Loveland Water and Power

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Big Thompson River Watershed Source Water Quality Conditions

Fall 2022

January 23, 2023

Common Acronyms

CB-T	Colorado-Big Thompson Project
CPF	Cameron Peak Fire
CFS	Cubic Feet per Second
LWP	Loveland Water and Power
mg/L	Milligrams per liter (parts per million)
$CaCO_3$	Calcium carbonate
NTU	Nephelometric Turbidity Unit
North Fork	North Fork of the Big Thompson River
SU	Standard Units
SWMP	Source Water Monitoring Program
TOC	Total Organic Carbon
ug/L	Micrograms per liter (parts per billion)
uS/cm	Microsiemens per centimeter
WQL	Loveland Water and Power Water Quality Laboratory

Executive Summary

Fall 2022 conditions were similar to summer patterns with regard to water quality. The effects of monsoon rains in August and the Cameron Peak Fire (CPF) were apparent with elevated levels of turbidity, total manganese, total iron, nitrate, and orthophosphate and turbidity were elevated primarily due to contributions from the North Fork of the Big Thompson River (North Fork) which is located in the most severely burned portion of the watershed. Fall 2022 results were particularly pronounced because the August sampling event occurred immediately after a substantial monsoon rain event. A total of 0.87 inches of rain fell during the night of August 15th and morning August 16th. August sampling occurred in the late morning and early afternoon of August 16th during relatively high flows. While the results obtained from the August sampling event did not reflect "normal" conditions, the inclusion of these data does reflect the effects that monsoon rains have on water quality in the Big Thompson River Watershed, particularly when they occur over areas that have recently experienced wildfire. Loveland Water and Power (LWP) staff were able to effectively adjust their water treatment processes in responses to these water quality changes and continue to provide high quality drinking water throughout the fall. The effects of the Cameron Peak Fire on water quality in the Big Thompson River Watershed are expected to decrease substantially in 2023 although they may persist to a low level for several additional years.

Loveland Water and Power Source Water Monitoring Program

The purpose of the Loveland Water and Power (LWP) Source Water Monitoring Program (SWMP) is to collect, analyze, and interpret water quality data that are of interest with regard to drinking water, wastewater, recreation, and aquatic ecosystems. These data are used to identify and quantify current issues, document management successes, evaluate regulatory compliance, evaluate the appropriateness of current water quality standards, and identify issues that may present themselves in the future.

One central component of the SWMP is the source water sampling and analysis that is accomplished by staff at the Loveland Water and Power Water Quality Laboratory (LWQL). LWP has collected operational source water data for over 30 years and a more targeted set of parameters for eight years from the three water sources utilized for drinking water (Colorado-Big Thompson Project (CB-T), Big Thompson River, and Green Ridge Glade Reservoir). The values for these targeted parameters are available in a short amount of time due to in-house laboratory capacity, and therefore can be used to inform more immediate water system operational decisions.

Water quality information is routinely collected from 15 sites. Of these sites, two are intake locations at the Loveland Water Treatment Plant (river intake and reservoir intake), two are tributary sites (Fall River and North Fork Big Thompson River), seven are associated with the CB-T and four are mainstem river sites (Table 1, Figure 1). All of these sites are located upstream of the Loveland drinking water intake and therefore water quality results from these locations have implications for Loveland water treatment and drinking water quality.

Table 1. Big Thompson Watershed sampling location descriptions.

Site Name	Type	Description
S-BTR-10	River	Big Thompson River below Mary's Lake Bridge
S-BTR-20	River	Downstream of Olympus Dam
S-BTR-30	River	Big Thompson mainstem above confluence with North Fork
S-BTR-40	River	Mainstem Big Thompson at Viestenz-Smith Park
S-BTR-50	River	Mainstem Big Thompson at Narrows Park
S-BTT-10	Tributary	Fall River Court bridge
S-BTT-20	Tributary	North Fork Big Thompson at Storm Mountain Rd
S-CBT-10	CB-T	Near gate at East Portal
S-CBT-20	CB-T	Shore of Mary's Lake
S-CBT-30	CB-T	Shore of Pinewood Reservoir
S-CBT-40	CB-T	Shore of Flatiron Reservoir
S-CBT-50	CB-T	Downstream of Flatiron Reservoir
S-CBT-60	CB-T	Hansen canal near outlet to Green Ridge Glade Reservoir
S-LNN-10	Intake	River line in laboratory
S-LNN-20	Intake	Reservoir line in laboratory

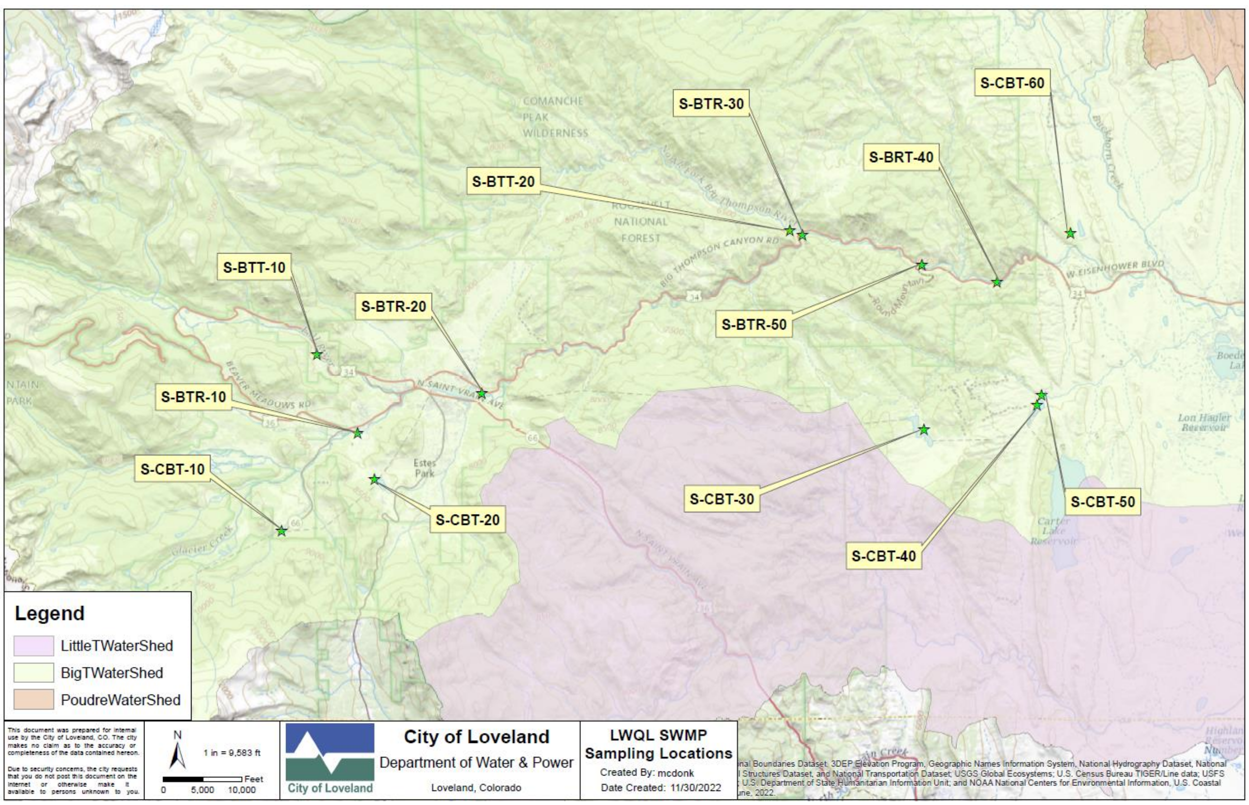

Figure 1. 2022 Source Water Monitoring Program water quality sampling sites.

