CHERRY CREEK BASIN WATER QUALITY AUTHORITY MONITORING REPORT

WATER YEAR 2023

SUBMITTED TO:
Cherry Creek Basin Water Quality Authority
PO Box 3166
Centennial, CO 80161

PREPARED BY:
LRE Water
1221 Auraria Parkway
Denver, CO 80224

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ACRONYMS/ABBREVIATIONS

Acronym	Definition
AF	Acre-feet
AOAC	Association of Official Analytical Chemists, now AOAC INTERNATIONAL
ASTM	American Society for Testing and Materials
Authority	Cherry Creek Basin Water Quality Authority
BMPs	Best Management Practices
CCBWQA	Cherry Creek Basin Water Quality Authority
CCR	Code of Colorado Regulations
CCSP	Cherry Creek State Park
CDPHE	Colorado Department of Public Health and Environment
Cells/mL	Cells per milliliter (phytoplankton)
CPW	Colorado Parks and Wildlife
CFR	Code of Federal Regulations
cfs	Cubic feet per second
chl α	Chlorophyll α
CM	Control Measures
CR72	Cherry Creek Reservoir Control Regulation 72
DM	Daily Maximum (for Temperature)
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
EPA	U. S. Environmental Protection Agency
IEH	IEH Laboratories
M	Meters
mg/L	Milligrams per liter
mV	Millivolts
µg/L	Micrograms per liter
Mi	Mile
µm	Micrometers
μm^3/mL	Cubic micrometers per milliliter
µS/cm	Microsiemens per centimeter
MS4	Municipal Separate Storm Sewer System
MWAT	Maximum Weekly Average Temperature
N	Nitrogen
N:P	Nitrogen to Phosphorus Ratio
NOAA	National Ocean and Atmospheric Administration

Acronym	Definition
ND	Non-detect
NH_3-N	Ammonia Nitrogen
NO_3+NO_2-N	Nitrate plus Nitrite Nitrogen
#/L	Number of animals per liter (zooplankton)
ORP	Oxidation Reduction Potential
%	Percent
POR	Period of record
PRF	Pollutant Reduction Facility
PRISM	Parameter-elevation Regression on Independent Slopes Model
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
Reg 31	WQCC Regulation No. 31
Reg 38	WQCC Regulation No. 38
SAP	Sampling and Analysis Plan
Reservoir	Cherry Creek Reservoir
SM	Standard Methods
SRP	Soluble Reactive Phosphorus
TDN	Total Dissolved Nitrogen
TOC	Total Organic Carbon
TN	Total Nitrogen
TDP	Total Dissolved Phosphorus
TP	Total Phosphorus
TSI	Trophic State Index
TSS	Total Suspended Solids
TVSS	Total Volatile Suspended Solids
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
VSS	Volatile Suspended Solids
WY	Water Year
WQCC	Water Quality Control Commission
WWTP	Wastewater Treatment Plant

EXECUTIVE SUMMARY

The Cherry Creek Basin Water Quality Monitoring Report – Water Year 2023 provides a comprehensive description of monitoring completed for the Cherry Creek Basin Water Quality Authority (CCBWQA) of Cherry Creek Reservoir (Reservoir) and watershed for the 2023 Water Year (WY 2023) between October 1, 2022 and September 30, 2023. The Reservoir and watershed monitoring programs are completed in accordance with the Cherry Creek Sampling and Analysis Plan (SAP), Quality Assurance Project Plan (QAPP), and regulatory requirements. The data were collected to evaluate how successful the requirements specified in Cherry Creek Reservoir Control Regulation 72 (CR 72) are at achieving the chlorophyll-α (chl α) water quality standard and the water quality standards for associated parameters as outlined in Water Quality Control Commission (WQCC) Regulation No. 31 (Reg 31) and Regulation No. 38 (Reg 38), as directed by the CCBWQA's Statute. The program includes regular monitoring of biological, physical, and chemical conditions of the Reservoir, the streams and tributaries that feed the Reservoir, and precipitation and groundwater in the basin. Highlights of the findings from the monitoring completed during WY 2023 in relation to water quality standards, beneficial uses, and other notable details are outlined in the Executive Summary below. All CCBWQA data can be accessed at the CCBWQA's data portal at https://www.ccbwqportal.org/.

Please note that some data and measurements normally collected under the monitoring program are not available for WY 2023 due to factors outside of the CCBWQA's control including damage to monitoring equipment and lost data due to excessive precipitation and associated flooding. Alternative calculations using the relative inflows of Cherry Creek and Cottonwood Creek and storage information from the USACE will be provided with the amended report later in 2024 to update pollutant load-related information.

STANDARDS

Regulation 38 (Reg 38) assigns water quality standards for Cherry Creek Reservoir to protect aquatic life and other beneficial uses. Cherry Creek Reservoir did not meet the chl α standard of 18 µg/L established in Reg 38 in WY 2023 (Figure ES-1), although concentrations were lower than the three prior years, despite much higher phosphorus loading associated with major flood events. Cherry Creek Reservoir met the standards for temperature, pH, and dissolved oxygen (DO), which are protective of the Class 1 Warm Water Aquatic Life use.

Figure ES-1. Seasonal Chl α concentrations in Cherry Creek Reservoir

RESERVOIR HIGHLIGHTS

The water quality in Cherry Creek Reservoir during WY 2023 was atypical due to the well-above-average precipitation in the spring and flooding that occurred on both Cherry Creek and Cottonwood Creek. Following the multi-day storm during May 11th and 12th, the Reservoir elevation increased by almost 10 feet and remained above normal operating elevation for the remainder of the season. The benefit of the increased inflow and precipitation were that the cooler water and increased water exchange through the Reservoir kept the algal blooms at bay in the early summer. However, in July, as soon as the precipitation tapered to more average levels and the temperatures warmed, the high nutrient concentrations present from the storm nutrient loads contributed to increased algal growth, chl-a concentrations, and cyanobacteria blooms.

Although the Reservoir met the DO standard, low DO concentrations were present at and near the bottom of the Reservoir during the warm summer months, increasing the potential for internal loading of phosphorus from the sediments due to anoxic conditions.

The seasonal phosphorus concentrations exceeded the interim nutrient criteria adopted by the WQCC in 2012 as well as the phosphorus standard that will be adopted statewide in lakes and reservoirs unless site-specific standards are adopted by 2027 (Figure ES-2). Although the seasonal nitrogen in the Reservoir was below the 2012 nutrient criteria, it exceeded the nitrogen standard that could be adopted in 2027.[1]

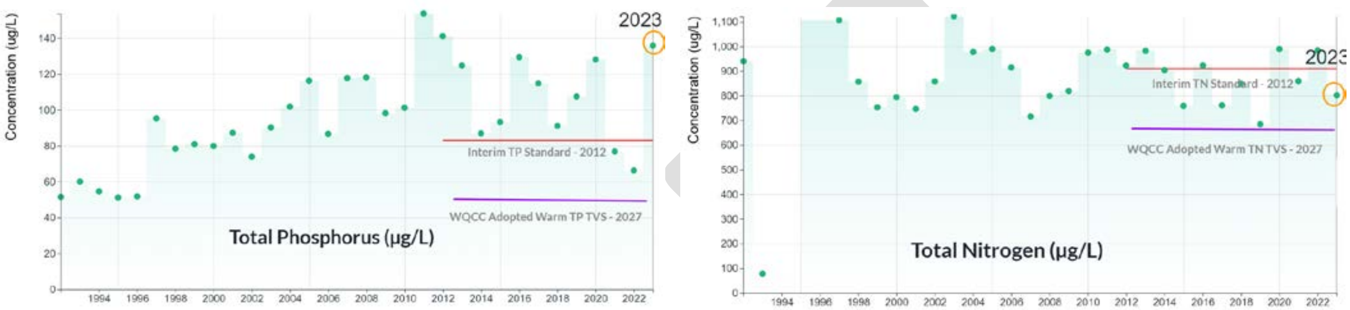

Figure ES-2. Seasonal Phosphorus and Nitrogen Concentrations in Cherry Creek Reservoir

The Trophic State Index (TSI) is a relative expression of the biological productivity of a lake using total phosphorus (TP), chl α, and transparency. The WY 2023 TSI for Cherry Creek Reservoir indicates that Cherry Creek Reservoir continues to be classified as eutrophic based on water transparency and chl α concentrations and hypereutrophic based on TP concentrations (Figure ES-3). Eutrophic and hypereutrophic conditions indicate elevated nutrient concentrations and often excessive productivity with increased probabilities of encountering nuisance algal blooms. Although there has been some fluctuation of the historical trophic state, Cherry Creek Reservoir has remained in the eutrophic to hypereutrophic range for the last 20+ years.

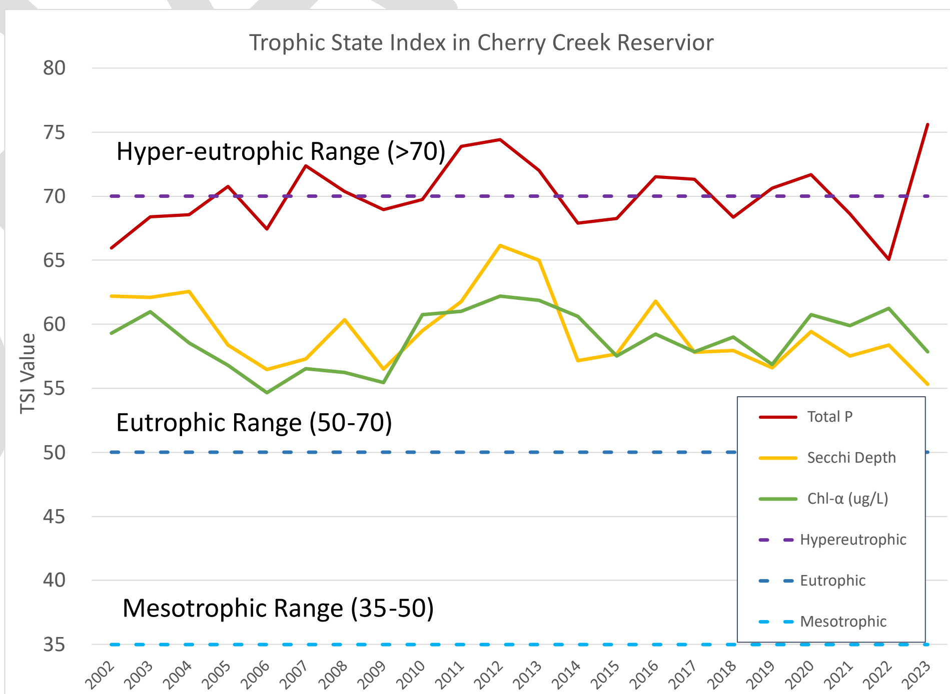

Figure ES-3. Trophic State in Cherry Creek Reservoir

In mid-July, a cyanobacteria bloom prompted Colorado Parks and Wildlife to post “Caution” signs to inform the public of the potential recreational risk. Ongoing monitoring detected toxin concentrations above the recreational threshold and a closure was implemented on July 28th in

[1] CCBWQA plans to propose site-specific standards for the Reservoir that differ from the statewide standards.

the area of the bloom and "Danger" signs were posted. Less than a week later, toxin levels had decreased to below the recreational threshold and the closure was lifted on Aug 4th and by mid-August the bloom had dissipated.

WATERSHED HIGHLIGHTS

The spring of WY 2023 received much higher-than-average precipitation that caused major flooding and damage along Cherry Creek and Cottonwood Creek. Multiple monitoring stations, equipment, and other infrastructure were damaged and required repair. The extended elevated water levels and equipment damage also impacted stream flow calculations.

The watershed received approximately 172% of the historical average precipitation in WY 2023, with 15-16" in May and June accounting for over 60% of the entire year.

In WY 2023, the Cherry Creek State Park (CCSP) meteorological station measured a total of 22.3 inches of precipitation. NOAA's Centennial Airport weather station KAPA site measured 25.6 inches, which is 172% of the historical average.

The WY 2023 median TP concentrations were higher in storm flows (💧) than baseflows, as usual (Figure ES-4; See Figure 2 for monitoring locations). Median TP instream concentrations were lower than the long-term baseline median at Cottonwood and Piney Creek sites under both baseflow and storm flow conditions and at Cherry Creek under baseflow conditions. For sites on Cherry Creek, WY 2023 TP concentrations were higher than the historic baseline median during storm conditions, likely due to significant erosion on Cherry Creek during major storm events.

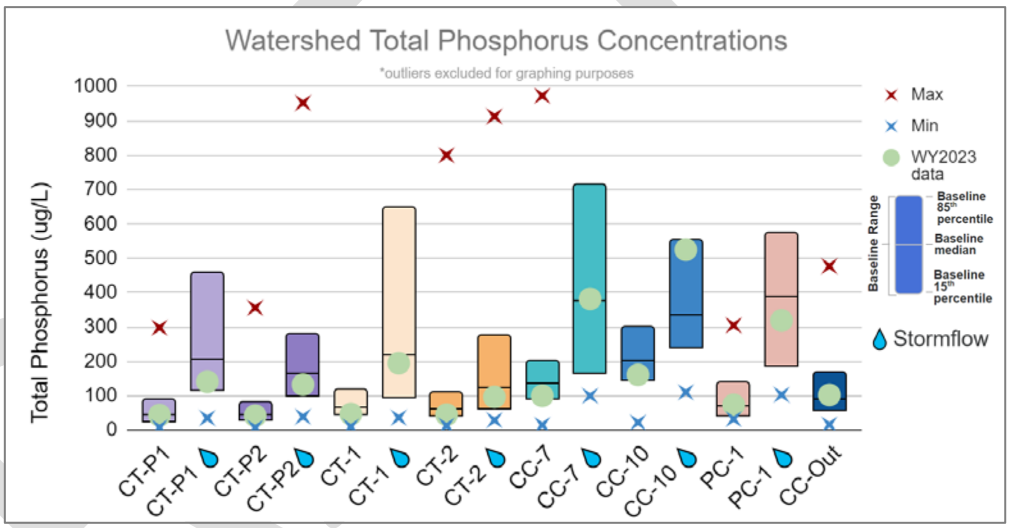

Figure ES-4. Cherry Creek Watershed Phosphorus Concentrations
(CT = Cottonwood Creek; CC = Cherry Creek ad PC = Piney Creek)

In contrast to TP, higher total nitrogen (TN) concentrations were not consistently observed during storm events (Figure ES-5). The WY 2023 median TN concentrations were higher than the baseline median at three sites on

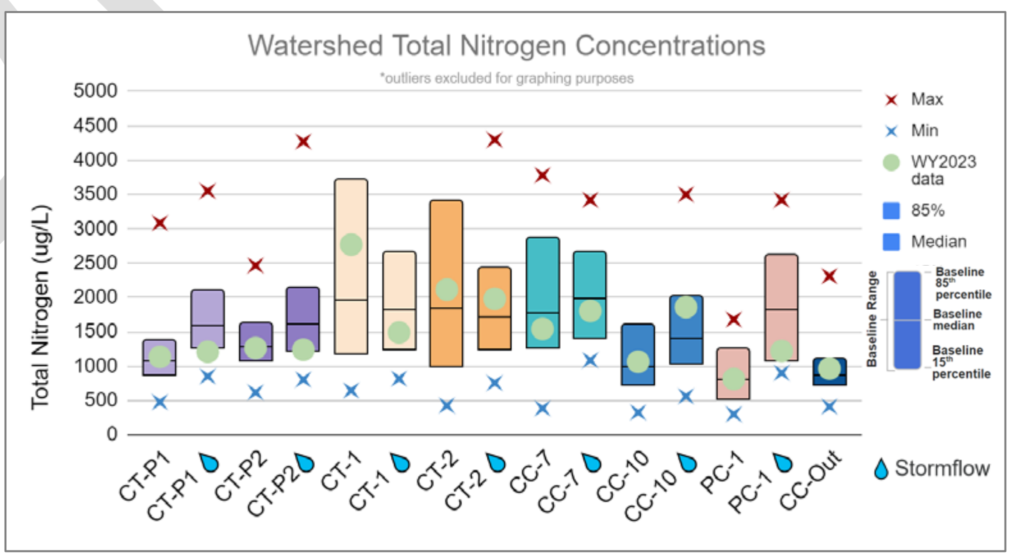

Figure ES-5. Cherry Creek Watershed Nitrogen Concentrations
(CT = Cottonwood Creek; CC = Cherry Creek ad PC = Piney Creek)

Cottonwood Creek (CT-P1, CT-1, and CT-2) during baseflows and during storm events at CT-2. The WY 2023 median TN on Cherry Creek at CC-10 and the outlet to the Reservoir (CC-0) were also higher than the baseline median during baseflow conditions.

POLLUTION REDUCTION FACILITIES (PRF) HIGHLIGHTS

The Pollution Reduction Facilities (PRFs) in the watershed are monitored on an ongoing basis to determine the effectiveness of water quality benefits upstream to downstream annually and over time.

Based on the water quality concentrations in baseflow and stormflow events during WY 2023 and the last 10 years, the Cottonwood Creek PRF ponds and treatment train as a whole reduced phosphorus and suspended sediment concentrations in downstream stormflows. During WY 2023, the Cottonwood Treatment Train showed statistically significant removal of TP, TSS and VSS upstream to downstream during storm flows which is also true when evaluating the trend over the last 10 years. Both forms of suspended solids were also significantly lower in baseflow during WY 2023 through the whole treatment train. Peoria Pond and the Perimeter Pond both showed significant removal of TP and TSS upstream to downstream during stormflow conditions over the same period. The Perimeter Pond PRF also demonstrated significant reductions in TP and TSS concentrations in base flow conditions. The McMurdo Gulch upstream to downstream concentration analysis also demonstrated a statistically significant reduction of all nutrients in WY 2023.

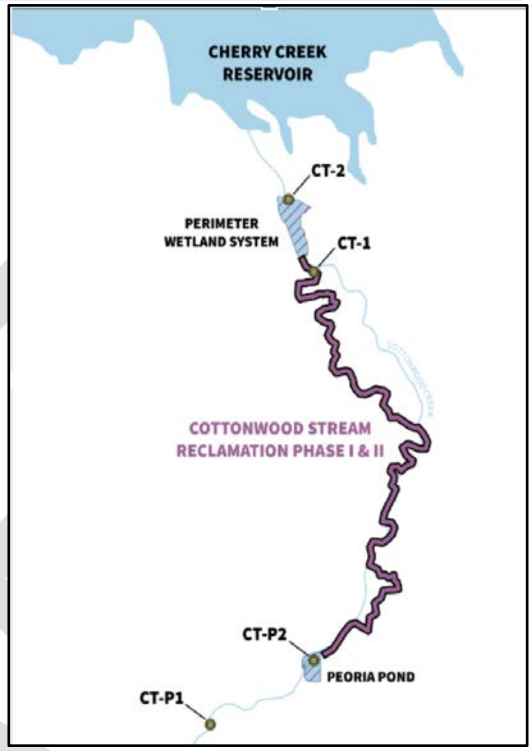

Figure ES-6. Cottonwood Creek Pollution Reduction Facilities (PRFs)

Table ES-1. Summary of Reductions in Nutrient and Suspended Solids in CCBWQA PRFs, WY 2023.

PRF	Cottonwood Treatment Train		Peoria Pond		Perimeter Pond		Cottonwood Creek btw Ponds		McMurdo Gulch
Analyte	Base	Storm	Base	Storm	Base	Storm	Base	Storm	Base
Nitrate+ Nitrite					●				●
Ammonia									●
Nitrogen, Total					●				○
Phosphorus, Soluble Reactive									●
Phosphorus, Dissolved			☐						●
Phosphorus, Total		●	☐	●	●	●			●
Total Suspended Solids	○	●		●	●	●			
Volatile Suspended Solids	●	●		☐	☐	●			

**Legend: ○ significant reduction of upstream to downstream medians in WY 2023, ☐ significant reductions of upstream to downstream medians (2014-2023), ● significant reduction of upstream to downstream medians in WY 2023 and 2014-2023, blank cells indicate no significant reduction or an increase upstream to downstream.*

GROUNDWATER HIGHLIGHTS

The groundwater and alluvium of Cherry Creek also play a role in nutrient dynamics as water moves down the watershed and flows into the Reservoir.

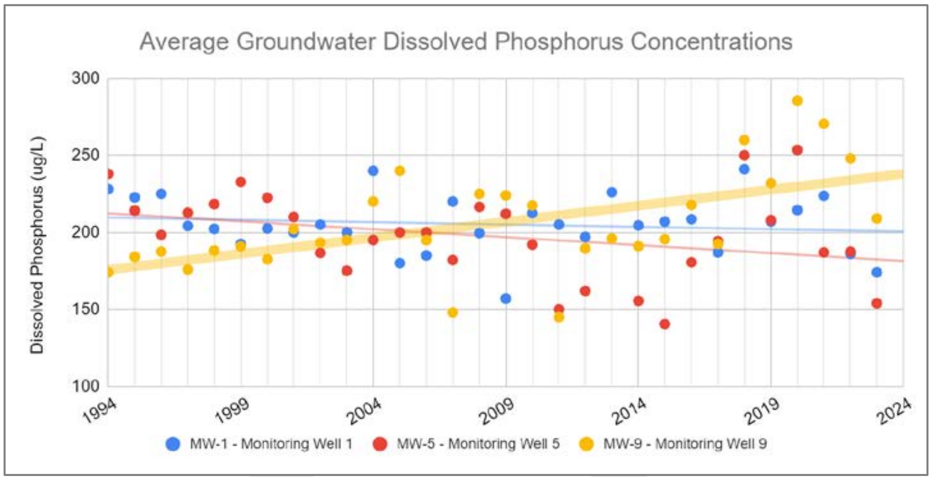

Figure ES-7. Groundwater Dissolved Phosphorus

Total dissolved phosphorus (TDP) and soluble reactive phosphorus (SRP) are used for long-term evaluation of groundwater phosphorus since they are the representative forms found in groundwater and a longer period of record is available for these forms. A Mann-Kendall statistical trend analysis demonstrated that TDP and SRP in the groundwater at MW-9 upstream of the Reservoir are significantly increasing over time, although there is not a similar statistically significant trend at the upstream monitoring well sites (MW-1 and MW-5) (Figure ES-7). Conductivity in the groundwater has a statistically significant increasing trend from upstream (MW-1) to downstream towards the Reservoir (MW-9).

WATER BALANCE HIGHLIGHTS

Due to circumstances beyond the control of the CCBWQA, including equipment damage due to significant flooding, some of the inflow data required for the calculations for the annual water balance are not available. To fill this data gap, the relative inflow discharge ratio of Cherry Creek to Cottonwood Creek from 2016-2022, along with the inflow, outflow and reservoir storage provided by the USACE will be used to estimate a water balance for WY 2023. However, as of the end of 2023, the storage information provided by the USACE is not available due to a discrepancy in the elevation datum shift. USACE plans to address this discrepancy by the end of January 2024, at which time the storage information will be provided, the required calculations can be completed, and an amended Monitoring Report will be issued.

NUTRIENT BALANCE HIGHLIGHTS

The nutrient concentrations of the inflows and the outflow of Cherry Creek Reservoir are used to calculate the mass storage on an annual basis. The flow-weighted influent phosphorus goal, derived as part of the 2009 Reg 38 rulemaking process to achieve the 18 µg/L chl α standard, is 200 µg/L. Flow-weighted nutrient concentrations and mass storage in the Reservoir for WY 2023 will be provided after the water balance has been completed.

WY 2023 CONCLUSIONS

The CCBWQA's comprehensive monitoring program and WY 2023 data provide insight into current conditions and long-term trends in the watershed and Cherry Creek Reservoir. Although Cherry Creek Reservoir did not meet the chl α seasonal standard for WY 2023, it did meet the Reg 38 standards for temperature, pH, and DO to support the Class 1 Warm Water Aquatic Life classification. Cherry Creek Reservoir's trophic state continues to remain eutrophic to hypereutrophic with elevated phosphorus concentrations, reduced water transparency, and algal growth. A cyanobacteria bloom in WY 2023 resulted in a brief closure to recreational users of the Reservoir due to the presence of toxins.

The WY 2023 weather conditions resulted in above-average stream inflows, higher water levels, and shorter residence time in Cherry Creek Reservoir which would normally be beneficial to water quality. However, the high phosphorus concentrations that entered the Reservoir during the flood events increased the potential for algal growth, cyanobacteria blooms, and high chl α concentrations during the summer months.

There are notable differences in water quality between Cherry Creek, Cottonwood Creek, and Piney Creek. Cherry Creek has much higher concentrations of phosphorus, whereas Cottonwood Creek has relatively higher concentrations of nitrogen. Although median watershed TP concentrations in WY 2023 were lower than baseline medians at most sites, the WY 2023 TP concentrations on Cherry Creek just upstream of the Reservoir were well above baseline medians. Since Cherry Creek contributes approximately 75 percent of the annual stream inflows to the Reservoir, water quality in the Reservoir is usually most impacted by Cherry Creek, with CC-10 reflecting TP concentrations entering the Reservoir.

Conductivity in the streams and groundwater is significantly increasing over time, which impacts the Reservoir water quality and dynamics. Although the sources of the increased conductivity have not been identified, potential sources could be deicing chemicals and other discharges.

In WY 2023, the constructed wetland PRF ponds on Cottonwood Creek functioned effectively to remove phosphorus and suspended solids during stormflow conditions. In addition, the PRF ponds on Cottonwood Creek have been functioning effectively when evaluating upstream to downstream concentrations on a long-term basis.

The above average spring precipitation in the Cherry Creek watershed caused flooding along Cherry Creek and Cottonwood Creek that damaged multiple monitoring stations and impacted data collection and stream flow calculations. Due to these factors and the associated data gaps, alternative calculations will be used in the water balance, nutrient balance and mass storage once data is available. These results will be provided in an amended report in 2024.

1.0 INTRODUCTION

The mission and vision of the Cherry Creek Basin Water Quality Authority (CCBWQA) are to benefit the public by improving, protecting, and preserving water quality in Cherry Creek and Cherry Creek Reservoir (Reservoir) for recreation, fisheries, and other warm water aquatic life, water supplies, and agriculture to achieve and maintain current water quality standards. The CCBWQA also supports effective efforts by partner counties, municipalities, special districts, and landowners within the basin providing for the protection of water quality, ensuring that new developments and construction activities pay their equitable share of costs for water quality preservation and facilities, and promoting public health, safety, and welfare.

The CCBWQA was formally created by statute in 1988 by the Colorado State Legislature. The CCBWQA Board consists of representatives from two counties and eight cities, along with one representative from each of the seven special districts that provide water and wastewater treatment in the basin, and seven public representatives appointed by the Governor.

The Cherry Creek Basin watershed includes over 386 square miles and 600 miles of creeks and streams (Figure 1). The U.S. Army Corps of Engineers (USACE) states that Cherry Creek Reservoir has a maximum surface area of 850 surface acres at an operating pool of 5550 ft elevation. The Reservoir is located near the base of the watershed, south of I-225 and west of Parker Rd., in Cherry Creek State Park (CCSP or the Park). The Park covers approximately 4,000 acres and is one of the most productive fisheries and widely enjoyed recreational areas in Colorado. The Park has miles of trails to view birds and wildlife with scenic views of the Rocky Mountains in the background.

USACE constructed the Reservoir between 1948 and 1950 for flood control. In 1951, the State Park Board leased Cherry Creek recreation area from the USACE and created Colorado's first state park, which was opened in 1959. In addition to providing flood control, the Reservoir is a recreational and aquatic life amenity, and water released from the Reservoir supports downstream agriculture and water supply uses.

The Water Quality Control Commission (WQCC) adopted use classifications and water quality standards for the Reservoir and watershed, most recently effective August 30, 2023. These numeric standards, as specified in Regulation No. 38 (5 CCR 1002-38) (Reg 38), include the mainstem of Cherry Creek to the inlet of the Reservoir and from the outlet to the confluence with the South Platte River, Cherry Creek Reservoir, Cottonwood Creek, and other tributaries, lakes, and reservoirs within the watershed. These standards are set to protect recreation, aquatic life, agriculture, and water supply uses. The CCBWQA focuses on improving, protecting, and preserving the water quality of Cherry Creek and Cherry Creek Reservoir, and on achieving and maintaining the existing water quality standards.

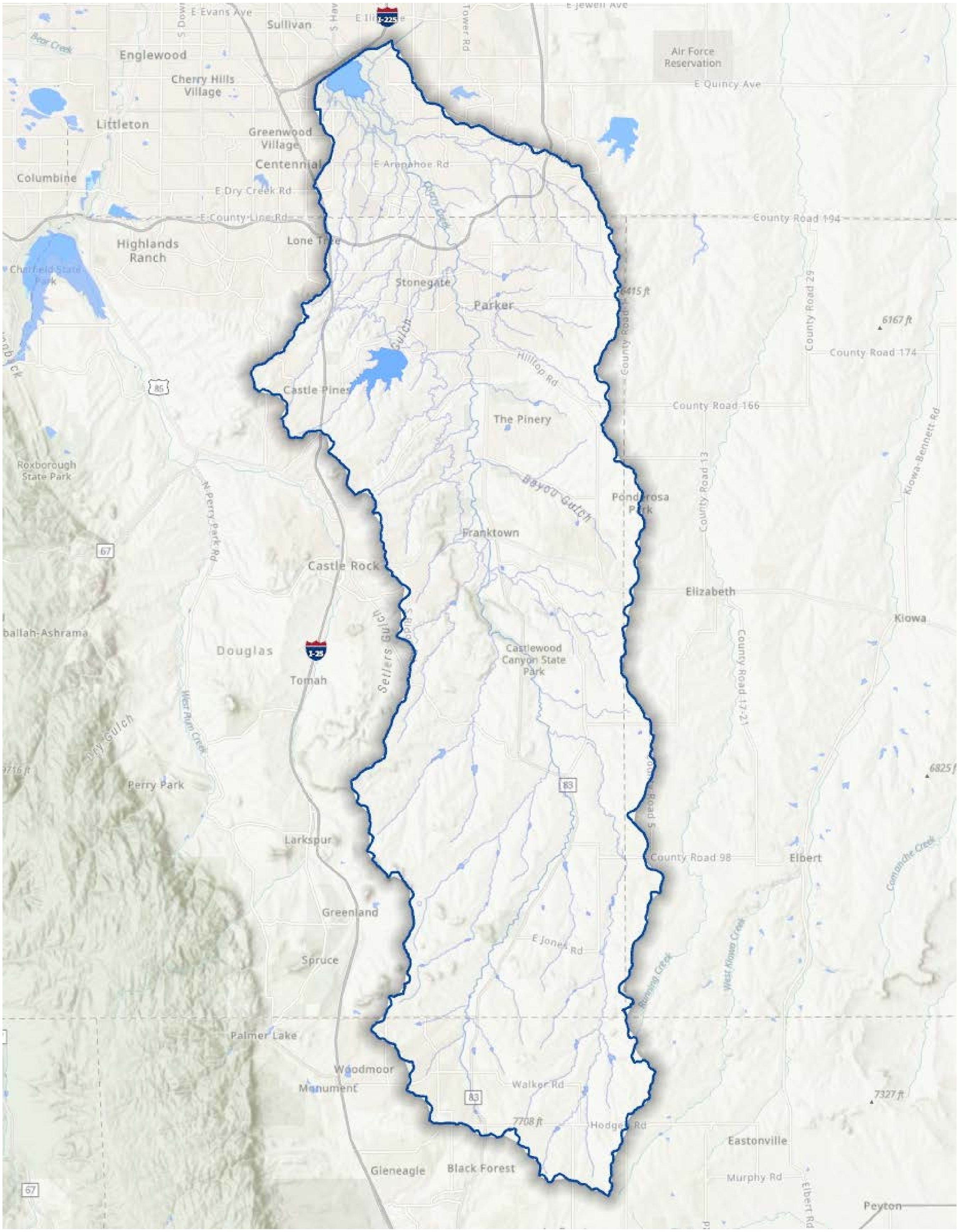

Figure 1. Cherry Creek Basin.

2.0 MONITORING PROGRAM

The WQCC's Cherry Creek Reservoir Control Regulation No. 72 (5 CCR 1002-72), (CR 72), requires that the CCBWQA execute a water quality monitoring program of the Cherry Creek watershed and Reservoir for water quality, inflow volumes, alluvial water quality, and non-point source flows. The program is implemented to determine total annual flow-weighted concentrations of nutrients to the Reservoir and to monitor the Pollutant Reduction Facilities (PRFs) to determine inflow and outflow nutrient concentrations. The sample collection and analysis provide data required to evaluate the nutrient sources and transport, characterize reductions in nutrient concentrations, and calculate and document compliance with associated water quality standards. In addition, these data are used to update the Reservoir and Watershed models.

The CCBWQA Sampling and Analysis Plan/Quality Assurance Project Plan (SAP/QAPP) provides the foundation for the sampling and analysis program, including sampling methods, QA/QC (quality assurance/quality control) and protocols. The monitoring program was designed to understand and quantify the relationships between nutrient loading and Reservoir productivity. The routine monitoring of surface water and groundwater was implemented to promote the concentration-based management strategy for phosphorus control in the basin, to determine the total annual flow-weighted concentration of nutrients to the Reservoir, to evaluate watershed nutrient sources and transport mechanisms, and to evaluate the effectiveness of PRFs including the cumulative effect of stormwater control measures (SCMs, also known as BMPs) implemented in the basin.

All monitoring activities and analytical work are performed in accordance with the SAP/QAPP, which includes details of the current monitoring program (monitoring locations, frequency, parameters analyzed, etc.) and can be found on the CCBWQA website, https://www.cherrycreekbasin.org/plans. The monitoring sites and details regarding station type, monitoring frequency, event types, and telemetry are shown in Figure 2.

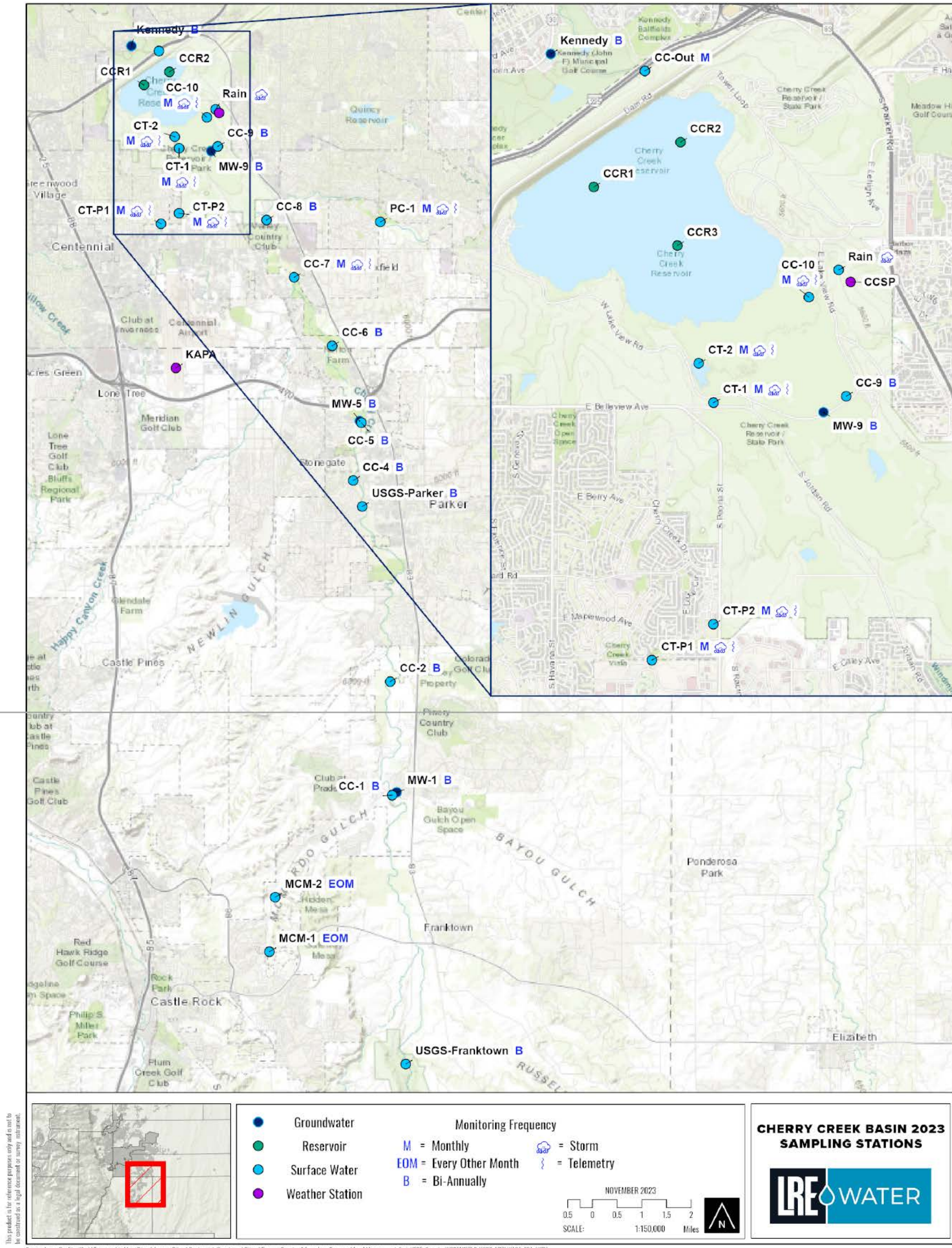

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Figure 2. CCBWQA Monitoring Sites and Details

This WY 2023 Monitoring Report summarizes data collected during the 2023 water year and includes an assessment and evaluation of data and results from the Reservoir and watershed sampling and analysis, including water quality and quantity of surface water, groundwater, stormwater, and the effectiveness of Pollutant Reduction Facilities (PRFs). The water quality data and results described herein are available on the CCBWQA's Data Portal, http://www.ccbwqportal.org.

2.1 MONITORING METHODS AND ANALYTE DESCRIPTIONS

The parameters analyzed in the monitoring program are useful for assessing attainment of water quality standards assigned to protect aquatic life and recreational use, collectively referred to as "beneficial uses." These parameters are also used to define lake trophic state and interactions between the chemical and biological components of lake ecosystems. Additional water quality standards apply for parameters such as metals; however, these are not included in the annual monitoring program.

All analyses were conducted using approved methods described by the U.S. EPA and/or Standard Methods and are detailed in the SAP/QAPP. A summary of the key parameters and metrics described in this report are described below.

pH

In simple terms, pH is the scale used to specify how acidic or basic water is. A pH of 7 is considered neutral, a pH less than 7 is considered acidic, while a pH greater than 7 is considered basic. Reg 38 establishes the acceptable range for pH in the Reservoir between 6.5 and 9.0 to protect aquatic life. Since pH is expressed on a logarithmic scale, each 1-unit change in pH represents a ten-fold increase or decrease in hydrogen ion concentration. Therefore, a pH of 6 would be 10 times more acidic than a pH of 7 and 100 times more acidic than a pH of 8. The pH of normal rainwater (containing no pollutants) is about 5.6.

Oxidation Reduction Potential

Oxidation reduction potential (ORP) measures the ability of a water body to breakdown contaminants or waste in the water. The value quantifies the exchange of electrons during chemical reactions in which the oxidation states of atoms are changed, also known as redox or oxidation-reduction reactions, or electrical activity is reported in millivolts (mV). ORP is measured in addition to dissolved oxygen since it provides additional information on water quality or pollution.

At the water/sediment boundary layer, microbial organisms facilitate the chemical reactions but do not actually oxidize or reduce the compounds. Redox reactions provide energy for microbial cells to carry out their metabolic processes (Wetzel 2001). The combination of microbial organisms and redox reactions are responsible for the breakdown of organic matter and development of anoxic conditions near the sediment boundary in reservoirs during the summer. Higher ORP values indicate an oxidizing environment and high potential to break down organic matter in the water. Low and negative values indicate a reducing environment and usually correlate to lower dissolved oxygen concentrations and higher microbial decomposition activity normally present at deeper sites and in the sediments of lakes.

Conductivity

Conductivity (specific conductance) is the ability of water to conduct an electrical current and is based on the dissolved inorganic solids (positive and negative ions) present. Conductivity is a useful general measure of water quality since values increase with salinity and can be an indicator of dissolved solids that can be considered "pollutants" in the water. The geology of the area, water source, and watershed affect conductivity.

Conductivity values of 50-1500 µS/cm are typical for surface water. Conductivity also varies in direct proportion with temperature with higher temperature increasing the conductivity. Thus, to allow direct comparison of samples collected at different temperatures, conductivity is typically corrected to 25^{o}C and reported as specific conductance (µmhos/cm @ 25 ^{o}C). For the sake of simplicity, specific conductance is referred to as "conductivity" in this report.

Dissolved Oxygen

Dissolved oxygen (DO) is the amount of oxygen gas dissolved in the water column. Small amounts of oxygen enter the water column by direct diffusion at the air/water interface and oxygen is also produced during photosynthesis. DO gradients provide an indication of mixing patterns and the effectiveness of mixing processes in a lake. DO concentrations also have an important bearing on the physical-chemical properties of lakes and the composition of a lake's biota. Lakes impacted by heavy sediment loads may experience low DO levels since the increased turbidity caused by suspended particles can reduce light penetration and limit photosynthesis. The breakdown of organic matter or decomposition can consume large amounts of oxygen from the water column and reduce DO. Fish require oxygen for respiration and may become stressed at levels less than 5.0 mg/L. DO can be expressed as concentration (mg/L) or as percent saturation. DO saturation is directly related to temperature and the capacity of water to absorb oxygen decreases as temperature increases.

Temperature

Water temperature affects the DO concentration of the water, the rate of photosynthesis, rates of chemical reactions, metabolic rates of aquatic organisms, and the sensitivity of organisms to toxins, parasites, and disease. All aquatic organisms are dependent on certain temperature ranges for optimal health. If temperatures are outside of this optimal range for a prolonged period of time, the organisms become stressed and can die. Water temperature generally increases with turbidity; as the particles absorb heat, the DO levels are reduced. Temperature is primarily controlled by climatic conditions but can also be impacted by human activities.

Secchi Depth

The Secchi depth of a waterbody is a way to quantify turbidity or water clarity. It is measured with an 8" black and white disk which is slowly lowered into the water column and the depth at which it is no longer visible becomes the Secchi depth. The measurement is based on both light absorption and the amount of light scattered by particles in the water column. The Secchi depth is higher when there is greater clarity or fewer particles in the water and is usually a representation of productivity of the water. Secchi depths of less than 6.6 feet (2.0 meters) have traditionally been considered undesirable for recreational uses in natural lakes; however, lower clarity is usually tolerated in reservoirs.

Light Transmission

Light transmission is a measurement of light absorption in the water column. The depth at which 1% of the surface light penetrates is considered the lower limit of algal growth and is referred to as the photic zone (see below). The measurement of 1% light transmission is accomplished by using both an ambient and an underwater quantum sensor attached to a data logger. The ambient quantum sensor remains on the surface, while the underwater sensor is lowered into the water on the shady side of the boat. The underwater sensor is lowered until the value displayed on the data logger is 1% of the value of the ambient sensor, and the depth is recorded.

Photic Zone

The Photic Zone of an aquatic resource is calculated as the depth at which light can penetrate or the depth of the water column where phytoplankton could complete photosynthesis based on light availability. Samples in Cherry Creek Reservoir are collected as a composite from what represents the common photic zone based on conditions, typically from 0-3 m. See Light Transmission above.

Chlorophyll α

Chlorophyll is the green pigment that allows plants to photosynthesize. The measurement of chl α in water provides an indirect indication of the quantity of photosynthesizing phytoplankton found in the water column. It is found in all algal groups, as well as in cyanobacteria. More specifically, chl α is a measurement of the portion of the pigment that was still actively photosynthesizing at the time of sampling and does not include dead biomass. In surface water, lower chl α concentrations (0-6 µg/L) correspond to oligotrophic or mesotrophic conditions, where higher concentrations indicate a eutrophic (6-40 µg/L) or hypereutrophic state (>40 µg/L).

Phosphorus

Phosphorus can be found in several forms in freshwater. The biologically available form that can contribute to nuisance plant and/or algal growth is soluble inorganic orthophosphate, also referred to as soluble reactive phosphorus. Inorganic phosphates quickly bind to soil particles and plant roots and, consequently, much of the phosphorus in aquatic systems is bound and moves through the system as sediment particles. Organic phosphates are phosphorus forms found in the cells of plants and other organisms and are biologically unavailable. Under anoxic (low oxygen) conditions, bound phosphorus can be released from bottom sediments, and the concentration of biologically available orthophosphate can increase dramatically. The erosion of soil particles from steep slopes, disturbed ground, and stream channels is often an important source of phosphorus in aquatic systems. Surface runoff containing phosphorus from fertilizers, wastewater effluent, and decaying organic matter also contribute to biologically available phosphorus enrichment.

> **Total Phosphorus (TP)** is the measure of all phosphorus in a sample as measured by persulfate digestion and includes inorganic, oxidizable organic, and polyphosphates. This includes what is readily available, has the potential to become available, and stable forms. In lakes and reservoirs, concentrations <12 µg/L are considered oligotrophic; 12-24 µg/L mesotrophic; 25-96 µg/L eutrophic; and >96 µg/L hypereutrophic.
>
> **Soluble Reactive Phosphorus (SRP)** is the measure of dissolved inorganic phosphorus (PO_4^{-3}, HPO_4^{-2}, $H_2PO_4^-$, and H_3PO_4). This form is readily available in the water column for phytoplankton growth.
>
> **Total Dissolved Phosphorus (TDP)** is a measure of all phosphorus forms (inorganic, organic, and polyphosphate) that are dissolved in water.

Nitrogen

Nitrogen has a complex cycle and can exist in organic, inorganic, particulate, gaseous, and soluble forms. The soluble, inorganic oxidized forms are nitrate (NO_3^-), and nitrite (NO_2^-), which are normally found in surface water. The reduced inorganic form is ammonia (NH_3), which is normally found in low-oxygen environments. The inorganic forms, NO_3^-, NO_2^-, and NH_3 are the most available for primary productivity or algal growth. However, atmospheric nitrogen (N_2) can also be used as a nutrient source by some species of algae or cyanobacteria, and various other reduced forms of nitrogen can be produced by decomposition processes. Particulate and dissolved organic forms of nitrogen are not immediately available to drive algal growth but can be converted to ammonia by bacteria and fungi and can be oxidized to form nitrites and then nitrates. Surface runoff can contain inorganic nitrogen from fertilizers and organic nitrogen from animal waste, wastewater, etc.

Total Nitrogen (TN) is the quantity of all nitrogen in the water and is calculated by adding the measured forms of organic nitrogen, nitrate, nitrite, and ammonia.

Nitrates and Nitrites (NO_3^-+ NO_2^-) are the sum of total oxidized nitrogen, often readily available for algal uptake.

Ammonia (NH_3-N) is a reduced form of dissolved nitrogen that is readily available for phytoplankton uptake. NH_3 is found where dissolved oxygen is lacking, such as in a eutrophic hypolimnion, and is produced by bacteria as a byproduct during decomposition.

Nitrogen/Phosphorus Levels and Ratios

Phytoplankton require both macronutrients, such as phosphorus, nitrogen, and carbon, and trace nutrients, including iron, manganese, and other minerals, for growth. Biological growth is limited by the substance that is present in the minimum quantity with respect to the needs of the organism. The ratio of total nitrogen (TN) to total phosphorus (TP) in a water body provides insight into nutrient limitation in the water body. Since many species of harmful cyanobacteria (blue-green algae) have the ability to fix nitrogen from the atmosphere, they have a competitive advantage over other algae in phosphorus-rich environments when nitrogen is limited and can become dominant over the more beneficial green algae species. Maintaining a molar TN:TP ratio greater than 16:1, or 7:1 ratio by weight, will favor a balanced phytoplankton diversity and reduce the potential for a cyanobacteria-dominated environment. The ratio of total inorganic nitrogen (nitrate, nitrite, and ammonia) to soluble reactive phosphorus (TIN:SRP) can sometimes be more indicative of phytoplankton growth potential since these are the nutrient forms most available in the water column.

