Loveland Water and Power

Loveland Water and Power

Big Thompson River Source Water Quality

2021 Annual Report

January 17, 2023

Contents

Common Acronyms

BTWF	Big Thompson Watershed Forum
CFS	Cubic Feet per Second
CPF	Cameron Peak Fire
CSWMP	Cooperative Source Water Monitoring Program
DO	Dissolved Oxygen
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
USGS	United States Geological Survey

Executive Summary

In general, the Big Thompson River continues to be a quality drinking water source for the City of Loveland, CO. Water quality in 2021 improved in some areas compared to recent years and some parameters also demonstrated continued improvement, as suggested by significant trends, over the past decade. 2021 also demonstrated some negative effects of the Cameron Peak Fire (CPF) and declining water quality with regard to some water quality parameters. While there were some negative water quality impacts from the CPF, Loveland Water and Power (LWP) staff were able to utilize drinking water sources and treatment to effectively manage these effects.

In 2021, the cooperative source water monitoring program (CSWMP) between Loveland Water and Power and the United States Geological Survey collected samples that provided information on 46 different water quality parameters, representing a variety of different aspects of water quality, from nine locations within the Big Thompson River watershed. Sampling occurred from February through November and sampling has also occurred at these locations for more than 20 years. This long time series and relatively broad range of parameters provides a good understanding of the state of water quality as well as changes over time.

Water quality was affected by the CPF particularly during the summer monsoon season and in the most severely burned portion of the watershed surrounding the North Fork of the Big Thompson River (North Fork). Water quality parameters including some metals, nutrients, and total organic carbon, were all substantially elevated during the spring runoff and summer monsoon season (May-September) particularly in the North Fork sampling location and these elevated values continued downstream below the confluence with the mainstem. These increases can be seen in the comparison of 2021 median values (February-November) to values documented in the previous years as well, although the effects are less clear due to the facts that median values reduce extreme events and most of the elevated values occurred only during the summer.

There were a number of parameters that were somewhat better in terms of water quality than the previous five-year period and some that were somewhat worse. Improvements in 2021 included: 1) relatively low concentrations of copper across sites, 2) low nitrate + nitrite concentrations at all sites except in the North Fork, and 3) very low orthophosphate concentrations, particularly at the site below the LWP Water Reclamation Facility discharge. Water quality also declined in 2021 with regard to some parameters including: 1) somewhat elevated total organic carbon concentrations above and at the LWP drinking water intake, 2) relatively low dissolved oxygen levels below the LWP Water Reclamation Facility outfall, 3) generally high turbidity across sites, and 4) elevated dissolved manganese concentrations in the North Fork and downstream of its confluence with the mainstem. Levels of some other parameters, while not necessarily considered positive or negative in their own right, were of note including: 1) elevated pH at the site near the Dille Diversion Tunnel, 2) somewhat low pH at the site below the LWP Water Reclamation Facility outfall, and 3) somewhat elevated alkalinity. Also of note is the fact that water temperature values seemed to be approximately average in 2021 compared to the previous 10 years despite the fact that 2021 was the fourth hottest year on record in Colorado (NCEI 2022). However, recent years have also been relatively hot compared to historical temperatures.

A number of water quality parameters demonstrated significant positive or negative trends at particular sites or portions of the river over the past decade. Dissolved copper concentrations decreased significantly across all sites with the exception of the site within Rocky Mountain National Park. These declines could be in part due to the fact that tree mortality associated with bark and pine beetles has decreased somewhat in the past decade (Fayram et al. 2019). Orthophosphate also declined significantly at several sites including those below the outfalls from the Thompson Sanitation District and the LWP Water Reclamation Facility. The Thompson Sanitation District has made several improvements over the past decade and the LWP Water Reclamation Facility installed a biological nutrient removal system in 2018. pH values have declined in several sites on the mainstem of the Big Thompson River. The cause of this decline is unknown. Finally, dissolved sodium has increased significantly in several sites in the Big Thompson River Canyon. This increase is potentially caused by the continued use of sodium chloride to improve driving conditions in the winter months.

Introduction

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 and 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 cooperative source water monitoring that occurs in partnership with the United States Geological Survey (CSWMP). The United States Geological Survey (USGS) is recognized as one of the world leaders in water quality data collection, analysis, and data storage. USGS has participated in data collection efforts in the Big Thompson River for over 20 years and its database includes a wide range of water quality parameters. Sites were previously sampled as a result of a cooperative agreement between the Big Thompson Watershed Forum (BTWF) and the USGS. Loveland Water and Power was a substantial contributor to the BTWF. The BTWF ceased data collection efforts in 2020. LWP, recognizing the importance of this dataset and its continuity, assumed the partnership role with the USGS in 2021. This partnership assured the continuation of important water quality data collection and allowed the efforts to better reflect the needs of LWP. The USGS collects and analyzes a subset of water quality samples as requested by LWP Water Quality Laboratory

Staff. Resulting data are statistically analyzed and summarized as appropriate to address water quality questions and issues of interest to LWP.

Historic USGS water quality data in the Big Thompson River are substantial in breadth and depth. For over 20 years, more than 40 parameters have been collected on a monthly basis from 9-15 core sites within the watershed. The fact that these data are standardized, easily available (https://www.waterqualitydata.us/), have a long time series, and include a large number of parameters, provides opportunities to quantitatively evaluate long term trends (e.g. Stets et al. 2020, Stevens 2003), investigate potential causes of changes in water quality (e.g. Fayram et al. 2019, Voelz et al. 2005), be included in broad-scale investigations that may be of local utility (Spahr et al. 2010, Kaushal et al. 2018), and characterize changes to water quality in response to management actions or natural events (e.g. Mast et al. 2016). The diversity of parameters sampled increases the likelihood that long-term historical data will exist to examine the status of various river segments with regard to new or changing regulations or circumstances. The ready access of current and historic data means that more people will be examining and utilizing Big Thompson River Watershed information. The greater the exposure, the higher the likelihood that analyses relevant to LWP and the watershed as a whole will take place.

Scope

Data, summary statistics, and results presented are those collected and analyzed by USGS staff at the direction of LWP (and previously BTWF) over the past 10 years. While the 10-year time period is an arbitrary length of time, it is long enough for significant trends to emerge, or begin to emerge, and also short enough to adequately reflect current ambient conditions. The annual sampling frequency of these data is 10 months/year (February-November) as this follows the historical data collection schedule. This frequency is also sufficient to capture seasonal events and is representative of annual conditions in general (Giardullo 2006). The objective of this annual report is to summarize CSWMP data collected in 2021, compare sample results to established water quality standards and comparable data collected over the past 10 years, and to quantify any significant temporal trends in water quality parameters which may exist. Results can aid in identifying emerging water quality issues, which can in turn be used to begin developing appropriate water treatment and watershed management activities.

Sampling Locations

The CSWMP includes nine core sites located from the headwaters of the Big Thompson River in Rocky Mountain National Park to the plains portion of the watershed past the City of Loveland (Figure 1, Table 1). Cumulatively, these sites provide an opportunity to understand the condition of the watershed as a whole. In addition, each sampling location has site specific characteristics of interest. For example, downstream or upstream of the LWP wastewater discharge.

Table 1. USGS Cooperative Surface Water Monitoring Program location descriptions.

Site	Water Body	Description	Latitude	Longitude
M10	Big Thompson River	Downstream of Moraine Park USGS Benchmark Site	40 21’ 14”	105 35’ 01”
M30	Big Thompson River	Downstream of Moraine Park USGS Benchmark Site	40 21’ 14”	105 35’ 01”
M50	Big Thompson River	Downstream of Moraine Park USGS Benchmark Site	40 21’ 14”	105 35’ 01”
M60	Big Thompson River	Downstream of Moraine Park USGS Benchmark Site	40 21’ 14”	105 35’ 01”
M70	Big Thompson River	Downstream of Moraine Park USGS Benchmark Site	40 21’ 14”	105 35’ 01”
M90	Big Thompson River	Downstream of Moraine Park USGS Benchmark Site	40 21’ 14”	105 35’ 01”
M130	Big Thompson River	Downstream of Moraine Park USGS Benchmark Site	40 21’ 14”	105 35’ 01”
M140	Big Thompson River	Downstream of Moraine Park USGS Benchmark Site	40 21’ 14”	105 35’ 01”
T10	North Fork Big Thompson River	Downstream of Moraine Park USGS Benchmark Site	40 21’ 14”	105 35’ 01”

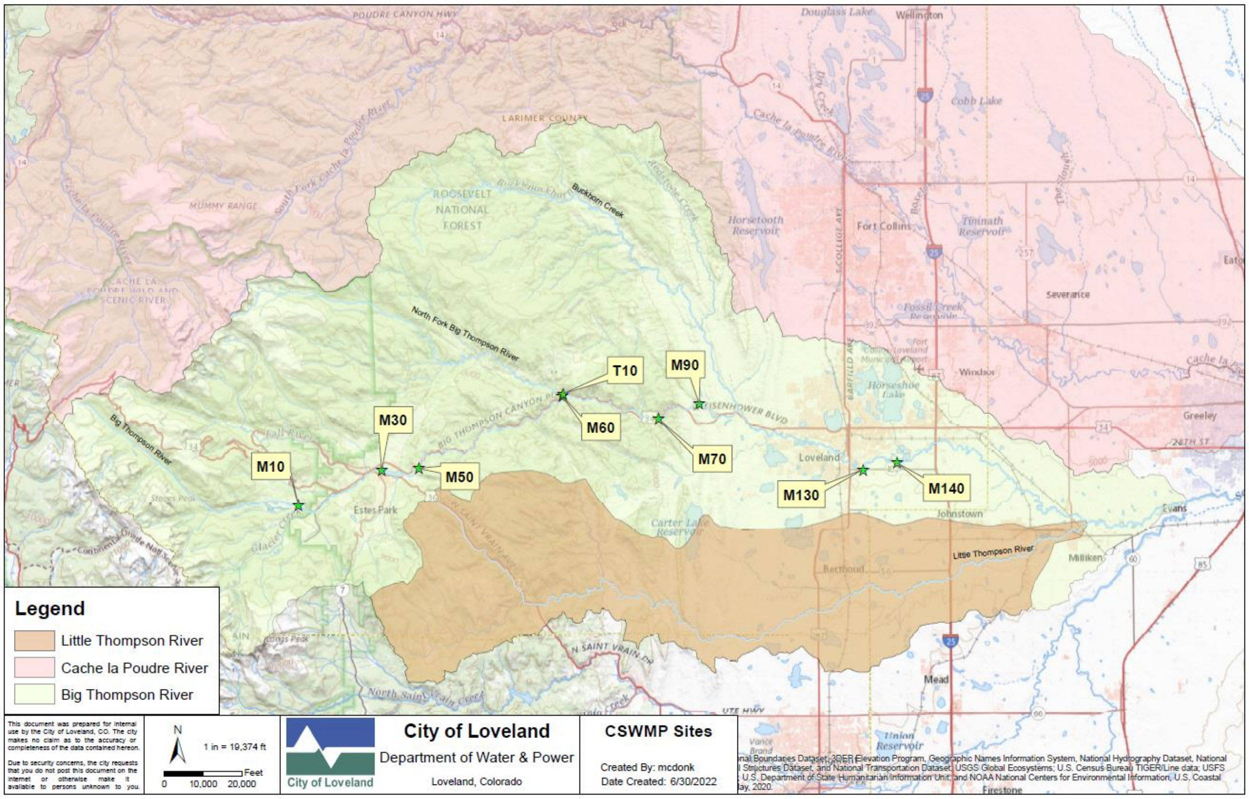


Figure 1. USGS Cooperative Surface Water Monitoring Program locations.

The sampling locations included in this report are those that have a long history of data collection as well as a specific rationale for inclusion. However, the USGS has historically collected water quality information at 37 sites within the Big Thompson Watershed and the eastern slope portion of the Colorado-Big Thompson Project. Data collected from some of the discontinued sites were collected for a specific short-term purpose and others were discontinued due to budgetary and/or logistic constraints.

Cameron Peak Fire

The Cameron Peak Fire (CPF) occurred between August 13th, 2020 and December 2nd, 2020 and burned 208,913 acres, of which 65,275 acres (31%) was in the Big Thompson River Watershed (Figure 2). In total 12% of the watershed was burned. Wildfires can have negative impacts on a wide array of water quality parameters and some of these parameters are of particular interest to water providers as they can negatively impact the drinking water supply. The impact of the fire was large enough to result in negative water quality impacts but was small enough that the LWP Water Treatment Plant was able to successfully adjust and treat the water and continue to provide safe and clean drinking water. However, additional costs were incurred.

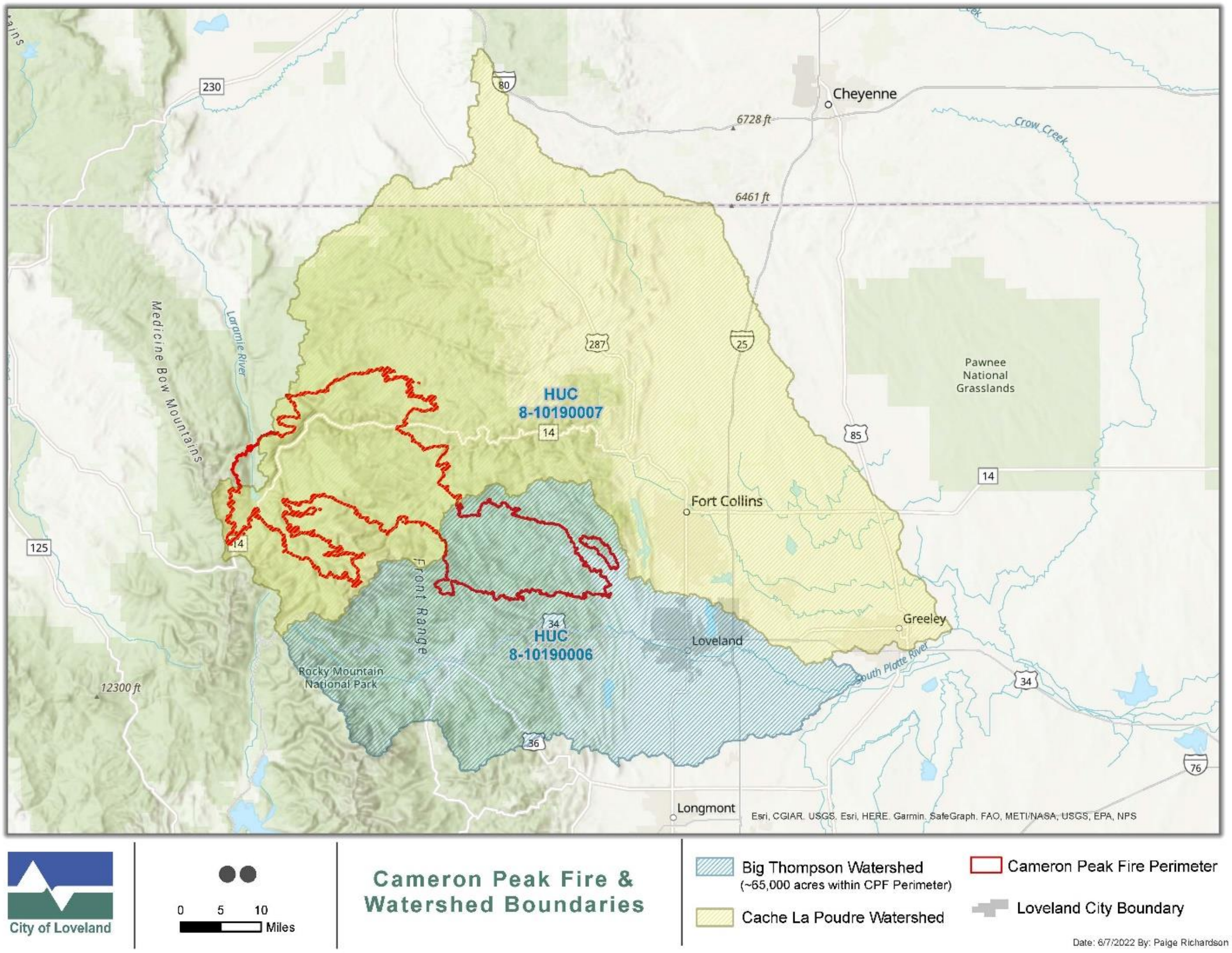


Figure 2. Cameron Peak Fire perimeter in the context of the Cache la Poudre and Big Thompson River Watersheds

A number of substantial water quality changes in the Big Thompson River in 2021 were associated with the CPF. Rust et al. (2018) compiled water quality responses to wildfire by collecting information on 159 different fires in the western United States to examine generalities in water quality response to wildfire. A number of changes in water quality documented by Rust et al. (2018) were reflected in the lower portion of the Big Thompson River (sites M70 and M90) and also in the North Fork of the Big Thompson River (North Fork) (T10). Conversely, some apparent water quality effects observed in 2021 were not predicted in Rust et al. (2018) which is not unexpected since water quality effects of wildfire are very watershed specific and there are also always other activities that can affect water quality that occur concurrently with wildfires.

Water quality effects from the wildfire are expected to persist for five or more years (Rust et al. 2018), particularly during summer monsoon events.

Water quality parameter summaries are often expressed in terms of median values for comparison to reduce the influence of seasonal effects and outliers which are common in water quality data sets. However, mean values are also of interest if minimum or maximum values were extreme for a particular time period, as might be expected after a wildfire.

Water quality effects of wildfire are most likely to occur in spring and summer months during runoff and monsoon rain events. To begin to quantify some effects of the CPF on water quality in the Big Thompson River Watershed, average spring/summer (May-September) values were compared to mean responses documented by Rust et al. (2018) and to values measured in 2020. Parameters included were those that Rust et al. (2018) documented as being relatively common (significant changes occurred in at least 25% of cases examined). Also included were any parameters with observed values that were greater than any values recorded in the previous five-year period. The most dramatic effects occurred in the most severely burned area in the North Fork watershed and as such values from the sampling location in the North Fork (T10) as well as two sites downstream of the confluence with the mainstem (M70 and M90) were included.

Average values from a number of parameters were substantially increased in the North Fork (T10) as well as the mainstem downstream of the North Fork (M70 and M90) in 2021 (Table 2) and were likely associated with the CPF although other activities (e.g. land use) may have contributed as well. These increases can often be seen when examining median values as well but their magnitude is not as clear. Nutrients, some metals (with the exception of dissolved copper), and total organic carbon concentrations were much higher in the North Fork than in previous years. These effects were seen downstream of the confluence of the North Fork with the mainstem (sites M70 and M90) although dilution reduced the magnitude of the increases.