The objective of these seasonal reports is to provide a description of notable events and a summary of important water quality parameters for those interested in the water quality of the Big Thompson River.

These comparisons provide the opportunity to understand recent conditions relative to the previous five-year time period and to established water quality standards. While water quality conditions have changed on time scales greater than five years, this relatively short time period provides context for recent conditions. Examination of longer-term trends and conditions can be found in Loveland Water and Power Big Thompson River Annual Reports. The results and findings presented in this report only represent source water and not the treated drinking water that is delivered to our customers. Drinking water information and the annual Consumer Confidence Report can be found on our website.

For this report, “fall” is defined as the months of August, September, and October This time period is representative of relatively stable flow conditions after runoff and snowmelt which generally occur primarily in May, June, and the first part of July. Average values were calculated from all samples collected during these months in 2022 and compared to the average value of all samples collected during these months from 2017 through 2021.

Summary Conditions

In general, most concentrations of water quality parameters in fall 2022 were close to the average values of the previous five-year time period. However, some parameters continued to be affected by the Cameron Peak and East Troublesome fires. The portion of the Big Thompson River Watershed primarily affected by the CPF was the area surrounding the North Fork. Intense monsoon rain events caused dramatic and relatively short-term increases in a number of water quality parameters particularly when the events occurred over the burned area of the watershed. These rain events caused markedly high total iron, total manganese, turbidity, nitrate, and orthophosphate at a number of locations starting with the North Fork site and propagating downstream. These levels were similar to values measured in summer 2022 and in 2021. Increases in manganese and iron can make water treatment more difficult and can result water discoloration issues if the water is not treated adequately. Increased turbidity is problematic because it is an indicator of high sediment load and as such, it can force LWP to use different sources of drinking water. Turbidity levels are also positively associated with total organic carbon levels which require additional water treatment efforts. Interestingly, nitrate levels continued to be elevated across most sampling locations in fall 2022 with particularly elevated levels associated with contributions from the North Fork. While elevated nitrate can have negative health consequences, the levels observed in fall 2022 were much lower than levels that might cause health concerns. However, elevated nitrate can be beneficial to algal growth and increase algal abundance which may result in taste and odor issues. Elevated nitrate is also of concern because increases in nitrate have been associated with increased biomass and toxicity of some blue-green algae species (Davis et al. 2015). Increases in concentrations of water quality parameters associated with the CPF were more substantial than anticipated in 2022 and are expected to continue for the next several years. In addition, total organic carbon levels were elevated compared to the five-year average value at virtually all sampling locations, a circumstance that continued from Summer 2022. Loveland Water and Power Drinking Water Treatment staff were able to continue to provide high quality drinking water despite these impacts, but additional effort and costs were incurred.

Water Quality Parameters

Precipitation

The amount of precipitation is directly proportional to the amount of water present in the Big Thompson River. In addition, the amount of precipitation can provide an indication of the relative quality of the water as large rain events and runoff often result in increased turbidity.

Despite the intense monsoon rain events that occurred in early fall (such as the event on August 15-16), fall precipitation overall was approximately average in comparison to the last five years (Figure 2). Although the monthly average precipitation values were not dramatically different from historic levels, localized and intense monsoon rain events caused dramatic flow changes,

particularly when the storms impacted watersheds that were affected by the CPF.

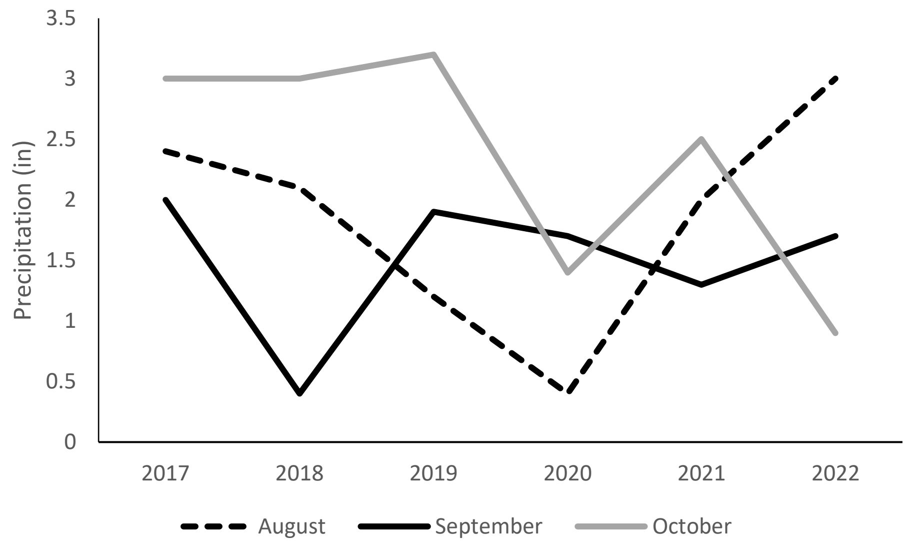

Figure 2. Monthly precipitation by year at the Bear Lake Natural Resources Conservation Service Snow Telemetry (SNOTEL) station.

Temperature

Aquatic organisms have preferred temperature ranges. These ranges can vary widely, and species with similar temperature tolerances are often associated with one another. Some organisms require relatively cold water to survive, particularly during spawning, egg/larval growth and development. Consequently, elevated water temperatures can cause mortality as well as reduced reproduction and growth. Conversely, water temperatures can be too low for optimal growth and survival of some species, particularly those found in the lower reaches of the Big Thompson River.

In addition, temperature is of interest to water treatment operators because the temperature of the water influences the speed at which chemical reactions used to treat drinking water take place. Chemical reactions generally take longer to complete in colder water.

Overall, fall 2022 water temperatures were close to, but somewhat below, average values in the past five years (Figure 3). Although temperatures in recent years have generally been hotter than they have been historically due to climate change, it appears that at least fall 2022 did not represent an acceleration of this trend.

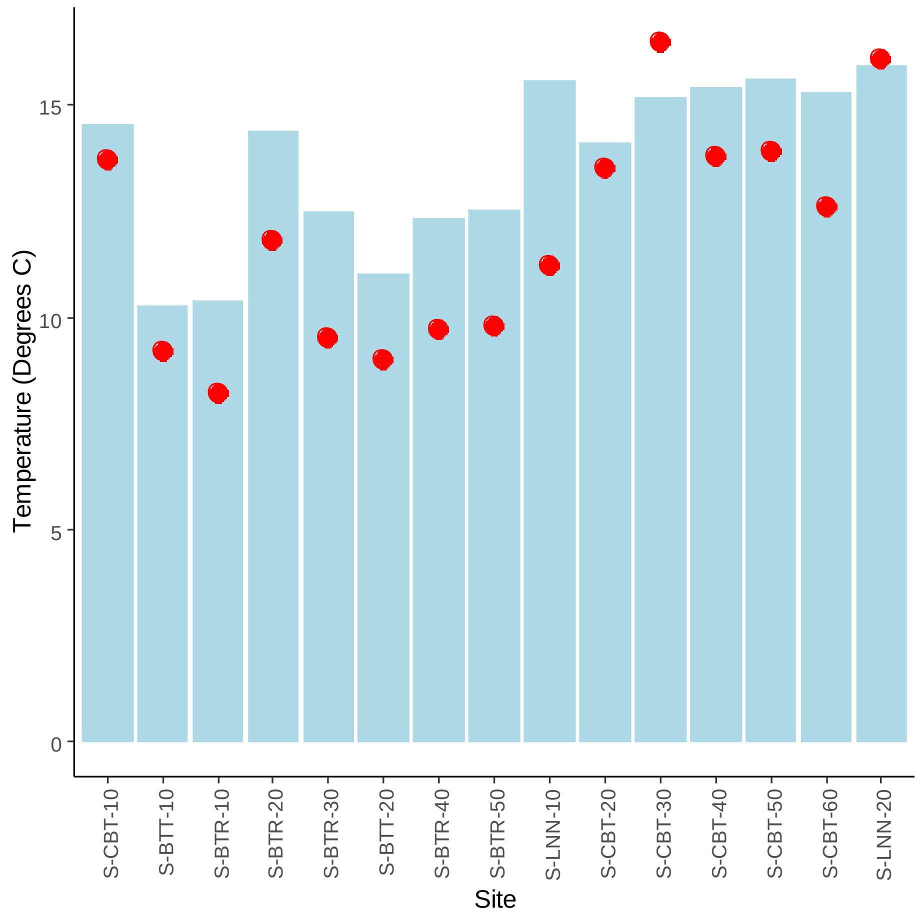

Figure 3. Average water temperature values for the months of August through October 2017-2021 (blue bar) and the 2022 average value (red dot) at sites included in the LWP SWMP.

