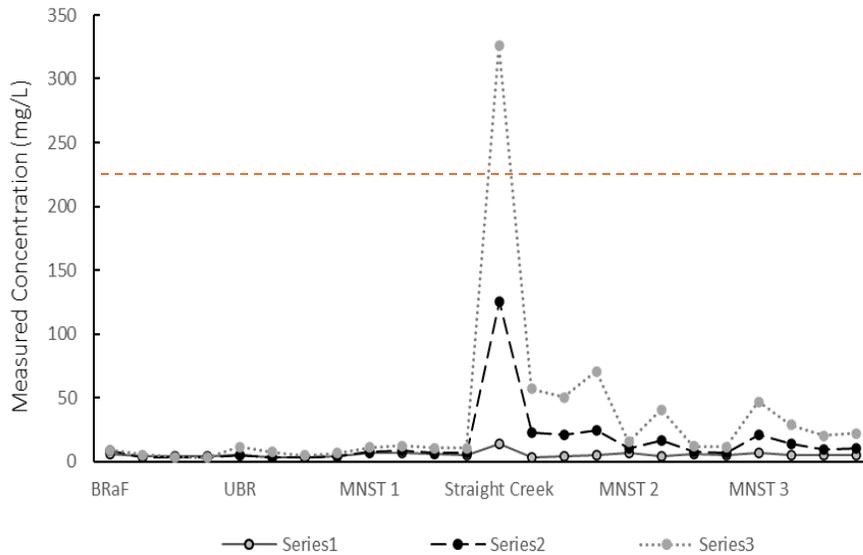


FIGURE 13. DISSOLVED CONCENTRATIONS OF MAGNESIUM (MG, SERIES 1), SODIUM (NA, SERIES 2), AND CHLORIDE (CL, SERIES 3) FROM MONTHLY SURFACE WATER SAMPLES COLLECTED FROM EACH WATER QUALITY STUDY SITE. EPA'S CHRONIC AQUATIC LIFE STANDARD OF 230 MG/L (DASHED ORANGE LINE).

It is apparent in from our study and from publicly available studies carried out in the region that deicing agents or sand/gravel mixtures that contain sodium chloride ( $\text{NaCl}^-$ ) may be more readily entrained as a non-point source than magnesium chloride ( $\text{MgCl}^-$ ). Surface water samples collected in 2021 and 2022 by Trout Unlimited all presented much higher dissolved concentrations of sodium when compared to magnesium. Conversely, because magnesium is a slow-reacting metal that is not solubilized in water as readily as sodium, it may be that total and dissolved concentrations of magnesium are often measured at lower concentrations than sodium. Distributions illustrated in Figure 13 suggest this may be the case, as the measured concentrations of chloride are 201 mg/L higher than sodium, and this spike in chloride may be caused by magnesium chloride and sodium chloride deicing agents being dissolved and transported in Straight Creek during the same snowmelt event.

The data presented in this section is from a single seasonal runoff cycle and this study was implemented to better understand current conditions in Straight Creek and the Blue River Watershed. The water quality study established the study site that monthly surface water quality sampling and continuous datalogger readings can inform resource managers within the watershed that the compounding effects of road deicers are apparent, and concentrations can exceed both acute and chronic surface water standards for the state of Colorado. This study was approached to identify and indicate the need for ongoing field studies and continued research. It should serve the Blue River Watershed Group as a tool for understanding water quality stressors, which can have compounding impacts on the aquatic ecology.

The following figures present conductivity values measured in 15-minute intervals from February 17<sup>th</sup> to July 20<sup>th</sup>, 2022. Instruments were removed on the 20<sup>th</sup> to avoid instrument loss during peak flow. Moreover, road deicers are most likely dissolved and observed in watercourses during diel winter snowmelt, seasonal spring snowmelt events, and spring and summer precipitation events. Removing instruments for the summer months reduces field and data management costs. The following figures are not presented with standardized y-axes (conductivity  $\mu\text{S}/\text{cm}$ ) due to the range of values measured at each site. For presentation and interpretation reasons, y-axes are tailored to the site but should be noted by the reader.