Table 2. Percent change pre- and post-fire in water quality parameters from Rust et al. (2018) that occurred in at least 25% of fires examined, the magnitude of the average change, and the change observed between 2020 and 2021 at sites M90, M70, and T10. Asterisks represent the fact that 2021 value was the highest value recorded in the previous 5 years.

Parameter	Rust et al. (2018)	M90	M70	T10
Phosphorus, Total	266%	35%*	38%*	304%*
Organic Nitrogen, Total	150%	59%*	50%*	642%*
Nitrate + Nitrate, Dissolved	64%	60%*	30%	91%*
Arsenic, Total	51%	10%*	23%*	116%*
Ammonia + Organic Nitrogen, Total	43%	33%*	37%*	126%*
Organic Carbon, Total	43%	15%	17%	37%
Mangansese, Dissolved	37%	13%	53%*	125%*
Total Nitrogen, Total	36%	44%*	34%*	114%*
Orthophosphate, Dissolved	32%	12%	-5%	575%*
Magnesium, Dissolved	26%	12%	14%*	42%*
Specific Conductance	23%	20%*	21%*	40%*
Sodium, Dissolved	6%	18%*	18%*	25%*
Sulfate, Dissolved	0.4%	31%*	38%*	65%*
Copper, Dissolved	-2%	-9%	-2%	-1%
Bicarbonate (Hardness)	-11%	12%*	14%*	36%*
Nickel, Disissolved	-15%	46%*	35%*	47%*
Lead, Dissolved	-27%	40%	40%	208%*

Turbidity events associated with the fire became evident in 2021, particularly associated with the burned area of the North Fork Watershed. Early in July 2021, flooding in the Black Creek/Miller Fork area of the North Fork of the Big Thompson Watershed caused increased turbidity which forced LWP to close the drinking water intake from the Big Thompson River and utilitze water from Green Ridge Glade Reservoir instead. The precipitation gage at the Dunraven Trailhead near Glen Haven recorded 0.5 inches of over several hours in the afternoon/evening of Thursday July 1st and 0.4 inches of rain over several hours in the afternoon/evening of Friday July 2nd. Turbidity in the Big Thompson River near the water intake spiked to 342 NTU on the evening of July 2nd and remained elevated for several days (Figure 3). Similarly, shorter but still intense storms on July 13th-14th (0.16 inches) and July 23rd-24th (0.19 inches) caused turbidity spikes (Figure 2).

The Black Creek/Miller Fork area was identified as an “Area of Greatest Concern” as well as being identified as “suitable for treatment” (i.e. moderate slope, high to moderate soil burn severity, and not bare ground) in Cameron Peak Fire Risk Assessment (Larimer County 2021). Flooding in Black Creek/Miller Fork overtopped many culverts and washed-out roads in several locations. To help mitigate these effects, LWP partnered with the City of Greeley and the Big Thompson River Coalition to provide mulch to cover 754 acres of the most severely burned portion of this area. In 2022, similar efforts are ongoing, with assistance from the United States Forest Service, to provide mulch to a similar area of appropriate burned locations. If additional rainfall occurs in this area, similar water quality impacts can be expected in 2022 and for the next several years (although with declining intensity).

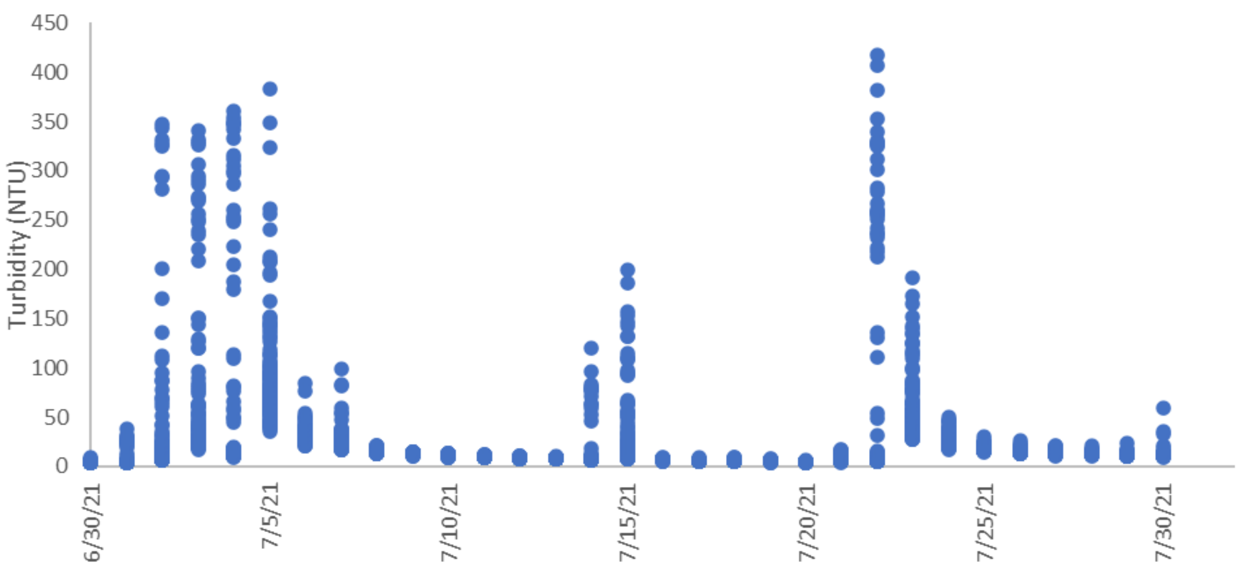


Figure 3. Turbidity measurements from LWP real-time monitoring station at Narrows Park below the confluence with the North Fork of the Big Thompson River between July 1st and July 30th, 2021.

The staff at LWP Water Treatment Plant were able to continue to provide water that meets and exceeds all relevant standards despite wildfire effects. The fact that water quality effects of the CPF were visible but also manageable provides the opportunity to prepare for likely effects of the next wildfire which may be more severe. LWP has partnered with USGS Research staff to utilize long term data from stations in the most severely burned areas to develop models that are intended to quantify the magnitude of changes in various water quality parameters that can be attributed to the CPF. With these models and available data, LWP can better prepare to respond to inevitable fire activity within the Big Thompson River Watershed.

Methods

Parameter Summaries

Each year, at least 42 different water quality parameters (Table 3) are quantified from water samples collected at nine sites in 10 months of the year. An additional four parameters are collected only at specific sites due to regulatory requirements (e.g., nitrite) or site-specific conditions (e.g. dissolved selenium). The months of December and January have historically been excluded from sampling efforts due to difficult field conditions and the fact that water quality parameters are generally fairly stable during the winter months.

Additional focus was placed on a subset of 15 parameters are either commonly used to characterize water quality or are of potential concern regarding water quality standards. These parameters include flow, water temperature, specific conductance, dissolved oxygen, pH, alkalinity, total organic carbon, hardness, sulfate, turbidity, dissolved copper, dissolved manganese, dissolved selenium, nitrate + nitrite, and orthophosphate. Specifically, the relative spread of data for each parameter at each site sampled between 2011 and 2021 was examined with box plots. The box plots also provide a reference point for the relative value of data collected in 2021.

A number of aquatic life use and drinking water standards apply to the principal parameters examined and 2021 data were examined relative to these standards to provide a relative indication of the degree to which they are being met at the sampling locations. These standards are meant to be protective of aquatic ecosystems and human health. Water quality standards are used to provide context for the purpose of evaluating water quality status within and/or between sites. These comparisons are not meant to substitute for a formal surface water quality regulatory assessment under the federal Clean Water Act.

Table 3. Name, associated laboratory, analysis method, and detection limits of parameters included in 2021 sampling efforts.

Parameter	Detection Level	Notes	Lab	USGS Method Code
Barometric Pressure	n/a	USGS field staff	NWQL	BAROM
Dissolved Oxygen	n/a	USGS field staff	NWQL	LUMIN
Gage Height	n/a	USGS field staff	NWQL	Various
Instantaneous Discharge	n/a	USGS field staff	NWQL	Various
pH	n/a	USGS field staff	NWQL	PROBE
Specific Conductance	n/a	USGS field staff	NWQL	SC001
Temperature, Water	n/a	USGS field staff	NWQL	THM01
Alkalinity	4 mg/L as CaCO3	Laboratory	NWQL	TT040
Aluminum, Total	3 ug/L	Laboratory	NWQL	PLM77
Ammonia + Organic Nitrogen, Total	0.07 mg/L as N	Laboratory	NWQL	KJ008
Ammonia as N (Dissolved)	0.02 mg/L as N	Laboratory	NWQL	SHC02
Arsenic, Dissolved	0.1 ug/L	Laboratory	NWQL	PLM10
Cadmium, Dissolved	0.03 ug/L	Laboratory	NWQL	PLM43
Cadmium, Total	0.03 ug/L	Laboratory	NWQL	PLM78
Calcium, Dissolved	0.02 mg/L	Laboratory	NWQL	PLA11
Chloride, Dissolved	0.02 mg/L	Laboratory	NWQL	IC022
Chlorophyll-a	0.1 mg/L	Laboratory	NWQL	00050
Chromium, Total	0.5 ug/L	Laboratory	NWQL	PLM77
Copper, Dissolved	0.4 ug/L	Laboratory	NWQL	PLM10
Copper, Total	0.4 ug/L	Laboratory	NWQL	PLM77
Dissolved Organic Carbon	0.23 mg/L	Laboratory	LWQL	CMB15
E. coli	1 cfu/100 mL	Laboratory	LWQL	Colilert® Quantitray*
Iron, Dissolved	5.0 ug/L	Laboratory	NWQL	PLA11
Iron, Total	5.0 ug/L	Laboratory	LWQL	PLO07
Lead, Dissolved	0.02 ug/L	Laboratory	NWQL	PLM43
Magnesium, Dissolved	0.01 mg/l as N	Laboratory	NWQL	PLA11
Manganese, Dissolved	0.4 ug/L	Laboratory	NWQL	PLM43
Manganese, Total	0.4 ug/L	Laboratory	NWQL	PLM78
Nickel, Dissolved	0.2 ug/L	Laboratory	NWQL	PLM10
Nitrite *	0.001 mg/L	Laboratory. M140 Reg 85 only.	NWQL	DZ001
Nitrite + Nitrate, Dissolved	0.01 mg/l as N	Laboratory	NWQL	RED02
Orthophosphate, Dissolved	0.004 mg/L as P	Laboratory	NWQL	PHM01
Phosphorus, Dissolved	0.003 mg/L	Laboratory	NWQL	CL020
Phosphorus, Total	0.003 mg/L	Laboratory	NWQL	CL021
Potassium, Dissolved	0.3 mg/L	Laboratory	NWQL	PLO03
Residue 180 C	20 mg/L	Laboratory	NWQL	ROE10
Selenium	0.05 ug/L	Laboratory	NWQL	PLM10
Silica, Dissolved	0.05 ug/L	Laboratory	NWQL	PLA11
Silver, Dissolved	1 ug/L	Laboratory	NWQL	PLM43
Sodium, Dissolved	0.4 mg/L	Laboratory	NWQL	PLA11
Specific Conductance	5 uS/cm @ 25C	Laboratory	NWQL	WHT03
Sulfate, Dissolved	0.02 mg/L	Laboratory	NWQL	IC022
Total Coliform	1 cfu/100 mL	Laboratory	LWQL	Colilert® Quantitray*
Total Organic Carbon	0.7 mg/L	Laboratory	LWQL	COMB9
Total Particulate Carbon	0.05 mg/L	Laboratory. M10 only	NWQL	COMB6
Total Particulate Nitrogen	0.03 mg/L	Laboratory. M10 only	NQWL	COMB7
Turbidity	2 NTU	Laboratory	NWQL	TS098
Zinc, Dissolved	2 ug/L	Laboratory	NWQL	PLM10

Temporal Trends

All 46 water quality parameters were analyzed for temporal trends over the past decade using a non-parametric seasonal Mann-Kendall trend test. Parameter values below detection limits were set to half of the detection limit or were omitted if detection limit values were not available. The non-parametric nature of this test indicates that data do not need to be normally distributed and that the effect of outliers is minimized, both of which are generally advantageous when analyzing water quality data. The primary disadvantages to this test are that the power to detect a trend is somewhat lower than for parametric tests (Mozejko 2012) and that a significant trend can include a somewhat misleading slope of zero. While a slope of zero intuitively implies lack of a trend, the Mann-Kendall test measures the direction of increases or decreases over time, not the magnitude. Therefore, it is possible that a large enough proportion of the samples are increasing (or decreasing) over time to provide a significant result, the offsetting magnitudes of increases and decreases may result in a slope of zero. For example, if a parameter were to increase each year by a small amount (e.g., 1 unit) for 10 years and then decrease by a large amount (e.g. 10 units) in the next year, the number of increases would be 10 and the number of decreases would be 1, providing evidence of a significant upward trend. However, the resulting slope based on the magnitude of the increases and decreases would be approximately flat or zero. An additional consideration in interpreting statistical results is the relationship between the large number of tests and the alpha level. The alpha level considered to be significant is $p = 0.05$ which suggests that one out of every twenty tests will appear to have a significant trend simply due to chance rather than an actual trend. Therefore, it is important to examine patterns or causative relationships that may be present in statistical test results. For example, if a decline in a particular parameter is significant across all sites or neighboring sites, it is more likely to be a valid trend than if it exists in isolation. To be included in the analysis for temporal trend, parameters needed to be sampled both in 2021 and in at least two other years in the previous 10-year period

Table 4. Metal standards according to Colorado Regulations 31 and 38 (WQCC 2020a, WQCCb). All standards listed are in dissolved form and in units of ug/L.

		Parameter						
Segment	Site	Copper (acute)[1]	Copper (chronic)[1]	Selenium (acute)	Selenium (chronic)	Manganese (acute)[1]	Manganese (chronic)[1]	Manganese (domestic water supply - chronic)
COSPBT01_B	M10	$e^{(0.9422*\ln(hardness)-1.7408)}$	$e^{(0.8545*\ln(hardness)-1.7428)}$	18.4	4.6	$e^{(0.3331*\ln(hardness)+6.4676)}$	$e^{(0.3331*\ln(hardness)+5.8743)}$	50
COSPBT02_C	M30	$e^{(0.9422*\ln(hardness)-1.7408)}$	$e^{(0.8545*\ln(hardness)-1.7428)}$	18.4	4.6	$e^{(0.3331*\ln(hardness)+6.4676)}$	$e^{(0.3331*\ln(hardness)+5.8743)}$	50
COSPBT02_A	M50	11	7.5	18.4	4.6	$e^{(0.3331*\ln(hardness)+6.4676)}$	$e^{(0.3331*\ln(hardness)+5.8743)}$	50
COSPBT02_A	M60	11	7.5	18.4	4.6	$e^{(0.3331*\ln(hardness)+6.4676)}$	$e^{(0.3331*\ln(hardness)+5.8743)}$	50
COSPBT02_F	M70	11	7.5	18.4	4.6	$e^{(0.3331*\ln(hardness)+6.4676)}$	$e^{(0.3331*\ln(hardness)+5.8743)}$	50
COSPBT02_D	M90	11	7.5	18.4	4.6	$e^{(0.3331*\ln(hardness)+6.4676)}$	$e^{(0.3331*\ln(hardness)+5.8743)}$	50
COSPBT03_B	M130	$e^{(0.9422*\ln(hardness)-1.7408)}$	$e^{(0.8545*\ln(hardness)-1.7428)}$	18.4	4.6	$e^{(0.3331*\ln(hardness)+6.4676)}$	$e^{(0.3331*\ln(hardness)+5.8743)}$	50
COSPBT04c	M140	$e^{(0.9422*\ln(hardness)-1.7408)}$	$e^{(0.8545*\ln(hardness)-1.7428)}$	18.4	4.6	$e^{(0.3331*\ln(hardness)+6.4676)}$	$e^{(0.3331*\ln(hardness)+5.8743)}$	50
COSPBT02	T10	11	7.5	18.4	4.6	$e^{(0.3331*\ln(hardness)+6.4676)}$	$e^{(0.3331*\ln(hardness)+5.8743)}$	50

1. Maximum hardness value for acute and chronic standard calculations is 400

Table 5. Water quality standards according to 31 and 38 (WQCC 2020a, WQCCb).

		Parameter									Clean Water Act 303(d)	
Segment	Site	Nitrate + Nitrate (domestic water supply - acute)	Sulfate (domestic water supply - chronic)	Dissolved Oxygen	pH (lower limit)	pH (upper limit)	Temperature (upper limit - acute)	Temperature (upper limit - chronic)	Temperature (upper limit - acute)	Temperature (upper limit - chronic)	Impairment	Priority
COSPBT01_B	M10	10	250	6	6.5	9	21.7 [1]	17 [1]	13 [2]	9 [2]	As, Cu, Hg, Zn	H, H, H, H
COSPBT02_C	M30	10	250	5	6.5	9	21.7 [1]	17 [1]	13 [2]	9 [2]	Macro, As, Cu, NO_3, Hg	H, L, M, H, H
COSPBT02_A	M50	10	250	5	6.5	9	21.7 [1]	17 [1]	13 [2]	9 [2]	As, Cu, Hg	L, H, H
COSPBT02_A	M60	10	250	5	6.5	9	21.7 [1]	17 [1]	13 [2]	9 [2]	As, Cu, Hg	L, H, H
COSPBT02_F	M70	10	250	5	6.5	9	21.7 [1]	17 [1]	13 [2]	9 [2]	As, Temp, Hg, Fe, Cu	L, H, H, H, H
COSPBT02_D	M90	10	250	5	6.5	9	21.7 [1]	17 [1]	13 [2]	9 [2]	As, Cu	L, M
COSPBT03_B	M130	10	250	5	6.5	9	29.0 [3]	24.2 [3]	24.6 [4]	12.1 [4]	As, Hg, Mn, Se	L, M, L , L
COSPBT04c	M140	100	-	5	6.5	9	29.0 [3]	24.2 [3]	24.6 [4]	12.1 [4]	-	-
COSPBT02	T10	10	250	5	6.5	9	21.7 [1]	17 [1]	13 [2]	9 [2]	As, Hg, Mn, Se	L, H

1:June-September
2: October-May
3: March-November
4: December-February

Parameter Descriptions and Results

General Parameters

Flow

Flow represents the volume of water passing by a given site in one second measured in cubic feet per second (cfs). Flow was measured at all nine stations. These flow rate data are presented are median values and as such do not address important components of flow such as seasonal dynamics. The data do, however, capture between site differences due to water diversions and tributary inputs as well as the relative flow compared to previous years. (e.g., North Fork Big Thompson River confluence between M60 and M70 and LWP diversion below M90).