Turbidity

Turbidity is a general measurement of water clarity, measured as NTU (Nephelometric Turbidity Unit). Water with higher turbidity levels has a greater number of suspended particles in it and is less clear. Elevated turbidity has negative impacts on municipal water treatment plants and aquatic communities. For example, LWP alters the location of their water collection to avoid high levels of turbidity as it is an indicator of high sediment load. Turbidity levels are also positively associated with total organic carbon (TOC) levels which in turn require additional water treatment efforts.

Elevated turbidity can have direct negative effects on aquatic organisms in addition to indirect effects such as increasing the levels of some dissolved metals. Elevated turbidity and suspended sediment can have negative effects on density and species richness of macroinvertebrates. Growth of trout species such as rainbow trout (*Oncorhynchus mykiss*) is negatively associated with increased turbidity and increased turbidity can lead to increased mortality as well. Effects of elevated turbidity become more severe with longer exposure.

Turbidity levels in fall of 2022 were near somewhat elevated for most locations although levels were considerably higher in the North Fork and sites immediately downstream (Figure 4). The area in the North Fork watershed above the sampling site was included in the area that was most severely burned during the CPF in Fall of 2020. This impact was magnified by the inclusion of data from the August sampling event which occurred immediately after a substantial monsoon rain event. Increased turbidity resulting from the aftereffects of wildfire can persist for several years and the elevated turbidity level in the North Fork is likely due to the continued effects of the CPF.

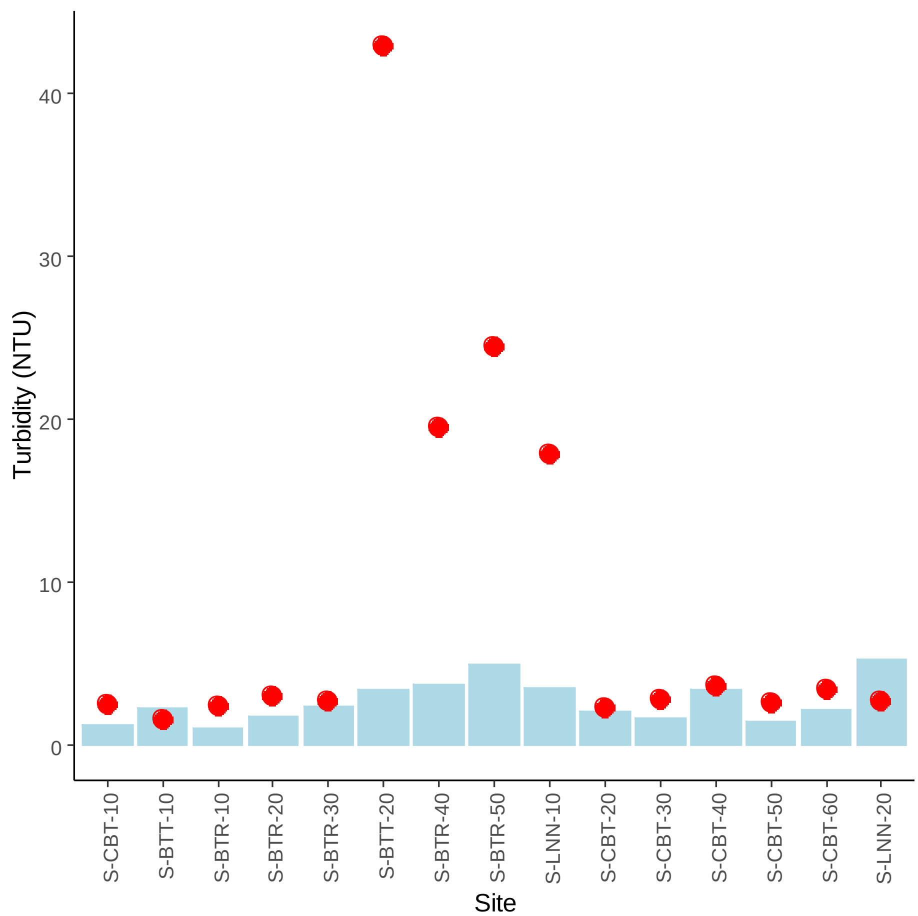

Figure 4. Average turbidity values for the months of August through October 2017-2021 (blue bar) and the 2022 average value (red dot) at sites included in the LWP SWMP.

pH

The pH value (SU, Standard Units) measures how acidic or basic the water is. A pH value of 7 is considered neutral, with lower values considered acidic and higher values considered basic. Colorado Regulations 31 and 38 establish a pH of 6.5 as a minimum and 9 as a maximum to protect aquatic life. Generally, pH values increase as water moves from the headwaters to lower in the watershed because additional dissolved materials become present in the water.

Mean pH values were generally near five-year average values for virtually all sites in fall 2022 (Figure 5). However, pH was somewhat elevated in Pinewood Reservoir and was somewhat depressed in the remaining CB-T locations. White ash is the lightest in weight the finest in terms of coarseness and therefore it is generally flushed from the system at a faster rate than black ash, it also generally has a higher pH than black ash (Rodela et al. 2022). Black ash can still be seen in the river during high water events. Relatively low pH values documented in the Colorado-Big Thompson Project (CB-T) sites are potentially due to black ash that remains in the system as a result of the East Troublesome Fire. The cause of the somewhat elevated pH in Pinewood Reservoir is unknown. Although the variations from the average values in the CB-T sites seem relatively small (~0.3 SU) it is important to note that pH is measured on a log scale. Therefore, a difference of ~0.3. SU is approximately equivalent of a doubling of the concentration of hydrogen ions. None of the measured pH values exceeded standards set to protect aquatic life in fall 2022.

