2023

THE CHERRY CREEK BASIN WATER QUALITY AUTHORITY

ROUTINE SAMPLING AND ANALYSIS PLAN/

QUALITY ASSURANCE PROJECT PLAN

SAP | QAPP

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1. Introduction

In 1985 the Cherry Creek Basin Water Quality Authority (CCBWQA) was created by an intergovernmental agreement and specially authorized by legislation in 1988 (Colorado Revised Statutes 25.8.5-101 et seq.). CCBWQA is a quasi-municipal corporation and political subdivision of the state, and is tasked with improving, protecting, and preserving the water quality and enhancing the beneficial uses of Cherry Creek and Cherry Creek Reservoir, as well as achieving and maintaining state water quality standards for the reservoir and watershed. CCBWQA has the power to study, develop, implement and recommend water quality control plans and projects for the reservoir and watershed.

This Sampling and Analysis Plan (SAP) and Quality Assurance Project Plan (QAPP) addresses long-term monitoring of nutrient levels within the reservoir and its tributaries, nutrient levels in precipitation and groundwater, and chlorophyll α levels within the reservoir. CCBWQA uses the monitoring program to assess attainment of water quality standards and the effectiveness of CCBWQA's actions. Additional data may be found at https://www.ccbwqportal.org.

2. Purpose

CCBWQA is required to sample biological, physical, and nutrient parameters in the Cherry Creek Reservoir and its tributaries under the Cherry Creek Control Regulation 72. Pursuant to this charge, the monitoring program is to meet the following purposes stemming from Regulation 72:

- Parameter-specific monitoring and additional non-specified monitoring determined by CCBWQA to be supportive of Authority goals
- Nutrient Pollutant Reduction Facility (PRF) monitoring
- Determining attainability of applicable water quality standards
- Evaluating nutrient sources and transport, evaluating fate and transport of phosphorus, and calculating flow-weighted phosphorus concentrations
- Calculating flow-weighted nitrogen concentrations and evaluating the fate and transport of nitrogen
- Calculating mass balances of phosphorus and nitrogen based on inputs and losses from the Reservoir
- Supporting and calibrating the reservoir and watershed water quality models
- Providing data for analysis and identification of potential watershed management options

3. Sampling Program Objectives

CCBWQA's long-term goals serve as assessment endpoints for the reservoir and watershed (for example, protection of beneficial uses, and preservation and enhancement of water quality). The sampling program helps CCBWQA evaluate whether it is attaining its long-term goals. Specific objectives of the sampling program are to:

- Determine biological productivity in the reservoir, as measured by chlorophyll α and plankton dynamics and their relationship to the potential effects to beneficial uses.
- Determine the concentrations of phosphorus and nitrogen species in the reservoir and streams, and changes over time.
- Determine annual flow-weighted phosphorus concentration entering and leaving the reservoir.
- Evaluate the effectiveness of Pollutant Reduction Facilities, and
- Provide data for CCBWQA's Internet Data Portal.

The SAP/QAPP identifies field and laboratory protocols necessary to achieve high quality data. The 2023 SAP/QAPP is intended to build off of previous Sampling and Analysis Plans and Quality Assurance Work Plans[1] and includes quality assurance objectives for the measurement of data in terms of accuracy, representativeness, comparability, and completeness; field sampling and sample preservation procedures, laboratory processing and analytical procedures; and guidelines for data verification and reporting; quality control check; corrective actions; and quality assurance reporting.

CCBWQA Goals and Objectives

Goals

- Use effective stewardship to implement sustainable reservoir and watershed water quality management strategies.
- Implement an efficient and effective organization with the expertise to achieve quality results.
- Work with Member Entities and Stakeholders to enhance partnerships on water quality policies and projects.
- Continue to develop leading edge, innovative water quality solutions
- Adapt as needed.

Objectives

- Better understand reservoir and watershed dynamics and linkages
- Identify the right "mix" of sustainable strategies that will preserve and enhance water quality for beneficial uses and/or prevent negative water quality impacts
- Ensure that the Authority Board maintains an adaptable organizational structure and expertise so

[1] 2021, 2018, Solitude Lake Management; 2016 Tetra Tech; 2008 GEI (prepared by)

4. Control Regulation 72 Requirements

The SAP is intended to meet the requirements of Section 72.8, listed below and the CCBWQA Board may request additional monitoring, following the adoption of a Special SAP. Wastewater facilities are not monitored by CCBWQA.

72.8 NUTRIENT MONITORING

1. *Monitoring of wastewater facilities shall be consistent with the requirements of section 72.4.4 of this control regulation. Wastewater facilities shall monitor nutrient concentrations including, but not limited to, nitrate, nitrite, ammonia, total phosphorus, total soluble phosphorus, and orthophosphate.*

2. *The Authority shall develop and implement, in conjunction with local governments, a routine annual water quality monitoring program of the Cherry Creek watershed and Cherry Creek Reservoir. The monitoring program shall include monitoring of the reservoir water quality and inflow volumes, alluvial water quality, and nonpoint source flows. Monitoring shall include, but not be limited to nitrate, nitrite, ammonia, total phosphorus, total soluble phosphorus, and orthophosphate concentrations.*
   - *(a) Routine monitoring of surface water, ground water, and the reservoir shall be implemented to determine the total annual flow-weighted concentration of nutrients to the reservoir.*
   - *(b) Monitoring of PRFs shall be implemented to determine inflow and outflow nutrient concentrations.*

3. *The Authority shall consult with the Division in the development of the monitoring program to ensure that the monitoring plan includes the collection of data to evaluate nutrient sources and transport, to characterize reductions in nutrient concentrations, and to determine attainment of water quality standards in Cherry Creek Reservoir.*

4. *The Authority shall consult with the Division and other appropriate entities in development of any water quality investigative special studies.*

   Special studies may include, but are not limited to, the following areas of investigation:
   - *(a) Feasibility study of nutrient removal from point sources.*
   - *(b) Quantification of effectiveness of nonpoint source concentration-based phosphorus control strategies called PRFs; and*
   - *(c) Quantification of effectiveness of regulated stormwater concentration-based phosphorus control strategies called BMPs; and*
   - *(d) Quantification of the effectiveness of source control BMPs that include low-impact development techniques.*

5. *The monitoring data shall be used by the Authority to determine phosphorus fate and transport, calculate annual flow-weighted phosphorus concentrations, document compliance with the applicable water quality standards, analyze long-term trends in water quality for both the reservoir and the Cherry Creek watershed, and calibrate water quality models.*

6. *The Authority shall maintain all data collected pursuant to this section in an electronic database for evaluation and transfer to the Division and other entities.*

5. Review and Updates

Updates to the sampling and analysis program are important, as the program is dynamic, and changes are needed from time to time based on:

- Monitoring objectives being met,
- New objectives being formulated,
- Changes to sampling methodology and technological advances in sampling,
- Duplicative efforts and opportunities to reduce costs,
- Meeting regulatory objectives or regulatory changes, and
- Opportunities to improve quality of data and sampling methodology to reflect sound science and limnology.

A review of the SAP/QAPP shall be performed by the Technical Advisory Committee (TAC) when there are material changes made to the sampling program (e.g., new monitoring sites, additional parameters, laboratory changes, changes in personnel, etc.), and any updates shall be made as needed. In addition, a review and update of the SAP/QAPP shall be conducted by the TAC in preparation for Water Quality Control Commission (WQCC) Rulemaking Hearings (RMH) and other special studies, as needed. Changes and amendments shall be incorporated into the SAP/QAPP in a timely manner and shall be well-documented. The final SAP/QAPP shall be approved by CCBWQA's Board of Directors.

6. Timeline

Sampling and data collection shall be implemented per Regulation 72, with the Water Year defined as October 1 – September 30. CCBWQA's work is subject to the WQCC Hearing timelines for the Regulation 72, and must meet water quality standards and requirements in the following regulations:

- 31, Basic Standards and Methodologies for Surface Water
- 38, Classifications & Numeric Standards for the South Platte River basin (including Cherry Creek)
- 22, Site Location and Design Regulations for Domestic Wastewater Treatment Works
- 43, On-site Wastewater Treatment System Regulation
- 61, Colorado Discharge Permit System
- 85, Nutrients Management
- 93, Colorado's Section 303(d) List of Impaired Waters and Monitoring and Evaluation List

As these regulations change, the SAP/QAPP may need to be revisited and may change. Table 1 below shows a potential future timeline of regulatory hearings pertaining to the Cherry Creek Basin; note that all dates labeled "TBD" are estimates only and may or may not be scheduled in these years.

