2021 ANNUAL REPORT

# Upper Cache la Poudre Watershed

## Collaborative Water Quality Monitoring Program

June 1, 2022

PREPARED FOR
City of Fort Collins
City of Greeley
Soldier Canyon Water Authority

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# EXECUTIVE SUMMARY

## BACKGROUND

The Upper Cache la Poudre Collaborative Water Quality Monitoring Program (hereafter referred to as the Upper CLP Monitoring Program) is designed to assist the City of Fort Collins, the City of Greeley and the Soldier Canyon Water Treatment Authority in meeting current and future drinking water treatment goals by reporting current water quality conditions, trends within the Upper Cache la Poudre River (CLP) watershed and summarizing issues that potentially impact watershed health and source water quality.

## SCOPE OF ANNUAL REPORT

This annual report summarizes climatic and hydrologic conditions in the Upper CLP watershed over the 2021 water year and water quality data collected as part of the Upper CLP Monitoring Program. Spatial trends in water quality are evaluated at key monitoring locations throughout the Mainstem and North Fork CLP watershed, and temporal trends are evaluated at monitoring sites located near water treatment facility intakes on the Poudre River. This report compares water quality information from 2021 to baseline conditions defined as the period of record from 2008 to 2012.

## UPPER CACHE LA POUDRE WATERSHED WATER QUALITY

The Upper CLP watershed continues to provide a high-quality drinking water supply to the City of Fort Collins, City of Greeley and surrounding communities served by the Soldier Canyon Water Treatment Authority; however, the Cameron Peak Fire resulted in notable changes to water quality in the Mainstem CLP River. No water quality concerns were identified in the North Fork CLP River.

The most notable impacts to water quality over the 2021 water year were associated with earlier than normal snowmelt runoff across the entire watershed, and post-fire water quality impacts to the Mainstem CLP River from the Cameron Peak Fire burn scar during and following the summer monsoon season.

Typical challenges for water treatment were observed on the Mainstem and the North Fork during snowmelt runoff. Water quality changes driven by snowmelt began one month earlier than normal. On the contrary, snowmelt driven impacts diminished earlier than normal posing less of a challenge to water treatment in June. The timing and magnitude of snowmelt runoff may have been influenced by the dramatic changes in landcover caused by the Cameron Peak Fire. Loss of tree and canopy cover likely shifted the energy dynamics influencing snowmelt, leading to a more rapid snowmelt response, especially at higher elevations in the watershed where the persistent snowpack occurs.

Additional water quality impacts were observed across the Mainstem CLP watershed during the summer monsoon season. High intensity precipitation events that occurred over the Cameron Peak Fire burn scar caused flooding, debris flows, and erosion in to the Mainstem CLP River resulting in periodic occurrences of severely degraded water quality. Elevated pH and alkalinity levels indicated delivery of ash from burned hillslopes into the Mainstem CLP River, while elevated turbidity, specific conductivity, total dissolved solids, and nutrients indicated excessive erosion and the delivery of sediment, debris, and dissolved constituents into the Mainstem CLP River. The Black Hollow debris flow and flood event in the Poudre Canyon, that occurred in late-July, resulted in drastic changes in water quality during and immediately following the event. Impacts to several water quality constituents persisted for several months after the event. Most of the post-fire storm events in 2021 exceeded turbidity thresholds for water treatment, which resulted in the shutdown of Poudre River water supply intakes and reliance on alternate water sources.

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| | |
|---|---|
| % | percent |
| cfs | cubic feet per second |
| CLP | Cache la Poudre River |
| DO | Dissolved Oxygen |
| DBP | Disinfection By-Product |
| EPA | Environmental Protection Agency |
| FCWQL | Fort Collins Water Quality Lab |
| FCWTF | Fort Collins Water Treatment Facility |
| JWC | Joe Wright Creek above the Poudre River (key monitoring site) |
| mg/L | milligrams per liter |
| NBH | North Fork of the Poudre River below Halligan Reservoir (key monitoring site) |
| NDC | North Fork of the Poudre River above Dale Creek Confluence (key monitoring site) |
| NFG | North Fork of the Poudre River below Seaman Reservoir (key monitoring site) |
| NFL | North Fork of the Poudre River at Livermore (key monitoring site) |
| ng/L | nanograms per liter |
| NTU | Nephelometric Turbidity Units |
| °C | degrees Celsius |
| °F | degrees Fahrenheit |
| PBD | Poudre River at the Bellvue Diversion (key monitoring site) |
| PBR | Poudre River below Rustic (key monitoring site) |
| PJW | Poudre River above the confluence with Joe Wright Creek (key monitoring site) |
| PNF | Poudre River above the North Fork (key monitoring site) |
| PSF | Poudre River below confluence with South Fork (key monitoring site) |
| ppt | parts per trillion |
| SCWTA | Soldier Canyon Water Treatment Authority |
| SNOTEL | Snow telemetry network |
| SWE | Snow water equivalent |
| T&O | Taste & Odor |
| TKN | Total Kjeldahl Nitrogen |
| TN | Total Nitrogen |
| TOC | Total Organic Carbon |
| TP | Total Phosphorus |
| µg/L | micrograms per liter |
| µS/cm | microSiemens per centimeter |
| USGS | United States Geological Survey |
| WTP | Water Treatment Plant |

# 1.0 INTRODUCTION

## 1.1 BACKGROUND

The Upper Cache la Poudre (CLP) River is an important source of high-quality drinking water supplies for communities served by the City of Fort Collins Water Treatment Facility (FCWTF), the City of Greeley-Bellvue Water Treatment Plant (WTP), and the Soldier Canyon Water Treatment Authority's (SCWTA) Soldier Canyon Filter Plant (SCFP). In the shared interest of sustaining this high-quality water supply, the City of Fort Collins, the City of Greeley, and the SCWTA partnered in 2007 to design the Upper CLP Collaborative Water Quality Monitoring Program (Program). The Program was subsequently implemented in spring 2008. The goal of this monitoring partnership is to assist the participants in meeting current and future drinking water treatment goals by providing up-to-date information about water quality and trends within the Upper CLP watershed.

Raw CLP River water quality parameters that have historically had the most impact on treatment at the three treatment plants include:

- turbidity
- total organic carbon (TOC)
- pH
- alkalinity
- temperature
- pathogens (*Giardia* and *Cryptosporidium*)
- taste and odor (T&O) compounds (geosmin and 2-methlyisoborneol)

Seasonal updates, annual water quality reports, and five-year reports for the Program are prepared by City of Fort Collins' Watershed Program staff to keep participants informed of current conditions, spatial trends, and short- and long-term trends in water quality of the Upper CLP watershed. Seasonal updates are provided throughout the monitoring season. These updates include a seasonal summary of the Upper CLP watershed that highlights precipitation, streamflow, and water quality conditions in the spring, summer, and fall. The purpose of annual reports is to summarize hydrologic, climatic, and water quality conditions for the previous water year. For the purposes of this report the water year is defined as the months of December through November as opposed to the months of October through September. The five-year trend report provides a more in-depth analysis of both spatial and temporal trends in watershed hydrology, climate, and water quality. The first five-year trend report was completed for the years 2008-2012 (Oropeza & Heath, 2013). The second five-year trend report was prepared in 2018 and evaluated trends for the 10-year period of record from 2008 through 2017 (Heath et al., 2018). The Program's reports are available on the City of Fort Collins Utilities Source Water Monitoring website:

*https://www.fcgov.com/utilities/what-we-do/water/water-quality/source-water-monitoring/water-quality-reports* .

> The goal of this monitoring program is to assist the participants in meeting current and future drinking water treatment goals…

## 1.2 WATERSHED DESCRIPTION AND SAMPLING LOCATIONS

Sampling efforts are divided between the Mainstem CLP River watershed (including Joe Wright Creek, the Big South, and the Little South Fork Cache la Poudre River) and North Fork CLP River watershed. Collectively these watersheds encompass approximately 645,500 acres of forest, other natural land types, and agricultural land (**Table 1**). An additional 4,700 acres, representing less than 1% of land surface, is developed for commercial, industrial, utility, urban or residential purposes.

**Table 1** – Land use comparison between Upper North Fork and Mainstem CLP watersheds. Areas were calculated using US Geological Survey Seamless Geographic Information System data sets.

| Land Use Comparison | North Fork (acres) | North Fork (%) | Mainstem (acres) | Mainstem (%) |
|---|---|---|---|---|
| Developed land (commercial, industrial, residential, urban, and utilities) | 2,817 | 0.8 | 1,945 | 0.7 |
| Agricultural use and grassland (cropland, pasture, other agriculture, scrub, and grasses) | 183,719 | 52.3 | 54,765 | 18.3 |
| Forest (forest and brush) | 154,654 | 44.1 | 213,879 | 71.5 |
| Natural lands (exposed rock, bare ground, wetlands, tundra, lakes) | 9,926 | 2.8 | 28,473 | 9.5 |
| **Total** | **351,116** | **100** | **299,062** | **100** |

The monitoring network consists of 18 sampling locations selected to characterize the headwaters, major tributaries, and downstream locations of the Upper CLP River near the City of Fort Collins, SCWTA, and City of Greeley raw water intake structures (**Figure 1.1**). A description and rationale for each location is provided in Attachment 1.

## 1.3 SAMPLING SCHEDULE AND PARAMETERS

The sampling frequency for the Program was based on both statistical performance and cost considerations. Parameters were selected based on analyses of historical data and aim to provide the best information possible within current budgetary constraints. Complete discussions of parameter selection and sampling frequency are provided in Sections 5.3 and 5.4, respectively, of the Program design document by Billica, Loftis and Moore (2008). The annual sampling schedule is provided in Attachment 4 of this report.

## 1.4 SAMPLE COLLECTION AND ANALYSIS

Field sampling is conducted by staff members from the City of Fort Collins' Watershed Program and Timberline Aquatics, Inc. Sampling methods, including those for the collection of physical field measurements for temperature, pH, conductivity, turbidity, and dissolved oxygen are documented in the Program's Standard Operating Procedures.

All water samples are analyzed by the City of Fort Collins Water Quality Lab (FCWQL). The analytical methods and detection limits for the FCWQL parameters are included in Attachment 3.

Consistent with the quality assurance guidelines outlined in Section 5.5 of Billica, Loftis and Moore (2008), field blanks and field duplicates are collected alongside at least ten percent of samples for a subset of parameters, which are identified in the Annual Operating Plan (Attachment 4). A summary of quality assurance and quality control field blanks and field duplicates is discussed in Section 4 of this document.

## 1.5 SCOPE OF 2021 ANNUAL REPORT

This annual report summarizes climate and hydrology in the Upper CLP watershed over the 2021 water year and water quality data collected as part of the Upper CLP Collaborative Water Quality Monitoring Program. In this this report, the water year is defined as December 1, 2020, to November 30, 2021. Spatial trends in water quality are evaluated at key monitoring locations throughout the Upper Mainstem and North Fork CLP watersheds, and temporal trends are evaluated at monitoring sites located near water treatment facility intakes on the Poudre River. The report compares water quality information from 2021 to baseline conditions, defined as the period of record from 2008 to 2012.

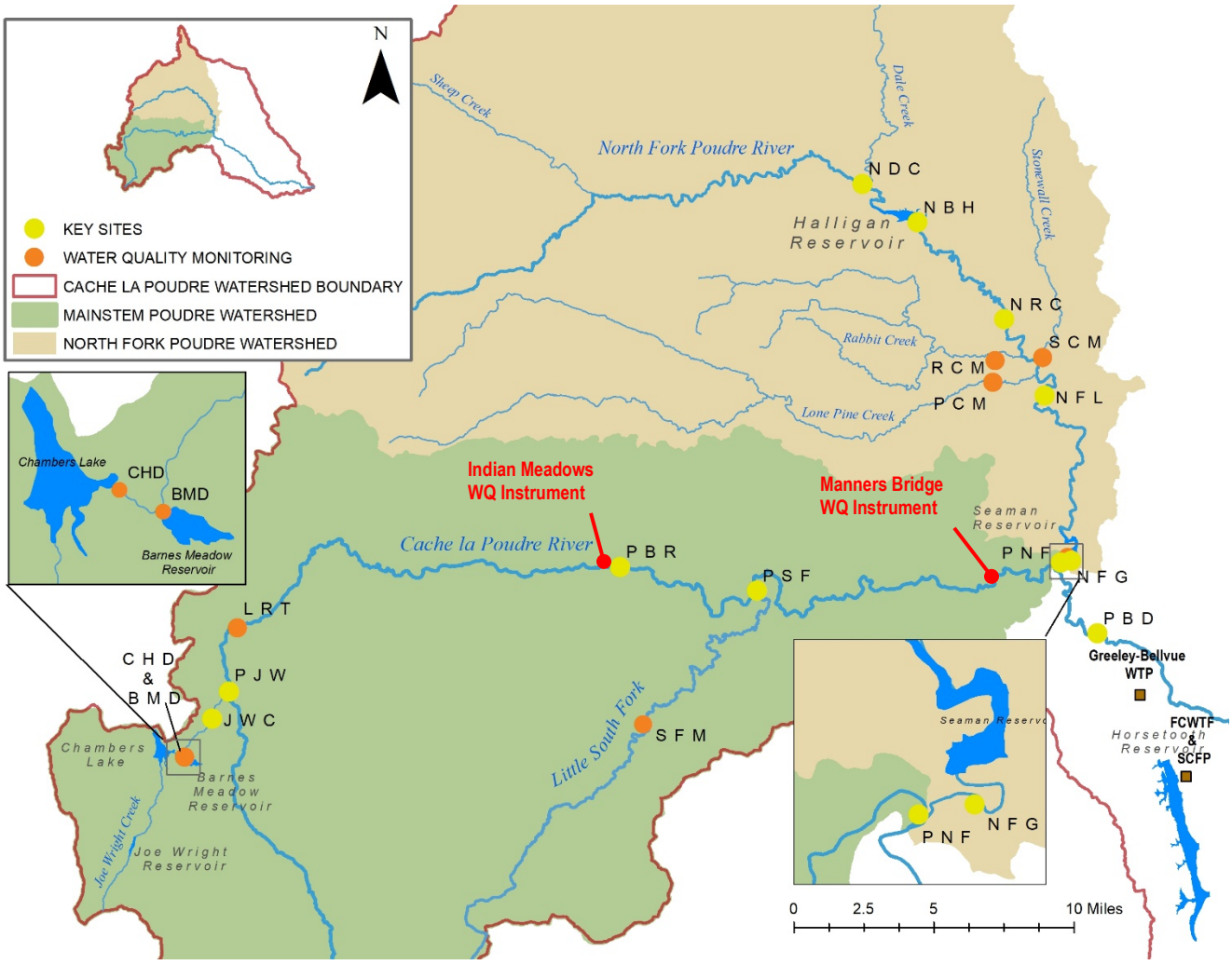


**Figure 1.1** – Map of the Upper CLP collaborative water quality monitoring network.

## 1.6 CAMERON PEAK FIRE

The Cameron Peak Fire ignited on Thursday, August 13th, 2020, near Chambers Lake in the upper elevations of CLP watershed near Cameron Pass. The Cameron Peak Fire is the largest wildfire in Colorado's history, burning just under 209,000 acres across both the Cache la Poudre and Big Thompson watersheds.

Several long-term water quality monitoring sites associated with the Upper CLP Collaborative Water Quality Monitoring Program are located either within or downstream of the area impacted by the wildfire. Water quality data collected as part of this monitoring program were very useful in understanding the impacts from the 2012 High Park Fire on water quality, as well as watershed recovery. Water quality impacts that were observed following the High Park Fire and that can be anticipated from the Cameron Peak Fire include:

1) Abrupt changes in turbidity and suspended sediment, especially during and following storm events and snowmelt runoff.
2) Elevated background (non-storm event) concentrations in alkalinity, hardness, and total dissolved solids.
3) Increased background (non-storm event) concentrations in nutrients.
4) Elevated turbidity, total organic carbon, nutrients, and metals (dissolved and total) during snowmelt runoff and storm events.

Water quality monitoring instruments were installed at two locations upstream of the Poudre supply intake facility in early April 2020. The Poudre at Indian Meadows site is located one mile downstream of the Town of Rustic and the Manners Bridge site is located approximately one mile upstream of the City's raw water intake (**Figure 1.1**). This monitoring system provides water treatment operations near real-time water quality data to quickly respond to changes in Poudre River water quality that result from runoff from the Cameron Peak burn area or other upstream events.

Both sites were valuable in detecting post-fire impacts from the Cameron Peak Fire during snowmelt runoff. Some post-fire water quality impacts to the Poudre River were observed during spring snowmelt runoff. Snowmelt and spring rainstorms eroded ash and sediment from burned hillslopes and drainages into the Poudre River; however, the magnitude of these events was relatively small, and the high volume of water in the river during snowmelt diluted these impacts downstream

The first significant post-fire water quality impact was observed on May 30, 2021, from a rain event that occurred over the burn scar. The water quality monitoring instrument in the Poudre River at Indian Meadows measured a maximum turbidity near 300 NTU during this event. The impact was diluted as it moved downstream, but still caused a spike in turbidity above 150 NTU at the Manners Bridge water quality monitoring instrument. The water quality instruments also measured a spike in both pH and conductivity during this event, indicating the presence of both suspended ash and sediment in the Poudre River. The event was relatively short in duration.

High-intensity precipitation events driven by the summer monsoon caused several significant post-fire debris flows and flooding events on the Poudre River over the summer season (**Figure 1.2**). The Manners Bridge real-time water quality instrument measured nearly a dozen post-fire storm events over the summer season. Many of these events resulted in severely impacted water quality ("black water") and required water treatment plants to shut down their raw water intakes on the Poudre River for an extended period.

The typical response in water quality during these events included a drastic increase in turbidity, pH, and specific conductivity, corresponding to elevated amounts of sediment and ash being delivered from burned hillslopes and tributary drainages into the Poudre River. The magnitude of these events was extreme with maximum turbidity values ranging from 400 NTU to 1,000 NTU compared to pre-storm event values of less than 5 NTU. The duration was relatively short lived. Water quality impacts lasted for approximately 24 hours following many of the storm events. In contrast, the Black Hollow debris flow event that occurred on July 20, 2021, resulted in elevated and highly variable turbidity values for over ten days (**Figure 1.2**). This devastating event was followed by two additional storm events. Water quality impacts following the Black Hollow debris flow persisted for months after the event.

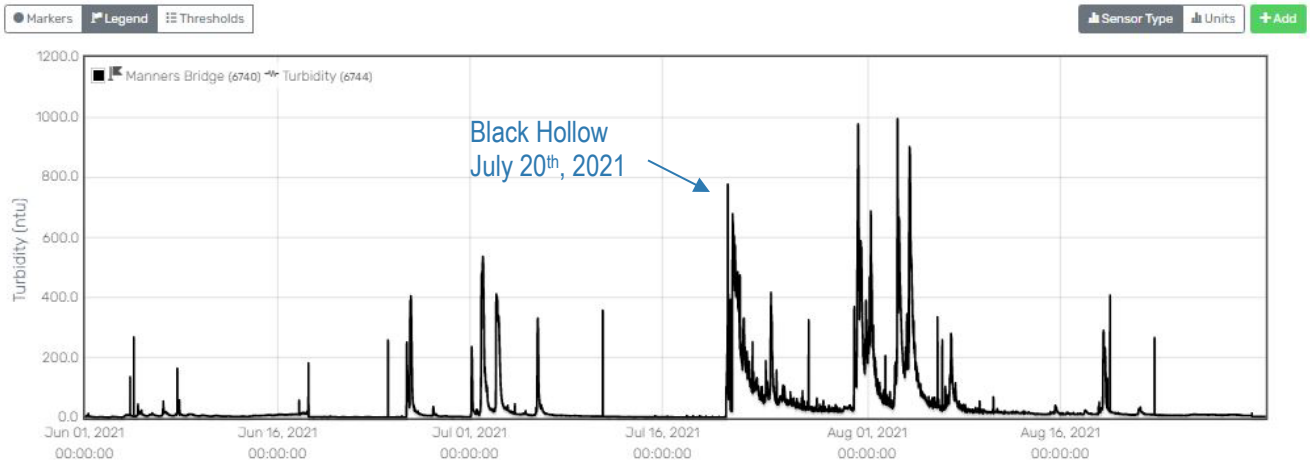


**Figure 1.2** – Turbidity measured in the Poudre River at the Manners Bridge real-time water quality instrument. Several rain events over the Cameron Peak burn scar caused turbidity in the river to increase rapidly over a short amount of time and remain elevated for several hours before returning to normal. The data presented above are raw data and outliers may exist.

# 2.0 HYDROLOGY & CLIMATE

Hydrology and climate play an important role in regulating the water quantity and quality in the Upper CLP watershed. Precipitation events and snowmelt runoff largely control the quantity and timing of deliveries of material to the river. The amount or volume of water in the system at a given time influences the concentration of most water quality constituents. Changes to the timing, magnitude, frequency and duration of snowmelt runoff and the associated effects on water quality have implications to water treatment operations.

*Hydrologic and Climatic Data Sources*

The snow telemetry (SNOTEL) network, managed by the Natural Resource Conservation Service, includes approximately 600 automated monitoring sites located in remote mountain watersheds throughout the United States that measure snow water equivalent (SWE), total precipitation and air temperature. Joe Wright SNOTEL is located near Joe Wright Reservoir at an elevation of 10,120 feet and contains the longest record of continuous measurements in the Cache la Poudre Watershed dating back to 1978.

The Cache la Poudre at Canyon Mouth near Fort Collins (CLAFTCCO) streamflow monitoring station is managed by the Colorado Department of Water Resources and contains the longest record of continuous streamflow in the Upper CLP watershed, dating back to 1883. The streamflow monitoring station is located at the Canyon Mouth and includes streamflow contributions from both the Mainstem and North Fork watersheds.