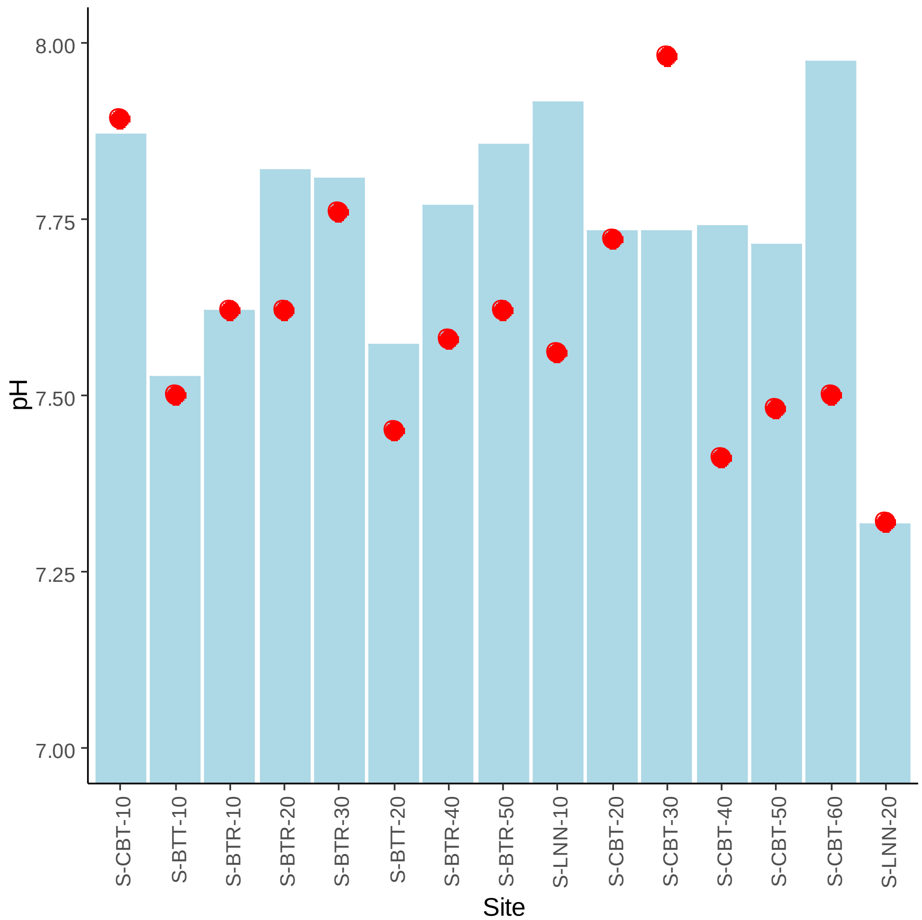

Figure 5. Average pH values for the months of August through October 2017-2021 (blue bar) and the 2022 average value (red dot) at sites included in the LWP SWMP.

Dissolved Oxygen

Dissolved oxygen levels are important to aquatic life, and drinking water facilities, and are affected by a number of factors such as temperature, altitude, turbulence, and biological activity. Turbulent cold water at a low altitude can have higher levels of dissolved oxygen than still warm water at a higher altitude. Biological activity (particularly photosynthesis) can increase dissolved oxygen during the day as photosynthesis occurs and can decrease dissolved oxygen levels at night when respiration dominates. Often biological activity has no net effect on dissolved oxygen levels, but it can increase the daily range of values with wider ranges being associated with greater biological activity. Virtually all aquatic organisms require dissolved oxygen to survive with the necessary concentration differing by species. For example, many fish species in the upper portion of the Big Thompson River have evolved to live in cold water streams and require higher concentrations of dissolved oxygen (e.g., cutthroat trout *Oncorhynchus clarki*) than those that evolved to persist in the lower warm water portion of the river (e.g., plains killifish *Fundulus zebinus*). Aquatic organisms can experience mortality if the dissolved oxygen levels drop below their threshold level for even a short time. Although some life stages require higher levels of dissolved oxygen, a minimum threshold to support most aquatic life is 6 mg/L (ppm, parts per million). In addition, dissolved oxygen levels regulate the degree to which some elements (like manganese) remain in solution. Relatively high dissolved oxygen levels allow these elements to precipitate out of the water column and make drinking water treatment easier.

Fall 2022 dissolved oxygen levels were slightly below historic averages across sites (Figure 6). However, with the exception of Green Glade Reservoir, all values were substantially above standards associated with aquatic life in lotic sites which is a positive indication for aquatic ecosystems in the Big Thompson River Watershed. Although it may appear that the five-year average fall value and the 2022 average fall value are below levels to protect aquatic life, it is very likely that these values are an artifact of drinking water operations in Green Ridge Glade Reservoir. Samples representative of Green Ridge Glade Reservoir are actually taken via the "Lab Line" which represents reservoir drinking water that just before it is treated to become drinking water. Water from the reservoir is obtained from different depths of Green Ridge Glade Reservoir depending on conditions. During the summer and fall water that is taken from very shallow depths can have taste and odor issues associated with algae while water that is taken from deeper depths below the thermocline can have taste and odor issues associated with manganese. As a result, water is often drawn from a portion of the reservoir very near the thermocline. Obtaining water in this fashion can result in some water in the "Lab Line" originating from the anoxic portion of the reservoir below the thermocline. Inclusion of this anoxic water in the Green Ridge Glade Reservoir sample makes the samples appear artificially low compared to actual conditions in the epilimnion of the reservoir. We have no reason to believe that dissolved oxygen levels are particularly low in the epilimnion of Green Ridge Glade Reservoir.

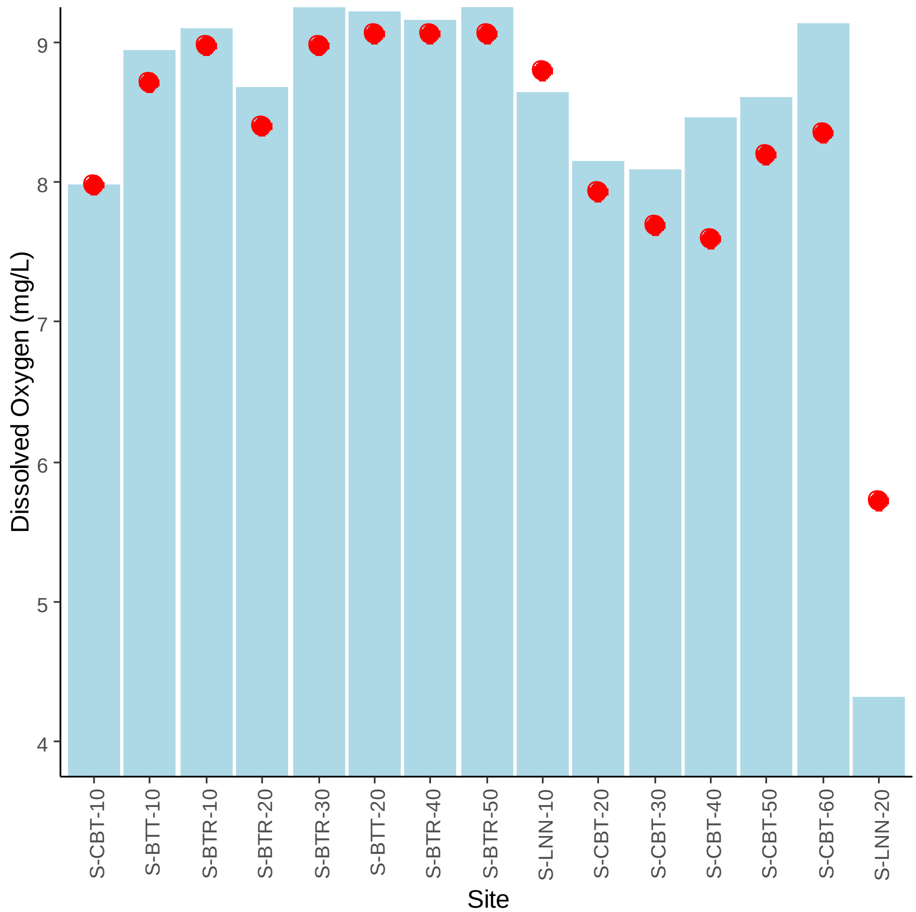

Figure 6. Average dissolved oxygen values for the months of August through October 2017-2021 (blue bar) and the 2022 average value (red dot) at sites included in the LWP SWMP.

Alkalinity

Alkalinity is a measure of the ability of water to neutralize acid and resist declines in pH. Alkalinity is generally determined by the amount of calcium carbonate in water. Calcium carbonate provides buffering capacity to protect aquatic life from acidic conditions and decreases the ability of water to corrode distribution pipes. Conversely, water treatment plants (including Loveland Water and Power) often use flocculation techniques to purify water and these techniques are generally optimized by altering the pH (Naceradska et al. 2019). High alkalinity makes this pH adjustment more difficult and requires higher doses while low alkalinity causes incomplete chemical reactions and poor flocculation.