Table 1. Water Quality Control Commission Regulation Hearing Timeline [2]

Hearing Date	Rule	Event	Potential Relevance to CCBWQA
March 2023	Regulation 43 – On-Site Wastewater Treatment System Regulation	RMH	Relevance low, track to understand proposed changes and if relevance to Regulation 72
April 2023	Control Regulation 72 – Cherry Creek Reservoir Control Regulation	Inform.	Relevance high, will determine the Scope for the CR72
	Control Regulation 65 – Regulation Controlling Discharges to Stormwater Sewers	RMH	Relevance low, but should traced to understand changes being proposed and if any changes are relevant to Regulation 72
May 2023	Regulation 93 - Colorado's Section 303(d) List and M&E List	RMH	Relevance likely low, CCR is currently on the 303(d) List for DO and Chlorophyll-a, Windmill Creek for selenium, and the Mainstem of Cherry Creek for *E. coli* and the M&E List for manganese
August 2023	Control Regulation 86 – Graywater Control Regulation	RMH	Relevance potentially high, scope includes the use of graywater in P Control Basins – Monitoring stakeholder workgroup to determine if participation in RMH is recommended
October 2023	Regulation 61 – Colorado Discharge Permit System Regulations	RMH	Relevance low, track to understand proposed changes and relevance to Regulation 72
November 2023	Regulation 38 - South Platte Water Quality Standards	ISH	Relevance potentially high, monitor to see potential issues, participate if proposal to bring forward
December 2023	Policy 10-1 – Aquatic Life Use Attainment Policy	AAH	Relevance likely low, however the Multi-Metric Index (MMI), used to assess the health of aquatic life in streams, to be revisited may be of interest because MMI may be difficult to meet in CC Basin streams
2023?	Control Regulation 72 – Cherry Creek Reservoir Control Regulation	RMH	Relevance high, reference google drive folder for potential changes
November 2024	Regulation 31 - Basic Standards for Surface Water	ISH	Relevance potentially high, CCBWQA should attend ISH to see what potential issues are for RMH in 2026
	Regulation 38 - South Platte Water Quality Standards	IFH	Relevance potentially high, attendance recommended to see what will likely be proposed for 2025 RMH and plan to participate if proposal to bring forward
December 2024	Regulations 32-38 - Temporary Modifications	RMH	Relevance low, unless temporary modifications applied to Cherry Creek Reservoir
March 2025	Regulation 22 – Site Location and Design Approval Regulation for Domestic Wastewater Treatment Works	RMH	Relevance potentially high, likely to address outstanding issues from March 2020 RMH such as historical lift stations. (Designated Mgmt. Agency roles revisited?)
May 2025	Regulation 93 - Colorado's Section 303(d) List and M&E List	RMH	Relevance likely low, See May 2023 RMH
June 2025	Regulation 38 - South Platte Water Quality Standards	RMH	Relevance potentially high

[2] Event" Definitions:
TRIH - Triennial Review Informational Hearing; ISH - Issues Scoping Hearing → IFH - Issues Formulation Hearing → RMH - Rulemaking Hearing

November 2025	Regulation 31 – Basic Standards for Surface Water	IFH	Relevance potentially high
	Control Regulations 85 - Nutrients Management Control Regulation	RMH	Relevance potentially high
June 2026	Regulation 31 – Basic Standards for Surface Water	RMH	Relevance potentially high
2027	Regulations 31-38 – Lakes & Reservoirs Nutrients	RMH	Relevance likely low, TN and TP standards for all lakes and reservoirs in Colorado

7. Project Description

CCBWQA tracks historical water quality data and has data from 1992 to the present on its data portal constituting an extensive site-specific data set for Cherry Creek Reservoir and its tributaries. This SAP has been designed to achieve the goals and objectives as outlined above. The following includes an overview of sampling site locations, sampling teams and structures, sampling parameters, and frequency of sampling.

7.1. Sample Site Locations

Reservoir, watershed, and PRF sampling shall be routinely conducted at 26 sites, including three sites in Cherry Creek Reservoir, nineteen stream monitoring sites (on Cherry Creek, Cottonwood Creek, Piney Creek, and McMurdo Gulch), and four alluvial groundwater sites along the Cherry Creek mainstem (Figure 1). Data from many of these monitoring sites are used to assess the effectiveness of several of CCBWQA's PRFs (Figure 2). Additional sites in the watershed may be monitored as directed by CCBWQA management if the investigation of background phosphorus concentrations, or other parameters of interest, is warranted.

All active sampling sites are summarized below. Site coordinates for the currently monitored sites can be found in Appendix A. Information on sites that were previously monitored but have been abandoned is found in Appendix B.

7.1.1. Cherry Creek Reservoir Monitoring Sites

CCR-1 This site is also called the Dam site and was established in 1987. Site CCR-1 corresponds to the northwest area within the reservoir (Knowlton, 1993). Sampling was discontinued at this site in 1996 and 1997 following determination that this site exhibited similar characteristics to the other two sites. Sampling recommenced in July 1998 at the request of consultants for Greenwood Village.

CCR-2 This site is also called the Swim Beach site and was established in 1987. Site CCR-2 corresponds to the northeast area within the reservoir (Knowlton, 1993).

CCR-3 This site is also called the Inlet site and was established in 1987. Site CCR-3 corresponds to the south area within the reservoir (Knowlton, 1993).

7.1.2. Stream Monitoring Sites

7.1.2.1. Cherry Creek

USGS@Franktown: This Castlewood site has been sampled since 1994 and was originally located in Castlewood Canyon State Park where the Homestead Trail crossed Cherry Creek, approximately 0.2 miles north of the USGS gaging station known as "Cherry Creek near Franktown." The USGS's Cherry Creek near Franktown gage (number 0671200) has a 76-year period of record, is located within Castlewood Canyon State Park, and has a drainage area of 169 mi^2. In 2017, in an effort to pair water quality and flow measurements to calculate pollutant loads, the monitoring site was moved to the USGS Cherry Creek near Franktown station.

CC-1 This site was established in 2012 on Cherry Creek. This site is located on Cherry Creek approximately 380 m upstream of where Bayou Gulch Road crosses Cherry Creek near Parker Road.

CC-2 This site has been sampled since 1994 and is located on Cherry Creek below the Pinery's wastewater treatment plant. This site is located approximately 0.85 km upstream of Stroh Road.

USGS@Parker: The USGS gaging station known as "USGS Station 393109104464500, Cherry Creek near Parker, CO, has a streamflow period of record since 1992. The USGS Cherry Creek near Parker gage is located approximately nine miles upstream of the Reservoir, about ½-mile upstream of Authority monitoring site CC-4 and has a drainage area of 287 mi^2. In 2017, water quality samples were also collected at this location in order to pair streamflow measurements with water quality concentrations to quantify pollutant loading.

CC-4 This site has been sampled since 1994 and is located on Cherry Creek below the confluence with Sulphur Gulch and below the outfall for Parker's AWT plant. This site is located approximately 0.50 km downstream of Main Street in Parker.

CC-5 This site has been sampled since 1994 and is located on Cherry Creek immediately downgradient of the confluence with Newlin Gulch. This site is located where Pine Lane crosses Cherry Creek, approximately 0.65 km west of Parker Road.

CC-6 This site has been sampled since 1994 and is located on Cherry Creek downgradient of Parker's North AWT plant. However, the discharge from this AWT plant is transported via pipeline to Sulphur Gulch. This site is located approximately 1.38 km downstream of Cottonwood Drive and 0.41 km west of Parker Road.

CC-7 EcoPark: This site was re-established in 2013 on Cherry Creek at the downstream boundary of Cherry Creek Valley Ecological Park (EcoPark). This site is approximately 1.7 kilometers (km) upstream (south) of Arapahoe Road, and serves to monitor water quality conditions downstream of the EcoPark Stream Reclamation Project (PRF). This site also provides more accurate flow estimates in this reach of Cherry Creek. (The original CC-7 site, located ¾ mile south of Arapahoe Road, was abandoned in 2000 due to development.)