*Evaluating annual and seasonal trends*

Average monthly mean air temperature, monthly total precipitation and total monthly streamflow volume for the 2021 water year are compared to the average calculated over the baseline period of record from 2008 to 2012. Seasonal statistics were calculated for winter (DJF), spring (MAM), summer (JJA), and fall (SON).

## 2.1 AIR TEMPERATURE

The average mean air temperature in 2021 was 35.6°F and measured 0.9°F warmer than baseline (**Table 2**). The water year ranked as the eighth warmest on record (32 years; 1990 to 2021) at the Joe Wright SNOTEL. Air temperature was near baseline over the winter and spring seasons, and warmer than baseline over the summer and fall seasons.

The average mean air temperature over the winter season was 18.3°F and measured 0.1°F cooler than baseline (**Table 2**). Temperature in the months of December and January measured 1.4°F and 0.4°F warmer than baseline, respectively. The month of December ranked as the seventh warmest on record. In contrast, temperature in the month of February measured 2.0°F cooler than baseline (**Figure 2.1**), which ranked as the ninth coldest February on record.

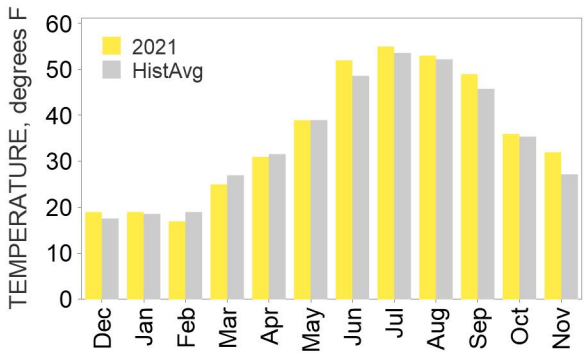


**Figure 2.1** –Monthly mean air temperature compared to baseline air temperature measured at the Joe Wright Snow Telemetry Station near Cameron Pass.

The average mean air temperature over the spring season was 31.7°F and measured 0.9°F cooler than baseline (**Table 2**). The months of March and April measured 2.0°F, and 0.6°F cooler than baseline, while the month of May measured the same as baseline **(Figure 2.1**).

The average mean air temperature over the summer season was 53.3°F and measured 1.9°F warmer than baseline (**Table 2**). The month of June measured 3.4°F

**Table 2** – Seasonal summary statistics for temperature, precipitation, and streamflow in Upper CLP watershed in 2021 compared to baseline (period of record is 2008 – 2012).

| Season | Period of Record | Temperature (deg F) | | Precipitation (in) | | Streamflow (acre-ft) | |
|---|---|---|---|---|---|---|---|
| | | *Average* | *Departure* | *Total* | *% Average* | *Total* | *% Average* |
| **Winter** | 2021 | 18.3 | -0.1 | 12.0 | 95% | 7,676 | 101% |
| | Baseline | 18.4 | | 12.7 | | 7,602 | |
| **Spring** | 2021 | 31.7 | -0.9 | 12.5 | 84% | 109,063 | 229% |
| | Baseline | 32.5 | | 15.0 | | 47,547 | |
| **Summer** | 2021 | 53.3 | 1.9 | 5.3 | 79% | 138,202 | 82% |
| | Baseline | 51.5 | | 6.7 | | 168,506 | |
| **Fall** | 2021 | 39.0 | 2.7 | 10.4 | 95% | 16,162 | 126% |
| | Baseline | 36.3 | | 11.0 | | 12,877 | |
| **Annual (WY)** | 2021 | 35.6 | 0.9 | 40.2 | 89% | 271,103 | 115% |
| | Baseline | 34.7 | | 45.3 | | 236,531 | |

warmer than baseline and ranked as the second warmest on record. The months of July and August measured 2.5°F warmer than baseline and ranked as the second and fifth warmest on record **(Figure 2.1**). As a result, the summer 2021 season ranked as the warmest summer on record.

The average mean air temperature over the fall season was 39.0°F and measured 2.7°F warmer than baseline (**Table 2**). The month of September measured 3.2°F warmer than baseline and ranked as the second warmest on record. Temperature over the month of October measured near baseline. Warmer temperatures returned in November, which measured 4.8°F and ranked as the second warmest on record **(Figure 2.1**). The unseasonably warm temperatures observed in September and November resulted in the second warmest fall on record.

## 2.2 PRECIPITATION

### Total Precipitation

Total precipitation over the 2021 water year was 89% of baseline with a total of 40.2 inches of water measured at the Joe Wright SNOTEL (**Table 2**). Precipitation measured below baseline for all seasons.

The total precipitation measured over the winter season was 95% of baseline and totaled 12.0 inches (**Table 2**). Precipitation over the months of December and January measured below baseline at 80% and 70%, respectively. The month of February was the wettest winter month over the 2021 winter season and measured 134% of baseline (**Figure 2.2**). The month of February ranked as the sixth wettest February on record (1979 to 2021; 42 years).

The total precipitation measured over the spring season was 84% of baseline and totaled 12.5 inches (**Table 2**). The highest amount of precipitation was observed during the month of March, which measured 128% of baseline. The months of April and May were notably drier than baseline and measured only 65% and 73% of baseline, respectively. (**Figure 2.2**).

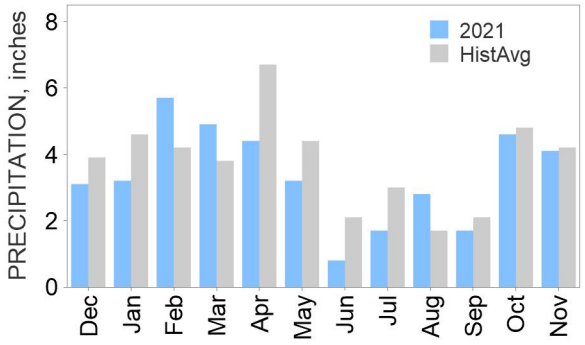


**Figure 2.2** – Monthly precipitation totals compared to baseline totals measured at the Joe Wright Snow Telemetry Station near Cameron Pass.

The total precipitation measured over the summer season was 79% of baseline and totaled 5.3 inches (**Table 2**). Precipitation measured over the months of June and July

was much lower than baseline and measured only 38% and 57% of baseline, respectively. The month of June ranked as the ninth driest on record. In contrast, precipitation in the month of August measured 167% of baseline. Despite the wet conditions observed over the month of August, the summer 2021 season ranked as the 11th driest summer on record.

Conditions improved slightly over the fall season. The total precipitation measured over the fall season was 95% of baseline and totaled 10.4 inches (**Table 2**). The month of September was the driest fall month and measured 82% of baseline. Precipitation over the months of October and November measured near baseline at 95% and 97% of baseline, respectively (**Figure 2.2**).

### Cache la Poudre Basin Snowpack

Snow water equivalent (SWE) data were analyzed from five NRCS SNOTEL stations to evaluate differences across the basin as well as between years (**Figure 2.3**). Deadman Hill and Black Mountain SNOTELs represent snow conditions in the North Fork watershed; Hourglass Lake SNOTEL represents conditions in the South Fork watershed; and Joe Wright and Long Draw SNOTELs represent conditions in the Upper Mainstem CLP watershed (**Figure 2.3**).

The maximum amount of water contained in the snowpack, referred to as peak SWE, across the entire Cache la Poudre Watershed was 105% of the expected peak SWE based on the long-term median (1981-2010). The North Fork and South Fork Poudre basins were above the long-term

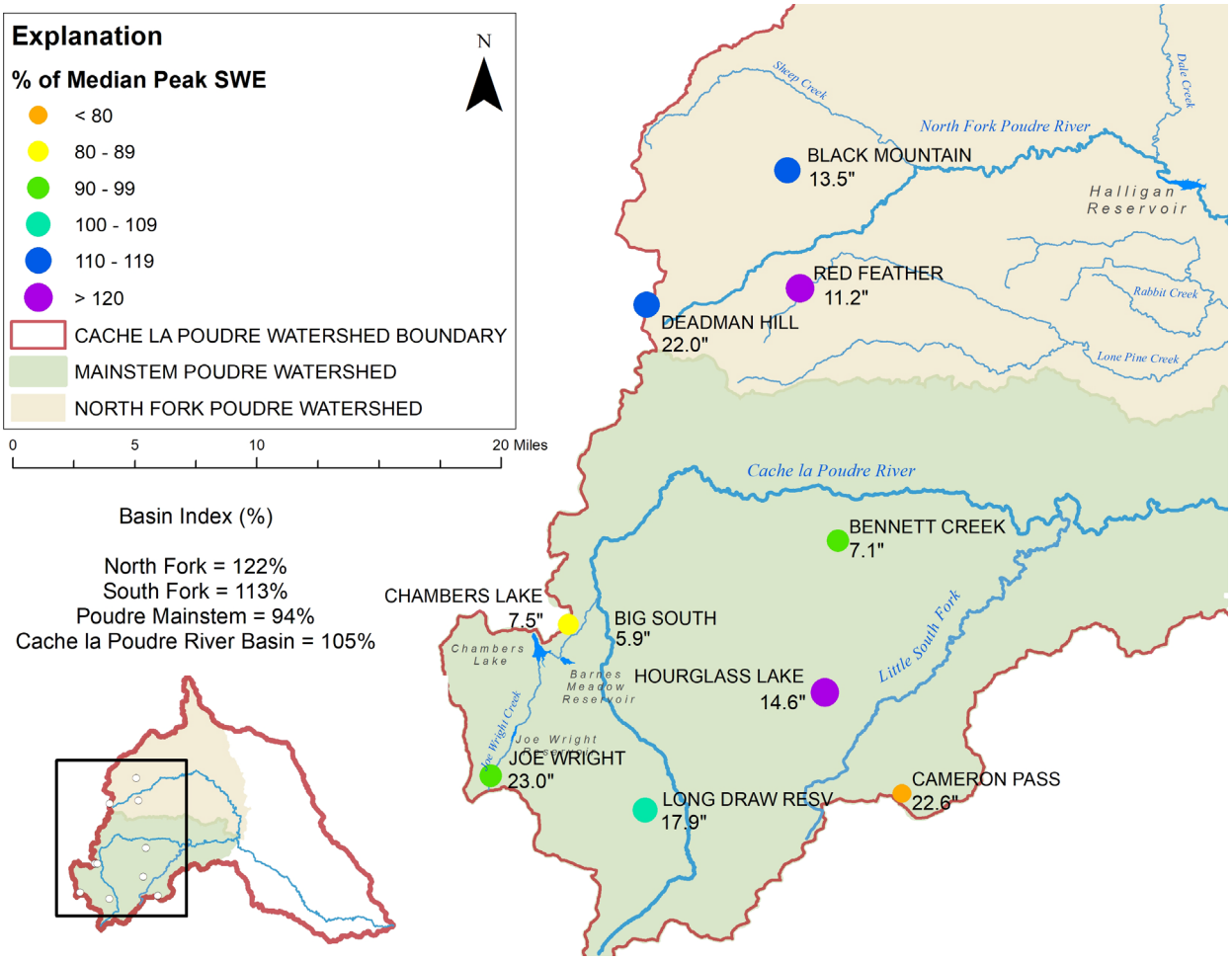


**Figure 2.3** – Locations of SNOTEL and snow course monitoring sites in the UCLP and percent of median peak snow water equivalent (SWE) in for the 2021 water year.

median at 122% and 113%, while the Mainstem was slightly below the long-term median at 94% (**Figure 2.3**).

Peak SWE measured 83% of baseline at the Joe Wright SNOTEL and was observed on May 6, 2021, which was slightly later than normal. Snowmelt began as expected, but the rate of snowmelt was quicker than normal over the 2021 snowmelt season. The snowpack at the Joe Wright SNOTEL station was completely melted by June 11th, which was nearly one month earlier than normal.

## 2.3 STREAMFLOW

The Mainstem and North Fork watersheds exhibit snowmelt-dominated hydrographs. Water is stored in the snowpack as snow accumulates through the winter and is subsequently released as runoff in the spring and summer as the snowpack melts.

**Mainstem Cache la Poudre River**

The total volume of water that flowed down the Mainstem CLP River over the 2021 water year (as measured at the Canyon Mouth stream gage) was 271,103 acre-feet, which was 115% of baseline (**Table 2**). Streamflow was above baseline over the winter, spring, and fall seasons and below baseline over the summer season.

Streamflow over the winter season measured 101% of baseline and totaled 7,676 acre-feet (**Table 2**). The month of December measured near baseline at 95%. Streamflow over the months of January and February measured 108% and 101% of baseline, respectively. The highest streamflow contribution over the winter season was measured in the month of January at 2,846 acre-feet.

Streamflow over the spring season measured 229% of baseline and totaled 109,063 acre-feet (**Table 2**). Streamflow remained higher than baseline in the months of March, April, and May at 162%, 158% and 246%, respectively. Consistent with the historical trends, the highest streamflow contribution over the spring season was measured in the month of May at 94,374 acre-feet. Peak streamflow was measured on May 23rd at 2,910 cubic feet per second. The peak streamflow in 2021 was 146% of the historical average peak streamflow (1881 – 2021) and occurred nearly three weeks earlier than average. Streamflow contributions over the spring season were notably higher than baseline, especially during the month of May (**Figure 2.4).**

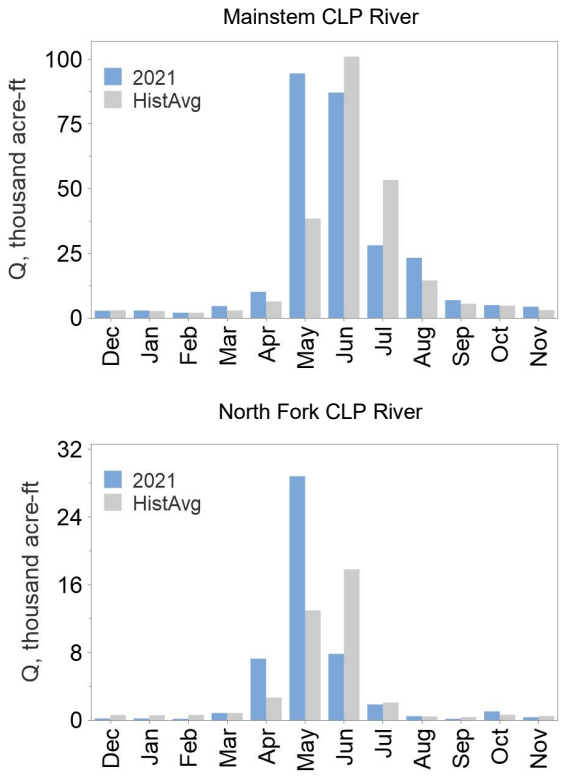


**Figure 2.4** –Total monthly streamflow in 2021 compared to average total monthly mean streamflow measured on the Mainstem CLP River near the Canyon Mouth (top) and North Fork CLP River near Livermore (bottom).

Streamflow over the summer season measured 82% of baseline and totaled 138,202 acre-feet (**Table 2**). Streamflow in the month of June was 86% of baseline. Streamflow in the month of July was well below baseline and measured 53% of baseline (**Figure 2.4).** Streamflow conditions improve in the month of August, which measured 160% of baseline. Consistent with the historical trends, the highest streamflow contribution over the summer season was measured in the month of June at 86,959 acre-feet (**Figure 2.4).**

Streamflow over the fall season measured 126% of baseline and totaled 16,162 acre-feet (**Table 2**). Streamflow over the months of September and November was higher than baseline and measured 126% and 143% of baseline, respectively. Streamflow over the month of October measured near baseline. As expected, the highest fall streamflow contributions were measured over the month of September at 6,877 acre-feet (**Figure 2.4).**

**North Fork Cache la Poudre River**

The total volume of water that flowed down the North Fork CLP River near Livermore (NFL) over the 2021 water year was 49,076 acre-feet, which was 122% of baseline (**Figure 2.4**). Streamflow was well below baseline over the winter and summer seasons, notably higher than baseline over the spring season and near baseline over the fall season.

Streamflow measured over the winter season was 30% of baseline with a total of 551 acre-feet of water. All winter months were well below baseline at 33%, 33% and 25% for the months of December, January, and February, respectively.

Streamflow measured over the spring season was 224% of baseline and totaled 36,861 acre-feet. Streamflow measured over the month of March was near baseline at 99% of baseline. The months of April and May were notably higher than baseline and measured 271% and 222% of baseline, respectively (**Figure 2.4).**

Streamflow measured over the summer season was 50% of baseline and totaled 10,130 acre-feet. Streamflow in the month of June was well below baseline and measured 44% of baseline. Streamflow conditions gradually improved in July and August, which measured 89% and 109% of baseline, respectively (**Figure 2.4).**

Streamflow measured over the fall season was 102% of baseline and totaled 1,534 acre-feet. The months of September and November measured below baseline at 42% and 46%, respectively, while the month of November measured above baseline at 158% (**Figure 2.4).**

**Streamflow Contributions**

There are several tributaries, diversions, and water storage reservoirs that contribute to the overall streamflow and water quality on the Mainstem CLP River above the North Fork. The two highest elevation trans-mountain diversions in the Upper CLP include Michigan River Ditch, which diverts water from the Upper North Platte basin to Joe Wright Reservoir and the Grand Ditch, which diverts water from the Upper Colorado River basin into Long Draw Reservoir. The contributions of these diversions are not presented in the report, but contributions released from the reservoirs in which these waters are stored are addressed. A summary of 2021 water contributions to the Mainstem CLP River above the Munroe Tunnel is presented in **Table 3**.

During snowmelt runoff, from April through June, most of the streamflow originated from the Big South and Mainstem tributaries. Contributions were more evenly distributed across the basin in July, August, and September. The highest contributions were from the Big South and associated releases from Long Draw Reservoir. Flow contributions over the fall season were dominated by mostly native flows from the Big South and Mainstem tributaries.

The combined volume of water from the Mainstem and North Fork, as measured at the City of Greeley's Diversion (PBD) on the CLP River was 290,495 acre-feet (**Figure 2.5**). The North Fork contributed 18% (52,084 acre-feet) of the total volume and the Mainstem contributed 82% (238,411 acre-feet) of the total volume (**Figure 2.5**). Approximately 20,455 acre-feet of water was diverted at the Poudre Valley Canal located upstream of the City of Greeley's Diversion.

An estimated 283,915 acre-feet of water flowed down the Poudre River above the Munroe Tunnel and North Fork in 2021 and a combined 45,504 acre-feet of water was diverted through the Munroe and City of Fort Collins diversions.

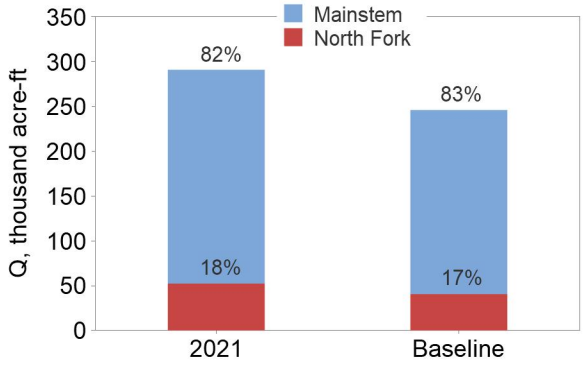


**Figure 2.5** – Proportion of average Mainstem and North Fork contributions at PBD in 2021 compared to baseline.

**Table 3** – Tributary contributions by month to the Mainstem Cache la Poudre River above the Munroe Tunnel in WY2021. Contributions highlighted in red indicated the greatest monthly contribution to the Mainstem. Note: AF = acre-feet.

*Total volume does not include water contributions from Long Draw Reservoir, which releases water to the Big South.

**Includes contributions from the Little South Fork Cache la Poudre River

| Month | Barnes Meadow | | Chambers Lake | | Laramie River Tunnel | | Long Draw Reservoir | | Big South* & Mainstem Tributaries** | | Poudre above Munroe | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AF | % | AF | % | AF | % | AF | % | AF | % | AF | % |
| Dec | - | - | 1268 | 35% | - | - | - | - | 2,394 | 65% | 3,662 | ------ |
| Jan | 159 | 4% | 1,171 | 30% | - | - | - | - | 2,562 | 66% | 3,892 | ------ |
| Feb | 185 | 6% | 2,720 | 90% | - | - | - | - | 119 | 4% | 3,024 | ------ |
| Mar | 246 | 5% | 2,534 | 50% | - | - | - | - | 2,273 | 45% | 5,052 | ------ |
| Apr | 6 | 0% | 847 | 6% | - | - | - | - | 12,236 | 93% | 13,089 | ------ |
| May | 543 | 1% | 2,981 | 4% | 43 | 0% | - | - | 77,952 | 96% | 81,519 | ------ |
| Jun | 161 | 0% | 10,024 | 11% | 4,004 | 4% | 5,877 | 7% | 70,035 | 78% | 90,101 | ------ |
| Jul | - | - | 4,422 | 12% | 3,142 | 9% | 7,103 | 20% | 20,715 | 59% | 35,381 | ------ |
| Aug | 29 | 0% | 3,933 | 15% | 1,763 | 7% | 6,685 | 25% | 14,603 | 54% | 27,014 | ------ |
| Sep | - | - | 3,490 | 32% | 372 | 3% | 2,070 | 19% | 4,926 | 45% | 10,858 | ------ |
| Oct | - | - | 1,135 | 20% | - | - | 92 | 2% | 4,418 | 78% | 5,645 | ------ |
| Nov | - | - | 821 | 18% | - | - | - | - | 3,858 | 82% | 4,679 | ------ |
| **Total** | **1,329 (0.5%)** | | **35,345 (12%)** | | **9,323 (3%)** | | **21,828 (8%)** | | **216,090 (76%)** | | **283,915** | |

# 3.0 SPATIAL TRENDS IN UPPER CACHE LA POUDRE WATER QUALITY

Spatial water quality trends discussed in the 2021 Annual Report focus primarily on monitoring sites located on the Mainstem and North Fork CLP Rivers that are considered representative of water quality conditions throughout the Mainstem and North Fork CLP watersheds. The following lists key sites from upstream to downstream:

- **Mainstem CLP River**
  - JWC – Joe Wright Creek above the Poudre River
  - PJW – Poudre above Joe Wright Creek
  - PBR – Poudre below Rustic
  - PSF – Poudre below South Fork
  - PNF – Poudre above North Fork
  - PBD – Poudre at Bellvue Diversion

- **North Fork CLP River**
  - NDC – North Fork above Dale Creek
  - NBH – North Fork below Halligan Reservoir
  - NRC – North Fork above Rabbit Creek
  - NFL – North Fork at Livermore
  - NFG – North Fork at Gage

Discussion of the results will focus primarily on these key sites; however, data from all sites were reviewed and analyzed and any notable events and trends are included in the discussion.