Average fall 2022 alkalinity values were generally very near average values (Figure 7). However, alkalinity was substantially lower in Mary's Lake and corresponds with the somewhat elevated pH seen there. Although the difference is not of particular concern, the cause of this difference is unknown.

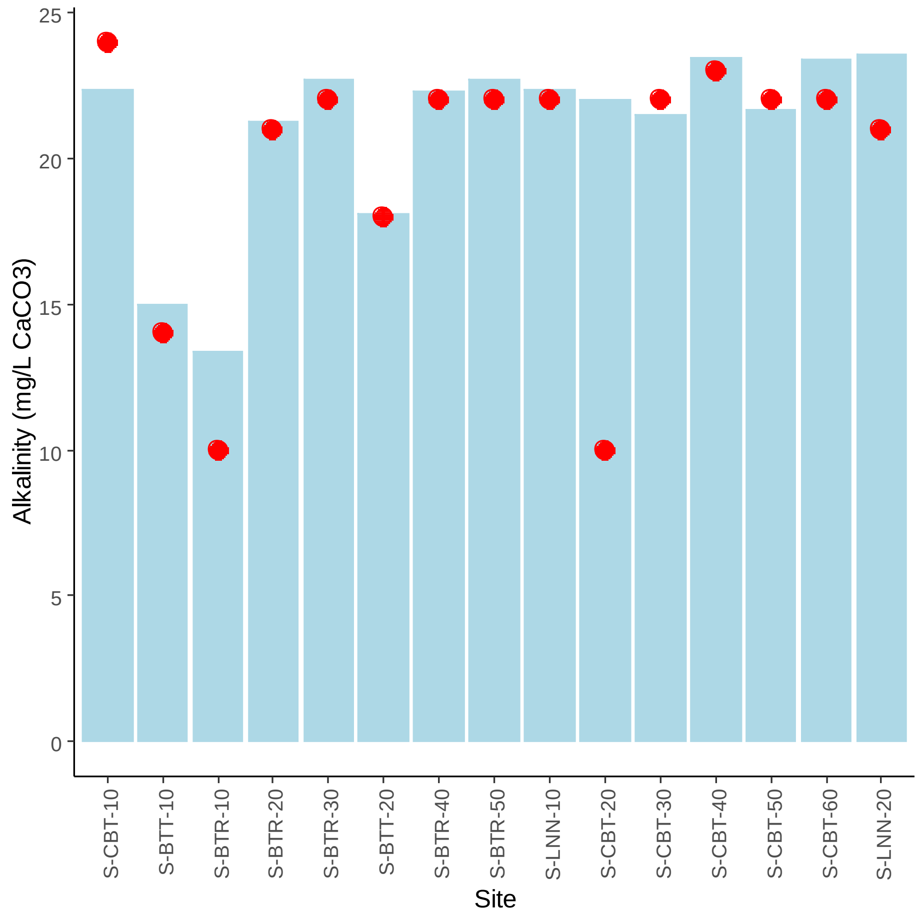

Figure 7. Average alkalinity values for the months of August through October 2017-2021 (blue bar) and the 2022 average value (red dot) at sites included in the LWP SWMP.

Manganese

Manganese is an element that is considered beneficial to human health at low levels and is one of the least toxic elements. However, elevated levels can cause non-health related effects such as bad taste and staining of clothes and plumbing fixtures. Elevated manganese levels can also cause problems for water distribution systems. Specifically, manganese may cause buildup in water distribution pipes. The relative toxicity of manganese to aquatic life is based on the hardness of the water, but manganese levels of concern to aquatic life are much higher than those present in fall 2022.

As with the average turbidity, the values for total manganese measured in fall 2022 were slightly elevated in general and particularly in the North Fork and sites downstream (Figure 7). This pattern was similar to conditions documented in summer 2022. High levels of turbidity are often associated with high concentrations of dissolved metals. In addition, increased total manganese levels have been associated with the aftereffects of wildfire (Rust et al. 2018). As such, elevated levels in the North Fork are likely due to continued effects of the CPF.

The EPA has a “secondary” standard of 0.05 mg/L (ppm) for total manganese. This level does not make water unsafe to drink, but the water may be aesthetically unpleasing due to a reddish/black/brown color which can stain laundry, plumbing, sinks, and showers. Several of the fall 2022 values were higher than this standard. Although some source water values were above the standard, all treated drinking water results remained below 0.05 mg/L total manganese.

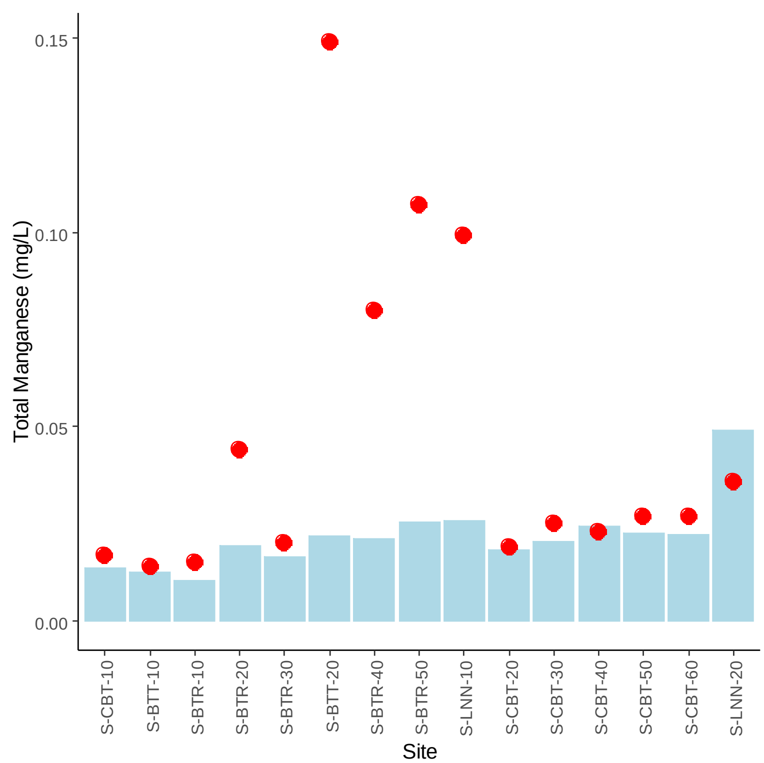

Figure 7. Average dissolved manganese values for the months of August through October 2017-2021 (blue bar) and the 2022 average value (red dot) at sites included in the LWP SWMP.

Copper

Dissolved copper is of interest primarily due to its potential effects on aquatic life. While copper is an essential nutrient, it can cause chronic and acute effects to aquatic life at higher concentrations. Acute effects include mortality; chronic effects include reduced survival, growth, and reproduction. Copper toxicity is determined in part by the hardness of the water. Copper toxicity to aquatic organisms is lower when hardness is higher because dissolved copper is less bioavailable when hardness is high.

Total copper levels continued to be at or below five-year average values in fall 2022 (Figure 8). In part, this circumstance could be due to somewhat lower tree mortality caused by bark beetles in recent years (USDA 2019) which would result in decreased dissolved copper in the Big Thompson River. Tree mortality caused by bark beetles may result in copper, which is naturally taken up and stored by trees, being released into surface water upon their death (Fayram et al. 2019). The fact that tree death resulting from the CPF did not result in an increase in dissolved copper in summer or fall 2022 could be due to the fact that the lack of back beetle mortality more than offset tree deaths caused by the fire or that the predicted increases in copper will only appear after the predicted lag of three years post mortality event (Fayram et al. 2019). If this is the case, copper levels are expected to begin to increase in 2023. Regardless of the cause, lower total copper levels are a positive indication of improving conditions for aquatic communities in the Big Thompson River Watershed. The average fall 2022 value at the S-BTR-40 (Viestenz-Smith Park) site appears to be substantially below the five-year average value, the very high five-year value is driven by a single extremely elevated value for total copper (49.19 ug/L) taken on August 6th, 2019. There were two analyses of this sample and the elevated total copper concentration was confirmed. Total copper samples collected on this date from other locations were not elevated and the cause of this extremely high and isolated value are unknown.