Trophic State

The Trophic state as described by Vollenweider (1970) is used as a guideline for describing water quality as it relates to the trophic state or biological productivity potential. Many indices assign numerical values to trophic state based on multiple water quality parameters. The following are typical characteristics of various trophic states:

Oligotrophic - lack of plant nutrients, low productivity, sufficient oxygen at all depths, clear water, deeper lakes can support trout.

Mesotrophic - moderate plant productivity, hypolimnion may lack oxygen in summer, moderately clear water, supports warm water fisheries only.

Eutrophic - contains excess nutrients, blue-green algae dominate during summer, algae scums are probable at times, hypolimnion lacks oxygen in summer, poor transparency, rooted macrophyte problems may be evident.

Hypereutrophic - algal scums dominate in summer, few macrophytes, no oxygen in hypolimnion, fish kills possible in summer and under winter ice.

Alkalinity

Alkalinity, expressed as mg $CaCO_3$/L, represents the presence of bicarbonates and carbonates in water and indicates the buffering capacity or ability to neutralize acids. A higher buffering capacity can reduce the potential for pH swings during photosynthesis (removing CO_2) by primary producers (algae) and plant growth. A minimum alkalinity of 20 mg/L is the aquatic life criteria recommended by the EPA.

Anions: Chloride and Sulfate

Chloride and sulfate are the major anions (negative ions) that play a role in conductivity and can be indicators of pollutants entering a watershed due to de-icing activities, treated wastewater discharge, stormwater runoff, naturally elevated conditions in groundwater, etc. Conductivity is a measure of the ability of water to conduct electricity, which is a function of all the dissolved ions in solution. Since chloride and sulfate are ions in solution, any increase in their concentrations increases conductivity.

Cations: Calcium, Magnesium, Sodium, and Potassium

The major cations (positive ions) that contribute to dissolved solids concentration in water typically are calcium, magnesium, sodium, and potassium. These ions can also indicate pollutants entering a watershed such as de-icing products, treated wastewater discharge, stormwater runoff, etc. Starting in 2022, these parameters were included in the data analysis for one reservoir site and three surface water sites twice a year so the major contributions to conductivity can be evaluated when enough data has been collected.

Suspended Solids

Total Suspended Solids (TSS) is a quantification of concentrations of suspended sediment and other particulates in water. Suspended solids in lakes include both organic material, such as algal cells and other microorganisms, and inorganic particulate matter, such as silt, clay, and other particles. Algae, other organisms, and smaller particles are usually the main source of TSS in lakes and reservoirs, while suspended silts, clays, and coarser particles play a larger role in stream or groundwater samples. Volatile Suspended Solids (VSS) is a measure of the amount of particulate organic material that is present in water. Suspended solids in the water can indirectly impact chl α concentrations by reducing the opportunity for algae to photosynthesize.

Organic Carbon

Organic carbon provides a measure of all organic compounds in a water body and can provide an assessment of the carbon-based components or pollution of water. Plant material is often a major component of organic carbon and refractory organic compounds from plants can impart a dark color to lake water. Both total and dissolved organic carbon are measured in analytical samples.

2.2 WATER QUALITY ANALYSIS

The water quality data collected during the CCBWQA monitoring program is analyzed to evaluate short- and long-term changes or trends, seasonal and spatial variability, as well as compliance with applicable water quality standards. The Cherry Creek Watershed experiences seasonal fluctuations that influence water quality and trends over time.

In this analysis, summary statistics are calculated for each parameter and monitoring location based on the entire or specified period of record (POR), which represents the baseline. The summary statistics and associated graphs in this report illustrate the median, 15^{th}, and 85^{th} percentiles of the POR data, as well as WY 2023 values. The central value of the dataset, known as the median, signifies the point where half of the sample set measurements are below, and half are above that value. The 85^{th} percentile indicates that 85% of the measured values fall below this statistic. Conversely, the 15th percentile represents the statistic that 15% of the measured values fall below. The use of 85th/15th percentile serves as upper/lower indicators while mitigating the influence of potential minimum and maximum measurement outliers and to review annual data in the context of baseline historical ranges rather than simple comparison to a baseline median. Due to the natural variability seasonally and from year to year, the selected range bounds 70% of the data set, so values outside of this range indicate values more extreme than the expected variability. The 15th/85th percentiles are also commonly used to characterize ambient conditions for many of CDPHE's standard assessments.

In addition to characterizing times series data using statistical summary values, it also is important to determine if there are statistically significant trends in long-term data sets. Since water quality data are typically non-parametric (do not conform to a normal distribution), a Mann Kendall trend analysis can quantify if time series data for a given location and parameter have a statistically significant trend. A p-value obtained from the MK trend test of less than 0.05 provides evidence of a significant monotonic trend in the time series. Conversely, if the p-value is greater than 0.05, it suggests that there is not enough evidence to conclude the presence of a significant monotonic trend.

3.0 WATERSHED MONITORING RESULTS

The watershed monitoring program includes an analysis of the quantity and quality of potential nutrient source inputs to Cherry Creek Reservoir. During WY 2023, surface water and groundwater sites in the watershed were monitored either monthly, every other month, on a bi-annual frequency, and/or during storm events to characterize spatial and temporal variability and differences in base and stormflow conditions.

The spring of 2023 received much higher-than-average precipitation, which caused major flooding and damage along Cherry Creek and Cottonwood Creek. Multiple monitoring stations, equipment, and other infrastructure were damaged and required repairs. These equipment issues and the extended elevated water levels impacted stream flow calculations. Please note that some data and measurements normally collected under the monitoring program are not available due to these factors outside of the CCBWQA's control and alternative calculations will be used and provided with an amended report in 2024.

3.1 PRECIPITATION

Precipitation in the watershed and on the surface of the Reservoir plays a major role in water quality in the streams and overall Reservoir dynamics. Historically, precipitation in the Cherry Creek watershed has been measured at NOAA's Centennial Airport weather station (KAPA) located at Latitude (Lat) 39.56°N, Longitude (Long) -104.85°W, and an elevation of 5,869 ft.

The meteorological station at Cherry Creek State Park (CCSP, located at Latitude (Lat) 39.63°N, Longitude (Long) -104.83°W, and an elevation of 5,631 ft was installed in 2021 (Figure 2). In WY 2023, the CCSP station measured a total of 22.3 inches of precipitation and the KAPA site measured 25.6 inches.

The watershed received approximately 172% of the historical average precipitation in WY 2023, with 15-16" in May and June accounting for over 60% of the entire year.

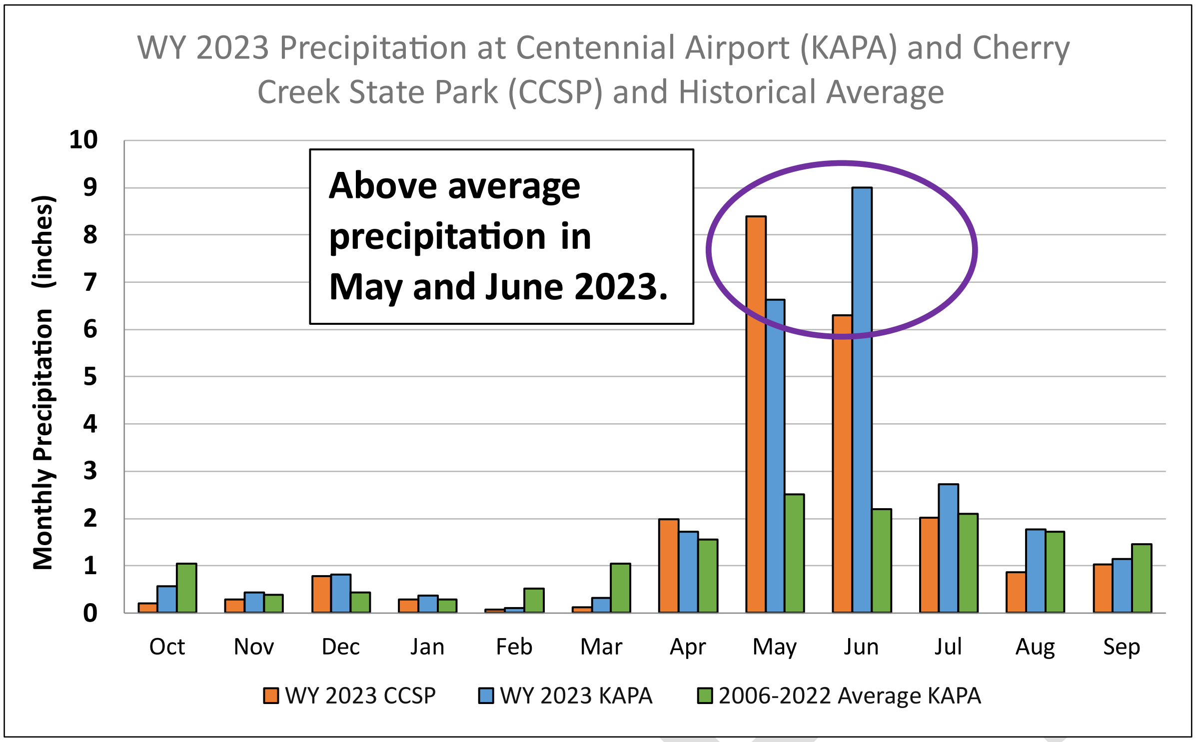


Figure 3. Monthly Watershed Precipitation in WY 2023 compared to (2006-2022) average.

Due to closer proximity to the Reservoir, the CCSP station should better represent the precipitation on the surface of the Reservoir and is used in water balance calculations. However, the KAPA site will continue to be used as a comparison and as a historical reference until a representative period of record can be developed for the CCSP site.

October 2022, and February, March and September 2023 received below average precipitation at both locations. However, May and June 2023 received much higher-than-average precipitation, accounting for over 60% of the precipitation for the entire year. The KAPA station measured a total of 25.6 inches of precipitation in WY 2023, approximately 172% of the historical average from 2006 to 2022 for this weather station (Figure 3).

STORM FREQUENCY ANALYSIS

On May 11, 2023, the 24-hour total precipitation recorded was 3.35”, and 2.33” was recorded on June 22, 2023, representing the top two ranked daily averages since 2006 at the KAPA site. These events represented a probability of 5-7% occurrence based on historical dates that have received greater than 1” of precipitation. Probability and recurrence intervals are likely to be different if evaluated based on a more specific time-period or at different locations in the watershed. The June 22nd storm intensity and duration was greater than 2” in 2 hours at the KAPA site near where the most notable stream flooding was observed on Cottonwood Creek, but less precipitation was observed at at the CCSP site during the same time period (Figure 3).

Evaluation of these storms using the Point Precipitation Frequency (PF) Estimates (NOAA, 2017) at the Cherry Creek Dam, Site ID 05-1547, indicates that the May 11th/ 12th storm, which recorded 6.48” in a 48-hour period at the CCSP Met station, has a recurrence interval of 500 years (Figure 4) and the >2” of precipitation observed in two hours at the KAPA site is estimated to have a 25-year recurrence interval (Figure 5).

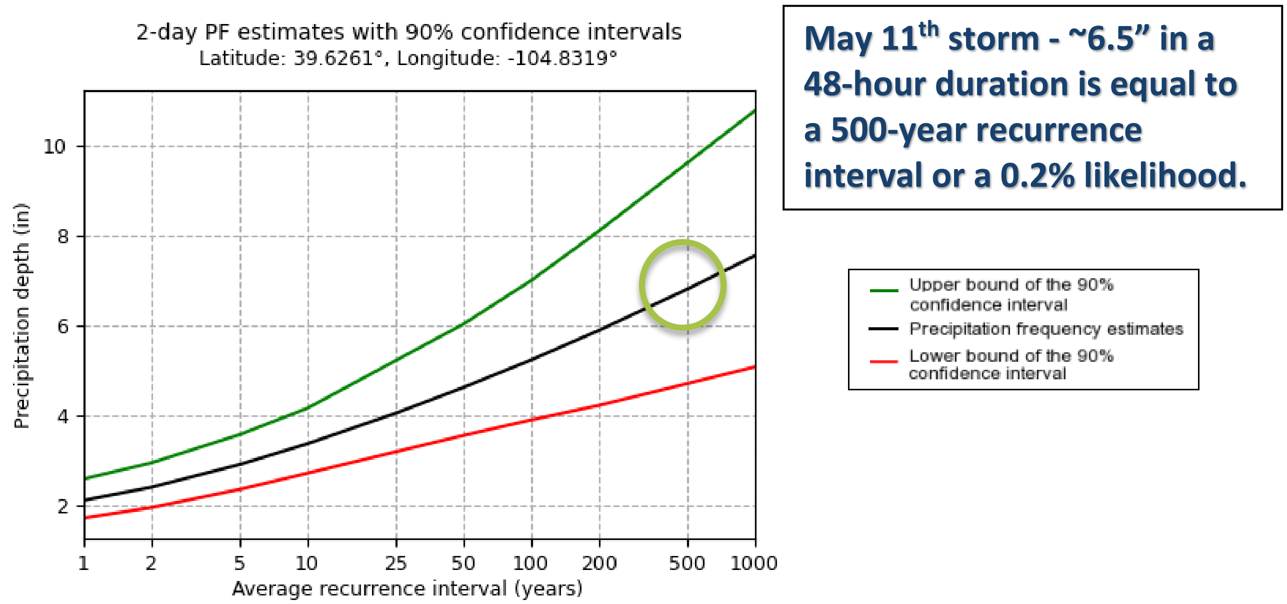


Figure 4. Average Recurrence Interval based on 48-hour Precipitation Frequency at Cherry Creek Dam site (NOAA)

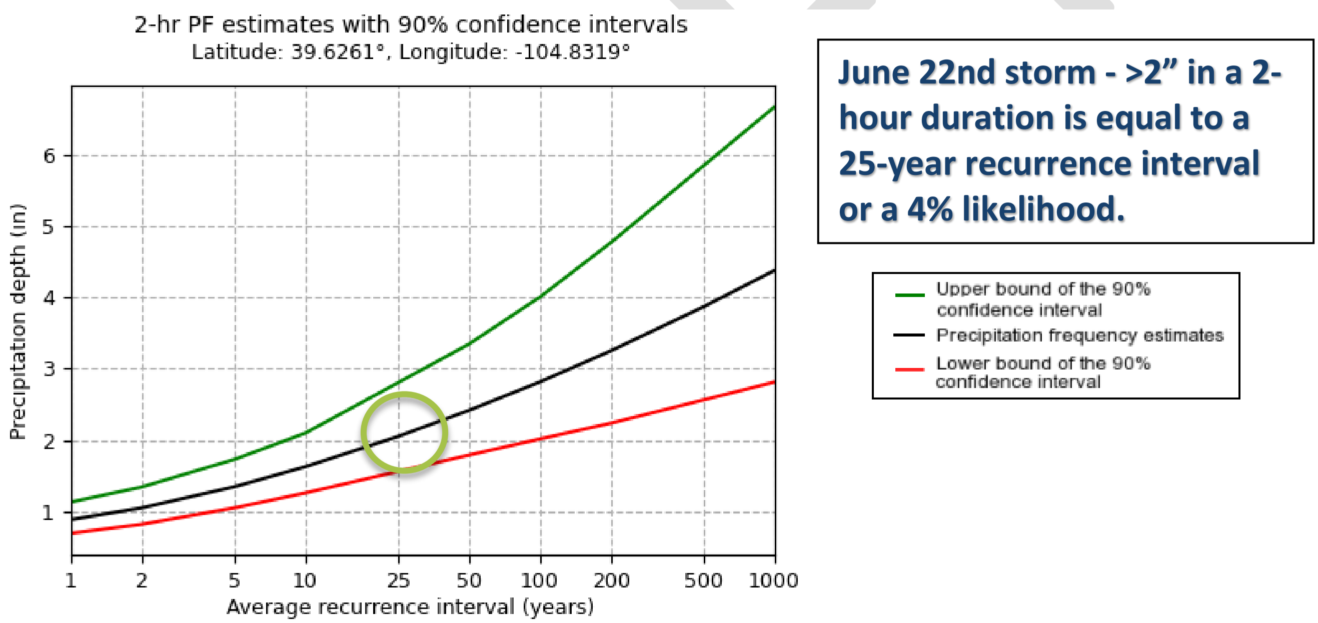


Figure 5. Average Recurrence Interval based on 2-hour duration at Cherry Creek Dam site, NOAA)

Additionally, when looking at NOAA's annual precipitation information, nearly all areas of the watershed received precipitation ranging between approximately 122 to 225 percent of normal when compared to the 30-year Parameter-elevation Regression on Independent Slopes Model (PRISM) normal from 1991-2020 (Figure 6). The watershed received approximately 200% of the 30-year average, while areas just above Cherry Creek Reservoir generally received less than average precipitation. This data is based on observed National Weather Service (NWS) precipitation from the CONUS River Forecast Centers and is displayed as a gridded resolution of roughly 4x4 km using bilinear interpolation in GIS.

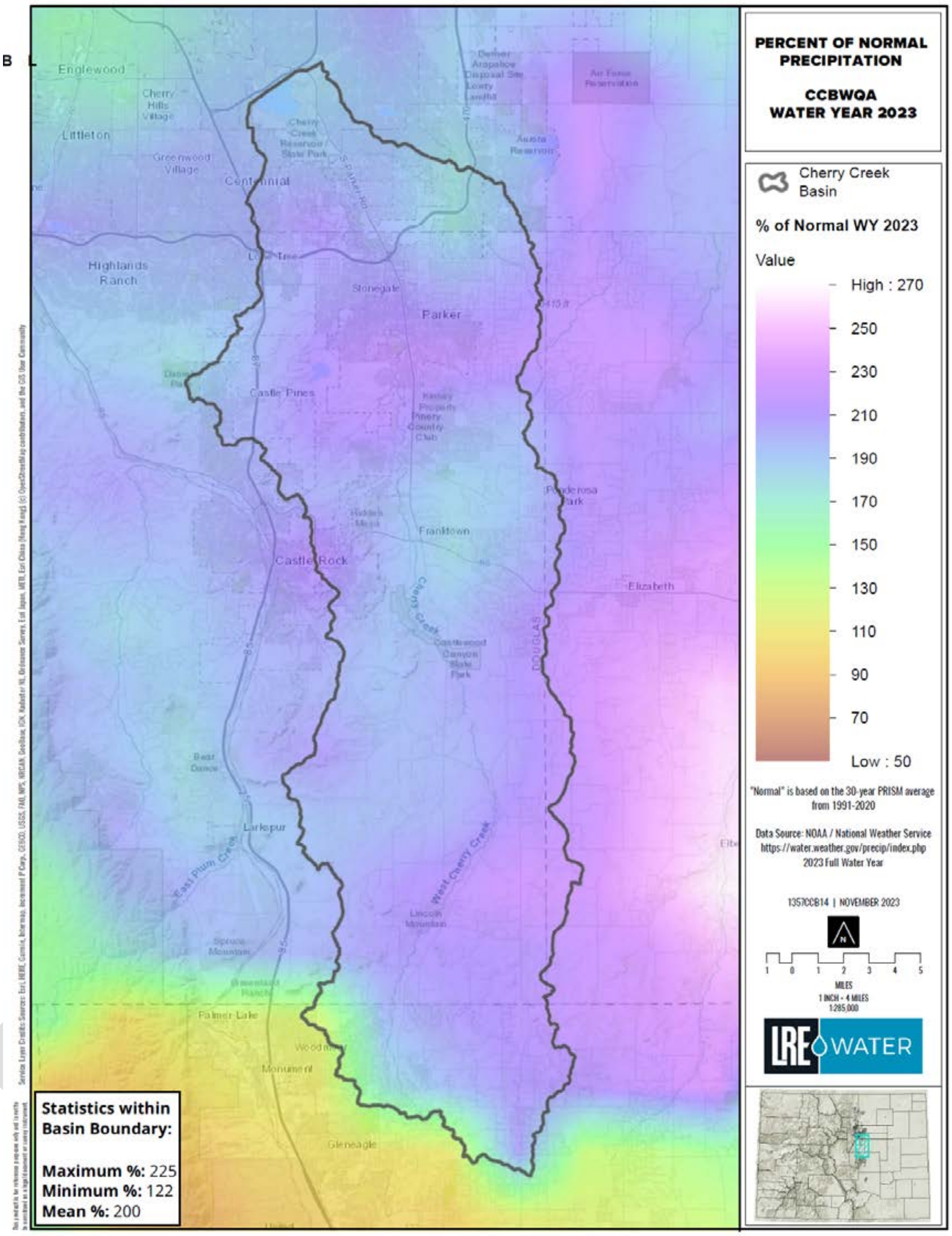


Figure 6. Percent of Normal Precipitation (30-year PRISM Average)

3.2 STREAM FLOWS

The U.S. Geological Survey (USGS) operates two gauging stations on Cherry Creek upstream of the Reservoir which are used as surface water monitoring locations for the SAP. The "Cherry Creek Near Franktown, CO" station (0671200) has an 80-year period of record (POR and the "Cherry Creek near Parker, CO" station (393109104464500) has a 29-year POR.

3.2.1 CHERRY CREEK NEAR USGS FRANKTOWN SITE

The USGS Cherry Creek Near Franktown station is in Castlewood Canyon State Park in Douglas County (Figure 2). The station, which represents the upper portion of the watershed, is 1.3 mi downstream from Castlewood Dam site, and 2.5 mi south of Franktown. The USGS WY 2023 summary statistics are listed in the text box to the right; Figure 7 shows the estimated daily discharge along with the historical daily mean from the last 82 years.

USGS Gage - Cherry Creek near Franktown
Hydrologic Unit 10190003 (39°21'21", 104°45'46)
Drainage Area: 169 sq mi.
2023 Statistics
Total Annual Flow: 4519 cfs/ 8960 AF/ Year
Annual Mean Flow Rate: 12.4 cfs 24.5 AF/day
Percent of Long-term Average (1940-2023): 139%
Percent of 31-year average (1992-2023): 163%

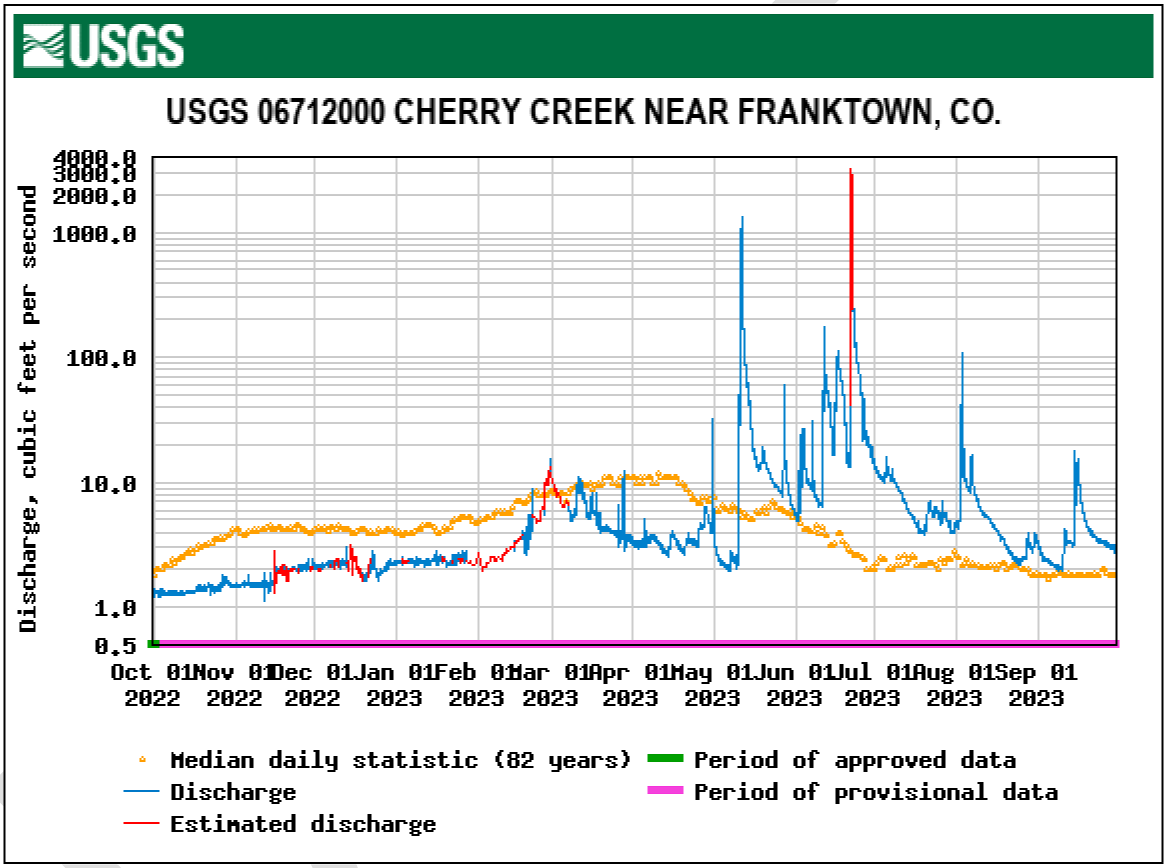


Figure 7. WY 2023 Daily Mean Discharge and Historical Median Flows for USGS Gauge near Franktown.

3.2.2 CHERRY CREEK NEAR USGS PARKER SITE

The USGS Cherry Creek near Parker station is located in Douglas County, 200 ft upstream from Main Street, 1,100 ft downstream from mouth of Sulphur Gulch, and 0.8 mi west of Parker Rd. This site is representative of the conditions in the middle of the watershed. The USGS WY 2023 summary statistics are listed in the text box to the right; Figure 8 shows the estimated daily discharge along with the historical daily mean from the last 31 years.

USGS Gage - Cherry Creek near Parker
Hydrologic Unit 10190003 (39°31'09",104°46'45")
2023 Statistics
Drainage Area: 287 sq mi
Total Annual Flow: 8,042 cfs/ 15,947 AF/year
Annual Mean Flow Rate: 22.0 cfs/ 44 AF/day
Percent of 31-year average (1992-2023): 190.5%

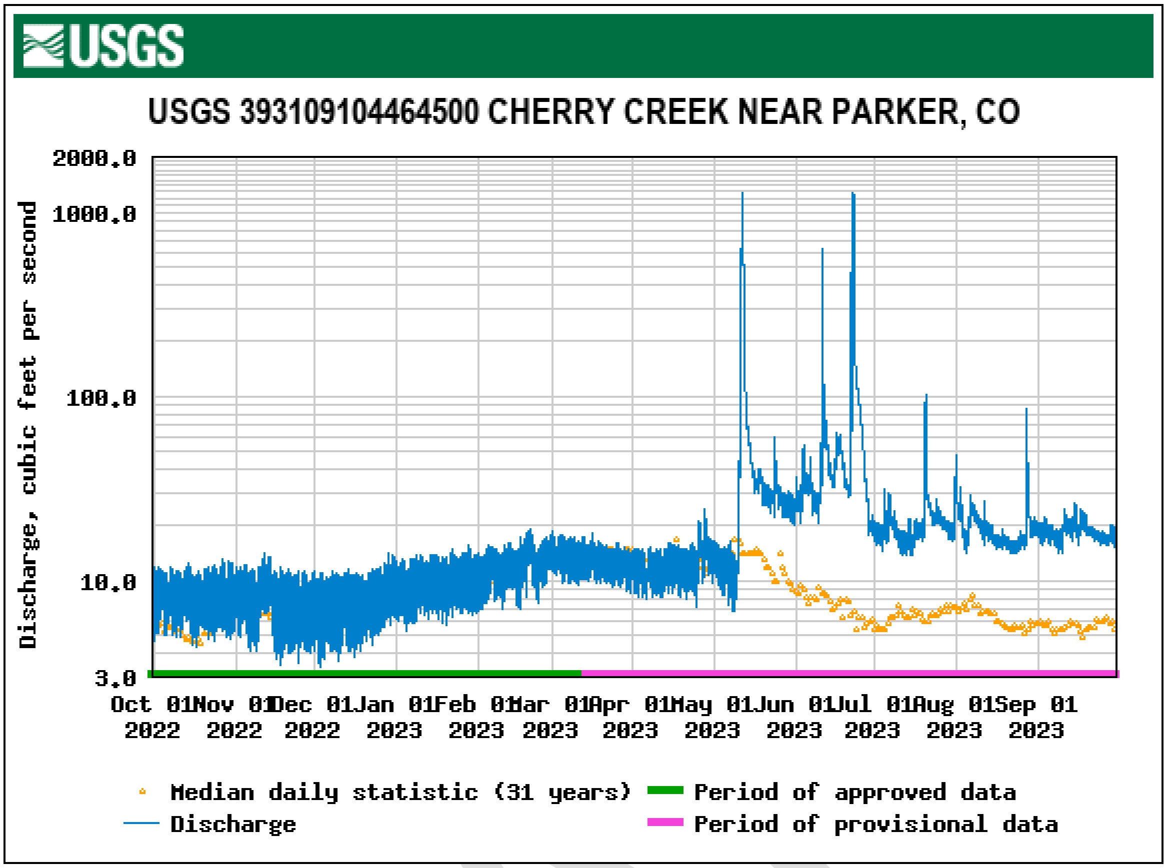


Figure 8. WY 2023 Daily Mean Discharge and Historical Median Flows for USGS Gauge near Parker.

3.2.3 CHERRY CREEK BELOW CHERRY CREEK LAKE

USGS Gage - Cherry Creek below Cherry Creek Lake
2023 Statistics:
Total Annual Flow: 20,015.3 cfs/ 39,690 AF
Annual Mean Flow Rate: 54.8 cfs/ 108 AF/day
Percent of 31-year average (1992-2023): 277%

Water is released from the Reservoir through the dam's outlet works. The USGS measures outflow at Station 06713000, Cherry Creek below Cherry Creek Lake, CO. The gauge is located approximately 2,300 ft downstream of the Reservoir. Other than releases from the Reservoir, there are no major surface water contributions to flow measured at this gauge. The USGS WY 2023 summary statistics are listed in the text box to the right; Figure 9 shows the estimated daily discharge along with the historical daily mean from the last 31 years.

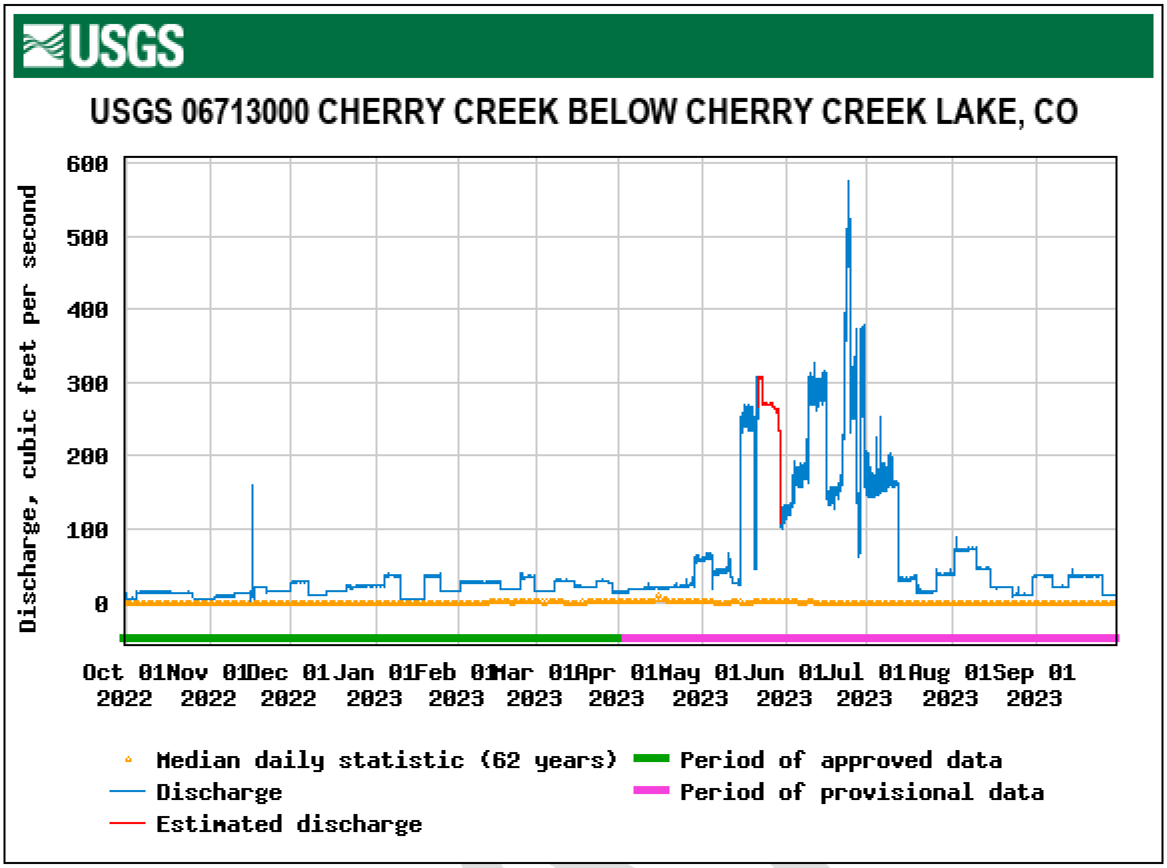


Figure 9. WY 2023 Daily Mean Discharge and Historical Median Flows for USGS Gauge Below Cherry Creek Lake.

3.3 RESERVOIR INFLOWS

Chery Creek, the main inflow to Cherry Creek Reservoir, flows from south to north to the Reservoir through a 234,000-acre drainage basin. The basin includes various types of land use, including agriculture in the upper basin and higher-density development closer to the Reservoir, as well as permitted discharges to Cherry Creek and its tributaries. Cottonwood Creek has the second largest surface water input to Cherry Creek Reservoir with a sub-basin of 9,050 acres, which includes developed land use, and multiple wastewater dischargers.

The elevation of Cherry Creek Reservoir reached 5556.7 ft during the storm event in May 2023, which is above the **10-year Flood Pool.**

The multiple large storm events in the Cherry Creek Watershed during 2023 affected stage measurements and associated flow calculations due to damaged equipment and inaccurate readings at the two stations on Cherry Creek and Cottonwood Creek upstream of the Reservoir that are used to calculate inflows (CC-10 and CT-2, respectively). (See Section 3.1)

Multiple calculations of the recurrence frequency of the precipitation events and stream flows in the Cherry Creek watershed are presented in Section 3.1. In addition, based on a Flood Hazard Delineation completed by the USACE (Figure 10), the reservoir elevation of 5556.74 during the mid-May storm exceeded the 10-year flood pool and approached the 10-year flood pool again in late June when it reached 5555.90 ft (Figure 11). The Reservoir rose ~10 feet during the May storm--the largest single event increase since the flood of 1965. The storm made local and national news due to the damage on Lakeview Drive, the main roadway through the State Park.

Based on the annual peak streamflow data at USGS station on Cherry Creek near Parker, CO from 1992-2023, the peak streamflow of 1,290 cfs on May 12th was the second highest daily flow since 2012 with a probability of only ~6% likelihood of occurrence.

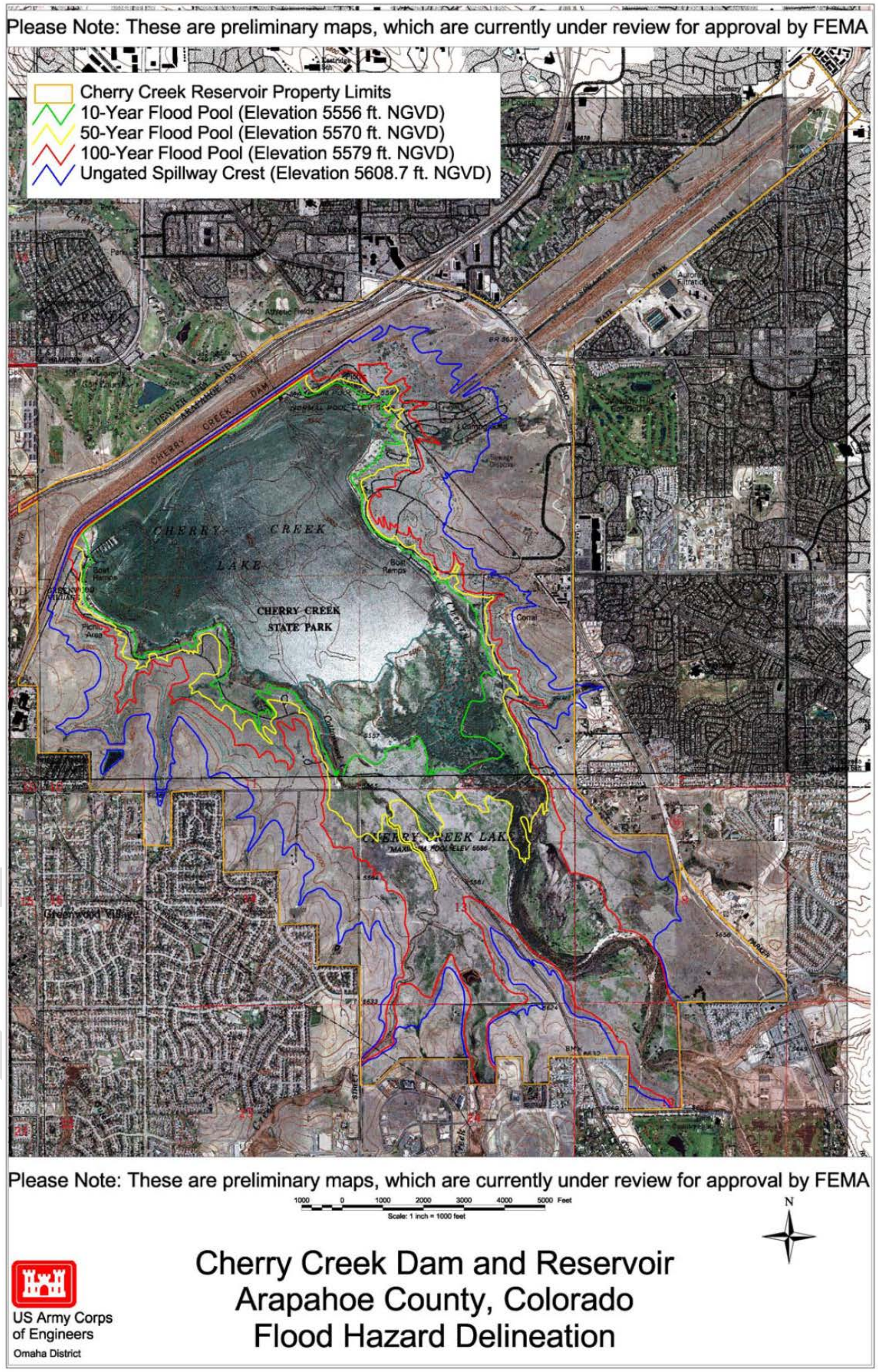


Figure 10. Cherry Creek Dam and Reservoir Flood Hazard Delineation

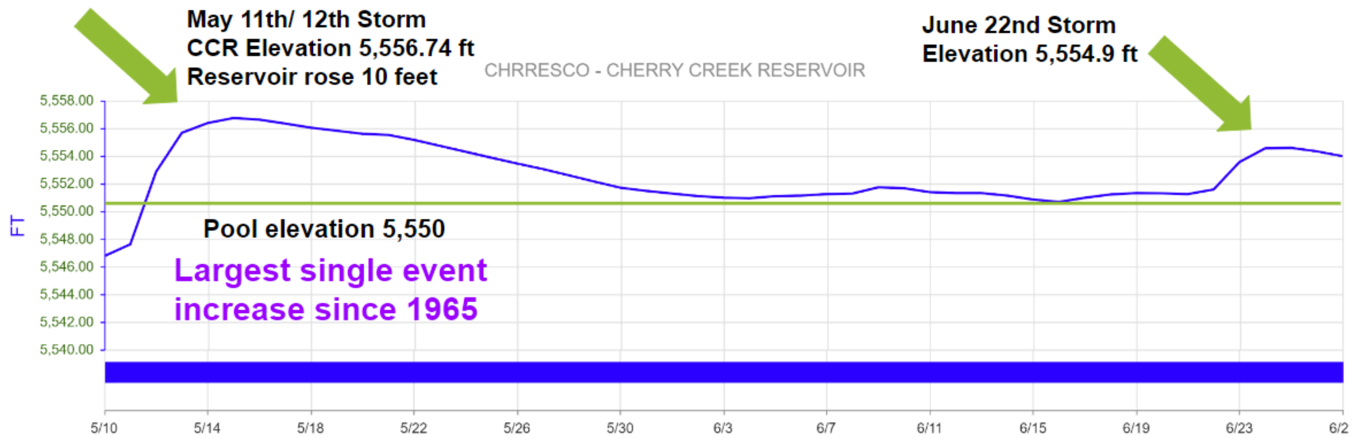


Figure 11. Reservoir Elevation May- June 2023 (CHRRESCO) (Colorado DWR).

3.3.1 CHERRY CREEK

CCBWQA monitors flows and water quality at CC-10, which is the site upstream on Cherry Creek just before it enters the Reservoir. The other sites on Cherry Creek and monitoring results are discussed in Section 3.4 below.

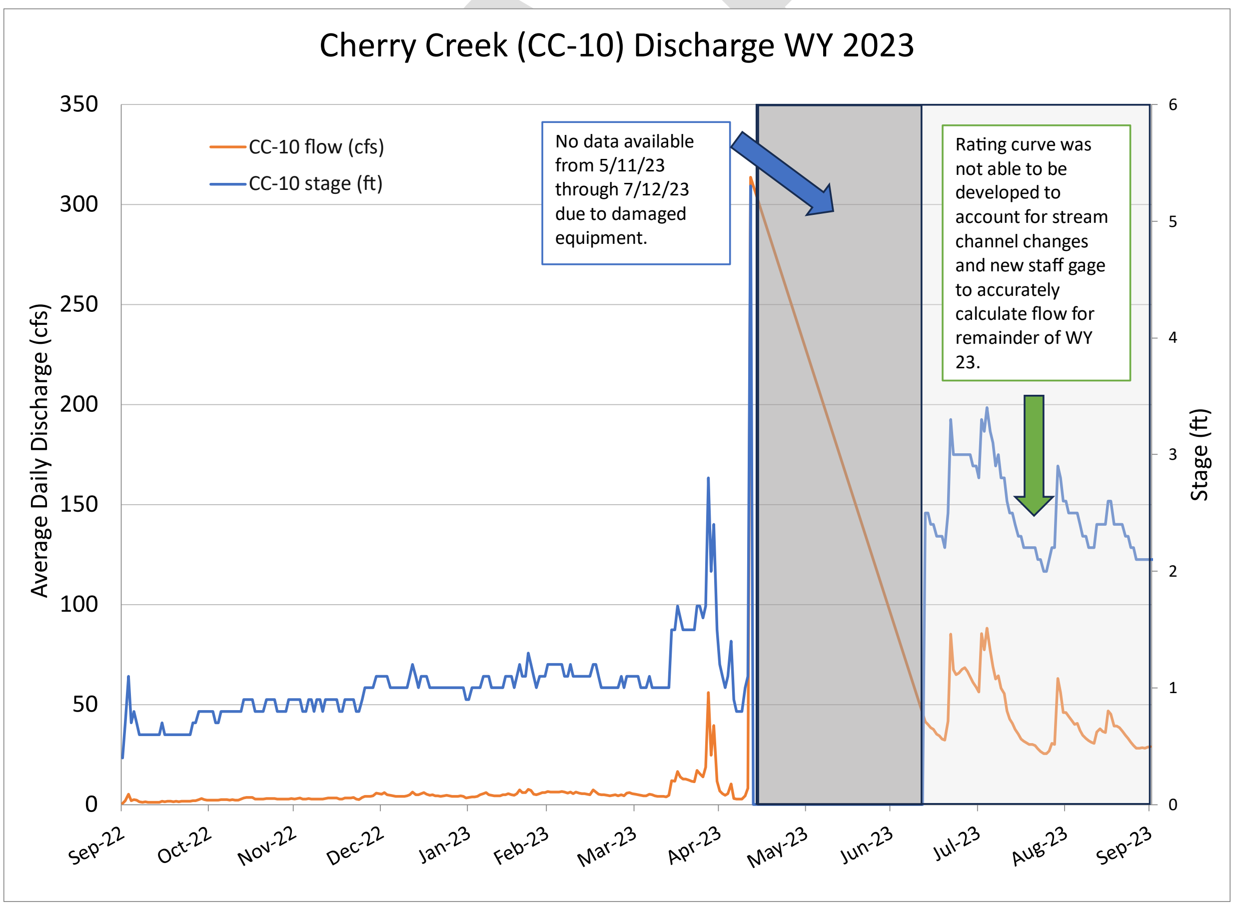


Figure 12. Cherry Creek Discharge at CC-10 upstream of Cherry Creek Reservoir.

Due to the major storm events in the Cherry Creek Watershed during 2023, stage measurements upstream of Cherry Creek Reservoir on Cherry Creek (CC-10) were not able to be collected following the May 11th storm event due to damaged equipment. Although the pressure transducer-based level sensor and staff gage at the

CC-10 were re-installed in mid-July, flow calculations require an updated rating curve due to the changes in stream channel and relocation of the staff gauge. A rating curve at CC-10 could not be generated since the water levels in the reservoir created a backwater effect at the site and the damage to the road upstream impacted the collection of accurate manual flow measurements to develop a new stage-discharge relationship in WY 2023. Stage and flow from CC-10 with the conditions affecting the values are displayed in Figure 12.

3.3.2 COTTONWOOD CREEK

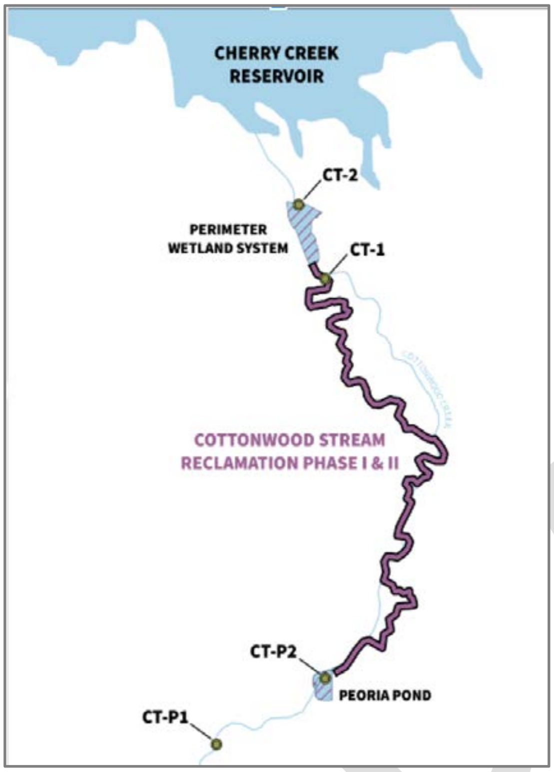


Figure 13. Cottonwood Creek Monitoring Locations and PRFs

Cottonwood Creek is the second largest surface water input to Cherry Creek Reservoir. Cottonwood Creek has a sub-basin of 9,050 acres. Compared to Cherry Creek, Cottonwood Creek sub basin has more developed land use, and multiple wastewater discharges. There are four monitoring sites on Cottonwood Creek. There are two sites upstream on Cottonwood Creek off Peoria St. and two sites in Cherry Creek State Park. These sites are monitored regularly and CT-1, CT-2, CT-P1, and CT-P2 have equipment to monitor stream levels and collect storm samples upstream and downstream of the PRF ponds and wetland systems (Figure 13).

