Loveland Water and Power

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# Big Thompson River Watershed Source Water Quality Conditions

# Spring 2022

January 17, 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

Spring 2022 was characterized as somewhat warm and dry, particularly compared to spring 2021, with a number of water quality parameters continuing to be affected by the Cameron Peak Fire (CPF) which occurred in fall 2020. In particular, nitrate was elevated in the area of the North Fork of the Big Thompson River (North Fork) although nitrate concentrations at other sites located in the Big Thompson Watershed were elevated as well. The North Fork is located in the most severely burned portion of the watershed. Turbidity, pH, and iron concentrations were also elevated in the North Fork in spring 2022. Each of these parameters causes different concerns with regard to water quality and water treatment but Loveland Water and Power (LWP) staff were able to continue to provide high quality drinking water throughout the summer despite these challenges. While the effects of the Cameron Peak Fire on water quality in the Big Thompson River Watershed are expected to decrease over time, they are also expected to be detectable 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 |

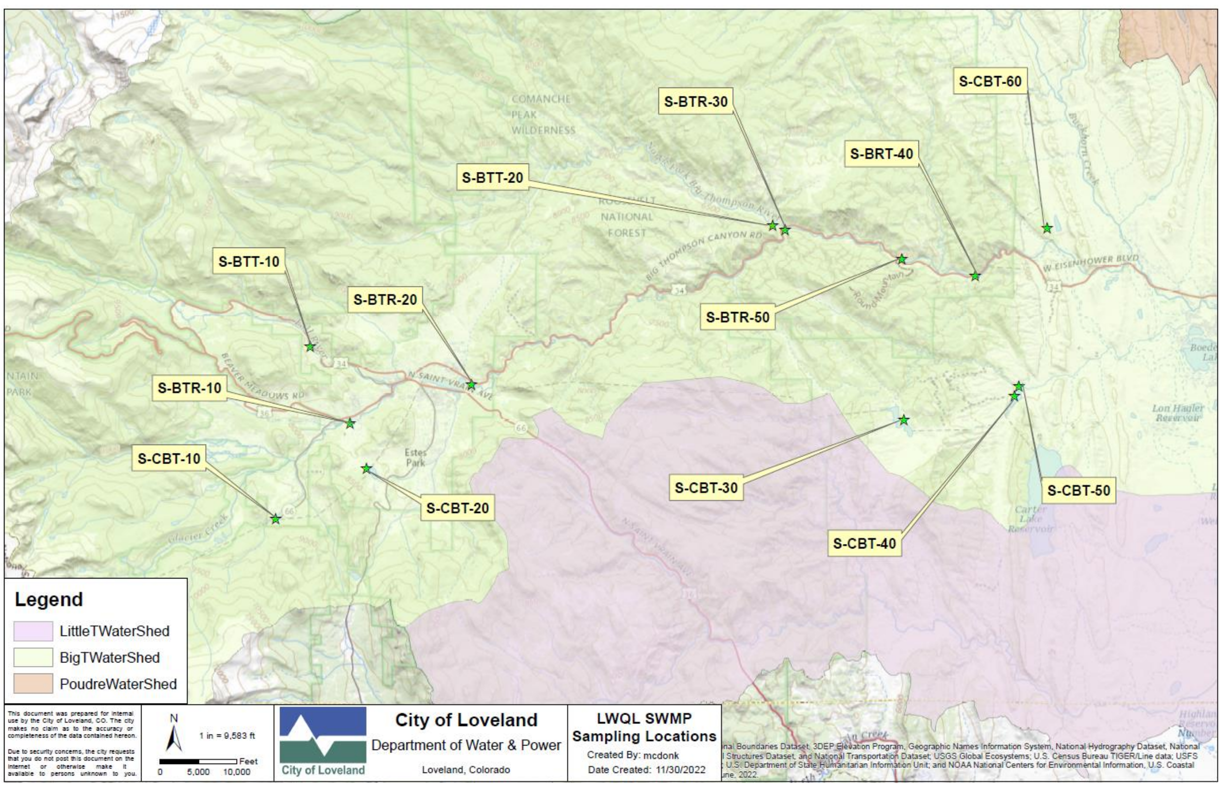


**Figure 1. 2022 Source Water Monitoring Program water quality sampling sites.**

*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, "spring" is defined as the months of February, March, and April. This time period is representative of relatively stable flow conditions prior to 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

Spring 2022 was characterized as somewhat warm with relatively low precipitation, particularly in comparison to spring 2021. The Cameron Peak and East Troublesome Fires continued to impact various water quality parameters including increased pH, dissolved manganese, turbidity, dissolved iron, and nitrate, although to a somewhat lesser degree than in 2021. Increases in manganese, iron, and pH can make water treatment more difficult and can result in taste and odor issues if the water is not treated adequately. While elevated nitrate can have negative health consequences, the levels observed in spring 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. 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 which can be more expensive. Turbidity levels are also positively associated with total organic carbon (TOC) levels which require additional water treatment efforts. These impacts were particularly notable in the area surrounding the North Fork of the Big Thompson River (North Fork), which was the most severely burned area of the

Big Thompson River Watershed. These impacts can be expected to continue for the next several years. Loveland Water and Power Drinking Water Treatment staff were able to continue to provide high quality drinking water despite these impacts, but additional 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.