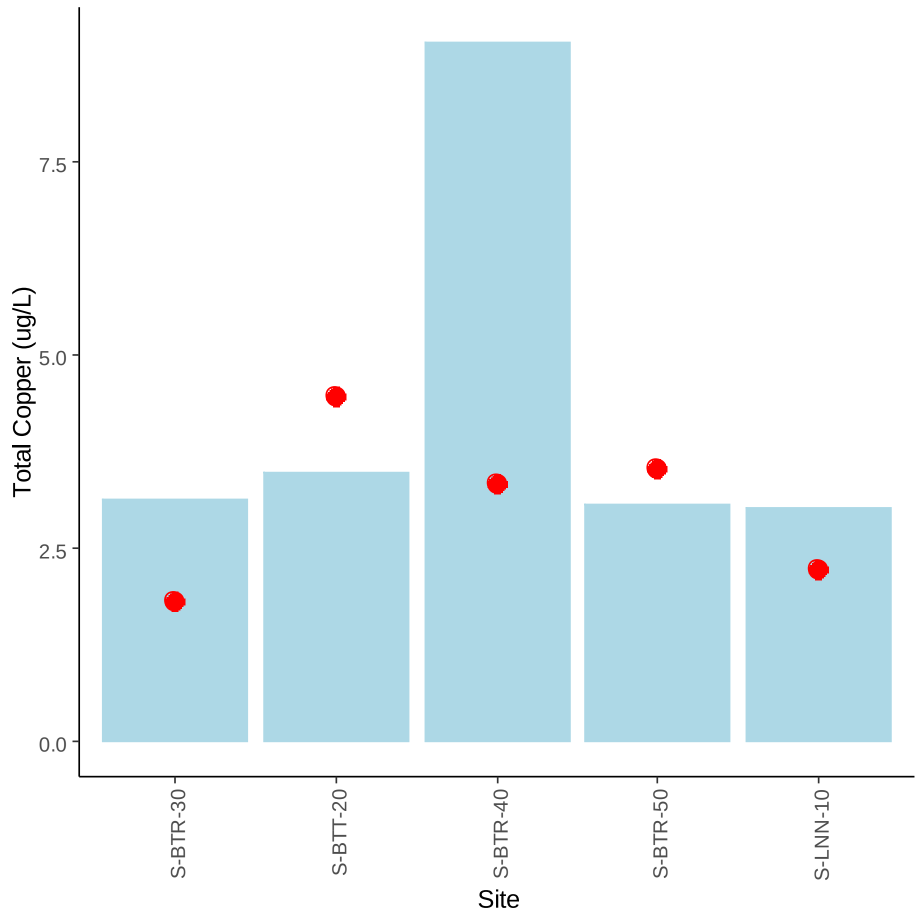

Figure 8. Average total copper values for the months of August through October 2017-2021 (blue bar) and the 2022 average value (red dot) at sites included in the LWP SWMP.

Iron

Iron is common in surface water although it is usually present at levels that are harmless to people and to aquatic life. However, water discoloration and staining issues can occur in water with total iron levels greater than 3,000 ug/L (ppb), and the drinking water standard is a 30-day average value of 300 ug/L (ppb). Detrimental effects to aquatic life can occur when levels of dissolved iron are above 1,000 ug/L (ppb). The levels of dissolved iron that can affect aquatic life are dependent in part on the hardness of the water. Less dissolved iron is necessary to negatively affect aquatic life in water with lower hardness values than in water with higher hardness values.

Average total iron concentrations in fall 2022 were substantially elevated in the North Fork as they were in spring and summer 2022 (Figure 9). However, unlike summer 2022, where elevated values were not apparent at locations downstream of the North Fork, average values in fall 2022 were elevated at locations downstream of the North Fork. This circumstance is likely due to the extremely elevated total iron concentrations at these sites that were documented in August 2022 resulting from a monsoon rain event just prior to sampling. The area in the North Fork watershed above the sampling site was included in the area that was most severely burned during the CPF in Fall of 2020. Increased total iron in waterbodies affected by wildfire is not uncommon. Rust et al. (2018) documented a mean increase in dissolved iron of 179% in waterbodies associated with 159 fires across the western United States. As such, elevated iron levels in the North Fork are expected to continue but decrease in magnitude over the next several years.

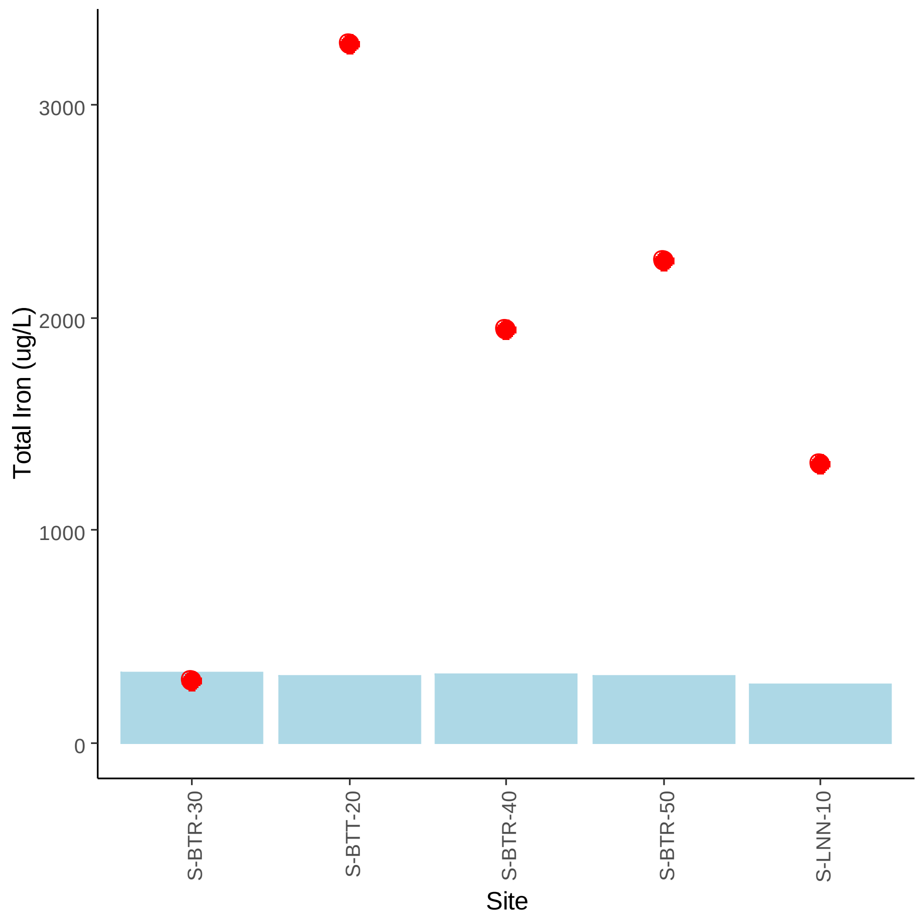

Figure 9. Average total iron values for the months of August through October 2017-2021 (blue bar) and the 2022 average value (red dot) at sites included in the LWP SWMP.

Nitrate

Nitrate and nitrite are of interest due to the role they play in aquatic plant growth and their potential effects on human health. Nitrate, along with ammonia, is a form of nitrogen that is available for immediate uptake by algae and is therefore of interest due to its role in determining the productivity of a given waterbody. At higher concentrations (e.g. >10 mg/L (ppm)), nitrate can be of concern in drinking water, because it can reduce the oxygen-carrying capacity of hemoglobin in humans and create a condition known as methemoglobinemia, particularly in those under two years of age. Nitrite is also available for uptake by algae but is rarely present at significant concentrations.