CC-8 This site has been sampled since 1994, and is located on Cherry Creek, approximately 0.5 miles north of Arapahoe Road.

CC-9 This site was re-established in 2012 on Cherry Creek and is in Cherry Creek State Park just upgradient of Cherry Creek Reservoir. This site is located immediately downstream of where East Lake View Drive crosses Cherry Creek in Cherry Creek State Park.

CC-10 This site is on Cherry Creek immediately downstream of the Shop Creek confluence, approximately 0.5 km upstream of Cherry Creek Reservoir. This site provides data to estimate phosphorus loads to the Reservoir from Cherry Creek and includes inputs from upstream tributaries, including Shop Creek. The ISCO sampler, pressure transducer and staff gauge are in the creek near the equipment enclosure.

CC-O This is the reservoir outfall site that was established in 1987, and is located on Cherry Creek downstream of Cherry Creek Reservoir and upstream of the Hampden Avenue-Havana Street junction in the Kennedy Golf Course near the historical USGS gage (06713000). In 2007, Site CC-O (also identified in the past as Site CC-Out at I-225) was relocated immediately downstream of the dam outlet structure and is used to monitor the water quality of the Reservoir outflow.

7.1.2.2. Cottonwood Creek

CT-P1 This site was established in 2002, and is located on Cottonwood Creek, just north of where Caley Avenue crosses Cottonwood Creek, and west of Peoria Street. This site monitors the water quality of Cottonwood Creek before it enters the Peoria Pond PRF, also created in 2001/2002 on the west side of Peoria Street. The ISCO sampler, pressure transducer and staff gauge are in the creek near the equipment enclosure.

CT-P2 This site was established in 2002 and is located on Cottonwood Creek at the outfall of the PRF, on the west side of Peoria Street. The ISCO® stormwater sampler and pressure transducer are located inside the outlet structure. This site monitors the effectiveness of the PRF on water quality.

CT-1 This site was established in 1987 where the Cherry Creek Park Perimeter Road crosses Cottonwood Creek. It was chosen to monitor the water quality of Cottonwood Creek before it enters the Reservoir. During the fall/winter of 1996, a PRF, consisting of a water quality/detention pond and wetland system, was constructed downstream of this site. As a result of the backflow from this pond inundating this site, this site was relocated approximately 250 m upstream near Belleview Avenue in 1997. In 2009, this site was relocated approximately 75 m upstream of the Perimeter Road as it crosses Cottonwood Creek, due to the Cottonwood Creek stream reclamation project. This site is now approximately 200 m upstream of the PRF. It is also used to evaluate the effectiveness of the PRF by documenting the stream concentrations above the PRF.

CT-2 This site was established in 1996 and was originally located downstream of the Perimeter Pond on Cottonwood Creek. The ISCO pressure transducer and staff gage were in a section of the stream relatively unobstructed by vegetation, and approximately 50 m downstream of the PRF. However, over the years the growth of vegetation considerably increased along the channel, creating problems with accurately determining stream flow. Eventually, when no accurate and reliable streamflow measurements could be performed in 2003, other locations were evaluated. In August 2004, the pressure transducer and staff gage were relocated inside of the outlet structure for the PRF to mitigate problems associated with streamflow measurements by providing a reliable multilevel weir equation. In 2013, modifications to the PRF overflow elevation and internal weir structure changed the relationship of the multilevel weir equation, resulting in unreliable stream flow estimates. In 2014, the weir elevations were resurveyed, and the weir equations were adjusted accordingly. Water quality samples are collected from the outlet structure. This site monitors the effectiveness of the PRF on Cottonwood Creek water quality and provides information on the streamflow and water quality before it enters the Reservoir.

7.1.2.3. Piney Creek

PC-1 This site was monitored in 2018 just south of East Maplewood Drive and S Fraser St. A permanent site was established in 2019 on Piney Creek upstream of the confluence with Cherry Creek. The site has access on the Piney Creek Trail off S Walden Way, just north of E Caley Pl. The site is just upstream of Piney Creek Hollow Park. The ISCO sampler, pressure transducer and staff gauge are in the creek near the equipment enclosure.

7.1.2.4. Mc Murdo Gulch

MCM-1 This site was established in 2012 on McMurdo Gulch, approximately 150 m upstream of the McMurdo Gulch Stream Reclamation Project boundary. This site is also 120 m upstream of the confluence with an unnamed tributary that receives runoff from the Castle Oaks Subdivision. This site serves as the upstream monitoring location for the McMurdo Gulch Stream Reclamation project.

MCM-2 This site was established in 2012 on McMurdo Gulch, approximately 80 m upstream of the Castle Oaks Drive Bridge crossing of McMurdo Gulch, near the North Rocky View Road intersection. This site serves as the downstream monitoring location for the McMurdo Gulch Stream Reclamation Project. This site is located within the project boundary, and consistently maintains base flows, whereas the reach further downstream was often dry due to surface flow becoming subsurface.

7.1.3. Precipitation Sampling Site

PRECIP: This site is located near the Quincy Drainage, upstream of the Perimeter Road. The sampler consists of a clean, inverted trash can lid used to funnel rainfall into a one-gallon container. While this collection vessel is maintained and cleaned on a routine basis, precipitation will wash any atmospheric dry fall that has accumulated between cleanings into the one-gallon container. Therefore, these data more appropriately represent a "bulk" atmospheric deposition component for the reservoir.

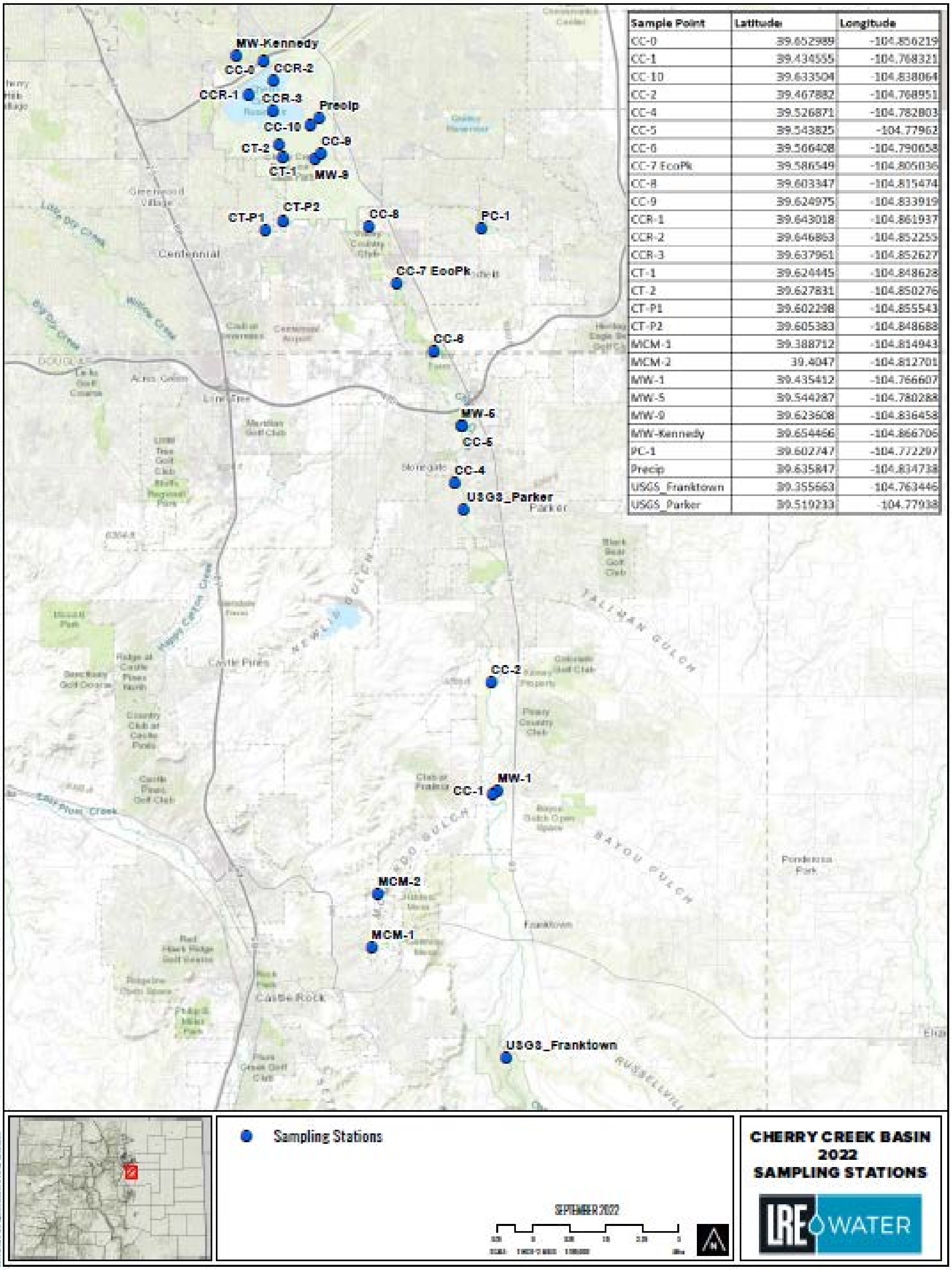
7.1.4. Alluvial Groundwater Sites

MW-1: This alluvial well monitor has been sampled since 1994 and is located approximately 270 m southeast of where Bayou Gulch Road crosses Cherry Creek near Parker Road.