CT-2 is the site upstream on Cottonwood Creek just before it enters the Reservoir, and it is representative of inflow water quality. The other Cottonwood Creek sites are discussed regarding the evaluation of the effects of the PRFs in Section 3.5 below.

The stage measurements at Cottonwood Creek at CT-2 were not accurately captured during one or more high flow events in WY2023 due to the location of the level sensor in the pond outlet structure. The maximum stage recorded at CT-2 on Cottonwood Creek was 2.6 ft on May 15, 2023; however, on May 11, 2023, Cottonwood Pond overflowed the side of the pond to the east.   Since the level sensor is located in the weir outlet structure, it does not accurately record the level in the pond during higher flow events (>2.2 ft). In 2024, the survey of the pond elevations will be reviewed to see if a level sensor at another location may more accurately represent high flow events. WY 2023 stage and flow from CT-2 along with the conditions affecting the values are displayed in Figure 14.

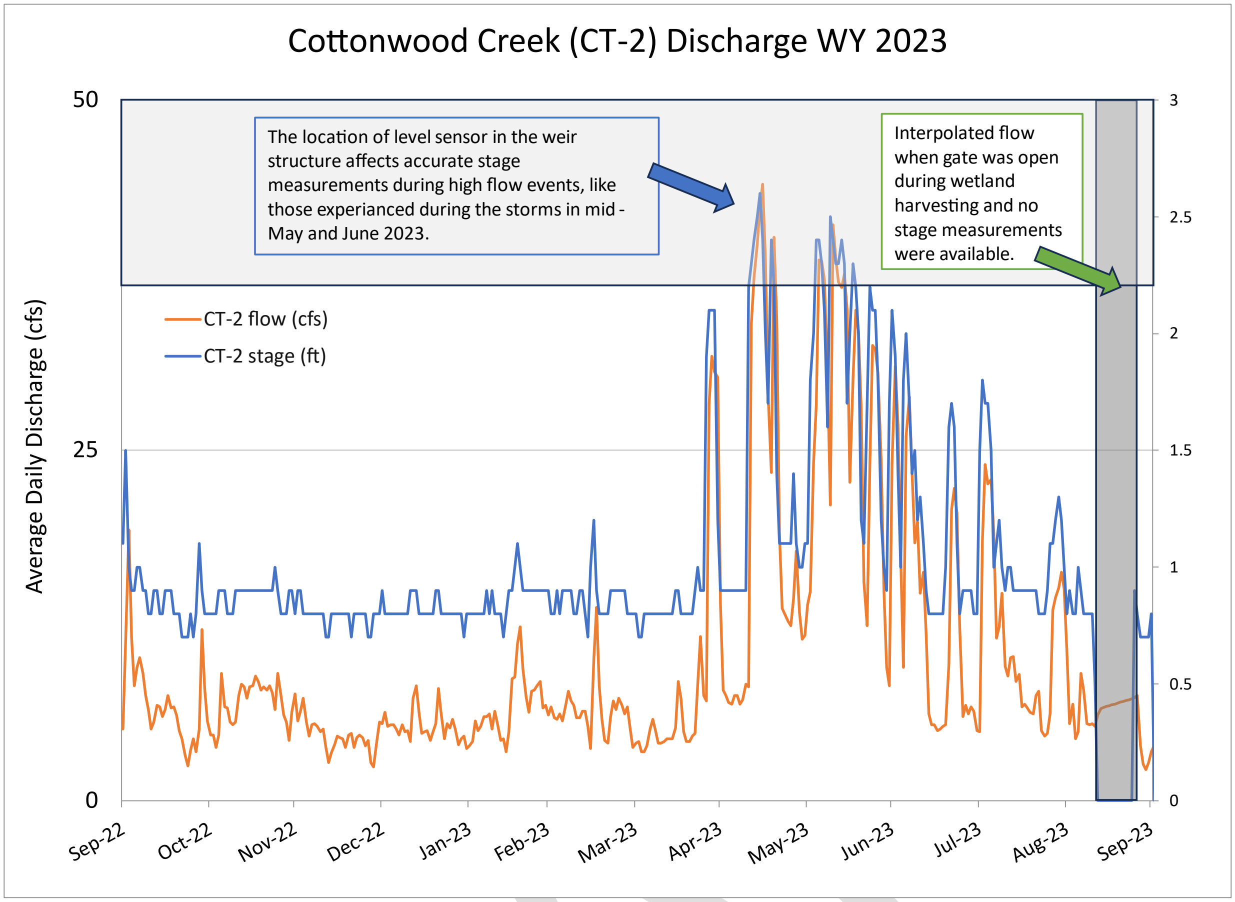


Figure 14. Cottonwood Creek Discharge at CT-2 upstream of Cherry Creek Reservoir.

3.4 WATERSHED WATER QUALITY

CCBWQA monitors Cherry Creek, Cottonwood Creek, Piney Creek, McMurdo Gulch and several alluvial groundwater wells at various frequencies in accordance with the SAP and as summarized in Table 1 and Figure 2 (in Section 2). A subset of sites is also monitored during storm flows. Table 1 also summarizes the period of record (POR) of monitoring at each site. The sections below outline the major parameters monitored, summary statistics, notable seasonal variation, and trends identified using a Mann Kendall trend analysis (see section 2.2) for the POR for each site.

Table 1. Watershed Monitoring Locations, Frequency, and Period of Record.
B-Bi-annual, EO – Every other Month, M-Monthly, 💧- Storm

Location Name	#/Yr	LOCID	Earliest Sampling Event	Most Recent Sampling Event	POR (Years)
CC-USGSFRANKTOWN	B	USGS-Franktown	8/11/1994	5/3/2023	29
CC-1 - Cherry Creek Station 1	B	CC-1	8/10/1994	5/3/2023	29
CC-2 - Cherry Creek Station 2	B	CC-2	11/8/1994	5/3/2023	29
CC-USGSPARKER	B	USGS-Parker	5/9/2017	5/3/2023	6
CC-4 - Cherry Creek Station 4	B	CC-4	8/10/1994	5/3/2023	29
CC-5 - Cherry Creek Station 5	B	CC-5	8/9/1994	5/3/2023	29
CC-6 - Cherry Creek Station 6	B	CC-6	8/9/1994	5/3/2023	29
CC-7 - Cherry Creek Station 7	M / 💧	CC-7	5/15/2012	9/13/2023	11
CC-8 - Cherry Creek Station 8	B	CC-8	3/15/1995	5/3/2023	28
CC-9 - Cherry Creek Station 9	B	CC-9	8/8/1994	5/3/2023	29
CC-10 - Cherry Creek Station 10	M / 💧	CC-10	4/3/1992	9/13/2023	31
CC-Out - Cherry Creek Reservoir Outflow	M	CC-Out	4/3/1992	9/13/2023	31
CT-1 - Cottonwood Creek PRF Site 1	M / 💧	CT-1	4/9/1992	9/13/2023	31
CT-2 - Cottonwood Creek PRF Site 2	M / 💧	CT-2	4/2/1996	9/13/2023	27
CT-P1 - Cottonwood Creek PRF Site P1	M / 💧	CT-P1	5/24/2002	9/13/2023	21
CT-P2 - Cottonwood Creek PRF Site P2	M / 💧	CT-P2	2/20/2002	9/13/2023	21
MCM-1 - McMurdo Gulch Station 1	EO	MCM-1	1/18/2012	8/9/2023	11
MCM-2 - McMurdo Gulch Station 2	EO	MCM-2	1/18/2012	8/9/2023	11
PC-1 - Piney Creek	M / 💧	PC-1	4/25/2018	9/13/2023	5
Rain Sampler	💧	PRECIP	4/4/2014	7/5/2023	9
MW-1 Monitoring Well 1	B	MW-1	8/10/1994	5/3/2023	29
MW-5 Monitoring Well 5	B	MW-5	8/16/1994	5/3/2023	29
MW-9 Monitoring Well	B	MW-9	8/12/1994	5/3/2023	29
MW-Kennedy Monitoring Well	B	MW- Kennedy	6/1/1999	5/4/2023	24

3.5.1 PHYSICAL PARAMETERS

The stream sites in the Cherry Creek Watershed are monitored monthly for physical conditions such as temperature, pH, dissolved oxygen, and conductivity which indicate major changes in water chemistry upstream to down and between streams and tributaries.

TEMPERATURE

The water temperatures in the streams monitored monthly in the Cherry Creek watershed vary seasonally and between locations. Overall, the sites on Cherry Creek (CC) and Piney Creek (PC) demonstrate less temperature variability than the sites on Cottonwood Creek (CT). The median water temperature in 2023 was at or below the baseline medians at all sites, except for the most upstream site, CT-P1, where it was slightly higher.

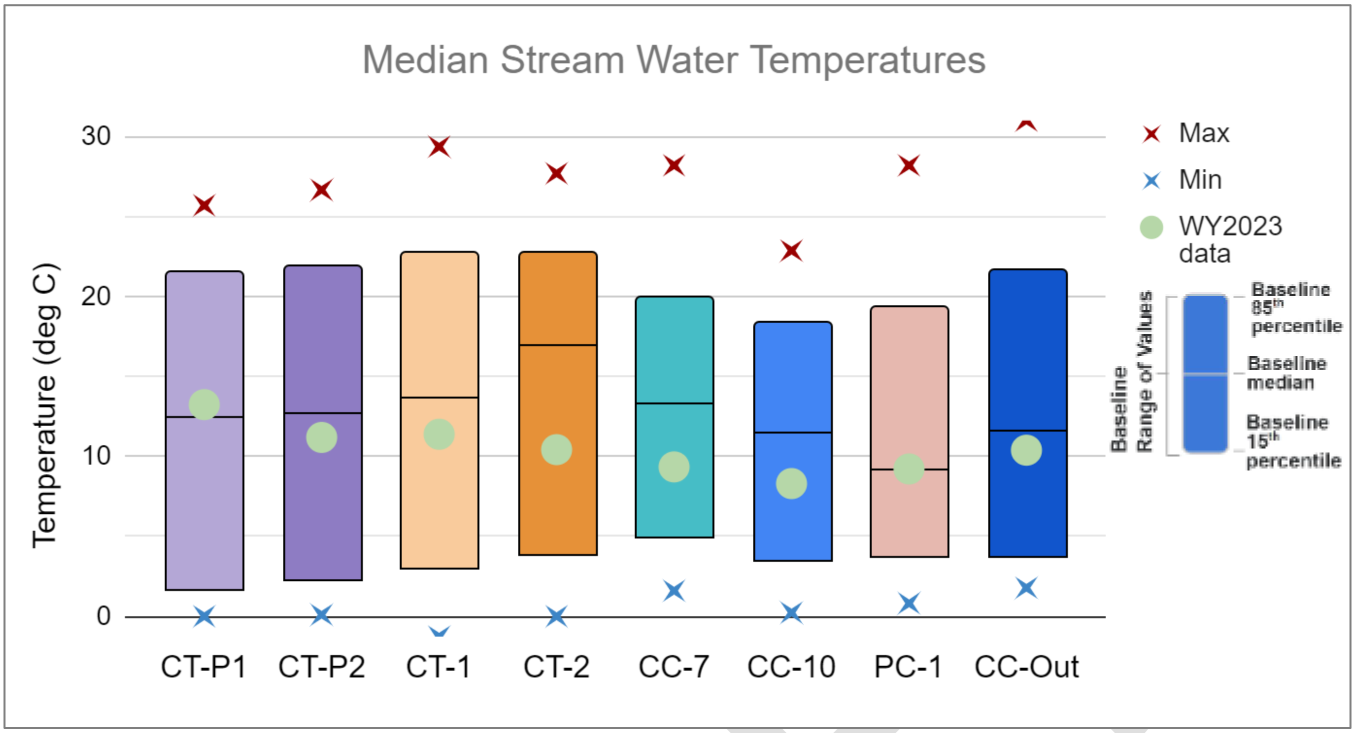


Figure 15. Stream Temperature Summary Statistics and WY 2023 medians.

PH

The pH in streams can affect aquatic life as well as alter the behavior of other compounds in the water. Often, major changes in pH can be traced back to human activities in the watershed, but plants and algae can also increase the pH as they remove carbon dioxide from the water during photosynthesis.

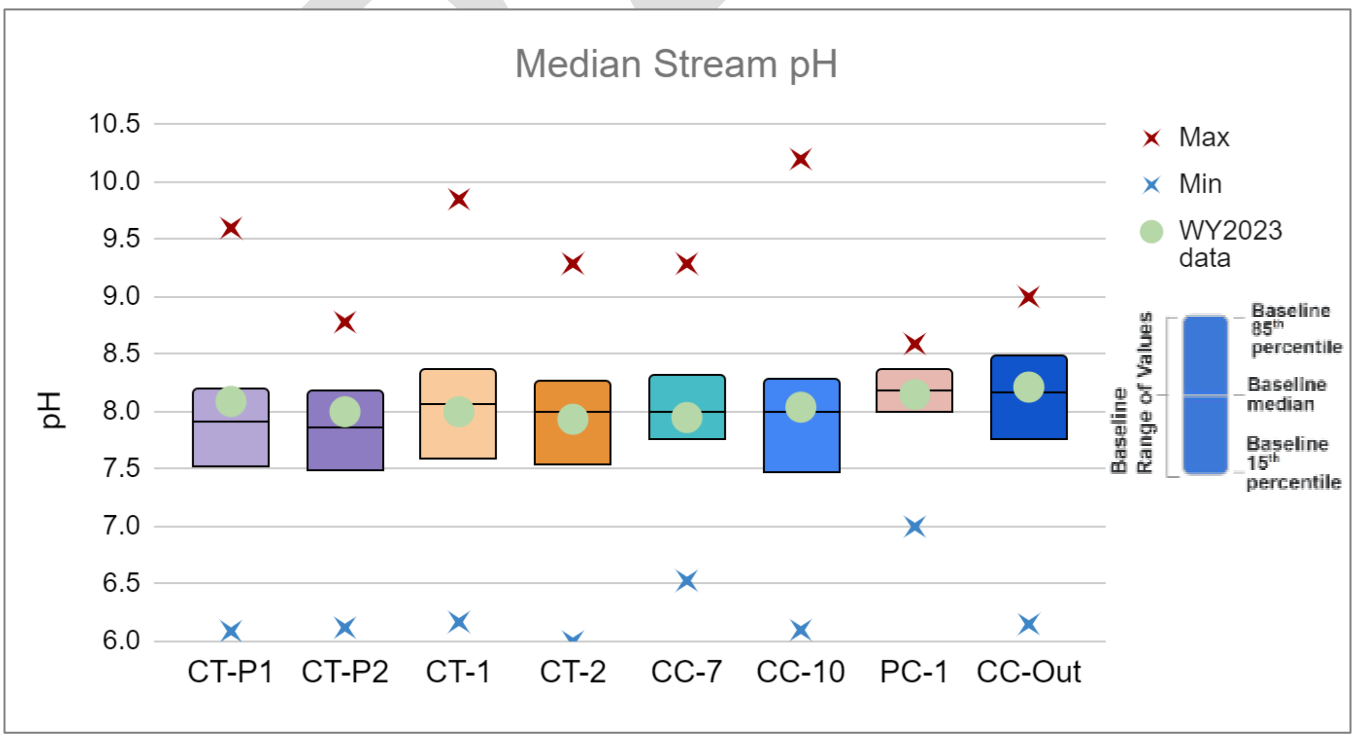


Figure 16. Stream pH Summary Statistics – POR Median and $15^{th}/85^{th}$ percentiles and WY 2023 Median

As illustrated in Figure 16, the pH in the streams monitored monthly during WY 2023 did not demonstrate any major differences spatially or temporally.

UP TO DOWNSTREAM CHERRY CREEK

Figure 17 shows the pH upstream to downstream on Cherry Creek from the bi-annual monitoring events from WY 2023 along with POR summary statistics. pH was similar or higher than November 2022 during May 2023 except for the outlet of the Reservoir, which was higher in November 2023. These pH values correlate with the fact that pH tends to be higher during the warmer months (e.g., May) as biological productivity in the water increases.

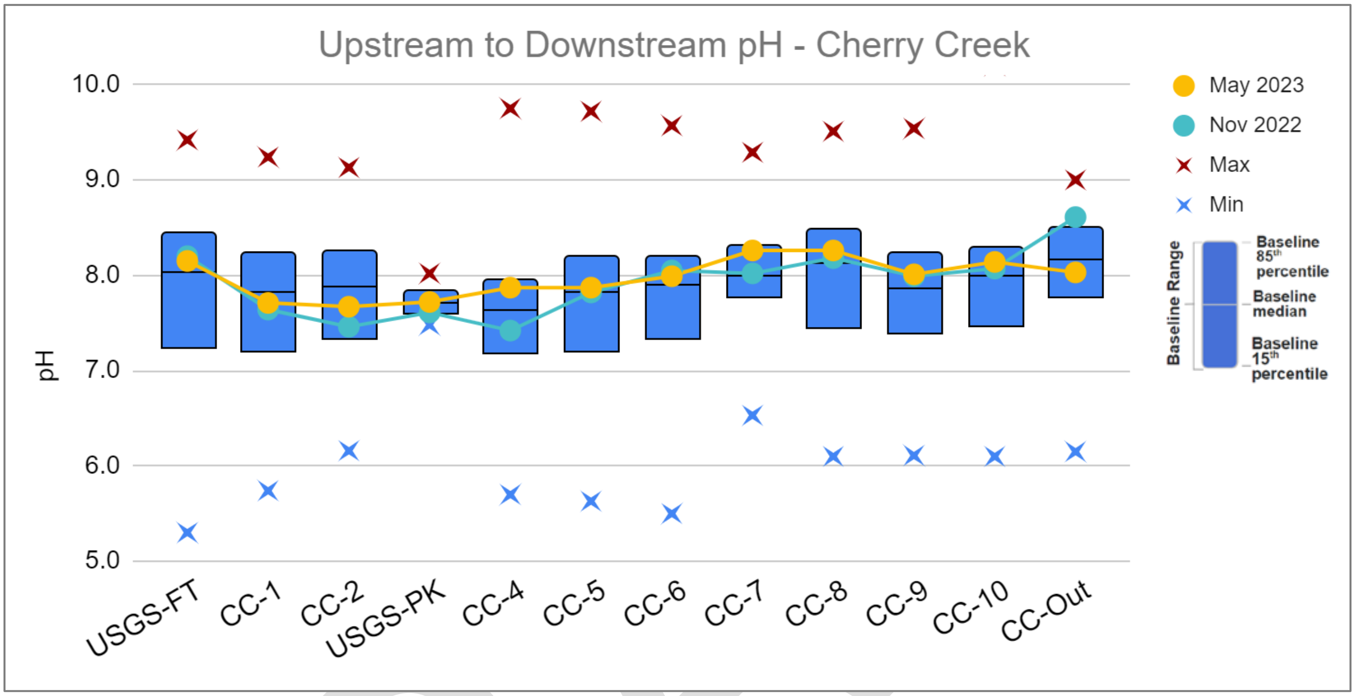


Figure 17. pH Upstream to Downstream on Cherry Creek, Baseline data 1994-2023 and WY 2023 – Nov 2022 and May 2023.

DISSOLVED OXYGEN

Dissolved oxygen in the water is required for aquatic life and generally decreases as water temperatures increase in the warmer months. The DO concentrations in the watershed demonstrate some variability seasonally and between sites (Figure 18).

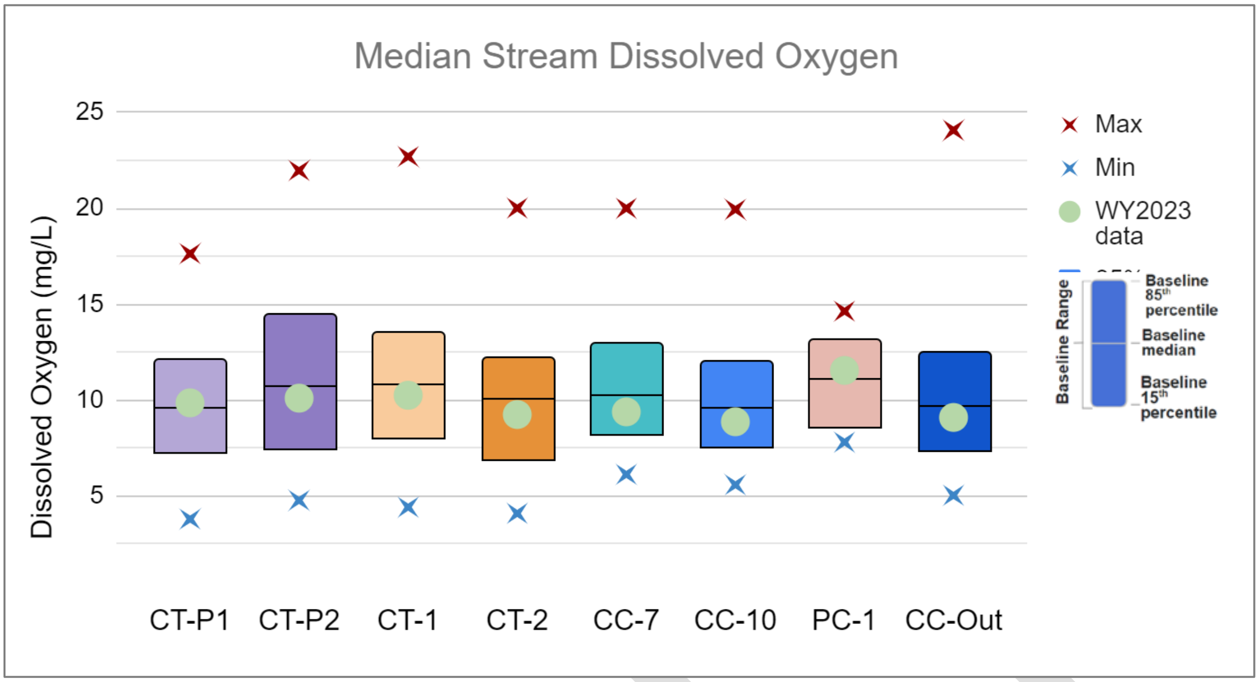


Figure 18. Dissolved Oxygen Concentration Summary Statistics - POR Median, 15th/85th percentile and WY 2023 Median.

MONTHLY STREAM SITES THROUGH THE WATERSHED

The baseline median DO concentration of the monthly stream sites is around 10 mg/L, and the WY 2023 median is slightly lower at 9.6 mg/L.

UP TO DOWNSTREAM CHERRY CREEK

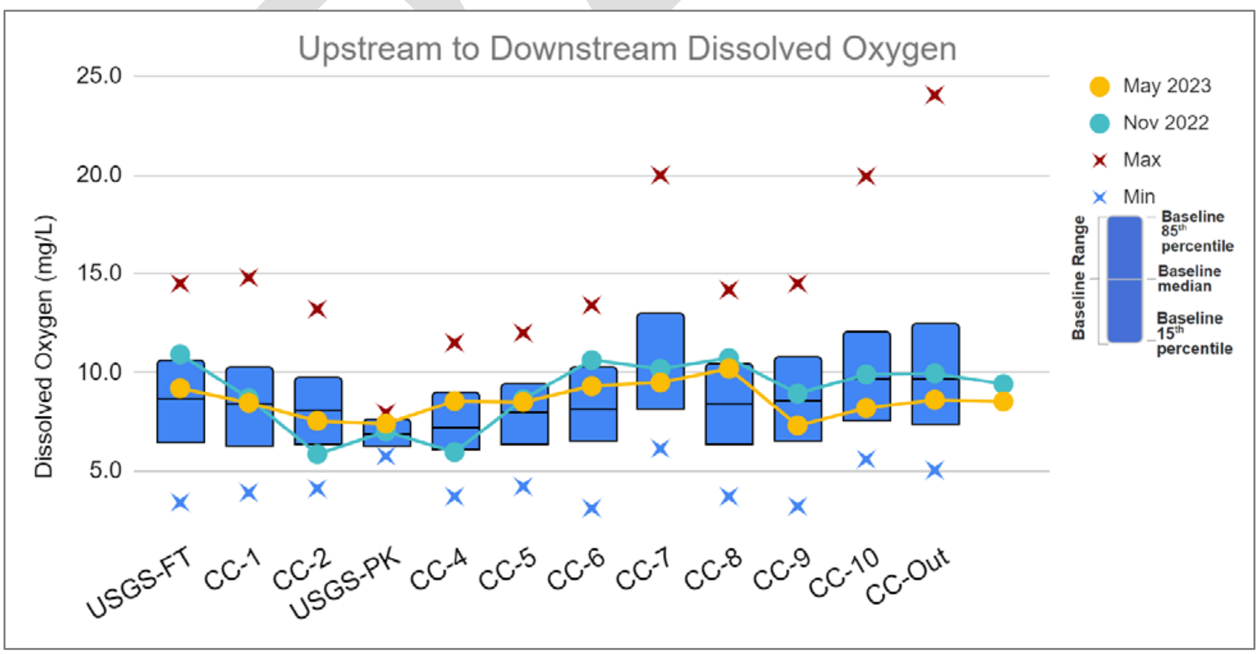


Figure 19. Dissolved Oxygen Concentrations Upstream to Downstream on Cherry Creek, Summary Statistics for POR and WY 2023 – Nov 2022 and May 2023.

Because higher water temperature decreases the solubility of oxygen in water, higher concentrations are usually observed in the colder months. In WY 2023, higher dissolved oxygen concentrations were observed in

November during the bi-annual upstream to downstream monitoring event on Cherry Creek, except for CC-2, USGS-Parker, and CC-4, which were higher in May (Figure 19).

CONDUCTIVITY

Conductivity, which indicates dissolved solids (i.e., salts minerals, etc.), demonstrates spatial variability within the Cherry Creek watershed. Although there are no conductivity standards for streams in the basin, the US EPA considers levels above 1,500 µS/cm above average for most streams in the US.

Figure 20 depicts the specific conductance at the sites monitored monthly over the entire period of record as well as the median values observed in WY 2023, with the EPA benchmark displayed on the for reference. Over the POR, the highest conductivity values are observed at the furthest upstream sites (CT-P1 and CT-P2) on Cottonwood Creek and decrease downstream towards the Reservoir. High conductivity has also been recorded on Piney Creek although the POR is shorter (2019-present). The lowest conductivity values are observed upstream on Cherry Creek at CC-7 and increase downstream at CC-10, just upstream of the Reservoir. The median conductivity at the outlet is slightly higher than Cherry Creek but lower than Cottonwood due to the relative inflow concentrations and mixing that occurs in the Reservoir. The WY 2023 median conductivity is similar to the baseline median at CC-7 but the WY 2023 medians are higher than the baseline medians for all other sites.

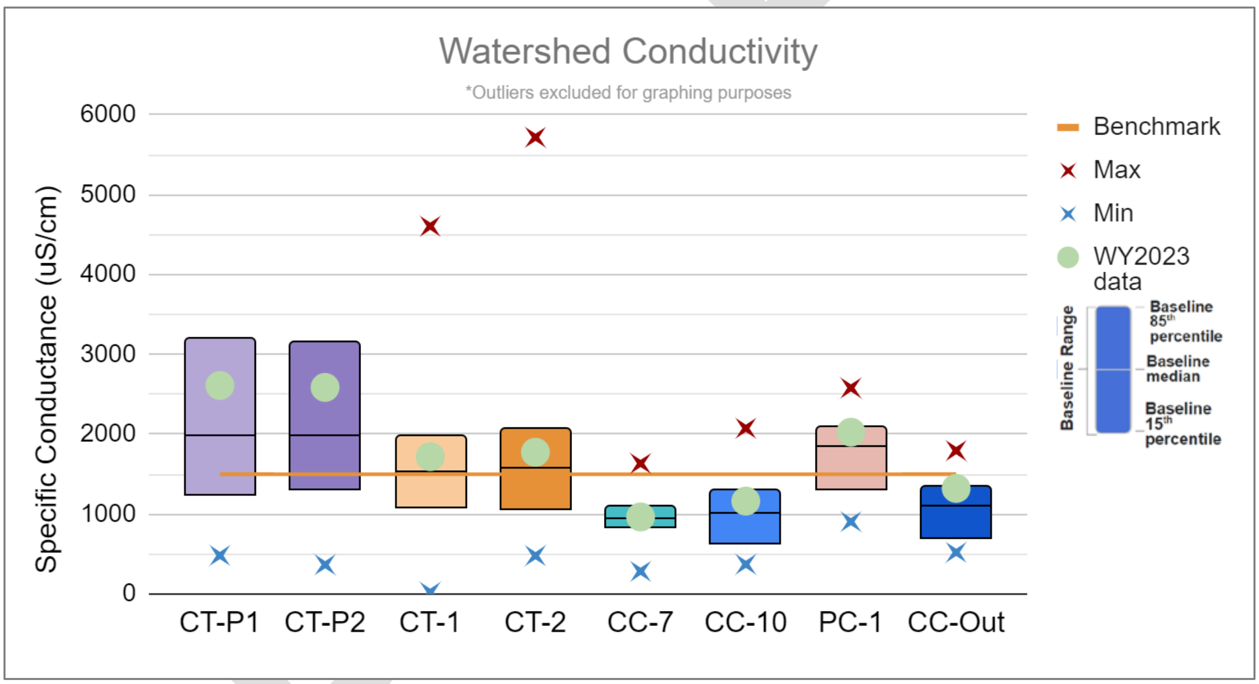


Figure 20. Watershed Stream Conductivity, Summary Statistics for POR and WY 2023 median.

MONTHLY STREAM SITES THROUGH THE WATERSHED

Within the watershed, conductivity varies seasonally. February has the highest historical maximum conductivity and January has the maximum in WY 2023 in Cherry Creek, Cottonwood Creek, and Piney Creek (Figure 21, Figure 22, and Figure 23). Lower conductivity values are observed during the summer months. The median conductivity on Cherry Creek was below the 1500 µS/cm EPA benchmark during WY 2023 (Figure 21) but the median values exceeded this threshold on Cottonwood Creek during all months except June, July, and September (Figure 22). The conductivity on Piney Creek demonstrated a similar pattern with only June and August values below the benchmark. Notably, the fall, winter and spring months of October through April, with the exception of February, all had conductivity at or near the maximum observed since monitoring started on Piney Creek in 2018 (Figure 23). Identifying source of elevated conductivity are beyond the scope of this report; however, higher winter concentrations suggest that road de-icing chemicals should be explored as a potential source.

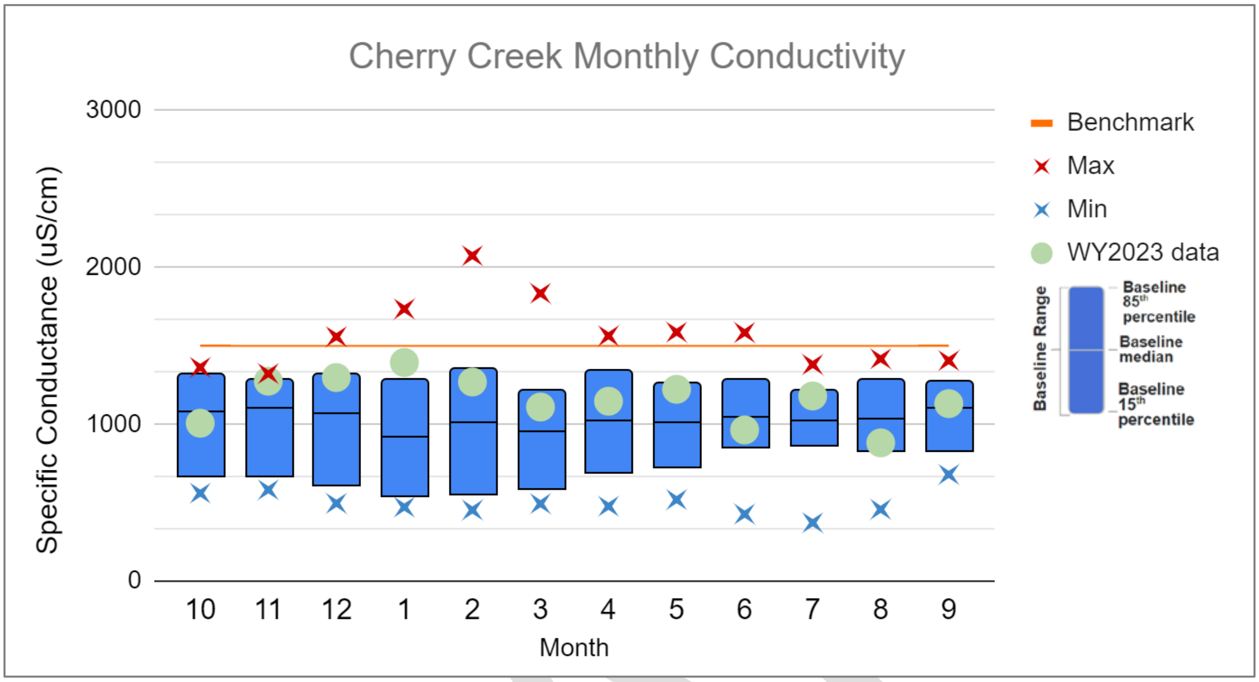


Figure 21. Monthly Conductivity on Cherry Creek at CC-10, POR Summary Statistics, and WY 2023.

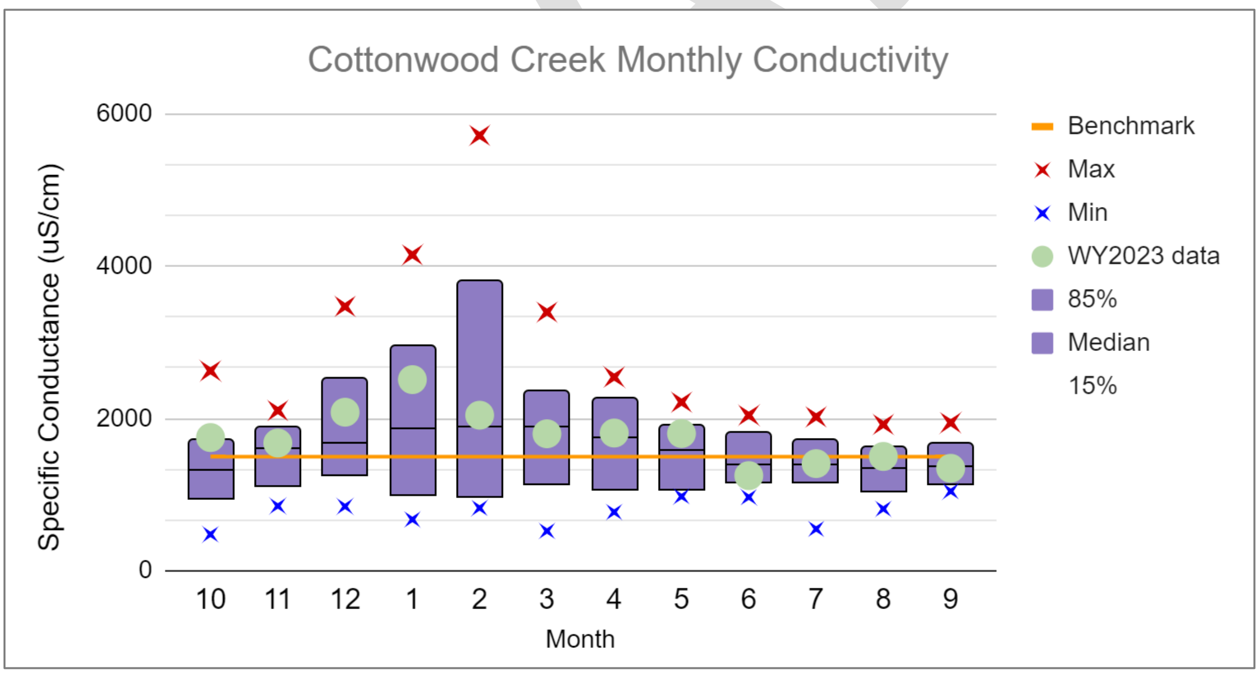


Figure 22. Monthly Conductivity on Cottonwood Creek at CT-2, POR Summary Statistics, and WY 2023.

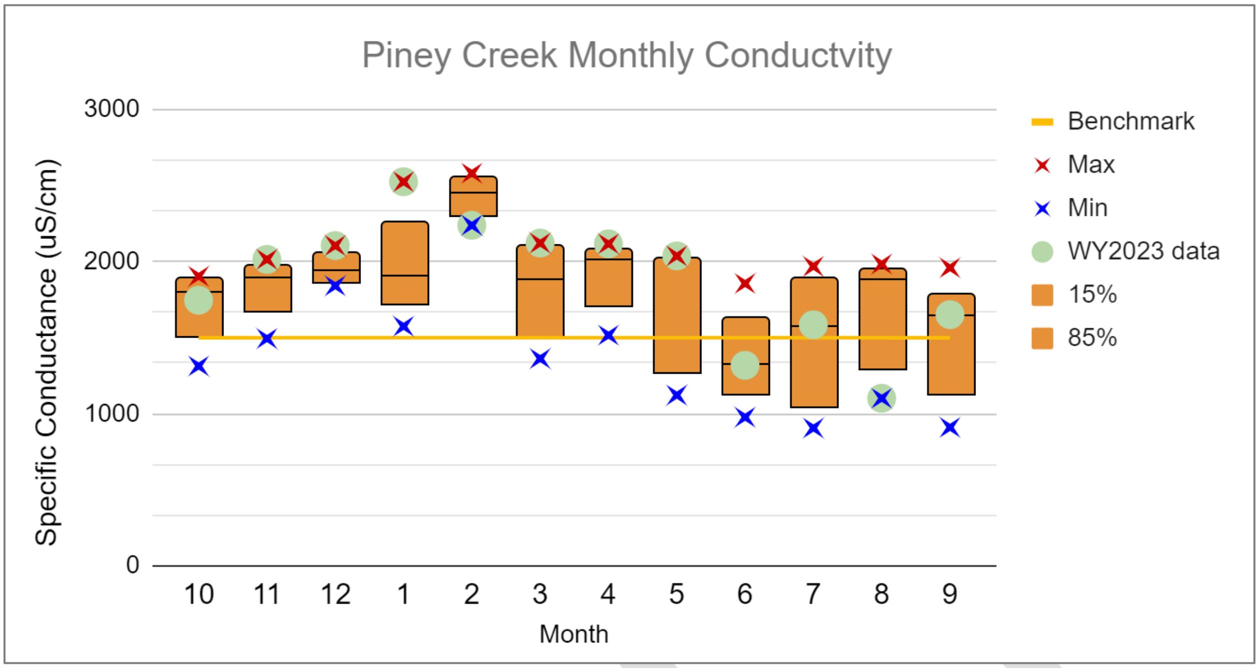


Figure 23. Monthly Conductivity on Piney Creek at PC-1, POR Summary Statistics, and WY 2023.

UP TO DOWNSTREAM CHERRY CREEK

Figure 24 illustrates the median conductivity upstream to downstream measurements in November 2022 and May 2023 on Cherry Creek along with the 1994 to 2023 POR summary statistics. A Mann Kendall trend analysis determined that the baseline and WY 2023 median conductivity significantly increases upstream to downstream (Figure 24). In addition, a Mann Kendall trend analysis demonstrates that the increasing trend of the annual mean conductivity of inflows to the Reservoir (Cherry Creek at CC-10 and on Cottonwood Creek at CT-2) is significant (Figure 25).

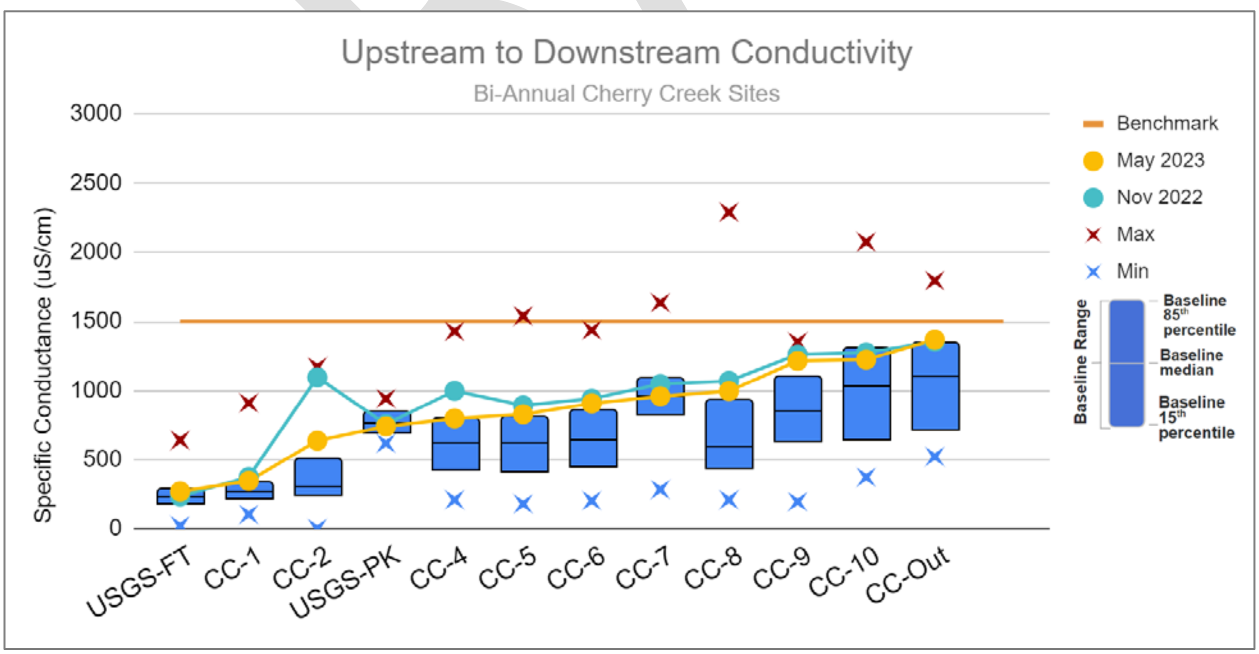


Figure 24. Conductivity Upstream to Downstream on Cherry Creek, Summary Statistics for POR and WY 2023 – Nov 2022 and May 2023.

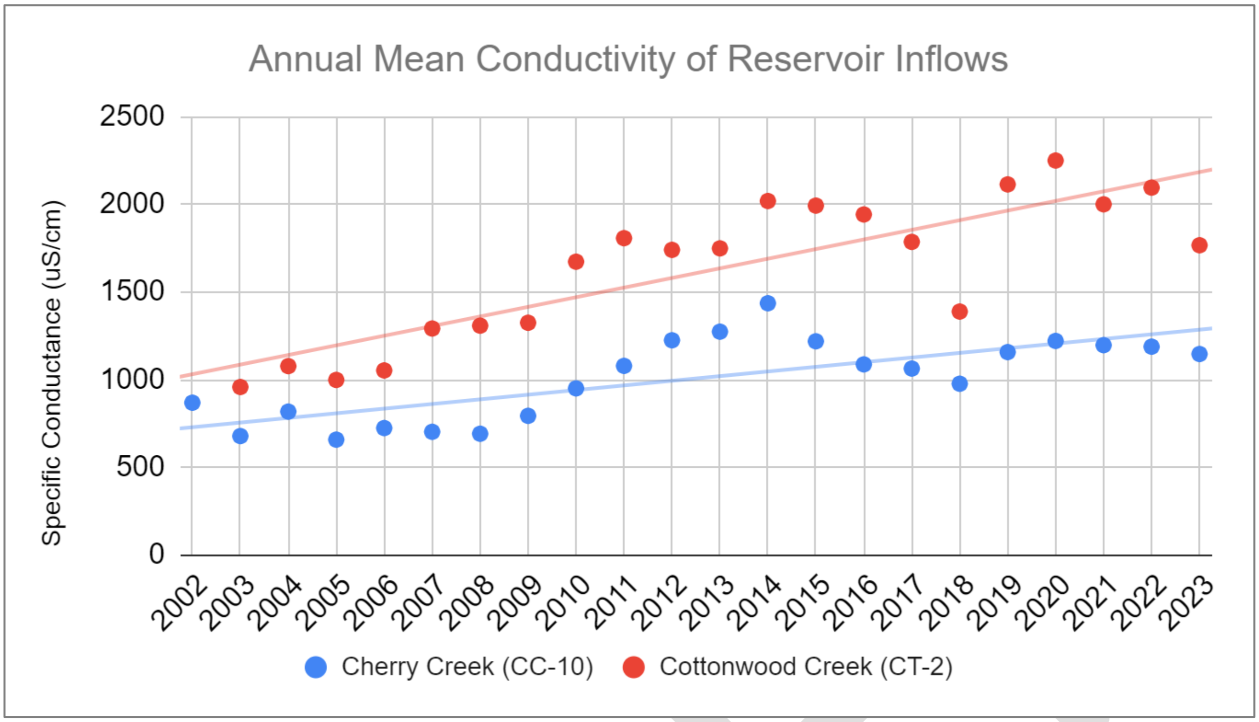


Figure 25. Historical Mean Conductivity on Cherry Creek and Cottonwood Creek.

NUTRIENTS AND SUSPENDED SOLIDS

Nutrients and suspended solids in the streams in the Cherry Creek Watershed have a direct impact on the water quality in the Reservoir. Nutrients demonstrate variable patterns and trends among sites and flow conditions. High stream flow increases suspended particles in the water, which is directly correlated to increased phosphorus concentrations. This is a key reason that CCBWQA supports stream stabilization projects and implementation of stormwater control measures in the watershed.

PHOSPHORUS

Figure 26 and Table 2 show the total phosphorus (TP) POR summary statistics and WY 2023 base and stormflow medians for each of the monthly stream sites. The maximum TP concentrations are observed during storm events with some extreme values not displayed for graphing purposes. Aligning with normal trends, the WY 2023 median TP concentrations were higher in storm flows than baseflows. Median TP instream concentrations were lower than the long-term baseline median at Cottonwood and Piney Creek sites under both baseflow and storm flow conditions and at Cherry Creek under baseflow conditions. For sites on Cherry Creek, WY 2023 TP concentrations were higher than the historic baseline median during storm conditions, likely due to significant erosion on Cherry Creek during major storm events. The higher TP concentrations in WY 2023 at these sites on Cherry Creek can be attributed to the major storm events that caused above average concentrations of suspended solids and phosphorus. The difference in medians upstream on Cherry Creek (CC-7) is minor, but the difference in medians at CC-10 was on the order of 200 ug/L higher. Piney Creek is the main tributary that enters Cherry Creek between these two sites. The WY 2023 median TP concentrations were also lower than the baseline at the outlet to the Reservoir (CC-0).