*Presentation of Results*

Boxplots presented in this report display summary statistics (maximum, median, and minimum) for the current monitoring year compared to baseline conditions defined as the period of record from 2008 through 2012. Arrows represent median values for the current monitoring year. A full list of monitoring sites, abbreviations and descriptions is available in Attachment 1. Finalized raw data are available upon request from the City of Fort Collins Watershed Program.

*Selected Variables and Monitoring Sites*

Data review and analyses were performed on all monitoring sites throughout the Upper CLP watershed for the water quality parameters listed below:

- **Field Parameters** – temperature, pH, specific conductivity, turbidity
- **General** – alkalinity, hardness, total dissolved solids
- **Total Organic Carbon**
- **Nutrients** – nitrogen and phosphorus
- **Biological** – *E. coli* and total coliforms
- **Metals**
- **Taste & Odor Compounds**
- **Macroinvertebrates**

These water quality parameters were selected because they either have a direct impact on water treatment processes or serve as key indicators for pollutants that may influence water treatment and source water quality.

## 3.1 FIELD PARAMETERS

**Water Temperature**

Water temperature influences other water quality parameters and is a major driver of biological activity, including algal growth in reservoirs and rivers. Some species of cyanobacteria can produce the taste and odor compounds, geosmin and 2-Methylisoborneol (2-MIB), which are discussed in Section 3.5.

Water temperature throughout the Mainstem and North Fork CLP watersheds was near or above baseline in 2021 at all monitoring sites (**Figure 3.1**).

*Mainstem*

Water temperature increased with decreasing elevation in the Mainstem over the monitoring season and ranged from a minimum temperature of 0°C in Joe Wright Creek (JWC) to a maximum temperature of 18.5°C at the City of Greeley's Diversion (PBD). Minimum water temperatures were warmer than baseline at all monitoring sites except in Joe Wright Creek (JWC) and in the Mainstem Poudre above Joe Wright Creek (PJW). Minimum water temperatures in the Mainstem were measured in early-April. Median water temperatures were cooler than baseline at high elevation monitoring sites (JWC and PJW) and low elevation monitoring sites (PNF and PBD), and warmer than baseline at mid-elevation monitoring sites

(PBR and PSF). The largest departures from baseline were measured from the Mainstem Poudre below Rustic (PBR) downstream to the Mainstem below the South Fork (PSF). Median water temperature was less than 2°C warmer at these sites in 2021. Maximum water temperatures were cooler than baseline at all monitoring sites. Maximum water temperatures in the Mainstem were measured in August at all sites.

*North Fork*

Water temperature in the North Fork ranged from a minimum temperature of 0.2°C in the North Fork above Dale Creek (NDC) to a maximum temperature of 22.5°C in the North Fork below Seaman Reservoir (NFG). Minimum water temperatures were near or below baseline at all sites except in the North Fork above Rabbit Creek (NRC) and the North Fork below Seaman Reservoir (NFG). Minimum water temperature at these sites was around 2°C warmer than baseline minimums. Median water temperatures were above baseline in the North Fork above and below Halligan Reservoir (NDC and NBH) and near baseline in the North Fork above Rabbit Creek (NRC) downstream to the North Fork below Seaman Reservoir (NFG). Maximum water temperatures were below baseline at all sites except on the North Fork below Halligan Reservoir (NBH). The maximum temperature at this site was 0.1°C warmer than the baseline maximum. The timing of maximum water temperature varied across the North Fork. Maximum water temperature in the North Fork near Livermore (NFL) was measured in June, while the maximum water temperature in the North Fork below Halligan Reservoir (NBH) was measured in September.

**pH**

pH is a measure of the amount of free hydrogen ($H^+$) and hydroxide ($OH^-$) ions in water and is measured on a logarithmic scale ranging from 0 to 14. Water with a pH near 7 is considered neutral, with more acidic conditions occurring below 7 and more basic, or alkaline conditions, occurring above 7. pH is an important water quality parameter to monitor because it influences the solubility and biological availability of chemical constituents, including nutrients and heavy metals.

pH values throughout the Mainstem and North Fork CLP watersheds were near or above baseline in 2021 at most monitoring sites (**Figure 3.1**).

*Mainstem*

pH values along the Mainstem followed expected seasonal trends. pH values were generally higher in the early-spring and decreased during the snowmelt runoff season. pH slowly increased over the late-summer and fall seasons but remained lower than values observed in early spring. In general, pH increased from the top of the watershed downstream to lower elevation monitoring locations. pH values ranged from 6.86 in the Mainstem above Joe Wright Creek (PJW) to 8.47 in the Poudre below Rustic (PBR). In general, pH values at the higher elevation monitoring sites (JWC and PJW) were lower compared to mid- and lower elevation monitoring sites. Minimum pH values were notably higher than baseline at all monitoring sites. Median pH values were near baseline in Joe Wright Creek (JWC) and in the Mainstem above Joe Wright Creek (PJW). Median pH values were above baseline from the Mainstem below Rustic (PBR) downstream to City of Greeley's Diversion (PBD). The largest departures from the baseline median pH were observed from the Mainstem below the South Fork (PSF) downstream to the City of Greeley's diversions (PBD). The median pH values at these sites were approximately 0.3 pH units greater than baseline. The notable shift in baseline at these sites suggests potential post-fire impacts, specifically from highly alkaline ash influencing pH in the Mainstem. Maximum pH values were notably higher than baseline in the Mainstem below Rustic (PBR) and below the South Fork (PSF). The maximum pH values at these sites were observed in April.

*North Fork*

pH in the North Fork was slightly more alkaline compared to the Mainstem especially in the North Fork above Rabbit Creek (NRC) downstream to the North Fork below Seaman Reservoir (NFG). Seasonal trends are less apparent in the North Fork. pH values in the North Fork ranged from a minimum pH of 7.23 in the North Fork below Halligan Reservoir (NBH) to 8.73 in the North Fork below Seaman Reservoir (NFG). There was slightly more variability between monitoring sites along the North Fork, specifically from the North Fork below Halligan Reservoir (NBH) downstream to the North Fork above Rabbit Creek (NRC). Minimum pH values were notably higher than baseline at all monitoring sites. Median pH was below baseline in the North Fork above Dale Creek (NDC) and below Halligan and Seaman Reservoirs (NBH and NFG). Median pH was above baseline from the North Fork below Rabbit Creek (NRC) downstream to the North Fork near Livermore (NFL). Maximum pH values were below baseline in the North Fork

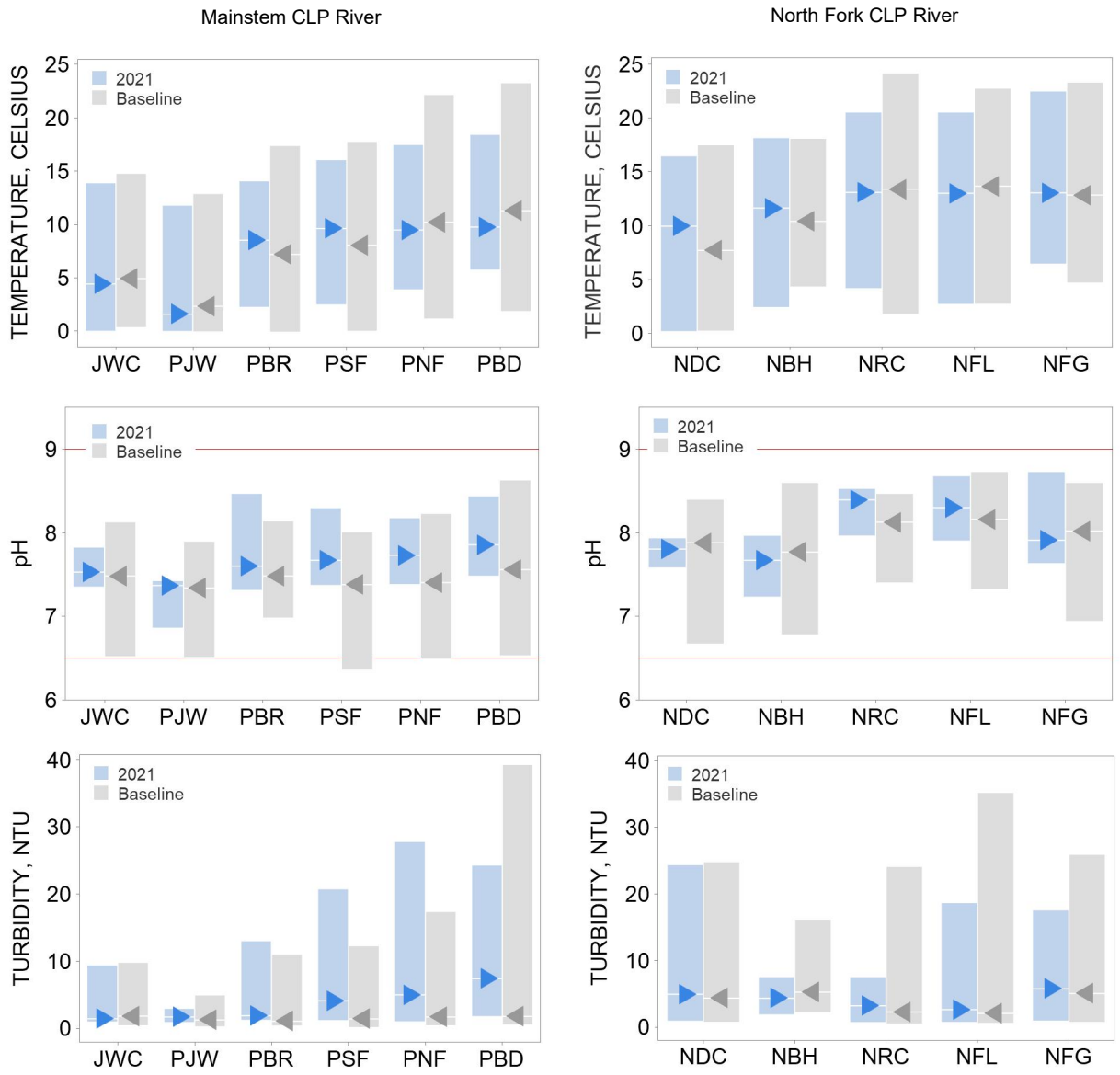


**Figure 3.1** – Water temperature, pH, and turbidity measured at key monitoring locations on the Mainstem CLP River (left) and North Fork CLP River (right) in 2021 compared to the baseline period of record. The red reference lines for pH indicate the Colorado Department of Public Health and Environment water quality standard to protect aquatic life.

above Dale Creek (NDC) and below Halligan Reservoir (NBH), and near or above baseline form the North Fork below Rabbit Creek downstream to the North Fork below Seaman Reservoir. The baseline maximum was exceeded in the North Fork below Rabbit Creek (NRC) and in the North Fork below Seaman Reservoir (NFG). The maximum pH value at these sites measured 8.53 and 8.73, which were observed in June and August, respectively.

### Turbidity

Turbidity is a measurement of the amount of light capable of passing through water. This water quality parameter is often monitored to track changes in water clarity, which is influenced by the presence of algae and/or suspended solids introduced to surface waters through various land use activities, including runoff and erosion, and urban storm water runoff and drainage from agricultural lands. Turbidity

concentrations can signal changes in land use activity. For water treatment, turbidity is an important indicator of the amount of suspended material that is available to harbor pollutants such as heavy metals, bacteria and other pathogens, nutrients, and organic matter.

Turbidity in the Mainstem CLP River was outside of the expected baseline range of values at most monitoring sites, while turbidity in North Fork CLP River was within the expected baseline range of values at all monitoring sites (**Figure 3.1**).

*Mainstem*

Turbidity was consistently higher than baseline in the Mainstem at nearly all monitoring sites in 2021. Turbidity ranged from a minimum of less than or equal to 1 NTU at all monitoring sites to a maximum of 27.8 NTU at the City of Fort Collins' Diversion (PNF). Minimum turbidity values were near baseline in Joe Wright Creek (JWC) and in the Mainstem above Joe Wright Creek (PJW). Minimum turbidity values were slightly elevated from the Poudre below Rustic (PBR) downstream to the City of Greeley's Diversion (PBD). Median turbidity values were near baseline in Joe Wright Creek (JWC) and in the Mainstem above Joe Wright Creek (PJW). In contrast, median turbidity values from the Poudre below Rustic (PBR) downstream to the City of Greeley's Diversion (PBD) were notably higher than baseline. The largest differences were observed at monitoring sites downstream of the South Fork (PSF, PNF, and PBD). Median turbidity at these sites was nearly five times greater than baseline. The elevated turbidity at these sites was driven primarily by unseasonable high turbidity levels observed in early spring, mid-summer, and fall. Turbidity values during these times of year are generally low, but elevated concentrations were observed due to earlier than expected runoff in the spring and post-fire events observed throughout most of the 2021 monitoring year. Maximum turbidity was much higher than baseline from the Poudre below Rustic (PBR) downstream to the City of Fort Collins' Diversion (PNF). The highest turbidity value was measured at the City of Fort Collins' Diversion (PNF) in late-April which was 10 NTU higher than the baseline maximum. In addition, a post-fire storm event prior to the August sampling date led to turbidity values in the Poudre below Rustic and below the South Fork (PBR and PSF) that exceeded the baseline maximum by approximately 2 NTU and 10 NTU, respectively.

*North Fork*

In contrast to previous years, turbidity was lower in the North Fork compared to the Mainstem. Turbidity values ranged from a minimum of less than 1 NTU at nearly all monitoring sites to a maximum of 24 NTU in the North Fork above Dale Creek (NDC). Minimum and median turbidity values were near baseline at all monitoring sites. Turbidity was generally higher and more variably in the North Fork above Dale Creek (NDC), in the North Fork near Livermore (NFL) and below Seaman Reservoir (NFG). Less variability was observed in the North Fork below Halligan Reservoir (NBH) and in the North Fork above Rabbit Creek (NRC). The differences in turbidity between the North Fork above Rabbit Creek (NRC) and the North Fork near Livermore (NFL) highlight the influence of the tributaries (PCM and RCM) on turbidity in the North Fork, especially during snowmelt runoff when turbidity values are high in these tributaries, and the influence of Halligan Reservoir on reducing turbidity in the North Fork above Rabbit Creek (NRC). Median turbidity values were generally consistent across monitoring locations but decreased slightly from the North Fork above Dale Creek (NDC) to the North Fork near Livermore (NFL). Median concentrations at these monitoring locations did not exceed 5 NTU. Median turbidity was slightly higher in the North Fork below Seaman Reservoir (NFG) and measured close to 6 NTU. Maximum turbidity was lower than baseline at all monitoring sites. A maximum turbidity of 24 NTU was measured in April. This value was only 1 NTU lower than the maximum turbidity measured in the North Fork below Dale Creek (NDC) over the baseline period of record.

## 3.2 GENERAL PARAMETERS

**Alkalinity, Hardness & Specific Conductance**

Specific conductance is an index of dissolved ionic solids in water, and hardness is an index of the total calcium (Ca) and magnesium (Mg) in water. Alkalinity is a measure of the effective acid buffering capacity of water and is derived from the dissociation of mineral carbonates ($CO_3^-$), bicarbonates ($HCO_3^-$), and hydroxides ($OH^-$). Conductivity, hardness, and alkalinity are influenced by local geology, as well as other dissolved constituents derived from land use practices throughout the watershed.

Concentrations of these constituents are influenced by the magnitude and timing of streamflow and by the size of the contributing watershed area. The highest concentrations are typically observed during times of low flow in late-fall

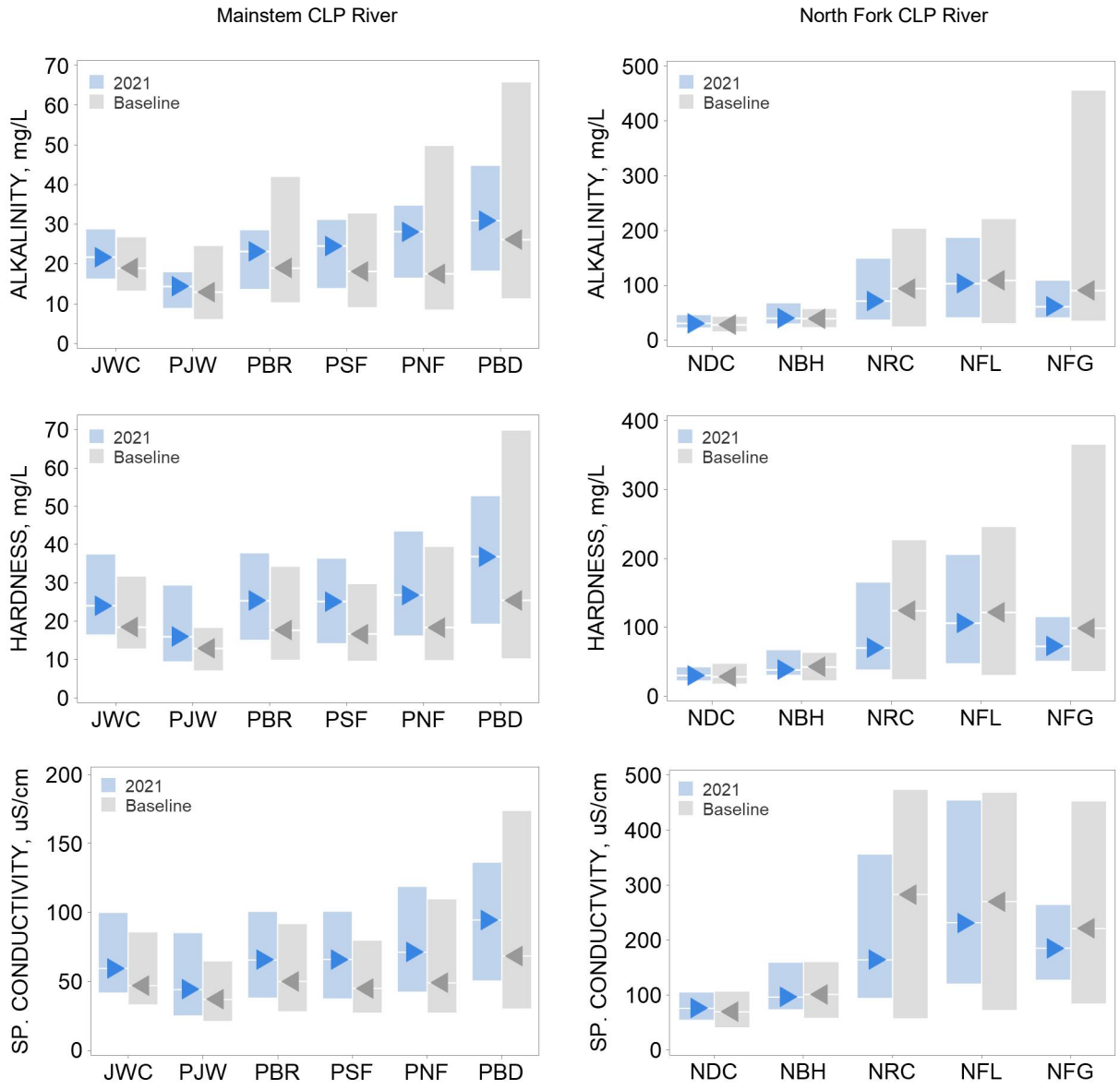


**Figure 3.2** – Alkalinity, hardness and specific conductivity measured at key monitoring locations on the Mainstem CLP River (left) and North Fork CLP River (right) in 2021 compared to the baseline period of record.

and winter, while minimum concentrations are observed during snowmelt runoff. In general, concentrations increase with decreasing elevation and increasing contributing watershed area.

Alkalinity, hardness, and specific conductivity concentrations in the Mainstem CLP River were elevated compared to baseline. These parameters were within the baseline range of values in the North Fork CLP River at most monitoring sites (**Figure 3.2**).

*Mainstem*

Alkalinity, hardness, and specific conductivity concentrations increased slightly from Joe Wright Creek (JWC) downstream to the City of Greeley's Diversion (PBD). Alkalinity concentrations ranged from 8.80 mg/L $CaCO_3$ to 45.0 mg/L $CaCO_3$; hardness concentrations ranged from 9.36 mg/L to 52.9 mg/L; and specific conductivity ranged from 25.0 µS/cm to 136.5 µS/cm. Minimum concentrations of these parameters were

observed in the Poudre above Joe Wright Creek (PJW) and maximum concentrations were observed at the City of Greeley's Diversion (PBD). Minimum concentrations were well above baseline at all monitoring sites. Minimum concentrations were measured in early June at all monitoring sites corresponding with high streamflow during snowmelt runoff. Median concentrations for all parameters were above baseline at all monitoring sites, but notably higher median concentrations were observed in the Poudre below Rustic (PBR) downstream to the City of Greeley's Diversion (PBD). Median alkalinity, hardness, and specific conductivity concentrations were around 1.5 times higher than baseline at these sites. Maximum alkalinity concentrations were below baseline at all monitoring sites except in Joe Wright Creek (JWC). Maximum hardness and specific conductivity concentrations were higher than baseline at all monitoring sites except at the City of Greeley's Diversion (PBD). The greatest difference in maximum concentrations was observed in the Mainstem below the South Fork (PSF). Elevated concentrations were also observed in the South Fork (SFM), which likely influenced downstream concentrations. Maximum concentrations were mostly observed in late April, however higher concentrations were observed in late fall when streamflow was low.