Precipitation in spring 2022 was somewhat lower than in previous years (Figure 2). However, there was near median snowpack in the Big Thompson River watershed during the winter and early spring. Since flow, water availability for municipal and agricultural use, and aquatic community health all depend to some degree on the amount of precipitation, near median values experienced in 2022 were a welcome reprieve from below normal precipitation in the recent past. However, these increases only resulted in values being near the long-term median value.

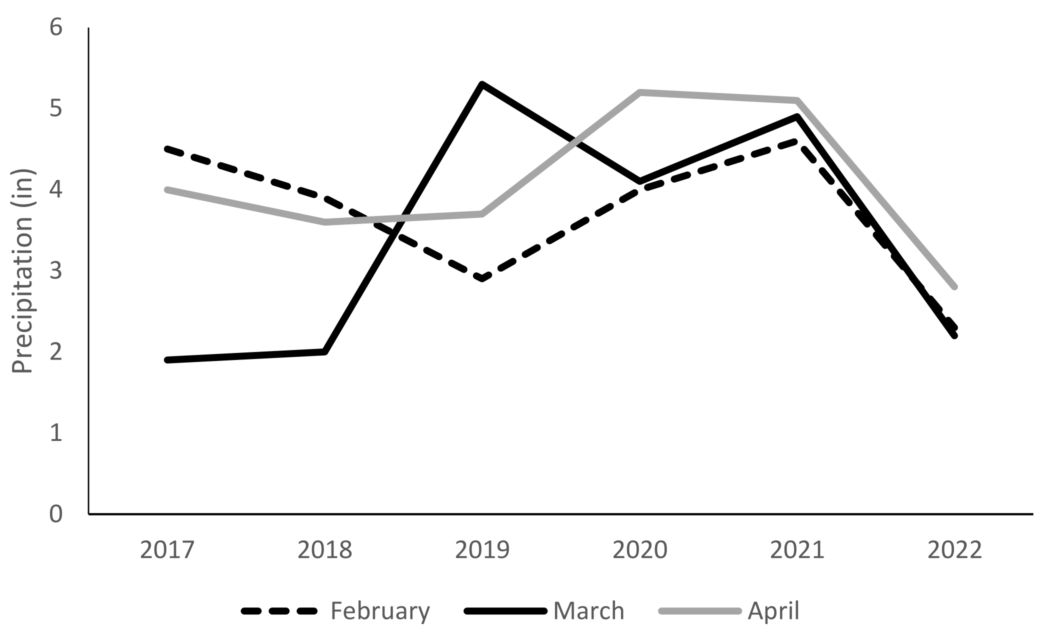


**Figure 2. Monthly precipitation by year at the Bear Lake Natural Resources Conservation Service Snow Telemetry (SNOTEL) station.**

## 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.

Spring 2022 temperatures were somewhat higher than average values in the past five years with the exception of sites located in the upper watershed and in Green Ridge Glade Reservoir (Figure 3). This circumstance aligns with expected increases in temperatures due to climate change in Colorado.

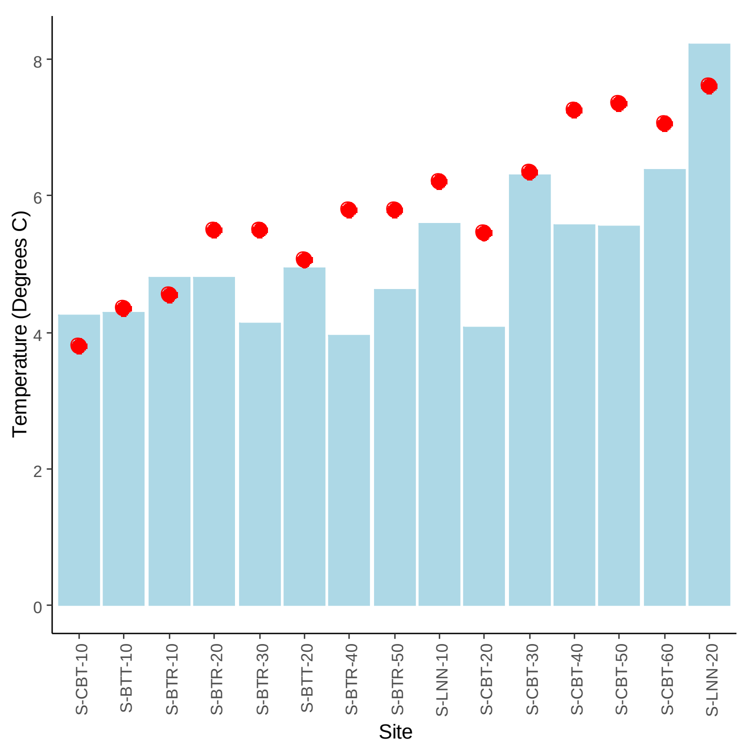


**Figure 3. Average water temperature values for the months of February through April 2017-2021 (blue bar) and the 2022 average value (red dot) at sites included in the LWP SWMP.**