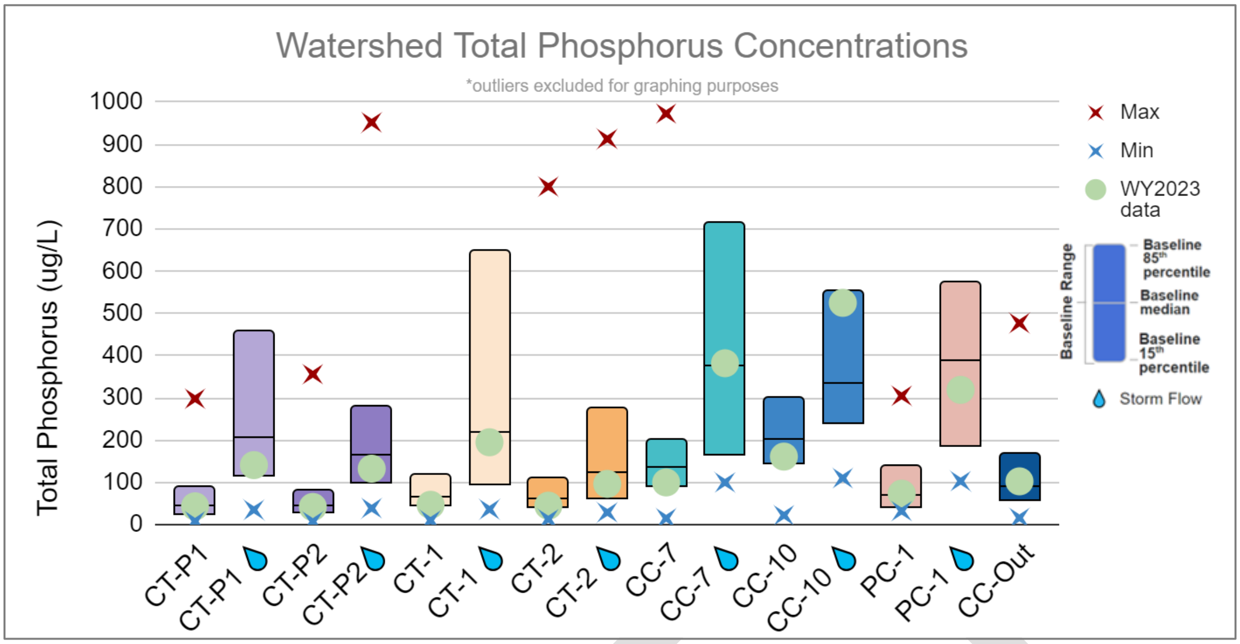


Figure 26. Watershed Phosphorus Concentrations (Base and Stormflow Conditions) POR Summary Statistics, and WY 2023.

Table 2. Total Phosphorus Concentration (µg/L) Baseline Summary Statistics and WY 2023 values, Base and Stormflow Conditions.

Site	Site/ Flow	POR Min	POR Median	POR Max	Count	WY2023 Median	Count
CT-P1 - Cottonwood Creek PRF Site P1	CT-P1	8	47	298	240	44	12
CT-P1 - Cottonwood Creek PRF Site P1	CT-P1 💧	35	210	2235	134	141	8
CT-P2 - Cottonwood Creek PRF Site P2	CT-P2	7	50	356	238	42	12
CT-P2 - Cottonwood Creek PRF Site P2	CT-P2 💧	39	168	952	124	133	8
CT-1 - Cottonwood Creek PRF Site 1	CT-1	10	69	*1461*	370	47	12
CT-1 - Cottonwood Creek PRF Site 1	CT-1 💧	36	222	*3570*	162	195	8
CT-2 - Cottonwood Creek PRF Site 2	CT-2	13	64	800	349	45	12
CT-2 - Cottonwood Creek PRF Site 2	CT-2 💧	29	127	913	163	97	8
CC-7 - Cherry Creek Station 7	CC-7	15	137	973	124	100	12
CC-7 - Cherry Creek Station 7	CC-7 💧	100	378	*2684*	43	382	7
CC-10 - Cherry Creek Station 10	CC-10	22	207	*2532*	378	161	12
CC-10 - Cherry Creek Station 10	CC-10 💧	110	336	*3110*	145	525	7
PC-1 - Piney Creek	PC-1	32	74	305	60	74	12
PC-1 - Piney Creek	PC-1 💧	103	390	*2250*	13	319	6
CC-Out - Cherry Creek Reservoir Outflow	CC-Out	16	95	477	340	103	12

Stormflow indicated with 💧 after site name.

*Values in *italics* were excluded from Figure 26 for graphing purposes.

During the upstream to downstream monitoring events in WY 2023, the TP concentrations were higher in May 2023 than November 2022 (Figure 27). Both events had TP concentrations that were lower than the respective baseline medians except for CC-7 and the outlet (CC-0) to the Reservoir in May.

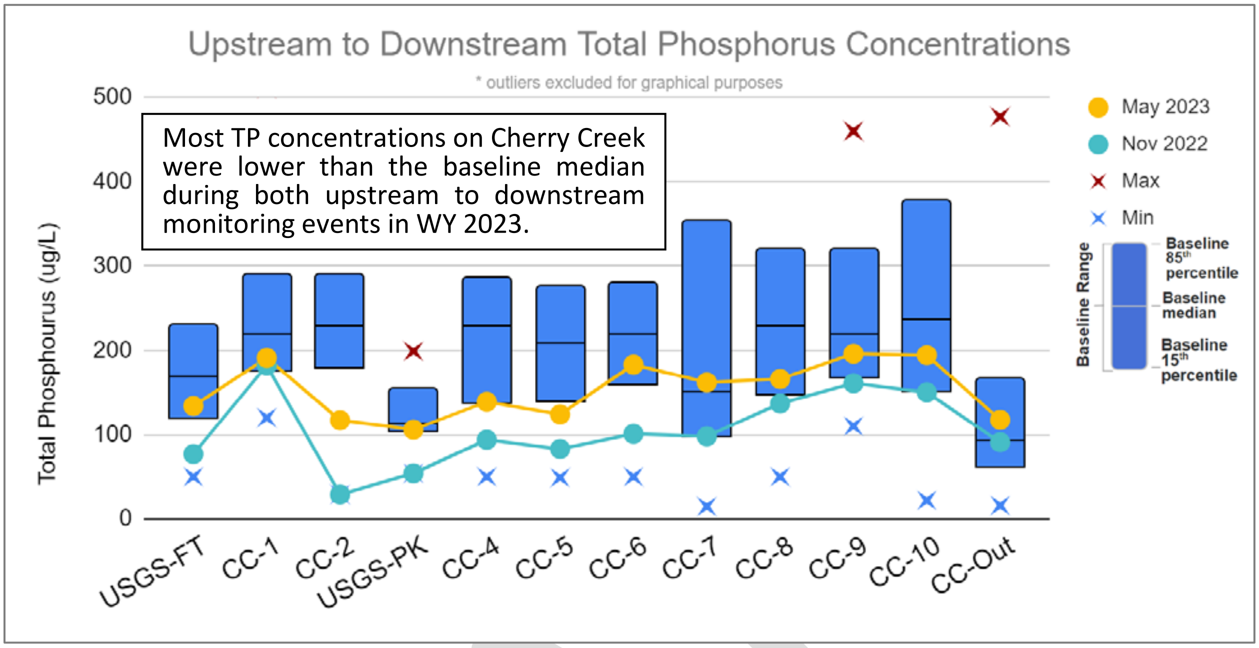


Figure 27. Upstream to Downstream Total Phosphorus Concentrations on Cherry Creek, Summary Statistics for POR and WY 2023 – Nov 2022 and May 2023.

NITROGEN

Nitrogen concentrations in the streams vary spatially throughout the watershed, seasonally and with different flow conditions. Figure 28 and Table 3 show the total nitrogen (TN) POR summary statistics and WY 2023 base and stormflow medians for each of the monthly stream sites. In contrast to TP, the maximum TN concentrations were not always observed during storm events (Table 2). The WY 2023 median TN concentrations were higher than the baseline median at three sites on Cottonwood Creek (CT-P1, CT-1, and CT-2) during baseflows and during storm events at CT-2. The WY 2023 median TN on Cherry Creek at CC-10 and the outlet to the Reservoir (CC-0) were also higher than the baseline medians during baseflow conditions.

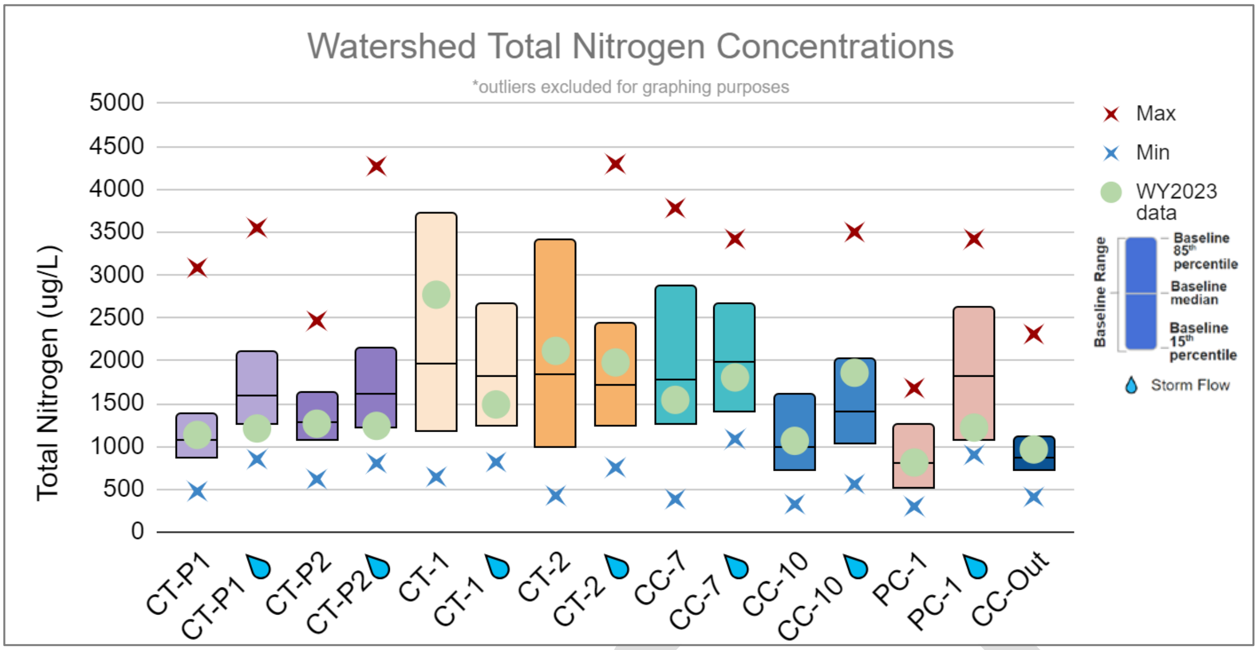


Figure 28. Watershed Nitrogen Concentrations (Base and Stormflow Conditions) Baseline Summary Statistics, and WY 2023.

Table 3. Total Nitrogen Concentration (µg/L) Baseline Summary Statistics and WY 2023 values, Base and Stormflow Conditions.

Site	Site/ Flow	Min	Median	Max	Count	WY2023 median	Count
CT-P1 - Cottonwood Creek PRF Site P1	CT-P1	477	1095	3084	239	1135	12
CT-P1 - Cottonwood Creek PRF Site P1	CT-P1 💧	851	1607	3550	133	1210	7
CT-P2 - Cottonwood Creek PRF Site P2	CT-P2	619	1294	2466	237	1265	12
CT-P2 - Cottonwood Creek PRF Site P2	CT-P2 💧	806	1615	4270	123	1240	7
CT-1 - Cottonwood Creek PRF Site 1	CT-1	645	1986	*6300*	301	2770	12
CT-1 - Cottonwood Creek PRF Site 1	CT-1 💧	818	1840	*7670*	129	1490	7
CT-2 - Cottonwood Creek PRF Site 2	CT-2	428	1858	*5761*	297	2115	12
CT-2 - Cottonwood Creek PRF Site 2	CT-2 💧	756	1733	4295	147	1980	7
CC-7 - Cherry Creek Station 7	CC-7	386	1800	3780	119	1544	12
CC-7 - Cherry Creek Station 7	CC-7 💧	1086	1988	3420	42	1805	6
CC-10 - Cherry Creek Station 10	CC-10	327	1002	*7980*	312	1065	12
CC-10 - Cherry Creek Station 10	CC-10 💧	562	1422	3500	122	1860	6
PC-1 - Piney Creek	PC-1	301	822	1680	59	813	12
PC-1 - Piney Creek	PC-1 💧	902	1840	3420	12	1220	5
CC-Out - Cherry Creek Reservoir Outflow	CC-Out	412	884	2310	291	965	12

Stormflow indicated with 💧 after site name.

*Values in *italics* were excluded from Figure 28 for graphing purposes.

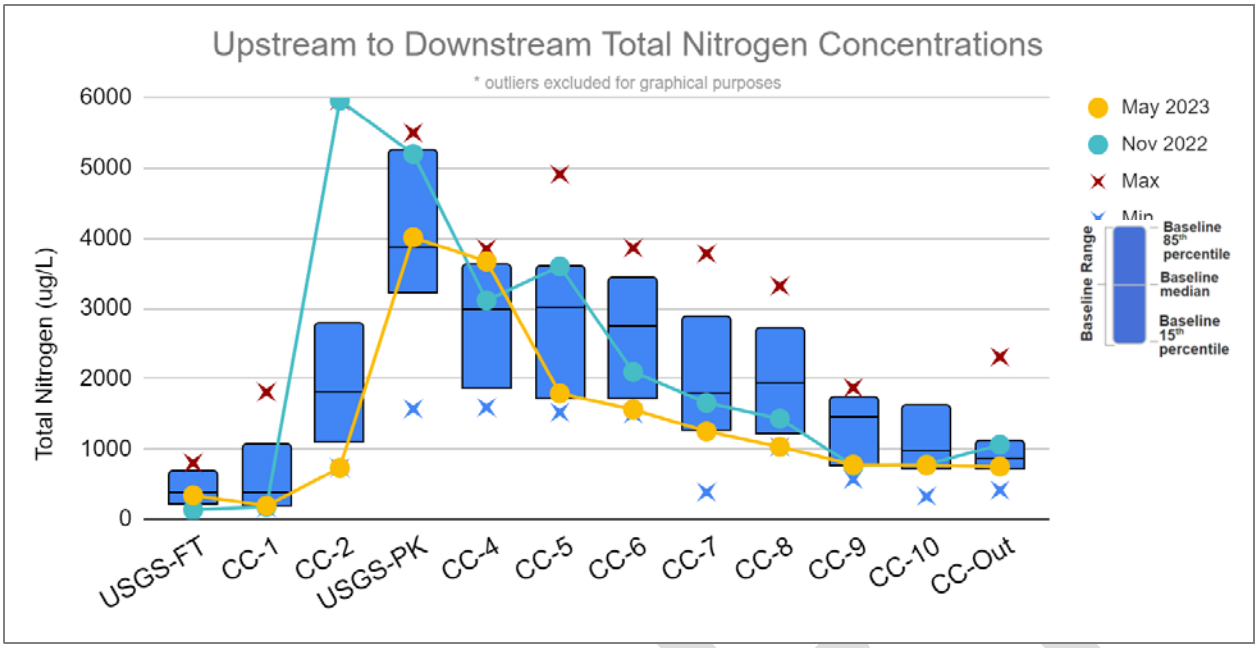


Figure 29. Upstream to Downstream Total Nitrogen Concentrations on Cherry Creek, Summary Statistics for POR and WY 2023 – Nov 2022 and May 2023.

During the upstream to downstream monitoring events in WY 2023, the TN concentrations were usually higher in November 2022 than in May 2023 (Figure 27). TN concentrations were only higher in May at the USGS Franktown site and CC-4. Both events had TN concentrations that followed a similar pattern to the baseline median with concentrations increasing between CC-2 and USGS Parker and then decreasing downstream towards the Reservoir. Discharges from WWTPs can impact stream nitrogen concentrations upstream to downstream and may vary seasonally.

SUSPENDED SOLIDS

Concentrations of TSS vary spatially throughout the watershed, seasonally and with different flow conditions. Figure 30 and Table 4 show the TSS POR summary statistics and WY 2023 base and stormflow medians for each of the monthly stream sites. As expected with high flow, TSS concentrations are higher during storm conditions when fast moving runoff transports eroded sediment from stream channels and other impervious areas. The WY 2023 median TSS concentrations were only higher than the baseline medians on Cherry Creek (CC-7 and CC-10) during storm events (Table 4). Of particular note are the very high TSS concentrations under storm conditions at CC-10, which are more than double the historic baselined for stormflows. These higher concentrations are consistent with the significant erosion and damage to the stream channel during the major 2023 storm events. CCBWQA is prioritizing stream restoration (Cherry Creek Reach 1) in the vicinity of CC-10, which is supported by WY2023 data.

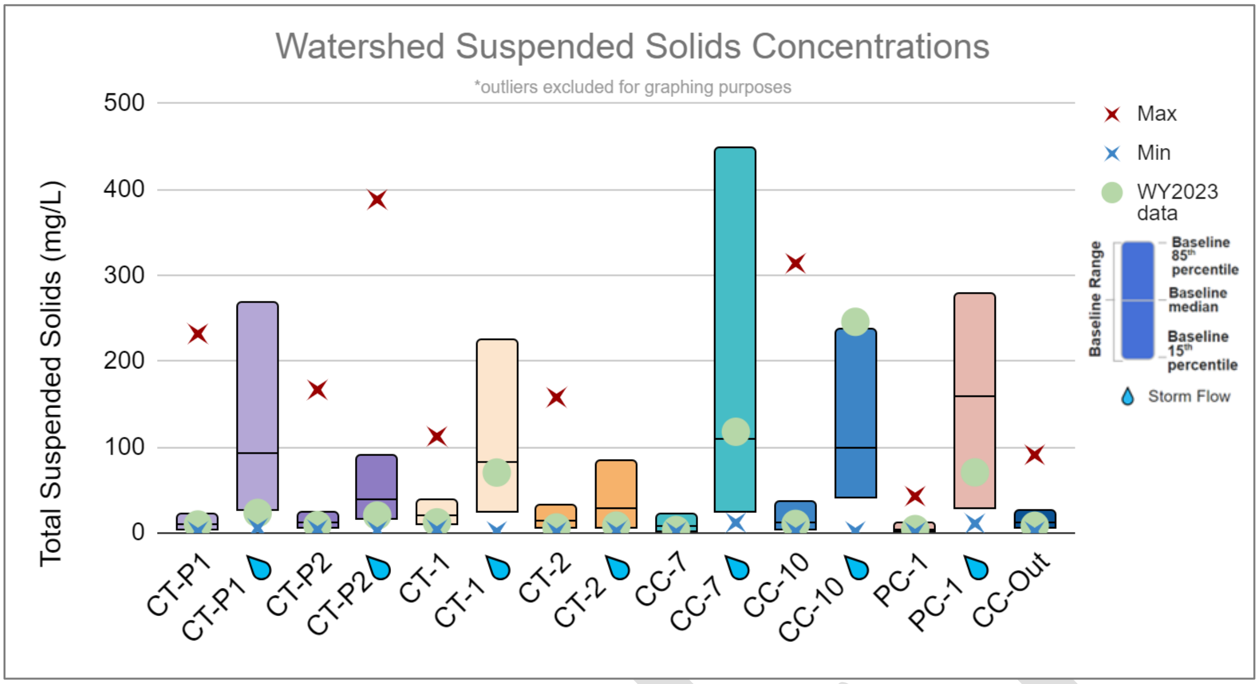


Figure 30. Median Suspended Solids Concentrations (Base and Stormflow Conditions) POR Summary Statistics, and WY 2023.

Table 4. Total Suspended Solids Concentration (mg/L) POR Summary Statistics and WY 2023 values.

Site	Site/ Flow	Min	Median	Max	Count	WY2023 median	Count
CT-P1 - Cottonwood Creek PRF Site P1	CT-P1	2	12	232	173	10	11
CT-P1 - Cottonwood Creek PRF Site P1	CT-P1 💧	6	94	*1053*	124	24	8
CT-P2 - Cottonwood Creek PRF Site P2	CT-P2	4	14	167	170	9	12
CT-P2 - Cottonwood Creek PRF Site P2	CT-P2 💧	3	40	388	114	21	8
CT-1 - Cottonwood Creek PRF Site 1	CT-1	4	22	113	192	13	12
CT-1 - Cottonwood Creek PRF Site 1	CT-1 💧	2	83	*1337*	110	71	8
CT-2 - Cottonwood Creek PRF Site 2	CT-2	1	15	158	197	7	12
CT-2 - Cottonwood Creek PRF Site 2	CT-2 💧	2	31	*782*	130	9	8
CC-7 - Cherry Creek Station 7	CC-7	1	8	*1060*	120	4	12
CC-7 - Cherry Creek Station 7	CC-7 💧	12	110	*1360*	43	118	7
CC-10 - Cherry Creek Station 10	CC-10	2	14	314	207	11	12
CC-10 - Cherry Creek Station 10	CC-10 💧	2	101	*1660*	110	246	7
PC-1 - Piney Creek	PC-1	1	5	43	60	5	12
PC-1 - Piney Creek	PC-1 💧	11	160	*685*	13	71	6
CC-Out - Cherry Creek Reservoir Outflow	CC-Out	2	14	91	196	9	12

Stormflow indicated with 💧 after site name.

*Values in *italics* were excluded from Figure 30 for graphing purposes.

3.5 POLLUTANT REDUCTION FACILITIES (PRFS)

The CCBWQA has completed multiple pollutant abatement projects (PAPs), which include PRFs, in various locations through the watershed. WQCC CR 72 states:

> *"Pollutant Reduction Facility (PRF) means projects that reduce nonpoint source pollutants in stormwater runoff that may also contain regulated stormwater. PRFs are structural measures that include, but are not limited to, detention, wetlands, filtration, infiltration, and other technologies with the primary purpose of reducing pollutant concentrations entering the Reservoir or that protect the beneficial uses of the Reservoir."*

The SAP includes an assessment of the effectiveness of selected PRF projects in relation to nutrients and sediment concentrations as water moves downstream. The current monitoring program includes assessment of the PRFs on Cottonwood Creek and McMurdo Gulch. Monitoring of PRFs is conducted in accordance with CR 72.8.1(b).

The Cottonwood Creek PRF is a series of wetland detention systems, along with an area where stream reclamation has been completed, collectively referred to as the Cottonwood Treatment Train (Figure 13). The monitoring program includes water quality samples during routine baseflow sampling and storm conditions above and below these sites. Table 5 summarizes whether median upstream-to-downstream concentrations significantly differ for each PRF for WY 2023. The same comparison is provided for the last 10 years (2014-2023) (Section 3.5.1).

Table 5. Significant Reductions in Nutrients and Suspended Solids in CCBWQA PRFs, WY 2023 and 2014-2023.*

PRF	Cottonwood Treatment Train		Peoria Pond		Perimeter Pond		Cottonwood Creek btw Ponds		McMurdo Gulch
Analyte	Base	Storm	Base	Storm	Base	Storm	Base	Storm	Base
Nitrate+ Nitrite					●				●
Ammonia									●
Nitrogen, Total					●				○
Phosphorus, Soluble Reactive									●
Phosphorus, Dissolved			□						●
Phosphorus, Total		●	□	●	●	●			●
Total Suspended Solids	○	●		●	●	●			
Volatile Suspended Solids	●	●		□	□	●			

**Legend:* ○ significant *reduction of upstream to downstream medians in WY 2023,* □ *significant reductions of upstream to downstream median (2014-2023),* ● *significant reduction upstream to downstream medians in WY 2023 and 2014-2023, blank cells indicate no significant reduction or an increase upstream to downstream*

While the limited results from each water year are often not sufficient to complete a robust statistical analysis, annual calculations are included for reference. This analysis leverages the "PRF Statistics Tool" from the data portal to evaluate the statistical significance of changes above and below PRFs during WY 2023. The tool applies a non-parametric Wilcoxon signed rank test to assess whether differences are present between two data sets, with statistically significant differences indicated by p values less than 0.05.

Table 6, Table 7, Table 8, and Table 9 list the median difference of the upstream to downstream paired data (sampled on the same day), and hypothesis test results regarding whether the data for the current water year indicate that the median downstream concentrations are significantly lower than the upstream in base and stormflows for WY 2023.

During WY 2023, the median concentrations of TSS and VSS downstream of Cottonwood Treatment Train as a whole were lower during both base and storm events (Table 6). The median TN and TDN concentrations were lower downstream during baseflow and stormflow and the NH_3-N and TDP, and TP were lower during storms sampled. The difference of median TP and TSS concentrations downstream during storms was significant.

Dissolved nutrient forms are typically harder to remove than particulate forms, which is supported by the water quality data from the Cottonwood Creek PRFs, as well as other national data sources such as the International Stormwater BMP Database (Clary, et al. 2020). Additionally, some nitrogen forms already have low concentrations, which may not be reducible. The NO_2+NO_3 concentrations at these sites are well below the nitrate standard of 10,000 ug/L, however the TN concentrations do exceed CDPHE's interim total nitrogen "value" of 2,010 ug/L during the fall and winter. This elevated concentrations during cooler months could be due to the decomposition of wetland plants. An additional factor that affects interpretation of the system as a whole is that Lone Tree Creek, which contains treated effluent from ACWWA, enters Cottonwood Creek between the two PRF ponds.

Table 6. Pollutant Reduction Analysis, Cottonwood Creek Treatment Train PRF, WY 2023.

Cottonwood Treatment Train	Baseflow				Stormflow			
Site	CT-P1	CT-2	Upstream to Downstream		CT-P1	CT-2	Upstream to Downstream	
Events (n)	12	12			8	8		
Analyte	Median Concentration		Median Difference	Significant	Median Concentration		Median Difference	Significant
NO_2+NO_3, µg/L	368	1,250	882		346	670	324	
NH_3-N, µg/L	21	42	33		25	19	-9	
TN, µg/L	1,135	2,115	1,105		1,210	1,980	600	
SRP, µg/L	5	5	-1		30	44	-5	
TDP, µg/L	10	13	2		44	50	-4	
TP, µg/L	44	45	-4		141	97	-41	Yes
TSS, mg/L	10	6	-4	Yes	24	9	-13	Yes
VSS, mg/L	3	2	-1	Yes	6	3	-3	Yes

Performance of the two PRF ponds (Peoria Pond and Perimeter Pond Wetland System) was also evaluated individually as shown in Table 7 and Table 8). Peoria Pond demonstrated reductions in median concentrations of all phosphorus and suspended solid forms in both base and stormflow conditions. The Perimeter Pond demonstrated higher reductions in TP, TSS, and VSS during storm events. The Perimeter Pond also demonstrated lower median concentrations downstream of all forms of NO_2+NO_3 and TN during baseflows. The median concentrations of TP and TSS downstream were significantly lower than upstream during WY 2023 storms sampled, which is similar to the long-term trends observed over time (Section 3.5.1).

Table 7. Pollutant Reduction Analysis, Peoria Pond PRF, WY 2023.

Peoria Pond	Baseflow				Stormflow 💧			
Site	CT-P1	CT-P2	Upstream to Downstream		CT-P1	CT-P2	Upstream to Downstream	
Events	12	12			8	8		
Analyte	Median Concentration		Median Difference	Significant	Median Concentration		Median Difference	Significant
NO_2+NO_3, µg/L	368	536	104		346	388	47	
NH_3-N, µg/L	21	15	-9		25	58	66	
TN, µg/L,	1,135	1,265	180		1,210	1,240	20	
SRP, µg/L	5	4	-1		30	26	-6	
TDP, µg/L	10	9	-1		44	37	-7	
TP, µg/L	44	42	-2		141	133	-11	
TSS, mg/L	10	9	-1		24	21	-2	
VSS, mg/L	3	2	-1		6	6	-1	

Table 8. Pollutant Reduction Analysis, Perimeter Pond PRF, WY 2023.

Perimeter Pond	Baseflow				Stormflow 💧			
Site	CT-1	CT-2	Upstream to Downstream		CT-1	CT-2	Upstream to Downstream	
Events (n)	12	12			8	8		
Analyte	Median Concentration		Median Difference	Significant	Median Concentration		Median Difference	Significant
NO_2+NO_3, µg/L	1,450	1,250	-280	Yes	453	670	342	
NH_3-N, µg/L	33	42	4		23	19	16	
TN, µg/L	2,770	2,115	-530	Yes	1,490	1,980	90	
SRP, µg/L	5	5	0		15	44	3	
TDP, µg/L	12	13	0		28	50	3	
TP, µg/L	47	45	-8	Yes	195	97	-112	Yes
TSS, mg/L	13	7	-4	Yes	71	9	-63	Yes
VSS, mg/L	3	2	-1		13	3	-10	Yes

Table 9. Pollutant Reduction Analysis, Cottonwood Treatment Train between the PRF ponds, WY 2023

Cottonwood Ck btwn Pnds	Baseflow				Stormflow 💧			
Site	CT-P2	CT-1	Upstream to Downstream		CT-P2	CT-1	Upstream to Downstream	
Events (n)	12	12			8	8		
Analyte	Median Concentration		Median Difference	Significant	Median Concentration		Median Difference	Significant
NO_2+NO_3, µg/L	536	1,450	972		388	453	-13	
NH_3-N, µg/L	15	33	22		58	23	-8	
TN, µg/L	1,265	2,770	1,440		1,240	1,490	150	
SRP, µg/L	4	5	0		26	15	-11	
TDP, µg/L	9	12	2		37	28	-10	
TP, µg/L	42	47	2		133	195	64	
TSS, mg/L	9	13	3		21	71	29	
VSS, mg/L	2	3	0		6	13	3	

There have been multiple stream restoration projects completed on Cottonwood Creek between the Peoria and Perimeter Pond. When evaluating the Cottonwood treatment train between the two ponds (Table 9), the concentrations downstream were the same or higher for all nutrients and suspended solids during baseflow. Although the median NO_2+NO_3, NH_3-N, SRP and TDP were lower in downstream stormflows during WY 2023, the difference was not significant. A significant limitation of this analysis is that loading from Lone Tree Creek, which includes ACWWA's discharger, is not accounted for in the table. It may be useful to compare the downstream site to pre-restoration concentrations or to remove add an estimate for ACWWA's load into the analysis.

One of the upper tributaries of Cherry Creek is McMurdo Gulch, which has had multiple reclamation projects co-sponsored by the Town of Castle Rock and CCBWQA completed early in the area's urbanization to install a proactive PRF designed to protect the gulch and reduce sediment and nutrient loading into Cherry Creek. In addition, over the last few years, other improvements have been completed in various reaches of the same area to further stabilize the channel. Routine water quality samples were collected every other month only under baseflow conditions from monitoring site MCM-1, upstream of the stream reclamation project area, and MCM-2, downstream.

In WY 2023, all median nutrients and suspended solids concentrations were similar or lower downstream of the multiple phases of the McMurdo stream reclamation projects (Table 10) when compared to the upstream site. The median concentrations of TN and TP were significantly lower downstream in WY 2023, which is similar to the long-term trend observed over the last 10 years (Section 3.5.1).

Table 10. Pollutant Reduction Analysis, McMurdo Gulch, WY 2023.

McMurdo Gulch	Baseflow			
Site	MCM-1	MCM-2	Upstream to Downstream	
Events	6	6		
Analyte	Median Concentration		Median Difference	Significant
NO_2+NO_3, µg/L	539	36	-403	Yes
NH_3-N, µg/L	3	3	0	
TN, µg/L,	1,002	613	-432	Yes
SRP, µg/L	261	157	-64	Yes
TDP, µg/L	274	182	-70	Yes
TP, µg/L	335	243	-67	Yes
TSS, mg/L	3	2	0	
VSS, mg/L	1	1	0	

4.5.1 LONG-TERM PRF EVALUATION

The long-term PRF evaluation also examines the statistical significance of changes above and below PRFs and over time using the non-parametric Wilcoxon signed rank test to assess whether the downstream concentrations are significantly lower than upstream during the period evaluated. Activities such as implementation of CMs and maintenance (e.g., dredging and wetland harvesting) may affect results during various time periods. If more detailed analysis is required to evaluate projects, maintenance activities, or other changes in the watershed, specific evaluations can be completed using the PRF Statistics Tool available on the CCBWQA data portal (https://www.ccbwqportal.org/prf-statistics-tool).

Using this tool, an analysis of upstream to downstream concentrations over the last 10 water years (WY 2014-2023) was completed to assess changes (Δ) in median concentrations during baseflow and stormflow conditions. Tables 11 through 15 summarize the median upstream and downstream concentrations, the median difference of the paired data, and if the statistical analysis indicate that the median downstream concentrations are significantly lower than the upstream during the specified time period. Cottonwood Treatment Train as a whole (Table 11), Peoria Pond (Table 12) and Perimeter Pond (Table 13) all showed statistically significant reductions of TP and TSS during stormflow conditions. Additionally, the Perimeter Pond PRF demonstrated statistically significant reductions in median TP, TN, and TSS concentrations in baseflow conditions as well. There was no significant difference in base or stormflow concentrations upstream to downstream between the two ponds from WY 2014-2023 (Table 10). As noted above this may be due to the nutrients added from Lone Tree Creek in this reach.

For the McMurdo Gulch PRF during WY 2014-2023 (Table 15), the upstream to downstream concentrations of TP and TN during baseflow conditions demonstrated a statistically significant reduction. Statistically significant changes during baseflow conditions were not present for TSS; however, TSS concentrations were extremely low.

Table 11. Pollutant Reduction Analysis of Cottonwood Treatment Train (2014-2023).

Cottonwood Treatment Train	Baseflow				Stormflow			
Site	CT-P1	CT-2	Upstream to Downstream		CT-P1	CT-2	Upstream to Downstream	
Analyte	Median Concentration		Median Difference	Significant	Median Concentration		Median Difference	Significant
TN, µg/L	1115	1764	605	No	1691	1690	130	No
TP, µg/L	46	49	1	No	221	84	-131	Yes
TSS, mg/L	11	10	-1	No	111	12	-89	Yes

Table 12. Pollutant Reduction Analysis of Peoria Pond (2014-2023).

Peoria Pond	Baseflow				Stormflow			
Site	CT-P1	CT-P2	Upstream to Downstream		CT-P1	CT-P2	Upstream to Downstream	
Analyte	Median Concentration		Median Difference	Significant	Median Concentration		Median Difference	Significant
TN, µg/L	1108	1325	210	No	1631	1683	-5	No
TP, µg/L	44	42	-1	No	141	147	-11	Yes
TSS, mg/L	11	12	1	No	111	27	-57	Yes

Table 13. Pollutant Reduction Analysis of Perimeter Pond (2014-2023).

Perimeter Pond	Baseflow				Stormflow			
Site	CT-1	CT-2	Upstream to Downstream		CT-1	CT-2	Upstream to Downstream	
Analyte	Median Concentration		Median Net Change	Significant	Median Concentration		Median Net Change	Significant
TN, µg/L	2050	1690	-280	Yes	1922	1740	-41	
TP, µg/L	62	50	-9	Yes	175	92	-86	Yes
TSS, mg/L	19	11	-7	Yes	64	12	-56	Yes

Table 14. Pollutant Reduction Analysis of Cottonwood Creek Between Ponds (2014-2023).

Cottonwood Ck btwn Pnds	Baseflow				Stormflow			
Site	CT-P1	CT-P2	Upstream to Downstream		CT-P1	CT-P2	Upstream to Downstream	
Analyte	Median Concentration		Median Net Change	Significant	Median Concentration		Median Net Change	Significant
TN, µg/L	1330	2146	920		1705	1993	238	No
TP, µg/L	50	61	8		148	183	7	No
TSS, mg/L	12	19	6		27	75	12	No

Table 15. Pollutant Reduction Analysis of McMurdo Gulch (2014-2023).

McMurdo Gulch	Baseflow			
Site	MCM-1	MCM-2	Upstream to Downstream	
Analyte	Median Concentration		Median Net Change	Significant
TN, µg/L	571	390	-179	Yes
TP, µg/L	334	253	-89	Yes
TSS, mg/L	2	3	1	No

GROUNDWATER

Groundwater in the Cherry Creek watershed is monitored to gain insight into interactions with surface water and the impacts of groundwater on the Reservoir. Although additional wells have been monitored historically, there are currently four active wells sampled twice a year in the spring and fall. The wells are located throughout the basin, including the top of the basin (MW-1), the middle of the basin (MW-5), and just upstream (MW-9) and downstream of the Reservoir (MW-Kennedy) (Figure 2) that are monitored bi-annually (Table 1).

5.5.1 GROUNDWATER WATER QUALITY

Groundwater is monitored for physical parameters such as temperature, pH, and dissolved oxygen and chemical composition including nutrients and dissolved solids.

PH

pH in the Cherry Creek Watershed tends to be relatively stable in groundwater, ranging between 6 and 8.5. Although there has been more variability in the pH of the monitoring wells historically, the pH during both upstream to downstream monitoring events were within or near the 15th and 85th percentile baseline ranges (Figure 31).

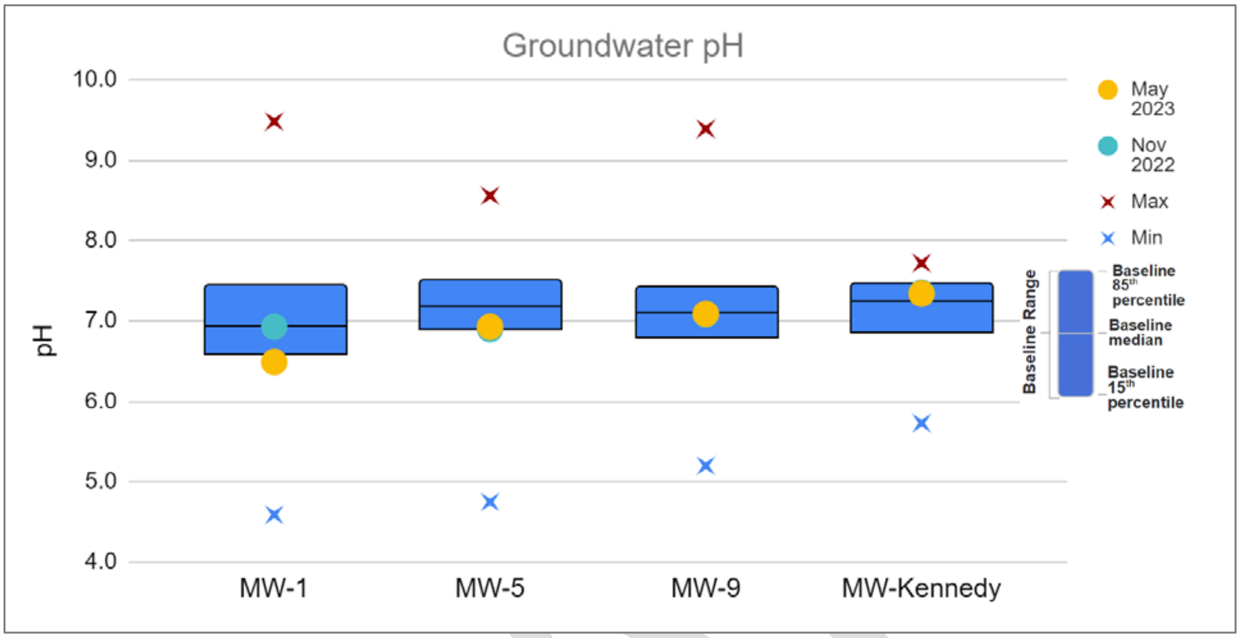


Figure 31. Median pH Groundwater Monitoring Wells

CONDUCTIVITY AND DISSOLVED SOLIDS

In addition to natural sources, conductivity in groundwater can be impacted due to interactions with surface water. Figure 32 shows the conductivity from the bi-annual monitoring events from WY 2023 along with POR summary statistics. All monitoring well results, with the exception of November MW-1, were higher than the 85th percentile POR value. A Mann Kendall trend analysis demonstrates that the increasing trend of the annual median conductivity of all monitoring wells upstream of the Reservoir as well as MW-Kennedy below the Reservoir is significant (Figure 33).

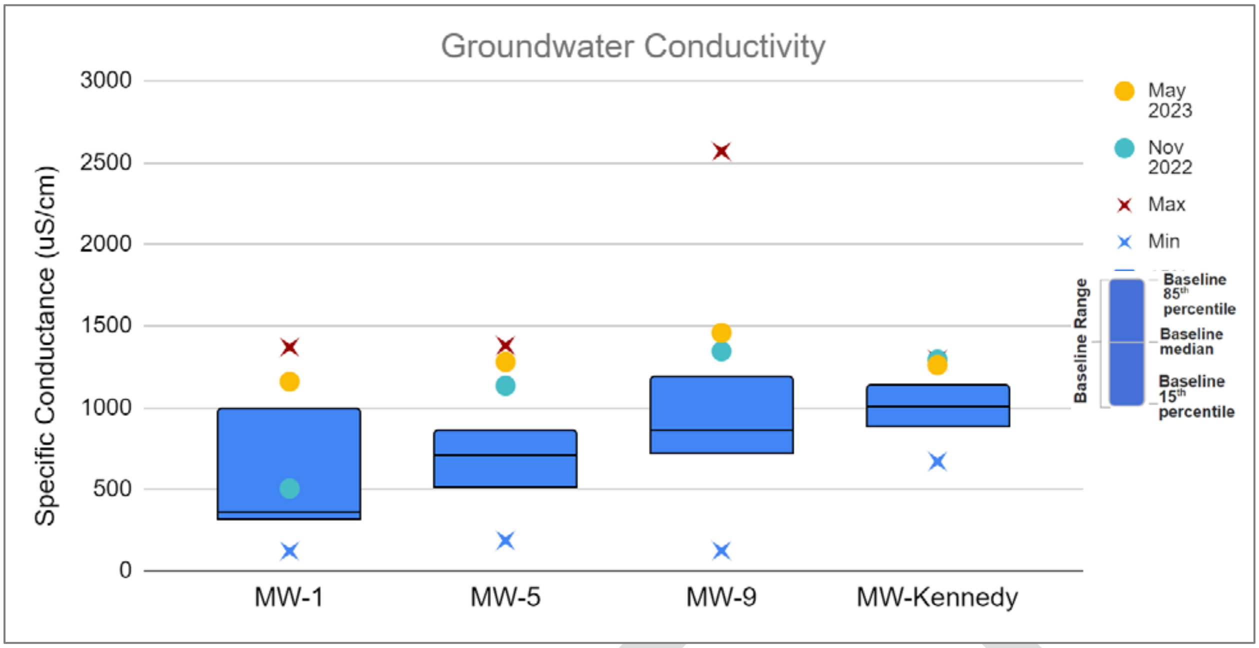


Figure 32. Groundwater Conductivity Summary Statistics and WY 2023 values (Nov 2022 and May 2023).

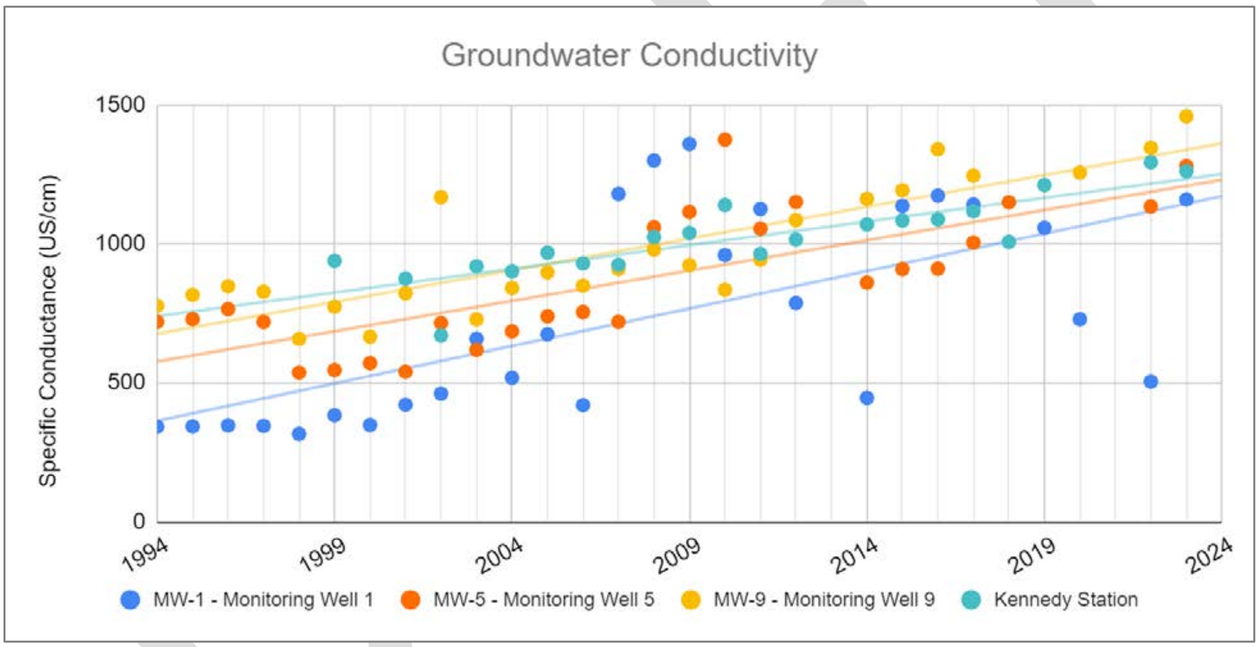


Figure 33. Historical Mean Conductivity in Groundwater Monitoring Wells

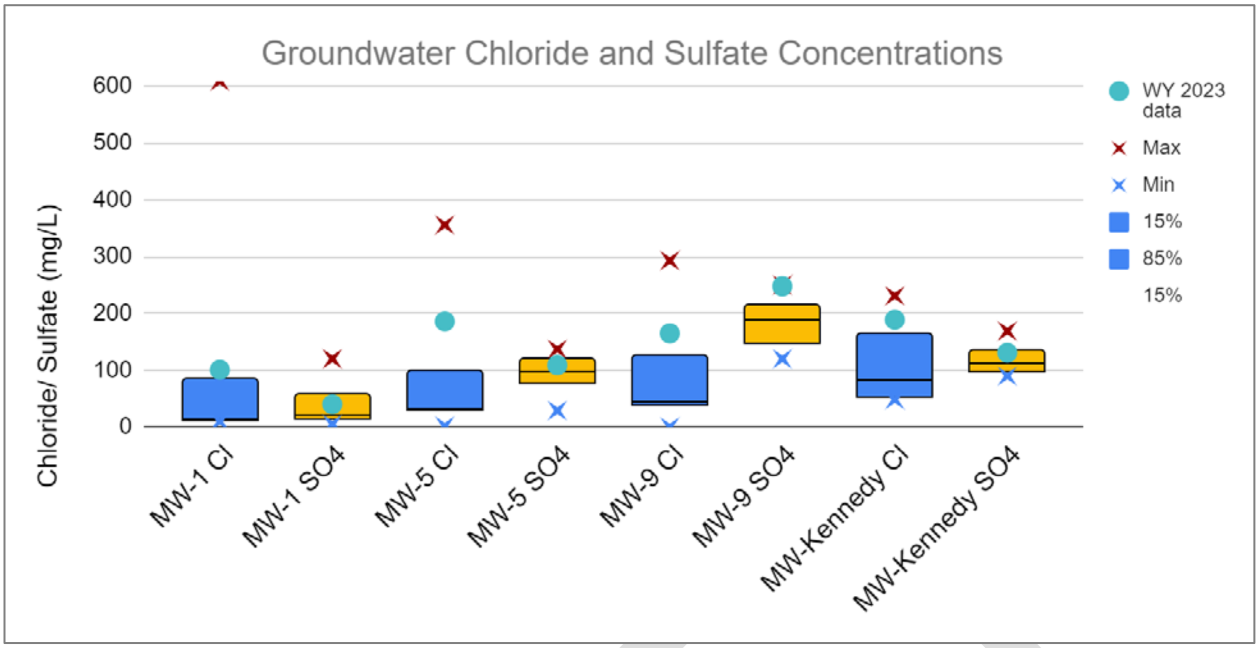


Figure 34. Groundwater Chloride and Sulfate Concentrations

Two of the major dissolved solids components contributing to conductivity are chloride and sulfate. Chloride and sulfate concentrations from the monitoring wells are depicted in Figure 34 with the median from the two monitoring events in WY 2023. The WY 2023 median chloride concentrations were higher than the baseline median and above the 85th percentile for the POR. The WY 2033 median sulfate concentrations were above the baseline median at all sites and MW-9 was above the 85th percentile for the POR. Although these are not drinking water wells, the state water supply standard for both chloride and sulfate is 250 mg/L (5 CCR 1002-41.8). MW-9 approached but did not exceed this value in May 2023 with a concentration of 248 mg/L.