Flows ranged from 2.4 cfs at site M10 in February to 838 cfs at site M140 in June. Flows were approximately average when compared to the previous 10-year time period although sites lower in the watershed had somewhat lower flows than experienced historically (Figure 4).

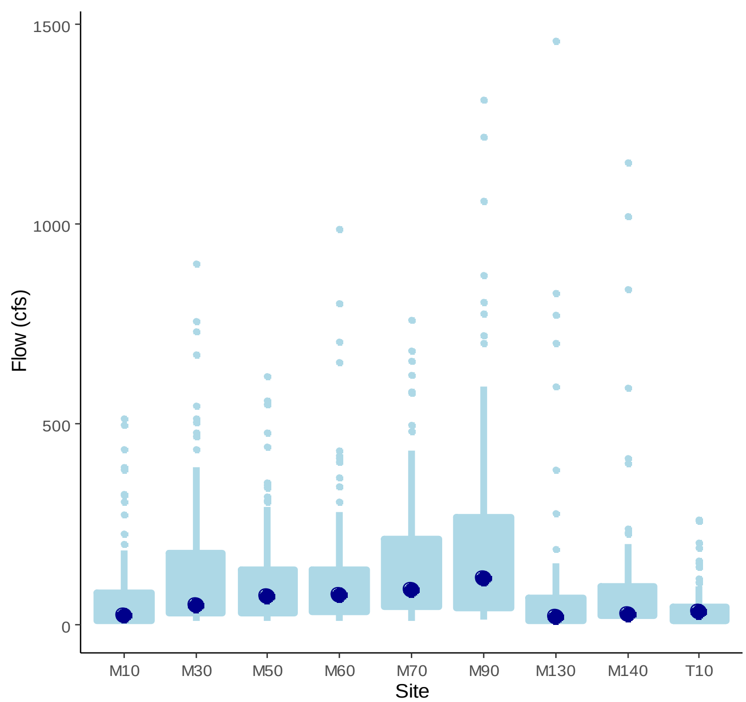


Figure 4. Box plot of flow data representing the 2011-2021 time period for each sampling location. Box represents 25th and 75th percentiles and blue circle represents 2021 median value.

Water temperature

Water temperature affects both aquatic organisms and drinking water treatment processes. Aquatic organisms have preferred and lethal temperatures. These temperatures 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 and other stressful time periods. Elevated water temperatures can cause reduced reproduction, growth, or mortality. 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. As such, temperature standards are based on species groups with similar thermal tolerances. Segments of the Big Thompson River are classified as Coldwater I, Coldwater II, or Warmwater II. 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.

Temperatures ranged from an expected 0ºC at a number of sites in the winter months to a high of 20.6ºC at site M90 in August. While there were no recorded instances where the acute temperature standards were exceeded (Table 5) but chronic standards were exceeded 14 times (16%) in 2021. Interestingly, there was an average decrease in river water temperature between M130 and M140 of 0.6 ºC during the summer months (June-September). This reduction took place because the water returned to the river via outfall from the LWP Water Reclamation Facility is generally colder than ambient river temperatures during this time period. These summer decreases were offset by slightly warmer contributions (relative to river water) from the Reclamation Facility in the winter, resulting in similar median values between sites M130 and M140 (Figure 5).

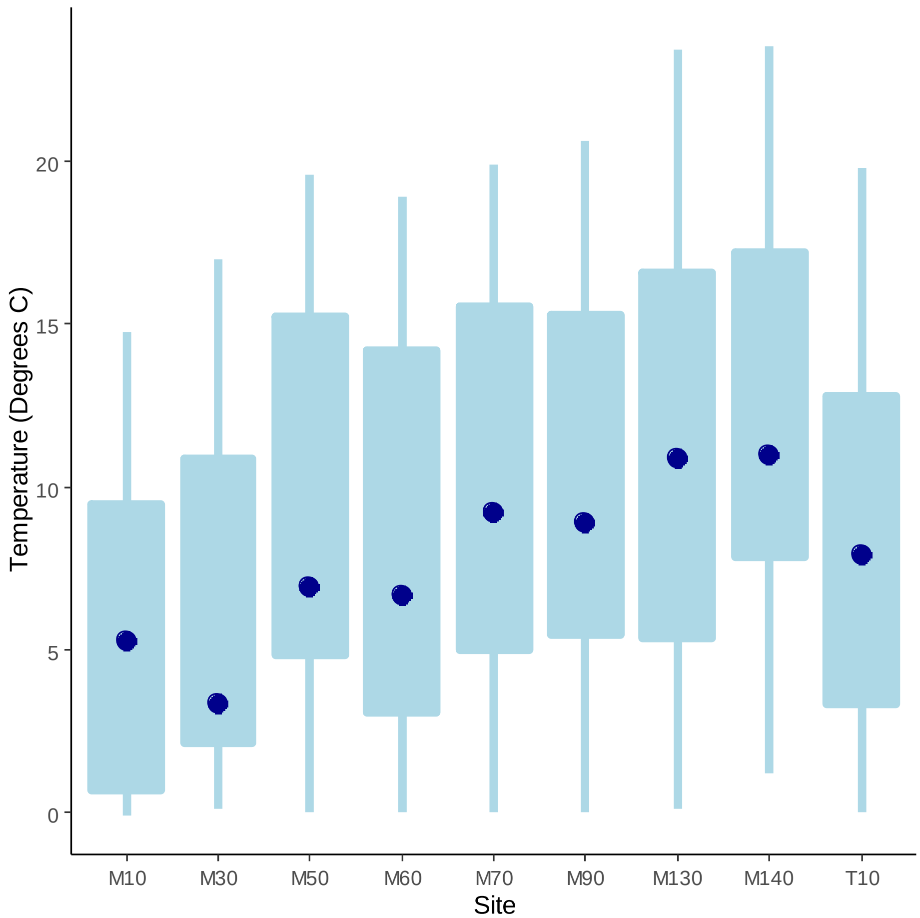


Figure 5. Box plot of temperature data representing the 2011-2021 time period for each sampling location. Box represents 25th and 75th percentiles and blue circle represents 2021 median value.

Specific conductance

Specific conductance is a measure of how well water conducts electricity. Specific conductance increases with increasing concentrations of ions that are dissolved in water such as chloride, sulfate, nitrate, phosphate, sodium, magnesium, calcium, potassium. and iron. Although specific conductance itself does not directly impact water quality, it is easily measured and indicates general seasonal and spatial differences in water quality. Specific conductance may also indicate whether an issue may exist that merits more detailed investigation. In 2021, specific conductance ranged from 18 µS/cm to 1,550 µS/cm at sites M10 in June and M130 in April respectively.

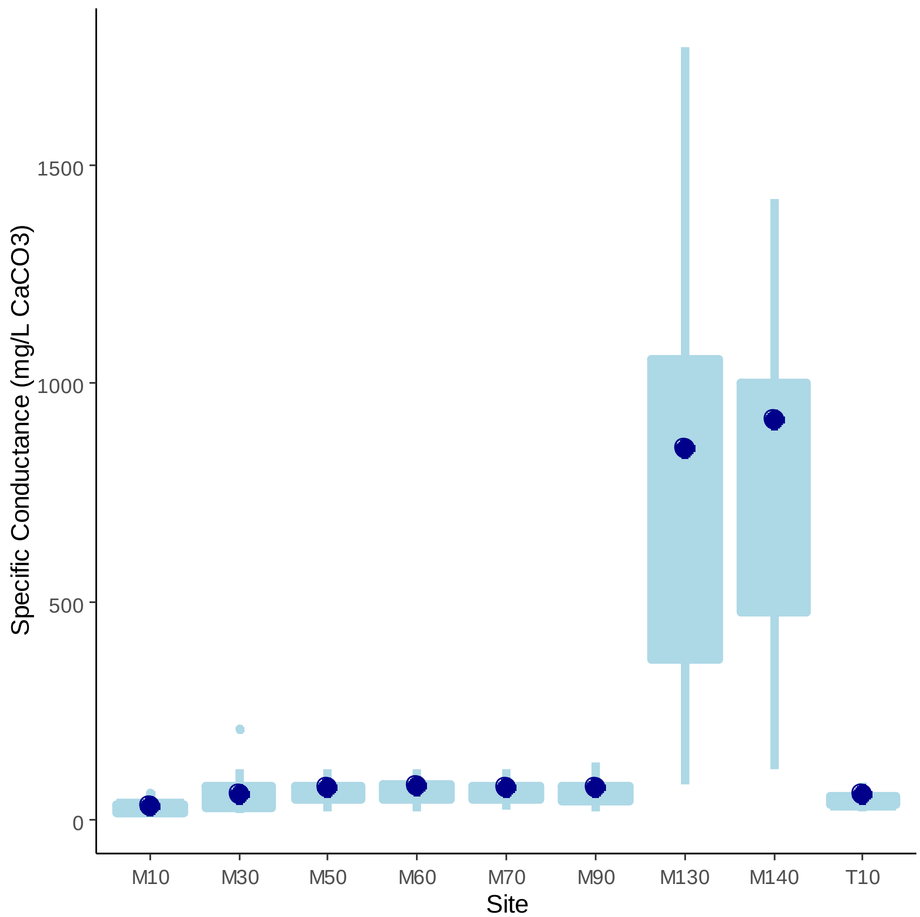


Figure 6. Box plot of specific conductance data representing the 2011-2021 time period for each sampling location. Box represents 25th and 75th percentiles and blue circle represents 2021 median value.

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. 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.

Dissolved oxygen levels ranged from a high of 12.3 mg/L at site M70 in February to a low of 6.1 mg/L at site M140 in April. There were no recorded instances of dissolved oxygen levels declining below aquatic life use standards in 2021. The cause of the relatively low median dissolved oxygen level at site M140 in 2021 is unknown and should continue to be monitored in coming years.

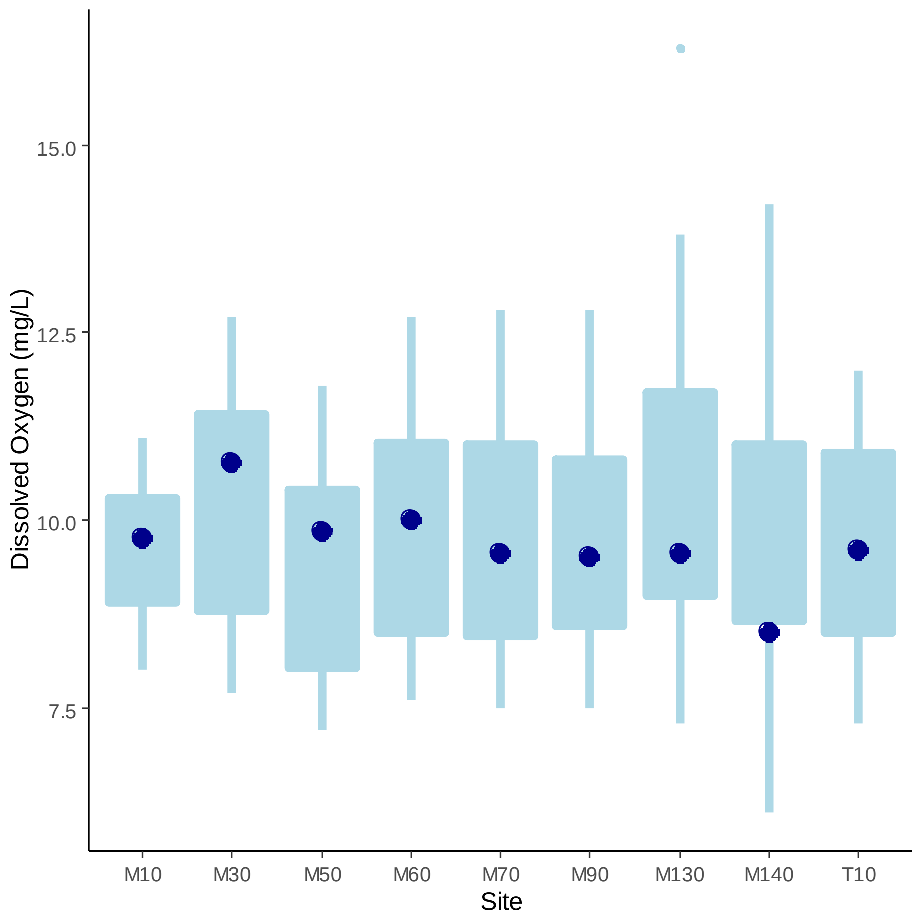


Figure 7. Box plot of dissolved oxygen data representing the 2011-2021 time period for each sampling location. Box represents 25th and 75th percentiles and blue circle represents 2021 median value.

pH

The pH of water is a measurement of the degree to which it is acidic or basic. The number represents the concentration of hydrogen ions on a log scale and ranges from 0 to 14 SU with acidic conditions resulting in lower values and basic conditions resulting in higher values. The relative acidity of water can affect both water treatment and aquatic life. Relatively high (> 9 SU) and low (< 6.5 SU) can cause the aquatic environment to be inhospitable for many aquatic organisms. Water treatment processes, particularly flocculation, depend in part on the pH of the water. Flocculation is a process by which a coagulant is added to the water to cause bonding between water impurities which then are more prone to settling and are easier to separate. Low pH levels can impede the flocculation process while high pH can cause flocculated particles to re-disperse before settling.

Measured pH values ranged from a high of 8.4 SU at site M50 in September to a low of 6.6 SU at site M10 in June. There were no recorded instances when water samples were either above or below water quality standards at any site.

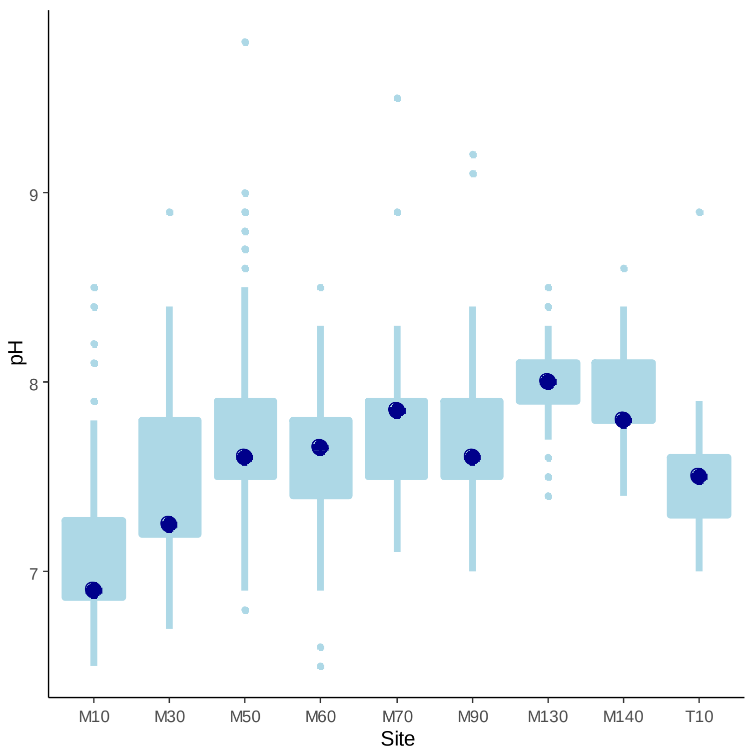


Figure 8. Box plot of pH data representing the 2011-2021 time period for each sampling location. Box represents 25th and 75th percentiles and blue circle represents 2021 median value.

Alkalinity

Alkalinity is a measure of the degree to which water can resist acidic changes in pH (or buffer changes in pH). This buffering capacity is measured by of the amount of carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) anions in the water and is described in terms of mg/L $CaCO_3$. These anions buffer changes in pH by absorbing hydrogen ions when the water is acid and releasing them when it is basic. Higher alkalinity means higher amounts of acid will need to be added to the water before a change in pH occurs.

Alkalinity levels affect aquatic ecosystems and water treatment. Water treatment plants 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. Conversely, aquatic ecosystems can benefit from elevated alkalinity because water with a pH lower than approximately 6.5 can have negative effects on aquatic life.

Elevated alkalinity causes pH levels of 6.5 or lower to be less likely. In 2021, alkalinity ranged from 4.2 mg/L $CaCO_3$ at site M10 in June to 194 mg/L $CaCO_3$ at site M130 in April.

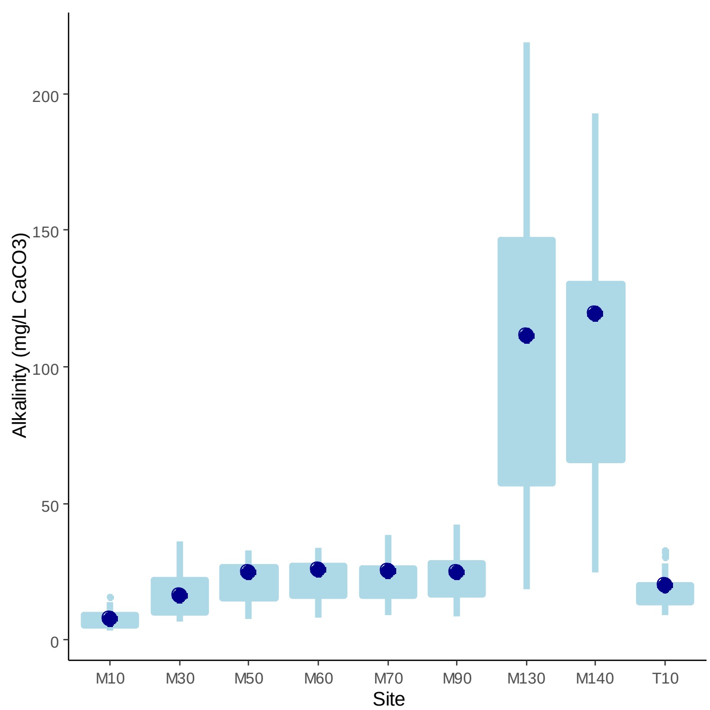


Figure 9. Box plot of alkalinity data representing the 2011-2021 time period for each sampling location. Box represents 25th and 75th percentiles and blue circle represents 2021 median value.