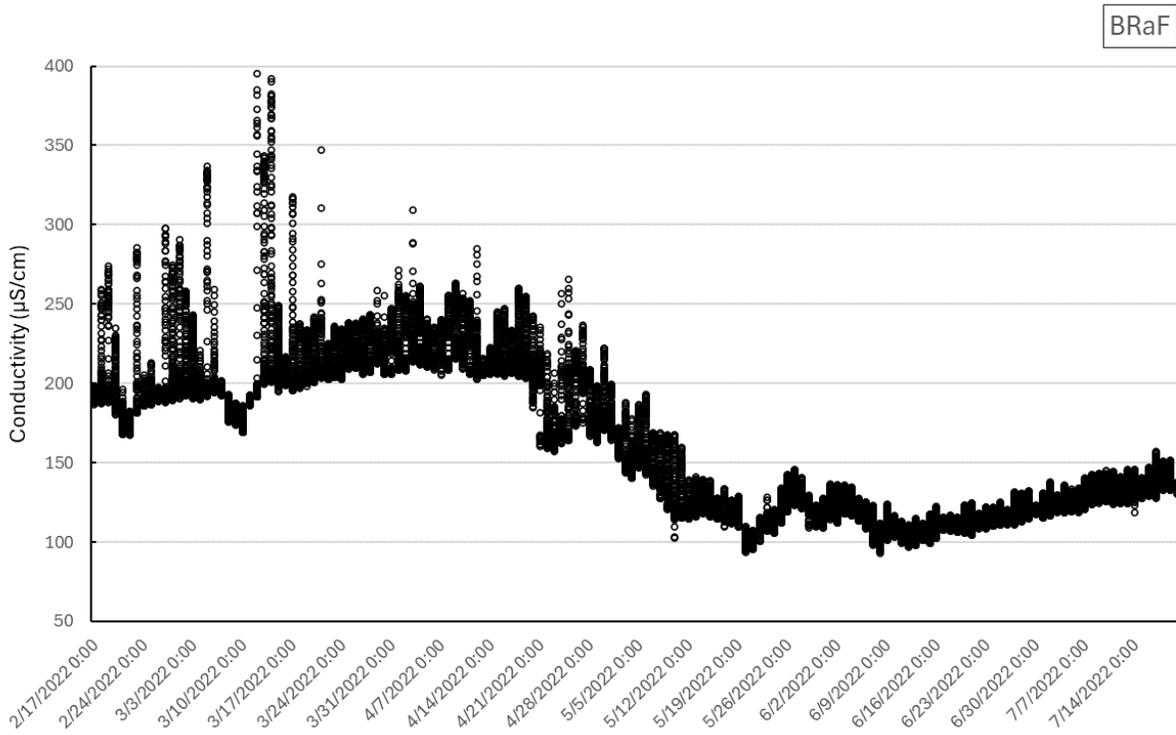


FIGURE 14. ONSET U24 DATALOGGER READINGS FROM THE BLUE RIVER ABOVE FRENCH GULCH. \*THIS LOGGER WAS DEPLOYED BELOW THE CONFLUENCE OF FRENCH GULCH AND THE BLUE RIVER DUE TO INTERMITTENT FLOW IN THE MAINSTEM.

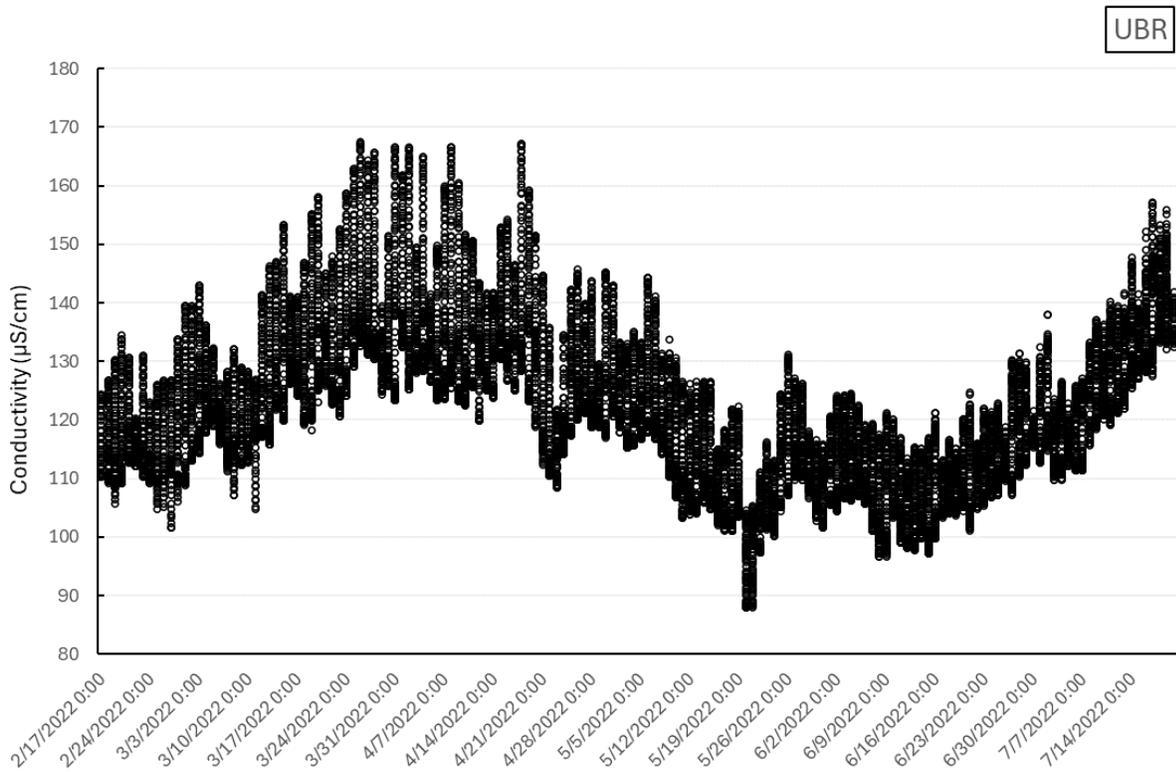


FIGURE 15. ONSET U24 DATALOGGER READINGS FROM THE UPPER BLUE RIVER, BELOW SWAN MOUNTAIN ROAD.