PHOSPHORUS

Although total phosphorus is the form evaluated most frequently in surface water, total dissolved phosphorus (TDP) and soluble reactive phosphorus (SRP) concentrations are more useful to compare in groundwater. These forms also have a longer POR and provide more representative concentrations because manual bailing used to sample the wells can increase suspended solids containing particulate phosphorus that skew the results for TP.

Figure 35 shows the median groundwater TDP concentrations and Figure 36 shows the summary statistics for soluble reactive phosphorus in all the monitoring wells that have been monitored historically in addition to the median concentrations from WY 2023 (November 2022 and May 2023). The concentrations of both TDP and SRP were higher in November at all three sites upstream but lower at the Kennedy well below the Reservoir.

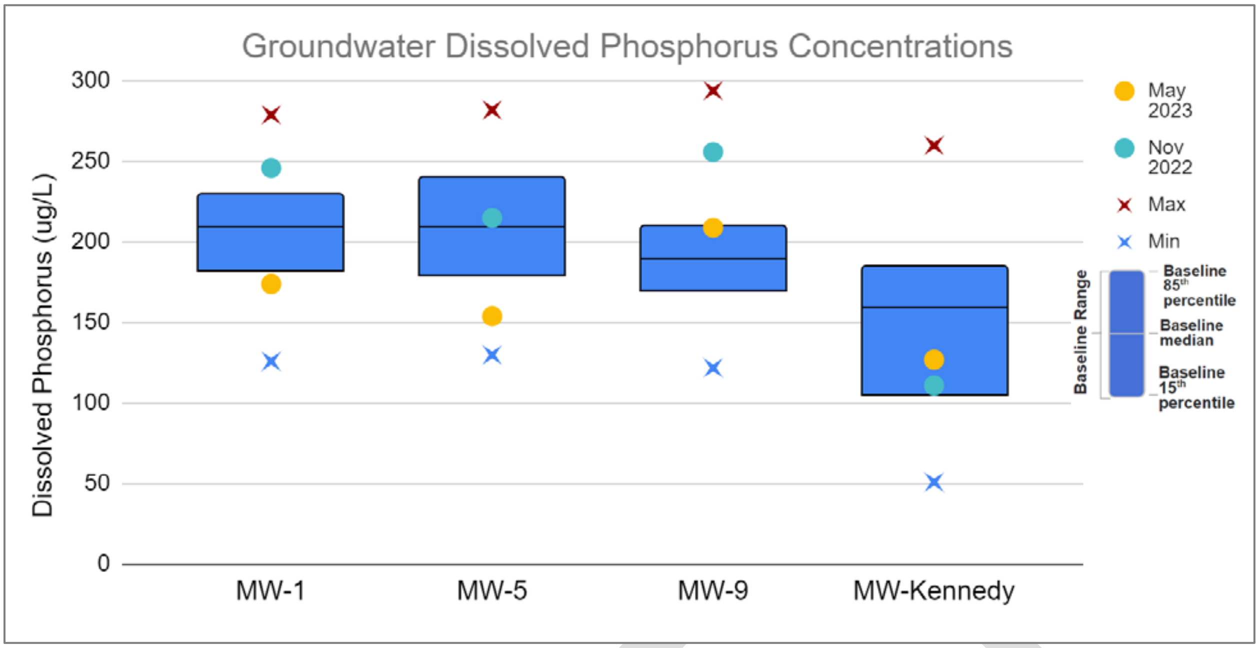


Figure 35. Groundwater Total Dissolved Phosphorus Concentrations, POR Summary Statistics, and WY 2023 (November 2022 and May 2023).

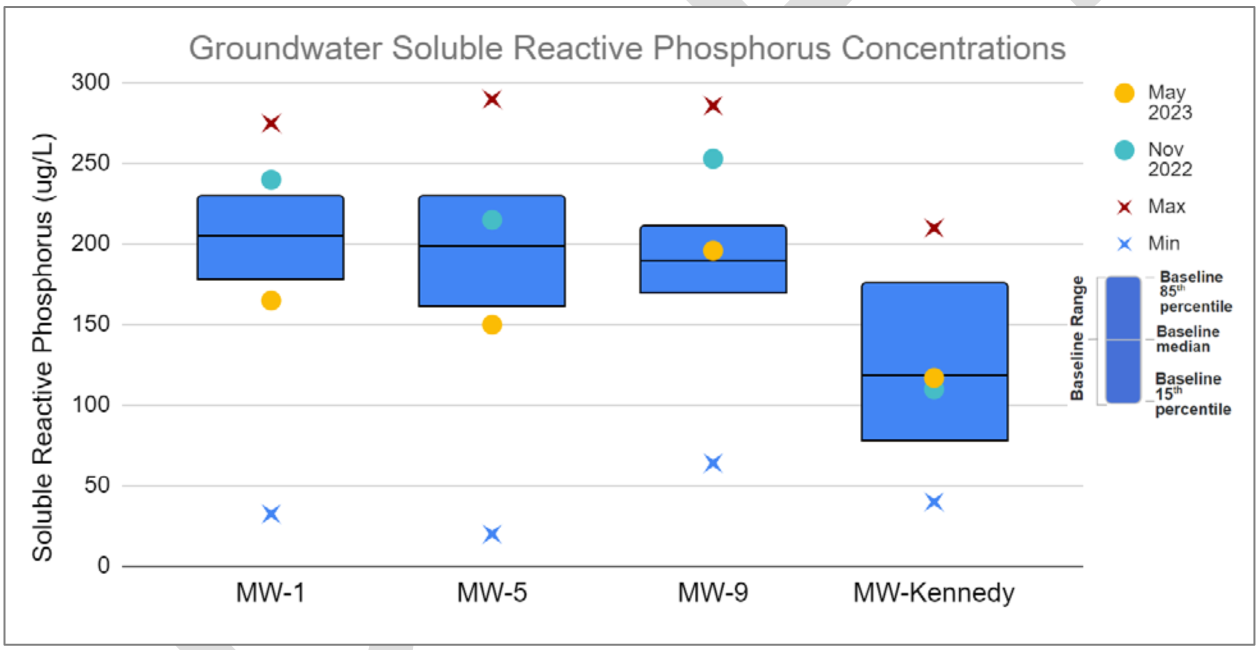


Figure 36. Groundwater Soluble Reactive Phosphorus Concentrations, POR Summary Statistics, and WY 2023 (November 2022 and May 2023).

On average, SRP makes up 86-88% of the TDP concentrations in MW-1 and MW-9 and 95% of the TDP concentration observed in MW-9 just upstream of the Reservoir. Table 16 includes the summary statistics for TDP concentrations for the POR and the median of the WY 2023 values.

Figure 37 depicts the annual mean TDP at the three monitoring wells upstream of the Reservoir. A Mann Kendall trend analysis demonstrates that there are statistically significant increases over time for TDP concentrations in the groundwater above the Reservoir (MW-9) (Figure 37), but not at the other two wells.

Table 16. Dissolved Phosphorus Concentrations (µg/L) Summary Statistics (1994-2023) and WY 2023 Median.

Site	Site Abv.	Min	Baseline Median	Max	Count	WY 2023 median
MW-1 - Monitoring Well 1	MW-1	126	210	279	121	210.0
MW-5 - Monitoring Well 5	MW-5	130	210	282	120	184.5
MW-9 - Monitoring Well 9	MW-9	122	190	294	142	232.5
Kennedy Station	MW-Kennedy	51	160	260	41	119.0

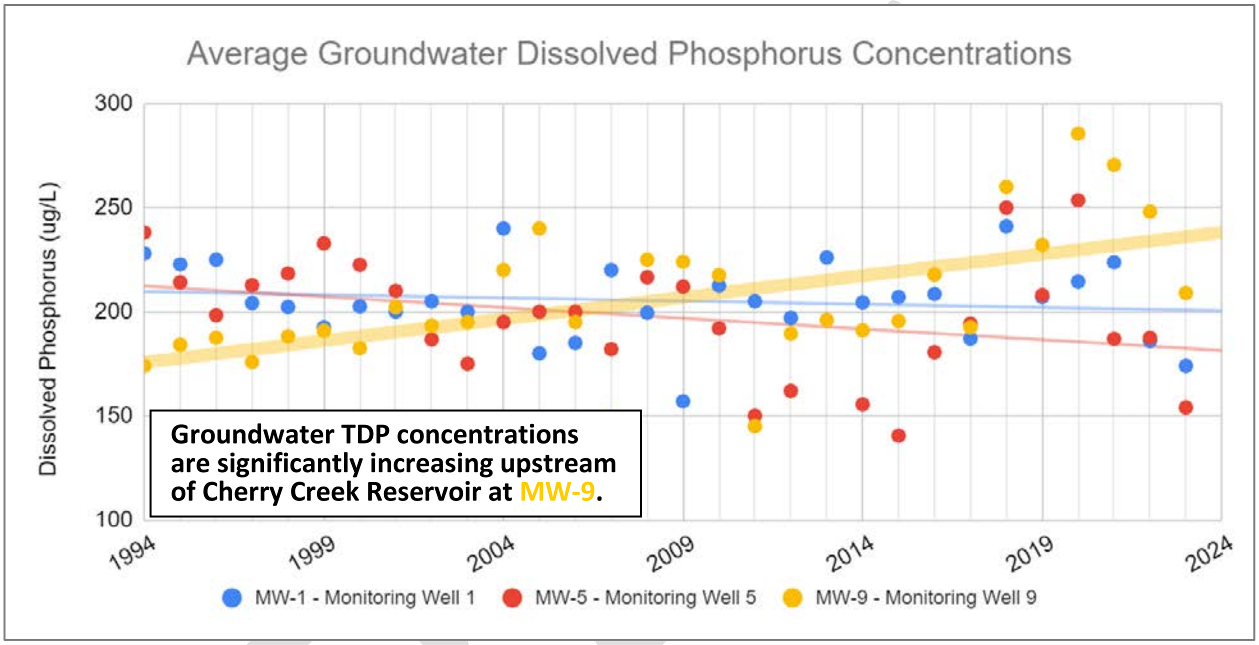


Figure 37. Annual Mean Dissolved Phosphorus in Groundwater Monitoring Wells Upstream of Cherry Creek Reservoir.

NITROGEN

Total Nitrogen (TN) in groundwater has been monitored since 2016 and Nitrate + Nitrite (NO_3+NO_2-N) since 2013. TN concentration summary statistics for all the monitoring wells that have been monitored historically by CCBWQA in addition to the median concentrations from WY 2023 (November 2022 and May 2023) are depicted in Figure 38 and NO_3+NO_2-N is shown in Figure 39.

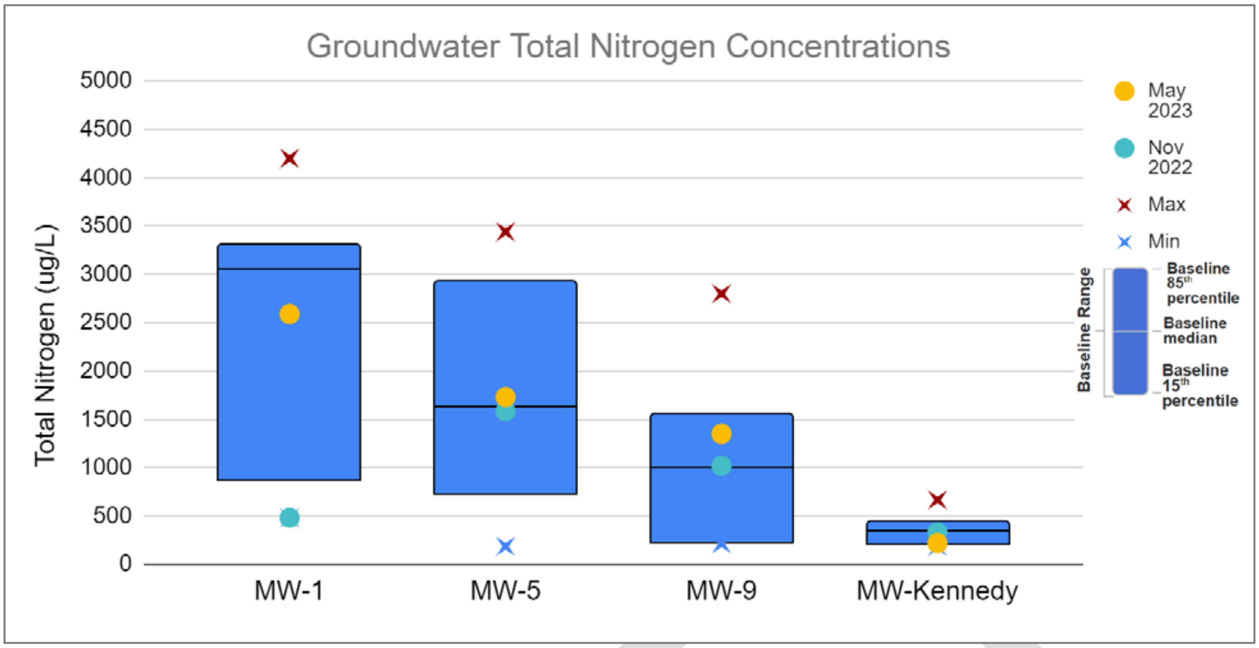


Figure 38. Groundwater Total Nitrogen Concentration Summary Statistics and WY 2023 values (Nov 2022 and May 2023).

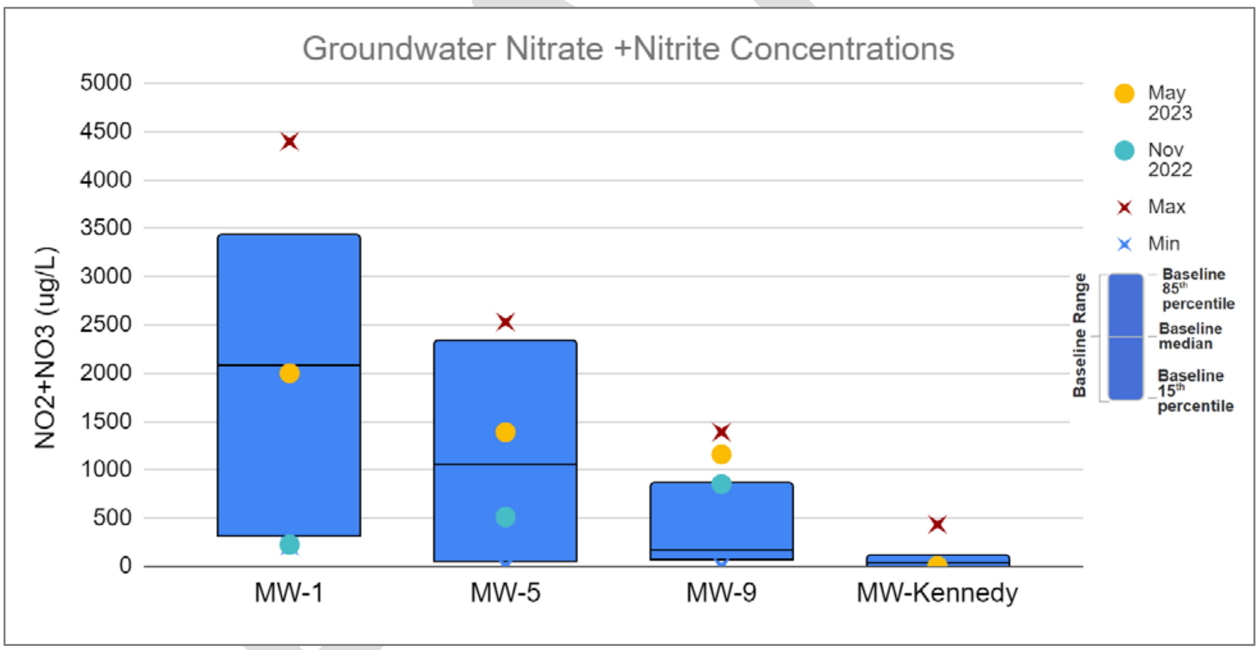


Figure 39. Groundwater Nitrate +Nitrite Concentration Summary Statistics (2013-2023), WY 2023 (November 2022 and May 2023).

The maximum and baseline median TN and NO2+NO3 concentrations decrease from upstream to downstream and below the Reservoir. The concentrations of TN and NO2+NO3 were higher in May 2023 at all three sites upstream, but TN was lower at the Kennedy well below the Reservoir. The WY 2023 concentrations of TN and NO2+NO3 were below the baseline median at MW-1 but were above the baseline median at MW-9 just upstream of the Reservoir. Ammonia has also been monitored in groundwater, but due to variability in detection limits and low concentrations, a trend analysis is not reliable for ammonia.

4.0 RESERVOIR MONITORING RESULTS

Reservoir monitoring focuses on data collection to support regulatory requirements and maintaining the beneficial uses of aquatic life, recreation, water supply, and agriculture. The primary concerns are nutrients, including multiple species of phosphorus and nitrogen, and chl α.

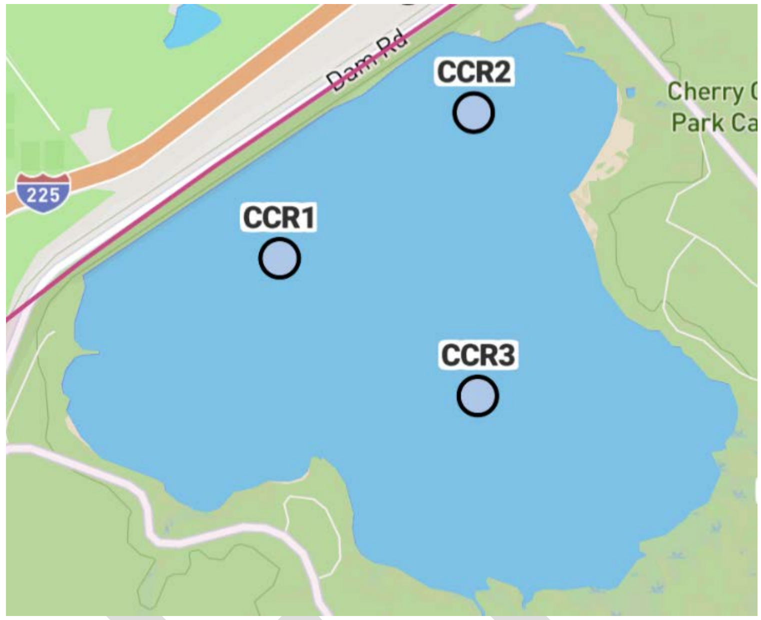


Figure 40. Cherry Creek Reservoir Monitoring Locations

Three sites in the Reservoir are included in the monitoring program: CCR-1, CCR-2, and CCR-3 (Figure 38). CCR-1, also called the "Dam site", is located in the northwest area within the Reservoir. CCR-2, called the "Swim Beach site", is located in the northeast area within the Reservoir nearest the swim beach and Reservoir outlet. CCR-3 is referred to as the "Inlet site" and corresponds to the south area within the Reservoir closer to where the streams enter the Reservoir.

Each site is sampled monthly though the year when ice-free conditions allow, and twice a month from May through September. Transparency, dissolved oxygen, temperature, and pH are included in the regular monitoring to support regulations protecting aquatic life and other beneficial uses.

Water quality samples are collected from the photic zone (0-3 m composite) at each site and from 4 m to the bottom at CCR-2. Physical parameters are measured at 1 m increments from the surface (0 m) to the bottom, which varied from 6.2 to almost 8 m during WY 2023 due to the high water levels. The depth profiles are also affected by the Reservoir elevation so some dates may have less values than others when water depth is lower at the monitoring locations.

In addition to the physical and chemical water quality monitoring, the analysis of reservoir plankton concentrations also helps determine the overall health of Cherry Creek Reservoir, the potential for environmental risks, and impacts on water quality. Plankton growth trends and population diversity through the seasons are analyzed through monthly sample collection throughout the year and twice a month through the summer months. Identification and enumeration are completed on all samples with biovolumes calculated on all phytoplankton samples and biomass calculated on all zooplankton samples.

4.1 USACE RESERVOIR GATE EXERCISE ACTIVITY

The USACE usually completes the annual gate operation activity at the outlet of Cherry Creek Reservoir in late May to verify the proper operation of the outlet gates. The activity was planned for May 24, 2023; however, due to active flood control operations at that time, the gates were operated and maintained at an average release rate of 250 cfs but no additional information was provided. It is assumed that this flushing exercise may release some of the nutrient-rich water and sediments from the bottom of the Reservoir.

4.2 TRANSPARENCY

Water transparency, characterized by Secchi depth, is used as an indicator for lake and reservoir water quality because primary productivity (algae) and turbidity of the water column reduce the depth at which light can penetrate. In addition, the photic zone, characterized by 1% Light Transmittance, is a measure of the depth at which light can penetrate the water column and algae can complete photosynthesis. Both Secchi depth and the 99% light attenuation (1% Light Transmission) were measured at all three Reservoir sites during each monitoring event

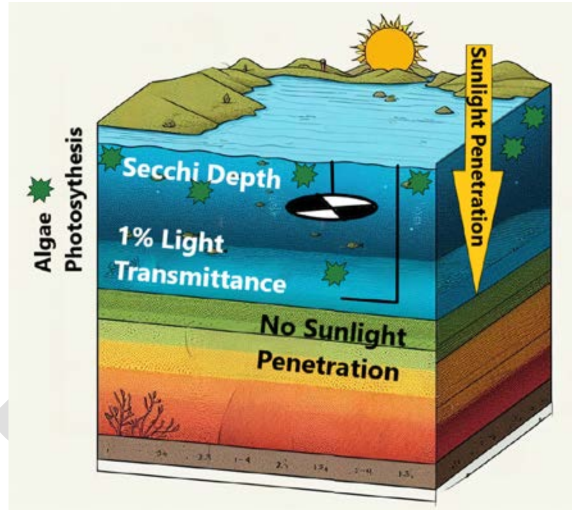


Image 1. Water Transparency - Secchi Depth and Photic Zone

Figure 41 illustrates the WY 2023 median Secchi depths along with the 1992 to 2023 POR summary statistics for each Reservoir site. The Secchi depths are similar between the three Reservoir sites, and the WY 2023 median Secchi depth measurements were similar to the baseline medians. The Secchi Depth values in the Reservoir represent low transparency and eutrophic conditions.

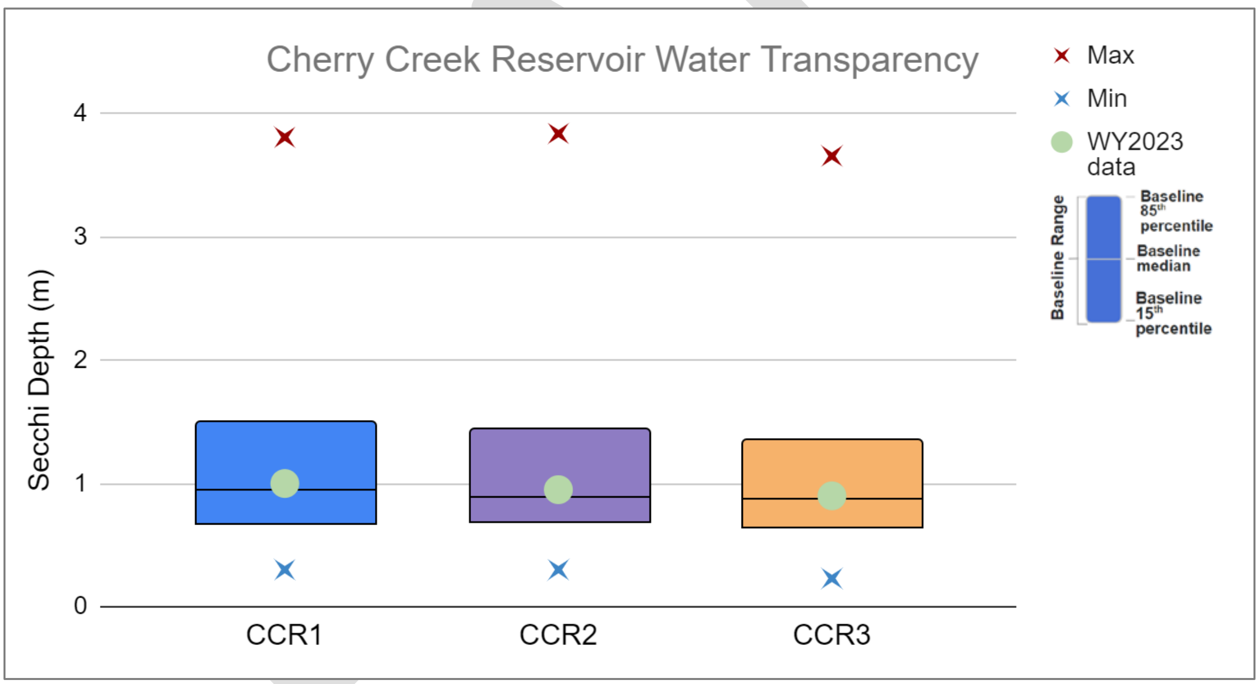


Figure 41. Cherry Creek Reservoir Water Transparency, Secchi Depth Summary Statistics and WY 2023 values.

Figure 42 shows monthly WY 2023 medians along with POR summary statistics. For the most part, the Secchi depth followed a similar seasonal pattern when compared to the historical monthly values. The Secchi depths were highest and above the baseline medians in May, June, and July 2023, which coincided with the period of above average precipitation. Storm events and periods of extended precipitation are responsible for reduced sunlight, increasing inflows to the reservoir, reducing water temperature, and likely assist with mixing, all of which reduce the potential for algae growth and increased water transparency.

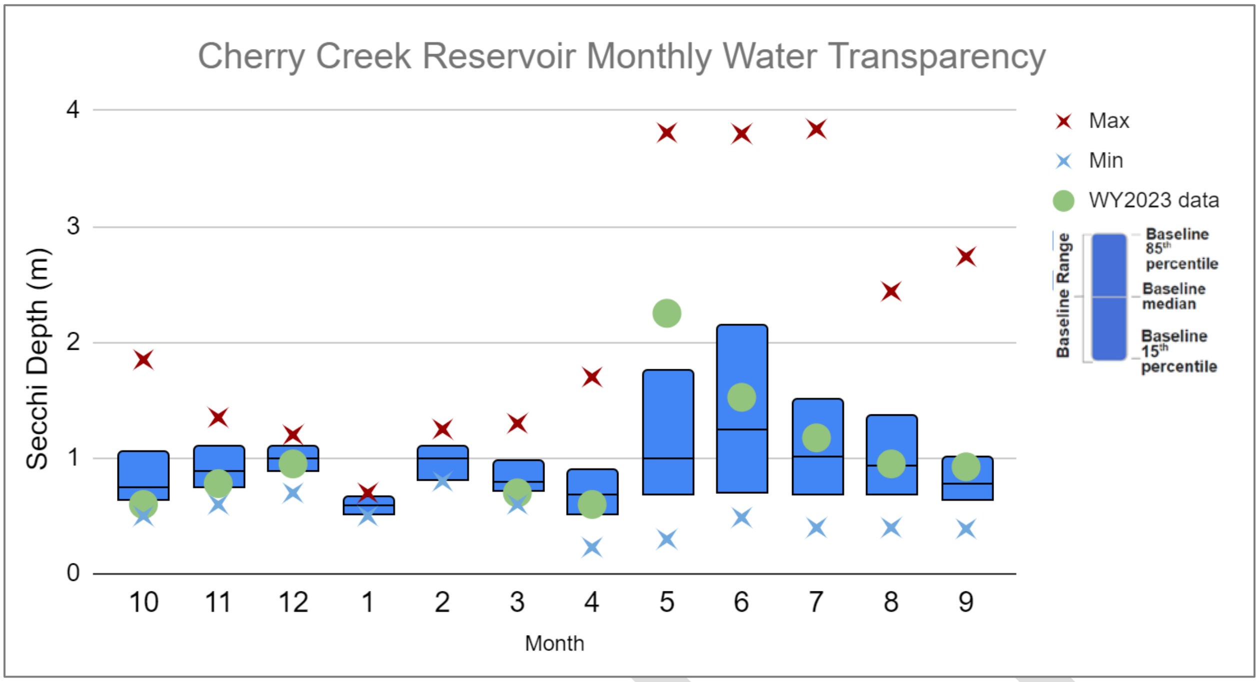


Figure 42. Monthly Medan Secchi Depth in Cherry Creek Reservoir from 1992-2022, Summary Statistics and WY 2023 values.

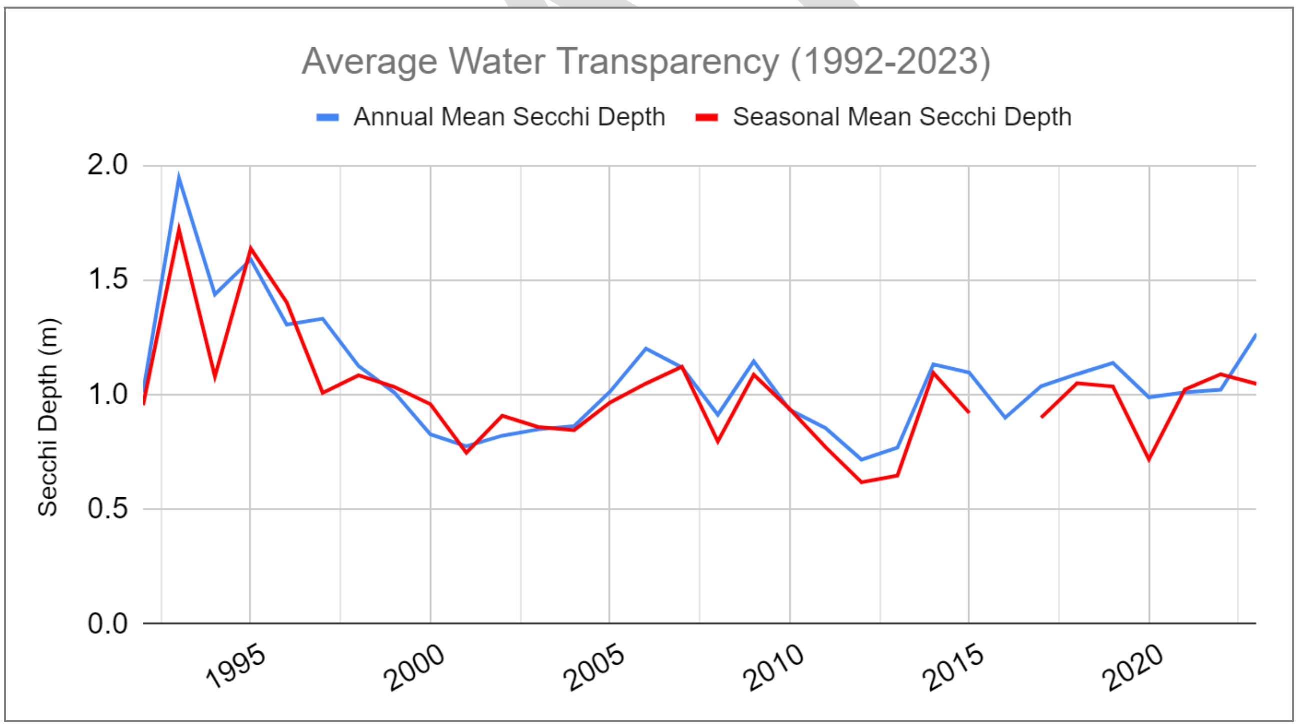


Figure 43. Annual and Seasonal Mean of Secchi Depth in Cherry Creek Reservoir from 1992-2023.

Figure 43 shows the historical annual and seasonal (July through September) mean Secchi depths for Cherry Creek Reservoir. From approximately 1998 to present, the annual mean Secchi depth has been in the eutrophic range, with all annual means less than 2 meters (See Section 4.15). A Mann Kendall trend analysis indicates that there is no significant increase or decrease over time in either annual or seasonal measurements.

The depth of 1% light transmittance is considered the photic zone, or the depth at which photosynthesis can occur; below that depth, primary productivity would be light limited. Like the Secchi depth measurements, the highest measurements of 1% light transmittance were observed in early spring and summer, decreasing through September (Figure 44). There is a clear relationship between the photic zone and water transparency; 1% light transmittance averages around three times the Secchi depth.

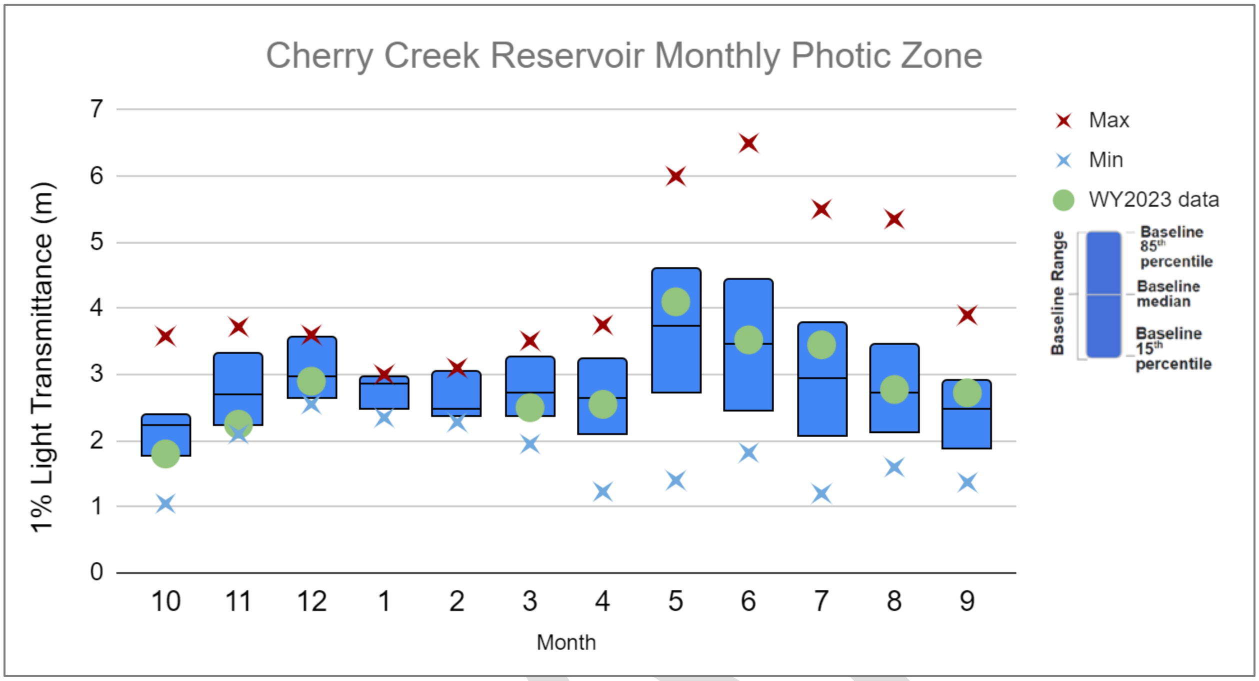


Figure 44. Cherry Creek Reservoir Monthly Photic Zone, Depth of 1% Light Transmittance Summary Statistics and WY 2023 median depths.

4.3 CHLOROPHYLL α

Cherry Creek Reservoir has a seasonal (July through September) chl α standard of 18 µg/L as set by WQCC Reg 38. During each sampling event in WY 2023, chl α levels were measured from composite samples collected from 0, 1, 2, and 3 meters at all three monitoring sites in the Reservoir. In WY 2023 no data were collected in January and February of 2023 due to ice on the Reservoir which is normal.

Figure 45 displays the chl α concentration summary statistics for 1992-2023 and the WY 2023 median values. The WY 2023 medians are similar to the baseline medians. Figure 46 illustrates the monthly chl α WY 2023 concentrations along with POR summary statistics. The WY 2023 seasonal chl α mean was 20.9 µg/L, which does not meet the Reg 38 standard of 18 µg/L (Figure 47). The standard only allows an exceedance frequency of once in five years; four of the last five (4/5) and eight of the last ten (8/10) years have exceeded this value. The Reservoir is not meeting the chl α water quality standard. For additional context, it is noteworthy that the WY 2023 seasonal chl α concentration was lower that the three prior years and was close to the CDPHE's proposed standard of 20 µg/L for warm water lakes (even though this standard does not apply for the Reservoir).

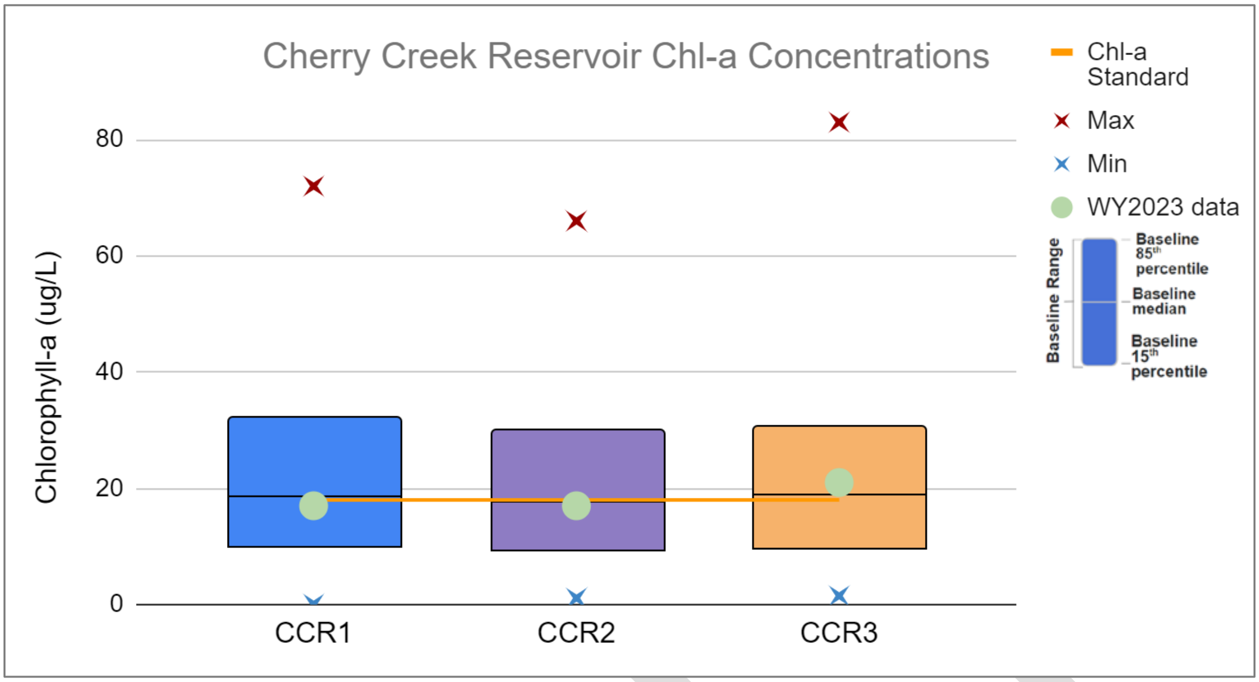


Figure 45. Cherry Creek Reservoir Chlorophyll α Concentrations, POR Summary Statistics and WY 2023 data.

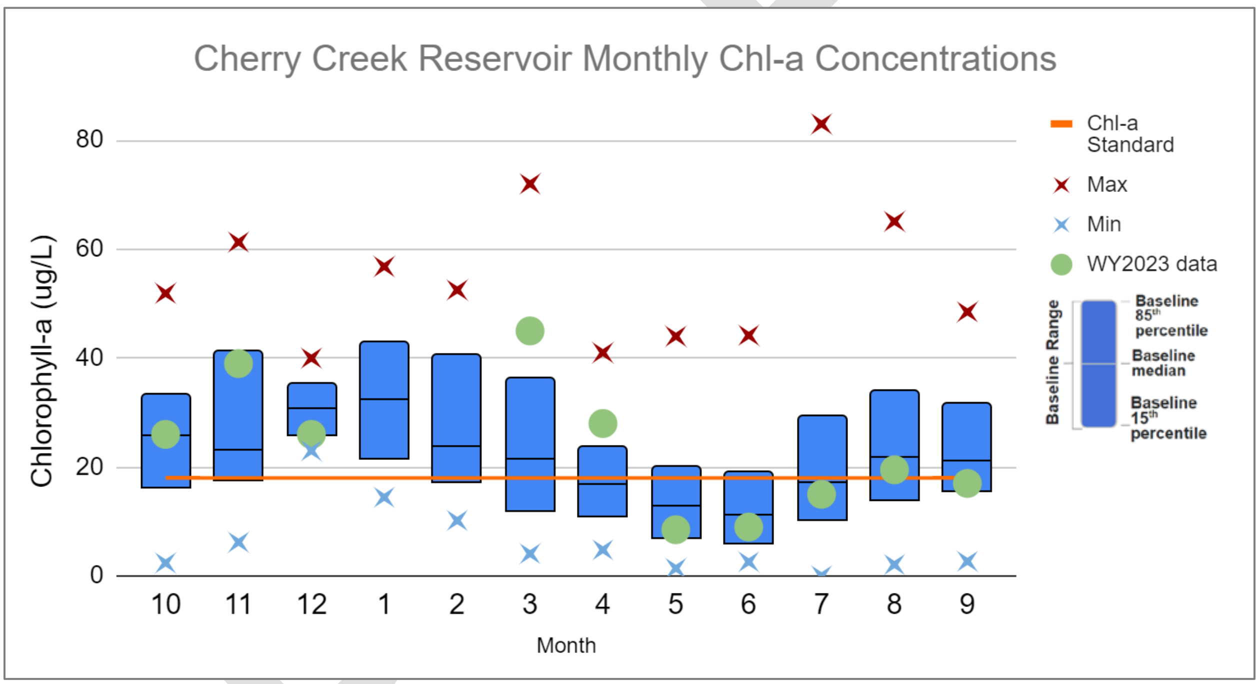


Figure 46. Monthly Median Chlorophyll α Concentrations in Cherry Creek Reservoir from 1992-2022, Summary Statistics and WY 2023 values.

The highest WY 2023 monthly median chl α concentrations were collected during the monitoring events in November and March and the lowest in May, June, and July, even though there was a bloom in late July. The low chl α values coincided with the highest water transparency in the Reservoir. However, as soon as the weather started to warm and the heavy precipitation from spring and early summer stopped, algae concentrations increased.

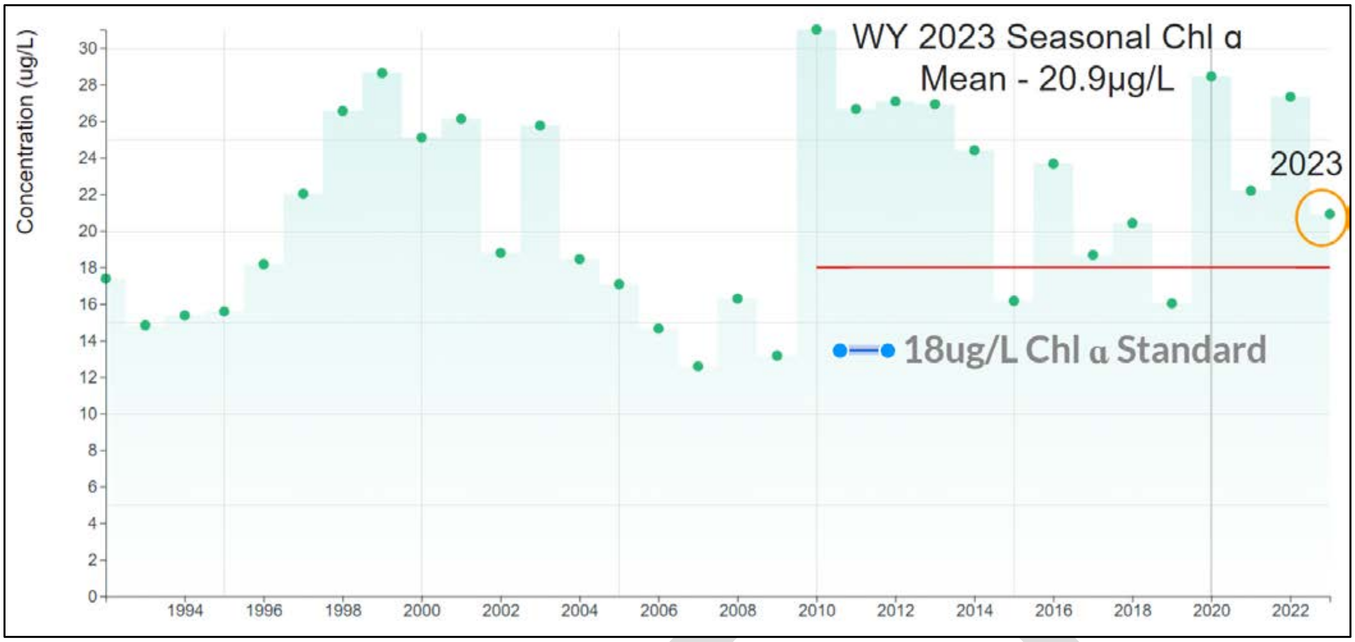


Figure 47. Seasonal Mean Chlorophyll *a* in Cherry Creek Reservoir WY 1991-2023.

Translating the impacts of chl α concentrations on water quality into terms that are meaningful to most recreational lake users is a complex task. Walmsley and Butty (1979) proposed some typical relationships between maximum chl α concentrations and observed impacts (Table 17) to describe perceptions of water quality by typical lake users.

Table 17. Impact of Chlorophyll *a* Concentrations on Perceived Water Quality

Chlorophyll *a* Concentration	Nuisance Value
0 to 10 µg/L	No problems evident
10 to 20 µg/L	Some algal scums evident
20 to 30 µg/L	Nuisance conditions encountered
Greater than 30 µg/L	Severe nuisance conditions encountered

The chl α concentrations in Cherry Creek Reservoir indicate that some algal scums to severe nuisance conditions are present throughout the year (Figure 46). When algal scums are evident, Colorado Parks and Wildlife monitors and tests for potential cyanobacteria toxins at multiple public areas.

On July 17th, a cyanobacteria bloom was observed in the marina along the shoreline but had very low concentrations of toxin (0.5 µg/L), well below the recreational threshold for closure of 8 µg/L. “Caution” signs were posted in the area to inform the public. Ongoing monitoring detected that the toxin increased to >10 µg/L and a closure was implemented on July 28th in the vicinity of the bloom and “Danger” signs were posted. On July 31st, the toxin levels had decreased to below the recreational threshold and the closure was lifted on Aug 4th following the results from laboratory analysis. By August 15th, the bloom had dissipated, and no toxin was present.

The pattern of short-duration cyanobacteria blooms is common when they are present in Cherry Creek Reservoir. There are many factors that drive and disrupt the blooms. Informing the public with appropriate signage in impacted areas is helpful to reduce risks associated with toxin.

4.4 TEMPERATURE

The Warm Water Aquatic Life classification for Cherry Creek Reservoir in Reg 38 has a chronic Maximum Weekly Average Temperature (MWAT) standard of 26.2˚C (79.2⁰F) and an acute Daily Maximum (DM) standard of 29.3˚C (84.6 ⁰F). Both of these standards were met in Cherry Creek Reservoir in WY 2023.

Continuous temperature monitoring is completed annually near site CCR-2 in Cherry Creek Reservoir. The temperature loggers are placed in even increments from one (1) meter of depth to the bottom of the Reservoir and are mounted on a marker buoy. However, after removal of the thermistor chain from the Reservoir in the fall of 2023, the chain and equipment could not be located so this data is not available for WY 2023.

During each monitoring event, temperature profiles were also collected during each monitoring event. Figure 46 illustrates the temperature profiles collected at Reservoir station CCR-2 during the routine monitoring events in WY 2023.