## 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 spring of 2022 were near average values for most locations although levels were considerably higher in the North Fork and considerably lower in sites located near the canyon mouth (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 Cameron Peak Fire in Fall of 2020. Increased turbidity resulting from the aftereffects of wildfire can persist for a number of years and the elevated turbidity level in the North Fork is likely due to the continued effects of the wildfire. The turbidities measured in Spring 2022 in the sites near the canyon mouth are relatively low likely due to very high turbidities that occurred during highway 34 construction activities near Drake, CO in March of 2018, which increased overall average values.

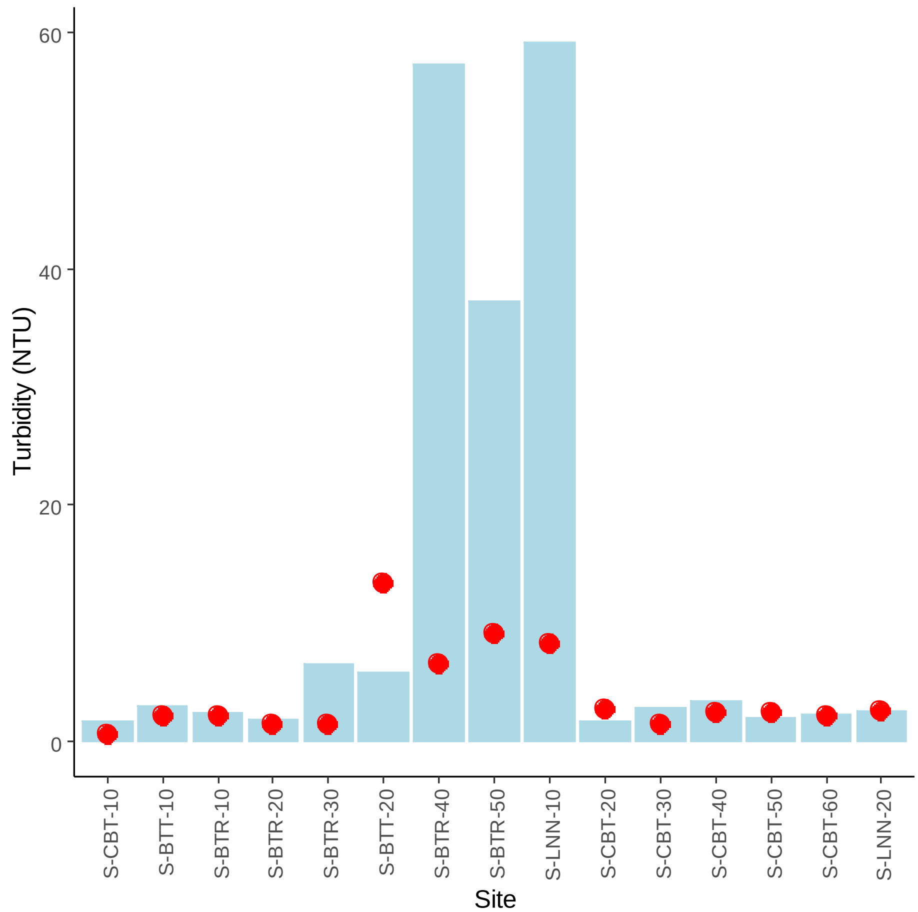


**Figure 4. Average turbidity values for the months of February through April 2017-2021 (blue bar) and the 2022 average value (red dot) at sites included in the LWP SWMP.**

## 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 slightly elevated for virtually all sites in spring 2022 (Figure 5). Higher pH values mean that the water was more basic in 2022 than in previous years. While these increases seem to be modest, pH is measured on a log scale so that a pH increase of one is actually equivalent to the water being 10 times more basic. White ash from wildfires is generally fairly basic. Since all of the sites continue to receive some amount of ash from either the

Cameron Peak Fire or the East Troublesome Fire, it is reasonable to expect pH levels to be somewhat higher than historic values for several years. Although the pH values were somewhat elevated in 2022, none of the values exceeded standards set to protect aquatic life.