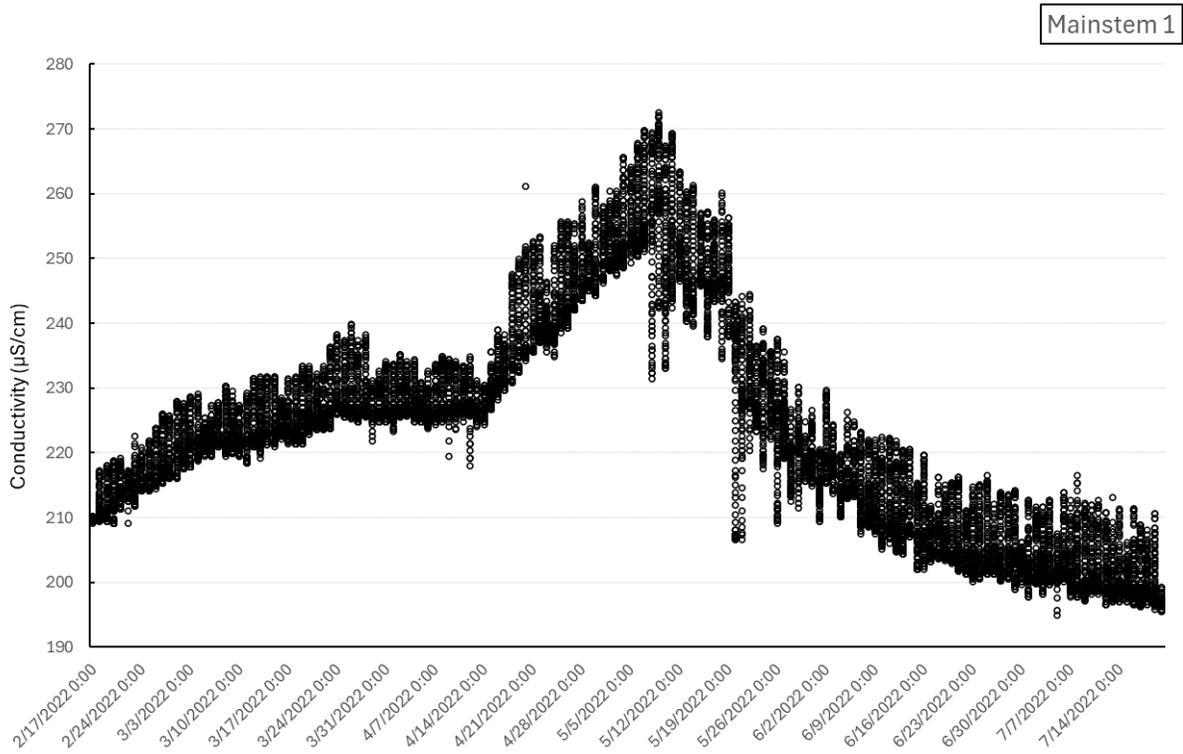


FIGURE 16. ONSET U24 DATALOGGER READINGS FROM THE MAINSTEM 1, ABOVE IWMP SITE BLUE 5.