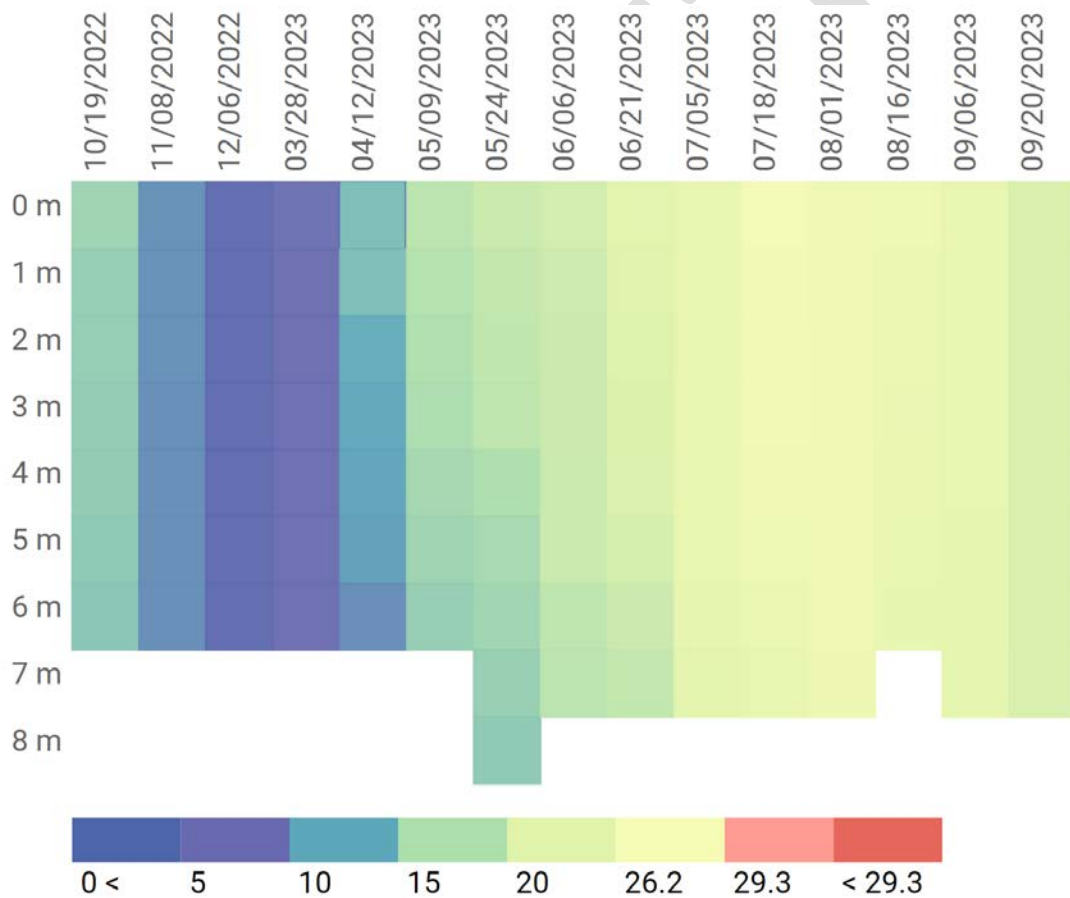


Figure 48. Temperature (˚C) Profile at CCR-2, Cherry Creek Reservoir, WY 2023.

The maximum temperature measured at the surface during the Reservoir monitoring events was 26.2 ˚C (79.16⁰F) at CCR-3 on July 18, 2023. On that same date, the temperature was 25.3 ˚C at CCR-2 and 24.9 ˚C at CCR-1. Cherry Creek Reservoir did not exceed the MWAT or DM standards in WY 2023 and therefore was in attainment. The biggest temperature range measured in the vertical profiles during the monitoring events was 4.5˚C on July 18, 2023 (Figure 48).

Although Cherry Creek Reservoir has a destratification system, some of the characteristics of seasonal and mid-season turnover, or mixing events, still occur. However, it is difficult to determine the main turnover events since the Reservoir is considered to be polymictic, or able to mix multiple times a season. There was some variability in temperature from the surface to the bottom, which was much more apparent during the warmer summer months of July and August, but during the rest of the year thermal stratification was limited in the Reservoir. Thermal stratification can lead to anoxic bottom conditions that result in release of nutrients from sediments.

4.5 DISSOLVED OXYGEN

Reg 38 assigns a minimum chronic dissolved oxygen standard of 5.0 mg/L to the Reservoir. The standard requires DO to be at least 5.0 mg/L in the upper portion of a lake or reservoir and that if DO is below 5.0 mg/L, adequate refuge for aquatic life (with DO above 5.0 mg/L) needs to be available at other depths or locations in the Reservoir during the same time period. DO concentrations are measured at 1 m depth intervals throughout the water column during each monitoring event at each site. Cherry Creek Reservoir met the DO standard in WY 2023.

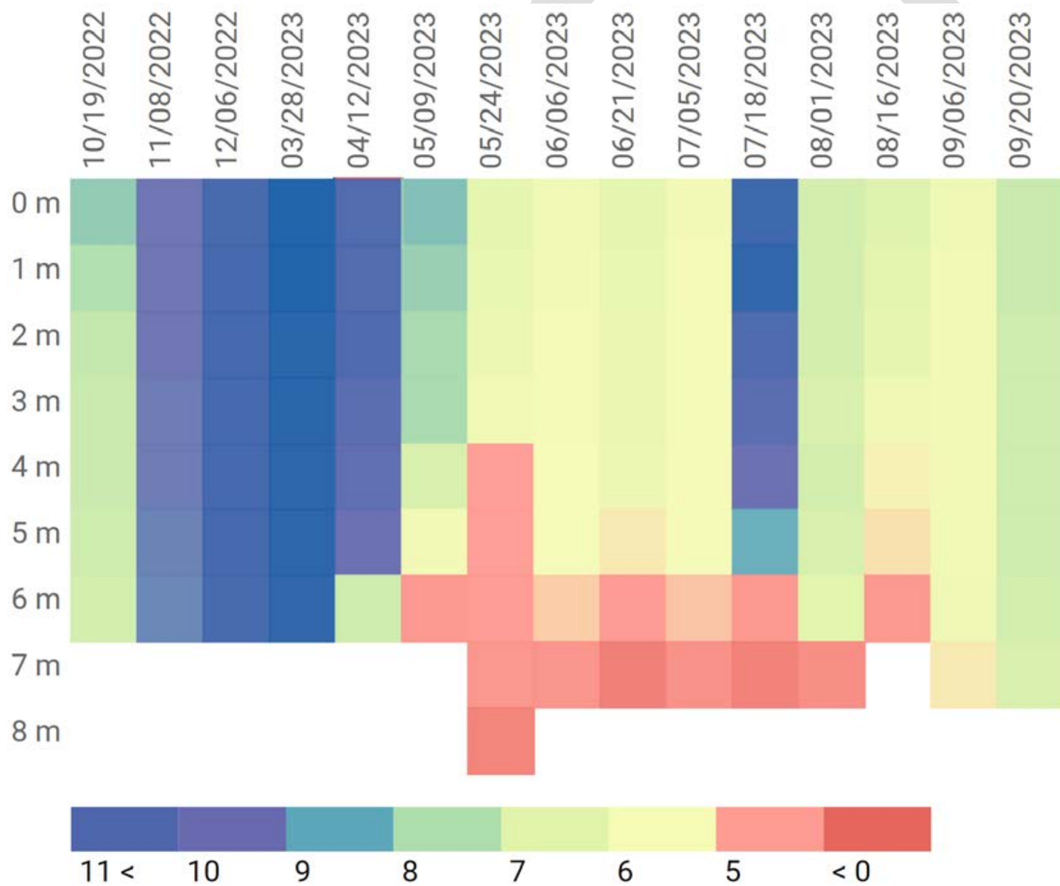


Figure 49. Dissolved Oxygen (mg/L) Profile at CCR-2, Cherry Creek Reservoir, WY 2023.

Figure 49 illustrates the DO concentrations from the surface (0 m) to the bottom in the Reservoir at station CCR-2 during WY 2023. The profiles from the other two sites (CCR-1 and CCR-3) are available on the data portal. DO concentrations below 5.0 mg/L at or near the bottom of the reservoir during the warm summer months are likely due to high microbial activity or decomposition in the hypolimnion and sediments that reduce DO concentrations. During these periods of low DO in the bottom of the Reservoir, internal loading of phosphorus from the sediments is likely. The internal loading patterns are affected by the thermal stratification of the water column.

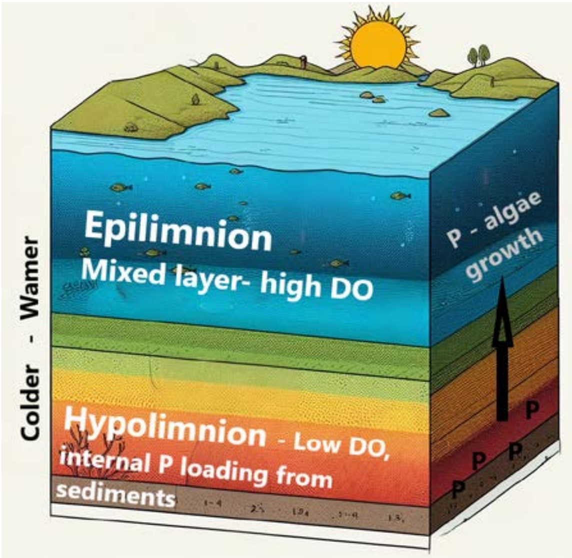


Figure 50. Stratification Layers and Internal Loading

The epilimnion of a lake or reservoir is the mixed layer near the surface. This is the layer in which most photosynthesis occurs because of its higher relative temperature and sunlight penetration. Aquatic macrophytes or rooted plants grow in the littoral (near shore) zone, but most phytoplankton exist in the epilimnion layer. The hypolimnion, or bottom layer, is cooler and denser than the layers above. This layer is where suspended materials, dead algae and other aquatic organisms and plants settle to the bottom to decompose. During the decomposition process, bacterial oxygen consumption exceeds the concentrations in the water, so the DO levels decline. These anoxic conditions at the bottom of the Reservoir in the hypolimnion lead to internal loading of phosphorus from the sediments (Figure 50). When the reservoir mixes, either seasonally or due to high inflows or wind, these high phosphorus concentrations reach the epilimnion where warmer conditions and sunlight penetration drives algae growth.

The reservoir destratification system (RDS) at Cherry Creek Reservoir, which pumps air to the bottom of the reservoir through diffusers, helps to mix the water column and is most effective in the spring and fall when there is less thermal stratification.

4.6 pH

Reg 38 assigns a pH standard for Cherry Creek Reservoir based on the acceptable pH range of 6.5 to 9.0 for protection of aquatic life.

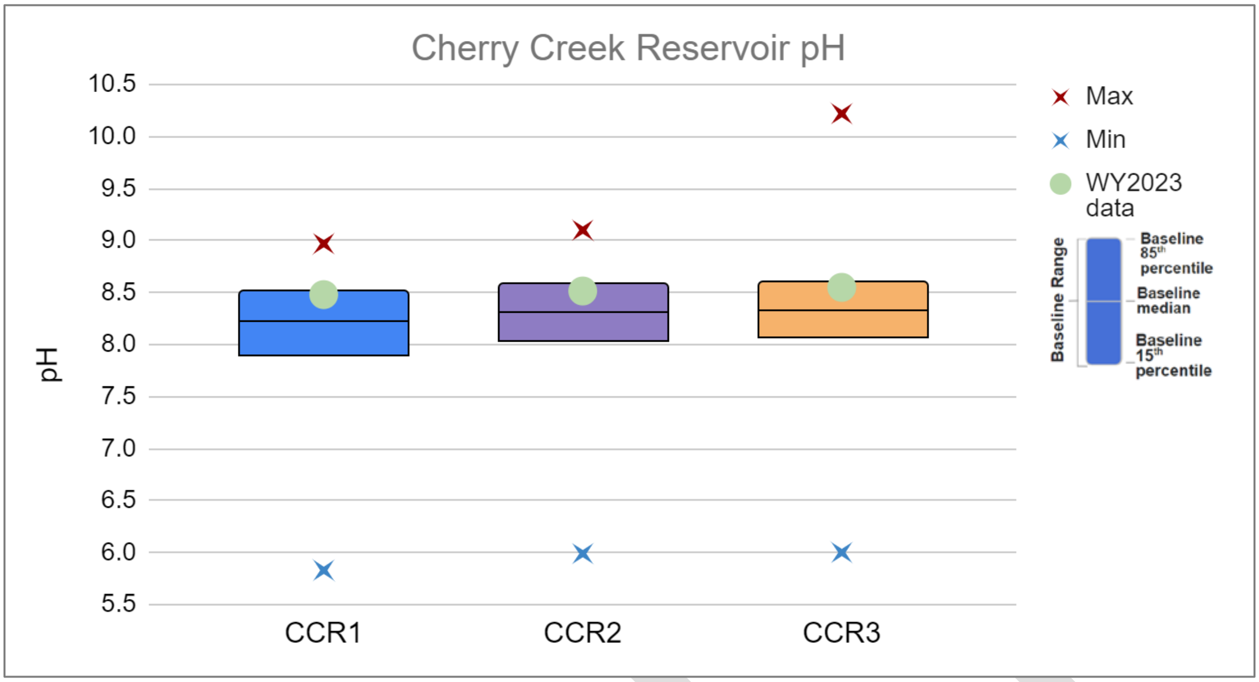


Figure 51. Cherry Creek Reservoir pH, Summary Statistics and WY 2023 medians.

Assessment of pH data is based on comparison of the 15th percentile of the data to a lower pH limit of 6.5 and comparison of the 85th percentile of the data to an upper pH limit of 9.0. Cherry Creek Reservoir attained the pH standard in WY 2023 although median values were above the baseline medians at each site (Figure 51).

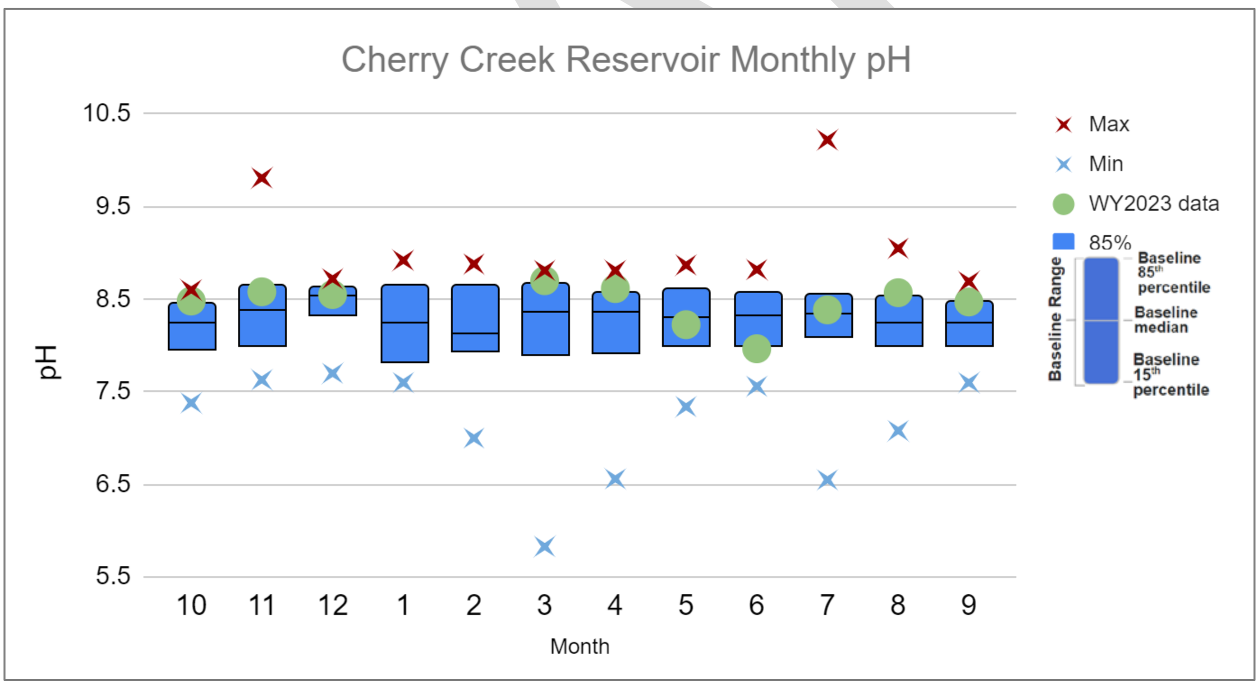


Figure 52. Cherry Creek Reservoir Monthly Median pH.

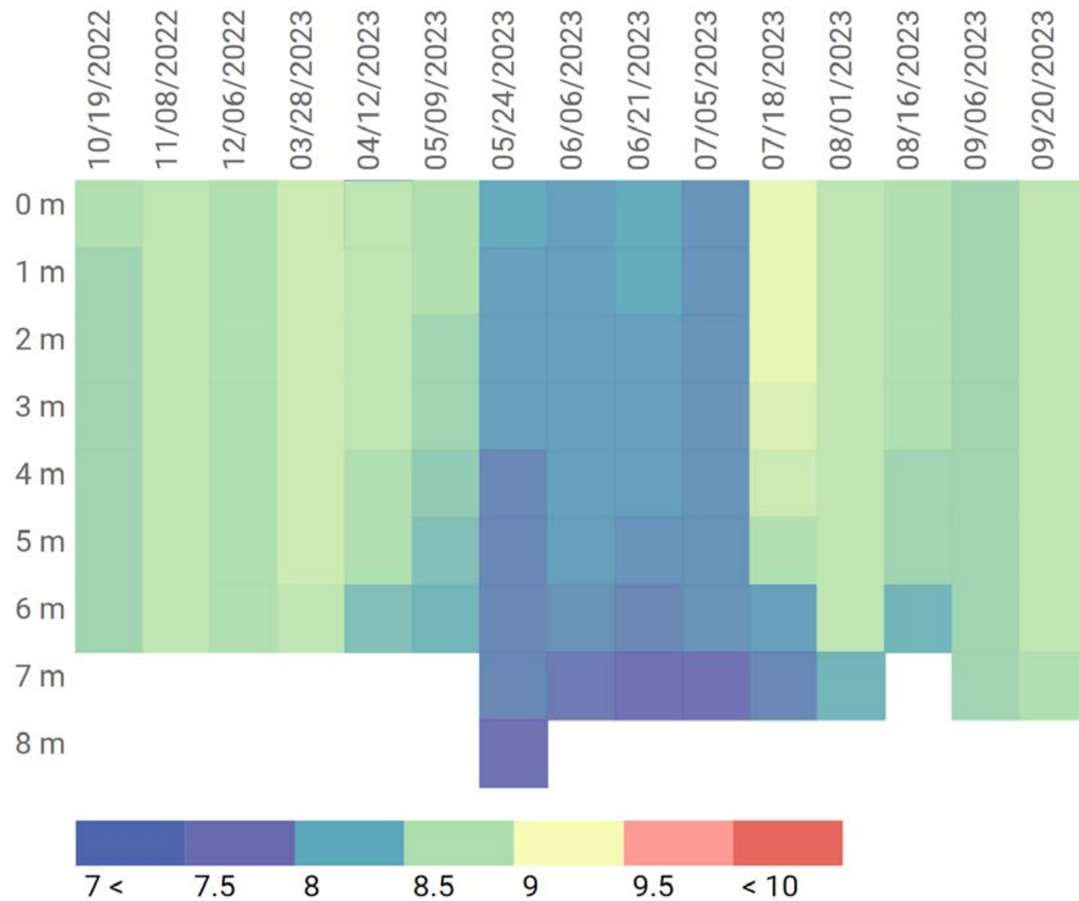


Figure 53. pH Depth Profile from CCR-2, Cherry Creek Reservoir, WY 2023.

The monthly median pH in WY 2023 was below the baseline median in May, June, and slightly below in July (Figure 52) but was near or above the baseline median in all other months. Figure 53 illustrates the pH depth profile for CCR-2. Profiles for the other two Reservoir sites are available on the data portal. The lowest pH values were recorded during the period of high precipitation in May through early July, but as algal productivity increased, the pH values observed were also higher but never exceeded 9.0. Lower pH values were present at or near the bottom of the Reservoir, which is typical.

Higher pH values are usually correlated with higher productivity and elevated chl α concentrations in the Reservoir. This occurs because photosynthesis removes carbon dioxide, a weak acid, from the water column. For example, the highest chl α concentration measured in WY 2023 was 38 µg/L on July 18th, which coincided with the pH of 8.9 on the same date.

4.7 OXIDATION REDUCTION POTENTIAL

Figure 54 shows the Oxidation Reduction Potential (ORP) WY 2023 monitoring values from CCR-2. Higher ORP values indicate an oxidative state and increased potential to break down organic material, whereas low and negative values indicate a reducing environment.

During WY 2023, the ORP in the photic zone was lowest on July 18th, 2023, when there was a bloom present in the Reservoir. In late September, ORP values were low through the water column. Lower ORP values indicate a reducing environment at the bottom of the Reservoir, which usually coincides with lower DO and lower pH measurements. These lower values are an indication of decomposition processes in the sediments and the sediment-water interface, as well as seasonal trends normally seen in the Reservoir. Higher ORP values, indicating an oxidizing environment, were present during periods with higher DO levels and colder water temperatures.

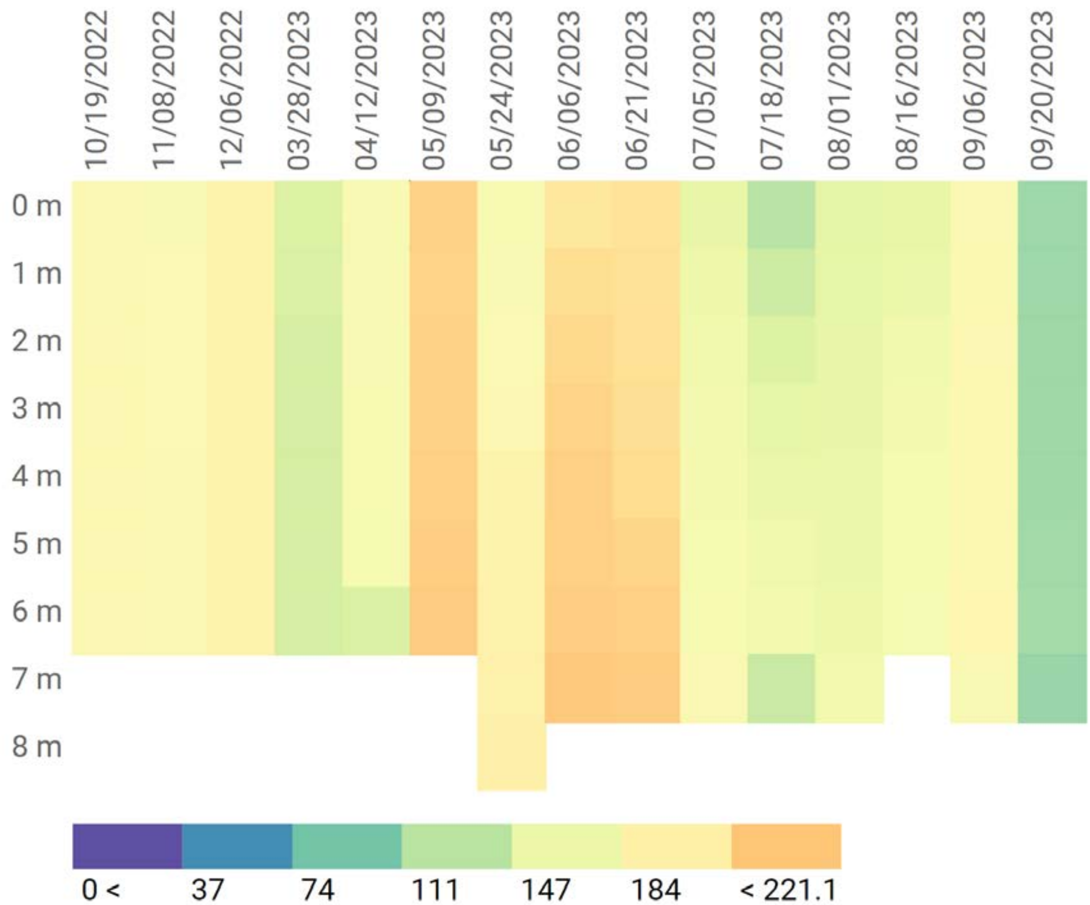


Figure 54. Oxidation Reduction Potential (mV) Depth Profile, CCR-2, Cherry Creek Reservoir, WY 2023.

4.8 CONDUCTIVITY

Specific conductance, or conductivity, is a representation of dissolved solids (e.g., salts, minerals) in Cherry Creek Reservoir. Although there is no water quality standard for conductivity, US EPA considers levels above 1,500 µS/cm above average for most streams in the US. Figure 55 shows the annual median specific conductance WY 2023 values along with the POR statistics for the Reservoir monitoring sites compared to the EPA benchmark. Reservoir WY 2023 median conductivity values were similar to baseline values and below EPA benchmarks. Figure 56 illustrates monthly conductivity in the Reservoir. During WY 2023, the conductivity was above the baseline median until May, during the period of above average precipitation, and then increased slowly through September. (Although conductivity differed throughout the year, there was limited variability observed from the top to bottom of the Reservoir and among the three monitoring sites (Figure 57).

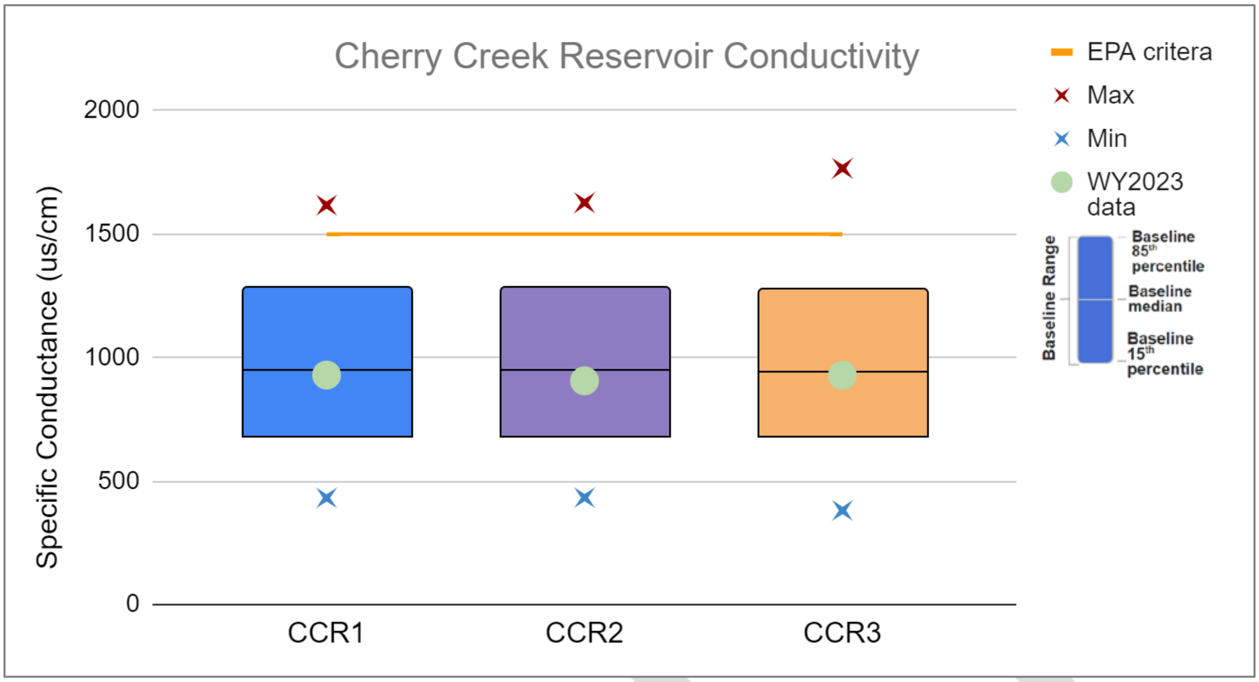


Figure 55. Cherry Creek Reservoir Conductivity, Summary Statistics (1999-2023), WY 2023 medians.

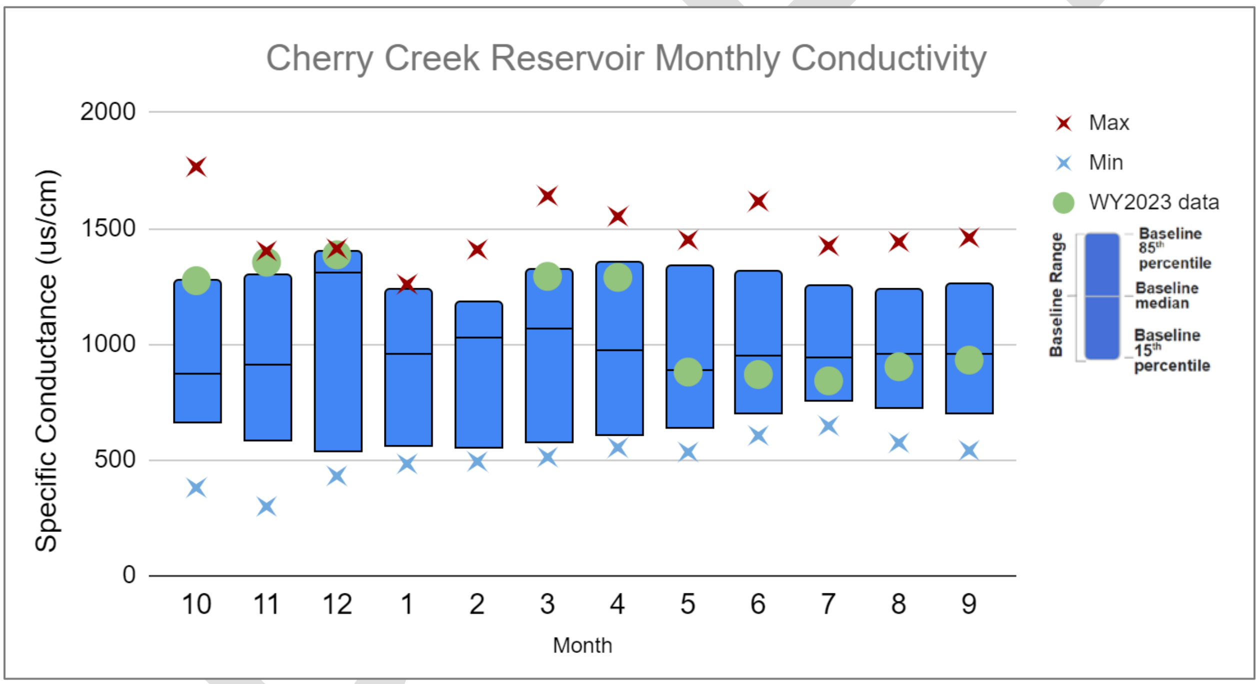


Figure 56. Monthly Conductivity in Cherry Creek Reservoir, Summary Statistics and WY 2023 medians.

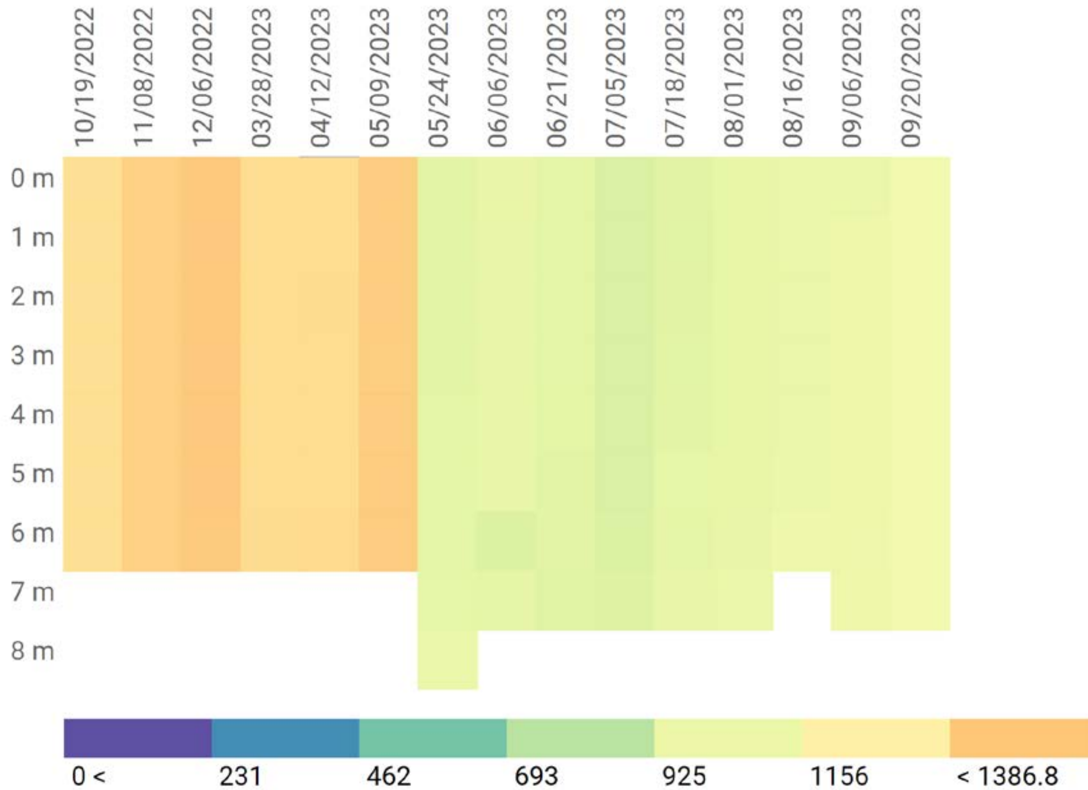


Figure 57. Conductivity (Specific Conductance µS/cm) Depth Profile, Cherry Creek Reservoir, CCR-2, WY 2023.

4.9 SUSPENDED SOLIDS

Total suspended solids (TSS) in a lake or reservoir represent all particles greater than 2 µm in the water column such as sand silt, clay, and algae. The TSS concentrations in Cherry Creek Reservoir impact water clarity and can indirectly affect chl α concentrations due to changes in depth of sunlight penetration.

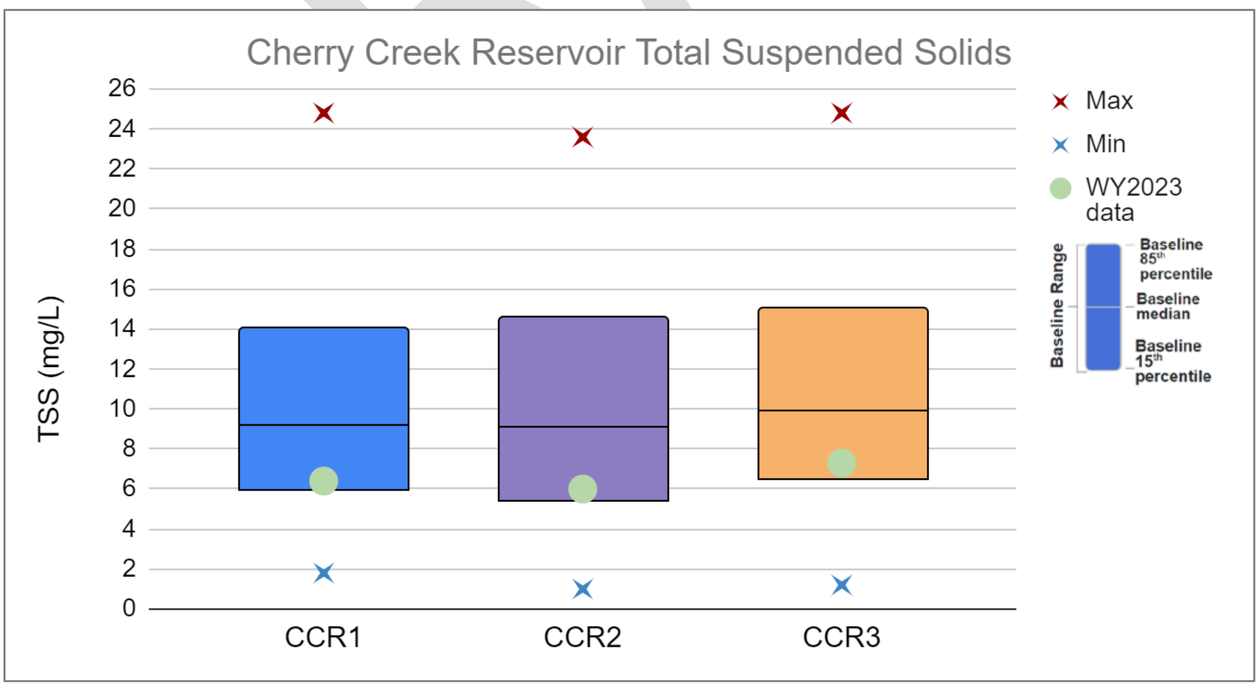


Figure 58. Total Suspended Solid Concentrations in Photic Zone, Cherry Creek Reservoir, Summary Statistics (1992-2023) and WY 2023 medians.

Although stormflows often have high TSS concentrations which can impact downstream lakes and reservoirs, the median concentrations in WY 2023 were below the baseline median (Figure 58.). In addition, the monthly medians following the high spring inflows were lower than the baseline medians and below the 15th percentile in May and June (Figure 59.).

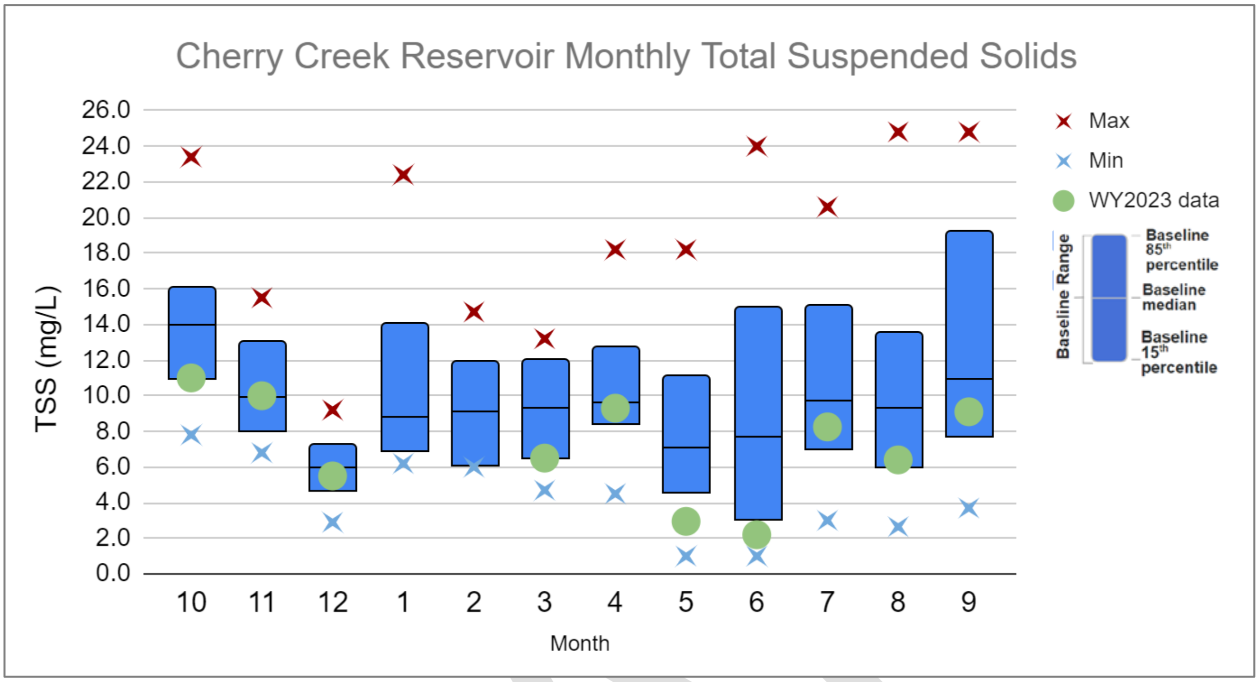


Figure 59. Monthly Total Suspended Solids in Cherry Creek Reservoir, Summary Statistics and WY 2023 medians.

4.10 TOTAL PHOSPHORUS

In many aquatic environments, phosphorus limits primary productivity or algal growth, but in eutrophic or nutrient-rich environments, like Cherry Creek Reservoir, phosphorus may not be limiting. Total phosphorus (TP) is made up of both particulate and dissolved phosphorus. Particulate phosphorus is what remains suspended in the water column instead of settling to the bottom of a lake or reservoir. It includes both inorganic material, such as soil particles and clay minerals, and organic phosphorus, which includes particulate forms such as algal cells and plant fragments.

Although there are no currently applicable standards for TP in Cherry Creek Reservoir, WQCC Regulation 31 (Reg 31) specifies interim nutrient criteria for warm water reservoirs greater than 25 acres. During the WQCC's April 2023 rulemaking hearing for lake nutrients, nutrient standards were adopted in all lakes and reservoirs upstream of domestic wastewater dischargers. For those lakes downstream of domestic wastewater dischargers, like Cherry Creek Reservoir, the standards were adopted with a delayed effective date of December 31, 2027. On the effective date, the standards will become effective in Cherry Creek Reservoir unless a site specific standard is developed and adopted by the WQCC. The 2012 warm water TP criterion for large warm reservoirs is 83 µg/L TP as a summer (July 1-September 30) average in the mixed layer (median of multiple depths), with an allowable exceedance frequency of one-in-five years. The WQCC TP standard will be 47 µg/L in 2027, unless a site-specific standard is adopted. Figure 60 shows the historical seasonal (July to September) median concentration and the WY 2023 median and mean for the three sites in the photic zone (0-3 m) plotted against the 2012 criteria represented by the orange line and the 2027 standards represented by the purple line. The WY 2023 seasonal mean of 135.9 µg/L is much higher than the last two years and the highest seasonal TP concentration observed since 2011 and 2012. The long-term median seasonal phosphorus concentrations average 92 ug/L between the three sites in Cherry Creek Reservoir (Figure 61).

In WY 2023, the monthly median concentrations were below the baseline median in October through December 2022, but at or above the baseline median for the rest of the year and above the 85th percentile from May through August 2023 (Figure 62). The WY 2023 data suggests that the elevated TP concentrations in the Reservoir throughout the year are contributing to the eutrophic conditions. However, it is also noteworthy that the chl α concentrations did not increase proportionally in response to the elevated TP and were among the five lowest since 2010.

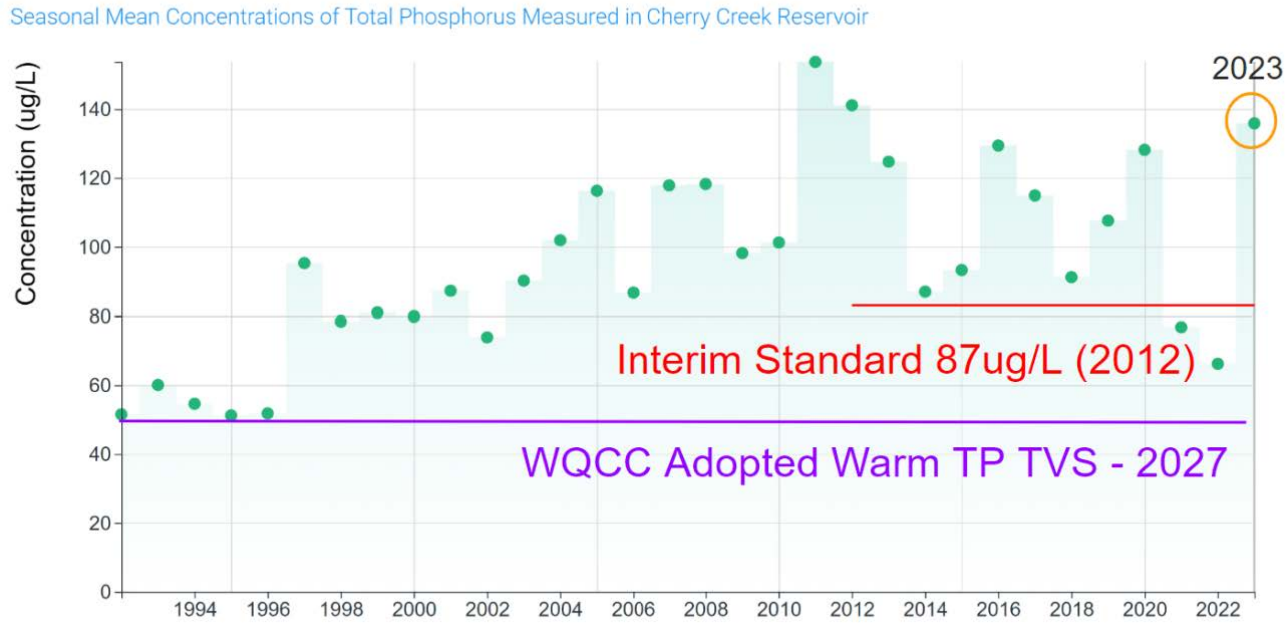


Figure 60. Seasonal Mean Total Phosphorus Concentrations in Cherry Creek Reservoir.

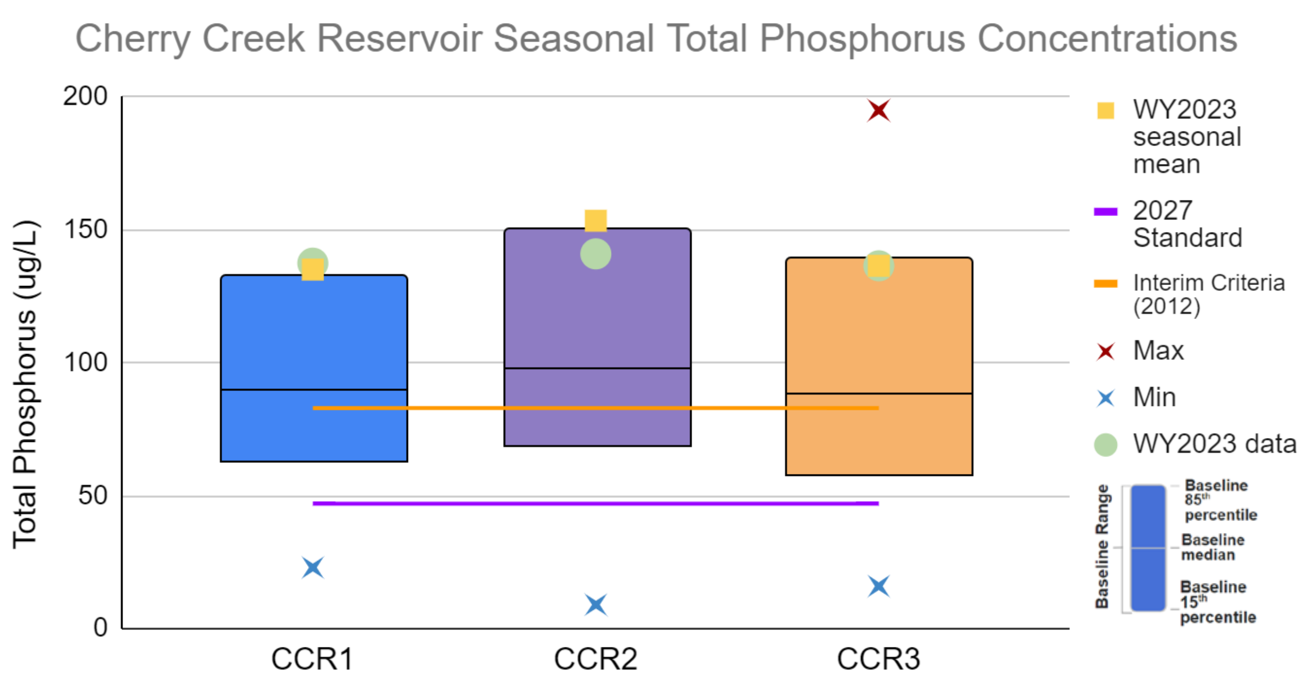


Figure 61. Seasonal TP Concentrations in Photic Zone, Cherry Creek Reservoir, Summary Statistics (1992-2023), WY 2023 medians and means.