*North Fork*

A notable increase in alkalinity, hardness and specific conductivity concentrations was measured between the North Fork below Halligan Reservoir (NBH) to the North Fork above the confluence with Rabbit Creek (NRC). This change is likely associated with significant changes in streamflow downstream of the North Poudre Canal; groundwater and return flows from agricultural land use practices on the North Fork as it enters and passes through the Livermore Valley; and contributions from the North Fork tributaries, Rabbit Creek (RCM), Stonewall Creek (SCM) and Lone Pine Creek (PCM). Concentrations slightly increased from the North Fork above Rabbit Creek (NRC) downstream to the North Fork near Livermore (NFL) due to contributions from North Fork tributaries. Concentrations were generally higher in Rabbit Creek (RCM), Stonewall Creek (SCM) and Lone Pine Creek (PCM). Alkalinity, hardness, and specific conductivity concentrations were lower and less variably in the North Fork below Seaman Reservoir (NFG) compared to upstream in the North Fork near Livermore (NFL).

Alkalinity concentrations at key sites ranged from 21.8 mg/L $CaCO_3$ to 188.0 mg/L $CaCO_3$; hardness concentrations ranged from 21.8 mg/L to 206.0 mg/L; and specific conductivity ranged from 53.3 µS/cm to 454.6 µS/cm. Minimum concentrations were measured in the North Fork above Dale Creek (NDC) and maximum concentrations were measured in the North Fork near Livermore (NFL). Minimum concentrations were above baseline at all monitoring sites. Median concentrations were near baseline above and below Halligan Reservoir (NDC and NBH) and below baseline from the North Fork above Rabbit Creek (NRC) downstream to the North Fork below Seaman Reservoir (NFG). Median concentrations were notably lower in the North Fork above Rabbit Creek (NRC) where concentrations were nearly 2 times lower than baseline. The lower concentrations at these monitoring sites were likely correlated to above average streamflow conditions observed in the North Fork. Maximum concentrations were below baseline at all monitoring sites except in the North Fork below Halligan Reservoir (NBH). Maximum concentrations were markedly lower than baseline in the North Fork above Rabbit Creek (NRC) and in the North Fork below Seaman Reservoir (NFG). The highest concentrations were generally observed in April and November in the North Fork above and below Halligan Reservoir (NDC and NBH), and in the late-summer and early-fall in the North Fork above Rabbit Creek (NRC) downstream to the North Fork below Seaman Reservoir (NFG).

**Total Dissolved Solids**

Total dissolved solids (TDS) provide a qualitative measure of dissolved ions comprised of inorganic salts (calcium, magnesium potassium, sodium, bicarbonates, chlorides, and sulfates) and a small portion of organic matter. Sources of TDS in surface water consist of natural weathering and erosion of geologic material, mining, industrial and sewage effluent, groundwater, and agriculture.

Elevated TDS concentrations in drinking-water sources do not pose a health risk, but high levels can cause aesthetic risks including corrosion, salty or brackish taste, and scale formation. Because of these potential risks the Environmental Protection Agency established a secondary TDS standard for surface waters with a drinking water supply designated use. Elevated TDS concentrations may also be used as an indicator of elevated ions; some of which have primary or secondary drinking water standards.

Total dissolved solids (TDS) were near or above baseline along the Mainstem CLP River and near or below baseline along the North Fork CLP River (**Figure 3.3**).

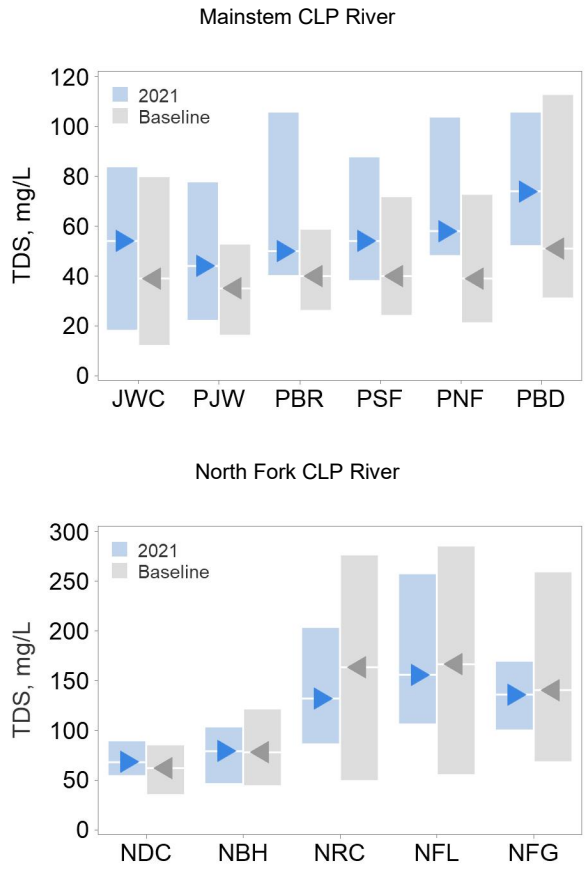


**Figure 3.3** – Total dissolved solids (TDS) measured at key monitoring locations on the Mainstem CLP River (top) and North Fork CLP River (bottom) in 2021 compared to the baseline period of record.

*Mainstem*

Total dissolved solids were elevated, with maximum values outside of the baseline range at all monitoring sites in 2021. Total dissolved solids concentrations generally increased from the Poudre above Joe Wright Creek (PJW) downstream to the City of Greeley's Diversion (PBD). Total dissolved solids ranged from a minimum of 18 mg/L in Joe Wright Creek (JWC) to a maximum of 106 mg/L measured in the Poudre below Rustic (PBR) and the City of Greeley's Diversion (PBD). Minimum total dissolved solids concentrations were higher than baseline at all monitoring sites, especially from the Mainstem below Rustic (PBR) downstream to the City of Greeley's Diversion (PBD) where minimum total dissolved solids concentrations exceeded baseline median concentrations. Median total dissolved solids concentrations were also higher than baseline at all monitoring sites. Concentrations were 1.25 to 1.5 times higher than baseline. The largest differences were observed at the cities of Fort Collins' and Greeley's Diversions (PNF and PBD). Maximum total dissolved solids concentrations were notably higher than baseline at all monitoring sites except at the City of Greeley's Diversion (PBD). The largest difference was observed in the Mainstem below Rustic (PBR) where maximum concentrations were nearly 2 times higher than the baseline maximum. The highest concentrations were generally observed in the early spring and late fall; however, elevated concentrations were periodically observed over the summer due to post-fire events impacting water quality in the Mainstem CLP River. The elevated TDS concentrations along the Mainstem indicate increased watershed wide erosion and a greater delivery of dissolved ions to the Poudre River from the Cameron Peak Fire burn scar. All major ions (calcium, magnesium potassium, sodium, bicarbonates, chlorides, and sulfates) were comparably elevated and followed similar spatial and temporal trends to TDS, which confirms the notable changes observed in TDS.

*North Fork*

In general, total dissolved solids increased from the North Fork above Dale Creek (NDC) downstream to the North Fork below Seaman Reservoir (NFG). Total dissolved solids concentrations increased slightly between the North Fork above Rabbit Creek (NRC) and North Fork near Livermore (NFL) suggesting influence from the North Fork tributaries where total dissolved solids concentrations were generally higher. Total dissolved solids concentrations ranged from a minimum 46 mg/L in the North Fork below Halligan Reservoir (NBH) to a maximum 258 mg/L on the North Fork near Livermore (NFL). There was a notable increase in the variability of total dissolved solids concentrations between the North Fork below Halligan Reservoir (NBH) and the North Fork above Rabbit Creek (NRC) downstream to the North Fork below Seaman Reservoir (NFG). This trend is likely associated with changes in hydrology below the North Poudre Canal, groundwater and return flow contributions, and contributions from the North Fork tributaries. Minimum concentrations were above baseline at all monitoring sites, especially from the North Fork above Rabbit Creek (NRC) downstream to the North Fork below Seaman Reservoir (NFG) and above Halligan Reservoir (NDC). Median total dissolved solids concentrations were near baseline above and below Halligan Reservoir (NDC and NBH) and in the North Fork below Seaman Reservoir (NFG). Median concentrations on the North Fork above Rabbit Creek

(NRC) to the North Fork near Livermore (NFL) were below baseline, especially in the North Fork above Rabbit Creek (NRC). The lower concentrations observed in the North Fork above Rabbit Creek (NRC) and in the North Fork near Livermore (NFL) may be associated with the above average streamflow observed in the North Fork CLP River in 2021. Maximum total dissolved solids concentrations were lower than baseline at all monitoring sites except in the North Fork above Halligan Reservoir (NDC). Maximum concentrations at this site were slightly higher than baseline. The highest concentrations were generally observed in April and November in the North Fork above and below Halligan Reservoir (NDC and NBH) and in the late-summer and early-fall in the North Fork above Rabbit Creek (NRC) downstream to the North Fork below Seaman Reservoir (NFG).

## 3.3 TOTAL ORGANIC CARBON

Total organic carbon (TOC) is a measure of the total concentration of dissolved and particulate organic matter in water. TOC is derived from both terrestrial and aquatic sources. Terrestrial TOC originates from soils and plant materials that are leached and/or delivered to surface waters during storms and spring snowmelt runoff, whereas aquatic-derived TOC originates from algal production and subsequent decomposition within surface waters.

Total organic carbon is an important indicator of water quality, particularly as it relates to water treatment. Water treatment requires the effective removal of TOC because the interaction between residual TOC and chlorine during treatment can form disinfection by-products (DBPs). DBPs are strictly regulated in finished water due to their carcinogenic potential. Increases in source water TOC concentrations pose concern due to the potential for higher residual TOC (post-filtration) and increased DBP formation potential. In addition, increased levels of TOC in source waters require additional removal requirements at the water treatment facility based on alkalinity levels (**Table 4**).

**Table 4** – Total organic carbon removal requirements for water treatment facilities based on source water alkalinity and total organic carbon concentrations.

| TOC (mg/L) | Source water alkalinity (mg/L as $CaCO_3$) | | |
|---|---|---|---|
| | <60 | 60-120 | >120 |
| 2-4 | 40% | 30% | 20% |
| 4-8 | 45% | 35% | 25% |
| >8 | 50% | 40% | 30% |

Total organic carbon concentrations were near or slightly above baseline at most monitoring sites along the Mainstem CLP River and North Fork CLP River (**Figure 3.4**).

*Mainstem*

Total organic carbon concentrations were similar across most monitoring sites on the Mainstem and ranged from a minimum 2.37 mg/L at the City of Fort Collins' Diversion

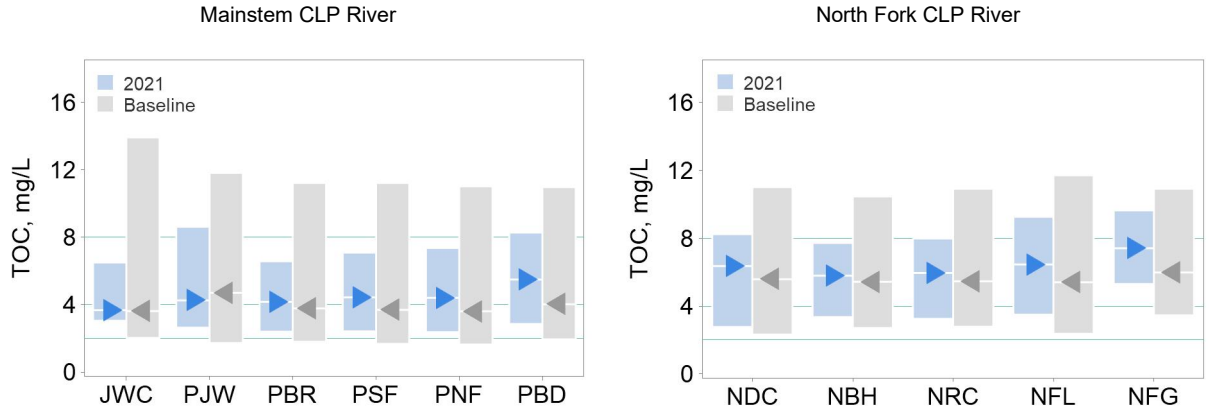


**Figure 3.4** – Total organic carbon (TOC) measured at key monitoring locations on the Mainstem CLP River (left) and North Fork CLP River (right) in 2021 compared to the baseline period of record. The green reference lines indicate thresholds for TOC removal requirements set by the Environmental Protection Agency. Note that the removal requirements also consider raw water alkalinity concentrations.

(PNF) to a maximum 8.61 mg/L in the Mainstem above Joe Wright Creek (PJW). Minimum total organic carbon concentrations were above baseline at all monitoring sites. Minimum concentrations between 2 – 4 mg/L at all monitoring sites. Minimum concentrations were observed in the fall from September through November. Median total organic carbon concentrations were near and below baseline in Joe Wright Creek (JWC) and in the Mainstem above Joe Wright Creek (PJW). Median concentrations were above baseline from the Poudre below Rustic (PBR) downstream to the City of Greeley's Diversion (PBD). In contrast to baseline, median concentrations were measured between 4 – 8 mg/L at all sites, except in Joe Wright Creek (JWC) where the median concentration was between 2 – 4 mg/L. Maximum total organic carbon concentrations were much lower than baseline at all monitoring sites. Maximum total organic carbon concentrations were measured in May at all sites and measured between the 2 – 4 mg/L threshold at all sites, except in the Mainstem above Joe Wright Creek (PJW) and at the City of Greeley's Diversion (PBD) where maximum concentrations were slightly higher than 8 mg/L. In general, maximum total organic carbon concentrations were approximately 3 – 7 mg/L lower than baseline in 2021. The largest difference was observed in Joe Wright Creek (JWC).

*North Fork*

Total organic carbon concentrations were similar across most monitoring sites in the North Fork CLP River and ranged from a minimum 2.77 mg/L in the North Fork above Dale Creek (NDC) to a maximum 9.63 mg/L in the North Fork below Seaman Reservoir (NFG). The North Fork above Dale Creek (NDC) and the North Fork near Livermore (NFL) had the greatest variability. The higher variability in the North Fork above Dale Creek (NDC) was likely associated with the more natural streamflow conditions above the water supply reservoirs. The highest total organic carbon concentrations were observed in Lone Pine Creek (PCM) and Rabbit Creek (RCM) during runoff, which slightly increased concentrations downstream in the North Fork near Livermore (NFL). Minimum total organic carbon concentrations were higher than baseline at all monitoring sites and fell within the 2 – 4 mg/L removal requirement threshold except in the North Fork below Seaman Reservoir (NFG) where minimum concentrations fell within the 4 – 8 mg/L removal requirement threshold. The minimum concentration at this site was much higher than baseline and closer to the baseline median value. Minimum total organic carbon concentrations in the North Fork were measured in the fall. Median total organic carbon concentrations were above baseline at all monitoring sites and fell within the 4 – 8 mg/L removal requirement threshold. The greatest departure from base was observed in the North Fork near Livermore (NFL) and in the North Fork below Seaman Reservoir (NFG) where concentrations were 1.0 – 1.4 mg/L higher. Maximum total organic carbon concentrations were lower than baseline at all monitoring sites and were observed in May. The maximum concentration of total organic carbon was greater than the 8 mg/L threshold at all sites except in the North Fork below Halligan Reservoir (NBH) where maximum concentrations were slightly below 8 mg/L.

## 3.4 NUTRIENTS

Nutrients are an important component of source water quality monitoring. In high concentrations and under certain environmental conditions, nutrients can lead to excessive algal growth. Elevated nutrients can also cause cyanobacteria blooms, which can produce cyanotoxins and taste and odor compounds in drinking water supplies. Potential sources of nutrients in aquatic systems include animal waste, leaking septic systems, fertilizer run-off, soil erosion, and atmospheric deposition.

Total nitrogen (TN) and total phosphorus (TP) serve as aggregate measures of potential nitrogen and phosphorus availability in aquatic systems.

**Nitrogen**

Total nitrogen (TN) is the sum of organic (TKN) and inorganic ($NO_3$-N and $NO_2$-N) nitrogen. Inorganic forms of nitrogen are more readily available for plant uptake. TKN is a measure of ammonia plus organic nitrogen and comprises the largest fraction of TN, with inorganic nitrogen representing a lesser fraction. In the calculation of TN (TKN + $NO_3$-N + $NO_2$-N), concentrations below their respective reporting limit were reported as half the reporting limit (Helsel and Hirsch, 2002).

*Mainstem*

Total nitrogen concentrations were elevated at nearly all monitoring sites on the Mainstem (**Figure 3.5)**. Concentrations ranged from a minimum 130 µg/L in the Mainstem below the South Fork (PSF) to a maximum 710 µg/L at the City of Greeley's Diversion (PBD). Minimum total nitrogen concentrations were higher than baseline (reporting limit) at all monitoring sites. The minimum total

nitrogen concentration at the City of Greeley's Diversion (PBD) had the largest departure from baseline and measured near the baseline median. Minimum concentrations were measured over the fall season. Median total nitrogen concentrations were above baseline at all monitoring sites, except in Joe Wright Creek (JWC). The largest departure from baseline was observed at the cities of Fort Collins' and Greeley's Diversions (PNF and PBD). Median concentrations were still well below the interim water quality standard for total nitrogen of 1,250 µg/L at all monitoring sites. Maximum total nitrogen concentrations were below baseline at all monitoring sites. Maximum concentrations were typically measured during snowmelt runoff in the spring; however, elevated concentrations were observed in August in the Poudre below Rustic (PBR) downstream to the City of Greeley's Diversion (PBD) following a post-fire event. Total nitrogen concentrations appeared to remain elevated throughout the fall season.

Nitrate concentrations were slightly elevated at all monitoring locations (**Figure 3.5**) except in Joe Wright Creek (JWC) and at the City of Fort Collins' Diversion (PNF). Minimum nitrate concentrations were near baseline and reported at the reporting limit (20 µg/L). Minimum nitrate concentrations were generally measured in the early spring and fall seasons. Median nitrate concentrations were 2 – 3 times higher than baseline at all monitoring sites except in Joe Wright Creek (JWC) and at the City of Fort Collins' Diversion (PNF). Median concentrations at these sites were at baseline (reporting limit). Maximum nitrate concentrations were lower than baseline at all monitoring sites expect in the Mainstem below Rustic (PBR) and in the Mainstem below the South Fork (PSF). Maximum concentrations at these locations were around 1.5 times higher than the baseline. Detectable concentrations were observed at most key sites in May and June during snowmelt runoff; however, concentrations were elevated in August following a post-fire flood event. As expected, the highest nitrate concentrations were observed in the

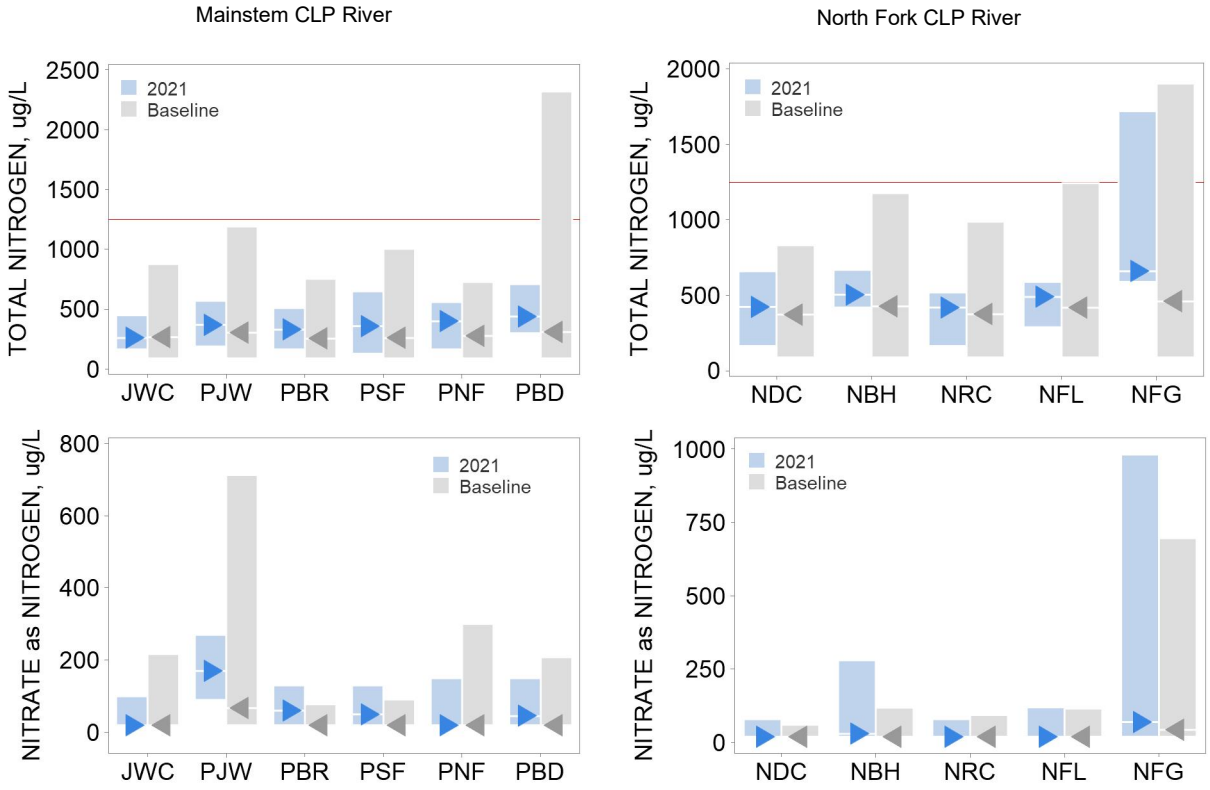


**Figure 3.5** – Total nitrogen (top) and nitrate (bottom) concentrations measured at key monitoring locations on the Mainstem CLP River (left) and North Fork CLP River (right) in 2021 compared to the baseline period of record. The red reference line indicates the interim TN water quality standard (TN = 1,250 µg/L) set by the Colorado Department of Public Health and Environment to protect aquatic life.