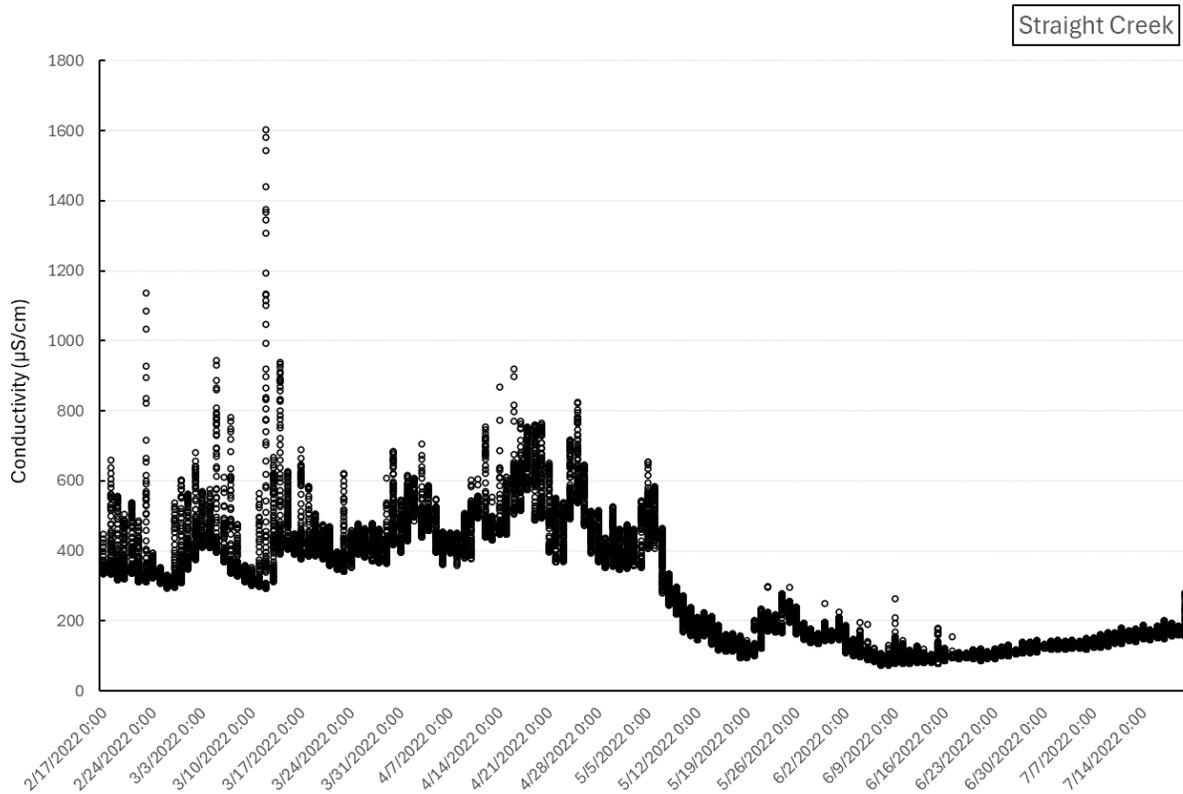


FIGURE 17. ONSET U24 DATALOGGER READINGS FROM STRAIGHT CREEK, BETWEEN STEPHENS WAY AND THE BLUE RIVER.

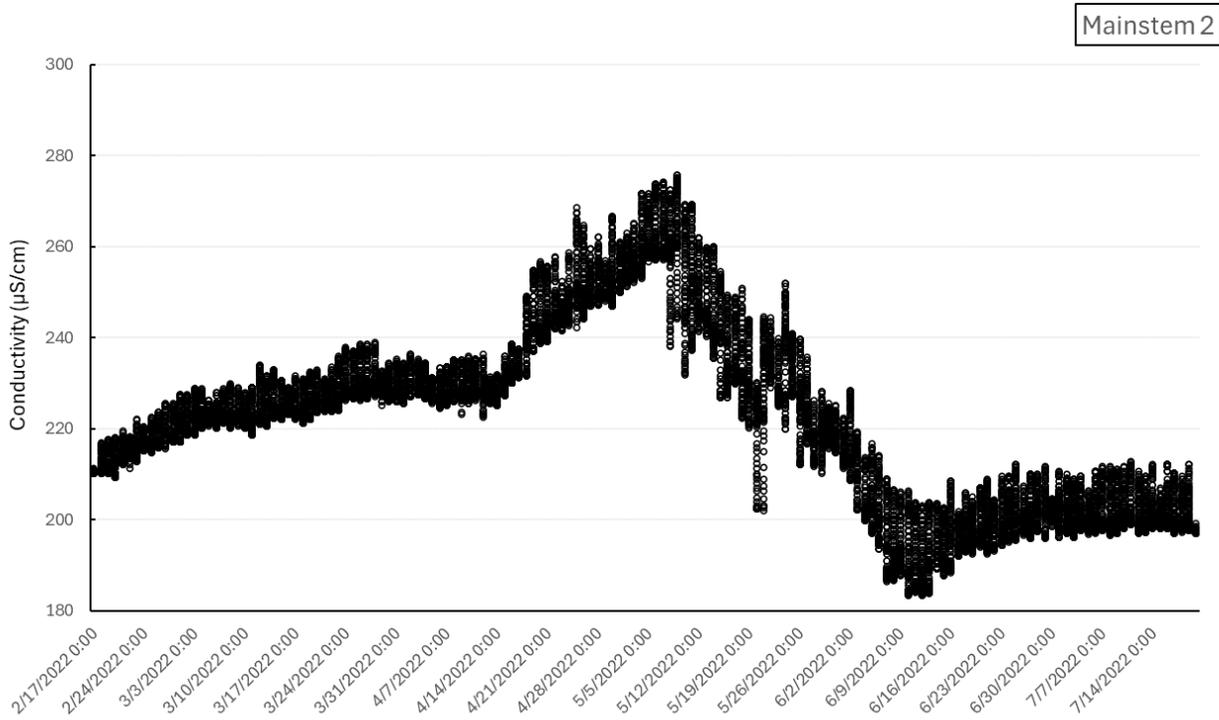


FIGURE 18. ONSET U24 DATALOGGER READINGS FROM MAINSTEM 2, BELOW THE STRAIGHT CREEK CONFLUENCE AND THE EAST-BOUND INTERSTATE-70 OVERPASS.