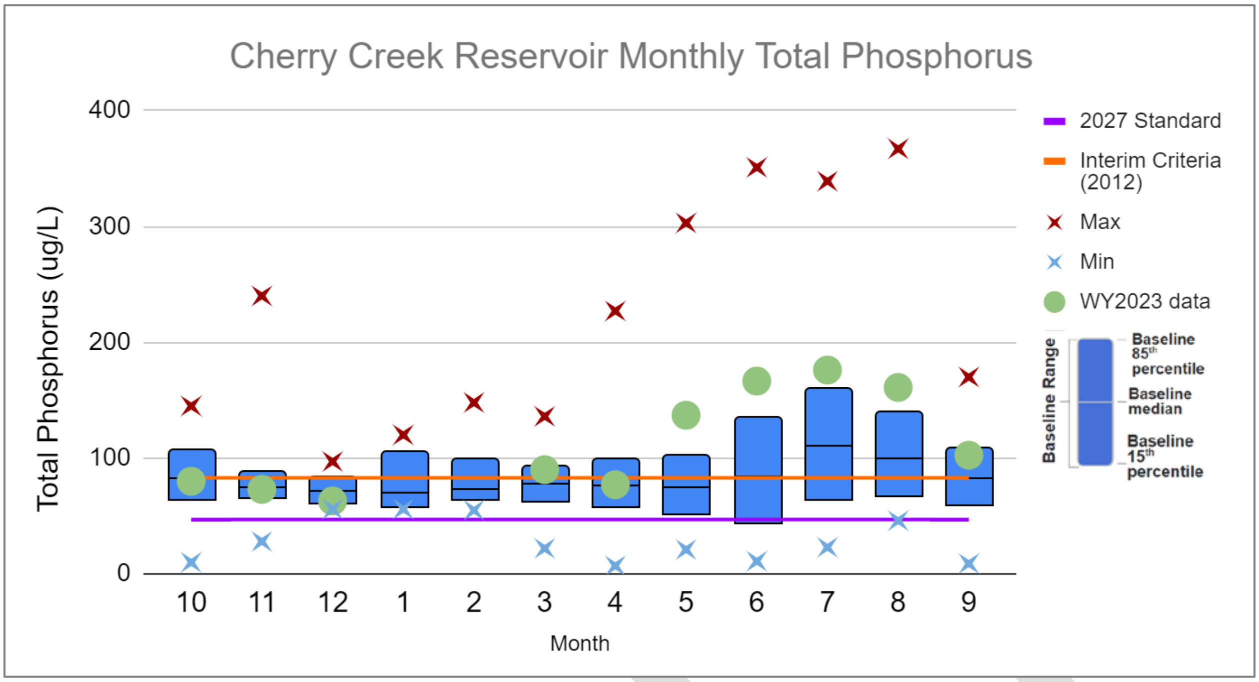


Figure 62. Monthly Median Total Phosphorus in Cherry Creek Reservoir, Summary Statistics and WY 2023 medians.

Figure 63 displays the TP concentrations depth variability through WY 2023 in Cherry Creek Reservoir. The highest concentrations in the photic zone (0-3 m) were seen during the late spring and summer of 2023. The samples from below the photic zone had TP concentrations generally increasing with depth and were highest in bottom samples from late May through September. The TP depth profiles at Reservoir monitoring station CCR-2, and the concentrations from the photic zone composite at CCR-1 and CCR-3, available on the data portal, show similar results.

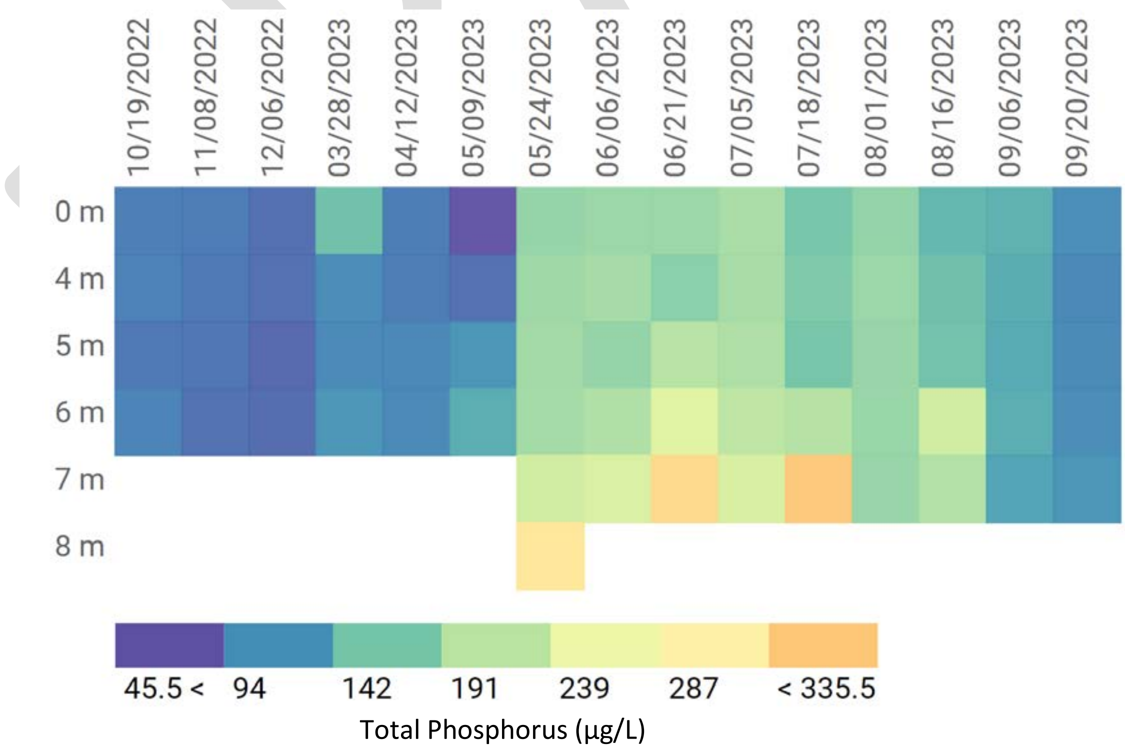


Figure 63. Total Phosphorus Profile at CCR-2, Cherry Creek Reservoir, WY 2023.

Phosphorus increases in the hypolimnion can be caused by internal legacy sediment loading or result from the decomposition of algal cells and other organic matter settling from higher levels in the water column. Inflows of cold runoff water, which has a higher density than warmer surface waters and sinks to the bottom as it enters a lake, can also directly increase hypolimnetic nutrient concentrations. In years with limited stormflows, the higher nutrient concentrations at depth are more likely due to organic deposition and decomposition or internal loading.

4.11 DISSOLVED AND SOLUBLE REACTIVE PHOSPHORUS

Total dissolved phosphorus (TDP) includes dissolved organic and inorganic material. Dissolved inorganic phosphorus is usually reported as soluble reactive phosphorus (SRP), which represents the bioavailable form of phosphorus that is readily available for uptake by algae.

Figure 64 and Figure 65 depict the profiles of TDP and SRP from site CCR-2 during WY 2023. Monthly median TDP concentrations average approximately 30% of the total phosphorus concentrations and SRP averages approximately 15%.

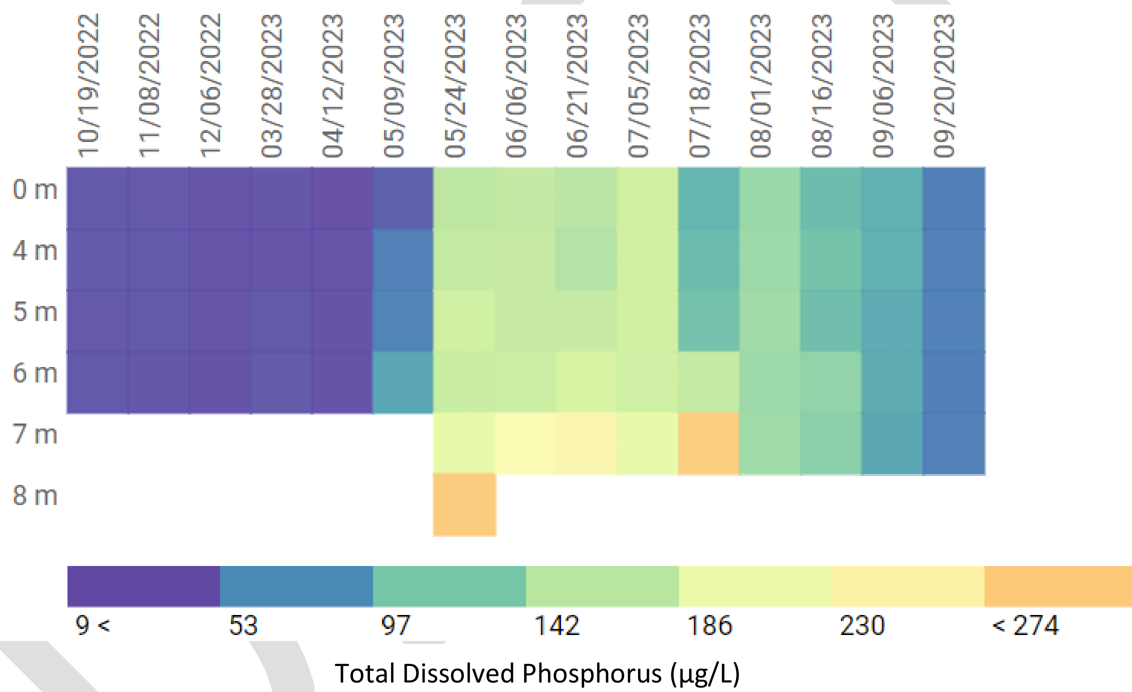


Figure 64. Total Dissolved Phosphorus Profile at CCR-2, Cherry Creek Reservoir, WY 2023.

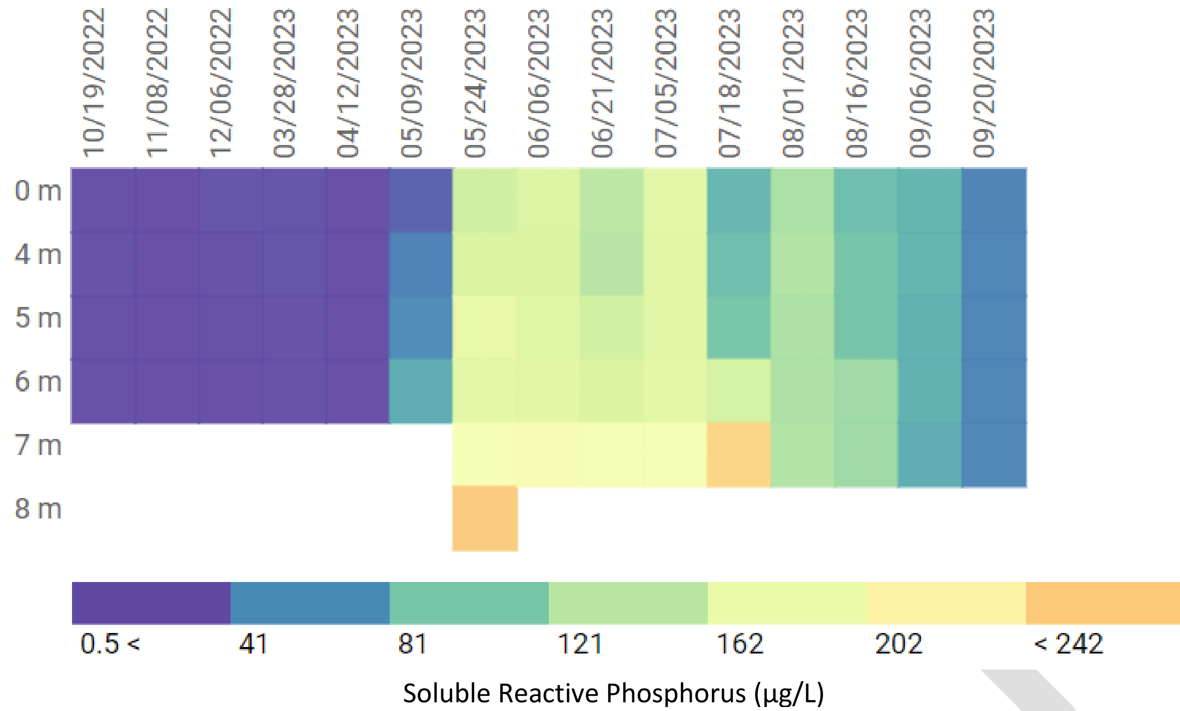


Figure 65. Soluble Reactive Phosphorus Profile at CCR-2, Cherry Creek Reservoir, WY 2023.

During WY 2023, both TDP and SRP remained relatively constant through late fall and winter, but levels throughout the water column show much more variability as the temperatures warm and the season progresses. Since SRP is the bioavailable form of phosphorus, it is typical to see decreases in SRP concentrations in the photic zone through the summer months as productivity increases and phytoplankton and other organisms incorporate SRP into cell material. There was an association of lower levels of TDP and SRP during events when DO levels were low and pH was elevated. Similar patterns of internal loading are observed with these forms of phosphorus during the warmer summer month when DO concentrations are low at the bottom of the Reservoir. As the season progressed, primary productivity in the photic zone was utilizing the available forms of phosphorus as they were released and mixed throughout the water column.

4.12 TOTAL NITROGEN

Nitrogen in aquatic systems comes from many possible natural and anthropogenic sources, including fertilizers, animal and human waste, organic plant matter, and even the air. Nitrogen is often abundant in lakes and reservoirs but when limited, cyanobacteria can utilize (or “fix”) nitrogen gas diffused in the water from the atmosphere that provides a competitive advantage over other algae species.

Although there are no currently applicable standards for TN in Cherry Creek Reservoir, WQCC Regulation 31 specifies interim nutrient criteria for warm water reservoirs greater than 25 acres. Like TP, TN standards were adopted in all lakes and reservoirs upstream of domestic wastewater dischargers. After December 31, 2027, standards adopted will become effective in Cherry Creek Reservoir unless site specific standards are developed and adopted by the WQCC. The 2012 warm water total nitrogen criterion for large reservoirs is 910 µg/L TP as a summer (July 1-September 30) average in the mixed layer (median of multiple depths), with an allowable exceedance frequency of one-in-five years. The WQCC standard for TN will be 640 µg/L in 2027 in the absence of a site-specific standard.

Figure 66 shows the historical seasonal mean (July to September) TN concentration from the three sites in the photic zone (0-3 m) plotted against the 2012 criteria represented by the red line and the 2027 standard represented by the purple line. The WY 2023 seasonal mean of 801.8 µg/L is lower than the last three years and the long-term median of 859 µg/L .

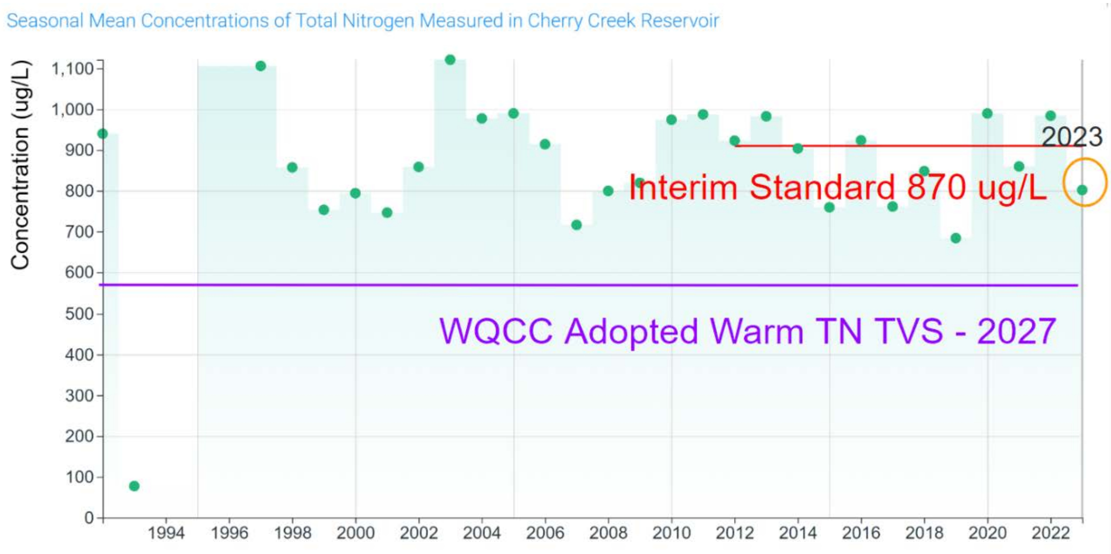


Figure 66. Seasonal Mean Total Nitrogen Concentrations in Cherry Creek Reservoir.

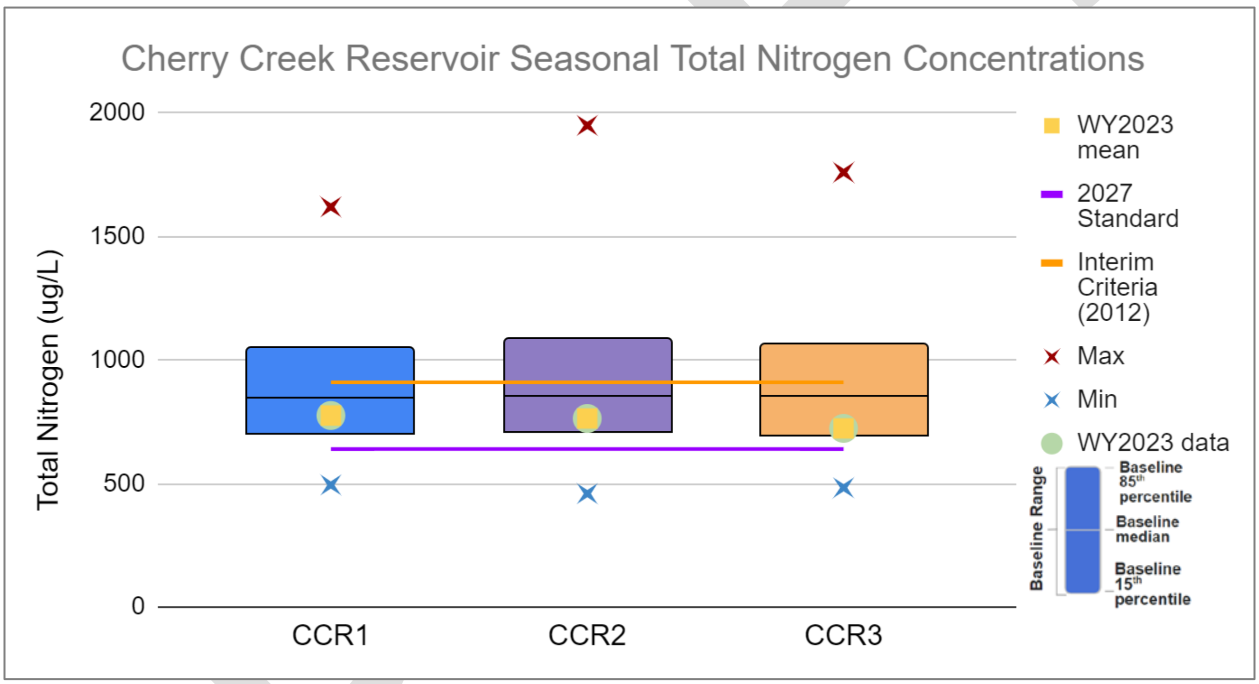


Figure 67. Seasonal Total Nitrogen Concentrations in the Photic Zone, Cherry Creek Reservoir, Summary Statistics (1992-2023), WY 2023 medians and means.

During WY 2023, the monthly median TN concentrations varied and were near or above the baseline monthly medians in October through December 2022 and March through April 2023 (Figure 68). However, concentrations were much lower in early May and then increased to well above the baseline median in June then decreased as the season progressed. When evaluating TN with depth from the samples collected at CCR-2 during WY 2023 (Figure 69), the seasonal changes concentrations observed were consistent throughout the water column. The data from the other two monitoring sites from the photic zone are available on the data portal.

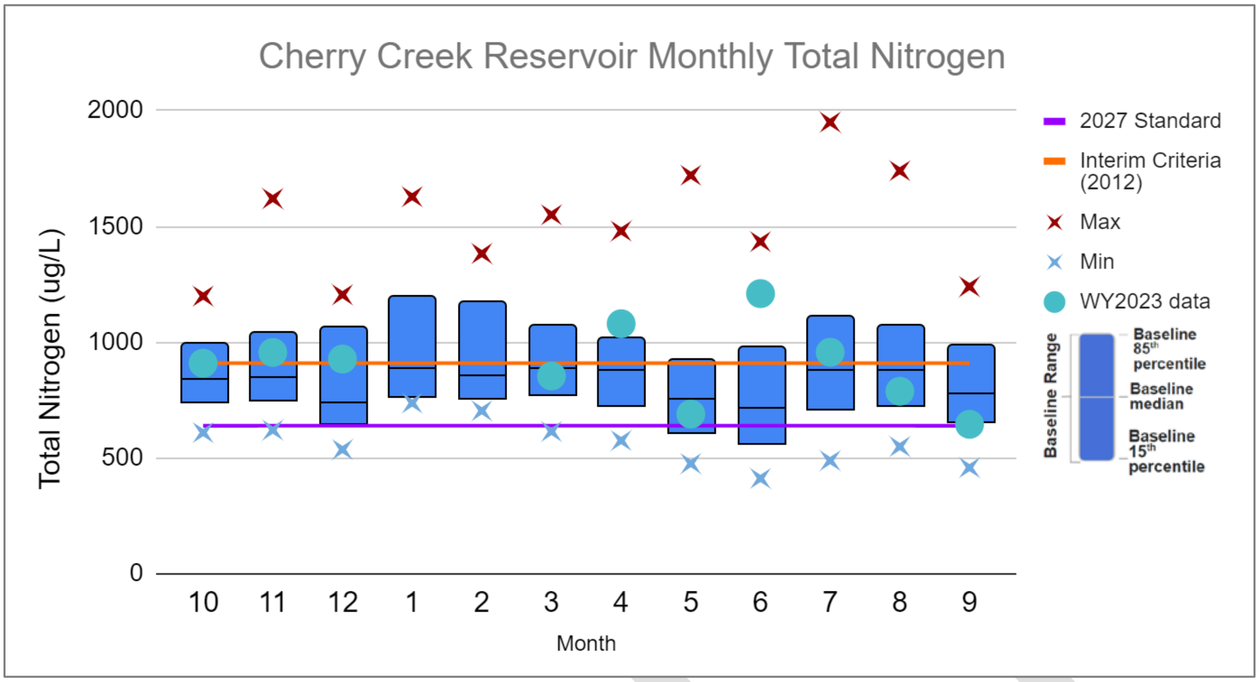


Figure 68. Monthly Total Nitrogen Concentrations, Summary Statistics and WY 2023 medians.

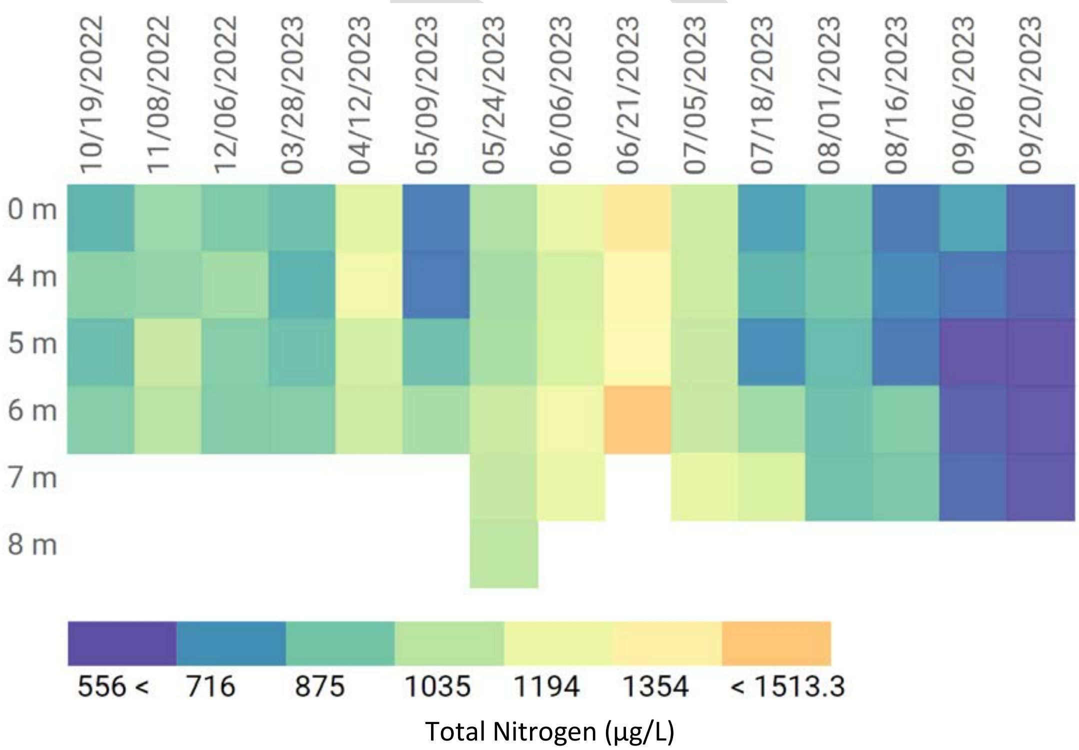


Figure 69. Total Nitrogen Depth Profile at CCR-2, Cherry Creek Reservoir, WY 2023.

4.13 TOTAL INORGANIC NITROGEN

Total Inorganic Nitrogen (TIN) is calculated as the sum of nitrate-nitrite-N (NO_3+NO_2-N) and ammonia-N (NH_3-N) concentrations and represents the forms of nitrogen that are immediately available for algal growth. Figure 70 and Figure 71 illustrate NO_3+NO_2-N and NH_3-N concentrations separately, but both were very low and often below the detection limit during WY 2023. TIN concentrations were elevated in June and July at the deeper sampling sites. Possible reasons for the high TIN concentrations in the hypolimnion are decomposition processes and internal nitrogen loading.

Nitrate is the predominant form of inorganic nitrogen when oxygen is present, and ammonia is the predominant form in the absence of oxygen. Phytoplankton can incorporate ammonia directly into cellular material but readily convert nitrate to ammonia when nitrate dominates.

Nitrates were generally low in the photic zone of Cherry Creek Reservoir throughout WY 2023 except for June and early July. On 11 of the 15 monitoring events in WY 2023, NO_3+NO_2-N concentrations were below the detection limit of 5 µg/L in the photic zone (0-3 m) at CCR-2. When NO_3+NO_2-N concentrations are low, it is an indicator that algal growth in the Reservoir is limited by nitrogen concentrations.

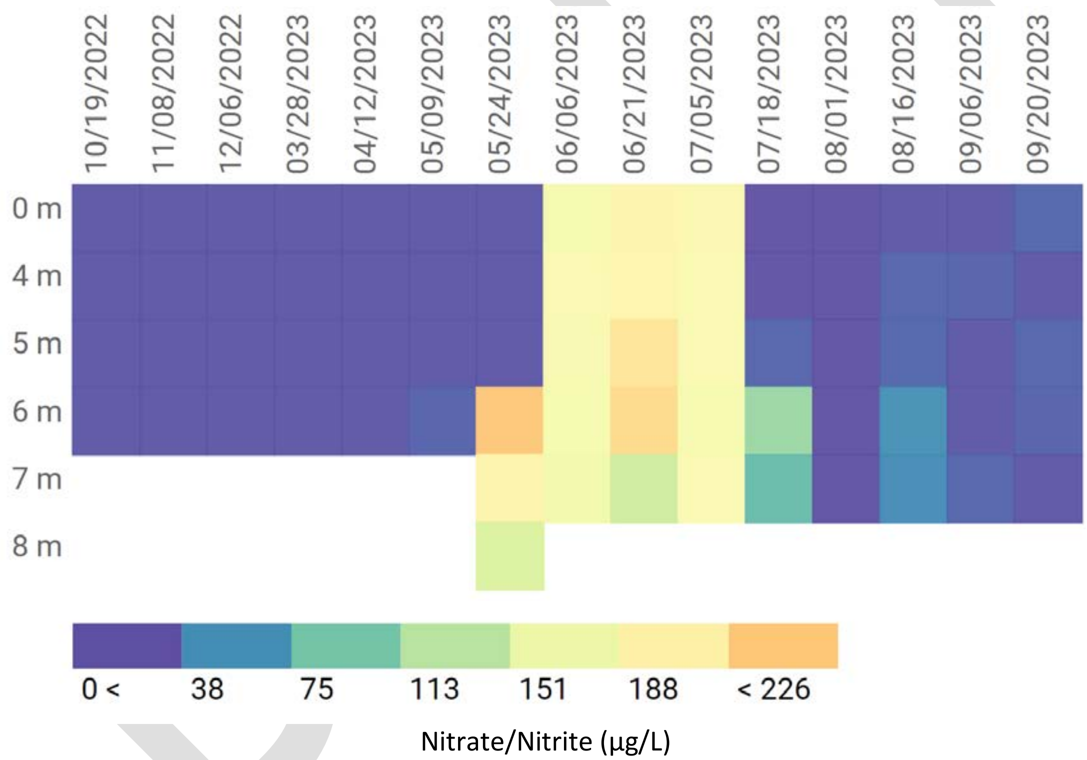


Figure 70. Nitrate/Nitrite Depth Profile at CCR-2, Cherry Creek Reservoir, WY 2023.

Ammonia concentrations, shown as NH_3-N (Figure 71) were elevated at depth from May through July, but lower in surface water on most dates. This is an indication of a highly productive reservoir. Ammonia, like nitrate, is a readily available form of nitrogen for algal growth.

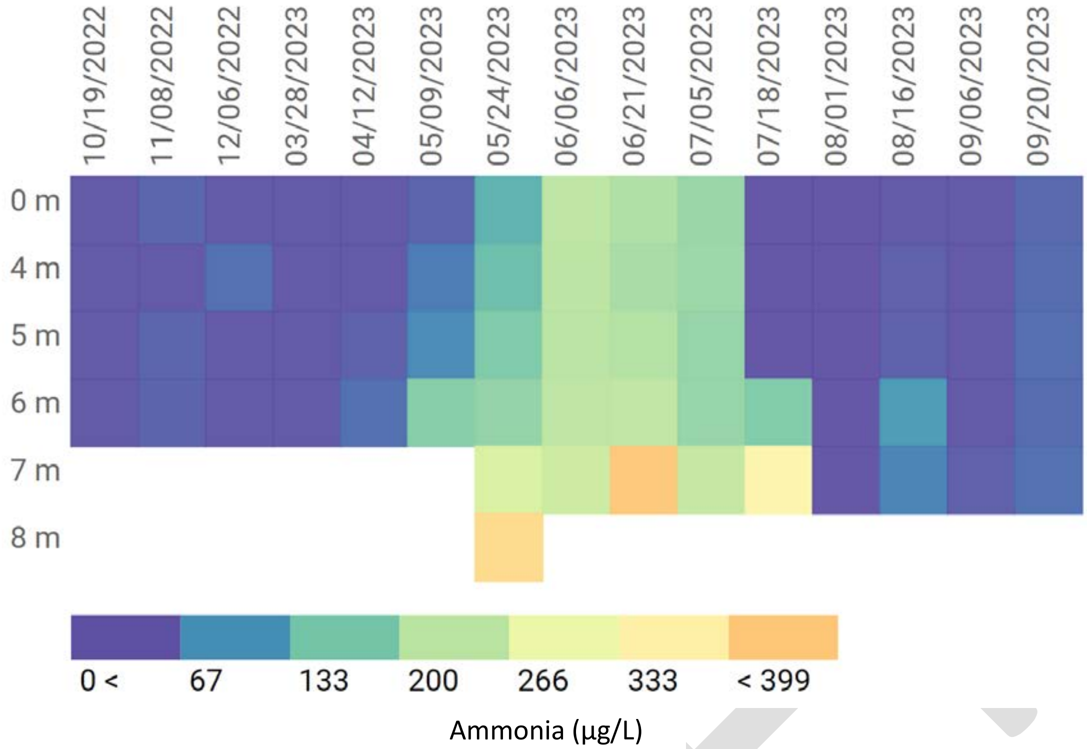


Figure 71. Ammonia Depth Profile at CCR-2, Cherry Creek Reservoir, WY 2023.

On 8 of the 15 monitoring events in WY 2023, NH_3-N, concentrations were below the detection limit of 5 µg/L in the photic zone (0-3 m) at CCR-2 and 11 of 13 concentrations were below 20 µg/L. The increases in ammonia concentrations in the deeper layers also correlated to the periods of lower oxygen at the bottom of the Reservoir. These elevated ammonia values also corresponded to the dates of the lower chl α concentrations. These concentrations are likely due to the release of ammonia from phytoplankton as the bloom that was present died off following the extended period of precipitation.

4.14 LIMITING NUTRIENT

Nitrogen and phosphorus are the nutrients that usually limit algal growth in natural waters. Both the relative concentrations of nitrogen and phosphorus and the absolute concentrations of these nutrients play important roles in structuring phytoplankton communities (Schindler, 1977; Reynolds, 1986). The average nitrogen to phosphorus (N:P) ratio of healthy, growing algal cells is about 7 to 1 by weight (or about 16 to 1 by molar ratio). This value, known as the Redfield ratio, is generally assumed to be the ratio in which these nutrients are ultimately required by algal cells (Reynolds, 1986). Generally, large N:P ratios (>7) indicate that the growth of the phytoplankton community will be limited by the concentration of phosphorus present, while small N:P ratios (<7) indicate that growth will be limited by nitrogen concentrations (Schindler, 1977). The ratios of total inorganic nitrogen (TIN = nitrate + nitrite-N + ammonia-N) to SRP may be more meaningful than the ratio of TN to TP because the inorganic nutrient forms are more directly available to support the growth of aquatic organisms. The potential for cyanobacteria to fix atmospheric nitrogen may be one of the main factors leading to a phytoplankton community dominated by cyanobacteria (see Section 5.1). In lakes and reservoirs with nitrogen limitation, cyanobacteria populations have an advantage over other types of algae and can easily dominate populations and limit diversity.

Figure 72 plots the nutrient mass ratios of TN:TP (in blue), TDN:TDP (in green), and TIN:SRP (in orange). The lines indicate the mass ratio of nitrogen to phosphorus indicating whether nitrogen or phosphorus is limiting. Chl α is plotted on the secondary axis in a red dotted line and the point of limitation is the purple dotted line.

The graph shows that for almost all of the growing season all forms of nitrogen were limited in Cherry Creek Reservoir. Although there was some variability, the concentrations of chl α had relatively higher values following limitation of one or more forms of nitrogen. (See Phytoplankton Section 4.15).

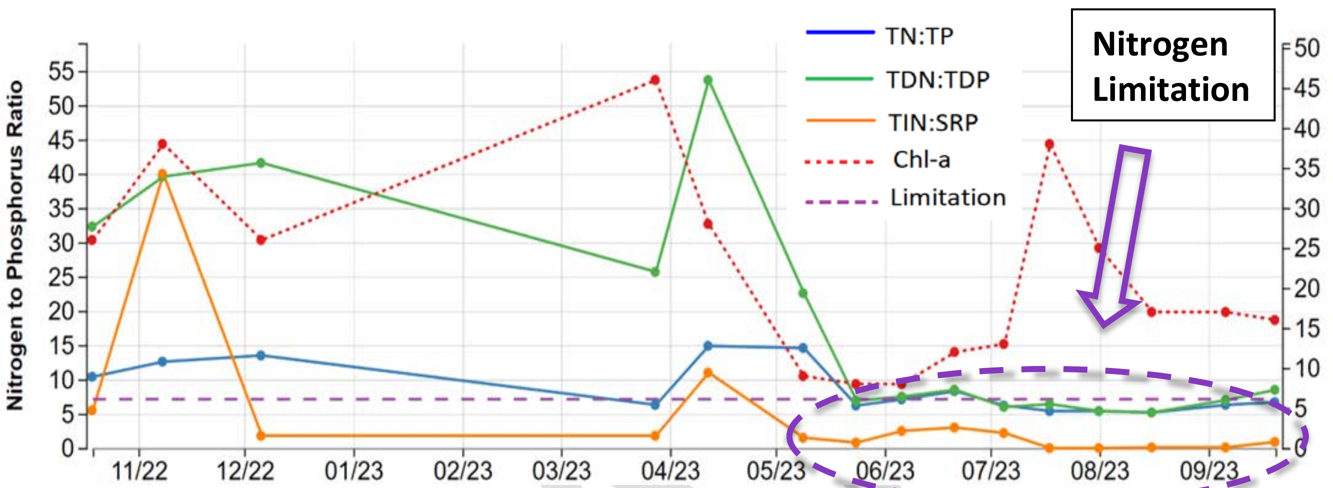


Figure 72. Nutrient Ratios for and Chlorophyll *α* in Cherry Creek Reservoir in WY 2023.

4.15 TROPHIC STATE ANALYSIS

The trophic state of a lake is a relative expression of the biological productivity of a lake. Two approaches to TSI are presented below, one based on the Carlson index and one based on EPA criteria.

Carlson Index

The Trophic State Index (TSI) developed by Carlson (1977) is among the most commonly used indicators of lake trophic state. This index is expressed as three separate indices based on observations of TP concentrations, chl α concentrations, and Secchi depths from a variety of lakes. TP is used in the index because phosphorus is often the nutrient limiting algal growth in lakes. Chl α is a plant pigment present in all algae and is used to provide an indication of the algal biomass in a lake. Secchi depth is a common measure of the transparency of lake water. The three are related in many lakes because transparency is often limited by algal growth and algal growth can be limited by phosphorus in productive lakes. However, the high phosphorus concentrations in Cherry Creek Reservoir often indicate nitrogen limiting conditions.

Mean values of TP, chl α, and Secchi depth for an individual lake are logarithmically converted to a scale of relative trophic state ranging from 1 to 100. Elevated values for the TSI are indicative of higher productivity. A TSI of less than 35 indicates oligotrophic conditions, a TSI between 35 and 50 indicates mesotrophic conditions, and a TSI greater than 50 indicates eutrophic conditions. Hypereutrophic, or excessively productive lakes, have TSI values greater than 70. Higher numbers are associated with increased probabilities of encountering nuisance conditions, such as algal scum.

Trophic state indices for Cherry Creek Reservoir from WY 2023 are presented in Table 18. These values were calculated using the average of the photic zone (0-3 m) composite samples collected at stations CCR-1, CCR-2, and CCR-3 during the months of May through September because Carlson (1977) suggested that summer average values may produce the most meaningful results.

Table 18. Trophic State Indices for Cherry Creek Reservoir WY 2018-2023.

Year	Trophic State Index (TSI)		
	Total P	Secchi Depth	Chlorophyll α
2023	76	55	58
Trophic State	**Hypereutrophic**	**Eutrophic**	**Eutrophic**

Figure 73 displays the historical TSI for Cherry Creek Reservoir for each of the parameters for the May-September averages for TP, Secchi depth, and chl α from 2002 to 2023. Based on this index, Cherry Creek Reservoir is considered eutrophic for Secchi depth and chl α, and ranges between eutrophic and hypereutrophic based on TP concentrations. Although the TSI has shown variability over time, the TSI for TP in WY 2023 was the highest observed since 2002. This high TSI value for TP can be attributed to the high concentrations of phosphorus in the stream inflows during the large storm events in WY 2023. It is noteworthy that the TSI values for Secchi depth and chl α declined in WY2023, despite the elevated phosphorus concentrations.

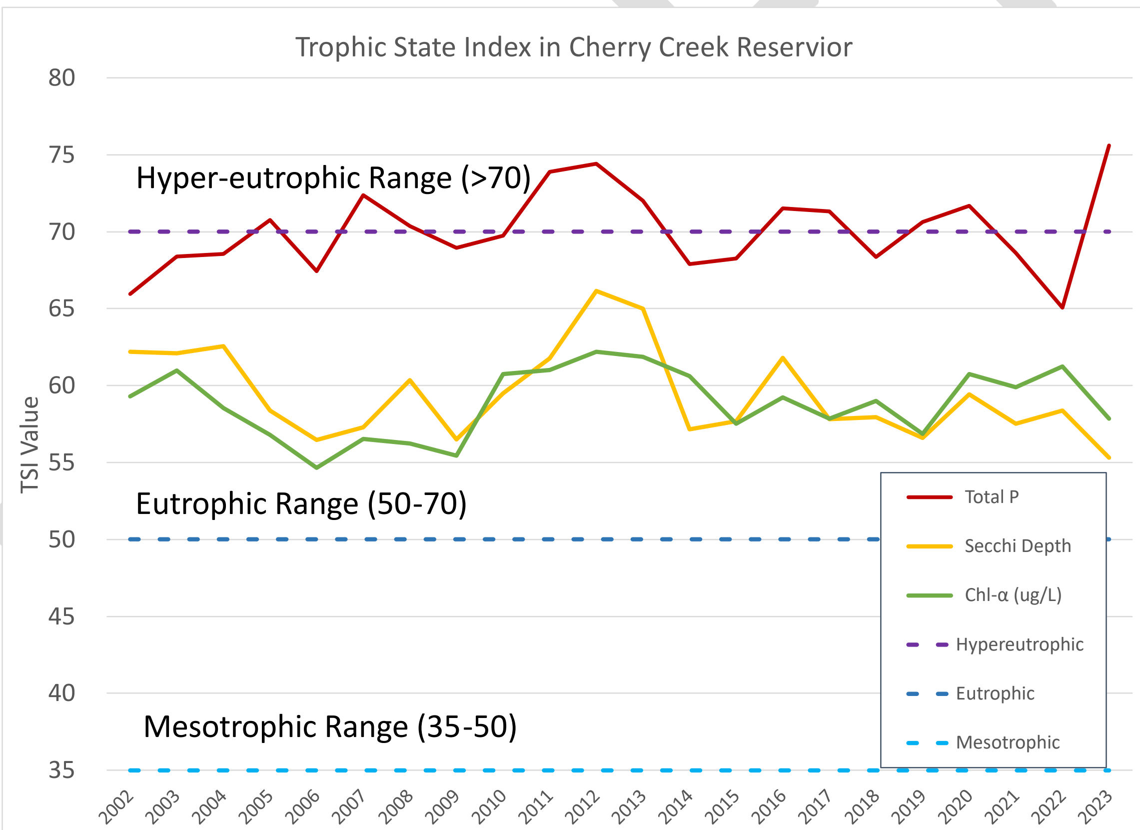


Figure 73. Trophic State Index for Cherry Creek Reservoir (2002-2023).

EPA Trophic State Criteria

Trophic state can also be assessed by comparing monitoring data to trophic state criteria, such as those developed by the U.S. EPA (1980). Table 19 presents a comparison of Cherry Creek Reservoir monitoring data from WY 2023 (May-September) to EPA trophic state criteria. Values for the various parameters were the same averages used to calculate the trophic state indices.

Table 19. Comparison of Cherry Creek Reservoir Monitoring Data to EPA Trophic State Criteria WY 2023.

Trophic State	Characteristic			
	Total P (mg/L)	Chlorophyll *a* (µg/L)	Secchi Depth (m)	Relative Productivity
Oligotrophic	< 0.005	< 2.0	> 8	Low
Mesotrophic	0.005 -0.030	2.0 - 6.0	4 – 8	Moderate
Eutrophic	0.030 - 0.100	**6.0 - 40.0**	2 – 4	High
Hypereutrophic	**> 0.100**	> 40.0	**< 2**	Excessive
Cherry Creek Reservoir	**0.142**	**16.16**	**1.38**	**High**

The trophic state criteria in Table 19, like calculated trophic state indices, are based on somewhat arbitrary concentrations that are typically found when the average lake user perceives that water quality problems exist. Comparison of monitoring data from Cherry Creek Reservoir to the EPA trophic state criteria indicate that conditions in Cherry Creek Reservoir are in the eutrophic range for chl α concentrations and hypereutrophic for TP and Secchi depth.

The trophic state based on the EPA criteria is slightly different than the Carlson index calculations. It is important to consider that sometimes the trophic state related to Secchi depth alone can be misleading since conventional trophic state criteria assume that Secchi depth is related primarily to algal turbidity. Inorganic turbidity can be a more important factor in determining water clarity for many reservoirs, where Secchi depth does not always provide a good indication of trophic state since these measurements cannot distinguish between algal productivity and inorganic suspended sediment. Inorganic turbidity plays a role in water transparency and associated Secchi depths in Cherry Creek Reservoir as well.

Although these two methods use slightly different calculations and ranges, both the Carson Index and EPA criteria indicate eutrophic to hypereutrophic conditions of Cherry Creek Reservoir for each of the individual parameters evaluated.

4.16 NUTRIENT CONCENTRATIONS IN DIRECT PRECIPITATION

The rain that falls in the watershed ending in the streams also falls directly on the Reservoir serving as a nutrient source and is considered an inflow in the nutrient balance. The TP and TN baseline median, summary statistics and median concentrations for the samples collected from the storms in WY 2023 are displayed in Figure 74. The baseline median is used to calculate the TP and TN added to the Reservoir based on daily precipitation and urface area. There is a high variability of the nutrient concentrations found in the precipitation samples collected but TP and TN concentrations measured in WY 2023 exceeded the 2027 CDPHE proposed lake nutrient standards which is not uncommon.

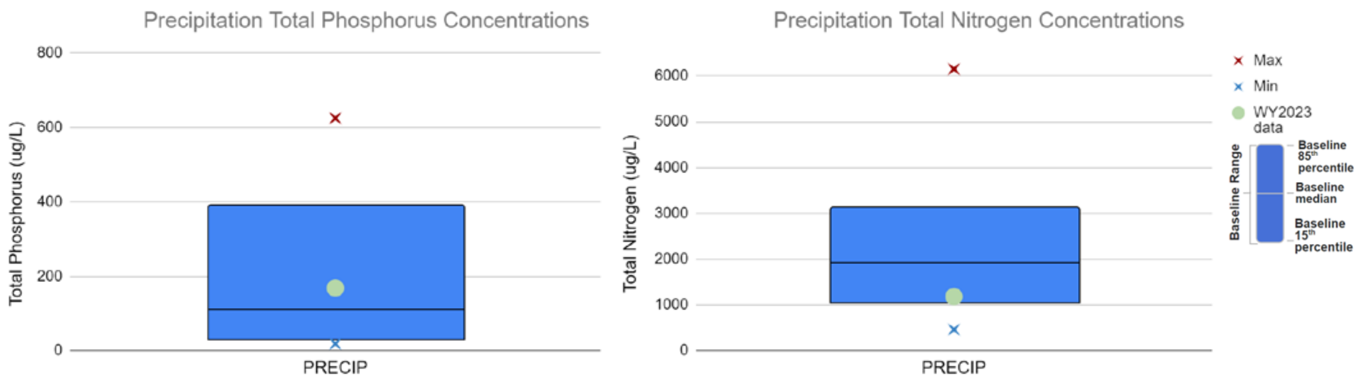


Figure 74. Total Phosphorus and Nitrogen in Precipitation, Summary Statistics and WY 2023.

4.17 PLANKTON DYNAMICS

Analyses of phytoplankton and zooplankton samples were used to assess biological conditions in Cherry Creek Reservoir during WY 2023. Both numbers of individuals (cells/mL for phytoplankton and animals/L for zooplankton) and biovolume (μm^3/mL for phytoplankton) or biomass (µg/L for zooplankton) were reported.

4.17.1 PHYTOPLANKTON

Phytoplankton are photosynthetic organisms that are the primary producers in aquatic systems. They form the base of aquatic food chains and are grazed upon by zooplankton and herbivorous fish. A healthy lake should support a diverse assemblage of phytoplankton, in which many algal groups are represented.