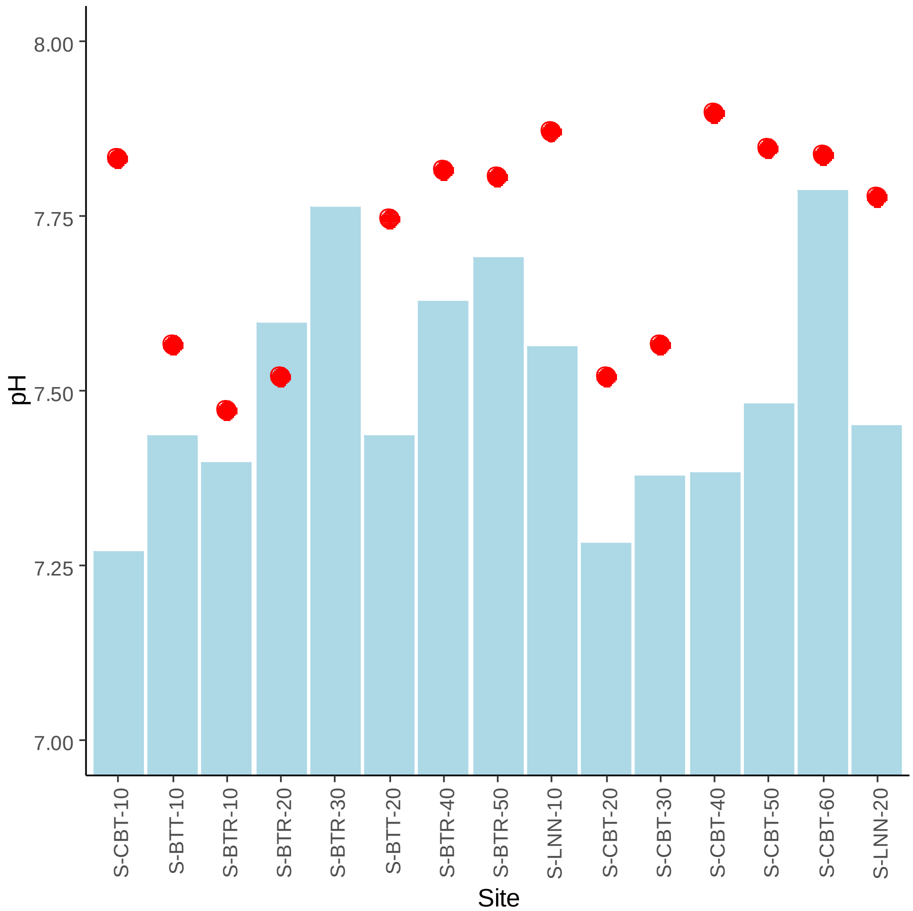


**Figure 5. Average pH values for the months of February through April 2017-2021 (blue bar) and the 2022 average value (red dot) at sites included in the LWP SWMP.**

## 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.

Spring 2022 dissolved oxygen levels were near historic averages across sites (Figure 6). All values were substantially above standards associated with aquatic life which is a positive indication for aquatic ecosystems in the Big Thompson River Watershed.

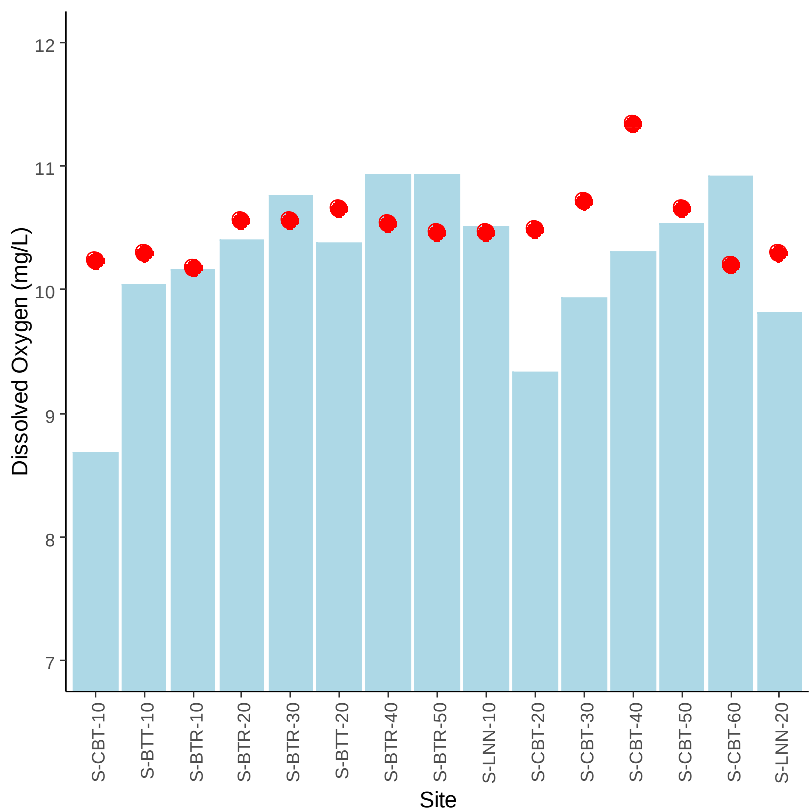


**Figure 6. Average dissolved oxygen values for the months of February through April 2017-2021 (blue bar) and the 2022 average value (red dot) at sites included in the LWP SWMP.**