MW-5: This alluvial well monitor has been sampled since 1994 and is located immediately downgradient of the confluence with Newlin Gulch. This site is located where Pine Lane crosses Cherry Creek, approximately 0.65 km west of Parker Road.

MW-9: This alluvial well monitor has been sampled since 1994 and is in Cherry Creek State Park near the Nature Center. This site is monitored to assess alluvial groundwater that is entering Cherry Creek Reservoir.

MW-Kennedy: This alluvial well monitor has been sampled since 1994 and is located on the Kennedy Golf Course to monitor groundwater quality downgradient from Cherry Creek Reservoir.



Sample Point	Latitude	Longitude
CC-0	39.652989	-104.856219
CC-1	39.434555	-104.768321
CC-10	39.633504	-104.838064
CC-2	39.467882	-104.768951
CC-4	39.526871	-104.782803
CC-5	39.543825	-104.77962
CC-6	39.566408	-104.790658
CC-7 EcoPk	39.586549	-104.805036
CC-8	39.603347	-104.815474
CC-9	39.624975	-104.833919
CCR-1	39.643018	-104.861937
CCR-2	39.646863	-104.852255
CCR-3	39.637961	-104.852627
CT-1	39.624445	-104.848628
CT-2	39.627831	-104.850276
CT-P1	39.602298	-104.855543
CT-P2	39.605383	-104.848688
MCM-1	39.388712	-104.814943
MCM-2	39.4047	-104.812701
MW-1	39.435412	-104.766607
MW-5	39.544287	-104.780288
MW-9	39.623608	-104.836458
MW-Kennedy	39.654466	-104.866706
PC-1	39.602747	-104.772297
Precip	39.635847	-104.834738
USGS_Franktown	39.355663	-104.763446
USGS_Parker	39.519233	-104.77938

Figure 1: Sample Sites on Cherry Creek Reservoir, Surface Water Monitoring Sites, and Alluvial Groundwater Sites.

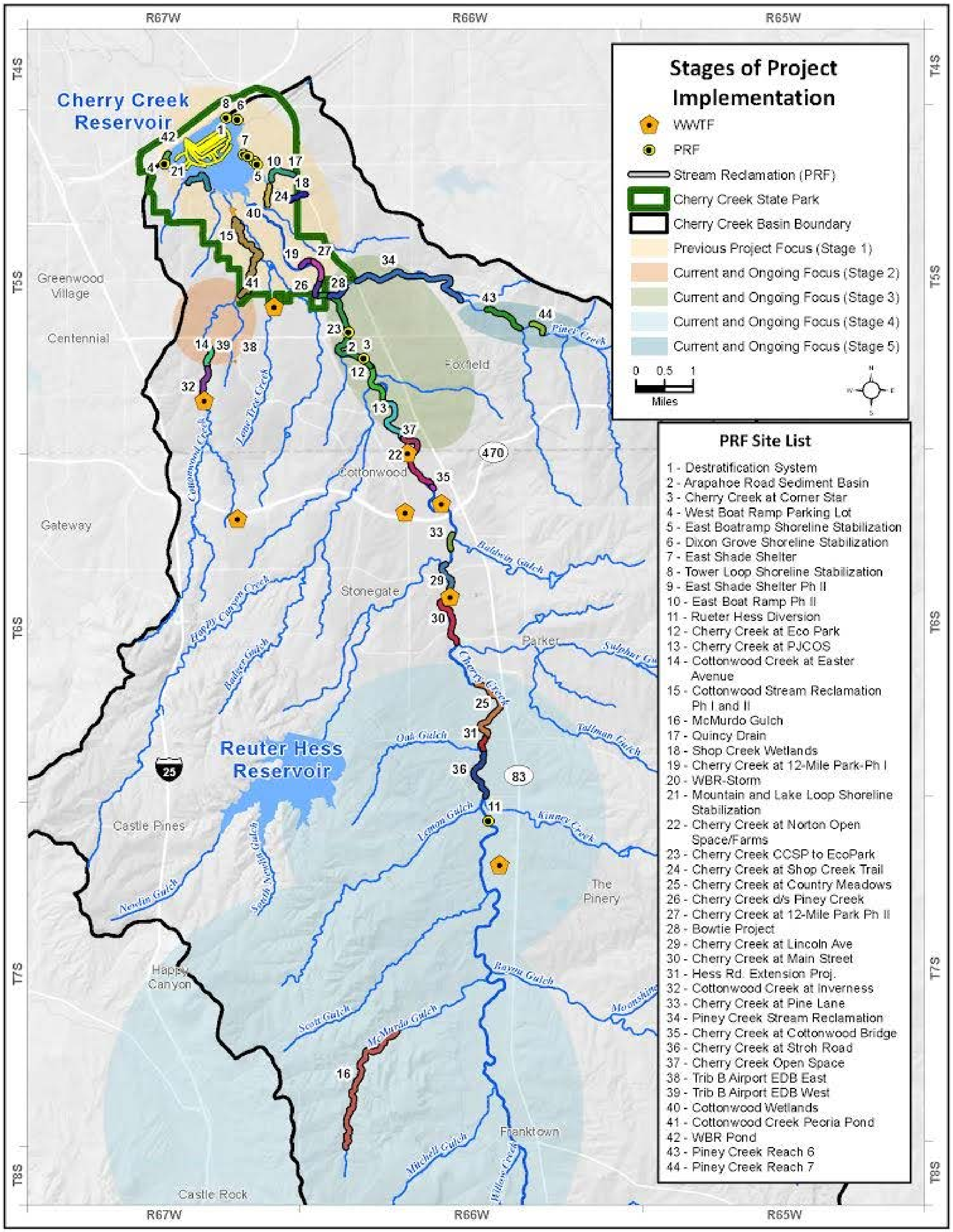


Figure 2: Pollutant Reduction Facility (PRF) Sites Located Throughout the Cherry Creek Watershed.

7.2. Sampling Parameters and Frequency

To ensure a high level of accuracy and precision, sampling and analyses shall be conducted according to the protocols and method and detection limits set forth in this SAP/QAPP. Monitoring parameters include physical, inorganic, organic, and biological parameters. Table 2 summarizes reservoir sampling parameters and sampling frequencies for sites within the reservoir. Table 3 summarizes similar information for stream and alluvial groundwater monitoring.

Table 2. Reservoir Sampling Parameters and Frequency.