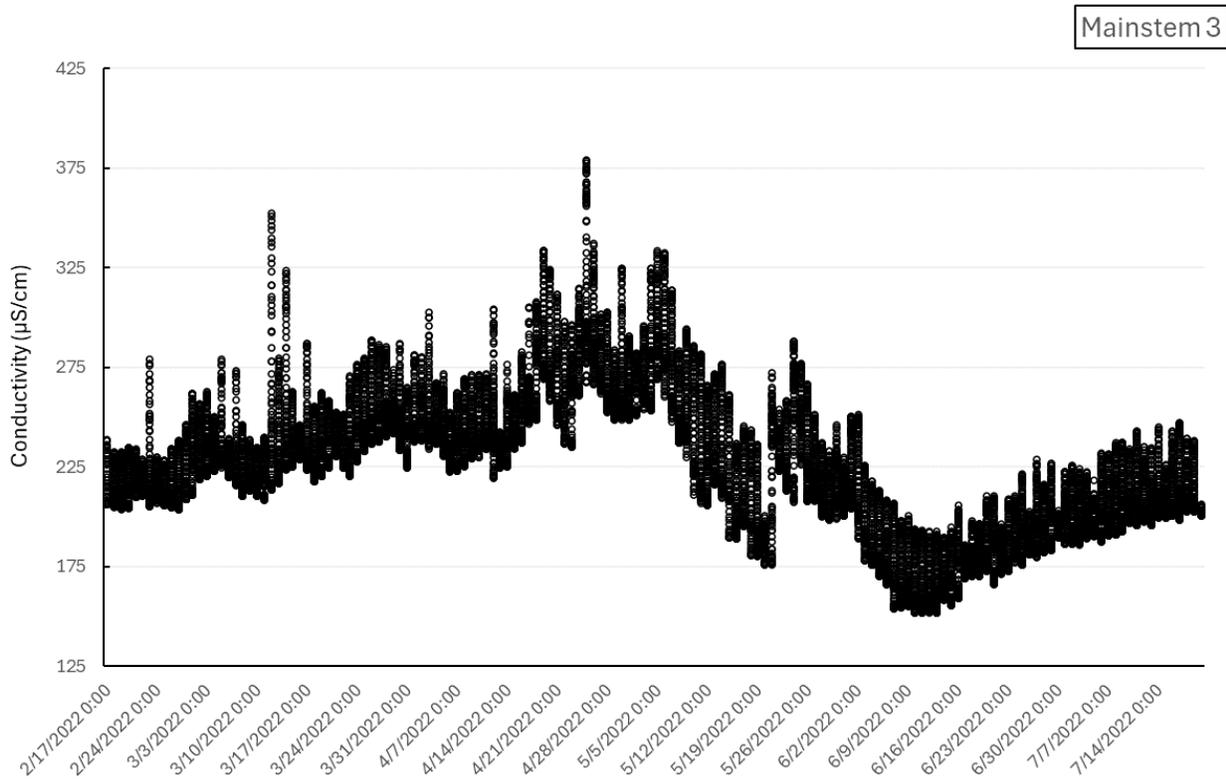


FIGURE 19. ONSET U24 DATALOGGER READINGS FROM MAINSTEM 3, DOWNSTREAM 13<sup>TH</sup> ST. STORMWATER OUTFALLS.

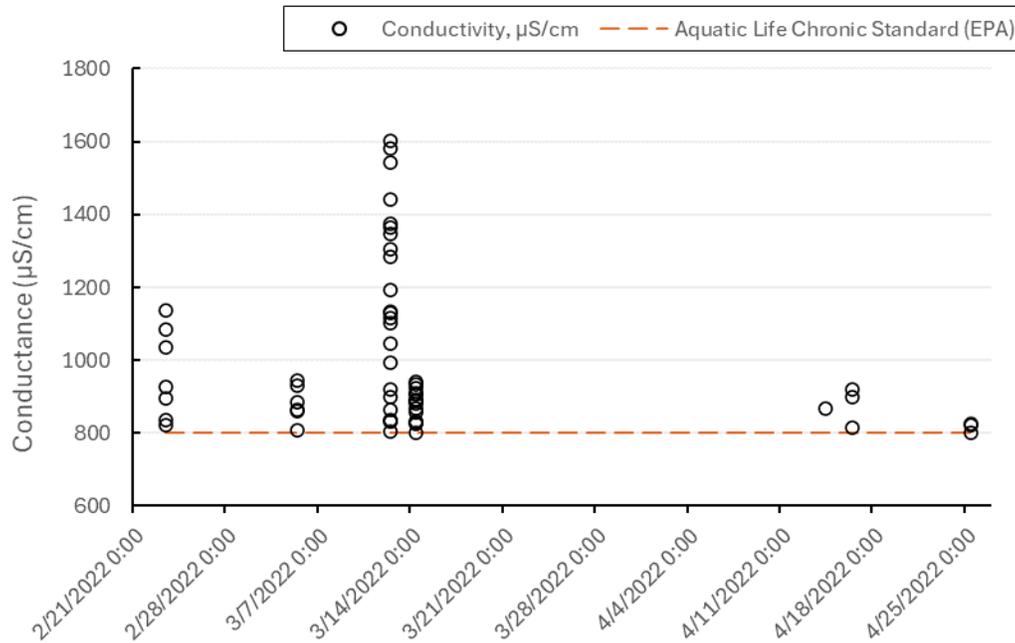


FIGURE 20. STRAIGHT CREEK CONDUCTIVITY VALUES CORRELATING CHRONIC CHLORIDE THRESHOLDS IDENTIFIED BY A 2019 STRAIGHT CREEK WATER QUALITY STUDY.

Clear Creek Consultants presented data results from a 19-year synoptic study of Straight Creek, from a CDOT study site at Laskey Gulch. The 2019 report details exceedances of EPA aquatic life standards in Clear Creek as well as Gore Creek, prominent freshwater tributaries that parallel Interstate-70, both east and west of the Continental Divide. With respect to Straight Creek, the 2019 CDOT report presents empirical data to suggest that when specific conductance values exceed 800 µS/cm, this generally correlates to a chloride aquatic life criteria exceedance (230 mg/L). The aquatic in-stream chronic standard is defined as a four-day average chloride concentration above the aquatic life threshold (EPA 1988). The EPA acute aquatic life threshold is 860 mg/L. There are no established segment standards for sodium. The Water Quality Control Division segment standard for chloride is 250 mg/L, but this standard is not targeted for non-point sources. The WQCD segment standard is most readily applied to point sources (i.e., water treatment facilities).