## 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.

Differences between average values in spring 2022 and average spring values over the previous five years were relatively small.  However, increases in alkalinity generally seemed to occur in reservoirs associated with the CB-T system while decreases occurred primarily in the mainstem of the Big Thompson River and its tributaries.

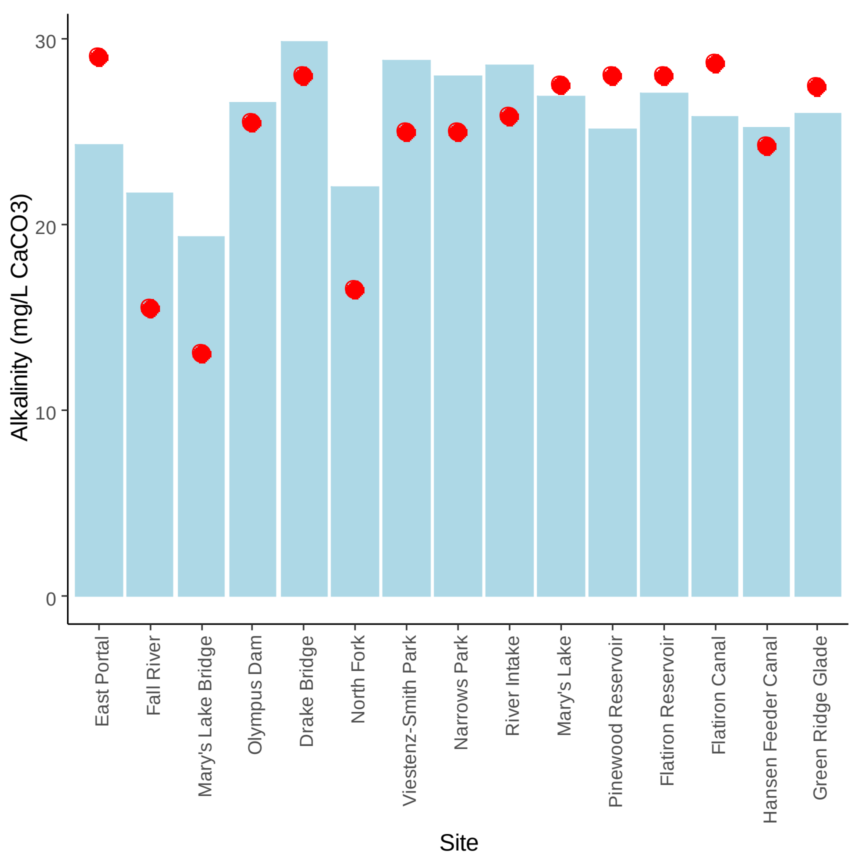


**Figure 7.  Average alkalinity values for the months of February through April 2017-2021 (blue bar) and the 2022 average value (red dot) at sites included in the LWP SWMP.**

## 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 the Big Thompson River.

As with the average turbidity levels measured in spring of 2022, the values for dissolved manganese measured in spring 2022 in the sites near the canyon mouth (Figure 7) are lower than average, likely due to very high turbidities in March of 2018 as a result of highway 34 construction activities near Drake, CO. High levels of turbidity are often associated with high concentrations of dissolved metals. In addition, increased dissolved manganese levels have been associated with the aftereffects of wildfire. As such, elevated levels in the North Fork are likely due to continued effects of the Cameron Peak Fire.

The EPA has a "secondary" standard of 0.05 mg/L (ppm) for dissolved 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. None of the average spring 2022 values were higher than this standard.