ANALYTE	Monthly Vertical Profile WQ Sonde (Oct – April)	Monthly[1] Nutrient-Biological Samples (Photic Zone)		Monthly[1] Nutrient Profile (4m-7m)	Bi-monthly Sonde & Nutrient Samples (May-Sept)	Precipitation
	CCR-1, CCR-2, CCR-3	CCR-1, CCR-3	CCR-2	CCR-2	CCR-1, CCR- 2, CCR- 3	Rain Sampler
Temperature	x				x	
Conductivity	x				x	
pH	x				x	
Dissolved Oxygen	x				x	
Oxidation/Reduction	x				x	
1% Transmittance	x				x	
Total Algae (Chl-a / Phycocyanin)	x				x	
Secchi depth	x				x	
Temperature, Continuous (15-minute interval)	x (CCR-2 only)					
Total Nitrogen		x	x	x	x	x
Ammonia as N		x	x	x	x	
Nitrate+Nitrite as N		x	x	x	x	
Total Dissolved Nitrogen		x	x	x	x	
Total Phosphorus		x	x	x	x	x
Total Dissolved P		x	x	x	x	
Orthophosphate as P		x	x	x	x	
Calcium			CCR-2 only Mar/ Sept	7m only Mar/ Sept		
Magnesium			CCR-2 only Mar/ Sept	7m only Mar/ Sept		
Sulfate			CCR-2 only Mar/ Sept	7m only Mar/ Sept		
Chloride			CCR-2 only Mar/ Sept	7m only Mar/ Sept		
Sodium			CCR-2 only Mar/ Sept	7m only Mar/ Sept		
Potassium			CCR-2 only Mar/ Sept	7m only Mar/ Sept		
Alkalinity			CCR-2 only Mar/ Sept	7m only Mar/ Sept		
Total Organic Carbon			x		CCR-2	
Dissolved Organic Carbon			x		CCR-2	
Volatile Suspended Solids		x	x		x	
Total Suspended Solids		x	x		x	
Chlorophyll *a*		x	x		x	
Phytoplankton			x		x	
Zooplankton			x		x	

[1]As safe and ice-free conditions allow.

Table 3. Stream and Groundwater Sampling Parameters and Frequency.

ANALYTE	Monthly Surface Water Samples	Every Other Month Surface Water Samples	Storm Event Surface Water ISCO Samples (7 events)	Bi-annual Surface Water Samples	Bi-annual Groundwater Samples
	9 sites (CC-0, CC-10, CC-7-EcoPark, CT-P1, CT-P2, CT-1 CT-2, PC-1)	2 sites (MCM-1, MCM-2)	**6 sites** (CC-10, CC-7-EcoPark, CT-1, CT-2, CT-P1, CT-P2, PC-1)	**9 sites** (USGS@Franktown, CC-1, CC-2. CC-4. CC-5, CC-6, USGS@ Parker, CC-8,**CC-9)**	**4 sites** (MW-1, MW-5, MW-6, MW-9, MW-Kennedy)
Physical					
Temperature	x			x	x
Conductivity	x			x	x
pH	x			x	x
Dissolved Oxygen	x			x	x
Oxidation/Reduction Potential					x
Water Level, Continuous (15-minute interval)			x		x **(MW-9 only)**
Discharge, Rating Curve			x		
Inorganics					
Total Nitrogen	x	x	x	x	
Ammonia as N	x	x	x	x	x
Nitrate+Nitrite as N				x	x
Total Dissolved Nitrogen	x				
Total Phosphorus	x	x	x	x	
Total Dissolved Phosphorus	x	x	x	x	x
Orthophosphate as P	x	x	x	x	x
Alkalinity	CT-P1, CT-2, CC-10 Mar/ Sept				
Calcium	CT-P1, CT-2, CC-10 Mar/ Sept				
Magnesium	CT-P1, CT-2, CC-10 Mar/ Sept				
Sodium	CT-P1, CT-2, CC-10 Mar/ Sept				
Potassium	CT-P1, CT-2, CC-10 Mar/ Sept				
Chloride	CT-P1, CT-2, CC-10 Mar/ Sept				x
Sulfate	CT-P1, CT-2, CC-10 March/ Sept				x
Organics					
Total Organic Carbon	x **CC-10/ CT-2 only**				x
Dissolved Organic Carbon	x **CC-10/ CT-2 only**				x
Volatile Suspended Solids	x	x	x		
Total Suspended Solids	x	x	x		

7.3. Authority Roles and Participation

CCBWQA is responsible for the following tasks:

- Manage the water quality monitoring contract
- Prepare the Annual Report to the Colorado Water Quality Control Commission
- Ensure periodic outside Peer Review is solicited at appropriate times
- Coordinate the monitoring program and budgetary needs arising from regulatory changes and new facility monitoring needs (e.g., PRFs)
- Identify and coordinate monitoring needs for any new special studies
- Periodically review and revise, as needed, the Sampling Program Objectives (see Section 3.0)
- Ensure the monitoring program complies with Regulation 72 requirements (see Section 4.0)
- Provide periodic review and updates to this SAP/QAPP (see Section 5.0)

7.4. Sampling Teams and Structure

The monitoring consultant shall be responsible for implementing sampling requirements per the SAP, which shall be referenced and/or included in the monitoring consultant's contract with CCBWQA. All personnel involved in the investigation and in the generation of data are a part of the overall project and quality assurance program. The following roles have specifically delegated responsibilities, which is structured to ensure the highest quality of data collection, management, and reporting.

7.4.1. Project Manager

The Project Manager is responsible for fiscal oversight and management of the project and for ensuring that all work is conducted in accordance with the Scope of Service, Sampling and Analysis Plan, and approved procedures. Tasks include:

- Maintain routine oversight and responsibility for the project's progress,
- Regularly review the project schedule and budget, and review all work products; and
- Evaluate impacts of the monitoring program on SAP objectives and the need for corrective actions based on quality control checks.

7.4.2. Quality Assurance Manager

The Quality Assurance Manager is responsible for the aquatic biological and field sampling portions of the project as well as the technical management of the monitoring program and reporting. The Quality Assurance Manager shall be responsible for evaluation and review of all data reports relevant to the project and perform data verification. The Quality Assurance Manager shall work with the Project Manager to determine the need for corrective actions and, together, will make recommendations for any needed changes to either sampling methodologies or laboratory analytical procedures. Tasks include:

- Ensure data collection is in accordance with the Sampling and Analysis Plan;
- Maintain a repository for all documents relating to this project; and
- Coordinate with CCBWQA, the WQCD, and CCBWQA's other consultants to ensure compliance with the Cherry Creek Reservoir Control Regulation 72.

7.4.3. Analytical and Biological Laboratory Manager

The Analytical Laboratory Manager will ensure that all water quality and chlorophyll *a* samples are analyzed in a technically sound and timely manner. The Analytical Laboratory Manager shall be responsible for ensuring all laboratory quality assurance procedures associated with the project are followed, including proper sample entry, sample handling procedures, and quality control records for samples delivered to the laboratory. The Analytical Laboratory Manager will be responsible for all data reduction and verification and ensure that the data is provided in a format agreed upon between the Project Manager, the Quality Assurance Manager, and CCBWQA.

The Biological Laboratory Manager(s) will ensure that phytoplankton and zooplankton identification, enumeration, and biovolume/biomass analyses are analyzed in a technically sound and timely manner, in accordance with the requirements of this SAP/QAPP. The Biological Laboratory Manager(s) shall be responsible for ensuring all laboratory quality assurance procedures associated with the project are followed, including proper sample entry, sample handling procedures, and delivery of quality control records for samples to the laboratory.

7.4.4. Sampling Crew

The field sampling efforts shall be conducted by individuals qualified in the collection of chemical, physical, and biological surface water samples. Field tasks and sampling oversight will be provided by the Project Manager and Quality Assurance Manager. The Sampling Crew shall be responsible for following all procedures for sample collection, including complete and accurate documentation.

7.5. Field Methodologies

7.5.1. Reservoir Sampling

7.5.1.1. Transparency

Transparency shall be determined using a Secchi disk and Licor quantum sensors. The Secchi disk shall be slowly lowered on the shady side of the boat, until the white quadrants disappear, at which point the depth is recorded. The disk is then lowered roughly 1 m further and slowly brought back up until the white quadrants reappear and again the depth is recorded. The Secchi depth is recorded as the average of these two readings.

Licor quantum sensors provide a quantitative approach to determine the depth at which 1 percent of the light penetrates the water column. This is considered the point at which light no longer can sustain photosynthesis in excess of oxygen consumption from respiration (Goldman and Horne 1983) and represents the deepest portion of the photic zone. This is accomplished by using an ambient and underwater quantum light sensor attached to a data logger. The ambient quantum light sensor remains on the surface, while the underwater sensor is lowered into the water on the sunny side of the boat. The underwater sensor is lowered until the value displayed on the data logger is 1 percent of the value of the ambient sensor, and the depth is recorded.

7.5.1.2. Depth Profile Measurements

Measurements for dissolved oxygen, temperature, conductivity, pH, and oxidation/reduction potential (ORP) shall be collected at 1 m intervals, including the surface and near the water/sediment interface, using a multi parameter sonde. The sonde shall be calibrated prior to each sampling episode to ensure accurate readings.