In many environmental instances, algal numbers (cells/mL) and algal biovolume (μm^3/mL) closely correlate with one another, but that is not always the case. It is possible, and a common occurrence, for a phytoplankton community to have a large number of very small-sized algal cells, particularly in systems, such as Cherry Creek Reservoir, that have high numbers of cyanobacteria (Cyanophyta), commonly referred to as blue-green algae. At other times, the phytoplankton community can be dominated by a few algal species that are very large in size.

Phytoplankton samples were collected at site CCR-2 from the photic zone (0-3 m composite sample) and analyzed to identify and quantify the populations present on each sampling date. The results from WY 2023 indicate high productivity with diverse populations.

Due to factors outside of the CCBWQA's control related to laboratory services, some of the phytoplankton data from the end of WY 2023 are not available. As soon as these data can be analyzed, the phytoplankton chapter will be completed and provided in the amended final report.

4.17.2 ZOOPLANKTON

Zooplankton are microscopic animals that consume algae and bacteria in the water column. Some types of zooplankton feed on algae, some on other zooplankton, and some take in both plant and animal particles. Monitoring populations is important because larger zooplankton can exert significant grazing pressure on algal cells; however, they are also subject to predation as they are a food source for larger crustaceans, aquatic insects, and fish. Zooplankton populations in lakes vary with temperature, food supply, and other environmental factors, with reported populations ranging from a few to several hundred individuals per liter (Hutchinson, 1967). Very little detailed information is available on zooplankton dynamics and populations in reservoirs, although turbidity, increased flow, and other factors probably reduce their numbers to below those observed in natural lakes (Marzolf, 1990).

Most freshwater zooplankton are part of only three phyla: *Arthropoda*, which includes cladocerans, copepods, and ostracods; *Rotifera*; and *Protozoa*. Cladocerans and copepods are microscopic crustaceans that feed primarily on phytoplankton, while ostracods are omnivores and eat both small phytoplankton and other organic material. Larger organisms in these groups can be an important food source for fish and can also exert grazing pressure on phytoplankton populations when present in high enough numbers. Rotifers are microscopic animals that feed on detritus and smaller organisms, such as bacteria. They can also serve as a food source for larger zooplankton. Protozoans are single-celled organisms that feed on other microorganisms, organic matter, and debris.

Zooplankton samples were collected as vertical tows from a depth of 6 m to the surface at station CCR-2 on each sampling date. Zooplankton numbers and diversity were both low compared to average phytoplankton populations in freshwater lakes.

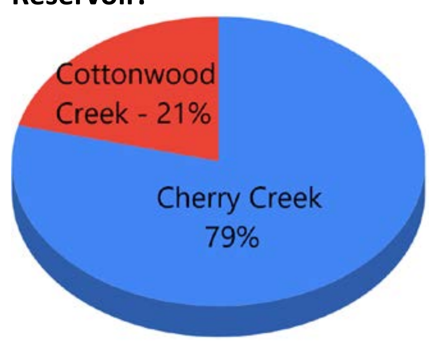
Due to factors outside of the CCBWQA's control related to laboratory services, some of the zooplankton data from the end of WY 2023 are not available. As soon as these samples can be analyzed, the zooplankton chapter will be completed and provided in the amended final report.

5.0 WATER BALANCE

Due to circumstances outside of the control of the CCBWQA due to flood events and equipment damage, and data not available from the USACE, some of the inflow and storage data required for the calculations in the water balance are not available. As an alternative, the relative inflow discharge ratio of Cherry Creek to Cottonwood Creek from 2016-2022, along with the inflow, outflow and reservoir storage provided by the USACE will be used. However, the storage information provided by the USACE is also not available due to a discrepancy in the elevation datum shift. This discrepancy should be fixed by the end of January at which time the storage information will be provided and the required calculations can be completed.

In order to represent the relative inflow contributions for Cherry Creek and Cottonwood as accurately as possible during the periods of time when no data were available, the average of the historical values from 2016-2022 will be used.

On average, Cherry Creek contributes 79% and Cottonwood Creek contributes 21% of the total surface water flows to Cherry Creek Reservoir.



6.0 FLOW WEIGHTED NUTRIENT CONCENTRATIONS

The nutrient concentrations of the inflows and the outflow of Cherry Creek Reservoir are used to calculate the mass storage on an annual basis. The flow-weighted influent phosphorus goal, derived as part of the 2009 Reg 38 rulemaking process to achieve the 18 µg/L chl α standard, is 200 µg/L. Flow-weighted nutrient concentrations and mass storage in the Reservoir for WY 2023 will be provided after the water balance has been completed.

8.0 NUTRIENT MASS BALANCES

Following the water balance and flow-weighted nutrient concentrations, the mass storage calculations for the Reservoir will be completed following the information provided by the USACE in early 2024.

9.0 WY 2023 WATER QUALITY SUMMARY

The results obtained from the CCBWQA's comprehensive monitoring program documents water quality within the watershed over time. Key findings from monitoring conducted during WY 2023 include:

- Cherry Creek Reservoir did not meet the chl α seasonal standard for WY 2023, but it did meet the Reg 38 standards for temperature, pH, and dissolved oxygen to support the Class 1 Warm Water Aquatic Life classification. Additionally, the seasonal chl α concentration was one of the five lowest since 2010, despite significantly elevated phosphorus concentrations.
- Cherry Creek Reservoir continues to remain eutrophic to hypereutrophic in regard to total phosphorus, chl α, and transparency of the water. There was a cyanobacteria bloom in late-July to mid-August 2023 resulting in posting of signage to inform the public of closures to recreational users of the Reservoir due to risk or presence of toxin.
- Surface water flows are the main contributor of nutrient concentrations in the inflows and nutrient loading of the reservoir. The WY 2023 weather and precipitation in the watershed directly impacted the water quantity and quality of Reservoir inflows, internal Reservoir dynamics, and the overall exchange rate.
- The WY 2023 Reservoir conditions due to above average inflows and precipitation resulted in higher water levels and reduced residence time. However, the high phosphorus concentrations from the flood events also increased the potential for algae growth and cyanobacteria blooms. High chl α concentrations were present shortly after the rain slowed and the temperatures warmed.
- There continues to be notable differences in water quality between Cherry Creek, Cottonwood Creek, and Piney Creek. Cherry Creek has much higher concentrations of phosphorus, and Cottonwood Creek has higher concentrations of nitrogen. Piney Creek continues to demonstrate lower concentrations of nutrients and suspended solids when compared to Cherry Creek during baseflow conditions. Stream characteristics vary in terms of stream channel morphology, flow patterns, wetlands, vegetation growth patterns, effects of storm events, watershed development, number of permitted wastewater treatment facility discharge outfalls, and differences in runoff from the watersheds. All of these factors play a role in water quality.
- Conductivity in the streams and groundwater is significantly increasing over time, which impacts Reservoir water quality and dynamics.
- In WY 2023, the constructed wetland PRF ponds on Cottonwood Creek functioned effectively to remove phosphorus and suspended solids during stormflow conditions. In addition, the PRF ponds on Cottonwood Creek have been functioning effectively when evaluating upstream to downstream concentrations on a long-term basis. The stream reclamation PRFs on McMurdo Gulch is also performing well.

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APPENDICES

APPENDIX A - Cherry Creek Basin Water Quality Authority Monitoring Data, WY 2023.

APPENDIX B – WY 2023 Cherry Creek Reservoir Daily Inflow and Outflow Data and Monthly Summary Information (will be included with amended report)

Appendix A – Cherry Creek Basin Water Quality Authority Monitoring Data, WY 2023

Table 1. Cherry Creek Reservoir, Physical Parameters, WY 2023

Constituent	*Units*	*Location Name*	10/19/202	11/8/2022	12/6/2022	3/28/2023	4/12/2023	5/9/2023	5/24/2023	6/6/2023	6/21/2023	7/5/2023	7/18/2023	8/1/2023	8/16/2023	9/6/2023	9/20/2023
Light Transmittance [99% Attenuation]	m	CCR-1	1.8	2.3	3.0	2.5	2.7	4.0	4.1	4.4	2.7	3.4	3.4	2.8	2.8	3.1	2.5
Light Transmittance [99% Attenuation]	m	CCR-2	1.9	2.4	2.8	2.4	2.6	3.8	4.1	5.0	2.6	3.6	4.0	2.6	2.8	2.9	2.6
Light Transmittance [99% Attenuation]	m	CCR-3	1.6	2.3	2.9	2.5	2.5	4.1	4.3	4.6	2.5	2.8	3.5	2.4	2.8	2.9	2.5
Light Transmittance [Secchi Depth]	m	CCR-1	0.6	0.8	1.0	0.8	0.7	1.5	2.8	2.5	0.7	1.5	1.2	1.1	1.0	1.1	0.9
Light Transmittance [Secchi Depth]	m	CCR-2	0.7	0.8	1.0	0.7	0.6	1.5	2.9	2.8	0.6	1.6	1.1	1.1	0.9	1.0	0.8
Light Transmittance [Secchi Depth]	m	CCR-3	0.6	0.8	0.9	0.7	0.6	1.7	2.8	2.4	0.6	1.1	1.2	1.0	0.8	1.0	0.8
Oxygen Dissolved	mg/L	CCR-1	8.1	9.9	11.4	12.8	11.1	8.5	7.0	6.4	6.7	6.3	11.8	7.1	7.1	6.0	6.7
Oxygen Dissolved	mg/L	CCR-2	8.4	9.9	11.6	13.1		8.6	6.9	6.3	6.8	6.2	12.0	7.4	7.1	6.4	7.5
Oxygen Dissolved	mg/L	CCR-3	8.4	10.3	11.3	13.1	10.7	8.4	6.8	6.7	6.8	6.2	12.0	7.6	7.5	6.5	7.5
pH	None	CCR-1	8.5	8.6	8.6	8.8	8.6	8.5	8.0	7.9	8.0	7.8	8.9	8.5	8.5	8.4	8.5
pH	None	CCR-2	8.5	8.6	8.5	8.7		8.5	8.0	7.9	8.0	7.9	8.9	8.6	8.5	8.4	8.6
pH	None	CCR-3	8.5	8.6	8.6	8.7	8.6	8.5	8.0	8.0	8.0	7.9	9.0	8.7	8.6	8.4	8.6
Specific Conductance	uS/cm	CCR-1	1,272	1,354	1,413	1,295	1,286	1,369	860	903	869	815	848	888	904	929	959
Specific Conductance	uS/cm	CCR-2	1,276	1,353	1,387	1,284		1,370	859	900	870	813	851	889	904	908	960
Specific Conductance	uS/cm	CCR-3	1,277	1,352	1,406	1,292	1,284	1,372	867	902	869	819	851	892	905	928	960
Temperature Water	deg C	CCR-1	14.0	7.8	2.7	5.0	10.6	15.7	17.8	18.0	19.7	21.9	24.9	24.0	23.2	21.9	18.8
Temperature Water	deg C	CCR-2	13.9	7.9	2.7	5.3		16.2	17.5	18.4	20.3	21.9	25.3	24.2	23.6	21.9	19.1
Temperature Water	deg C	CCR-3	14.2	7.9	3.0	5.0	10.3	16.6	17.8	18.8	19.8	21.6	26.2	24.2	23.9	22.0	19.5

Table 2. Cherry Creek Reservoir Nutrients and Chemical Parameters, WY 2023

Constituent	Units	Location Name	10/19/202	11/8/2022	12/6/2022	3/28/2023	4/12/2023	5/9/2023	5/24/2023	6/6/2023	6/21/2023	7/5/2023	7/18/2023	8/1/2023	8/16/2023	9/6/2023	9/20/2023
Chlorophyll-a	ug/L	CCR-1	25	39	26	42	26	11	6	8	8	14	37	16	17	17	17
Chlorophyll-a	ug/L	CCR-2	26	38	26	46	28	9	8	8	12	13	38	25	17	17	16
Chlorophyll-a	ug/L	CCR-3	27	43	27	45	31	11	8	9	10	15	38	24	22	14	20
Phaeo-a	ug/L	CCR-1	4	50	50	50	50	50	50	50	50	50	2	50	1	10	7
Phaeo-a	ug/L	CCR-2	1	50	50	50	3	50	50	50	50	50	50	50	50	12	7
Phaeo-a	ug/L	CCR-3	4	50	50	3	50	50	50	50	50	50	50	50	50	11	7
Soluble Reactive Phosphorus as P	ug/L	CCR-1	535	538	514	344	499	492	1,010	1,050	1,230	1,050	523	637	489	506	346
Soluble Reactive Phosphorus as P	ug/L	CCR-2	484	554	499	334	483	451	975	1,100	1,180	935	509	638	448	534	350
Soluble Reactive Phosphorus as P	ug/L	CCR-3	522	553	494	348	489	474	940	1,050	1,120	1,020	503	637	440	436	365
Dissolved Phosphorus	ug/L	CCR-1	2	1	5	4	1	8	132	137	116	133	62	101	71	66	36
Dissolved Phosphorus	ug/L	CCR-2	1	1	3	3	1	13	135	145	123	152	67	111	73	66	33
Dissolved Phosphorus	ug/L	CCR-3	1	1	2	5	1	14	133	139	118	144	63	108	73	60	32
Total Phosphorus	ug/L	CCR-1	17	14	11	12	10	19	139	138	140	151	82	116	90	75	46
Total Phosphorus	ug/L	CCR-2	15	14	12	13	9	20	142	147	140	157	80	118	86	76	41
Total Phosphorus	ug/L	CCR-3	15	12	12	13	11	23	139	140	129	153	75	114	92	69	47
Nitrate + Nitrite as N	ug/L	CCR-1	77	72	62	90	77	50	159	157	149	167	139	155	136	123	91
Nitrate + Nitrite as N	ug/L	CCR-2	79	72	64	107	81	69	193	178	197	186	204	164	153	116	90
Nitrate + Nitrite as N	ug/L	CCR-3	82	79	62	83	76	60	157	153	149	177	137	162	136	112	95
Total Ammonia as N	ug/L	CCR-1	3	3	3	3	12	3	3	162	192	191	3	3	11	3	3
Total Ammonia as N	ug/L	CCR-2	3	3	3	3	3	3	3	163	184	176	3	3	3	3	12
Total Ammonia as N	ug/L	CCR-3	3	3	12	3	12	3	3	164	188	184	3	3	11	3	3
Dissolved Nitrogen as N	ug/L	CCR-1	3	19	21	3	20	14	105	194	182	157	3	3	13	3	22
Dissolved Nitrogen as N	ug/L	CCR-2	3	17	3	3	3	16	105	203	188	165	3	3	3	3	19
Dissolved Nitrogen as N	ug/L	CCR-3	3	3	3	3	17	20	86	185	171	154	3	3	3	3	14

Total Nitrogen as N	ug/L	CCR-1	535	538	514	344	499	492	1,010	1,050	1,230	1,050	523	637	489	506	346
Total Nitrogen as N	ug/L	CCR-2	484	554	499	334	483	451	975	1,100	1,180	935	509	638	448	534	350
Total Nitrogen as N	ug/L	CCR-3	522	553	494	348	489	474	940	1,050	1,120	1,020	503	637	440	436	365
Total Organic Carbon	mg/L	CCR-2	7.3	7.2	7.3	6.6	6.4	6.8	7.1	6.9	6.8	7.6	7.3	7.0	6.8	6.9	7.3
Dissolved Organic Carbon	mg/L	CCR-2	7.2	7.1	6.7	6.3	6.0	6.4	6.6	6.5	6.1	6.9	7.1	6.4	5.9	6.7	6.3
Total Suspended Solids	mg/L	CCR-1	11	8	6	7	9	4	2	2	3	5	9	7	6	7	6
Total Suspended Solids	mg/L	CCR-2	11	10	6	6	11	4	1	1	2	3	9	6	6	9	9
Total Suspended Solids	mg/L	CCR-3	11	11	3	7	9	4	1	2	2	7	10	10	6	9	9
Total Volatile Suspended Solids	mg/L	CCR-1	6	4	3	6	5	2	1	2	2	1	3	3	1	3	2
Total Volatile Suspended Solids	mg/L	CCR-2	7	5	5	5	9	2	1	1	2	1	4	3	2	4	3
Total Volatile Suspended Solids	mg/L	CCR-3	7	5	3	6	6	2	1	1	1	1	3	4	1	3	3

Table 3. Cherry Creek Watershed Streams Sites Physical Parameters, WY 2023.

Constituent	*Units*	*Location Name*	10/19/2022	11/7-8/2022	12/6/2022	1/10/2023	2/14/2023	3/14/2023	4/12/2023	5/3-4/2023	6/15/2023	7/10/2023	8/9/2023	9/13/2023
Conductivity	umhos/cm	CC-1		394						374				
Conductivity	umhos/cm	CC-2		1170						689				
Conductivity	umhos/cm	CC-4		1060						866				
Conductivity	umhos/cm	CC-5		951						893				
Conductivity	umhos/cm	CC-6		1004						966				
Conductivity	umhos/cm	CC-7		1101						1023				
Conductivity	umhos/cm	CC-8		1118						1057				
Conductivity	umhos/cm	CC-9		1324						1278				
Conductivity	umhos/cm	CC-10		1339				1205		1298				

Conductivity	umhos/cm	CC-Out		1384						1451				
Conductivity	umhos/cm	CC-USGSFRANKTOWN		247						289				
Conductivity	umhos/cm	CC-USGSPARKER		798						797				
Conductivity	umhos/cm	CT-1		1665						1854				
Conductivity	umhos/cm	CT-2		1714						1920				
Conductivity	umhos/cm	CT-P1		2580				4270		3000				
Conductivity	umhos/cm	CT-P2		2450						2970				
Conductivity	umhos/cm	PC-1		2150				2340		2190				
Dissolved Oxygen	mg/L	CC-1		9						8				
Dissolved Oxygen	mg/L	CC-2		6						8				
Dissolved Oxygen	mg/L	CC-4		6						9				
Dissolved Oxygen	mg/L	CC-5		9						8				
Dissolved Oxygen	mg/L	CC-6		11						9				
Dissolved Oxygen	mg/L	CC-7	9	10	10	12	11	10	8	9	8	8	8	8
Dissolved Oxygen	mg/L	CC-8		11						10				
Dissolved Oxygen	mg/L	CC-9		9						7				
Dissolved Oxygen	mg/L	CC-10	8	10	11	11	11	11	9	8	8	7	7	8
Dissolved Oxygen	mg/L	CC-Out	9	10	11	11	11	10	10	9	8	7	7	7
Dissolved Oxygen	mg/L	CC-USGSFRANKTOWN		11						9				
Dissolved Oxygen	mg/L	CC-USGSPARKER		7						7				
Dissolved Oxygen	mg/L	CT-1	11	11	11	10	11	11	11	10	8	7	8	9
Dissolved Oxygen	mg/L	CT-2	10	10	11	11	10	10	9	8	7	7	6	6
Dissolved Oxygen	mg/L	CT-P1	9	10	11	12	12	11	10	11	8	7	8	8
Dissolved Oxygen	mg/L	CT-P2	11	11	12	11	11	11	8	10	7	7	8	8
Dissolved Oxygen	mg/L	PC-1	10	15	13	13	14	12	11	13	8	9	9	9
Dissolved Oxygen, Saturation	%	CC-1		84						93				
Dissolved Oxygen, Saturation	%	CC-2		63						88				
Dissolved Oxygen, Saturation	%	CC-4		68						105				
Dissolved Oxygen, Saturation	%	CC-5		96						104				

Dissolved Oxygen, Saturation	%	CC-6		114						115				
Dissolved Oxygen, Saturation	%	CC-7	99	108	96	112	103	100	91	119	96	98	96	94
Dissolved Oxygen, Saturation	%	CC-8		114						130				
Dissolved Oxygen, Saturation	%	CC-9		93						95				
Dissolved Oxygen, Saturation	%	CC-10	88	103	106	98	112	111	112	104	96	94	92	98
Dissolved Oxygen, Saturation	%	CC-Out	99	104	102	100	101	96	106	96	103	100	101	101
Dissolved Oxygen, Saturation	%	CC-USGSFRANKTOWN		103						100				
Dissolved Oxygen, Saturation	%	CC-USGSPARKER		92						92				
Dissolved Oxygen, Saturation	%	CT-1	123	121	100	85	100	115	150	126	110	96	105	117
Dissolved Oxygen, Saturation	%	CT-2	113	107	99	91	96	97	112	105	85	102	84	71
Dissolved Oxygen, Saturation	%	CT-P1	103	106	104	106	108	101	127	132	101	95	119	104
Dissolved Oxygen, Saturation	%	CT-P2	120	117	116	96	99	110	87	118	86	100	114	109
Dissolved Oxygen, Saturation	%	PC-1	99	159	133	128	128	114	120	161	99	123	111	111
Dissolved Oxygen, Saturation	%	CC-2		63						88				
pH		CC-1		8						8				
pH		CC-2		7						8				
pH		CC-4		7						8				
pH		CC-5		8						8				
pH		CC-6		8						8				
pH		CC-7	8	8	8	8	8	7	8	8	8	8	8	8
pH		CC-8		8						8				
pH		CC-9		8						8				
pH		CC-10	8	8	8	8	8	7	8	8	8	8	8	8

pH		CC-Out	8	9	9	8	8	7	9	8	8	8	9	8
pH		CC-USGSFRANKTOWN		8						8				
pH		CC-USGSPARKER		8						8				
pH		CT-1	8	8	8	8	8	7	8	8	8	8	8	8
pH		CT-2	8	8	8	8	8	7	8	8	8	8	8	8
pH		CT-P1	8	8	8	8	8	7	8	8	8	8	8	8
pH		CT-P2	8	8	8	8	8	7	8	8	8	8	8	8
pH		PC-1	8	8	8	8	8	7	8	8	8	8	8	8
Specific Conductance	uS/cm	CC-1		375						346				
Specific Conductance	uS/cm	CC-2		1095						637				
Specific Conductance	uS/cm	CC-4		997						799				
Specific Conductance	uS/cm	CC-5		893						829				
Specific Conductance	uS/cm	CC-6		941						907				
Specific Conductance	uS/cm	CC-7	1214	1047	1110	1177	1062	918	944	958	763	973	594	935
Specific Conductance	uS/cm	CC-8		1069						996				
Specific Conductance	uS/cm	CC-9		1260						1214				
Specific Conductance	uS/cm	CC-10	1007	1275	1298	1394	1270	1110	1147	1223	964	1181	882	1132
Specific Conductance	uS/cm	CC-Out	1272	1353	1392	1496	1507	1467	1293	1368	867	855	896	942
Specific Conductance	uS/cm	CC-USGSFRANKTOWN		234						270				
Specific Conductance	uS/cm	CC-USGSPARKER		757						741				
Specific Conductance	uS/cm	CT-1	1755	1635	1997	2682	2049	1684	1830	1757	1374	1426	1595	1458
Specific Conductance	deg C	CT-2	1751	1680	2084	2512	2045	1801	1810	1804	1252	1409	1503	1347
Specific Conductance	deg C	CT-P1	2440	2472	3419	4034	3327	3904	3308	2751	1875	1548	2013	1739
Specific Conductance	deg C	CT-P2	2456	2347	3456	3922	3137	3746	3257	2719	1847	1547	2004	1761
Specific Conductance	deg C	PC-1	1746	2015	2105	2525	2239	2122	2117	2037	1318	1585	1102	1651
Water Temperature	deg C	CC-1		5						10				
Water Temperature	deg C	CC-2		9						13				
Water Temperature	deg C	CC-4		11						15				
Water Temperature	deg C	CC-5		10						15				
Water Temperature	deg C	CC-6		9						15				
Water Temperature	deg C	CC-7	9	8	4	5	4	5	10	16	15	18	17	15
Water Temperature	deg C	CC-8		8						17				

Water Temperature	deg C	CC-9		8						18				
Water Temperature	deg C	CC-10	8	7	3	2	5	7	14	17	17	21	17	17
Water Temperature	deg C	CC-Out	13	8	2	3	4	4	10	11	17	22	23	21
Water Temperature	deg C	CC-USGSFRANKTOWN		4						10				
Water Temperature	deg C	CC-USGSPARKER		18						16				
Water Temperature	deg C	CT-1	11	9	2	1	4	7	19	16	19	22	20	21
Water Temperature		CT-2	10	8	2	0	3	6	17	16	18	22	20	17
Water Temperature		CT-P1	13	8	5	1	2	4	18	14	18	22	22	21
Water Temperature		CT-P2	12	9	3	1	2	6	11	14	17	23	22	20
Water Temperature		PC-1	7	9	6	5	3	4	9	15	14	19	18	14

Table 4. Cherry Creek Watershed Streams Sites Nutrients and Chemical Parameter Concentrations, WY 2023, Baseflow.

Constituent	*Units*	*Location Name*	10/19/2022	11/7-8/2022	12/6/2022	1/10/2023	2/14/2023	3/14/2023	4/12/2023	5/3-4/2023	6/15/2023	7/10/2023	8/9/2023	9/13/2023
Nitrate + Nitrite as N	ug/L	CC-10	313	277	684	915	827	345	259	361	*	352	516	502
Nitrate + Nitrite as N	ug/L	CC-7	765	710	1,430	1,190	1,290	490	471	572		512	675	839
Nitrate + Nitrite as N	ug/L	CC-Out	3	3	18	123	165	16	3	3		171	3	16
Nitrate + Nitrite as N	ug/L	CT-1	1,410	1,450	2,810	1,680	2,030	2,950	1,010	1,182		844	1,410	1,580
Nitrate + Nitrite as N	ug/L	CT-2	1,250	1,250	2,530	1,770	2,070	2,820	472	491		495	459	679
Nitrate + Nitrite as N	ug/L	CT-P1	368	326	495	620	508	331	152	173		185	422	439
Nitrate + Nitrite as N	ug/L	CT-P2	544	402	599	708	536	518	327	259		270	618	590
Nitrate + Nitrite as N	ug/L	MCM-1	309		555		709		539				334	
Nitrate + Nitrite as N	ug/L	MCM-2	3		126		306		13				36	
Nitrate + Nitrite as N	ug/L	PC-1	152	77	197	304	151	200	28	92		355	404	405
Total Ammonia as N	ug/L	CC-10	3	3	3	18	3	22	3	23	*	21	16	26
Total Ammonia as N	ug/L	CC-7	10	10	3	19	13	22	3	34		11	22	35
Total Ammonia as N	ug/L	CC-Out	15	36	9	248	361	167	3	3		253	3	62
Total Ammonia as N	ug/L	CT-1	13	15	24	33	374	88	101	46		38	17	28

Total Ammonia as N	ug/L	CT-2	56	50	19	33	276	99	42	37		42	42	68
Total Ammonia as N	ug/L	CT-P1	22	14	14	21	13	66	22	3		31	3	43
Total Ammonia as N	ug/L	CT-P2	24	3	3	12	3	39	22	3		15	37	53
Total Ammonia as N	ug/L	MCM-1	3		3		3		14				3	
Total Ammonia as N	ug/L	MCM-2	3		3		3		3				3	
Total Ammonia as N	ug/L	PC-1	3	3	3	13	3	20	3	3			3	43
Dissolved Nitrogen as N	ug/L	CC-10			1,220	1,570	1,420	800	900		*	1,010	1,320	810
Dissolved Nitrogen as N	ug/L	CC-7			2,140	2,530	2,050	587	1,310			1,300	1,500	1,270
Dissolved Nitrogen as N	ug/L	CC-Out			553	1,130	1,390	710	790			1,070	720	320
Dissolved Nitrogen as N	ug/L	CT-1			3,810	3,690	3,280	3,240	2,210			1,950	2,720	2,250
Dissolved Nitrogen as N	ug/L	CT-2			3,680	3,730	3,240	2,820	1,380			1,430	1,400	1,230
Dissolved Nitrogen as N	ug/L	CT-P1			1,060	1,290	1,150	890	910			920	1,250	850
Dissolved Nitrogen as N	ug/L	CT-P2			1,200	1,500	1,120	1,050	1,130			1,060	1,560	1,010
Dissolved Nitrogen as N	ug/L	PC-1			658	930	810	480	540			1,143	1,280	557
Total Nitrogen as N	ug/L	CC-10	814	776	1,320	1,680	1,460	810	970	768	1,480	1,160	1,580	960
Total Nitrogen as N	ug/L	CC-7	1,430	1,657	2,220	2,600	2,120	920	1,350	1,250	1,960	1,400	1,750	1,350
Total Nitrogen as N	ug/L	CC-Out	841	1,060	924	1,310	1,610	980	1,270	748	950	1,280	920	560
Total Nitrogen as N	ug/L	CT-1	2,770	3,560	3,970	3,780	3,640	3,430	2,500	2,090	1,900	2,280	2,770	2,520
Total Nitrogen as N	ug/L	CT-2	2,520	2,940	3,860	3,830	3,400	2,990	1,710	1,190	1,510	1,570	1,580	1,350
Total Nitrogen as N	ug/L	CT-P1	1,060	1,130	1,200	1,510	1,230	970	960	660	1,380	1,140	1,390	980
Total Nitrogen as N	ug/L	CT-P2	1,210	1,220	1,280	1,510	1,410	1,250	1,300	840	1,800	1,170	1,700	1,200
Total Nitrogen as N	ug/L	MCM-1	737		983		1,230		1,170		900		1,020	
Total Nitrogen as N	ug/L	MCM-2	293		418		810		520		815		705	
Total Nitrogen as N	ug/L	PC-1	669	506	766	1,070	860	500	750	530	1,120	1,250	1,400	930
Soluble Reactive Phosphorus as P	ug/L	CC-10	128	126	92	87	73	83	95	170	*	218	196	155
Soluble Reactive Phosphorus as P	ug/L	CC-7	71	78	52	51	41	42	49	124		164	168	114
Soluble Reactive Phosphorus as P	ug/L	CC-Out	1	5	2	31	65	15	1	24		162	90	49
Soluble Reactive Phosphorus as P	ug/L	CT-1	3	3	3	2	4	5	5	8		29	20	10
Soluble Reactive Phosphorus as P	ug/L	CT-2	5	5	3	2	3	4	4	7		39	31	20
Soluble Reactive Phosphorus as P	ug/L	CT-P1	6	3	4	3	4	6	5	3		35	23	26
Soluble Reactive Phosphorus as P	ug/L	CT-P2	4	2	3	2	3	4	4	8		31	45	21
Soluble Reactive Phosphorus as P	ug/L	MCM-1	387		261		193		198				418	

Soluble Reactive Phosphorus as P	ug/L	MCM-2	248		145		157		134				366	
Soluble Reactive Phosphorus as P	ug/L	PC-1	43	42	45	47	37	31	34	54		119	116	101
Dissolved Phosphorus	ug/L	CC-10	136	129	93	91	83	85	96	174	*	224	205	156
Dissolved Phosphorus	ug/L	CC-7	82	82	58	57	48	44	56	126		174	169	117
Dissolved Phosphorus	ug/L	CC-Out	13	16	13	41	77	26	8	30		178	111	61
Dissolved Phosphorus	ug/L	CT-1	9	9	9	12	12	12	12	13		54	30	20
Dissolved Phosphorus	ug/L	CT-2	13	12	8	13	10	11	10	13		52	41	30
Dissolved Phosphorus	ug/L	CT-P1	9	9	8	11	10	10	8	8		50	33	34
Dissolved Phosphorus	ug/L	CT-P2	7	8	6	10	9	8	7	15		44	54	30
Dissolved Phosphorus	ug/L	MCM-1	411		274		193		210				419	
Dissolved Phosphorus	ug/L	MCM-2	270		171		182		140				380	
Dissolved Phosphorus	ug/L	PC-1	49	46	46	49	47	33	36	61		126	129	103
Total Phosphorus	ug/L	CC-10	172	150	112	102	102	105	121	194	245	297	370	250
Total Phosphorus	ug/L	CC-7	102	98	71	72	71	61	76	162	241	218	287	149
Total Phosphorus	ug/L	CC-Out	85	91	64	97	116	99	68	118	178	228	158	106
Total Phosphorus	ug/L	CT-1	41	36	32	35	45	43	49	52	79	85	77	66
Total Phosphorus	ug/L	CT-2	34	46	23	25	31	39	48	44	86	74	76	54
Total Phosphorus	ug/L	CT-P1	64	42	40	31	36	41	30	45	87	95	72	64
Total Phosphorus	ug/L	CT-P2	38	29	19	27	43	41	41	62	83	91	102	70
Total Phosphorus	ug/L	MCM-1	429		333		196		241		337		446	
Total Phosphorus	ug/L	MCM-2	291		180		194		142		345		411	
Total Phosphorus	ug/L	PC-1	66	46	70	61	77	45	50	87	146	151	174	122
Total Alkalinity	mg/L	CC-10						228						232
Total Alkalinity	mg/L	CT-2												165
Total Alkalinity	mg/L	CT-P1						281						201
Calcium	mg/L	CC-10						114						121
Calcium	mg/L	CT-2												121
Calcium	mg/L	CT-P1						293						157
Magnesium	mg/L	CC-10						17						17
Magnesium	mg/L	CT-2												25
Magnesium	mg/L	CT-P1						68						35
Potassium	mg/L	CC-10						8						8

Potassium	mg/L	CT-2						7						6
Potassium	mg/L	CT-P1						8						8
Sodium	mg/L	CC-10						109						97
Sodium	mg/L	CT-2												133
Sodium	mg/L	CT-P1						492						167
Total Chloride	mg/L	CC-10						166						160
Total Chloride	mg/L	CT-2												224
Total Chloride	mg/L	CT-P1						904						295
Total Organic Carbon	mg/L	CC-10	5	4	4	5	5	4	4	5	7		6	6
Total Organic Carbon	mg/L	CT-2	7	7	6	7	6	7	7	7	7		8	9
Dissolved Organic Carbon	mg/L	CC-10	4	4	4	4	4	4	4	4	6		6	6
Dissolved Organic Carbon	mg/L	CT-2	7	7	6	7	6	7	7	7	6		8	9
Total Sulfate as SO4	mg/L	CC-10						122						123
Total Sulfate as SO4	mg/L	CT-2												160
Total Sulfate as SO4	mg/L	CT-P1						529						250
Total Suspended Solids	mg/L	CC-10	16	4	3	4	6	5	9	12	34	29	68	45
Total Suspended Solids	mg/L	CC-7	4	2	2	3	2	3	3	7	22	14	49	8
Total Suspended Solids	mg/L	CC-Out	13	12	6	3	3	5	7	7	10	15	14	17
Total Suspended Solids	mg/L	CT-1	11	6	11	13	13	12	14	8	8	18	17	18
Total Suspended Solids	mg/L	CT-2	13	5	7	6	7	10	9	8	6	5	4	4
Total Suspended Solids	mg/L	CT-P1	20	18	17	10	7	9	6		12	5	8	10
Total Suspended Solids	mg/L	CT-P2	12	8	5	8	6	9	12	10	10	9	14	15
Total Suspended Solids	mg/L	MCM-1	0		1		1		13		9		5	
Total Suspended Solids	mg/L	MCM-2	0		0		4		1		13		5	
Total Suspended Solids	mg/L	PC-1	5	3	11	6	5	4	1	4	8	3	19	5
Total Volatile Suspended Solids	mg/L	CC-10	1	1	1	1	1	1	1	3	6	5	6	7
Total Volatile Suspended Solids	mg/L	CC-7	0	0	1	0	1	1	1	2	4	3	9	2
Total Volatile Suspended Solids	mg/L	CC-Out	5	6	4	3	2	3	6	4	3	4	3	3
Total Volatile Suspended Solids	mg/L	CT-1	1	1	1	2	2	3	3	2	3	4	4	8
Total Volatile Suspended Solids	mg/L	CT-2	3	1	2	1	1	2	2	4	2	4	1	2
Total Volatile Suspended Solids	mg/L	CT-P1	3	4	5	2	2	3	2		4	3	2	2
Total Volatile Suspended Solids	mg/L	CT-P2	2	2	1	2	1	2	4	4	3	4	3	0

Total Volatile Suspended Solids	mg/L	MCM-1	0		1		1		3		2		1	
Total Volatile Suspended Solids	mg/L	MCM-2	0		0		1		0		2		1	
Total Volatile Suspended Solids	mg/L	PC-1	0	1	2	1	1	1	1	2	1	2	4	2

Table 5. Cherry Creek Watershed Streams Sites Nutrients and Chemical Parameter Concentrations, WY 2023, Stormflow.

Constituent	*Units*	*Location Name*	10/2/2022	4/28/2023	5/11/2023	6/5/2023	6/12/2023	6/22/2023	7/5/2023	7/21/2023
Nitrate + Nitrite as N	ug/L	CC-10				249	409		369	585
Nitrate + Nitrite as N	ug/L	CC-7				429	2450		476	795
Nitrate + Nitrite as N	ug/L	CT-1	558			172	328		453	573
Nitrate + Nitrite as N	ug/L	CT-2	958			190	670		820	364
Nitrate + Nitrite as N	ug/L	CT-P1	413			138	346		311	467
Nitrate + Nitrite as N	ug/L	CT-P2	822			185	462		309	388
Nitrate + Nitrite as N	ug/L	PC-1				162	259		222	50
Total Ammonia as N	ug/L	CC-10				22			3	3
Total Ammonia as N	ug/L	CC-7				25	15		3	3
Total Ammonia as N	ug/L	CT-1	3			21			24	84
Total Ammonia as N	ug/L	CT-2	3			73	19		55	3
Total Ammonia as N	ug/L	CT-P1	20				57		30	3
Total Ammonia as N	ug/L	CT-P2	109			48			12	68
Total Ammonia as N	ug/L	PC-1 - Piney Creek							3	3
Dissolved Nitrogen as N	ug/L	CC-10							1100	
Dissolved Nitrogen as N	ug/L	CC-7							1400	
Dissolved Nitrogen as N	ug/L	CT-1							1200	
Dissolved Nitrogen as N	ug/L	CT-2							1800	
Dissolved Nitrogen as N	ug/L	CT-P1							1200	
Dissolved Nitrogen as N	ug/L	CT-P2							1000	
Dissolved Nitrogen as N	ug/L	PC-1							1000	

Total Nitrogen as N	ug/L	CC-10		1920	2980	1050	2380		1360	1800
Total Nitrogen as N	ug/L	CC-7		1460	3420	1350	2550		1400	2150
Total Nitrogen as N	ug/L	CT-1	1370	2300	4120	863	1230		1490	1900
Total Nitrogen as N	ug/L	CT-2	1810	2610	3180	891	1320		2220	1980
Total Nitrogen as N	ug/L	CT-P1	1210	990	3050	1030	1060		1270	1360
Total Nitrogen as N	ug/L	CT-P2	2000	890	4070	979	1080		1240	1750
Total Nitrogen as N	ug/L	PC-1			3420	1050	1120		1220	1860
Soluble Reactive Phosphorus as P	ug/L	CC-10				177	213		170	217
Soluble Reactive Phosphorus as P	ug/L	CC-7				110	86		155	92
Soluble Reactive Phosphorus as P	ug/L	CT-1	10			46	15		50	4
Soluble Reactive Phosphorus as P	ug/L	CT-2	13			44	32		53	53
Soluble Reactive Phosphorus as P	ug/L	CT-P1	21			4	40		30	58
Soluble Reactive Phosphorus as P	ug/L	CT-P2	20			73	26		24	38
Soluble Reactive Phosphorus as P	ug/L	PC-1				164	22		154	6
Dissolved Phosphorus	ug/L	CC-10				183	216		179	218
Dissolved Phosphorus	ug/L	CC-7				119	92		164	102
Dissolved Phosphorus	ug/L	CT-1	28			52	20		65	18
Dissolved Phosphorus	ug/L	CT-2	23			50	33		68	69
Dissolved Phosphorus	ug/L	CT-P1	27			14	45		44	73
Dissolved Phosphorus	ug/L	CT-P2	30			79	30		37	50
Dissolved Phosphorus	ug/L	PC-1 - Piney Creek				168	22		180	20
Total Phosphorus	ug/L	CC-10		412	602	189	1040	590	368	525
Total Phosphorus	ug/L	CC-7		225	1050	191	617	529	378	382
Total Phosphorus	ug/L	CT-1	86	604	731	103	207	183	117	271
Total Phosphorus	ug/L	CT-2	78	96	102	84	70	97	104	126
Total Phosphorus	ug/L	CT-P1	98	141	348	141	94	939	141	152
Total Phosphorus	ug/L	CT-P2	154	115	333	96	87	952	119	146
Total Phosphorus	ug/L	PC-1 - Piney Creek			2250	193	160	379	259	493
Total Suspended Solids	mg/L	CC-10		246	265	53	930	330	107	138
Total Suspended Solids	mg/L	CC-7		52	717	31	460	240	118	84
Total Suspended Solids	mg/L	CT-1	18	460	240	16	64	77	21	151

Total Suspended Solids	mg/L	CT-2	9	21	15	8	9	6	12	7
Total Suspended Solids	mg/L	CT-P1	24	23	150	36	14	870	18	17
Total Suspended Solids	mg/L	CT-P2	26	18	155	19	12	280	16	22
Total Suspended Solids	mg/L	PC-1			685	21	32	109	33	235
Total Volatile Suspended Solids	mg/L	CC-10		28	35	6	120	55	7	15
Total Volatile Suspended Solids	mg/L	PC-1			685	21	32	109	33	235
Total Volatile Suspended Solids	mg/L	CC-10		28	35	6	120	55	7	15
Total Volatile Suspended Solids	mg/L	CC-7		6	117	4	70	30	12	12
Total Volatile Suspended Solids	mg/L	CC-Out	4	65	53	3	11	14	2	25
Total Volatile Suspended Solids	mg/L	CT-1	3	7	4	2	3	3	3	1
Total Volatile Suspended Solids	mg/L	CT-2	6	6	33	9	3	130	5	2
Total Volatile Suspended Solids	mg/L	CT-P1	8	5	45	5	3	55	3	7
Total Volatile Suspended Solids	mg/L	CT-P2			55	5	9	23	7	55

Table 6. Cherry Creek Watershed Groundwater Monitoring Data, WY 2023.

Constituent	*Units*	*Location Name*	November 2022	May 2023
Dissolved Oxygen	mg/L	Kennedy Station	6.5	5.7
Dissolved Oxygen	mg/L	MW-1 - Monitoring Well 1	2.4	5.0
Dissolved Oxygen	mg/L	MW-5 - Monitoring Well 5	0.6	1.1
Dissolved Oxygen	mg/L	MW-9 - Monitoring Well 9	0.6	1.1
Dissolved Oxygen, Saturation	%	Kennedy Station	74	66
Dissolved Oxygen, Saturation	%	MW-1 - Monitoring Well 1	28	57
Dissolved Oxygen, Saturation	%	MW-5 - Monitoring Well 5	8	12
Dissolved Oxygen, Saturation	%	MW-9 - Monitoring Well 9	7	12
pH		Kennedy Station	7.3	7.3
pH		MW-1 - Monitoring Well 1	6.9	6.5
pH		MW-5 - Monitoring Well 5	6.9	6.9
pH		MW-9 - Monitoring Well 9	7.1	7.1
Specific Conductance	uS/cm	Kennedy Station	1,294	1,262
Specific Conductance	uS/cm	MW-1 - Monitoring Well 1	505	1,160
Specific Conductance	uS/cm	MW-5 - Monitoring Well 5	1,135	1,281
Specific Conductance	uS/cm	MW-9 - Monitoring Well 9	1,346	1,459
Water Temperature	deg C	Kennedy Station	12	12

Water Temperature	deg C	MW-1 - Monitoring Well 1	12	11
Water Temperature	deg C	MW-5 - Monitoring Well 5	16	11
Water Temperature	deg C	MW-9 - Monitoring Well 9	10	11
Soluble Reactive Phosphorus as P	ug/L	Kennedy Station	110	117
Soluble Reactive Phosphorus as P	ug/L	MW-1 - Monitoring Well 1	240	165
Soluble Reactive Phosphorus as P	ug/L	MW-5 - Monitoring Well 5	215	150
Soluble Reactive Phosphorus as P	ug/L	MW-9 - Monitoring Well 9	253	196
Dissolved Phosphorus	ug/L	Kennedy Station	111	127
Dissolved Phosphorus	ug/L	MW-1 - Monitoring Well 1	246	174
Dissolved Phosphorus	ug/L	MW-5 - Monitoring Well 5	215	154
Dissolved Phosphorus	ug/L	MW-9 - Monitoring Well 9	256	209
Total Phosphorus	ug/L	Kennedy Station	234	220
Total Phosphorus	ug/L	MW-1 - Monitoring Well 1	331	199
Total Phosphorus	ug/L	MW-5 - Monitoring Well 5	224	173
Total Phosphorus	ug/L	MW-9 - Monitoring Well 9	257	261
Nitrate + Nitrite as N	ug/L	Kennedy Station	3	3
Nitrate + Nitrite as N	ug/L	MW-1 - Monitoring Well 1	226	2,000
Nitrate + Nitrite as N	ug/L	MW-5 - Monitoring Well 5	512	1,390
Nitrate + Nitrite as N	ug/L	MW-9 - Monitoring Well 9	853	1,160
Total Ammonia as N	ug/L	Kennedy Station	109	55
Total Ammonia as N	ug/L	MW-1 - Monitoring Well 1	2.5	13.0
Total Ammonia as N	ug/L	MW-5 - Monitoring Well 5	2.5	2.5
Total Ammonia as N	ug/L	MW-9 - Monitoring Well 9	2.5	2.5
Total Nitrogen as N	ug/L	Kennedy Station	334	220
Total Nitrogen as N	ug/L	MW-1 - Monitoring Well 1	481	2,590
Total Nitrogen as N	ug/L	MW-5 - Monitoring Well 5	1,585	1,730
Total Nitrogen as N	ug/L	MW-9 - Monitoring Well 9	1,020	1,350
Total Organic Carbon	mg/L	Kennedy Station	3.1	4.4
Total Organic Carbon	mg/L	MW-1 - Monitoring Well 1	4.1	2.8
Total Organic Carbon	mg/L	MW-5 - Monitoring Well 5	3.4	4.2
Total Organic Carbon	mg/L	MW-9 - Monitoring Well 9	2.8	3.6
Dissolved Organic Carbon	mg/L	Kennedy Station	2.8	3.2
Dissolved Organic Carbon	mg/L	MW-1 - Monitoring Well 1	3.9	2.3
Dissolved Organic Carbon	mg/L	MW-5 - Monitoring Well 5	3.2	3.9
Dissolved Organic Carbon	mg/L	MW-9 - Monitoring Well 9	2.5	2.9
Conductivity	umhos/cm	Kennedy Station	1,302	1,356
Conductivity	umhos/cm	MW-1 - Monitoring Well 1	505	1,248

Conductivity	umhos/cm	MW-5 - Monitoring Well 5	1,186	1,376
Conductivity	umhos/cm	MW-9 - Monitoring Well 9	1,414	1,560
Total Chloride	mg/L	Kennedy Station	197	181
Total Chloride	mg/L	MW-1 - Monitoring Well 1	46	156
Total Chloride	mg/L	MW-5 - Monitoring Well 5	152	186
Total Chloride	mg/L	MW-9 - Monitoring Well 9	153	165
Total Sulfate as SO4	mg/L	Kennedy Station	130	132
Total Sulfate as SO4	mg/L	MW-1 - Monitoring Well 1	18	62
Total Sulfate as SO4	mg/L	MW-5 - Monitoring Well 5	107	111
Total Sulfate as SO4	mg/L	MW-9 - Monitoring Well 9	210	248

Table 6. Cherry Creek Watershed Precipitation Nutrient Concentrations, WY 2023.

Constituent	*Units*	*Location Name*	4/28/2023	5/11/2023	6/5/2023	6/12/2023	6/22/2023	7/5/2023
Total Nitrogen as N	ug/L	Rain Sampler	836	851	1980	1180		2200
Total Phosphorus	ug/L	Rain Sampler	42	19	338	140	465	196