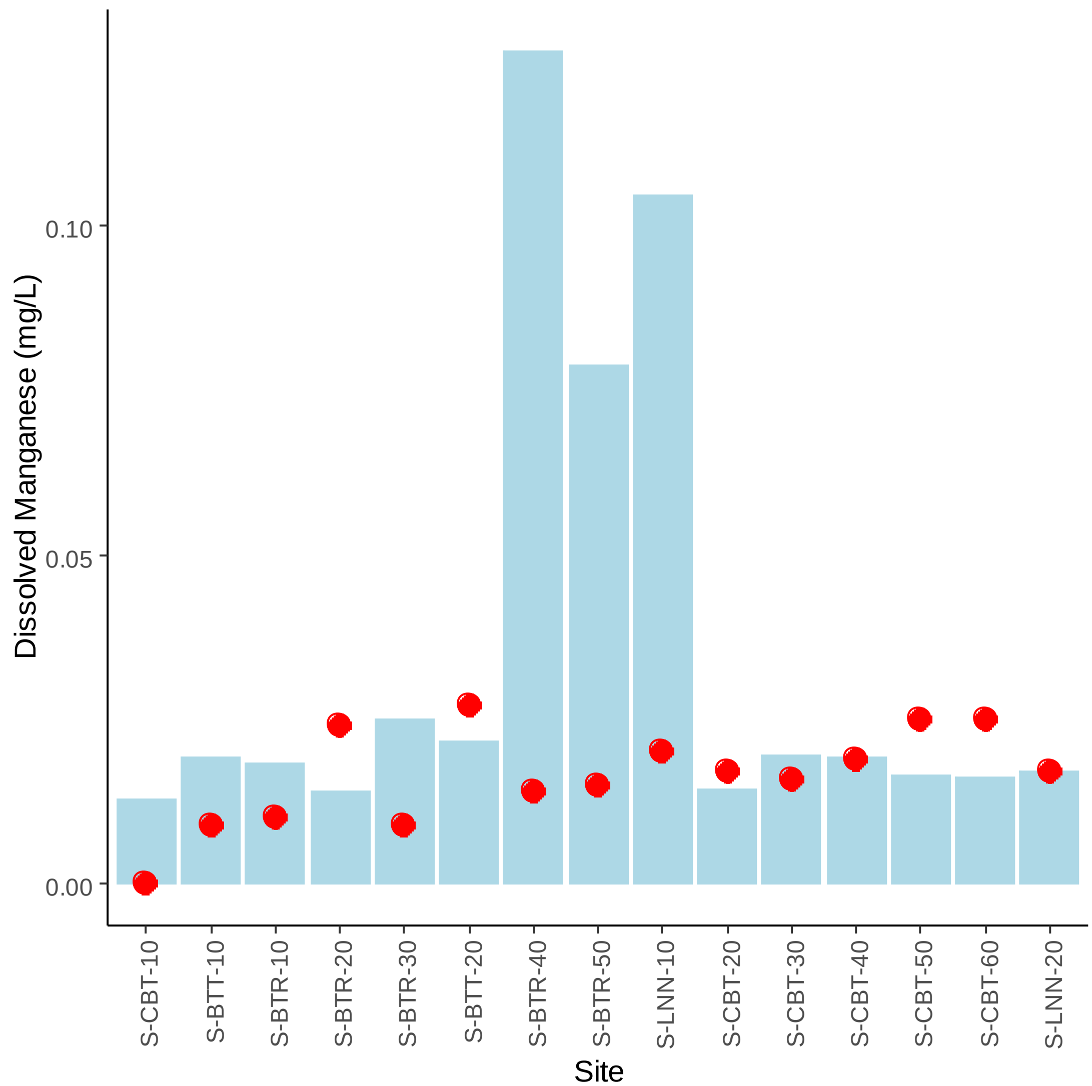


**Figure 7. Average dissolved manganese values for the months of February through April 2017-2021 (blue bar) and the 2022 average value (red dot) at sites included in the LWP SWMP.**

## 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.

Dissolved copper levels were generally near or substantially below five-year average values in spring 2022 (Figure 8). In part, this 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). Regardless of the cause, lower dissolved copper levels are a positive indication of improving conditions for aquatic communities in the Big Thompson River Watershed.