Total organic carbon

Total organic carbon (TOC) is a measure of the amount of dissolved and particulate organic matter in a water sample. 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 byproducts that are regulated as potential carcinogens. As such, TOC levels are of concern to drinking water treatment facilities.

The 2021 TOC levels ranged from a high value of 11.2 mg/L in May at site T10 to a low value of 1.6 mg/L in February at site M10. Unusually low median pH values occurred at site M130 in 2021 (Figure 10). The cause of the relatively low value is unknown.

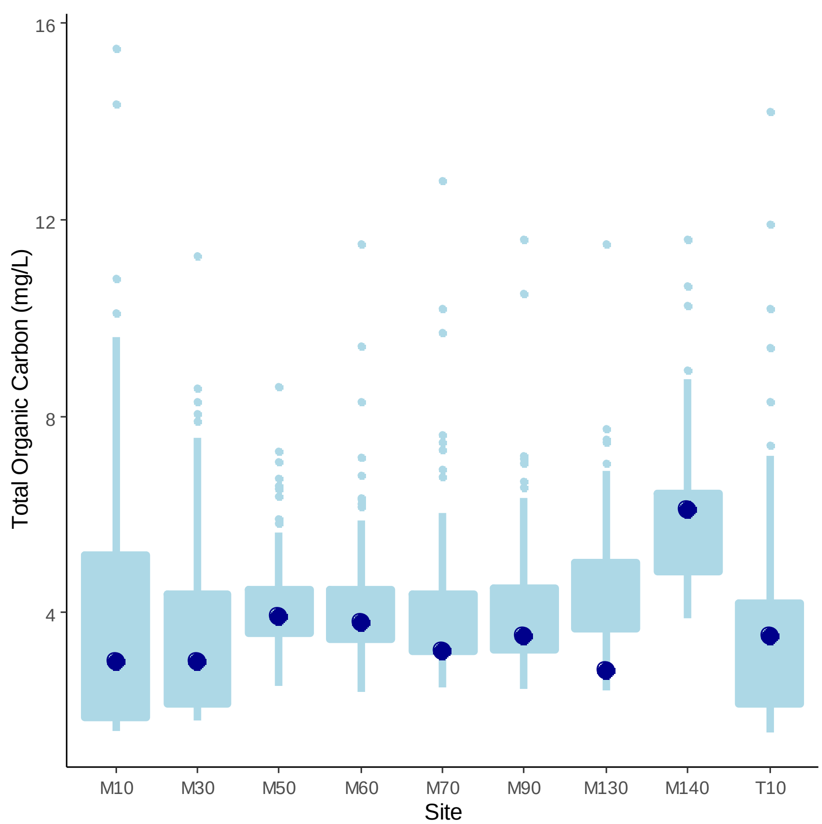


Figure 10. Box plot of total organic carbon data representing the 2011-2021 time period for each sampling location. Box represents 25th and 75th percentiles and blue circle represents 2021 median value.

Hardness

Hardness is a measure of the concentration of metal ions, primarily calcium and magnesium but also other metals such as iron, measured as mg/L of $CaCO_3$. The presence of elevated hardness reduces the toxicity of dissolved metals such as copper (Chakoumakos et al. 1979) and manganese (Stubblefield et al. 1997) at a given concentration by reducing the ability of these metal to bind to the gills of aquatic organisms. Therefore, even low levels of dissolved metals in water with low hardness can be an issue of concern. In 2021, hardness values ranged from 6.2 mg/L $CaCO_3$ at site M10 in April to 672 mg/L $CaCO_3$ at site M130 in June.

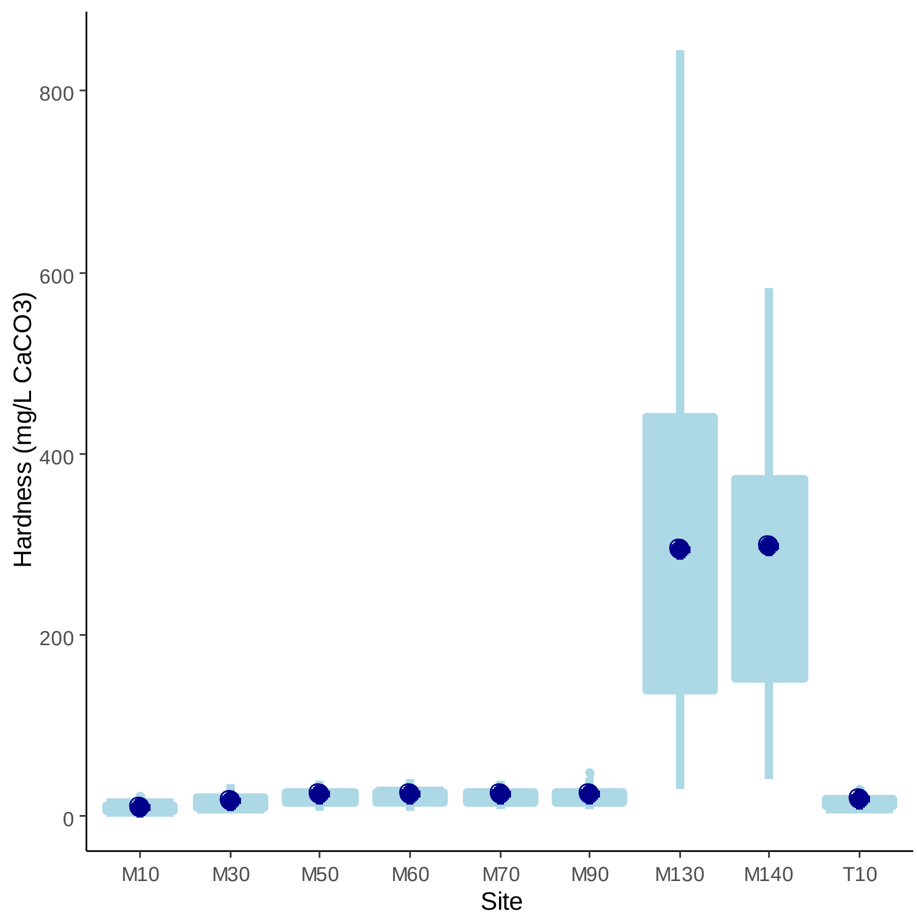


Figure 11. Box plot of hardness data representing the 2011-2021 time period for each sampling location. Box represents 25th and 75th percentiles and blue circle represents 2021 median value.

Sulfate

Sulfate is a common ion which is naturally occurring and is the primary form that sulfur takes in oxygenated waters such as the Big Thompson River. Sulfate is of interest due to taste and gastrointestinal issues that elevated levels may cause in drinking water. A treated drinking water secondary maximum contaminant standard of 250 mg/L (non-enforceable guidance level for aesthetic quality) has been adopted for sulfate. Sources of sulfate include the decay of organic matter, acid mine drainage, industrial effluent, runoff from fertilized agricultural lands, atmospheric deposition, and wastewater treatment plant effluent. Sulfate can be present in surface and ground waters at elevated concentrations due to interactions with soluble evaporite minerals such as gypsum in sedimentary bedrock. Pierre Shale, a source of selenium within the lower portion of the watershed, is also a source of sulfate.

Sulfate values ranged from 1.6 mg/L to 615 mg/L at sites M10 in February and M130 in April respectively. There were eight occasions when the drinking water standard of 250 mg/L was exceeded. The exceedances occurred in the months of February-May at sites M130 and M140. Although the values at M140 (below the Wastewater Reclamation Facility outfall) were above the drinking water standard in the spring, the values during this time period were lower at M140 than they were at M130 (above the Wastewater Reclamation Facility outfall) in each of the months with elevated sulfate levels. These results suggest that the WRF outfall acts to dilute sulfate levels in the Big Thompson River, at least during time periods with elevated sulfate levels in the river.

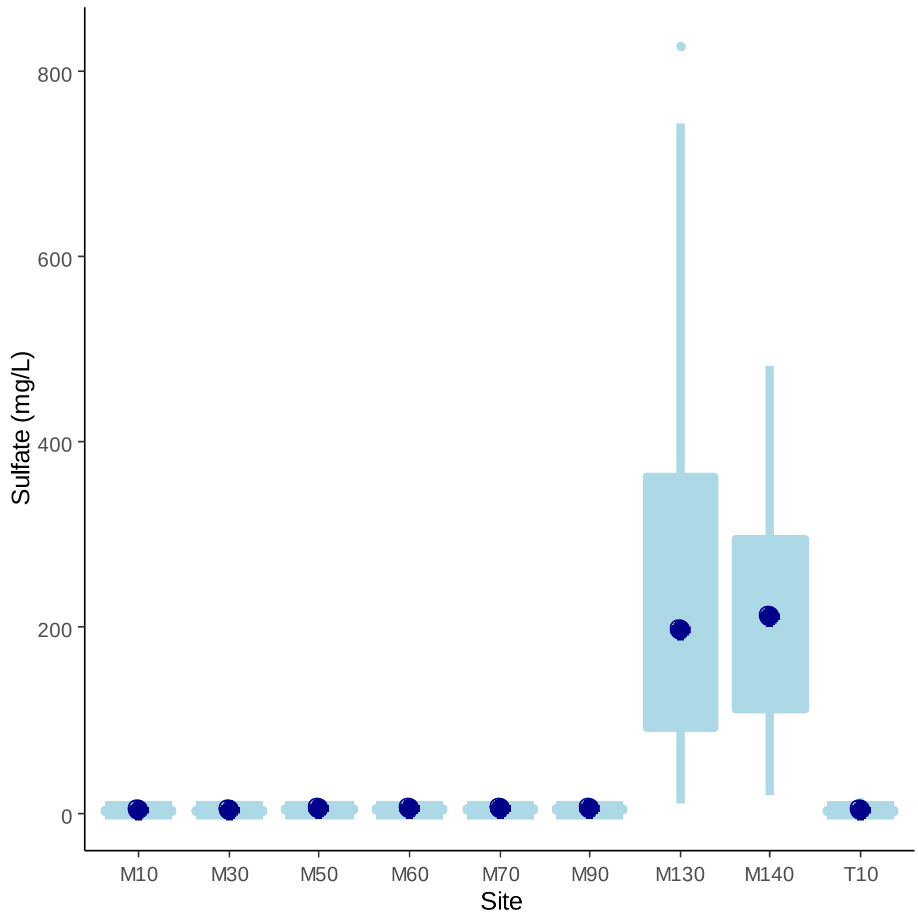


Figure 12. Box plot of sulfate data representing the 2011-2021 time period for each sampling location. Box represents 25th and 75th percentiles and blue circle represents 2021 median value.

Turbidity

Turbidity is essentially a measure of water clarity. Water with higher turbidity levels is less clear because it contains a higher number of suspended particles. Elevated turbidity has negative impacts on municipal water treatment plants and aquatic communities. High turbidity generally means there is an increased sediment present in the water. Accommodating sediment is a challenge to drinking water utilities. Turbidity levels are also positively associated with TOC levels which in turn require additional water treatment. LWP alters the location of their water collection when turbidity levels rise above 100 NTU. 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 negatively affect macroinvertebrate and fish densities and can also negatively affect macroinvertebrate species richness. Effects of elevated turbidity become more severe with longer exposure.

Turbidity ranged from a low of 1 NTU at a number of stations and months (primarily during the low flow period (October-April) to a high of 85 NTU at site M140 in June. Turbidity levels were relatively high at all sites in 2021, particularly at the sites in the lower portion of the river. These relatively high levels are likely the result of runoff associated with the CPF.

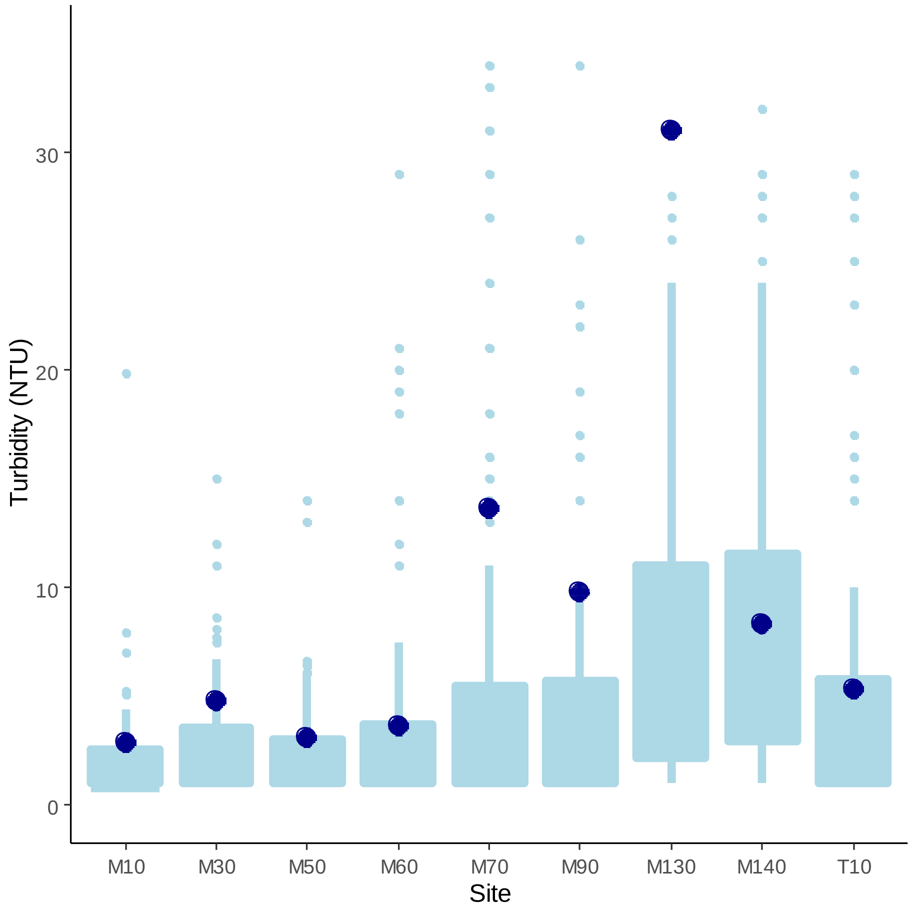


Figure 13. Box plot of turbidity data representing the 2011-2021 time period for each sampling location. Box represents 25th and 75th percentiles and blue circle represents 2021 median value.

Metals

Copper

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

Dissolved copper values ranged from 0.4 mg/L at site M130 during winter-early spring months to 2.9 mg/L at site M140 in May. While there were no instances of dissolved copper concentrations exceeding the hardness based acute standard, there were six instances where measured values exceeded the chronic standard. All of the measured values that exceeded the chronic standard occurred in the upper portion of the watershed (four at site M10 and two at site M30) in the summer months. Copper levels in the upper portion of the watershed are fairly low but are of concern because hardness values are also low enough to cause dissolved copper to be very bioavailable.

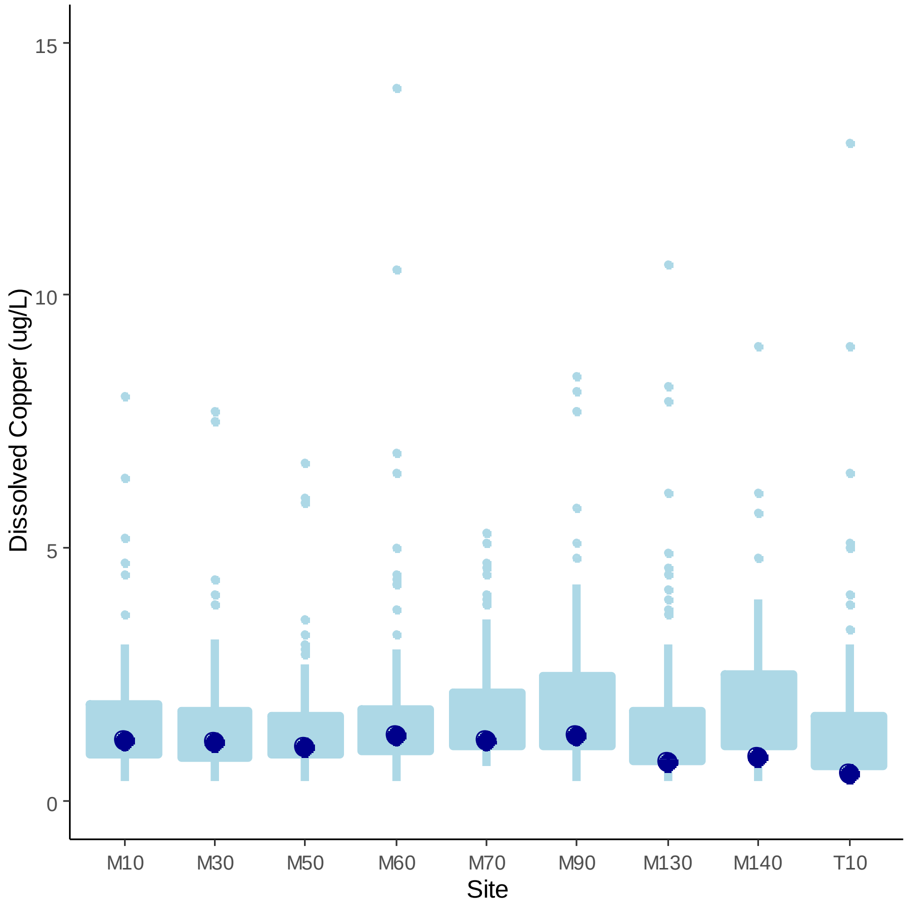


Figure 14. Box plot of dissolved copper data representing the 2011-2021 time period for each sampling location. Box represents 25th and 75th percentiles and blue circle represents 2021 median value.

Manganese

Dissolved manganese is only a health concern in drinking water at very high levels (>300 ug/L) but a secondary standard of 50 ug/L exists due to the ability of dissolved manganese to produce reddish/black/brown stains on laundry, plumbing, sinks, and showers. In addition, drinking water with dissolved manganese levels greater than 50 ug/L can have a metallic taste. Aquatic organisms can be negatively affected by particularly elevated dissolved manganese levels that are based on the hardness of the water and are much higher than the secondary drinking water standard.