The figure above illustrates conductance values in Straight Creek that exceeded 800 µS/cm, an established conductance threshold for this waterbody where chloride concentrations exceed 230 mg/L (Figure 20, dashed line). These correlations were presented in the 2019 CDOT report, and it is well understood that conductivity is an accurate surrogate for measuring ion concentrations in water (Kaushal et. al. 2005, Griffith 2014, Clements and Kotalik 2016). A recent study undertaken by Kotalik et. al (2017) performed a stream mesocosm study in Colorado streams to study the effects of magnesium chloride (MgCl<sub>2</sub>) on freshwater macroinvertebrates using EPA surface water aquatic life standards. The study found that sensitive EPT taxa (Ephemeroptera, Plecoptera, and Trichoptera) showed significant reductions in abundance, species richness, and community biomass below EPA chronic aquatic life thresholds. Specifically, Ephemeroptera (mayflies) and Plecoptera (stoneflies) show significant declines in species richness, abundance, and biomass when magnesium chloride concentrations are as low as 75 mg/L (Kotalik et. al, 2017). Figure 21 illustrates that when you use a threshold of 400 µS/cm, corresponding to 75 mg/L of chloride, the Straight Creek conductance values above that threshold by nearly 4,000 occurrences, and exceeding that threshold for consecutive days and weeks.

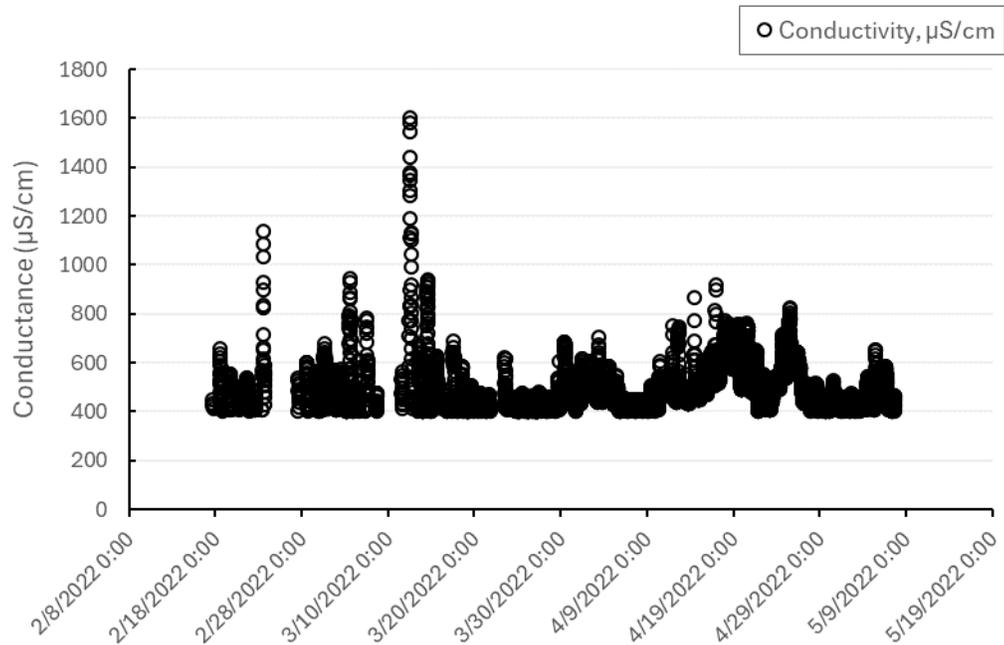


FIGURE 21. STRAIGHT CREEK CONDUCTIVITY VALUES CORRELATING MAGNESIUM CHLORIDE THRESHOLDS IDENTIFIED BY A KOTALIK ET AL. 2017.

An interesting finding of the water quality study was the seasonal spikes in conductance at the French Gluch confluence with the Blue River. Figure 14 illustrates that conductance spikes in the Blue River from February through April. Based on the footprint of legacy mining in French Gulch and active water treatment at the Country Boy Mine, dissolved metals are presumed to be the cause of a spike in conductivity. Dissolved salts may also be contributing to the observed values. This claim is speculative without paired surface water samples for heavy metals and road deicer analytes.

## SECTION 6 -- DISCUSSION

Inference about the status of Blue River periphyton communities has proven difficult due to a series of important factors. Numerous physical and chemical stressors could impact the composition of sensitive aquatic biological communities. As various resource managers come together to strategize about conserving the ecological value of the Blue River Watershed, a central goal of mitigating the compounding physiological impacts on aquatic biological communities is likely to produce measurable responses.

Regarding water quality, adapting reservoir operations to coincide with natural flow regimes to provide a dilution factor may be more critical, given seasonal chemical inputs from non-point sources such as dissolved metals from legacy mines and dissolved salts used in road deicers. For flow-regulated reaches of the Blue River, seasonal discharge from Dillon and Green Mountain Reservoir can initiate seasonal biological life cycles while offsetting impacts from unnatural hydrologic conditions downstream of regulated reservoirs.