In an effort to minimize probe contamination at the water/sediment interface, a depth sounding line is used to determine maximum depth. The bottom profile measurement is collected approximately 10 cm from the bottom of the water column.

7.5.1.3. Continuous Temperature and Dissolved Oxygen Monitoring

Continuous temperature monitoring to document the water column profile shall be performed at one location in the Reservoir, near CCR-2. The Onset HOBO® Water Temp Pro data loggers shall be deployed at 1 m increments, from the 1 m layer to near the sediment/water interface and configured to collect 15-minute interval temperature data.

In addition, continuous DO loggers will be installed at 0.5m below the water surface and 7m of depth configured to collect data on 15-minute intervals. Due to changes in water level, the bottom logger may have some variability in distance from the bottom sediment. If significant water level fluctuations occur, adjustments may be necessary to avoid the bottom logger sitting in sediment. PME MiniDOT loggers with wiper attachments are currently being used for this application.

The temperature arrays shall be deployed using a buoy system (the State Park's safety buoys or a private buoy, such as the sailing club, with permission). The thermistor chain shall be installed at the beginning of April and operated through October/November, with periodic downloading of data to minimize potential loss of data. This deployment schedule will overlap with the proposed operational schedule of the destratification system.

7.5.1.4. Water Samples

A primary task of the monitoring program is to characterize the chemical and biological constituents of the upper 3 m layers of the reservoir. This layer represents the most active layer for algae production (photic zone), and represents approximately 54 percent of the total lake volume given the typical lake level of 5550 ft. At each reservoir site, water from the surface (0 m), 1 m, 2 m, and 3 m depths are sampled individually using a 2-liter vertical Van Dorn water sampler and combined into a clean 5-gallon container to create a composite photic zone sample (Table 4). The vertical Van Dorn sampler is lowered to the appropriate depth, such that the middle of the sampler is centered on the selected depth. The "messenger" is sent to activate the sampler and the water is retrieved. Required sample volumes are collected from the composite photic zone sample and stored on ice, until transferred to the laboratory for chemical and biological analyses (Table 4). Nutrient analyses shall be performed on all reservoir water samples. Chlorophyll *a* analyses shall be performed on all photic zone composite samples. Phytoplankton analyses shall be performed on photic zone composite samples from CCR-2 only. See Table 5 for the list of analytes, laboratory methods, and detection limits.

At Site CCR-2, profile water samples are also collected on 1 m increments, starting from 4 m and continuing down to the 7 m depth. The 7 m sample is collected as close to the water/sediment interface as possible, without disturbing the sediment. At times, if the reservoir is unusually full, it may be necessary to collect an additional profile water sample, such as occurred after the September 2013 precipitation events. If the reservoir water level is low, the 7 m sample depth may be adjusted accordingly to avoid disturbing the sediment. The sampler and 5-gallon container are rinsed thoroughly with lake water between sites. Based on this sampling scheme, the number of samples collected at each site is shown in Table 4 below:

Table 4. Number of Reservoir Samples Collected.

Reservoir Site	Upper 3 m Composite (Photic zone)	1 m Depth Profiles (4, 5, 6, 7 m)	Number of Samples
CCR-1	1	0	1
CCR-2	1	4	5
CCR-3	1	0	1
Total Samples/Sample Event	**3**	**4**	**7**

7.5.1.5. Zooplankton Samples

Zooplankton samples shall be collected at reservoir site CCR-2. The zooplankton sample should always be collected following the collection of water samples, so as not to compromise the integrity of the water samples. Collection of a vertical water column zooplankton sample is performed using an eight-inch mouth, 80 µm mesh Turtox Student Net. The zooplankton net is rinsed with reservoir water and lowered to the 6 m depth at site CCR-2. The net is slowly retrieved, and the concentrated sample is drained into the sample container with all organic matter being rinsed from the net and into the sample container.

One site tow at CCR-2 is pulled per sampling event. The sample is preserved with 70% alcohol. The diameter of the tow net and combined length of each tow is recorded to provide an estimate of the water volume sampled. The zooplankton species are identified, enumerated, and estimates of biomass are performed.

7.5.2. Stream Sampling

7.5.2.1. Monthly Base Flow Sampling

One sample shall be collected from each of the following stream sites on a monthly basis, when there is sufficient flow; CT-P1, CT-P2, CT-1, CT-2, CC-10, CC-7 EcoPark, CC-O and PC-1. Samples shall be collected as mid-stream mid-depth grab samples. Samples are collected from this grab sample and stored on ice, until transferred to the laboratory for chemical analyses.

The following constituents are monitored at these sites:

- Total Nitrogen
- Total Dissolved Nitrogen
- Nitrite + Nitrate
- Ammonia
- Total Phosphorus
- Total Dissolved Phosphorus
- Soluble Reactive Phosphorus (Orthophosphate)
- Total and Volatile Suspended Solids
- Total and Dissolved Organic Carbon (TOC/DOC) CC-10 and CT-2 only
- Calcium, Chloride, Magnesium, Sodium, Sulfate, Potassium, Alkalinity (see table 3 for sites and frequency)

7.5.2.2. Every Other Month Base Flow Sampling

One sample shall be collected from each of the following stream sites every other month, when there is sufficient flow: MCM-1, and MCM-2. Samples shall be collected as mid-stream mid-depth grab samples. Required sample volumes are collected from this grab sample and stored on ice, until transferred to the laboratory for chemical analyses. The same constituents as the monthly sites are monitored at these sites.

7.5.2.3. Storm Event Sampling

Samples from storm flow events are collected using ISCO automatic samplers, which are programmed to collect samples when the flow reaches a threshold level. The threshold level is determined by analyzing annual hydrographs from each stream and determining historical storm levels which has been determined to be the 90^{th} percentile. When this threshold is reached, the ISCO is programmed to collect a sample every 15 minutes for 6 hours (i.e., a timed composite) or until the water recedes below the threshold level. This sampling procedure occurs at CT-P1, CT-P2, CT-1, CT-2, CC-10, CC-7 EcoPark, and PC-1. Following the storm event, water collected by the automatic samplers is combined (timed composite) into a clean 5-gallon container, and the required sample volumes filled from the composited sample and stored on ice until transferred to the laboratory for analysis. Approximately 4 L would be collected from the 24 bottles, with each bottle contributing a sample amount representative of the flow at which it was collected. Up to seven storm samples shall be collected from each of the monitoring sites during the April to October storm season.

7.5.2.4. Continuous Water Level Monitoring

At sites containing an ISCO automated sampler, continuous water level is also monitored using an ISCO flow module and pressure transducer. The monitoring locations at CT-2, CT-P2 and CC-7 have weir calculations that are used to calculate flow based on the level measurements. For the other stream sites, rating curves are developed by measuring stream discharge (ft^3/sec) with a portable velocity flowmeter and recording the water level at the staff gage (ft) and ISCO flowmeter (ft). Discharge is measured using methods outlined in Harrelson et al. 1994. To determine flow rate, the level must be translated into flow rate using a stage-discharge relationship. Since stage-discharge relationships can change over the years, the relationship is calibrated annually using a flow meter to record stream flow measurements three to four times per year at a range of flows. These data are combined with historical data, as long as stream geomorphology conditions are similar, to validate and modify the stage-discharge relationship for that site. If the staff gage is reset, moved to a new location, or geomorphology conditions have changed, then a new stage-discharge relationship is created for that site.

Water level data are collected on 15-minute intervals and stored in the ISCO sampler. This equipment is set up on telemetry to direct the data to the CCBWQA data portal. The flow data and stage-discharge rating curves shall be checked throughout the year by comparing calculated flow estimates to actual flow measurements recorded in the field with a flowmeter. [Note: In summer 2017, CCBWQA began augmenting the aging ISCO recorders at key inflow stations CC-10 and CT-2 with Sutron Accubar Constant Flow (CF) bubbler systems to measure stream stage, which is converted to discharge as with the pressure transducer data. The pressure transducer and bubbler systems will be operated in parallel at CC-10, CT-2, in order to provide redundancy in case of equipment failure or data loss. At locations difficult where site conditions (freezing conditions in winter months, low water levels, etc.), make level reading difficult at certain times of the year, additional equipment may be deployed as needed in order to determine if more accurate levels can be obtained. The use of a HOBO level sensors have been used as a trial at the CC-7 site so levels can be obtained when the stilling well freezes.