Dissolved manganese values in 2021 ranged from 1.5 mg/L at site M60 in to 160 mg/L at site M130 in April 2021. There were no recorded instances of chronic or acute exceedances of hardness based aquatic life standards but 14 instances of exceeding the secondary drinking water standard (50 mg/L). All exceedances occurred in the lower portion of the river at sites M130 and M140.

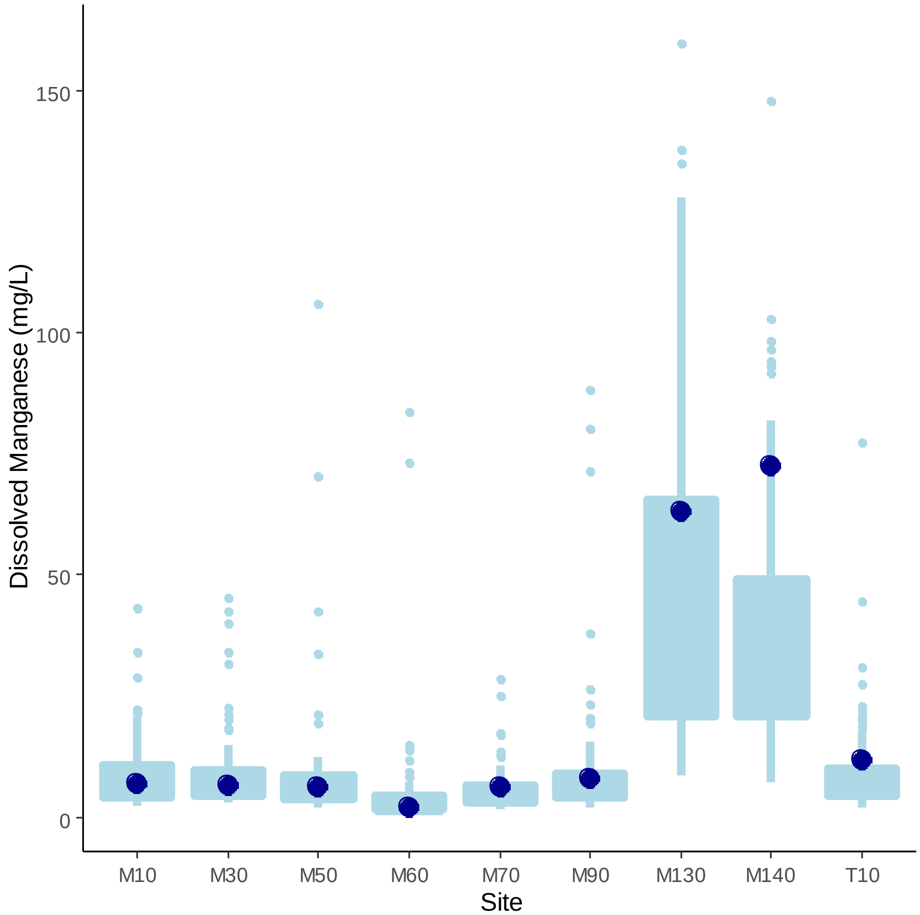


Figure 15. Box plot of flow dissolved manganese representing the 2011-2021 time period for each sampling location. Box represents 25th and 75th percentiles and blue circle represents 2021 median value.

Selenium

Elevated selenium levels in water can negatively affect aquatic organisms and are therefore included in this report. Acute and chronic aquatic life standards of 18.4 µg/L and 4.6 µg/L, respectively, have been adopted for all stream segments in the Big Thompson Watershed. Several segments of the Big Thompson River are listed as impaired for selenium on Colorado's 303(d) List. However, selenium occurs at elevated levels primarily due to the bedrock geology of the watershed. The lower portion of the watershed, below the canyon mouth, includes a type of bedrock called Pierre Shale (Hart 1974) which is enriched in selenium.

Selenium values reflected the prevalence of Pierre Shale bedrock with concentrations near zero at site M90 and as high as 7.4 mg/L at site M130 in April. Dissolved selenium levels are generally highest during low flow periods of December-April. Values during this time period were lower at M140 than they were at M130 (above the Wastewater Reclamation Facility outfall) suggesting that the WRF outfall acts to dilute dissolved selenium levels in the Big Thompson River, at least during time periods with elevated sulfate levels in the river.

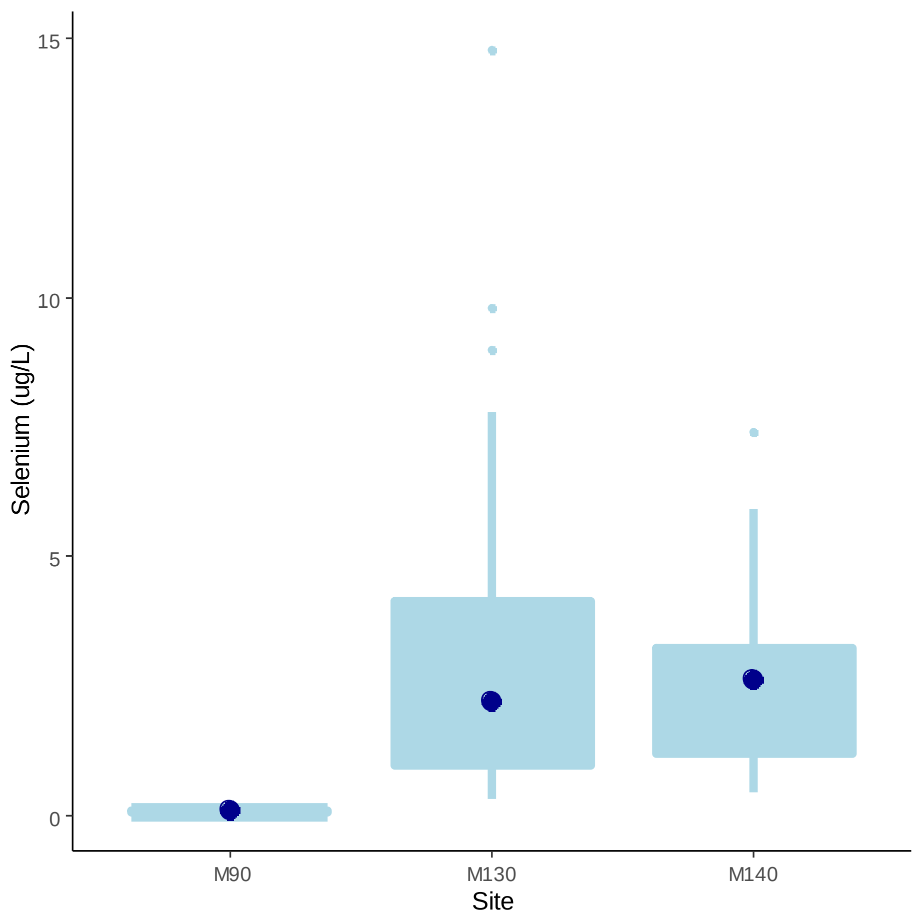


Figure 16. Box plot of dissolved selenium data representing the 2011-2021 time period for each sampling location. Box represents 25th and 75th percentiles and blue circle represents 2021 median value.

Nutrients

Nitrate + Nitrite

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) 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. Inorganic nitrogen levels ranged from 0.06 mg/L (the detection limit) at site T10 in May to a high of 4.54 mg/L at site M140 in April.

There were no recorded instances of inorganic nitrogen levels exceeding the drinking water standard of 10 mg/L. Nitrate levels continued to be substantially lower at site M140 in 2021 due to the activation of a biological nutrient removal system at the WRF in 2019. Biological Nutrient Removal is a process in wastewater treatment designed to utilize particular microbial populations to reduce nutrients such as orthophosphate and nitrate. The process utilizes anoxic and oxic environments to encourage the nutrient reducing actions of particular bacteria.

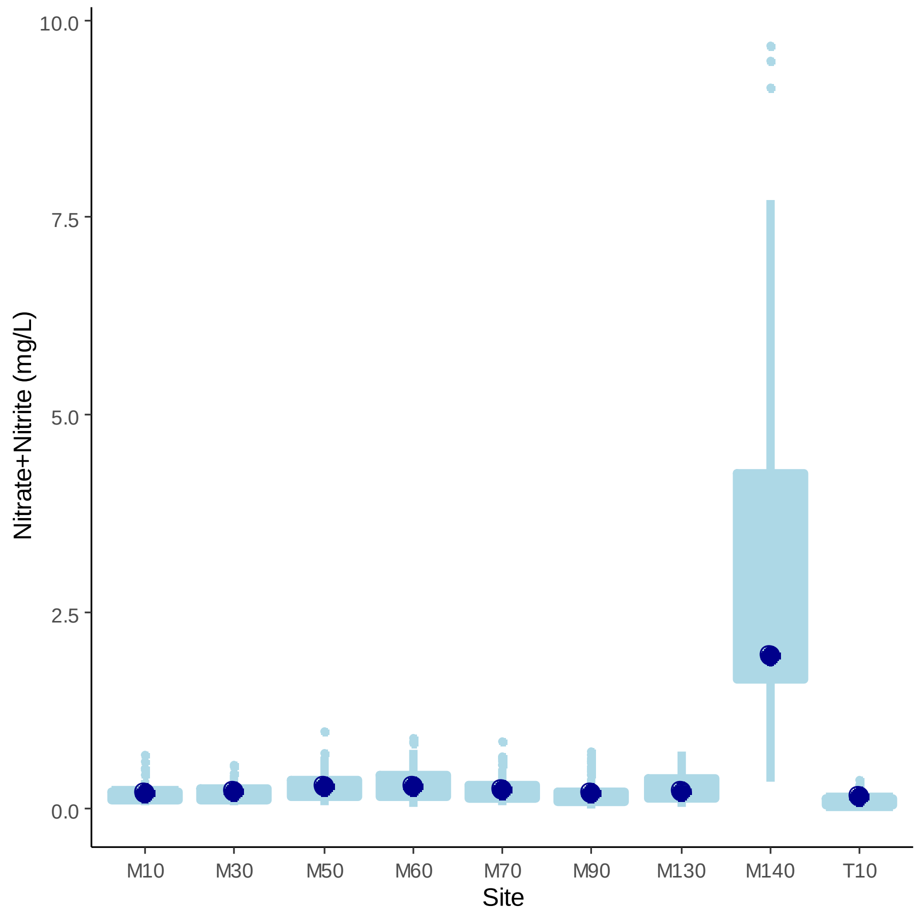


Figure 17. Box plot of nitrate + nitrite data representing the 2011-2021 time period for each sampling location. Box represents 25th and 75th percentiles and blue circle represents 2021 median value.

Orthophosphate (Ortho-P)

Orthophosphate is a dissolved form of phosphorus and is the only form that is immediately available for uptake by algae. Sources of orthophosphate include the decay of plant debris and other organic matter, the minerals that make up rocks, soils, and sediments in the watershed, wastewater treatment plant effluent, failing individual sewage disposal systems, runoff from fertilized agricultural lands and urban areas, and erosion of stream channels, dirt roads, construction sites, and other land surfaces.

Orthophosphate levels ranged from 0.002 mg/L (half of the detection limit) at several sites in several different months to a high of 0.193 at site M50 in March. Similar to nitrate+nitrite levels, orthophosphate was dramatically lower in 2021 at site M140 than in previous years due to the installation of a Biological Nutrient Removal system at the LWP Water Reclamation Facility in 2018.

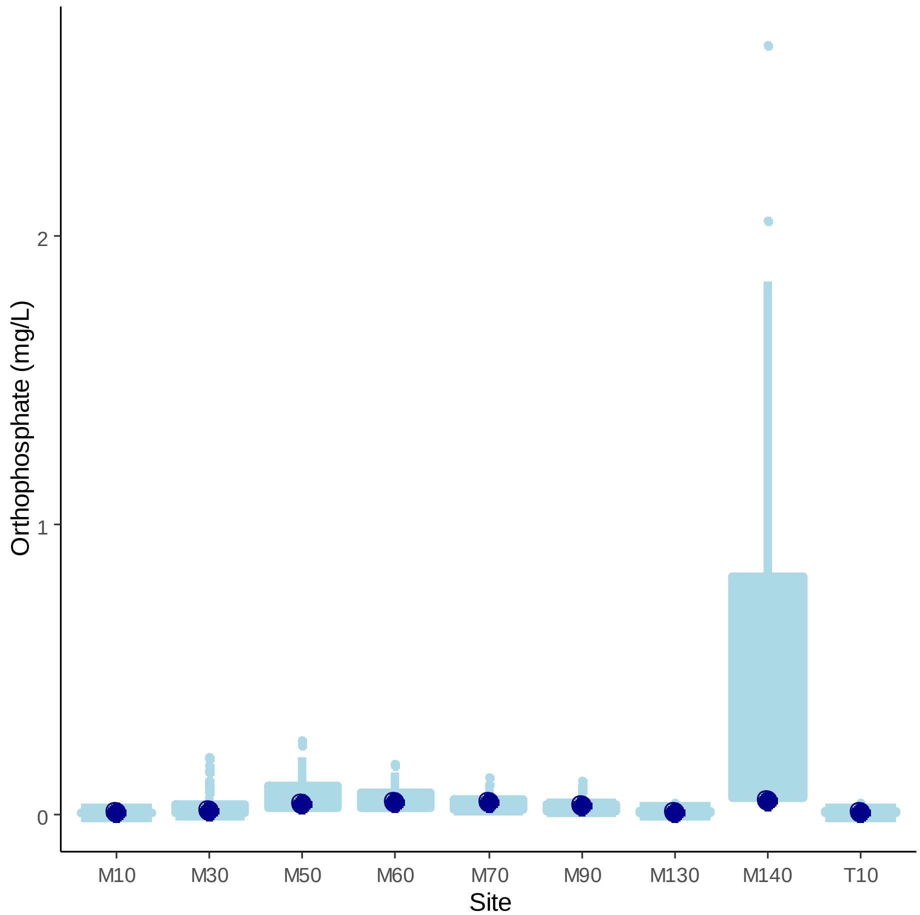


Figure 18. Box plot of orthophosphate data representing the 2011-2021 time period for each sampling location. Box represents 25th and 75th percentiles and blue circle represents 2021 median value.

Temporal Trends

Significant temporal trends over the previous 10-year period were detected for a number of parameters at each sampling location. However, given a p-value of 0.05 and more than 40 parameters examined at each site, one would expect one or two significant results at each site simply due to chance rather than any real increase or decrease over time. Consistent results among sites (or groups of

sites) or additional site-specific information is useful in increasing confidence in significant trend results.

There were significantly decreasing orthophosphate concentrations at a number of sites including below waste water discharges (M30 and M140) as well as at a site in the lower portion of the river (M130) and in the North Fork (T10). Site M30 is located below the Estes Park Sanitation District where a number of operational and structural improvements were made between 2016 and 2021 (Hydros 2021). Similarly, site M140 is located below the LWP Water Reclamation Facility outfall. In 2018, Loveland Water and Power installed a biological nutrient removal system which caused a marked decline in phosphorus and orthophosphate levels. While there were decreases at two other sites, these decreases were relatively small (-0.001 mg/L/year at site T10 and -0.002 mg/L/year at site M130) when compared to the decreases associated with water reclamation facility discharges (-0.250 mg/L/year at site M30 and -0.110 mg/l/year at site M140). This decline in orthophosphate is can generally be viewed as a positive result for the river because it indicates that the impacts of cultural eutrophication (such as through waste water discharges) are being successfully addressed. The decline in orthophosphate below water reclamation facility discharges was also noted by Hawley and Rodriquez-Jeangros (2021) over a longer time period.

Dissolved copper concentrations declined significantly across all sites except in the uppermost site in Rocky Mountain National Park (M10). The overall average decline in dissolved copper concentration was 0.14 ug/L/year. Sites in the upper watershed had a smaller decline than those in the lower watershed. The decline in dissolved copper was also documented for several of these sites over a 15-year period ending in 2021 by Hawley, C. & Rodriquez-Jeangros (2021). This result also matches with the suggestion somewhat lower tree mortality caused by bark beetles in recent years (USDA 2019) would result in decreased dissolved copper in the Big Thompson River. Tree mortality caused by bark beetles may result in copper, which had been taken up and stored by trees, being released into surface water upon their death (Fayram et al. 2019).

Water has become more acidic at a number of sites M30, M50, M90, and T10. The declines were relatively modest at most sites (declines of -0.006 to -0.02 SU/year) although the decline at site M90 was somewhat greater (-0.029 SU/year). Because the trend was observed at several sites and was negative in each case, the trend is more likely to be valid. However, the cause of these declines is unknown.

Many of the sites in the lower portion of the Big Thompson River Canyon (sites M50-M90) as well as the site on the North Fork of the Big Thompson River (T10) showed a significant increase in dissolved sodium. There was also a significant increase in chloride at the two lower sites (M70 and M90) and at the North Fork Big Thompson River site (T10). These two results suggest that the increases may be due to the use of sodium chloride as a de-icing agent on area roads during the winter. Given the proximity of Highway 34 to the mainstem and Highway 43 to the North Fork, this mechanism seems reasonable. The increase in dissolved sodium concentration at these sites over the last decade is 0.074 mg/L/year or approximately 0.74 mg/L overall. Similarly, Kaushal et al. (2018) documented a mainstem wide increase in sodium concentration in the Big Thompson River in recent decades.

Acknowledgements

We thank all USGS staff for collecting and analyzing data presented in this report. In particular, we thank Greg Smith and Tanner Chapin from USGS. The GIS support provided by Paige Richardson is very much appreciated. We also thank the Loveland City Council, Utilities Commission, former BTWF staff, and BTWF Board members for continuing these data collection efforts for many years.

References

Chakoumakos, C., Russo, R.C., and Thurston, R.V. 1979. Toxicity of Copper to Cutthroat Trout (*Salmo clarki*) under Different Conditions of Alkalinity, pH, and Hardness. Environmental Science & Technology 13: 213-219.

Fayram, A.H., Monahan, W.B., Krist Jr., F.J., and Sapio, F.J. 2019. The relationship between tree mortality from a pine beetle epidemic and increased dissolved copper levels in the upper Big Thompson River, Colorado. Environmental Monitoring and Assessment 191: 188.

Giardullo, M.J. 2006. Evaluation of the Cooperative Water Quality Monitoring Program in Colorado's Big Thompson Watershed. Master of Science Thesis. Colorado State University.

Hawley, C. & Rodriquez-Jeangros, N. 2021. Big Thompson State of the Watershed 2021. Hydros Consulting, 1628 Walnut St., Boulder, CO 80302.