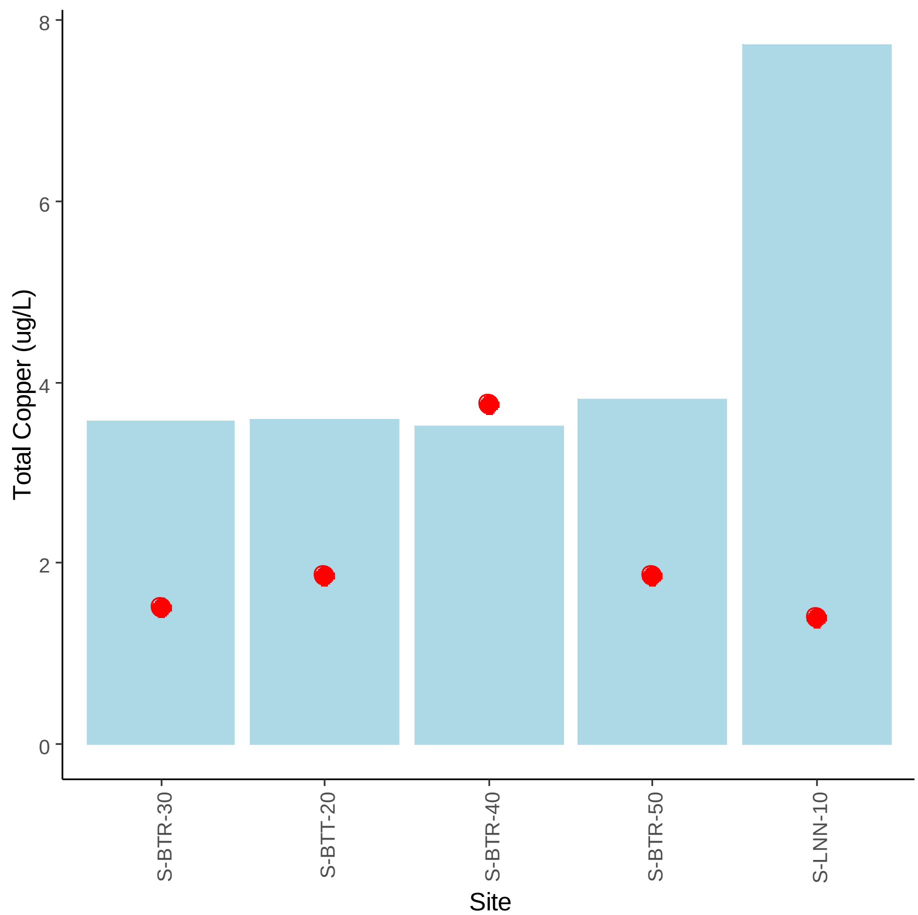


**Figure 8. Average dissolved copper values for the months of February through April 2017-2021 (blue bar) and the 2022 average value (red dot) at sites included in the LWP SWMP.**

## Iron

Dissolved 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 dissolved iron levels greater than 3000 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 1000 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 dissolved iron concentrations in spring 2022 were somewhat elevated in the North Fork and downstream to Viestenz-Smith Park compared to the five-year historic average (Figure 9). The area in the North Fork watershed above the sampling site was included in the area that was most severely burned during the Cameron Peak Fire in Fall of 2020.  Increased dissolved iron resulting from the after effects of wildfire can persist for a number of years and the elevated dissolved iron level in the North Fork likely due to the continued effects of the wildfire.

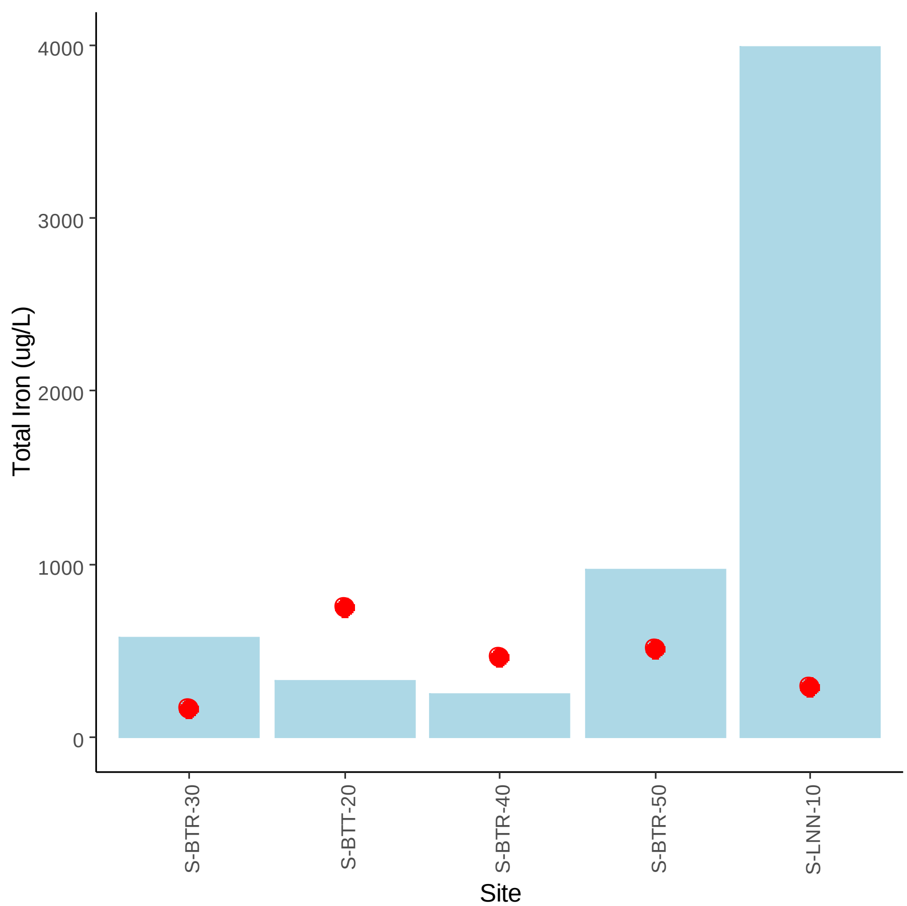


**Figure 9.  Average dissolved iron values for the months of February through April 2017-2021 (blue bar) and the 2022 average value (red dot) at sites included in the LWP SWMP.**

## 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.

Spring 2022 nitrate concentrations were generally elevated, compared to the five-year spring average values, at most sites in the mainstem of the Big Thompson River and its tributaries while concentrations in the reservoirs were near average (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 after effect of wildfire), it is possible that water in the reservoirs may have lower nitrate values due to the longer water residence time. In the reservoir environment, particulate nitrate would have longer to settle out and dissolved nitrate would have a longer period of time to be taken up by plants and phytoplankton.