Mainstem above Joe Wright Creek (PJW). Concentrations were detected above the reporting limit at this site throughout the entire monitoring season.

As expected, nitrite concentrations were measured below the reporting limit (40 µg/L) at all monitoring sites.

Ammonia concentrations were within the baseline range of values at all monitoring sites. Median ammonia concentrations were at or below the reporting limit (10 µg/L) at all sites. Detectable concentrations were measured in the spring and early-summer, but no discernable trends were observed between sites. The highest concentrations were measured at monitoring locations in the upper elevations of the watershed (CHR, BMR, and PJW) and at the City of Greeley's Diversion (PBD). The higher concentrations of ammonia at these locations are likely due to their proximity to water storage reservoirs and the release of ammonia from these water bodies.

*North Fork*

Total nitrogen concentrations were similar across most monitoring sites on the North Fork except in the North Fork below Seaman Reservoir (NFG) (**Figure 3.5)**. Concentrations ranged from 165 µg/L in the North Fork above Dale Creek (NDC) to a maximum 1,720 µg/L in the North Fork below Seaman Reservoir (NFG). Minimum total nitrogen concentrations were higher than baseline and detected above the reporting limit (90 µg/L) at all monitoring sites. The minimum concentrations in the North Fork below Halligan and Seaman Reservoir (NBH and NFG) were notably higher and measured 4.5 and 6.5 times greater than the baseline minimum. Minimum concentrations at these monitoring sites were observed in early April, while minimum total nitrogen concentrations in the North Fork above Dale Creek (NDC), above Rabbit Creek (NRC) and near Livermore (NFL) were observed over the fall season. Median total nitrogen concentrations were above baseline

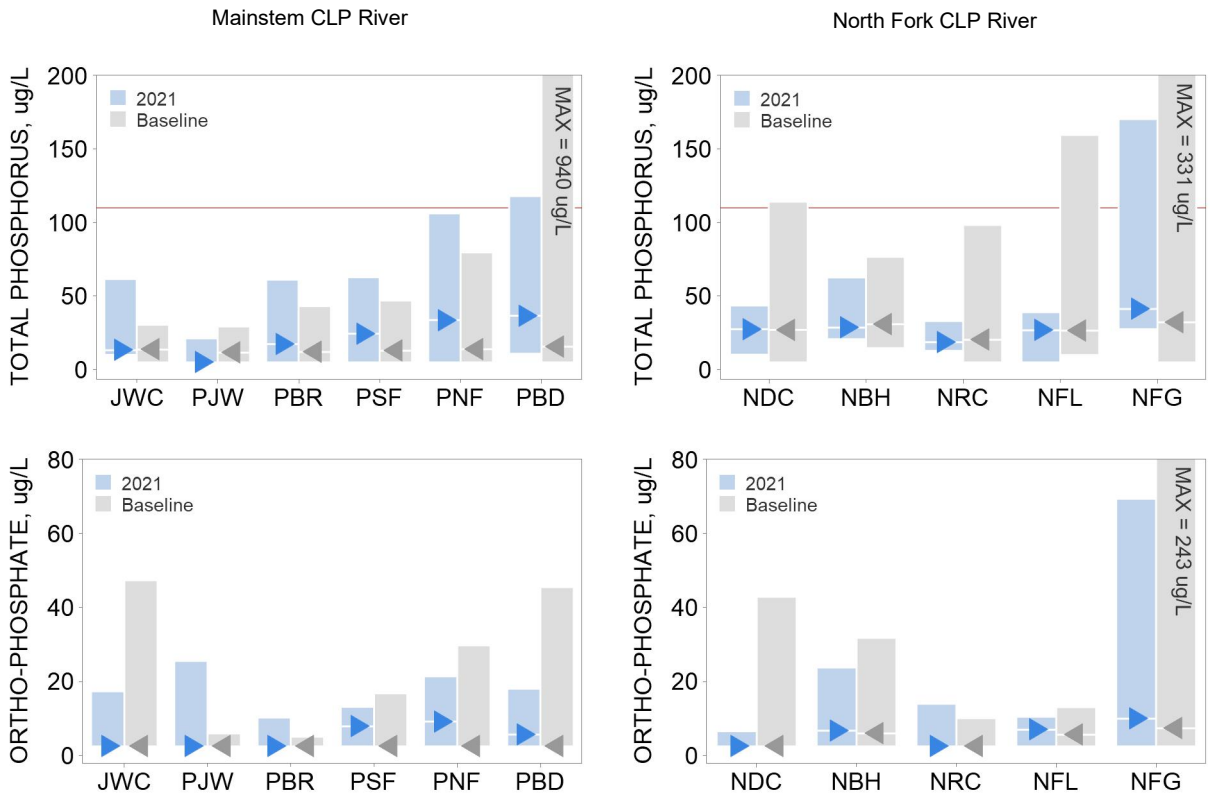


**Figure 3.6** – Total phosphorus (top) and ortho-phosphate (bottom) measured at key monitoring locations on the Mainstem CLP River (left) and North Fork CLP River (right) in 2021 compared to the baseline period of record. The red reference line indicates the interim TP water quality standard (TP = 110 ug/L) set by the Colorado Department of Public Health and Environment to protect aquatic life.

at all monitoring sites and below the interim water quality standard for total nitrogen of 1,250 µg/L. Median concentrations were slightly higher in the North Fork near Livermore compared to the North Fork above Rabbit Creek (NRC) signifying nitrogen inputs from the North Fork tributaries (SCM, RCM, and PCM). Median total nitrogen concentrations at these sites were higher than median concentrations measured at nearly all North Fork CLP River monitoring sites. Maximum total nitrogen concentrations were well below baseline at all monitoring sites; however, the maximum concentration in the North Fork below Seaman Reservoir (NFG) was near the baseline maximum. The maximum concentration at this site was measured in September and exceeded the interim water quality standard for total nitrogen. Total nitrogen concentrations were also elevated in the North Fork below Halligan Reservoir (NBH). Typically, higher concentrations are measured in the fall season at monitoring sites located below reservoirs (NBH and NFG). In contrast, maximum concentrations at other sites along the North Fork CLP River were observed during snowmelt runoff in April and May.

Nitrate concentrations were generally low across North Fork sites (**Figure 3.5**). Minimum and median concentrations were near baseline and below the reporting limit (10 µg/L) at all monitoring sites except in the North Fork below Seaman Reservoir (NFG). Detectable concentrations were measured at all sites during snowmelt runoff but quickly fell below the reporting limit in the early-summer and remained below the reporting limit through the fall. The exception to this trend was in the North Fork below Halligan and Seaman Reservoir (NBH and NFG) where detectable levels of nitrate were measured throughout the monitoring season. Elevated nitrate concentrations were measured in the fall which were likely caused by anoxic conditions in the reservoirs and the release of nutrients from reservoir sediments into the North Fork. Maximum nitrate concentrations were higher than baseline at all monitoring sites except in the North Fork above Rabbit Creek (NRC). Maximum concentrations were notably higher in the North Fork below Halligan and Seaman Reservoirs (NBH and NFG) where maximum concentrations measured over 2 times higher at NBH and nearly 1.5 times higher at NFG.

Nitrite concentrations were measured below the reporting limit at all monitoring sites except in the North Fork below Seaman Reservoir (NFG). Nitrite was detected at this monitoring site in September and measured 140 µg/L, which was 1.5 times greater than the baseline maximum. The high concentration of nitrite during this time of the year was likely caused by anoxic conditions in Seaman Reservoir and the release of nutrients from reservoir sediments into the water column and then into the North Fork CLP River.

Ammonia concentrations were near baseline at all monitoring sites. The highest concentrations were observed in the North Fork below Halligan and Seaman Reservoirs (NBH and NFG). Concentrations were consistently above the reporting limit at these sites, but the highest concentrations were measured in the fall when the reservoirs were anoxic. Maximum concentrations of 110 µg/L and 140 µg/L were measured below Halligan and Seaman Reservoirs (NBH and NFG) in August and September, respectively. Maximum ammonia concentrations were higher than baseline in the North Fork above Rabbit Creek (NRC) and in the North Fork near Livermore (NFL). Maximum concentrations at the sites were observed independently of one another in June and October, respectively.

**Phosphorus**

Total phosphorus (TP) is a measure of dissolved phosphorus as well as phosphorus bound to sediments and organic matter. Orthophosphate is more readily available for plant uptake.

*Mainstem*

Total phosphorus concentrations were elevated at nearly all monitoring sites along the Mainstem CLP (**Figure 3.6)**. Concentrations ranged from near or below the reporting limit (10 µg/L) at all key monitoring sites to a maximum 118 µg/L at the City of Greeley's Diversion (PBD). Minimum total phosphorus concentrations were near baseline at all monitoring sites. Minimum concentrations were measured in November at all monitoring sites. Median total phosphorus concentrations were near and below baseline in Joe Wright Creek (JWC) and in the Mainstem above Joe Wright Creek (PJW), respectively. Median total phosphorus concentrations were much higher than baseline in the Poudre below Rustic (PBR) downstream to the City of Greeley's Diversion (PBD). Concentrations were 1.5 times higher than baseline in the Poudre below Rustic (PBR) and greater than 2 times higher than baseline in the Poudre below the South Fork (PSF) downstream to the City of Greeley's Diversion (PBD). The greatest difference was observed at the City of Fort Collins' Diversion (PNF) where median total phosphorus concentrations were nearly 2.5

times higher than baseline. In general, total phosphorus concentrations were the highest during snowmelt runoff in May; however, total phosphorus was detected at all sites from April through October. Total phosphorus concentrations were notably elevated in August, especially in the Poudre below Rustic (PBR) downstream to the City of Greeley's Diversion (PBD), due to a post-fire flood event that occurred prior to sampling. Total phosphorus concentrations measured on this date were the highest concentrations observed in the Mainstem below Rustic (PBR) downstream to the City of Greeley's Diversion (PBD). Concentrations were also elevated in Joe Wright Creek (JWC) and in the Mainstem above Joe Wright Creek (PJW), but slightly higher concentrations were observed at these sites in late May during snowmelt runoff. Maximum total phosphorus concentrations were greater than baseline at all sites except in the Poudre above Joe Wright Creek (PJW) and at the City of Greeley's Diversion (PBD). Although this concentration was lower than baseline, the maximum total phosphorus concentration at the City of Greeley's Diversion (PBD) did exceed the interim water quality standard for total phosphorus (110 µg/L). Maximum concentrations in the Poudre below Rustic (PBR) downstream to the City of Fort Collin's Diversion (PNF) were approximately 1.3 times higher than baseline. The largest difference from baseline was measured in Joe Wright Creek (JWC) where maximum concentrations were 2 times greater than baseline.

Orthophosphate concentrations were elevated and measured above the reporting limit (5 µg/L) at all monitoring sites for most of the year, especially in the Mainstem below the South Fork (PSF) downstream to the City of Greeley's Diversion (PBD) (**Figure 3.6)**. Minimum orthophosphate concentrations were measured below the reporting limit at all sites and the timing varied across monitoring locations. Median orthophosphate concentrations were measured near baseline in Joe Wright Creek (JWC), in the Mainstem above Joe Wright Creek (PJW) and in the Mainstem below Rustic (PBR). In contrast, median concentrations in the Mainstem below the South Fork (PSF) downstream to the City of Greeley's Diversion (PBD) were much greater than baseline. Detectable concentrations were measured at these sites from May through September. Elevated orthophosphate was observed in August following a post-fire flood event that occurred in late-July. Maximum orthophosphate concentrations were below baseline at all monitoring sites except in the Mainstem above Joe Wright Creek (PJW) and in the Mainstem below Rustic (PBR). The timing of maximum orthophosphate concentrations varied across monitoring locations, but the highest concentrations were generally observed during snowmelt runoff or following post-fire storm events.

*North Fork*

Total phosphorus concentrations were within the baseline range of values for all monitoring sites (**Figure 3.6)**. Concentrations ranged from below the reporting limit (10 µg/L) in the North Fork near Livermore (NFL) to a maximum 170 µg/L in the North Fork below Seaman Reservoir (NFG). Higher concentrations were measured in the North Fork tributaries (RCM and PCM) and marginally influenced concentrations downstream in the North Fork near Livermore (NFL). Minimum total phosphorus concentrations were higher than baseline at all monitoring sites except in the North Fork near Livermore (NFL). Minimum concentrations were observed in the late fall, except in the North Fork below Halligan and Seaman Reservoir (NBH and NFG) where higher concentrations were measured due to in-reservoir dynamics. In contrast, minimum total phosphorus concentrations at these sites were observed in April. Median total phosphorus concentrations were near baseline at all monitoring sites except in the North Fork below Seaman Reservoir (NFG) where concentrations measured slightly higher than baseline. Maximum total phosphorus concentrations were below baseline at all monitoring sites in the North Fork CLP River. Maximum total phosphorus concentrations were generally observed during snowmelt runoff in April and May except at monitoring sites directly downstream of the reservoirs (NBH and NFG). The interim water quality standard for total phosphorus of 110 µg/L was exceeded on the North Fork below Seaman Reservoir (NFG) in August and September, which was likely due to anoxic conditions in the reservoir.

Orthophosphate concentrations were within the baseline range of values at all monitoring sites except in the North Fork above Rabbit Creek (NRC) (**Figure 3.6)**. Concentrations ranged from below the reporting limit (5 µg/L) at all monitoring sites to a maximum of 69 µg/L in the North Fork below Seaman Reservoir (NFG). Orthophosphate followed similar seasonal trends to total phosphorus as discussed above. Minimum orthophosphate concentrations were near baseline for all monitoring sites. Median orthophosphate concentrations were near or slightly above baseline. Maximum concentrations were lower than baseline at all monitoring sites except in the North Fork above Rabbit Creek (NRC). The highest concentrations were measured in the North

Fork tributaries (RCM and PCM), which influenced downstream orthophosphate concentrations in the North Fork near Livermore (NFL). Higher concentrations were also observed in the North Fork below Halligan and Seaman Reservoirs (NBH and NFG), which were generally observed in the late-summer and fall due to anoxic conditions in the reservoir.

## 3.5 TASTE & ODOR COMPOUNDS

Geosmin and 2-Methylisoborneol (2-MIB) are naturally occurring organic compounds that are produced by some species of cyanobacteria. These compounds can introduce an earthy odor to drinking water that can be detected by the most sensitive individuals at concentrations as low as 4 nanograms per liter (ng/L) or 4 parts per trillion (ppt). These compounds do not pose a public health risk but are of concern because they can negatively affect customer confidence in the quality of drinking water. Early detection of elevated concentrations of these compounds is important so that they can be removed during the water treatment process.

**Table 5** – Poudre River geosmin and 2-MIB concentrations (ng/L or ppt). Note: Reporting limits are 2 ng/L for geosmin and 5 ng/L for MIB. Concentrations below the reporting limits are estimates. n.s. = no sample collected

| Month | PBR | | PNF | |
|---|---|---|---|---|
| | Geosmin | 2-MIB | Geosmin | 2-MIB |
| April | 4.68 | <5 | 5.01 | <5 |
| May | n.s | n.s | <2 | <5 |
| Jun | <2 | 14 | <2 | <5 |
| Jul | <2 | <5 | <2 | <5 |
| Aug | n.s. | n.s. | n.s. | n.s. |
| Sep | <2 | <5 | 2.41 | <5 |
| Oct | 2.68 | 10.8 | <2 | <5 |
| Nov | 3.22 | 5.84 | <2 | <5 |

Geosmin and 2-MIB are monitored on the Mainstem below Rustic (PBR) and at the City of Fort Collins' Diversion (PNF) during routine upper CLP water quality monitoring events. A summary of geosmin and 2-MIB concentrations can be found in **Table 5**. No discernable spatial or temporal trends were observed for geosmin or 2-MIB over the 2021 water year. Geosmin was measured above the reporting limit in April, October, and November in the Mainstem below Rustic (PBR) and in April and September at the City of Fort Collins' intake (PNF). 2-MIB was measured above the reporting limit in June, October, and November in the Mainstem below Rustic (PBR). 2-MIB was not detected in any months at the City of Fort Collins' Diversion (PNF).

## 3.6 METALS

The presence of metals in source water supplies is most often due to mineral weathering and soil erosion. Metals enter the river via snowmelt runoff, wind, precipitation, and other natural processes. Additional sources of metals may include atmospheric deposition. Snowmelt runoff generally results in elevated metals concentrations, as do storm events. Metals were sampled throughout the monitoring season at select locations, but for the purposes of this report are only reported in the spring (May) and fall (October) at the City of Fort Collins' Diversion (PNF) and in the North Fork below Seaman Reservoir (NFG).

A summary of dissolved metals concentrations can be found in **Table 6**. As anticipated, detectable metals (aluminum, copper, iron, manganese) were higher in the spring during spring snowmelt runoff, except for manganese in the North Fork below Seaman Reservoir (NFG), which was likely due to anoxic conditions in the reservoir and the release of manganese from reservoir sediments. Lead was detected slightly above the reporting limit in the spring at the City of Fort Collins' Diversion and arsenic was detected slightly above the reporting limit in the North Fork below Seaman Reservoir in the fall.

**Table 6** – Dissolved metals concentrations measured in spring (May 24/25) and fall (October 18/19) of 2021 on the Mainstem and North Fork Poudre River.

| Metal (ug/L) | Spring | | Fall | |
|---|---|---|---|---|
| | PNF | NFG | PNF | NFG |
| Al | 156 | 298 | <10 | <10 |
| As | <1 | <1 | <1 | 1 |
| Cd | <1 | <1 | <1 | <1 |
| Cr | <1 | <1 | <1 | <1 |
| Cu | 2 | 1 | <1 | <1 |
| Fe | 130 | 265 | 61 | 23 |
| Mn | 6 | 9 | 5 | 34 |
| Ni | <1 | <1 | <1 | <1 |
| Pb | 1 | <1 | <1 | <1 |
| Se | <5 | <5 | <5 | <5 |
| Zn | <10 | <10 | <10 | <10 |

## 3.7 MICROORGANISMS

Coliforms are types of bacteria that are found naturally in the environment in plant and soil material but can also be found in the digestive tracts of warm-blooded animals, including humans. Disease causing bacteria, viruses, and protozoa can be introduced to source water supplies from fecal contamination. Total coliforms were used as an indicator of the presence of these pathogenic microorganisms. In addition, *Escherichia coli* (*E. coli*) was measured and used as an indicator of human or animal fecal waste pollution since the origin is more specific than total coliforms.

### Total Coliform

Total coliform concentrations were similar across monitoring sites on the Mainstem over the 2021 water year, and notably higher on the North Fork below Seaman Reservoir (NFG). The higher concentrations in the North Fork appeared to have a minimal influence on downstream concentrations at the City of Greeley's Diversion (PBD) (**Figure 3.7**). Concentrations ranged from a minimum 78 cells/100 mL in the Mainstem below Rustic (PBR) to a maximum 17,300 cells/100 mL on the North Fork below Seaman Reservoir (NFG). Minimum and median total coliform concentrations were near baseline at all monitoring sites except in the North Fork below Seaman Reservoir (NFG). Minimum concentrations were observed in the early spring and late fall. Median concentrations at this monitoring site were much higher than baseline. Maximum concentrations were below baseline in the Mainstem except below Rustic (PBR) where the maximum concentration was slightly higher than baseline. Maximum total coliform concentrations were notably higher than baseline in the North Fork below Seaman Reservoir (NFG). Maximum concentrations were generally observed during snowmelt runoff in the North Fork below Seaman Reservoir (NFG) and remained elevated through September. In contrast, maximum concentrations in the Mainstem were observed in August.

### *Escherichia coli*

*Escherichia coli* (*E. coli*) concentrations were generally similar across monitoring sites over the 2021 water year. Concentrations were more variable along the Mainstem and ranged from a minimum 0 – 1 cells/100 mL at all monitoring sites to a maximum of 57 cells/100 mL in the Mainstem below the South Fork (PSF) (**Figure 3.7**). Concentrations were generally higher in the Mainstem

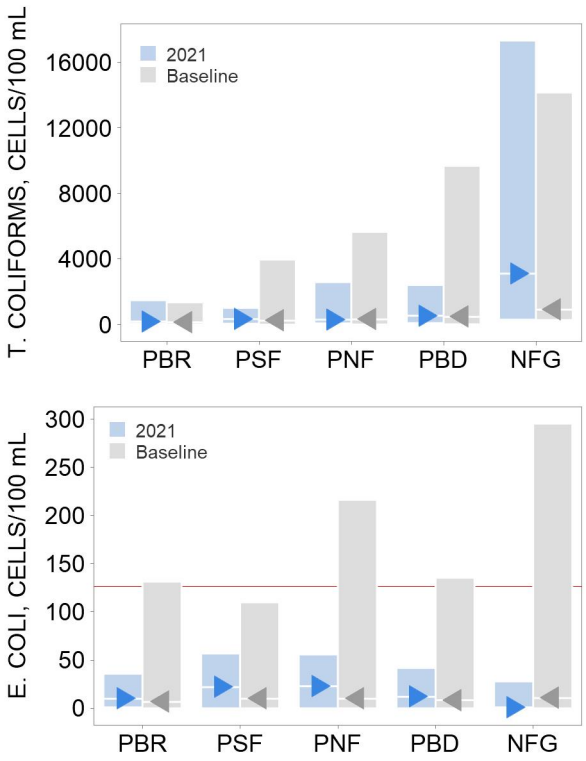


**Figure 3.7** – Total coliforms (top) and E. coli (bottom) concentrations measured at key monitoring locations on the Mainstem CLP River and North Fork CLP River – mainstem and NF sites in this figure are combined, as opposed to other figures – in 2021 compared to the baseline period of record. The red reference line indicates the E. coli water quality standard set by the Colorado Department of Public Health and Environment to protect recreational use.

below the South Fork and at the City of Fort Collins' Diversion (PSF and PNF). Minimum concentrations were near baseline at all Mainstem monitoring sites. Median *E. coli* concentrations were above baseline at all monitoring sites, especially in the Mainstem below the South Fork and at the City of Fort Collins' Diversion (PSF and PNF). Maximum concentrations, which were observed following snowmelt runoff in late-June, were much lower than baseline at all Mainstem monitoring sites and below the water quality standard. Concentrations remained elevated following snowmelt runoff into September.