Kaushal, S. S., Likens, G.E. Pace, M.L., Utz, R.M., Haq, S., Gorman, J., & Grese, M. 2018. Freshwater salinization syndrome on a continental scale. Proceedings of the National Academy of Sciences: January 9, 2018. https://www.pnas.org/doi/full/10.1073/pnas.1711234115

Larimer County 2021. Cameron Peak Fire Risk Assessment: Summary Results of the Cameron Peak Fire Risk Assessment and Hydrology Analysis.

Mast, A., Murphy, S.F., Clow, D.W., Penn, C.A., and Graham, A.A. 2016. Water-quality response to a high-elevation wildfire in the Colorado Front Range. Hydrological Processes 30: 1811-1823.

Mozejko, J. 2012. Detecting and Estimating Trends of Water Quality Parameters, Water Quality Monitoring and Assessment, Dr. Voudouris (Ed.), ISBN: 978-953-51-0486-5, InTech, Available from: http://www.intechopen.com/books/water-quality-monitoring-and-assessment/detecting-and-estimating-trendsof-water-quality-parameters

Naceradska, J., Pivokonska, L., & Pivokonsky. 2019. On the importance of pH value in coagulation. Journal of Water Supply: Research and Technology-Aqua 68: 222-230. https://doi.org/10.2166/aqua.2019.155

NCEI. 2022. National Temperature and Precipitation Maps. National Oceanographic and Atmospheric Administration. https://www.ncei.noaa.gov/

Spahr, N.E., Dubrovsky, N.M., Gronberg, J.M., Franke, O.L., and Wolock, D.M. 2010, Nitrate loads and concentrations in surface-water base flow and shallow groundwater for selected basins in the United States, water years 1990–2006: U.S. Geological Survey Scientific Investigations Report 2010–5098, 39 p.

Stets, E.G., Sprague, L.A., Oelsner, G.P., Johnson, H.M., Murphy, J.C., Ryberg, K., Vecchia, A.V., Zuellig, R.E., Falcone, J.A., and Riskin, M.L. 2020. Landscape drivers of dynamic change in water quality of U.S. rivers. Environmental Science & Technology 54(7):4336-4343.

Stevens, M.R. 2003. Water Quality and Trend Analysis of Colorado–Big Thompson System Reservoirs and Related Conveyances, 1969 Through 2000. Water-Resources Investigations Report 03–4044. US Department of the Interior. U.S. Geological Survey, Information Services Box 25286, Denver Federal Center Denver, CO 80225.

Stubblefield, W.A., Brinkman, S.F., Davies, P.H., Garrison, T.D., Hockett, J.R., & McIntyre, M.W. 1997. Effects of water hardness on the toxicity of manganese to developing brown trout (*Salmo trutta*). Environmental Toxicity and Chemistry 16: 2082-2089.

USDA. 2019. US Forest Service 2019 Rocky Mountain Region Aerial Survey Results. https://www.fs.usda.gov/detail/r2/forest-grasslandhealth/?cid=fseprd696221

Voelz, N.J., Zuelling, R.E., Shieh, S., and Ward, J.V. 2005. The effects of urban areas on benthic macroinvertebrates in two Colorado plains rivers. Environmental Monitoring and Assessment 101: 175-202.

WQCC. 2020a. Regulation No. 31 The Basic Standards and Methodologies for Surface Water; 5 CCR1002-31. Colorado Department of Public Health and Environment Water Quality Control Commission; EFFECTIVE: June 30, 2020.

WQCC. 2020b. Regulation No. 38 Classifications and Numeric Standards for South Platte River Basin, Laramie River Basin Republican River Basin, Smoky Hill River Basin; 5 CCR1002-38. Colorado Department of Public Health and Environment Water Quality Control Commission; Effective: December 31, 202

Appendix A.

Number of samples, Mann-Kendall trend test results, maximum value, minimum value, median value and range of years represented for each water quality parameter at each sampling location. Yellow highlights represent significant ($p < 0.05$) trend.

				M10			
Parameter	Count	Slope	p value	Maximum	Minimum	Median	Date Range
Acidity, (H+) (mg/L)	104	0.000	0.753	0.0004	0.00001	0.00009	2011-2021
Alkalinity, Dissolved (mg/L)	120	0.010	0.063	15.5	3.31	7.3	2011-2021
Ammonia and ammonium, Dissolved (mg/L)	-	-	-	-	-	-	-
Ammonia as NH_4 (mg/L)	105	0.000	0.125	0.029	0.0065	0.0065	2011-2021
Arsenic, Dissolved (mg/L)	73	0.167	0.007	0.28	0.02	0.11	2011-2021
Barometric pressure (mm/Hg)	110	0.125	0.267	577	556	569	2011-2021
Calcium, Dissolved (mg/L)	120	-0.036	0.073	6.075	1.11	2.475	2011-2021
Carbon dioxide, Total (mg/L)	104	0.043	0.222	5.5	0.1	1.2	2011-2021
Chloride, Dissolved (mg/L)	120	0.013	0.067	1.295	0.05815	0.3	2011-2021
Copper, Dissolved (mg/L)	109	-0.010	0.464	8	0.56	1.5	2011-2021
Hardness, Ca, Mg (mg/L $CaCO_3$)	120	0.011	0.473	22.75	3.9033	8.945	2011-2021
Iron, Dissolved (mg/L)	111	0.000	0.604	312	43.9	85.2	2011-2021
Kjeldahl nitrogen, Total (mg/L)	106	0.000	1.000	0.44	0.035	0.125	2011-2021
Lead, Dissolved (mg/L)	67	-0.105	<0.001	0.107	0.0125	0.037	2011-2021
Magnesium, Dissolved (mg/L)	120	-0.003	0.211	1.845	0.274	0.6685	2011-2021
Manganese, Dissolved (mg/L)	110	0.500	0.626	43.3	2.3	5.74	2011-2021
Nickel, Dissolved (mg/L)	81	0.000	0.773	1.6	0.1	0.31	2011-2021
Nitrate + Nitrite, Dissolved (mg/L)	120	0.001	0.861	0.6925	0.059	0.17	2011-2021
Nitrate, Dissolved (mg/L)	74	0.000	0.002	0.5095	0.04	0.18133	2016-2021
Nitrite, Dissolved (mg/L)	12	0.000	0.431	0.006	0.0005	0.00175	2011-2021
Nitrogen, mixed forms (NH3), (NH4), organic, (NO2) and (NO3), Dissolved (mg/L)	120	-0.071	0.083	0.935	0.11	0.28	2011-2021
Nitrogen, mixed forms (NH_3), (NH_4), organic, (NO_2) and (NO_3),Total (mg/L)	120	0.002	0.462	0.899	0.115	0.29	2011-2021
Nitrogen, Suspended (mg/L)	113	0.003	<0.001	0.394	0.0085	0.015	2011-2021
Organic carbon, Dissolved (mg/L)	118	0.000	0.522	11.78	1.32	2.1075	2011-2021
Organic carbon, Total (mg/L)	110	0.010	0.473	15.5	1.6	2.57	2011-2021
Organic Nitrogen, Total (mg/L)	-	-	-	-	-	-	-
Orthophosphate, Dissolved as P (mg/L)	112	0.000	0.337	0.007	0.002	0.002	2011-2021
Orthophosphate, Dissolved as $P0_4$ (mg/L)	106	0.000	0.689	0.023	0.006	0.006	2011-2021
Oxygen, Dissolved (%)	110	0.000	0.953	113	81	102	2011-2021
Oxygen, Dissolved (mg/L)	110	-0.025	0.043	11.1	8	9.75	2011-2021
pH (SU)	104	0.000	0.590	8.5	6.5	7.1	2011-2021
Phosphorus, Total (mg/L)	113	0.004	0.034	0.0495	0.002	0.008	2011-2021
Phosphorus, Dissolved (mg/L)	82	0.000	0.246	0.013	0.0015	0.005	2011-2021
Potassium, Dissolved (mg/L)	-	-	-	-	-	-	2011-2021
RBP Stream width (ft)	110	-0.635	<0.001	43	12.4	30	2011-2021
Selenium, Dissolved (mg/L)	-	-	-	-	-	-	-
Sodium adsorption ratio [(Na)/(sq root of 1/2 Ca + Mg)]	120	0.000	1.000	0.34	0.12667	0.21	2011-2021
Sodium, Dissolved (mg/L)	120	0.010	0.866	3.33	0.61	1.5	2011-2021
Sodium, total cations (%)	120	0.003	0.353	29	19	26	2011-2021
Specific conductance (µS/cm)	118	0.000	1.000	62.5	12	27	2011-2021
Stream flow (cfs)	110	-0.100	0.667	147	1.6	23.75	2011-2021
Sulfate, Dissolved (mg/L)	120	0.002	0.001	10.2	0.9333	2.61875	2011-2021
Temperature, water (°C)	120	0.000	0.819	14.75	-0.1	5.143	2011-2021
Total dissolved solids, Dissolved, Dried 180 (mg/L)	114	0.000	0.848	56	6	24.8222	2011-2021
Total dissolved solids, Dissolved, Filtered (mg/L)	120	0.029	0.616	39	7	18	2011-2021
Turbidity (NTU)	110	0.000	0.113	19.85	1	1	2011-2021
Zinc, Dissolved (mg/L)	-	-	-	-	-	-	-

Parameter	Count	Slope	p value	M30 Maximum	Minimum	Median	Date Range
Acidity, (H+) (mg/L)	109	0.000	0.070	0.0005	0.00001	0.000-4	2011-2021
Alkalinity, Dissolved (mg/L)	110	-0.058	0.590	36	6.7	14.7	2011-2021
Ammonia and ammonium, Dissolved (mg/L)	85	0.001	0.015	0.54	0.005	0.02	2011-2021
Ammonia as NH_4 (mg/L)	111	0.000	0.449	0.69	0.0065	0.016	2011-2021
Arsenic, Dissolved (mg/L)	74	0.000	0.963	1.1	0.86	2.75	2011-2021
Barometric pressure (mm/Hg)	111	0.000	0.300	588	568	580	2011-2021
Calcium, Dissolved (mg/L)	110	-0.027	0.308	9.85	1.54	3.89	2011-2021
Carbon dioxide, Total (mg/L)	108	0.043	0.034	4.3	0.1	1	2011-2021
Chloride, Dissolved (mg/L)	110	-0.002	0.932	42.4	0.42	2.995	2011-2021
Copper, Dissolved (mg/L)	108	-0.100	<0.001	7.7	0.4	0.11	2011-2021
Hardness, Ca, Mg (mg/L $CaCO_3$)	110	0.090	0.307	36.1	5.55	14.3	2011-2021
Iron, Dissolved (mg/L)	110	-1.520	0.223	372	47.4	107	2011-2021
Kjeldahl nitrogen, Total (mg/L)	111	-0.003	0.377	0.79	0.11	0.22	2011-2021
Lead, Dissolved (mg/L)	83	<-0.001	0.598	0.189	0.0125	0.039	2011-2021
Magnesium, Dissolved (mg/L)	110	0.006	0.294	2.8	0.411	1.12	2011-2021
Manganese, Dissolved (mg/L)	110	-0.080	0.166	45.1	2.93	6.965	2011-2021
Nickel, Dissolved (mg/L)	82	0.001	0.598	1.6	0.1	0.28	2011-2021
Nitrate + Nitrite, Dissolved (mg/L)	111	0.003	0.111	0.57	0.0505	0.02	2011-2021
Nitrate, Dissolved (mg/L)	-	-	-	-	-	-	-
Nitrite, Dissolved (mg/L)	-	-	-	-	-	-	-
Nitrogen, mixed forms (NH3), (NH4), organic, (NO2) and (NO3), Dissolved (mg/L)	-	-	-	-	-	-	-
Nitrogen, mixed forms (NH_3), (NH_4), organic, (NO_2) and (NO_3),Total (mg/L)	111	0.003	0.443	0.99	0.19	0.42	2011-2021
Nitrogen, Suspended (mg/L)	-	-	-	-	-	-	-
Organic carbon, Dissolved (mg/L)	-	-	-	-	-	-	-
Organic carbon, Total (mg/L)	109	-0.014	0.357	11.25	1.79	2.7	2011-2021
Organic Nitrogen, Total (mg/L)	111	-0.003	0.210	0.445	0.055	0.135	2011-2021
Orthophosphate, Dissolved as P (mg/L)	93	-0.001	0.091	0.195	0.002	0.011	2011-2021
Orthophosphate, Dissolved as $P0_4$ (mg/L)	109	-0.002	<0.001	0.598	0.006	0.0265	2011-2021
Oxygen, Dissolved (%)	111	-0.250	0.008	126	98	105	2011-2021
Oxygen, Dissolved (mg/L)	111	0.000	0.863	12.7	7.7	9,7	2011-2021
pH (SU)	109	-0.020	0.014	8.9	6.7	7.45	2011-2021
Phosphorus, Total (mg/L)	111	-0.001	<0.001	0.259	0.009	0.029	2011-2021
Phosphorus, Dissolved (mg/L)	111	-0.001	0.003	0.239	0.004	0.013	2011-2021
Potassium, Dissolved (mg/L)	109	0.010	0.001	1.22	0.27	0.61	2011-2021
RBP Stream width (ft)	111	-1.268	0.003	124	17	60	2011-2021
Selenium, Dissolved (mg/L)	-	-	-	-	-	-	-
Sodium adsorption ratio [(Na)/(sq root of 1/2 Ca + Mg)]	110	0.033	0.052	2.35	0.17	0.37	2011-2021
Sodium, Dissolved (mg/L)	110	0.030	0.193	28.3	0.93	3.19	2011-2021
Sodium, total cations (%)	109	0.000	0.576	68	24	31	2011-2021
Specific conductance (µS/cm)	111	0.081	0.549	208	17	48	2011-2021
Stream flow (cfs)	110	-1.000	0.106	901	8.4	58.5	2011-2021
Sulfate, Dissolved (mg/L)	110	-0.022	0.084	7.32	0.86	2.75	2011-2021
Temperature, water (^oC)	111	-0.147	0.002	17	0.1	6.8	2011-2021
Total dissolved solids, Dissolved, Dried 180 (mg/L)	110	0.708	0.003	117	6	38.5	2011-2021
Total dissolved solids, Dissolved, Filtered (mg/L)	110	0.000	0.931	104	6	25	2011-2021
Turbidity (NTU)	110	0.000	0.167	50	1	2	2011-2021
Zinc, Dissolved (mg/L)	71	0.017	0.605	11.1	0.7	2.9	2011-2021

Parameter	Count	Slope	p value	M50 Maximum	Minimum	Median	Date Range
Acidity, (H+) (mg/L)	108	0.000	0.541	0.0005	0.00001	0.00003	2011-2021
Alkalinity, Dissolved (mg/L)	110	0.067	0.712	32.6	7.8	22.3	2011-2021
Ammonia and ammonium, Dissolved (mg/L)	96	-0.006	<0.001	0.47	0.005	0.0425	2011-2021
Ammonia as NH_4 (mg/L)	107	-0.007	<0.001	0.611	0.0065	0.042	2011-2021
Arsenic, Dissolved (mg/L)	110	-0.002	0.035	1	0.1	0.165	2011-2021
Barometric pressure (mm/Hg)	111	0.000	0.527	590	568	583	2011-2021
Calcium, Dissolved (mg/L)	110	0.032	0.350	10.6	1.8	6.24	2011-2021
Carbon dioxide, Total (mg/L)	108	0.060	0.002	6.4	0.05	0.9	2011-2021
Chloride, Dissolved (mg/L)	110	0.014	0.777	10.7	0.71	2.805	2011-2021
Copper, Dissolved (mg/L)	108	-0.128	<0.001	28.3	0.4	1.2	2011-2021
Hardness, Ca, Mg (mg/L $CaCO_3$)	110	0.071	0.379	38.5	6.51	21.2	2011-2021
Iron, Dissolved (mg/L)	110	-0.186	0.888	1080	24	63.65	2011-2021
Kjeldahl nitrogen, Total (mg/L)	111	-0.011	<0.001	1.3	0.16	0.29	2011-2021
Lead, Dissolved (mg/L)	78	-0.002	0.024	0.529	0.0125	0.0395	2011-2021
Magnesium, Dissolved (mg/L)	110	0.010	0.365	2.93	0.487	1.34	2011-2021
Manganese, Dissolved (mg/L)	110	-0.150	0.166	106	1.9	5.95	2011-2021
Nickel, Dissolved (mg/L)	88	-0.007	0.119	1.6	0.045	0.27	2011-2021
Nitrate + Nitrite, Dissolved (mg/L)	111	-0.001	0.843	0.99	0.06	0.25	2011-2021
Nitrate, Dissolved (mg/L)	-	-	-	-	-	-	-
Nitrite, Dissolved (mg/L)	-	-	-	-	-	-	-
Nitrogen, mixed forms (NH3), (NH4), organic, (NO2) and (NO3), Dissolved (mg/L)	-	-	-				-
Nitrogen, mixed forms (NH_3), (NH_4), organic, (NO_2) and (NO_3),Total (mg/L)	111	-0.014	0.033	1.6	0.23	0.54	2011-2021
Nitrogen, Suspended (mg/L)	-	-	-	-	-	-	-
Organic carbon, Dissolved (mg/L)	-	-	-	-	-	-	-
Organic carbon, Total (mg/L)	110	-0.026	0.101	8.6	2.52	4.04	2011-2021
Organic Nitrogen, Total (mg/L)	107	-0.008	0.005	1	0.09	0.24	2011-2021
Orthophosphate, Dissolved as P (mg/L)	109	0.002	0.051	0.256	0.002	0.05	2011-2021
Orthophosphate, Dissolved as $P0_4$ (mg/L)	109	0.066	0.062	0.784	0.006	0.153	2011-2021
Oxygen, Dissolved (%)	111	-0.264	0.048	125	87	105	2011-2021
Oxygen, Dissolved (mg/L)	111	-0.012	0.512	11.8	7.2	9.3	2011-2021
pH (SU)	109	-0.040	0.001	9.8	6.8	7.6	2011-2021
Phosphorus, Total (mg/L)	111	0.002	0.174	0.347	0.021	0.071	2011-2021
Phosphorus, Dissolved (mg/L)	111	0.002	0.074	0.277	0.007	0.58	2011-2021
Potassium, Dissolved (mg/L)	109	0.008	0.120	6.39	0.35	0.8	2011-2021
RBP Stream width (ft)	111	0.110	0.629	85	19	42	2011-2021
Selenium, Dissolved (mg/L)	-	-	-	-	-	-	-
Sodium adsorption ratio [(Na)/(sq root of 1/2 Ca + Mg)]	110	0.007	<0.001	0.59	0.19	0.33	2011-2021
Sodium, Dissolved (mg/L)	110	0.086	0.014	7.07	1.1	3.37	2011-2021
Sodium, total cations (%)	109	0.333	0.001	35	19	26	2011-2021
Specific conductance (µS/cm)	111	0.125	0.549	117	22	61	2011-2021
Stream flow (cfs)	111	-0.536	0.461	621	9.6	83	2011-2021
Sulfate, Dissolved (mg/L)	110	-0.007	0.712	5.85	1.05	3.43	2011-2021
Temperature, water (°C)	111	-0.250	0.691	19.6	0	8.7	2011-2021
Total dissolved solids, Dissolved, Dried 180 (mg/L)	110	0.690	0.133	78	6	44.5	2011-2021
Total dissolved solids, Dissolved, Filtered (mg/L)	110	0.000	0.510	58	7	32	2011-2021
Turbidity (NTU)	110	0.000	0.253	14	1	2.2	2011-2021
Zinc, Dissolved (mg/L)	71	0.207	<0.001	7.5	0.7	2.5	2011-2021