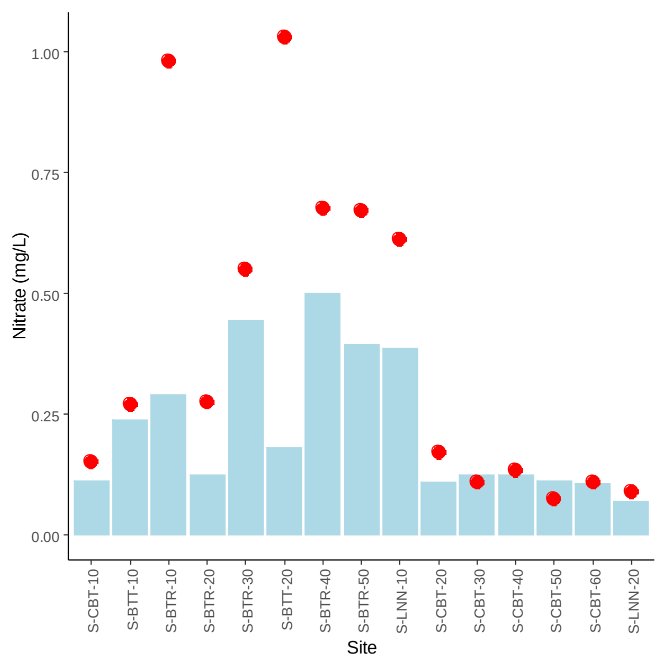


**Figure 10. Average nitrate values for the months of February through April 2017-2021 (blue bar) and the 2022 average value (red dot) at sites included in the LWP SWMP.**

## 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 CHCl3). As such, TOC levels are of concern to drinking water treatment facilities.

Spring 2022 TOC values were near five-year average values (Figure 11). A notable exception is in Green Ridge Glade Reservoir where values were somewhat high in 2022. TOC values have been increasing in Green Ridge Glade Reservoir over the past several years. While the exact cause of this increase is unknown, the age of the reservoir and the connection to a wetland on the north side of the reservoir are potential contributors.

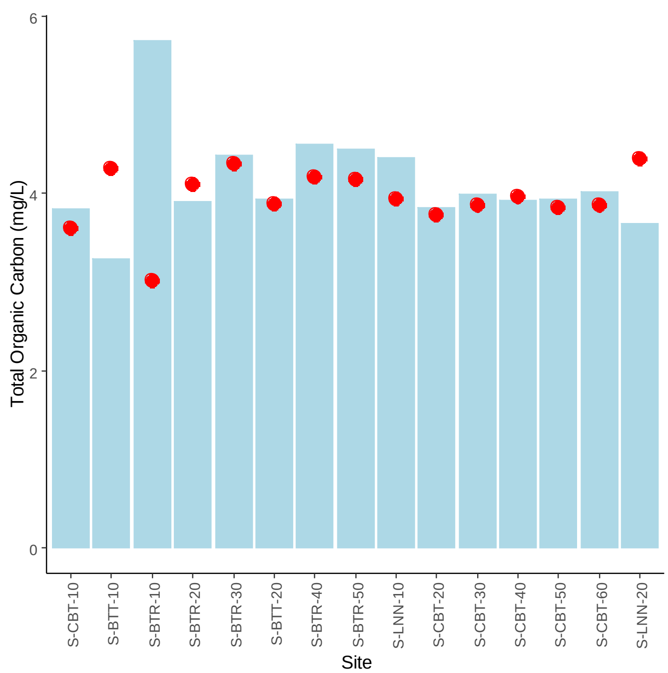


**Figure 11. Average total organic carbon values for the months of February through April 2017-2021 (blue bar) and the 2022 average value (red dot) at sites included in the LWP SWMP.**

# Conclusions

LWP continued to provide high quality drinking water despite ongoing impacts from the CPF in spring 2022. Fire effects will likely continue for several years and the potential effects of some, such as increased nitrate levels, are unknown at this time. LWP is attempting 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, and to construct aerial mulching and point mitigation projects in affected areas. Although water quality continued to be relatively good despite fire effects, we expect that these efforts, along with natural regenerative processes, will result in improved water quality in the coming years.

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