The USACE also reports daily inflow to Cherry Creek Reservoir as a function of storage, based on changes in reservoir level. This daily inflow value incorporates information regarding measured outflow, precipitation, and evaporation. CCBWQA monitors inflow to the Reservoir using gaging stations on Cherry Creek and Cottonwood Creek to provide a daily surface inflow record. Given the differences in the two methods for determining inflow, combined with the potential of unmonitored alluvial and surface flows that may result in greater seepage through the adjacent wetlands during storm events, and other unmonitored surface inflows (i.e., Belleview and Quincy drainages), an exact match between USACE and calculated inflows is not expected. Therefore, CCBWQA normalizes its streamflow data to match the USACE computed inflow value which are referred to as ungauged flows

7.5.2.5. Bi-annual Surface Water Sampling

The Cherry Creek mainstem monitoring was initiated in 1994. The monitoring includes semi-annual sampling (e.g. May and November) at nine surface water sites along Cherry Creek (USGS@Franktown, CC-1, CC-2, USGS@Parker, CC-4, CC-5, CC-6, CC-8, and CC-9). Other sites are included on the Cherry Creek mainstem (e.g., CC-7 (EcoPark), CC-10, and CC-O) which are monitoring on a more frequent basis as part of the Reservoir and PRF efforts. The following constituents are monitored on a semi-annual basis at the nine Cherry Creek mainstem sites:

- Total Nitrogen
- Nitrite + Nitrate
- Ammonia
- Total Phosphorus
- Total Dissolved Phosphorus
- Soluble Reactive Phosphorus (Orthophosphate)
- Calcium, Chloride, Magnesium, Sodium, Sulfate, Potassium, Alkalinity (see table 3 for sites and frequency)

7.5.3. Alluvial Groundwater Sampling

Cherry Creek alluvial groundwater sites are generally paired with mainstem surface water sites to provide corresponding data. Groundwater sampling was initiated in 1994, and includes semiannual sampling at four alluvial sites along Cherry Creek (MW-1, MW-5, MW-9, and MW-Kennedy) for the following constituents:

- Total Nitrogen
- Nitrite + Nitrate
- Ammonia
- Total Phosphorus
- Total Dissolved Phosphorus
- Soluble Reactive Phosphorus (AKA Orthophosphate)
- Chloride
- Sulfate
- TOC/DOC

7.5.4. *Precipitation Sampling*

The precipitation station (PRECIP) is used during the storm season (April- October) to collect rain during storm events. After each of the monitored storm events, samples shall be filled from collection container, stored on ice, and transferred to the laboratory for analysis of total phosphorus and total nitrogen. The collection container shall be inspected and cleaned of any accumulations of insignificant precipitation or debris on a weekly basis. This will minimize extraneous "dry fall" from being washed into the sampler between monitored storm events. A precipitation event of greater than 0.25 inches at the Centennial Airport KAPA weather station is generally a sufficient storm event that activates ISCO samplers and storm event monitoring.

The following constituents are monitored at these sites:

- Total Nitrogen
- Total Phosphorus

7.5.5. *Sediment Sampling*

7.5.5.1. Stream Bed and Bank Sampling

Sediment stream bank and bed sampling shall be completed in areas where stream restoration projects are planned to occur. Prior to planned projects, sediment samples will be collected and analyzed for size and phosphorus concentration to estimate the water quality benefit and quantify estimated phosphorus immobilization for each stream improvement project. It is estimated that sediment sampling will take place in 1-2 areas of the watershed annually for an estimated 8-12 sites total. For each project reach, 4-6 cross sections will be selected for sampling. At each cross section, one (1) bed/toe sample will be collected at a location equidistant between the edge of the bank and average water flow, and one (1) bank sample will be collected at the vertical location equidistant from the bed and overbank. Prior to each sample collection, the top 1" of material will be cleared away and approximately 1000g of sample will be provided to the lab for analysis.

The following constituents are monitored at these sites:

- Sieve Analysis for Particle Size (can be modified based on expected sizes)
  - Standard - #4 - 4.75 mm, #10 – 2 mm, #40 - 0.425 mm, #70 - 0.212 mm, #200 - 0.075 mm
- Total Phosphorus (each size)
- Phosphate (Reactive P) (each size)

7.5.5.2. Pond Sediment Sampling

Soil sampling of dredged materials removed from PRF ponds will occur during maintenance activities (sediment removal). During the maintenance activity or active dredging, three (3) representative soil samples of stockpiled material will be collected and analyzed for nutrient and moisture content. The results will be used to estimate mass of Phosphorus and Nitrogen retained in the PRF ponds between maintenance events. It is estimated that soil sampling during pond maintenance activities will take place in the watershed once every 3-5 years or as maintenance activities are scheduled.

The following constituents are monitored:

- Total Phosphorus
- Total Nitrogen (Total Kjeldahl/ Nitrate+Nitrite)
- Percent Solids

7.6. *Laboratory Procedures*

The sampling and analyses shall be conducted in accordance with the methods and detection limits provided in Table 5 below.

The turnaround time is variable and generally ranges from 30 days for most routine chemical analyses up to 90 days for biological (i.e., phytoplankton and zooplankton) analyses, but the turnaround time will depend on the analyses to be performed, the number of samples, and the laboratory backlog. Rapid turnaround time is generally available for an additional fee by most laboratories.

Table 5. List of Analytes, Abbreviations, Analytical Methods, Recommended Hold Times, and Detection Limits for Chemical Laboratory Analyses.

Parameter	Abbreviation	Analytical Method	Recommended Hold Times	Detection Limit
Physicochemical				
Total Nitrogen	TN	SM20 4500NC	< 24 hrs before digestion; < 7 days after digestion	2 µg/L
Total Dissolved Nitrogen	TDN	SM20 4500NC	48 hours	5ug/L
Nitrate/Nitrite Nitrogen	NO_3+NO_2	SM18 4500NO3F	48 hrs	10 µg/L
Ammonium Ion Nitrogen	NH_4	SM18 4500NH3H	24 hrs	10 µg/L
Total Phosphorus	TP	SM18 4500PF	< 24 hrs before digestion	2 µg/L
Total Dissolved Phosphorus	TDP	SM18 4500PF	48 hrs	2 µg/L
Soluble Reactive Phosphorus	SRP	SM18 4500PF	48 hrs	1 µg/L
Total Suspended Solids	TSS	SM 2540D	7 days	0.5 mg/L
Volatile Suspended Solids	TVSS	SM 2540 E	7 days	0.5 mg/L
Total Organic Carbon	TOC	SM 5310 B	28 days	0.25 mg/L
Dissolved Organic Carbon	DOC	SM 5310 B	28 days	0.25 mg/L
Chloride	Cl	EPA 325.3/SW846 9056	28 days	0.5 mg/L
Sulfate	SO_4	EPA 375.4/SW846 9056	28 days	1.0 mg/L
Magnesium	Mg	EPA 200.7	28 days	0.1 mg/L
Calcium	Ca	EPA 200.7	28 days	0.1 mg/L
Potassium	K	EPA 200.7	28 days	0.5 mg/L
Sodium	Na	EPA 200.7	28 days	0.5 mg/L
Alkalinity (as $CaCO_3$)		EPA 310.1	14 days	1.0 mg/L
Biological				
Chlorophyll *a*	Chl	SM 10200 H	< 24 hrs before filtration	0.1 µg/L
Phytoplankton	--	SM 10200 B.2.a, C.2, D.2, E.4, F2C =	NA	NA
Zooplankton	--	SM 10200 B.2.B, C.4, D.4, E.4, G =	NA	NA
Soils				
Stream Bed and Bank Samples				
Total Phosphorus	TP	EPA 3051A	-	1ug/L
Phosphate (Reactive Phosphorus)	PO4	Olson P/ Mehlich 3 (pH)	-	1ug/L
Pond Sediment				
Total Phosphorus	TP	EPA 365.1	-	17 mg/Kg
Total Kjeldahl Nitrogen	TNK	EPA 351.2	-	370 mg/Kg
Nitrate + Nitrite	NO_3+NO_2	9056A	-	10 mg/Kg

* TP and TN can be measured from same digest.