Parameter	Count	Slope	p value	M60 Maximum	Minimum	Median	Date Range
Acidity, (H+) (mg/L)	105	0.000	0.349	0.0005	0.00001	0.00002	2011-2021
Alkalinity, Dissolved (mg/L)	109	0.060	0.539	33.9	8.2	22.5	2011-2021
Ammonia and ammonium, Dissolved (mg/L)	67	0.000	0.902	0.24	0.005	0.01	2011-2021
Ammonia as NH_4 (mg/L)	104	0.000	0.010	0.306	0.0065	0.013	2011-2021
Arsenic, Dissolved (mg/L)	109	-0.003	0.007	0.28	0.1	0.17	2011-2021
Barometric pressure (mm/Hg)	108	0.000	0.608	617	597	609	2011-2021
Calcium, Dissolved (mg/L)	109	0.003	0.953	111.1	1.9	6.48	2011-2021
Carbon dioxide, Total (mg/L)	105	0.040	0.026	11	0.2	1	2011-2021
Chloride, Dissolved (mg/L)	109	0.057	0.254	10.9	0.83	3.11	2011-2021
Copper, Dissolved (mg/L)	108	-0.103	<0.001	14.1	0.4	1.3	2011-2021
Hardness, Ca, Mg (mg/L $CaCO_3$)	109	0.075	0.682	40.5	6.76	22.2	2011-2021
Iron, Dissolved (mg/L)	109	-0.125	1.000	487	16	51	2011-2021
Kjeldahl nitrogen, Total (mg/L)	109	-0.004	0.164	0	0.15	0.25	2011-2021
Lead, Dissolved (mg/L)	85	0.000	1.000	0.208	0.0125	0.041	2011-2021
Magnesium, Dissolved (mg/L)	109	0.010	0.280	3.07	0.488	1.42	2011-2021
Manganese, Dissolved (mg/L)	109	-0.113	0.017	83.7	0.81	2.29	2011-2021
Nickel, Dissolved (mg/L)	90	0.000	1.000	0.94	0.045	0.27	2011-2021
Nitrate + Nitrite, Dissolved (mg/L)	109	-0.012	0.038	0.89	0.02	0.27	2011-2021
Nitrate, Dissolved (mg/L)	-	-	-	-	-	-	-
Nitrite, Dissolved (mg/L)	-	-	-	-	-	-	-
Nitrogen, mixed forms (NH3), (NH4), organic, (NO2) and (NO3), Dissolved (mg/L)	-	-	-	-	-	-	-
Nitrogen, mixed forms (NH_3), (NH_4), organic, (NO_2) and (NO_3),Total (mg/L)	109	-0.020	0.003	1.3	0.23	0.53	2011-2021
Nitrogen, Suspended (mg/L)	-	-	-	-	-	-	-
Organic carbon, Dissolved (mg/L)	-	-	-	-	-	-	-
Organic carbon, Total (mg/L)	109	-0.030	0.094	11.5	2.38	3.81	2011-2021
Organic Nitrogen, Total (mg/L)	104	-0.008	0.034	0.49	0.075	0.18	2011-2021
Orthophosphate, Dissolved as P (mg/L)	109	0.001	0.114	0.17	0.005	0.04	2011-2021
Orthophosphate, Dissolved as $P0_4$ (mg/L)	109	0.004	0.108	0.52	0.015	0.124	2011-2021
Oxygen, Dissolved (%)	107	-0.200	0.010	110	98	102	2011-2021
Oxygen, Dissolved (mg/L)	108	-0.050	0.004	12.7	7.6	9.5	2011-2021
pH (SU)	105	-0.013	0.146	8.5	6.5	7.6	2011-2021
Phosphorus, Total (mg/L)	109	0.003	0.024	0.627	0.02	0.074	2011-2021
Phosphorus, Dissolved (mg/L)	109	0.002	0.037	0.188	0.007	0.048	2011-2021
Potassium, Dissolved (mg/L)	109	0.005	0.429	1.42	0.34	0.85	2011-2021
RBP Stream width (ft)	109	-1.357	0.005	62	12.3	40.5	2011-2021
Selenium, Dissolved (mg/L)	-	-	-	-	-	-	-
Sodium adsorption ratio [(Na)/(sq root of 1/2 Ca + Mg)]	109	0.005	0.029	0.6	0.19	0.35	2011-2021
Sodium, Dissolved (mg/L)	109	0.063	0.047	7.72	1.15	3.67	2011-2021
Sodium, total cations (%)	109	0.200	0.047	34	19	27	2011-2021
Specific conductance (µS/cm)	109	0.875	0.094	118	20	64	2011-2021
Stream flow (cfs)	107	0.000	0.976	987	10	77	2011-2021
Sulfate, Dissolved (mg/L)	109	0.008	0.838	6.44	1.03	3.5	2011-2021
Temperature, water (^oC)	109	0.050	0.275	18.9	0	8.5	2011-2021
Total dissolved solids, Dissolved, Dried 180 (mg/L)	109	1.000	0.006	90	10	43	2011-2021
Total dissolved solids, Dissolved, Filtered (mg/L)	109	0.286	0.316	61	111	34	2011-2021
Turbidity (NTU)	109	0.000	0.887	470	1	2.1	2011-2021
Zinc, Dissolved (mg/L)	-	-	-	-	-	-	-

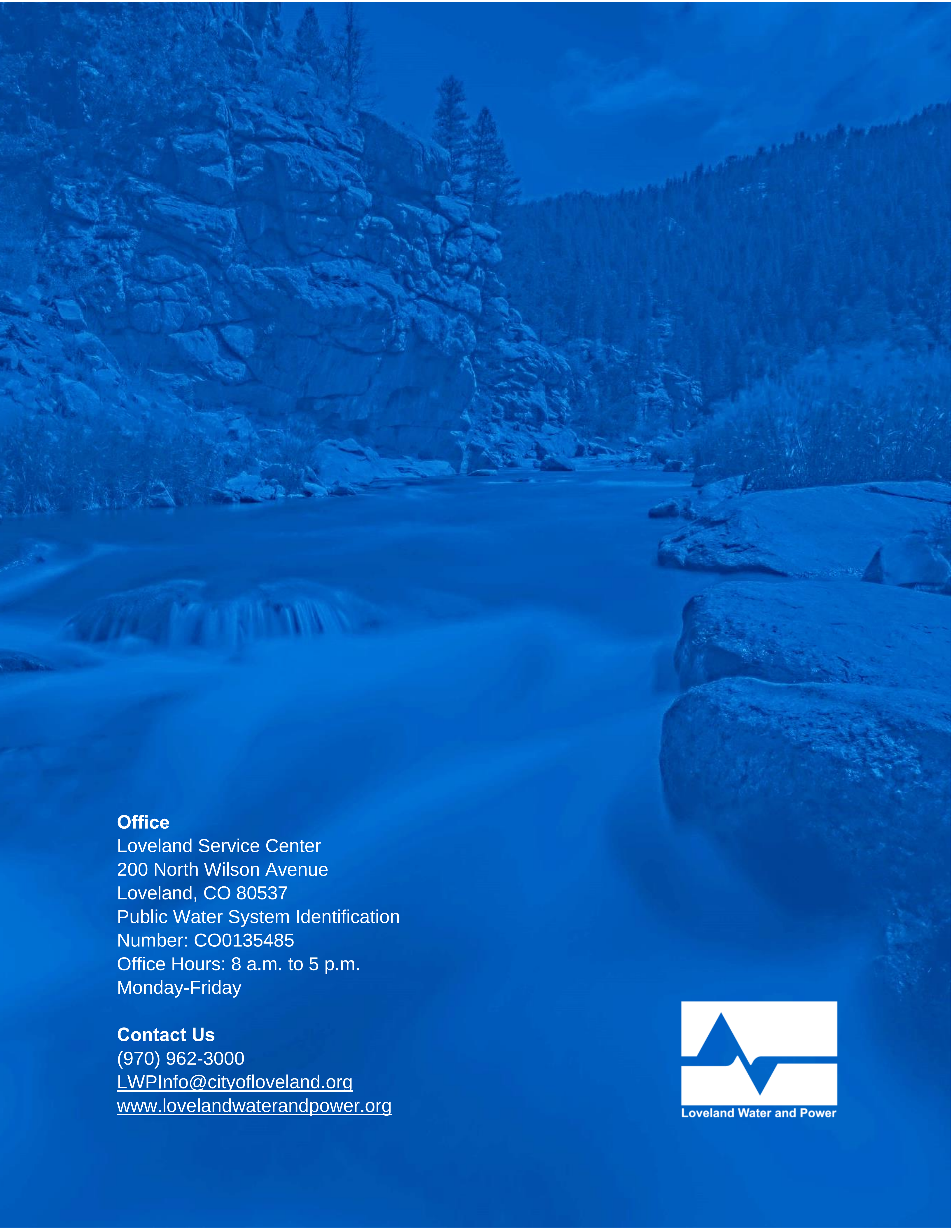
				M70			
Parameter	Count	Slope	p value	Maximum	Minimum	Median	Date Range
Acidity, (H+) (mg/L)	108	0.000	0.093	0.0005	0.00001	0.00002	2011-2021
Alkalinity, Dissolved (mg/L)	108	0.100	0.399	38.6	9.1	22.15	2011-2021
Ammonia and ammonium, Dissolved (mg/L)	67	-0.008	0.011	0.23	0.005	0.01	2011-2021
Ammonia as NH_4 (mg/L)	99	0.000	0.501	0.29	0.0065	0.01175	2011-2021
Arsenic, Dissolved (mg/L)	106	-0.001	0.087	0.28	0.11	0.16	2011-2021
Barometric pressure (mm/Hg)	107	0.000	0.479	635	611	622.5	2011-2021
Calcium, Dissolved (mg/L)	108	0.059	0.201	11.4	2.03	6.31	2011-2021
Carbon dioxide, Total (mg/L)	108	-0.014	0.288	2.7	0.05	0.8	2011-2021
Chloride, Dissolved (mg/L)	108	0.048	0.008	8.22	0.81	2.915	2011-2021
Copper, Dissolved (mg/L)	107	-0.148	<0.001	15.3	0.71	1.5	2011-2021
Hardness, Ca, Mg (mg/L $CaCO_3$)	108	0.177	0.181	39.8	7.13	21.4	2011-2021
Iron, Dissolved (mg/L)	108	-0.524	0.541	418	21.9	59.2	2011-2021
Kjeldahl nitrogen, Total (mg/L)	108	-0.003	0.521	0.59	0.13	0.25	2011-2021
Lead, Dissolved (mg/L)	88	0.000	1.000	0.444	0.0125	0.0395	2011-2021
Magnesium, Dissolved (mg/L)	108	0.013	0.076	2.83	0.503	1.37	2011-2021
Manganese, Dissolved (mg/L)	108	-0.081	0.222	28.6	1.69	4.53	2011-2021
Nickel, Dissolved (mg/L)	91	0.010	0.038	0.97	0.045	0.27	2011-2021
Nitrate + Nitrite, Dissolved (mg/L)	107	-0.005	0.092	0.85	0.046	0.209	2011-2021
Nitrate, Dissolved (mg/L)	-	-	-	-	-	-	-
Nitrite, Dissolved (mg/L)	-	-	-	-	-	-	-
Nitrogen, mixed forms (NH3), (NH4), organic, (NO2) and (NO3), Dissolved (mg/L)	-	-	-	-	-	-	-
Nitrogen, mixed forms (NH_3), (NH_4), organic, (NO_2) and (NO_3),Total (mg/L)	108	-0.007	0.180	1.3	0.15	0.4625	2011-2021
Nitrogen, Suspended (mg/L)	-	-	-	-	-	-	-
Organic carbon, Dissolved (mg/L)	-	-	-	-	-	-	-
Organic carbon, Total (mg/L)	108	-0.034	0.013	12.8	2.47	3.515	2011-2021
Organic Nitrogen, Total (mg/L)	97	-0.004	0.244	0.58	0.065	0.1725	2011-2021
Orthophosphate, Dissolved as P (mg/L)	108	<0.001	0.167	0.126	0.005	0.029	2011-2021
Orthophosphate, Dissolved as $P0_4$ (mg/L)	108	-0.001	0.415	0.386	0.014	0.08825	2011-2021
Oxygen, Dissolved (%)	107	-0.200	0.136	115	97	103.5	2011-2021
Oxygen, Dissolved (mg/L)	107	0.000	0.591	12.8	7.5	9.45	2011-2021
pH (SU)	108	0.012	0.102	9.5	7.11	7.7	2011-2021
Phosphorus, Total (mg/L)	108	0.003	0.034	0.3225	0.021	0.068	2011-2021
Phosphorus, Dissolved (mg/L)	108	0.001	0.256	0.146	0.008	0.0365	2011-2021
Potassium, Dissolved (mg/L)	108	0.012	0.025	1.48	0.35	0.845	2011-2021
RBP Stream width (ft)	108	0.023	0.006	126	15	50	2011-2021
Selenium, Dissolved (mg/L)	-	-	-	-	-	-	-
Sodium adsorption ratio [(Na)/(sq root of 1/2 Ca + Mg)]	108	0.008	<0.001	0.58	0.2	0.35	2011-2021
Sodium, Dissolved (mg/L)	108	0.090	<0.001	7.25	1.25	3.705	2011-2021
Sodium, total cations (%)	108	0.286	0.040	34	20	28	2011-2021
Specific conductance (µS/cm)	108	1.000	0.020	115	23.5	61.5	2011-2021
Stream flow (cfs)	108	-0.889	0.460	761	8.3	92	2011-2021
Sulfate, Dissolved (mg/L)	108	0.017	0.336	8.59	1.12	3.315	2011-2021
Temperature, water (°C)	108	-0.118	0.108	19.9	0	10	2011-2021
Total dissolved solids, Dissolved, Dried 180 (mg/L)	108	0.708	0.064	86	10	45	2011-2021
Total dissolved solids, Dissolved, Filtered (mg/L)	108	0.500	0.043	64	12	33	2011-2021
Turbidity (NTU)	108	0.047	0.081	210	9.1	22.05	2011-2021
Zinc, Dissolved (mg/L)	-	-	-	-	-	-	-

				M90			
Parameter	**Count**	**Slope**	**p value**	**Maximum**	**Minimum**	**Median**	**Date Range**
Acidity, (H+) (mg/L)	108	0.000	0.186	0.0005	0.00001	0.00002	2011-2021
Alkalinity, Dissolved (mg/L)	110	0.100	0.410	42.2	8.8	22.8	2011-2021
Ammonia and ammonium, Dissolved (mg/L)	78	0.000	0.115	0.11	0.005	0.01	2011-2021
Ammonia as NH_4 (mg/L)	105	0.000	0.575	0.142	0.0065	0.015	2011-2021
Arsenic, Dissolved (mg/L)	106	-0.001	0.217	0.33	0.1	0.17	2011-2021
Barometric pressure (mm/Hg)	109	-0.167	0.232	640	606	629	2011-2021
Calcium, Dissolved (mg/L)	110	0.055	0.142	13.8	2.04	6.485	2011-2021
Carbon dioxide, Total (mg/L)	108	0.033	0.012	3	0.05	0.8	2011-2021
Chloride, Dissolved (mg/L)	110	0.066	0.017	11.7	0.72	2.62	2011-2021
Copper, Dissolved (mg/L)	109	-0.175	<0.001	8.4	0.66	1.5	2011-2021
Hardness, Ca, Mg (mg/L $CaCO_3$)	110	0.200	0.077	47.8	7.14	21.8	2011-2021
Iron, Dissolved (mg/L)	110	-0.600	0.427	4670	24.3	58.1	2011-2021
Kjeldahl nitrogen, Total (mg/L)	110	-0.005	0.047	0.94	0.14	0.26	2011-2021
Lead, Dissolved (mg/L)	92	0.000	1.000	3.12	0.0125	0.041	2011-2021
Magnesium, Dissolved (mg/L)	110	0.015	0.094	3.3	0.492	1.355	2011-2021
Manganese, Dissolved (mg/L)	110	-0.074	0.557	88.1	1.76	6.095	2011-2021
Nickel, Dissolved (mg/L)	90	0.005	0.206	2.6	0.045	0.26	2011-2021
Nitrate + Nitrite, Dissolved (mg/L)	110	-0.004	0.091	0.73	0.01	0.16	2011-2021
Nitrate, Dissolved (mg/L)	-	-	-	-	-	-	-
Nitrite, Dissolved (mg/L)	-	-	-	-	-	-	-
Nitrogen, mixed forms (NH3), (NH4), organic, (NO2) and (NO3), Dissolved (mg/L)	-	-	-	-	-	-	-
Nitrogen, mixed forms (NH_3), (NH_4), organic, (NO_2) and (NO_3),Total (mg/L)	110	-0.010	0.051	1.4	0.18	0.41	2011-2021
Nitrogen, Suspended (mg/L)	-	-	-	-	-	-	-
Organic carbon, Dissolved (mg/L)	-	-	-	-	-	-	-
Organic carbon, Total (mg/L)	110	-0.010	0.480	11.6	2.43	3.565	2011-2021
Organic Nitrogen, Total (mg/L)	105	-0.007	0.024	0.92	0.075	0.19	2011-2021
Orthophosphate, Dissolved as P (mg/L)	107	0.000	0.711	0.116	0.005	0.019	2011-2021
Orthophosphate, Dissolved as $P0_4$ (mg/L)	110	0.000	1.000	0.354	0.006	0.058	2011-2021
Oxygen, Dissolved (%)	109	-0.200	0.015	127	98	104	2011-2021
Oxygen, Dissolved (mg/L)	109	-0.046	0.043	12.8	7.5	9.5	2011-2021
pH (SU)	108	-0.029	0.007	9.2	7	7.7	2011-2021
Phosphorus, Total (mg/L)	110	0.001	0.275	0.922	0.018	0.052	2011-2021
Phosphorus, Dissolved (mg/L)	110	<0.001	0.460	0.135	0.006	0.0245	2011-2021
Potassium, Dissolved (mg/L)	110	0.010	0.077	2.8	0.32	0.83	2011-2021
RBP Stream width (ft)	110	-0.250	0.746	86	14.2	49.75	2011-2021
Selenium, Dissolved (mg/L)	109	0.000	0.148	0.21	0.03	0.07	2011-2021
Sodium adsorption ratio [(Na)/(sq root of 1/2 Ca + Mg)]	110	0.004	0.004	0.6	0.2	0.325	2011-2021
Sodium, Dissolved (mg/L)	110	0.055	0.007	7.55	1.2	3.505	2011-2021
Sodium, total cations (%)	110	0.200	0.023	43	19	26	2011-2021
Specific conductance (µS/cm)	110	1.290	0.004	132	21	61.5	2011-2021
Stream flow (cfs)	110	-2.333	0.186	1310	11	132	2011-2021
Sulfate, Dissolved (mg/L)	110	0.033	0.010	8.71	1.09	3.255	2011-2021
Temperature, water (^{o}C)	110	0.067	0.408	20.6	0	10.9	2011-2021
Total dissolved solids, Dissolved, Dried 180 (mg/L)	110	1.000	0.031	121	10	42	2011-2021
Total dissolved solids, Dissolved, Filtered (mg/L)	110	0.375	0.057	70	12	33	2011-2021
Turbidity (NTU)	110	0.000	0.783	560	1	3.3	2011-2021
Zinc, Dissolved (mg/L)	-	-	-	-	-	-	-