There was less variability in the North Fork below Seaman Reservoir (NFG) where concentrations ranged from 1 cells/100 mL to 28 cells/100 mL. Minimum concentrations were near baseline. Median and maximum *E. coli* concentrations were less than baseline. Concentrations were low throughout much of the monitoring season. The highest *E. coli* concentration was measured in late-May and was below the water quality standard.

## 3.8 MACROINVERTEBRATES

Aquatic macroinvertebrates are animals that live in water, lack a backbone and are visible without the aid of a microscope. The Poudre River supports a diverse community of aquatic macroinvertebrates, including insects, shrimp, crayfish, worms, leeches, snails, clams and other groups. These animals live most of their lives on or within the streambed of the river, where they occupy a wide variety of ecological roles or "niches" in terms of their modes of feeding habits, habitat preferences, life cycles and other factors.

Key monitoring locations occur in three separate *EPA Level IV Ecoregions* (**Table 7**). The Mainstem above Joe Wright Creek (PJW) is located within the Crystalline Subalpine Forests Ecoregion; the Mainstem below Rustic (PBR), the Mainstem below the South Fork (PSF) and the Mainstem near the City of Fort Collins' Diversion (PNF) are located within the Crystalline Mid-Elevation Forests; and the Mainstem near the City of Greeley's Diversion (PBD) is located within the Foothills Shrublands Ecoregion. Macroinvertebrate communities in the Crystalline Subalpine Forests Ecoregion are naturally less productive, are structured differently and are not directly comparable to communities in the two lower elevation ecoregions. Communities in monitoring locations in the Crystalline Mid-Elevation Forests and Foothills Shrublands are considered directly comparable for the purposes of this report.

Macroinvertebrate community metrics are often used to evaluate water quality and ecological health in streams and can be particularly useful when paired with chemical and physical water quality data to better understand cause and effect relationships between pollutants and the biota. Baseline biological condition was determined by calculating averages of routine macroinvertebrate community metrics using data from 2019 and 2020. Baseline (pre-fire) data were compared to 2021 data (post-fire) to understand macroinvertebrate community changes within and between key study locations following the Cameron Peak Fire. Differences in metric values of 20% or greater between baseline and 2021 data were deemed notable and are highlighted below (**Table 7**). It is important to note that analyses in subsequent years will be expanded to include short-and long-term trends, and to monitor impacts and recovery following the fire.

**Species Diversity**

Species diversity is a measure of the number of different macroinvertebrate species within a community. Communities with good water quality generally have higher species diversity than those with poor water quality. Species diversity was lower at all study locations in 2021 as compared to baseline, with PJW (-24%) and PBR (-22%) seeing the largest declines. Communities within these two locations were likely impacted to a greater degree by post-fire sedimentation than other study locations due to their proximity to burned hillslopes. In addition, PBR was heavily impacted by sedimentation from the Black Hollow debris flow.

**Shannon's H**

Shannon's H combines measures of species diversity and the relative abundance of each species within a macroinvertebrate community. Values > 3 generally indicate good community condition and water quality, whereas values <1 indicate poor community condition and water quality. Shannon's H declined across all monitoring locations in 2021, and only PBR (3.1) and PBD (3.1) maintained values above three. Shannon's H decreased by greater that 20% at PBR, PSF, and PNF following the fire. The decline in Shannon's H across all monitoring locations generally indicated that macroinvertebrate community condition has declined because of post-fire pollution.

**EPT Diversity and % EPT**

EPT is an abbreviation for the sum of Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) species. EPT are widely regarded as intolerant of water quality pollution, and therefore, higher measures of EPT diversity and percent of EPT in a community generally indicate that water quality is good. EPT diversity declined within the burn scar at PBR (-33%) but remained relatively consistent with baseline conditions at downstream study locations. The notable change in EPT diversity at PBR is likely related to post fire pollution, particularly sedimentation from the Black Hollow debris flow. Percent EPT was consistently high across all monitoring locations, except PNF, where there was a 28% decrease as compared to baseline. The reason for this decline is unclear.

**Density**

Density is a measure of the number of individual organisms per square meter of the streambed. Changes in density can be associated with water quality pollution. Macroinvertebrate density was the highest at the Mainstem near the City of Greeley's Diversion (PBD) (6,529), but this value represents a 21% decrease from baseline. The density of macroinvertebrates at PJW declined by 30%, which is likely due to post-fire pollution impacts. Interestingly, densities at PSF and PNF increased by 42%. These changes in density are likely a post-fire community response at these study locations.

**Collector-Gatherers**

Percent collector-gatherers refers to the percentage of macroinvertebrate species that feed on tiny organic particles deposited on or within the streambed, rather than through filtration. The percentage of collector-gatherers in 2021 remained consistent with baseline at PJW and PBR; however, the percentage of collector-gatherers at PSF (-38%), PNF (-33%) and PBD (-33%) decreased substantially. The decrease in the percentage of collector gatherers at these study locations corresponds to an increase in the percentage of algae scrapers at PSF and PBD and collector-filterers at PNF. These changes may be related to a higher nutrient load consistently high across all sites during post-fire runoff.

**Algae Scrapers**

Percent algae scrapers is the relative percentage of macroinvertebrates that scrape algae from the tops of rocks and logs. Algae scrapers can become more abundant in the presence of elevated nutrients as algal productivity increases and can decline due to excessive sedimentation. The concentration of nutrients has increased following the Cameron Peak Fire, which may explain the shift to more algal scrapers at PSF (+54%) and PBD (+27%).

**Collectors-Filters**

Percent filter-feeders refers to the percentage of macroinvertebrate species in a community that feed by filtering tiny organic particles suspended in the streamflow. The abundance of these organisms often dramatically increases in locations exposed to elevated organic pollution. The percentage of collector-filterers on the Mainstem was mostly consistent with baseline data. The exception was at PNF, where the percentage of collector-filterers increased by 36%. A corresponding increase in TOC was not observed at PNF. The change in the relative percentage of this feeding group may simply be related to the decline in abundance of other feeding groups.

**Leaf Shredders**

Percent shedders refers to the percentage of macroinvertebrate species that feed on leaves, pine needles, twigs and other large organic matter that is washed into the river. Decreases in the percent of shredders in a community can indicate that riparian vegetation has been impacted and is providing less food for these organisms. Shredders generally made up a larger percentage of the community at the Mainstem above Joe Wright Creek (PJW) (2%), the Mainstem below Rustic (PBR) (7%) and the Mainstem below the South Fork (PSF) (4%). Shredders at the Cities of Fort Collins' and Greeley's Diversions (PNF and PBD) made up around 0% and 1% of the of the community, respectively; the reason for the decrease in shredders at these downstream sites follows trends in baseline data. Shredders are expected to naturally decrease as rivers transition from headwaters downstream.

**MMI Version 4**

The MMI Version 4 is the Colorado Department of Public Health and Environment's (CDPHE) multi-metric water quality index, which combines several ecological metrics into a single score that is compared to reference conditions. The Mainstem above Joe Wright Creek (PJW) is in CDPHE's biotype 1. The Mainstem below Rustic (PBR), the Mainstem below the South Fork (PSF), the Mainstem near the City of Fort Collins' Diversion (PNF) and the Mainstem near the City of Greeley's Diversion (PBD) are located in CDPHE's biotype 2. The MMI Version 4 is used by CDPHE to determine whether a stream community meets the State's surface water quality standards for the Aquatic Life Use. All study locations continued to attain CDPHE's MMI Version 4 aquatic life standards thresholds.

**Table 7** – Routine 2021 macroinvertebrate community metric results from key study locations along the Mainstem CLP. Data were compared to baseline data (average of 2019 and 2020 data) and notable negative and positive percentage departures are indicated in parentheses in red and blue, respectively.

| | PJW | PBR | PSF | PNF | PBD |
|---|---|---|---|---|---|
| **Level IV Ecoregion** | Crystalline Subalpine Forests | Crystalline Mid-Elevation Forests | Crystalline Mid-Elevation Forests | Crystalline Mid-Elevation Forests | Foothills Shrublands |
| **Species Diversity** | 26 (-24%) | 32 (-22%) | 36 | 31 | 32 |
| **Shannon's H** | 2.8 | 3.1 (-22%) | 2.8 (-33%) | 2.3 (-31%) | 3.1 |
| **EPT Diversity** | 16 | 15 (-33%) | 22 | 18 | 23 |
| **Percent EPT** | 81 | 72 | 84 | 53 (-28%) | 88 (+20%) |
| **Density (#/m$^2$)** | 3,091 (-30%) | 2,773 | 3,621 (+42%) | 3,479 (+42%) | 6,529 (-21%) |
| **Percent Collector-Gatherers** | 65% | 54% | 12% (-38%) | 15% (-33%) | 18% (-33%) |
| **Percent Algae Scrapers** | 23% | 14% | 68% (+54%) | 38% | 59% (+27%) |
| **Percent Predators** | 6% | 5% | 8% | 1% | 4% |
| **Percent Collector-Filterers** | 5% | 20% | 8% | 45% (+36%) | 9% |
| **Percent Leaf Shredders** | 2% | 7% | 4% | 0% | 1% |
| **CDPHE Biotype** | 1 | 2 | 2 | 2 | 2 |
| **MMI version 4** | 69.5 (Attainment) | 66.3 (Attainment) | 76.3 (Attainment) | 66.1 (Attainment) | 76.5 (Attainment) |

# 4.0 SOURCE WATER QUALITY TRENDS AND TREATMENT IMPLICATIONS

The temporal trends discussed in Section 4 focus primarily on monitoring sites located near the City of Fort Collins' Diversion upstream of the confluence with the North Fork CLP River (PNF) and the City of Greeley's Poudre River Diversion downstream of the confluence with the North Fork CLP River (PBD). It is assumed that water quality measured at PNF is representative of water quality upstream at the Munroe Tunnel Diversion where Soldier Canyon Drinking Water Authority diverts their Poudre River water supplies. Monthly trends in water quality are strongly correlated with changes in hydrology and seasonal weather patterns.

*Presentation of Results*

Bar charts presented in Section 4 display monthly median values measured over the 2021 monitoring season for the months of April, May, and June when sampling is conducted twice per month, and monthly values from July through November. These data are compared to baseline median values calculated over the period of record from 2008 to 2012. Please note that samples were not collected at the City of Greeley's Diversion (PBD) in July due to road construction activities and restricted access to the sampling location.

*Selected Variables*

The water quality parameters listed below are the focus of these trend analyses because they have a direct impact on water treatment processes.

- **Alkalinity**
- **pH**
- **Total Organic Carbon**
- **Turbidity**

## 4.1 ALKALINITY

Alkalinity was much higher than the baseline median at both the City of Fort Collins' Diversion (PNF) and City of Greeley's Diversion (PBD) (**Figure 3.2**). Seasonal trends in alkalinity were comparable to baseline at both monitoring locations with lower concentrations measured during snowmelt runoff and higher concentrations in the spring prior to snowmelt runoff and as streamflow receded through the summer and fall months. In general, monthly concentrations were greater than baseline at both monitoring locations throughout the entire monitoring season.

*City of Fort Collins' Diversion*

The median alkalinity concentration at the City of Fort Collins' Diversion was 28.2 mg/L, which was 1.6 times higher than baseline. Concentrations ranged from a minimum of 18.8 mg/L in the month of June to a maximum 34.2 mg/L measured in the month of November. Alkalinity was greater than baseline over the spring season (April – May) and measured 32.1 mg/L in April and 23.3 mg/L in May. Alkalinity was lower during the summer months, but still measured well above baseline. Concentrations ranged from 18.8 mg/L in the month of June to 22.8 mg/L in the month of August. The largest departure from baseline was observed in the month of June when concentrations were 1.6 times higher than baseline. Alkalinity concentrations remained elevated over the fall months from September through November. Concentrations ranged from 28.6 mg/L in September to 34.2 mg/L in November. The largest departure from baseline was observed in the month of September when concentrations measured 1.7 times higher than baseline (**Figure 4.1**).

*City of Greeley's Diversion*

The median alkalinity concentration at the City of Greeley's Diversion was 31.0 mg/L, which was 1.2 times higher than baseline. Concentrations ranged from a minimum of 20.4 mg/L in the month of June to a maximum of 45.0 mg/L measured in the month of October. Alkalinity was greater than baseline in April and below baseline in May. Concentrations over the spring season measured 42.1 mg/L in the month of April and 28.6 mg/L in the month of May. Alkalinity was slightly higher than baseline over the summer season (June and August). Concentrations over the summer season measured 20.4 mg/L in June and 24.0 mg/L in August. Alkalinity concentrations remained above baseline through the fall season. Concentrations ranged

from 29.0 mg/L in September to 45 mg/L in October. The largest departure from baseline was measured in the month of October when the concentration measured 1.5 times higher than baseline (**Figure 4.1**).

## 4.2 pH

pH was higher than the baseline median at both the City of Fort Collins' Diversion (PNF) and City of Greeley's Diversion (PBD) in 2021 (**Figure 3.1**). Seasonal trends in pH were comparable to baseline at both monitoring locations during the spring season. Notable differences were observed in pH during the summer and fall seasons at both monitoring locations. In general, pH slightly decreased in the spring and early summer. pH was elevated after snowmelt runoff and remained elevated through the summer and fall seasons.

*City of Fort Collins' Diversion*

The median pH value at the City of Fort Collins' Diversion was 7.73, which was 0.32 pH units higher than baseline. Concentrations ranged from a minimum 7.46 in the month of June to a maximum 8.10 measured in the month of April. pH measured slightly above baseline over the spring months of April and May. pH measured above baseline over the summer season. In the early summer month of June, pH was slightly higher than baseline, but measured much higher than baseline in July and August. pH measured 0.34 and 0.56 pH units higher than baseline in these months, respectively. pH remained elevated through the fall season. The largest departure in pH over the fall season was observed in the month of September when the pH was 0.45 units greater than baseline. The higher pH values observed over the 2021 season, especially during the summer and fall seasons, were likely a result of post-fire impacts to Poudre River water quality, specifically from ash inputs from burned hillslopes into the river (**Figure 4.1**).

*City of Greeley's Diversion*

The median pH value at the City of Greeley's Diversion was 7.86 compared to the baseline median of 7.56. Concentrations ranged from a minimum of 7.49 in the month of June to a maximum 8.39 measured in the month of April. pH values were greater than baseline throughout the monitoring season. A notable divergence from the baseline seasonal trend was observed over the summer and fall months from August through November. pH measured slightly above baseline over the spring months of April and May. pH measured above baseline over the summer season. In the early summer month of June, pH remained slightly above baseline, but measured 0.26 pH units higher than baseline in August. pH was even more elevated through the fall season. The largest departure in pH over the fall season was observed in the month of September when the pH was 0.70 units greater than baseline. The higher pH values observed over the 2021 season, especially during the summer and fall seasons, were likely a result of post-fire impacts to Poudre River water quality, specifically from ash inputs from burned hillslopes into the river (**Figure 4.1**).

## 4.3 TOTAL ORGANIC CARBON

Total organic carbon was higher than the baseline median at both the City of Fort Collins' Diversion (PNF) and City of Greeley's Diversion (PBD) in 2021 (**Figure 3.4**). Seasonal trends in total organic carbon were comparable to baseline at both monitoring locations with higher concentrations measured during snowmelt runoff and lower concentrations following runoff in the summer and fall months; however, there were a few anomalies that occurred at both monitoring locations resulting in elevated total organic carbon concentrations.

*City of Fort Collins' Diversion*

The median TOC concentration at the City of Fort Collins' Diversion was 4.40 mg/L compared to the baseline median of 3.60 mg/L. Monthly concentrations ranged from a minimum of 2.73 mg/L in the month of October to a maximum of 7.33 mg/L measured in the month of May. In contrast to baseline trends, the highest concentrations were observed earlier in the monitor season due to an early start to snowmelt runoff in the lower portions of the watershed. Total organic carbon concentrations were well above baseline in April when concentrations measured nearly 2 times higher than baseline and exceeded the 4 mg/L removal requirement threshold (**Table 3**). Concentrations were closer to baseline in the month of May and much lower than baseline in the early summer month of June. Total organic carbon concentrations measured 2 mg/L lower than baseline during this time. Total organic carbon measured near baseline in the month of July but measured notably higher than baseline in the month of August. Total organic carbon in August was nearly 1.5 times higher than baseline. The elevated total organic carbon measured in the river during this time was a result of a post-fire event that was observed in late-July. TOC remained elevated into September before falling to near baseline levels in October and November (**Figure 4.1**).

*City of Greeley's Diversion*

The median total organic carbon concentration at the City of Greeley's Diversion was 5.49 mg/L compared to the baseline median of 4.03 mg/L. Monthly concentrations ranged from a minimum 2.85 mg/L in the month of October to a maximum 8.08 mg/L measured in the month of May. Like the trends observed upstream at the City of Fort Collins Diversion (PNF), the highest concentrations were observed earlier in the monitoring season due to an early start to snowmelt runoff in the lower portions of the watershed. Total organic carbon concentrations were well above baseline in April when concentrations measured 2 times higher than baseline and exceeded the 4 mg/L removal requirement threshold (**Table 3**). Concentrations remained above baseline in the month of May, contrary to the trend observed upstream, which may be attributed to contributions from the North Fork. Total organic carbon was much lower than baseline in the early summer month of June and higher than baseline in the late summer and fall months. In contrast to trends observed upstream at the City of Fort Collins' Diversion (PNF), total organic carbon concentrations remained above baseline in October and November. Total organic carbon concentrations were generally higher at the City of Greeley's Diversion (PBD) compared to the City of Fort Collins' Diversion (PNF) due to contributions from the North Fork (**Figure 4.1**).

## 4.4 TURBIDITY

Turbidity was higher than the baseline median at both the City of Fort Collins' Diversion (PNF) and City of Greeley's Diversion (PBD) in 2021 (**Figure 3.1**). Seasonal trends in turbidity differed from baseline with elevated turbidity levels in the early spring, late summer and fall seasons, rather than just during runoff.

*City of Fort Collins' Diversion*

The median turbidity at the City of Fort Collins' Diversion was 5.0 NTU compared to the baseline median of 1.7 mg/L. Concentrations ranged from a minimum of less than 1 NTU in the month November to a maximum of 24.4 NTU measured in the month of August. Turbidity was much higher than baseline in the spring months of April and May. Turbidity in the month of April measured 16 NTU, which was 25 times higher than baseline. Elevated turbidity continued into May with turbidity levels measuring two times higher than baseline. The higher values during this time were likely related to early snowmelt runoff and above average streamflow conditions. Turbidity levels dropped closer to baseline in the month of June but were abnormally higher than baseline from July through October. Turbidity levels in November returned to more normal conditions and measured near baseline. The elevated turbidity levels observed in the summer through fall seasons was caused by frequent post-fire storm events that were observed throughout the summer monsoon season. Turbidity in the month of August was particularly high due to a large post-fire flood event that occurred in late July. Turbidity levels in the month of August measured 14 times higher than baseline. The impacts on river turbidity from this event persisted through October (**Figure 4.1**).

*City of Greeley's Diversion*

The median turbidity at the City of Greeley's Diversion was 7.4 NTU compared to the baseline median of 1.8 NTU. Concentrations ranged from a minimum of 1.8 NTU in the month of November to a maximum of 24.3 NTU measured in the month of August. Turbidity was much higher than baseline in the spring months of April and May. Turbidity in the month of April measured 13.5 NTU, which was 13 times higher than baseline. Elevated turbidity continued into May with turbidity levels measuring 1.7 times higher than baseline. Like observations at the City of Fort Collins' Diversion (PNF), the higher values during this time were likely related to early snowmelt runoff and above average streamflow. In contrast to trends observed upstream at the City of Fort Collins' Diversion (PNF), elevated turbidity levels continued into the month of June. Turbidity during this time was over three times higher than baseline. The higher values during this time were likely related to contributions from the North Fork CLP River. Turbidity in the month of August was particularly high due to a large post-fire flood event that occurred in late July. Turbidity levels in the month of August measured 15 times higher than baseline. The impacts on river turbidity from this event persisted through November, although the elevate turbidity during the fall season may also have been influenced by contributions from the North Fork CLP River (**Figure 4.1**).