Results from the periphyton study indicate that the sampling approach and frequency of collections can serve as useful baseline conditions for the Blue River, but a long-term study would be required to eliminate standard error associated with the small sample size afforded in this study. Based on the periphyton communities measured as part of this study, it is apparent that site Blue 5 (downstream of Dillon Reservoir), supports algal communities that are not observed at any other site in this Blue River Study. Conclusions for this anomaly is that consistent flow and a lack of flows that could activate the particles in this reach are seldom observed. Moreover, unnaturally high primary productivity in this reach is largely due to persistent algal mats and rapid uptake of soluble nutrients released from Dillon Reservoir. Moving

downstream to DRD (Dillon Ranger District), the riffle selected for this study may be prone to unforeseen physical conditions—large substrate and high velocities at this riffle reach may often scour. Sites such as D5, Blue 2, and Blue 1 support anticipated algal communities and abundance according to the regional MMI and for what is expected for high alpine Rocky Mountain streams. Seasonal algal communities at IWMP sites SCR (Slate Creek Ranch) and BCR (Below Brush Creek) present low abundance, but relatively high taxa richness when compared to site Blue 5. Dense formations of anchor ice at these sites may have a measurable affect on biomass. Moreover, site BCR is below what is commonly referred to as the “Slate Hole”, a large shale outcropping that abuts the Blue River, and evidenced by our field records, small shale particles are an active sediment load and that may affect both benthic algae and macroinvertebrate communities (Figure 4D).

Synoptic water quality studies are data-intensive and require continuous maintenance and management. Due to the number of variables that have the potential to impact dissolved concentrations of focal constituents, a surface water study should strongly consider utilizing partners such as the USGS, WQCD, University labs, or the EPA that have the expertise and sampling instrumentation required to reduce 'noise' in the data. A laboratory study on the salinization of Colorado's freshwater stream and wetlands would likely produce empirically robust datasets to identify the extent of impacts on biological communities. While TU is encouraged by the data collected and presented in this report, a valuable take-home allows isolation of variables (i.e., consistent concentrations of the analyte of concern, consistent flow, consistent water temperature, consistent standing crop of benthic algae, etc.)

Based on measured concentrations and long-term datasets maintained by the USGS or various unaffiliated partners, the seasonal increase in chloride and sodium concentrations in Straight Creek could likely affect biological communities in this tributary and may impact biological communities in the Blue River. Because of where Straight Creek is situated in the watershed, this tributary has the potential to provide ecological uplift to the Blue River if anthropogenic stressors can be addressed. The data suggests that chloride often exceeds aquatic life standards at Straight Creek, but likely dilutes to non-lethal concentrations in the Blue River. Management efforts to thwart the impacts major ions (deicer agents) have on the receiving water should take place. Importantly, improvements to streamside management are not limited to travel corridors but should include municipalities actively managing snow removal in locations that will not become non-point sources of water quality impacts. Moreover, development along riparian corridors could be managed to reduce impacts on riparian and wetland habitats and reduce impervious surfaces constructed in these areas.

Based on the results of this water quality study and in conjunction with ongoing studies carried out in region, the data suggests segment standards need to be established for segment that parallel highway infrastructure/ agencies should comprehensive analysis of the complexities surrounding road deicers, salinization of freshwater habitats, and water quality concerns should be addressed by state water quality commissions or a multi-year study using regulatory collection methods.

Due to the temporal confines of an Integrated Water Management Plan, multi-year studies can provide a means to collect a great deal of data, however, when compared to the timescale of the processes impacting the resource, the dataset needs to follow suit. To amass a comprehensive understanding of the Blue River Watershed, long-term water quality, temperature, and biomonitoring studies are strongly recommended.