				M130			
Parameter	Count	Slope	p value	Maximum	Minimum	Median	Date Range
Acidity, (H+) (mg/L)	126	0.000	0.253	0.0005	0.00001	0.00001	2011-2021
Alkalinity, Dissolved (mg/L)	110	0.343	0.671	219	18.5	88.95	2011-2021
Ammonia and ammonium, Dissolved (mg/L)	91	0.000	0.583	0.08	0.005	0.01	2011-2021
Ammonia as NH_4 (mg/L)	119	0.000	0.291	0.103	0.0065	0.016	2011-2021
Arsenic, Dissolved (mg/L)	109	-0.002	0.629	1.3	0.15	0.35	2011-2021
Barometric pressure (mm/Hg)	127	0.000	0.378	651	626	637	2011-2021
Calcium, Dissolved (mg/L)	110	0.256	0.692	191	8.24	55.95	2011-2021
Carbon dioxide, Total (mg/L)	109	0.000	0.706	6.2	0.5	1.5	2011-2021
Chloride, Dissolved (mg/L)	110	0.356	0.025	97.5	2.34	12.65	2011-2021
Copper, Dissolved (mg/L)	105	-0.175	<0.001	10.6	0.4	1.2	2011-2021
Hardness, Ca, Mg (mg/L $CaCO_3$)	110	0.979	0.865	846	30	220	2011-2021
Iron, Dissolved (mg/L)	104	-0.940	0.157	902	6.5	28.45	2011-2021
Kjeldahl nitrogen, Total (mg/L)	126	-0.006	0.019	1.9	0.14	0.29	2011-2021
Lead, Dissolved (mg/L)	84	0.000	0.453	3.78	0.0075	0.029	2011-2021
Magnesium, Dissolved (mg/L)	110	0.016	0.955	91.6	2.28	19.25	2011-2021
Manganese, Dissolved (mg/L)	110	0.807	0.165	160	8.6	37.25	2011-2021
Nickel, Dissolved (mg/L)	109	-0.200	0.041	2.4	0.27	0.76	2011-2021
Nitrate + Nitrite, Dissolved (mg/L)	127	-0.013	<0.001	0.73	0.036	0.254	2011-2021
Nitrate, Dissolved (mg/L)	93	-0.021	0.792	0.72	0.051	0.249	2014-2021
Nitrite, Dissolved (mg/L)	93	0.000	0.961	0.09	0.001	0.003	2014-2021
Nitrogen, mixed forms (NH3), (NH4), organic, (NO2) and (NO3), Dissolved (mg/L)	-	-	-	-	-	-	-
Nitrogen, mixed forms (NH_3), (NH_4), organic, (NO_2) and (NO_3),Total (mg/L)	127	-0.200	<0.001	2.1	0.2	0.58	2011-2021
Nitrogen, Suspended (mg/L)	-	-	-	-	-	-	-
Organic carbon, Dissolved (mg/L)	-	-	-	-	-	-	-
Organic carbon, Total (mg/L)	110	-0.017	0.350	11.5	2.4	4.235	2011-2021
Organic Nitrogen, Total (mg/L)	119	-0.008	0.011	1.9	0.035	0.24	2011-2021
Orthophosphate, Dissolved as P (mg/L)	94	>-0.001	0.067	0.037	0.002	0.009	2011-2021
Orthophosphate, Dissolved as $P0_4$ (mg/L)	120	-0.002	<0.001	0.113	0.006	0.022	2011-2021
Oxygen, Dissolved (%)	126	0.333	0.184	200	84	107.5	2011-2021
Oxygen, Dissolved (mg/L)	126	0.000	0.718	16.3	7.3	10.4	2011-2021
pH (SU)	126	0.000	0.141	8.5	7.4	8	2011-2021
Phosphorus, Total (mg/L)	127	-0.001	0.102	0.603	0.004	0.032	2011-2021
Phosphorus, Dissolved (mg/L)	121	>-0.001	<0.001	0.112	0.003	0.01	2011-2021
Potassium, Dissolved (mg/L)	110	-0.007	0.591	4.36	0.64	1.795	2011-2021
RBP Stream width (ft)	127	-0.500	0.134	63	12	27	2011-2021
Selenium, Dissolved (mg/L)	78	-0.004	0.930	14.8	0.25	1.9	2011-2021
Sodium adsorption ratio [(Na)/(sq root of 1/2 Ca + Mg)]	110	-0.003	0.865	1.77	0.3	0.6	2011-2021
Sodium, Dissolved (mg/L)	110	0.045	0.843	115	3.83	20.6	2011-2021
Sodium, total cations (%)	110	-0.167	0.036	28	13	17	2011-2021
Specific conductance (µS/cm)	127	3.750	0.532	1770	82	526	2011-2021
Stream flow (cfs)	127	-0.500	0.278	1460	1.5	37	2011-2021
Sulfate, Dissolved (mg/L)	110	-0.071	0.977	828	9.99	159	2011-2021
Temperature, water (^oC)	127	0.150	0.047	23.4	0.1	12	2011-2021
Total dissolved solids, Dissolved, Dried 180 (mg/L)	110	-0.778	0.955	1380	55	334.5	2011-2021
Total dissolved solids, Dissolved, Filtered (mg/L)	110	0.786	0.734	1380	42	321	2011-2021
Turbidity (NTU)	110	0.008	0.189	150	1	4.85	2011-2021
Zinc, Dissolved (mg/L)	-	-	-	-	-	-	-

				M140			
Parameter	Count	Slope	p value	Maximum	Minimum	Median	Date Range
Acidity, (H+) (mg/L)	127	0.000	0.433	0.0005	0.00001	0.00001	2011-2021
Alkalinity, Dissolved (mg/L)	110	0.552	0.350	193	24.8	95.05	2011-2021
Ammonia and ammonium, Dissolved (mg/L)	124	0.000	0.015	5.97	0.005	0.03	2011-2021
Ammonia as NH_4 (mg/L)	126	0.002	0.014	7.69	0.0065	0.03375	2011-2021
Arsenic, Dissolved (mg/L)	110	0.000	0.711	1	0.125	0.37	2011-2021
Barometric pressure (mm/Hg)	127	0.000	0.362	651	627	638.5	2011-2021
Calcium, Dissolved (mg/L)	110	0.742	0.157	134	11.2	59.65	2011-2021
Carbon dioxide, Total (mg/L)	110	0.039	0.192	6.8	0.5	1.9	2011-2021
Chloride, Dissolved (mg/L)	110	0.510	0.031	80.7	3.62	20.4	2011-2021
Copper, Dissolved (mg/L)	108	-0.157	<0.001	16.2	0.6	1.8	2011-2021
Hardness, Ca, Mg (mg/L $CaCO_3$)	110	2.300	0.351	583	40.6	234.5	2011-2021
Iron, Dissolved (mg/L)	110	-0.375	0.282	584	8.7	36.6	2011-2021
Kjeldahl nitrogen, Total (mg/L)	127	0.001	0.744	7.3	0.31	0.67	2011-2021
Lead, Dissolved (mg/L)	109	-0.006	<0.001	0.536	0.029	0.094	2011-2021
Magnesium, Dissolved (mg/L)	110	0.131	0.571	60.2	3.08	23.3	2011-2021
Manganese, Dissolved (mg/L)	110	0.600	0.127	148	7.09	31.05	2011-2021
Nickel, Dissolved (mg/L)	110	-0.013	0.108	2	0.35	0.95	2011-2021
Nitrate + Nitrite, Dissolved (mg/L)	127	-0.053	0.187	9.68	0.354	2.41	2011-2021
Nitrate, Dissolved (mg/L)	95	0.016	0.792	9.63	0.35	2.32	2014-2021
Nitrite, Dissolved (mg/L)	95	0.006	<0.001	1.1	0.002	0.016	2014-2021
Nitrogen, mixed forms (NH3), (NH4), organic, (NO2) and (NO3), Dissolved (mg/L)	-	-	-	-	-	-	-
Nitrogen, mixed forms (NH_3), (NH_4), organic, (NO_2) and (NO_3),Total (mg/L)	127	-0.050	0.342	11	0.77	3.2	2011-2021
Nitrogen, Suspended (mg/L)	-	-	-	-	-	-	-
Organic carbon, Dissolved (mg/L)	-	-	-	-	-	-	-
Organic carbon, Total (mg/L)	110	-0.040	0.126	11.6	3.88	5.5075	2011-2021
Organic Nitrogen, Total (mg/L)	126	-0.006	0.643	1.9	0.165	0.59	2011-2021
Orthophosphate, Dissolved as P (mg/L)	127	-0.036	0.004	2.66	0.012	0.357	2011-2021
Orthophosphate, Dissolved as PO_4 (mg/L)	127	-0.110	0.005	8.15	0.038	1.095	2011-2021
Oxygen, Dissolved (%)	126	-0.267	0.601	146	66	109.5	2011-2021
Oxygen, Dissolved (mg/L)	126	-0.063	0.093	14.2	6.1	9.5	2011-2021
pH (SU)	127	0.000	0.617	8.6	7.4	7.9	2011-2021
Phosphorus, Total (mg/L)	127	-0.035	0.019	3.14	0.049	0.4625	2011-2021
Phosphorus, Dissolved (mg/L)	127	-0.038	0.011	2.97	0.024	0.391	2011-2021
Potassium, Dissolved (mg/L)	110	-0.001	1.000	10.6	0.92	3.315	2011-2021
RBP Stream width (ft)	127	-1.908	<0.001	63.5	20	43	2011-2021
Selenium, Dissolved (mg/L)	78	0.025	0.256	7.4	0.3	2.1	2011-2021
Sodium adsorption ratio [(Na)/(sq root of 1/2 Ca + Mg)]	110	0.001	0.932	2.04	0.37	0.96	2011-2021
Sodium, Dissolved (mg/L)	110	0.115	0.843	104	5.64	33.15	2011-2021
Sodium, total cations (%)	110	0.000	0.382	35	18	24	2011-2021
Specific conductance (µS/cm)	127	5.750	0.266	1420	118	651	2011-2021
Stream flow (cfs)	127	-1.750	0.008	1155.5	12	54	2011-2021
Sulfate, Dissolved (mg/L)	110	-0.114	0.932	482	20.2	179.5	2011-2021
Temperature, water (°C)	127	0.105	0.065	23.55	1.2	13	2011-2021
Total dissolved solids, Dissolved, Dried 180 (mg/L)	110	0.417	0.887	1040	79	411.5	2011-2021
Total dissolved solids, Dissolved, Filtered (mg/L)	110	1.633	0.734	987	63	386	2011-2021
Turbidity (NTU)	110	0.118	0.208	150	1	5.9	2011-2021
Zinc, Dissolved (mg/L)	105	0.045	0.906	40	1.7	8.2	2011-2021

				T10			
Parameter	Count	Slope	p value	Maximum	Minimum	Median	Date Range
Acidity, (H+) (mg/L)	105	0.000	0.722	0.0005	0.00001	0.00003	2011-2021
Alkalinity, Dissolved (mg/L)	110	0.067	0.429	32.6	8.9	16.95	2011-2021
Ammonia and ammonium, Dissolved (mg/L)	47	0.000	0.037	0.02	0.005	0.0005	2011-2021
Ammonia as NH_4 (mg/L)	101	0.000	1.000	0.03	0.0065	0.0065	2011-2021
Arsenic, Dissolved (mg/L)	110	0.001	0.344	0.32	0.07	0.12	2011-2021
Barometric pressure (mm/Hg)	110	0.000	0.835	618	598	608	2011-2021
Calcium, Dissolved (mg/L)	110	0.053	0.047	9.02	1.9	4.075	2011-2021
Carbon dioxide, Total (mg/L)	105	0.000	0.731	3	0.05	1	2011-2021
Chloride, Dissolved (mg/L)	110	0.081	<0.001	6.19	0.36	1.405	2011-2021
Copper, Dissolved (mg/L)	105	-0.120	<0.001	20.3	0.4	1.1	2011-2021
Hardness, Ca, Mg (mg/L $CaCO_3$)	110	0.200	0.121	31	6.46	14.3	2011-2021
Iron, Dissolved (mg/L)	110	-2.263	0.085	439	35.9	82.2	2011-2021
Kjeldahl nitrogen, Total (mg/L)	109	-0.003	0.165	3	0.07	0.17	2011-2021
Lead, Dissolved (mg/L)	79	0.003	0.102	0.704	0.0125	0.042	2011-2021
Magnesium, Dissolved (mg/L)	110	0.013	0.209	2.28	0.415	0.9855	2011-2021
Manganese, Dissolved (mg/L)	110	-0.309	<0.001	77.5	2.07	5.965	2011-2021
Nickel, Dissolved (mg/L)	78	0.020	0.001	0.72	0.045	0.265	2011-2021
Nitrate + Nitrite, Dissolved (mg/L)	109	0.000	0.547	0.37	0.004	0.09	2011-2021
Nitrate, Dissolved (mg/L)	-	-	-	-	-	-	-
Nitrite, Dissolved (mg/L)	-	-	-	-	-	-	-
Nitrogen, mixed forms (NH3), (NH4), organic, (NO2) and (NO3), Dissolved (mg/L)	-	-	-	-	-	-	-
Nitrogen, mixed forms (NH_3), (NH_4), organic, (NO_2) and (NO_3),Total (mg/L)	110	-0.002	0.557	3.1	0.06	0.27	2011-2021
Nitrogen, Suspended (mg/L)	-	-	-	-	-	-	2011-2021
Organic carbon, Dissolved (mg/L)	-	-	-	-	-	-	-
Organic carbon, Total (mg/L)	110	-0.038	0.293	14.2	1.55	2.83	2011-2021
Organic Nitrogen, Total (mg/L)	101	-0.003	0.052	3	0.03	0.085	2011-2021
Orthophosphate, Dissolved as P (mg/L)	110	0.000	0.005	0.038	0.002	0.007	2011-2021
Orthophosphate, Dissolved as $P0_4$ (mg/L)	107	-0.001	<0.001	0.117	0.006	0.018	2011-2021
Oxygen, Dissolved (%)	109	0.000	0.282	107	95	102	2011-2021
Oxygen, Dissolved (mg/L)	109	-0.006	0.008	12	7.3	9.5	2011-2021
pH (SU)	105	0.000	0.798	8.9	7	7.5	2011-2021
Phosphorus, Total (mg/L)	110	>-0.001	0.206	2.24	0.006	0.017	2011-2021
Phosphorus, Dissolved (mg/L)	107	>-0.001	0.039	0.044	0.003	0.007	2011-2021
Potassium, Dissolved (mg/L)	110	0.010	0.169	1.42	0.34	0.64	2011-2021
RBP Stream width (ft)	110	-0.500	0.028	66	8.75	23	2011-2021
Selenium, Dissolved (mg/L)	-	-	-	-	-	-	-
Sodium adsorption ratio [(Na)/(sq root of 1/2 Ca + Mg)]	110	0.003	0.002	0.56	0.24	0.33	2011-2021
Sodium, Dissolved (mg/L)	110	0.046	0.002	5.25	1.43	2.955	2011-2021
Sodium, total cations (%)	100	0.000	0.569	41	21	29.5	2011-2021
Specific conductance (µS/cm)	110	0.833	0.073	87	20	44	2011-2021
Stream flow (cfs)	110	-0.140	0.481	262	2.8	17.5	2011-2021
Sulfate, Dissolved (mg/L)	110	-0.012	0.350	12.9	1.12	2.47	2011-2021
Temperature, water (^oC)	110	0.160	0.033	19.8	0	8.5	2011-2021
Total dissolved solids, Dissolved, Dried 180 (mg/L)	110	1.000	0.026	78	10	37	2011-2021
Total dissolved solids, Dissolved, Filtered (mg/L)	110	0.286	0.014	58	11	24.5	2011-2021
Turbidity (NTU)	110	0.000	0.707	1060	1	2.45	2011-2021
Zinc, Dissolved (mg/L)	-	-	-	-	-	-	-



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