Nitrate concentrations in fall 2022 continued to be elevated at many sites compared to the five-year fall average values, particularly in the North Fork and at locations immediately downstream (Figure 10). While the elevated values seen in the mainstem and tributaries may be the continuing effects of the Cameron Peak and East Troublesome fires (increased nitrate can be an aftereffect of wildfire (Rust et al. 2018)), the cause of elevated nitrate levels in other locations is less clear.

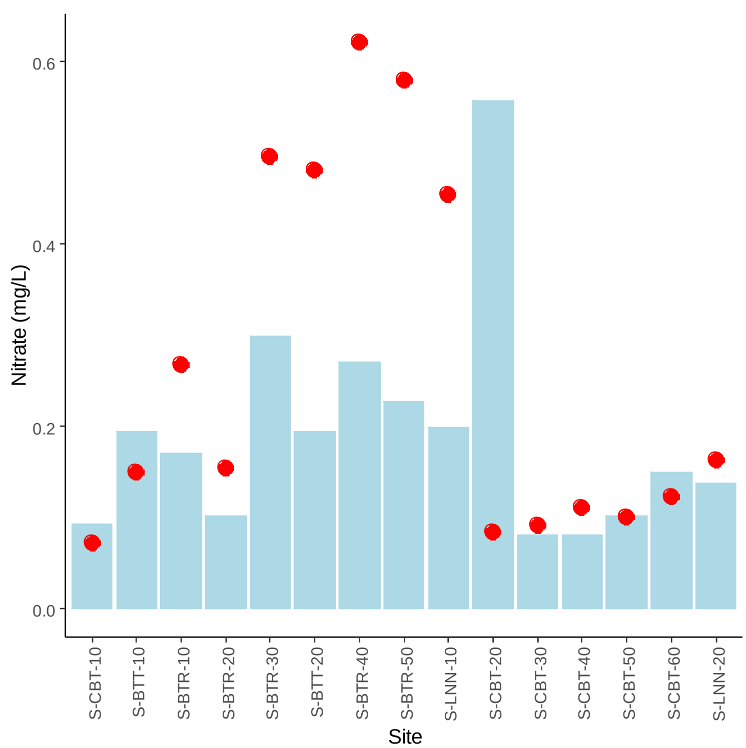

Figure 10. Average nitrate values for the months of August through October 2017-2021 (blue bar) and the 2022 average value (red dot) at sites included in the LWP SWMP.

Orthophosphate

Orthophosphate is a biologically available form of phosphorus and is the only form that is immediately available for uptake by algae. Elevated orthophosphate levels can contribute to algal blooms, taste and odor issues in drinking water supplies, increased densities of toxic algae species, and decreased dissolved oxygen.

Orthophosphate values were elevated in the North Fork as well as locations downstream while concentrations at other locations were near or below five-year average values (Figure 11). Although orthophosphate levels were elevated in the North Fork due to continued effects of the CPF, they were likely particularly so due to the timing of the August 2022 sampling event immediately following a monsoon rain event. In addition, orthophosphate levels in the reservoir sites were below five-year averages which is a positive result with regard to problematic algal blooms that can occur during the summer months.

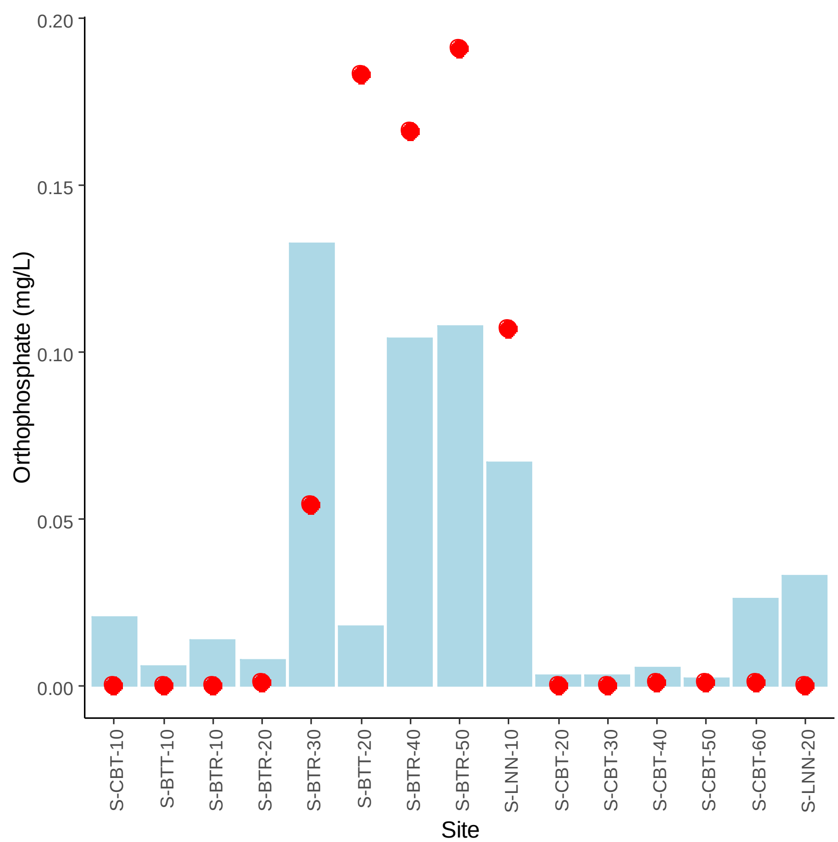

Figure 11. Average orthophosphate values for the months of August through October 2017-2021 (blue bar) and the 2022 average value (red dot) at sites included in the LWP SWMP.

Total Organic Carbon (TOC)

TOC (Total Organic Carbon) is a measure of the amount of dissolved and particulate organic matter in a water sample. Dissolved organic carbon compounds are the result of the decomposition of organic matter such as algae, terrestrial plants, animal waste, detritus, and organic soils. The higher the carbon or organic content of a water body, the more oxygen is consumed as microorganisms break down the organic matter.

Although TOC is not a direct human health hazard, the dissolved portion of the TOC can react with chemicals (chlorine and others) used for drinking water disinfection to form disinfection by-products that are regulated as potential carcinogens (e.g. chloroform $CHCl_3$). As such, TOC levels are of concern to drinking water treatment facilities.

Fall 2022 TOC values were somewhat elevated compared to five-year average values at all sampling locations (Figure 12). TOC values have been increasing in Green Ridge Glade Reservoir over the past several years, but this trend was not apparent in fall 2022. The cause of the somewhat elevated TOC values is unknown. It is important to note that despite these elevated TOC values in source water, TOC values remained low in finished drinking water thanks to treatment processes.