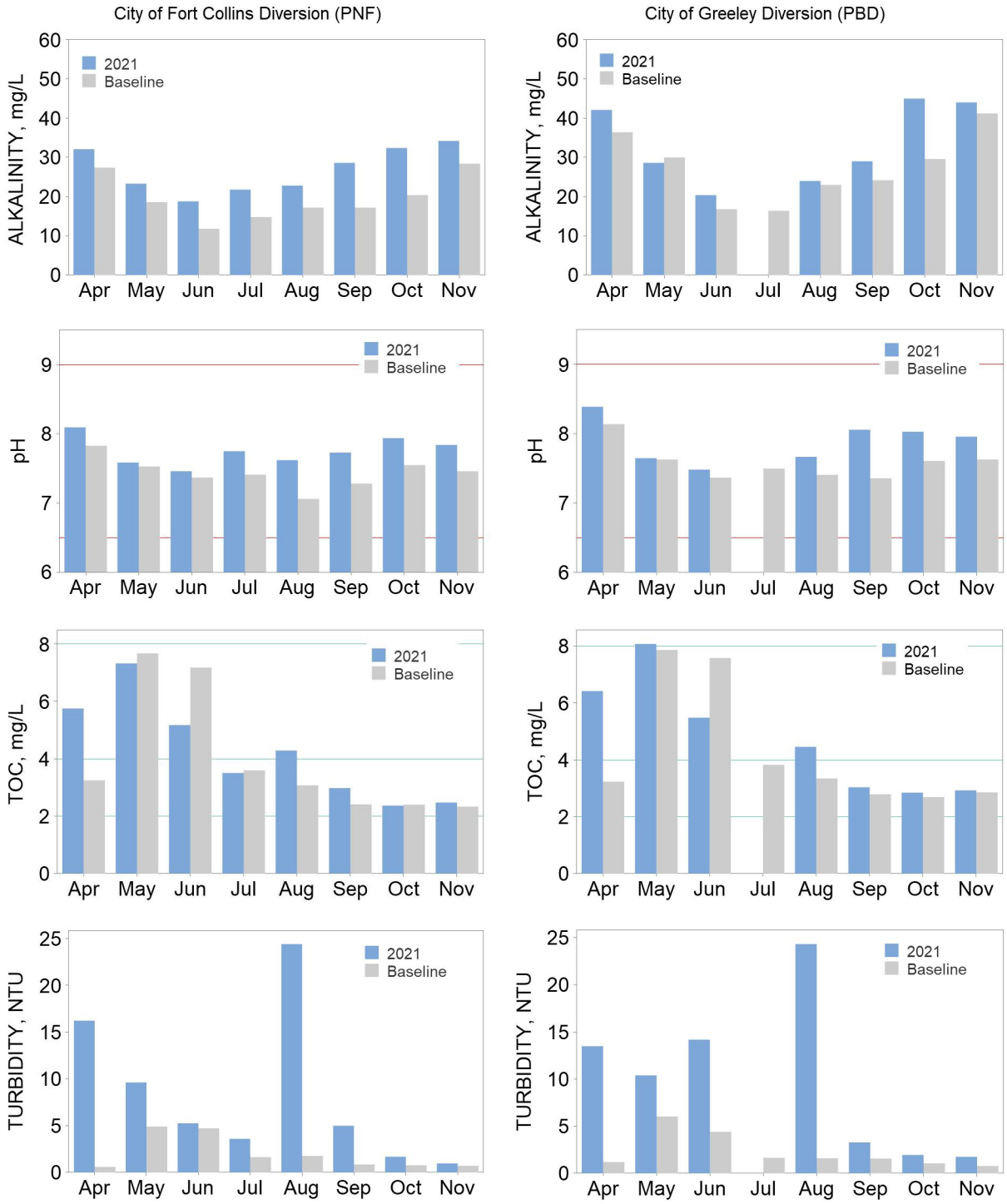


**Figure 4.1** – Monthly median alkalinity, pH, total organic carbon, and turbidity levels measured on the Mainstem CLP River at the City of Fort Collins Diversion (left) and City of Greeley Diversion (right) in 2021 compared to the baseline period of record. The red reference lines for pH indicate water quality standards set by the Colorado Department of Public Health and Environment to protect aquatic life and green reference lines for TOC indicate thresholds for TOC removal requirements. Note that the TOC removal requirements also consider raw water alkalinity concentrations.

# 5.0 SUMMARY

## 5.1 PROGRAM PERFORMANCE

Review of the 2021 Upper CLP Collaborative Water Quality Monitoring Program data indicates that the program adequately captures temporal trends in water quality and provides a spatial context for examining notable events. The results of the field quality assurance and control sampling indicate that data precision and accuracy were acceptable.

## 5.2 HYDROLOGY AND CLIMATE

Air temperature measured over the 2021 water year was warmer than baseline and ranked as the 8th warmest on record (31 years; 1990 to 2020) at the Joe Wright SNOTEL. Cooler conditions were observed over the winter and spring season followed by record breaking temperatures in the summer and fall. The summer season ranked as the warmest summer on record and the fall season ranked as the 2nd warmest fall on record.

Total precipitation measured less than the baseline average. Peak snow water equivalent across the entire Cache la Poudre Watershed was slightly above average. The rate of snowmelt occurred faster than normal with complete melt out at the Joe Wright SNOTEL occurring one month earlier than normal. Precipitation measured below baseline for all seasons resulting in expanding drought conditions across the Upper CLP watershed through the 2021 monitoring season.

The total volume of water that flowed down the Mainstem CLP River, as measured at the Canyon Mouth stream gage, was 115% of baseline. Streamflow was above baseline over the winter, spring, and fall seasons and below baseline over the summer season. Peak streamflow measured 146% of the historical average peak (1881 – 2021) and occurred nearly three weeks earlier than expected.

## 5.3 UPPER CACHE LA POUDRE RIVER WATER QUALITY

No significant water quality concerns were identified for the North Fork CLP watershed; however, notable water quality changes were observed in the Mainstem CLP watershed, specifically related to erosion, debris flows, and flooding from the Cameron Peak Fire burn scar.

The most notable impacts to water quality over the 2021 water year were associated with earlier than normal snowmelt runoff across the entire basin, and post-fire water quality impacts to the Mainstem CLP River from the Cameron Peak Fire burn scar during and following the summer monsoon season. The Black Hollow debris flow and flood event in the Poudre Canyon that occurred in late-July resulted in drastic changes in water quality during and immediately following the event. Impacts to several water quality constituents persisted for several months after the event.

The typical challenges for water treatment were observed on the Mainstem and the North Fork during snowmelt runoff; however, the water quality response from snowmelt runoff began earlier than normal, specifically in lower elevations of the watershed because of snowmelt from a large spring storm that impacted the foothills of the CLP watershed in March. Water quality changes driven by snowmelt began one month earlier than normal as indicated by elevated turbidity, specific conductivity and dissolved solids, and total organic carbon in April and May. On the contrary, snowmelt driven impacts diminished earlier than normal posing less of a challenge to water treatment in June. The timing and magnitude of snowmelt runoff may have also been influenced by the dramatic changes in landcover caused by the Cameron Peak Fire. Loss of tree and canopy cover likely shifted the energy dynamics influencing snowmelt leading to a more rapid snowmelt response, especially at higher elevations in the watershed where the persistent snowpack occurs.

"… notable water quality changes were observed in the Mainstem CLP watershed, specifically related to erosion from the Cameron Peak Fire burn scar."

Additional water quality impacts were observed across the Mainstem CLP watershed during the summer monsoon season. High intensity precipitation events that occurred over the Cameron Peak Fire burn scar caused flooding, debris flows, and erosion in the CLP River resulting in periodic occurrences of severely impaired water quality. Elevated pH and alkalinity levels indicated delivery of ash from burned hillslopes into the Mainstem CLP River, while elevated turbidity, specific conductivity, total dissolved solids, and nutrients indicated excessive erosion and the delivery of sediment, debris, and dissolved constituents into the Mainstem CLP River. The largest impacts were observed in the Poudre below Rustic (PBR) downstream to the City of Greeley's Diversion (PBD) and in the South Fork (SFM). Post-fire impacts were observed at higher elevation monitoring locations in Joe Wright Creek (JWC) and in the Mainstem above Joe Wright Creek (PJW), but the magnitude of these impacts was less severe. This may be due to a smaller contributing watershed area and water supply reservoirs absorbing post-fire impacts and Lessing the direct impact downstream. Most of the post-fire storm events in 2021 exceeded turbidity thresholds for water treatment indicating poor water quality, which resulted in the shutdown of Poudre River water supply intakes and reliance on alternate water sources.

Physical parameters, including water temperature, pH, and turbidity were within the baseline range of values in the North Fork CLP River. pH and turbidity were elevated in the Mainstem CLP River. Median turbidity at most sites along the Mainstem CLP River was five times higher than baseline. The elevated turbidity at these sites was driven primarily by unseasonable high turbidity levels observed in early spring, mid-summer, and fall. Post-fire impacts persisted throughout most of the monitoring season resulting in much higher turbidity levels later in the year when turbidity is typically very low.

General parameters, including alkalinity, hardness, and specific conductivity concentrations were within the baseline range of values in the North Fork CLP River and elevated in the Mainstem CLP River. Median alkalinity, hardness, and specific conductivity concentrations were 1.5 times higher than baseline in the Mainstem CLP River.

Total dissolved solids were within the baseline range of values in the North Fork CLP River and elevated in the Mainstem CLP River. Median total dissolved solids concentrations were higher than baseline at all monitoring sites along the Mainstem CLP River and measured 1.25 to 1.5 times higher than baseline. The largest differences were observed at the cities of Fort Collins' and Greeley's Diversions (PNF and PBD).

Total organic carbon concentrations were near baseline along the Mainstem CLP River and North Fork CLP River. Median concentrations were slightly higher than baseline from the Poudre below Rustic (PBR) downstream to the City of Greeley's Diversion (PBD). Seasonal trends in total organic carbon were comparable to baseline; however, there were a few occurrences resulting in elevated total organic carbon concentrations.

Nutrients were within the baseline range of values in the North Fork CLP River, although anoxic conditions in both Halligan and Seaman Reservoir during the late summer and fall resulted in elevated nutrient concentrations in the North Fork CLP River. In-reservoir dynamics were driven by the above average temperatures and extremely dry conditions observed during this time. Elevated concentrations were measured at monitoring sites directly downstream of the reservoirs and appeared to have minimal impact to lower elevation monitoring sites. Nutrients were higher than baseline in the Mainstem CLP River. The greatest change was observed in total phosphorus, although nitrate concentrations were also higher than baseline. Total phosphorus concentrations were 1.5 – 2 times higher than baseline, and notably higher following the Black Hollow flooding event. Despite the higher nutrient concentrations, no discernable spatial or temporal trends were observed for geosmin or 2-MIB over the 2021 water year.

Macroinvertebrate communities were impacted by post fire pollution to varying degrees. Most concerning were the reductions in community diversity and density at PJW and PBR, both of which are located within the Cameron Peak Fire burn scar. PBR showed the greatest impacts of all study locations, likely due to cumulative impacts of post-fire erosion and sedimentation, including the Black Hollow debris flow. Study locations PSF, PNF and PBD are further downstream and were impacted to a lesser degree, but still showed changes in densities and relative percentages of feeding groups, which indicates stress. It is likely that the impacts observed in these macroinvertebrate communities across all study locations was due to chemical toxicity and physical stress (e.g. smothering, abrasion and loss of food or habitat resources). In 2022, these communities are expected to further degrade due to a combination of these same stressors as well as reduced reproductive success and limited addition of new individuals to the community.

In summary, the Upper CLP watershed continues to supply a high-quality drinking water supply to the City of Fort Collins, City of Greeley and surrounding communities served by the Soldier Canyon Water Treatment Authority. The Cameron Peak Fire has resulted in notable changes to water quality compared to baseline conditions and storm events have posed challenges to drinking water treatment due to severely impaired water quality. Despite these challenges, early warning systems and alternate water sources have proven critical to avoiding or mitigating these impacts. Emerging trends will be important to monitor into the future to further help inform water treatment operations, track watershed health, and evaluate the impacts of the Cameron Peak Fire on this important water supply.

# 6.0 DATA QUALITY ASSURANCE AND CONTROL

The Upper CLP watershed collaborative monitoring program assures comparability and validity of data by complying with monitoring methods and implementing quality assurance and quality control (QAQC) measures. QAQC measures are good practice in environmental monitoring and can be used to determine potential error in data due to contamination of water samples, sampling error, equipment contamination, and/or laboratory error. The Upper CLP monitoring sites are representative of the goals and objectives outlined previously and demonstrate the true character of the watershed at the time of sampling. The remainder of this section summarizes QAQC data collected over the 2021 monitoring season.

## 6.1 FIELD QUALITY CONTROL

Field duplicates and field blanks were obtained at PNF and NFG during each monitoring event to determine precision of data and to identify potential for sample contamination. The field data quality sampling schedule is outlined in the 2021 annual sampling plan (Attachment 4). QAQC samples and accuracy of field equipment are reviewed by Watershed Program staff.

In 2021, eight percent (421 out of 5169) of the environmental samples collected were blank samples and nine percent (447 out of 5169) of the environmental samples collected were field duplicates. The results of the field quality assurance and control sampling indicate that precision and accuracy were acceptable.

**Field Duplicates**

Precision is a measure of the deviation from the true value. For most constituents, duplicate determinations should agree within a relative percent difference of 10%. Duplicate samples with measured concentrations that differ by greater than 10% from field samples were flagged for further quality assurance and control evaluation. **Table 8** (a and b) outlines relative percent difference statistics for duplicate samples and illustrates that Upper CLP water quality data are of high precision. All duplicate samples were within 10% agreement at the 75$^{th}$ percentile during North Fork sampling, except total coliforms (15%) and total kjeldhal nitrogen (13%) (**Table 8a**). This result indicates that most of the duplicate samples were in agreement during North Fork sampling events. During Mainstem sampling, greater than 75% of the total coliform and *E. coli* samples and greater than 50% of the total kjeldhal nitrogen samples exceeded a relative percent difference of 10% (**Table 8b**). The high variability in total coliform and *E. coli* samples was not unexpected. All other duplicate samples collected on the Mainstem were less than a relative percent difference of 10% for at least 75% of the samples. Detectable metals (not all listed in Table 8) were all within a relative percent difference of less than 10%.

**Field Blanks**

Blank samples should not contain analytes above the reporting limit. Field blanks were analyzed in the laboratory for a total of 33 different water quality parameters in 2021. Ninety-seven percent of field blank samples reported below the constituent's respective reporting limits. The 3% of field blank samples that were detected above the reporting limits included alkalinity, ammonia, hardness, magnesium, orthophosphate, potassium, sodium, total dissolved solids, total kjeldahal nitrogen, and 2-methylisoborneol (**Table 9**). The reporting limit was only exceeded once for each of these constituents except for total dissolved solids, which exceed the reporting limit twice.

Concentration exceedances were reported only slightly above the reporting limit for most samples and concentrations were minimal compared to concentrations of environmental samples. Alkalinity, hardness, and total kjeldahal nitrogen exceedances were observed during North Fork sampling events. The exceedance in alkalinity and hardness were observed on the same sample date (8/10/2021). All other listed exceedances were observed during Mainstem sample events. The one exceedance of major ions was observed on the same sample date (5/24/2021).

Potential causes of these contaminants are listed below:

- Atmosphere/particulates in the air slightly increasing ammonia and total dissolved solids.
- Inadequate rinsing of sample bottles either in the field or laboratory may have left residuals increasing total dissolved solids.

- Ammonia, TKN, and orthophosphate contamination may be introduced by the field sampler and/or laboratory staff accidentally breathing on the sample (ammonia), touching sample bottle or lid, or introduced by the lab instrument, if not properly cleaned.

**Instrument Accuracy**

Accuracy is a measure of the degree of closeness a measurement is to the true measurement. Equipment calibrations were conducted prior to field monitoring exhibitions using certified standards to assure the accuracy of sensors on the multi-parameter water quality sonde. Quality assurance checks were conducted following field sampling missions to verify sensor accuracy.

## 6.2 LABORATORY QUALITY CONTROL

Upper CLP water quality samples analyzed by the Fort Collins Water Quality Laboratory are reviewed by the Quality Assurance Coordinator to ensure data are free of sample contamination, analytical, and/or data entry errors.

*Water quality laboratory staff analyze samples at the City of Fort Collins Water Quality Laboratory.*

The City of Fort Collins Water Quality Laboratory implements analytical QAQC measures by conducting laboratory blank, duplicate, replicate, and spiked samples. The City of Fort Collins WQL conducts most analyses for the Source Water Quality Monitoring Program and is a U.S. EPA Certified Drinking Water Laboratory with an established QA plan that is applied to all samples received by the laboratory (Elmund et al, 2013). The primary features of their QA protocol include:

- Precision: one duplicate sample is analyzed for every 10 samples; relative deviation should be less than 10%.

- Accuracy: one external QCS sample is analyzed with each set of samples analyzed. Methods may specify an acceptable recovery range. In general, Standard Methods limits are ± 5% and EPA methods are ± 10%.

- Recovery: one sample is spiked for every 10 samples; if there are different matrices, at least one sample per matrix is spiked. Limits for most methods are ± 15%. If one type of matrix spike fails and all other QC passes, those samples may be flagged.

A complete description of laboratory personnel, equipment, and analytical QA methods is outside of the scope of this report and is not addressed in detail here. As part of the City's Water Quality Services Division the WQL operates under the guidance of a general QA plan (Hill, 2019)

**Table 8a** – Data quality assurance statistics calculated for duplicated samples collected at NFG. The range in sample concentrations (minimum and maximum) was calculated for the combined environmental and duplicate samples collect over the monitoring season. The absolute mean difference was calculated by taking the difference between the environmental and duplicate sample concentration for individual monitoring events and then by calculating and average difference for the monitoring season. The relative percent difference was calculated by taking the difference between the environmental and duplicate sample concentrations divided by the average concentration between samples for each monitoring event. Percentiles (25th, 50th and 75th percentiles) were then calculated from these data to describe the distribution of relative percent differences for each constituent.

| a) NFG constituents | Range in QAQC sample concentration | | Reporting Limit | Absolute Mean Difference | Relative Percent Difference (%) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Percentile | | |
| | *min* | *max* | | | *25th* | *50th* | *75th* |
| Aluminum - S, ug/L | 5 | 510 | 10 | 6 | 0.00 | 0.85 | 2.24 |
| Aluminum - TR, ug/L | 37 | 1040 | 10 | 13 | 0.52 | 1.28 | 2.15 |
| Ammonia as N, ug/L | 20 | 100 | 10 | 3 | 0.00 | 0.00 | 2.78 |
| Arsenic - S, ug/L | 0.5 | 1.56 | 2 | 0.006 | 0.00 | 0.00 | 0.52 |
| Arsenic - TR, ug/L | 0.5 | 1.79 | 2 | 0.003 | 0.00 | 0.00 | 0.08 |
| Calcium, mg/L | 14.8 | 30.5 | 0.5 | 0.38 | 0.86 | 1.94 | 2.31 |
| Chloride, mg/L | 6.4 | 12.6 | 1 | 0.01 | 0.00 | 0.06 | 0.08 |
| Coliforms, Total, cfu | 236 | 326 | | 13 | 6.82 | 10.8 | 14.8 |
| Copper - S, ug/L | 0.5 | 1.32 | 3 | 0.12 | 0.28 | 0.92 | 10.1 |
| Copper - TR, ug/L | 0.5 | 1.27 | 3 | 0.007 | 0.00 | 0.00 | 0.81 |
| Hardness, mg/L | 102 | 102 | 5 | 0.1 | 0.49 | 0.49 | 0.49 |
| Iron - S, ug/L | 22.8 | 378 | 10 | 4.82 | 0.53 | 1.18 | 2.44 |
| Iron - TR, ug/L | 380 | 892 | 10 | 6.7 | 0.36 | 0.54 | 0.71 |
| Magnesium, mg/L | 3.28 | 6.36 | 0.2 | 0.095 | 1.06 | 1.34 | 2.96 |
| Manganese - S, ug/L | 9.04 | 66 | 1 | 0.318 | 0.00 | 0.15 | 0.72 |
| Manganese - TR, ug/L | 28.4 | 102 | 1 | 1.64 | 0.58 | 0.95 | 1.60 |
| Nitrate, ug/L | 0.05 | 0.12 | 40 | 0.002 | 0.00 | 0.00 | 1.09 |
| Orthophosphate, ug/L | 2.5 | 52 | 5 | 17 | 0.94 | 2.89 | 7.00 |
| Potassium, mg/L | 1.02 | 1.45 | 0.3 | 0.022 | 0.90 | 1.61 | 3.00 |
| Sodium, mg/L | 5.8 | 9.31 | 0.4 | 0.12 | 0.49 | 1.35 | 2.76 |
| Sulfate, mg/L | 2.5 | 8.83 | 5 | 0.005 | 0.06 | 0.08 | 0.10 |
| Total Dissolved Solids, mg/L | 106 | 170 | 10 | 8.6 | 2.37 | 3.84 | 5.75 |
| Total Kjeldahl Nitrogen, ug/L | 370 | 630 | 100 | 0.078 | 4.60 | 8.65 | 13.0 |
| Total Organic Carbon, mg/L | 5.45 | 8.35 | 0.5 | 0.112 | 0.37 | 0.51 | 0.93 |
| Total Phosphorus, ug/L | 25 | 111 | 10 | 0.00121 | 0.46 | 0.88 | 1.91 |

*cfu = colony forming units

**Table 8b** – Data quality assurance statistics calculated for duplicated samples collected at PNF. The range in sample concentrations (minimum and maximum) was calculated for the combined environmental and duplicate samples collect over the monitoring season. The absolute mean difference was calculated by taking the difference between the environmental and duplicate sample concentration for individual monitoring events and then by calculating and average difference for the monitoring season. The relative percent difference was calculated by taking the difference between the environmental and duplicate sample concentrations divided by the average concentration between samples for each monitoring event. Percentiles (25th, 50th and 75th percentiles) were then calculated from these data to describe the distribution of relative percent differences for each constituent.