## SECTION 7 – LITERATURE CITED

- Biggs, B.J., & Kilroy, C., (2000) Stream Periphyton Monitoring Manual, Prepared for the New Zealand Ministry for the Environment
- Blinn, D.W., Shannon, J.P., Benenati, P.L., Wilson, K.P., (1998) Algal Ecology in Tailwater Stream Communities: The Colorado River Below Glenn Canyon Dam, Arizona. Department of Biological Sciences, Northern Arizona University, Flagstaff, Arizona. *Academia, Journal of Phycology*.
- Blinn, D. W. & Cole, G. A., (1991) Algal and invertebrate biota in the Colorado River: comparison of pre- and post-dam conditions. In Committee on Glen Canyon Environmental Studies [Eds.] *Colorado River Ecology and Dam Management*. National Academy Press, Washington, DC, pp. 85–104.
- Carlisle, D.M., (2022) Data Release for: A Web-Based Tool for Assessing the Condition of Benthic Diatom Assemblages in Streams and Rivers of the Conterminous United States: US Geological Survey data release, Colorado Water Quality Control Division (WQCD), Standard Operating Procedures for the Collection of Streams Periphyton Samples.
- Clements, W.H. & Kotalik, C., (2016) Effects of Major Ions on Natural Benthic Communities: An Experimental Assessment of the US Environmental Protection Agency Aquatic Life Benchmark for Conductivity. *Freshwater Science*., DOI: 10.1086/685085.
- Colorado Department of Transportation., (2001) Evaluation and Comparison of Three Chemical Deicers for Use in Colorado. Report No. CDOT-DTD-R-2001-17, Phase II – Final Report.
- Colorado Department of Transportation., (2020) Data Summary Report, Interstate 70 Mountain Corridor Storm Event/Snowmelt Water Quality Monitoring (2000-2019). Clear Creek Consultants, Inc.
- Corsi, S.R., Graczyk, D.J., Geis, S.W., Booth, N.L., Richards, K.D., (2010). A Fresh Look at Road Salt: Aquatic Toxicity and Water-Quality Impacts on Local, Regional, and National Scales. *Environmental Science and Technology*, 44(19), 7376-7382.
- Dodds, W.K. & Welch, E.B., (2010) Establishing Nutrient Criteria In Streams, *Journal of the North American Benthological Society—now Freshwater Science*, Volume 19, Number 1.
- Griffith, M.B., (2014) Natural variation and current reference for specific conductivity and major ions in wadeable streams of the conterminous USA. *Freshwater Science*. 33: 1-17.
- Hauer, R.F. & Lamberti, G.A., (2007) *Methods in Stream Ecology*, Second Edition. Academic Press, Elsevier., Burlington, MA.
- Heck, M.P., Schultz, L.D., Hockman-Wert, D., Dinger, E.C., and Dunham, J.B., (2018) Monitoring stream temperatures—A guide for non-specialists: US Geological Survey Techniques and Methods, book 3, chap. A25, 76 p.
- Kaushal, S.S., Groffman, P.M., Likens, G.E., Belt, K.T., Stack, W.P., Kelly, V.R., Band, L.E., & Fisher, G.T., (2005) Increased Salinization of Fresh Water in the Northeastern United States. *Proceedings of the National Academy of Science of the United States of America*. 102:13517-13520.
- Kotalik, C.J., Clements, W.H., Cadmus, P., (2017) Effects of Magnesium Chloride Road Deicer on Montana Stream Benthic Communities. *Hydrobiologia*. 799:193-202.
- Kumar, H.D & Singh, H.N., (1979) *A Textbook on Algae*. Macmillan International College Edition.
- Lewis, W.M., & McCutchan, J.H., (2010) Ecological Responses to Nutrients in Streams and Rivers of the Colorado Mountains and Foothills, *Freshwater Biology*, Center for Limnology, Cooperative Institute for Research in Environmental Sciences, Department of Ecology and Evolutionary Biology, University of Colorado, Boulder, CO.

- Lewis, W.M., & McCutchan, J.H., (2012) Evaluation and Interpretation of Multi-Metric Index (MMI) Information on Invertebrate Communities of the Blue River below the Dillon Reservoir Dam, Summit County, Colorado, Rpt. 337.
- Lewis, W.M., & McCutchan, J.H., (2013) Results of a Field Survey of Benthic Chlorophyll Abundance and its Possible Relationship to Nutrient Concentrations for Streams within and Just Below the Lake Dillon Watershed, Rpt. 328.
- Lewis, W.M., & McCutchan, J.H., Roberson, J., (2016) Chlorophyll and Nutrient Concentrations for Selected Sites in the Lake Dillon Watershed, Rpt. 378.
- Oertel, N. & Salánki, J., (2003) Biomonitoring and Bioindicators in Aquatic Ecosystems. In: Ambasht RS, Ambasht NK (Eds. Modern trends in applied aquatic ecology. Kluwer Academic/Plenum Publishers, New York, pp. 219-246.
- Rosenberg, D.M., (1998) A National Aquatic Ecosystem Health Program for Canada: We should go against the flow. Bull. Entomol. Soc. Can., 30(4):144-152.
- Rost, A.L., & Fritsen, C.H., (2014) Influence of a tributary stream on benthic communities in *Didymosphenia geminata* impacted stream in the Sierra Nevada, USA, Diatom Research, 29:3, 249-257, DOI: 10.1080/0269249X.2014.929029.
- Steinman et al., (2006) Biomass and Pigments of Benthic Algae. Methods of Stream Ecology: Second Edition, Edited by F. Richard Hauer and Gary A. Lamberti, Ch. 17, 357-368.
- Stevens, L. E., Shannon, J. P. & Blinn, D. W., (1997) Colorado River benthic ecology in Grand Canyon, Arizona, USA: dam, tributary and geomorphological influences. Regul. Rivers 13:129-49.
- Stevenson R.J., Bothwell M.L., Lowe R.L., (1996) Algal Ecology: Freshwater Benthic Ecosystems. Academic Press, NY.
- Stickler, M. & Alfredsen, K.T., (2009), Anchor ice formation in streams: a field study. Hydrol. Process., 23: 2307-2315.
- Plafkin J.L., Barbour M.T., Porter K.D., Gross S.K. & Hughes R.M., (1989) Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish. US Environmental Protection Agency, EPA/444/4-89-001. Office of Water, Washington, DC.
- Puccinelli, C.M., Marcheggiani, (2019) A Patented Rapid Method for Identification of Italian Diatom Species. International Journal of Environmental Restoration and Public Health.
- YSI ProDSS Calibration Guide., (2017)  
[https://www.ysi.com/File%20Library/Documents/Guides/W89\\_YSI\\_ProDSS\\_Calibration\\_Guide.pdf](https://www.ysi.com/File%20Library/Documents/Guides/W89_YSI_ProDSS_Calibration_Guide.pdf)