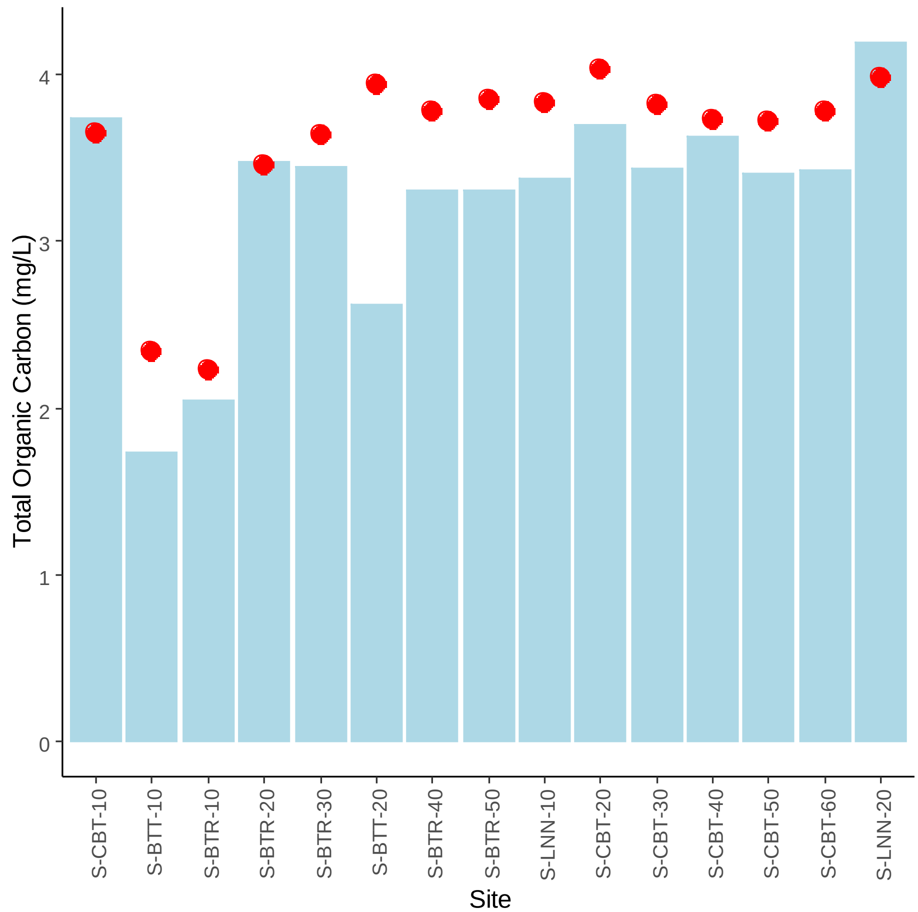

Figure 12. Average total organic carbon values for the months of August through October 2017-2021 (blue bar) and the 2022 average value (red dot) at sites included in the LWP SWMP.

Other Water Quality Parameters of Note

Although the water quality parameters outlined above represent many of the most important or indicative parameters of interest, there are many other parameters that are less frequently of acute interest but can be of general interest particularly if concentrations are notably elevated or depressed. In fall 2022, total chromium was one such parameter, particularly since documented total chromium values were elevated in summer 2022.

Chromium continued to be substantially elevated in fall 2022 compared to the previous five-year period with increases on the order of 500%, even greater than summer 2022 (Figure 13). This increase is likely to be due to continued effects of the CPF as increases of this magnitude have been documented in association with wildfires in the western United States (Rust et al. 2018).

Chromium can have negative effects on human and environmental health. However, background levels of this metal have historically very low and increases in 2022 resulted in concentrations that were still considerably below human health and environmental standards. The drinking water standard for total chromium is 50 ug/L (ppb) and the aquatic life use standards for chromium (VI) are 11 ug/L (ppb) for chronic exposure 16 ug/L (ppb) for acute exposure.

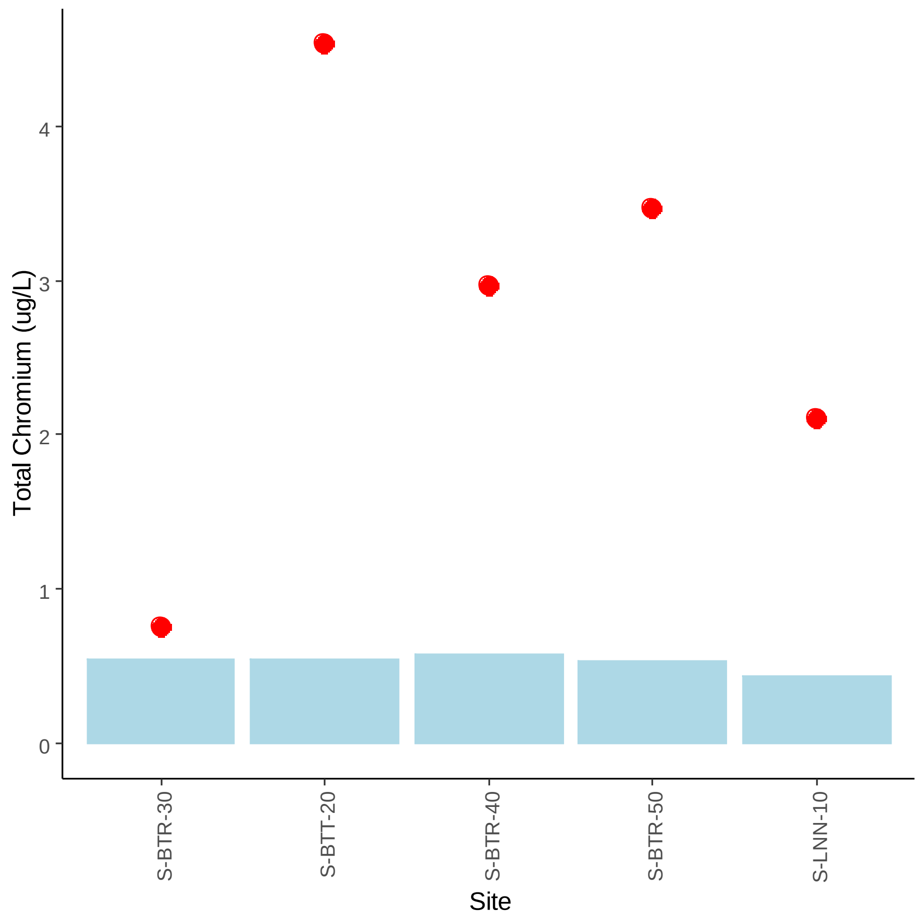

Figure 13. Average total chromium values for the months of August through October 2017-2021 (blue bar) and the 2022 average value (red dot) at sites included in the LWP SWMP.

Conclusions

LWP continued to provide high quality drinking water despite ongoing impacts from the CPF in fall 2022. Fire effects will likely continue for several years and the potential longer-term effects of some, such as increased nutrient levels, are unknown at this time. Elevated nitrate and orthophosphate loading can affect phytoplankton growth in reservoirs, such as Green Ridge Glade Reservoir, in complex ways for years after the loading event. The effect of elevated nitrate on phytoplankton growth depends on a number of factors including the concentration of phosphorus in the sediment (Ma et al. 2021). LWP has attempted to mitigate these effects by partnering with organizations such as the U.S. Forest Service, Big Thompson Watershed Coalition, City of Greeley, City of Fort Collins, Larimer County, Coalition for the Poudre River Watershed, and Ayers Associates to conduct aerial mulching and point mitigation projects in areas affected by the CPF. In August 2022, approximately 600 acres in the Upper Miller Creek Watershed received aerial mulching. An additional 600 acres in the Buckhorn Creek Watershed also received mulch. Point mitigation construction (e.g. catchment basin construction, large wood material stabilization, armored drainage crossings etc.) and sediment removal efforts will occur in spring 2023. These projects are expected to reduce both the duration and severity of water quality impacts in comping years. An additional effort to characterize available nutrients in Green Ridge Glade Reservoir in general as well as in response to the CPF will be made in summer 2023. Sediment samples from various locations in Green Ridge Glade Reservoir will be sampled and analyzed for nutrients as well as other compounds, as well as other compounds. These samples will provide a better understanding of nutrient availably and algal response. However, regardless of concentrations found in the sediments of Green Ridge Glade Reservoir. we expect that watershed restoration efforts, along with natural regenerative processes, will continue to improve water quality in the coming years.

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Office
Loveland Service Center
200 North Wilson Avenue
Loveland, CO 80537
Public Water System Identification
Number: CO0135485
Office Hours: 8 a.m. to 5 p.m.
Monday-Friday

Contact Us
(970) 962-3000
LWPInfo@cityofloveland.org
www.lovelandwaterandpower.org

Loveland Water and Power