| b) PNF constituents | Range in QAQC sample concentration | | Reporting Limit | Absolute Mean Difference | Relative Percent Difference (%) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Percentile | | |
| | *min* | *max* | | | *25th* | *50th* | *75th* |
| Calcium, mg/L | 4.6 | 12.2 | 0.5 | 0.05 | 0.16 | 0.32 | 0.49 |
| Chloride, mg/L | 1.05 | 6.97 | 1 | 0.01 | 0.00 | 0.10 | 0.37 |
| Total Coliforms, cfu | 144 | 1430 | | 132 | 14.3 | 17.1 | 17.6 |
| E. coli, cfu | 5 | 59 | | 3 | 13.0 | 16.7 | 18.0 |
| Magnesium, mg/L | 1.11 | 3.28 | 0.2 | 0.02 | 0.42 | 0.60 | 1.03 |
| Potassium, mg/L | 0.69 | 3.73 | 0.3 | 0.24 | 0.00 | 0.58 | 0.75 |
| Sodium, mg/L | 1.87 | 5.05 | 0.4 | 0.03 | 0.21 | 0.36 | 0.52 |
| Sulfate, mg/L | 2.5 | 12.2 | 5 | 0.01 | 0.00 | 0.00 | 0.06 |
| Total Dissolved Solids, mg/L | 44 | 84 | 10 | 3 | 1.33 | 2.04 | 5.45 |
| Total Kjeldahl Nitrogen, ug/L | 125 | 460 | 100 | 88 | 3.85 | 7.14 | 41.2 |
| Total Organic Carbon, mg/L | 2.38 | 7.33 | 0.5 | 0.03 | 0.14 | 0.21 | 0.42 |
| Total Phosphorus, ug/L | 12 | 93 | 10 | 4 | 2.90 | 3.53 | 4.64 |

*cfu = colony forming units

**Table 9** – Blank samples detected above their respective reporting limit (RL), percent (%) exceedance and the percent of quality assurance and quality control samples collected over the 2021 monitoring season.

| WQ Parameter | Sample >RL | Total QAQC samples | % Exceedance | Total Samples | %QAQC |
|---|---|---|---|---|---|
| Alkalinity | 1 | 1 | 100% | 176 | 1% |
| Aluminum | 0 | 16 | 0% | 187 | 9% |
| Ammonia as N | 1 | 15 | 7% | 176 | 9% |
| Arsenic | 0 | 16 | 0% | 186 | 9% |
| Cadmium | 0 | 16 | 0% | 186 | 9% |
| Calcium | 1 | 12 | 8% | 177 | 7% |
| Chloride | 0 | 12 | 0% | 121 | 10% |
| Chromium | 0 | 16 | 0% | 186 | 9% |
| Coliforms, Total | 0 | 6 | 0% | 52 | 12% |
| Copper | 0 | 16 | 0% | 184 | 9% |
| E. coli | 0 | 6 | 0% | 52 | 12% |
| Hardness | 1 | 1 | 100% | 175 | 1% |
| Iron | 0 | 16 | 0% | 186 | 9% |
| Lead | 0 | 16 | 0% | 186 | 9% |
| Magnesium | 1 | 12 | 8% | 178 | 7% |
| Manganese | 0 | 16 | 0% | 186 | 9% |
| Mercury | 0 | 17 | 0% | 192 | 9% |
| Nickel | 0 | 16 | 0% | 186 | 9% |
| Nitrate | 0 | 15 | 0% | 178 | 8% |
| Nitrite | 0 | 15 | 0% | 178 | 8% |
| Orthophosphate | 1 | 15 | 7% | 176 | 9% |
| Potassium | 1 | 11 | 9% | 116 | 9% |
| Selenium | 0 | 16 | 0% | 185 | 9% |
| Silver | 0 | 16 | 0% | 193 | 8% |
| Sodium | 1 | 11 | 9% | 116 | 9% |
| Sulfate | 0 | 12 | 0% | 116 | 10% |
| Total Dissolved Solids | 2 | 15 | 13% | 175 | 9% |
| Total Kjeldahl Nitrogen | 1 | 15 | 7% | 176 | 9% |
| Total Organic Carbon | 0 | 15 | 0% | 176 | 9% |
| Total Phosphorus | 0 | 15 | 0% | 177 | 8% |
| Zinc | 0 | 16 | 0% | 185 | 9% |
| 2-Methylisoborneol (MIB) | 1 | 3 | 33% | 25 | 12% |
| Geosmin | 0 | 3 | 0% | 25 | 12% |

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# 7.0 REFERENCES


Billica, Loftis and Moore, 2008. Design of a Collaborative Water Quality Monitoring Program for the Upper Cache la Poudre River. July 14, 2008.

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Helsel, D.R. and R.M. Hirsch, 2002. Statistical Methods in Water Resources, Techniques of Water-Resources Investigations of the United States Geological Survey, Book 4, Hydrological Analysis and Interpretation, *United States Geological Survey*, 524 pages.

Hill, L., 2019. Quality Assurance Plan, *Internal Water Quality Services Division Document,* City of Fort Collins, June 1, 2019, 20 pages.

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# ATTACHMENT 1

## UPPER CLP COLLABORATIVE WATER QUALITY MONITORING PROGRAM SAMPLING SITES

| | Site ID | Station Name | Lat/Long |
|---|---|---|---|
| *Mainstem* | 100CHR | Joe Wright Creek below Chambers Lake | 40.60065, -105.8367 |
| | 101CHD | Joe Wright Creek below Chambers Lake Dam | 40.6023, -105.843 |
| | 090BMR | Barnes Meadow Reservoir Outflow | 40.60065, -105.8367 |
| | 091BMD | Barnes Meadow Reservoir Dam | 40.60044, -105.837 |
| | 080JWC | Joe Wright Creek | 40.61979, -105.819 |
| | 070PJW | Poudre above Joe Wright | 40.63411, -105.807 |
| | 060LRT | Laramie River Tunnel | 40.66803, -105.808 |
| | 050PBR | Poudre Below Rustic | 40.70002, -105.545 |
| | 040SFM | South Fork above Mainstem | 40.61824, -105.5254 |
| | 041SFC | South Fork at Confluence | 40.68506, -105.447 |
| | 030PSF | Poudre below South Fork | 40.69464, -105.448 |
| | 020PNF | Poudre Above North Fork | 40.70157, -105.241 |
| | 010PBD | Poudre at Bellvue Diversion | 40.66436, -105.217 |
| *North Fork* | 280NDC | North Fork above Dale Creek | 40.89759, -105.376 |
| | 270NBH | North Fork below Halligan Reservoir | 40.87763, -105.3386 |
| | 240SCM | Stonewall Creek Mouth | 40.80754, -105.2535 |
| | 260NRC | North Fork above Rabbit Creek | 40.8092, -105.2685 |
| | 250RCM | Rabbit Creek Mouth | 40.81023, -105.2857 |
| | 230PCM | Lone Pine Creek Mouth | 40.79478, -105.2873 |
| | 220NFL | North Fork at Livermore | 40.78773, -105.2525 |
| | 200NFG | North Fork below Seaman Reservoir | 40.70222, -105.234 |

# ATTACHMENT 2

## 2021 UPPER CLP MONITORING PARAMETER LIST

| | | |
|---|---|---|
| **Field Parameters** | | |
| Specific Conductance | Indicator of total dissolved solids. | All sites with water quality sonde. |
| Dissolved Oxygen | Profile indicates stratification, importance for aquatic life and chemical processes. | All sites with water quality sonde. |
| Temperature | Reflects seasonality; affects biological and chemical processes; water quality standard. | All sites with water quality sonde. |
| pH | Measure of acidity. | All sites with water quality sonde. |
| **General & Miscellaneous Parameters** | | |
| Alkalinity | Indicator of carbonate species concentrations; Acid neutralizing capacity of water; treatment implications. | |
| Discharge | Necessary for flow dependent analysis and load estimation. | Measured during sampling at NRC, RCM, SCM, PCM, PJW, SFM when conditions allow |
| Geosmin | Taste and odor compound | Measured monthly at PBR and PNF |
| Hardness | Treatment implications. Hard water causes scaling and soft water is considered corrosive. | |
| Total Dissolved Solids (TDS) | Indicator of overall water quality; includes both ionic and non-ionic species. | |
| Total Organic Carbon (TOC) | Important parameter for water treatment; precursor of disinfection byproducts. | |
| Turbidity | Indicator of suspended material; important for water treatment. | |
| **Nutrients** | | |
| Nitrogen, Ammonia | Primary source of nitrogen to algae, indicator of pollution by sewage, septic tanks, agriculture and atmospheric deposition; water quality standard. | |
| Nitrate | Primary source of nitrogen to algae; indicator of pollution by sewage, septic tanks, agriculture, and atmospheric deposition; water quality standard. | |
| Nitrite | Toxic inorganic nitrogen species; rarely encountered at significant concentrations; water quality standard. | |
| Total Kjeldahl Nitrogen | Sum of organic nitrogen and ammonia. | |
| Orthophosphate (Soluble Reactive Phosphorus) | Form of phosphorous (dissolved $PO_4^{-3}$) most available to algae; indicator of pollution by sewage, septic tanks, agriculture and atmospheric deposition. | |
| Total Phosphorus | Includes dissolved and adsorbed, organic and inorganic forms of phosphorus, indicator of pollution by sewage, septic tanks, agriculture and atmospheric deposition. | |

| | | |
|---|---|---|
| **Major Ions** | | |
| Calcium | Major ion. | 6x/yr |
| Chloride | Major ion. | 6x/yr |
| Magnesium | Major ion. | 6x/yr |
| Potassium | Major ion, minor importance as a nutrient. | 6x/yr |
| Sodium | Major ion. | 6x/yr |
| Sulfate | Major ion. | 6x/yr |
| **Biological Constituents** | | |
| *E. Coli* | Indicator of human or animal waste contamination; water quality standard. | Only from Rustic downstream, and NFG |
| Total Coliform | Indicator of human or animal waste contamination. | Only from Rustic downstream, and NFG |
| Macroinvertebrates | Community species metrics can be used to indicate pollution and overall watershed health. | PJW, PBR, PSF, PNF, PBD |
| **Metals** | | |
| Aluminum, total & dissolved | Natural occurs in rocks and soil. Indicator of pollution from mining activity at elevated levels; Aesthetic effects to drinking water | Only PNF & NFG |
| Arsenic, total & dissolved | Natural occurs in rocks and soil. Indicator of pollution from mining activity at elevated levels; water quality standard. | Only PNF & NFG |
| Cadmium, total & dissolved | Natural occurs in rocks and soil. Indicator of pollution from mining activity at elevated levels; water quality standard. | Only PNF & NFG |
| Chromium, dissolved | Natural occurs in rocks and soil. Water quality standard. | Only PNF & NFG |
| Copper, dissolved | Natural occurs in rocks and soil. Water quality standard. | Only PNF & NFG |
| Iron, total & dissolved | Natural occurs in rocks and soil. Affects aesthetic quality of treated water. | Only PNF & NFG |
| Lead, total & dissolved | Natural occurs in rocks and soil. Indicator of pollution from mining activity at elevated levels; water quality standard. | Only PNF & NFG |
| Manganese, total & dissolved | Natural occurs in rocks and soil. Aesthetic effects to drinking water; water quality standard | Only PNF & NFG |
| Nickel, dissolved | Natural occurs in rocks and soil. Indicator of pollution from mining activity at elevated levels; water quality standard. | Only PNF & NFG |
| Silver, dissolved | Natural occurs in rocks and soil. Indicator of pollution from mining activity at elevated levels. | Only PNF & NFG |
| Zinc, total & dissolved | Natural occurs in rocks and soil. Indicator of pollution from mining activity at elevated levels. | Only PNF & NFG |

# ATTACHMENT 3

## ANALYTICAL METHODS, REPORTING LIMITS, SAMPLE PRESERVATION, AND HOLDING TIMES

| | Parameter | Method | Reporting Limit | Preser-vation | Holding Time |
|---|---|---|---|---|---|
| Micro-biological | Total Coliform, *E.coli* - QT | SM 9223 B | 0 | cool, 4C | 6 hrs |
| | *Giardia & Cryptosporidium* (CH Diagnostics) | EPA 1623 | 0 | cool, 4C | 4 days |
| | Algae I.D. (Phyto Finders) | SM 10200E.3, SM 10200F.2c1 | | Lugol's Solution, cool, 4C | 12 mo |
| General & Misc. | Alkalinity, as $CaCO_3$ | SM 2320 B | 2 mg/L | cool, 4C | 14 days |
| | Chlorophyll a | SM10200H modified | 0.6 ug/L | cool, 4C | 48 hrs |
| | Hardness, as $CaCO_3$ | SM 2340 C | 2 mg/L | none | 28 days |
| | Specific Conductance | SM 2510 B | | cool, 4C | 28 days |
| | Total Dissolved Solids | SM 2540 C | 10 mg/L | cool, 4C | 7 days |
| | Turbidity (NTU) | SM2130B,EPA180.1 | 0.01 units | cool, 4C | 48 hrs |
| Nutrients | Ammonia - N | Lachat 10-107-06-2C | 0.01 mg/L | $H_2SO_4$ | 28 days |
| | Nitrate | EPA 300 (IC) | 0.04 mg/L | cool, 4C (eda) | 48 hrs |
| | Nitrite | EPA 300 (IC) | 0.04 mg/L | cool, 4C (eda) | 48 hrs |
| | Total Kjeldahl Nitrogen | EPA 351.2 | 0.1 mg/L | $H_2SO_4$ pH<2 | 28 days |
| | Phosphorus, Total | SM 4500-P B5,F | 0.01 mg/L | $H_2SO_4$ pH<2 | 28 days |
| | Phosphorus, Ortho | SM 4500-P B1,F | 0.005 mg/L | filter, cool 4C | 48 hrs |
| Major Ions | Calcium | EPA 200.8 | 0.05 mg/L | $HNO_3$ pH <2 | 6 mos |
| | Chloride | EPA 300 (IC) | 1.0 mg/L | none (eda) | 28 days |
| | Magnesium, flame | EPA 200.8 | 0.2 mg/L | $HNO_3$ pH <2 | 6 mos |
| | Potassium | EPA 200.8 | 0.2 mg/L | $HNO_3$ pH <2 | 6 mos |
| | Sodium, flame | EPA 200.8 | 0.4 mg/L | $HNO_3$ pH <2 | 6 mos |
| | Sulfate | EPA 300 (IC) | 5.0 mg/L | cool, 4C (eda) | 28 days |
| Metals | Cadmium | EPA 200.8 | 0.1 ug/L | $HNO_3$ pH <2 | 6 mos |
| | Chromium | EPA 200.8 | 0.5 ug/L | $HNO_3$ pH <2 | 6 mos |
| | Copper | EPA 200.8 | 3 ug/L | $HNO_3$ pH <2 | 6 mos |
| | Iron, (total & dissolved) | EPA 200.8 | 10 ug/L | $HNO_3$ pH <2 | 6 mos |
| | Lead | EPA 200.8 | 1 ug/L | $HNO_3$ pH <2 | 6 mos |
| | Nickel | EPA 200.8 | 2 ug/L | $HNO_3$ pH <2 | 6 mos |
| | Silver | EPA 200.8 | 0.5 ug/L | $HNO_3$ pH <2 | 6 mos |
| | Zinc | EPA 200.8 | 50 ug/L | $HNO_3$ pH <2 | 6 mos |
| TOC | TOC | SM 5310 C | 0.5 mg/L | $H_3PO_4$pH <2 | 28 days |
| Analysis conducted by City of Fort Collins Water Quality Lab (FCWQL), unless otherwise noted. | | | | | |
| Reporting Limit = lowest reportable number based on the lowest calibration standard routinely used. | | | | | |

# ATTACHMENT 4

## UPPER CLP COLLABORATIVE WATER QUALITY MONITORING PROGRAM 2021 SAMPLING PLAN

| 2021 Upper Cache la Poudre Water Quality Monitoring Program | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mainstem Cache la Poudre River** | | | | | | | | | | | |
| | **Apr 11** | **Apr 25** | **May 9** | **May 23** | **Jun 13** | **Jun 27** | **Jul 11** | **Aug 8** | **Sep 12** | **Oct 10** | **Nov 7** |
| **CHD** | F,GM,N | F,GM,I,N | F,GM,I,N | F,GM,I,N | F,GM,I,N | F,GM,I,N | F,GM,N | F,G,GM,I,N | F,G,GM,N | F,G,GM,I,N | F,G,GM,I,N |
| **BMD**[1] | F,GM,N | F,GM,I,N | F,GM,I,N | F,GM,I,N | F,GM,I,N | F,GM,I,N | F,GM,N | F,GM,I,N | F,GM,N | F,GM,I,N | F,GM,I,N |
| **JWC** | F,GM,N | F,GM,I,N | F,GM,I,N | F,GM,I,N | F,GM,I,N | F,GM,I,N | F,GM,N | F,GM,I,N | F,GM,N | F,GM,I,N | F,GM,I,N |
| **PJW** | F,GM,N | F,GM,I,N | F,GM,I,N | F,GM,I,N | F,GM,I,N | F,GM,I,N | F,GM,N | F,G,GM,I,N | F,G,GM,Mc,N | F,G,GM,I,N | F,G,GM,I,N |
| **LRT** | F,GM,N | F,GM,I,N | F,GM,I,N | F,GM,I,N | F,GM,I,N | F,GM,I,N | F,GM,N | F,GM,I,N | F,GM,N | F,GM,I,N | F,GM,I,N |
| **PBR** | E,F,G,GM,N | E,F,GM,I,N | E,F,G,GM,I,N | E,F,GM,I,N | E,F,G,GM,I,N | E,F,GM,I,N | E,F,G,GM,N | E,F,G,GM,I,N | E,F,G,GM, Mc,N | E,F,G,GM,IN | E,F,G, GM,I,N |
| **SFM** | D,F,GM,N | D,F,GM,I,N | D,F,GM,I,N | D,F,GM,I,N | D,F,GM,I,N | D,F,GM,I,N | D,F,GM,N | D,F,G,GM, I,N | D,F,G, GM,N | D,F,G,GM, I,N | D,F,G,GM, I,N |
| **PSF** | E,F,GM,N | E,F,GM,I,N | E,F,GM,I,N | E,F,GM, I,N | E,F,GM,I,N | E,F,GM, I,N | E,F,GM,N | E,F,GM, I,N | E,F,GM, Mc,N | E,F,GM, I,N | E,F,GM, I,N |
| **PNF**[2,3] | E,F,G,GM, M,N | E,F,GM,I, M,N | E,F,G,GM,I, M,N | E,F,GM,I, M,N | E,F,G,GM,I M,N | E,F,GM,I, M,N | E,F,G,GM, M,N | E,F,G,GM,I, M,N | E,F,G,GM,Mc, M,N | E,F,G,GM,I, M,N | E,F,G,GM,I, M,N |
| **PBD** | E,F,GM, M,N | E,F,GM,I, M,N | E,F,GM,I, M,N | E,F,GM,I, M,N | E,F,GM,I M,N | E,F,GM,I, M,N | E,F,GM, M,N | E,F,GM,I, M,N | E,F,GM,Mc, M,N | E,F,GM,I, M,N | E,F,GM,I, M,N |
| **North Fork Cache la Poudre River** | | | | | | | | | | | |
| | **Apr 12** | **Apr 26** | **May 10** | **May 24** | **Jun 14** | **Jun 28** | **Jul 12** | **Aug 9** | **Sep 13** | **Oct 11** | **Nov 8** |
| **NDC** | F,GM,M,N | F,GM,I,M,N | F,GM,M,N | F,GM,I,M,N | F,GM,M,N | F,GM,I,M,N | F,GM,M,N | F,GM,I,M,N | F,GM,M,N | F,GM,I,M,N | F,GM,I,M,N |
| **NBH** | F,GM,M,N | F,GM,I,M,N | F,GM,M,N | F,GM,I,M,N | F,GM,M,N | F,GM,I,M,N | F,GM,M,N | F,GM,I,M,N | F,GM,M,N | F,GM,I,M,N | F,GM,I,M,N |
| **NRC** | D,F,GM, M,N | D,F,GM,I, M,N | D,F,GM, M,N | D,F,GM,I, M,N | D,F,GM, M,N | D,F,GM,I, M,N | D,F,GM, M,N | D,F,GM,I, M,N | D,F,GM, M,N | D,F,GM,I, M,N | D,F,GM,I, M,N |
| **RCM** | D,F,GM, M,N | D,F,GM,I, M,N | D,F,GM, M,N | D,F,GM,I, M,N | D,F,GM, M,N | D,F,GM,I, M,N | | | | | |
| **SCM** | D,F,GM, M,N | D,F,GM,I, M,N | D,F,GM, M,N | D,F,GM,I, M,N | D,F,GM, M,N | D,F,GM,I, M,N | | | | | |
| **PCM** | D,F,GM, M,N | D,F,GM,I, M,N | D,F,GM, M,N | D,F,GM,I, M,N | D,F,GM, M,N | D,F,GM,I, M,N | | | | | |
| **NFL** | F,GM,M,N | F,GM,I,M,N | F,GM,M,N | F,GM,I,M,N | F,GM,M,N | F,GM,I,M,N | F,GM,M,N | F,GM,I,M,N | F,GM,M,N | F,GM,I,M,N | F,GM,I,M,N |
| **NFG**[2] | E,F,GM, M,N | E,F,GM,I, M,N | E,F,GM, M,N | E,F,GM,I, M,N | E,F,GM, M,N | E,F,GM,I, M,N | E,F,GM, M,N | E,F,GM,I, M,N | E,F,GM, M,N | E,F,GM,I, M,N | E,F,GM,I, M,N |

[1]Call River Commissioner to determine whether water is flowing.
[2] Field blanks and duplicates (denoted with red text in table) will be collected for the following parameters: *E. coli*; general and miscellaneous; major ions; metals; nutrients and TOC; and geosmin/MIB

D = discharge
E = *E. coli* and total coliform
F = field data (dissolved oxygen, pH, temperature and turbidity)
G = geosmin/MIB
GC = *Giardia/Cryptosporidium*
GM = general and miscellaneous (alkalinity, hardness as $CaCO_3$ and total dissolved solids)
I = major ions (sulfate, chloride, calcium, potassium, sodium, magnesium)
M = metals (aluminum, arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver and zinc
N = nutrients (ammonia-N, nitrate-N, nitrite-N, Total Kjeldahl Nitrogen, Total Phosphorus and ortho phosphorus) and TOC