Method References:

American Public Health Association, American Water Works Association, and Water Environment Federation. (2005). *Standard Methods for Examination of Water and Wastewater.* (21st Edition). Washington DC 1985.

Mehlich, "Mehlich 3 Soil Test Extractant: A Modification of Mehlich 2 Extractant," Communications in Soil Science and Plant Analysis, Vol. 15, No. 12, 1984, pp. 1409-1416. doi:10.1080/00103628409367568

Olsen, Cole, Watanabe and Dean, “Estimation of Available Phosphorus in Soils by Extraction with Sodium Bicarbonate,” USDA Circular 939, US Govt. Printing Office, Washington DC, 1954.Pfaff, John D. August 1993. Method 300.0 - Determination of Inorganic Anions by Ion Chromatography, Inorganic Chemistry Branch, Chemistry Research Division, Revision 2.1. Environmental Monitoring Systems Laboratory, Office Of Research and Development, U.S. Environmental Protection Agency. Cincinnati, Ohio 45268 http://water.epa.gov/scitech/methods/cwa/bioindicators/upload/2007_07_10_methods_method_300_0.pdf

http://www.epa.gov/wstew/hazard/testmethods/sw846/online/index.htm

2018 MEMO CCBWQA Analytical Methods and Detection Limits, Solitude Lake Management Presented to Board on October 18, 2018

SW846 = "Test Methods For Evaluating Solid Waste, Physical/Chemical Methods", Third Edition, November 1986 And Its Updates.

7.6.1. Biological Laboratory Analysis

Biological analyses for the samples collected in the study, include chlorophyll α, phytoplankton (identification, enumeration, and biovolume), and zooplankton (identification, enumeration, and biomass). The methods of these analyses, with appropriate QA/QC procedures shall be in accordance with the methods provided in Table 5.

8. Program Quality Assurance/Quality Control Protocols

8.1. *Field Sampling*

All field team members will be responsible for visually inspecting and monitoring for contamination and should a bottle be contaminated it will be replaced with a clean one. To provide Quality Control/Quality Assurance (QC/QA) information on the field samples, both field blanks and field duplicates shall be collected and will comprise approximately 10 percent of the total number of samples analyzed for the project. The field blank and duplicate samples will be labeled and stored with the field collected samples and analyzed using the same laboratory methods. The QC/QA samples will provide information on sampling and analytical error.

8.2. *Laboratory*

The analytical and biological laboratories will follow their in-house Quality Assurance Plans (QAP), which will be consistent with specific state requirements. These documents will be available to CCBWQA upon request.

Analytical laboratory equipment calibrations are performed[3] every time new standards are prepared in accordance with laboratory standard operating procedures. Instrument values are compared to known standard concentration and if the correlation coefficient of the standard curve is less than 0.999, the instrument is recalibrated or standards are remade, with the process being completed until the instrument passes the test. Pseudo-replicate analyses are performed on each sample analyzed (i.e., sample analyzed twice) and the percent difference must be within 10 percent, if the resultant concentration is above the minimum detection limit. If the difference of the pseudo-replicate analyses is >10 percent, a new analytical sample is placed in a clean test tube and analyzed. During a sample analysis run, check standards are analyzed between every 5 samples (or 10 replicates). The check standards consist of one high range standard, one mid-range standard, and the control blank (zero). Check standards analyzed before and after each group of

[3] Specifics available upon request

samples must be within 10 percent of the theoretical value. If standards are outside of this range, new analytical samples and standards are placed in clean test tubes and analyzed to try to determine the source of the error. Sample values are not accepted until the problem has been resolved and all check standards pass the QC criteria. One matrix spike is run for every 10 samples analyzed (or 20 replicates). The percent recovery for matrix spikes must be ± 20 percent.

Following sample analyses, a final QC check is performed to determine if all parameters measured are in agreement. Final analyses for each sample are compared to ensure that concentrations of total phosphorus ≥ total dissolved phosphorus ≥ orthophosphate and that the concentration of total nitrogen ≥ total dissolved nitrogen ≥ nitrate/nitrite an ammonia. If parameters are not in agreement samples are reanalyzed.

9. Data Validation and Usability

All field data and chain-of-custody (COC) forms will be reviewed the Field Team Leader for completeness and correctness. The QA Manager will be responsible for data validation, and will review the field book, laboratory's results and reports for accuracy and will report any issues to the Project Manager. Laboratory data will be reviewed to ensure that appropriate methods were used, and that data are qualified appropriately, and method detection limits provided. Any problems that arise will be brought to the attention of the Project Manager and it is this person's responsibility to accept or reject the data.

10. Data Verification, Reduction, and Reporting

Data verification shall be conducted to ensure that raw data are not altered. All field data, such as those generated during any field measurements and observations, will be entered directly into a bound Field Book. Sampling Crew members will be responsible for proofreading all data transfers, if necessary. All data transfers will be checked for accuracy.

The Quality Assurance Project Manager will conduct data verification activities to assess laboratory performance in meeting quality assurance requirements. Such reviews include verification that:

1) The correct samples were analyzed and reported in the correct units.
2) The samples were properly preserved and not held beyond applicable holding times.
3) Instruments are regularly calibrated and meeting performance criteria; and
4) Laboratory QA objectives for precision and accuracy are being met.

Data reduction for laboratory analyses is conducted by Consultant's personnel in accordance with EPA procedures, as available, for each method. Analytical results and appropriate field measurements are input into a computer spreadsheet. No results will be changed in the spreadsheet unless the cause of the error is identified and documented.

A data control program will be followed to ensure that all documents generated during the project are accounted for upon their completion. Accountable documents include: Field Books, Sample Chain of Custody, Sample Log, analytical reports, quality assurance reports, and interpretive reports.

After the data has been QA/QCed, Contractor will format the monitoring data in the specific template format provided and upload the data to CCBWQA's Data Portal. Contractor will work with the Data Portal manager to reconcile any inconsistent values (such as parameter names, monitoring location IDs, and units) prior to data upload. CCBWQA's Data Portal is the central repository for historical and ongoing data collection. It is used for data download and analysis, as well as to provide updates to the Technical Advisory Committee and Board of Directors and to generate information used in the Annual Report.

11. References

AMEC Earth & Environmental, Inc., Alex Horne Associates, Hydrosphere Resource Consultants, Inc. (December 5, 2005). *Feasibility Report Cherry Creek Reservoir Destratification.*

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U.S. Environmental Protection Agency (EPA). (August 1999). *Site-Specific Sampling and Analysis Plan Template.*

U.S. Environmental Protection Agency. (December 2000). *Peer Review Handbook, 2nd Edition.* Washington, DC 20460: Science Policy Council.

12. APPENDIX A – Sampling Site Locations

Waterbody	ID	Latitude	Longitude
Cherry Creek Reservoir	CCR-1	39°38'34.68"N	104°51'41.88"W
Cherry Creek Reservoir	CCR-2	39°38'49.09"N	104°51'08.15"W
Cherry Creek Reservoir	CCR-3	39°38'17.46"N	104°51'09.69"W
Cherry Creek	USGS@Franktown	39°21'21"N	104°45'46"W
Cherry Creek	CC-1	39°25'57.80"N	104°46'05.10"W
Cherry Creek	CC-2	39°28'6.90"N	104°46'04.20"W
Cherry Creek	USGS@Parker	39°31’09"N	104°46'45"W
Cherry Creek	CC-4	39°31'33.10"N	104°46'50.50"W
Cherry Creek	CC-5	39°32'38.70"N	104°46'46.00"W
Cherry Creek	CC-6	39°33'59.40"N	104°47'25.70"W
Cherry Creek	CC-7	39°35'12.06"N	104°48'18.63"W
Cherry Creek	CC-8	39°36'10.40"N	104°48'55.10"W
Cherry Creek	CC-9	39°37'28.10"N	104°50'03.60"W
Cherry Creek	CC-10	39°38'00.46"N	104°50'17.22"W
Cherry Creek	CC-O	39°39'10.60"N	104°51'22.52"W
Cottonwood Creek	CT-P1	39°36'07.96"N	104°51'20.03"W
Cottonwood Creek	CT-P2	39°36'19.23"N	104°50'55.01"W
Cottonwood Creek	CT-1	39°37'27.73"N	104°50'54.95"W
Cottonwood Creek	CT-2	39°37'40.27"N	104°51'00.94"W
Piney Creek (new)	PC-1 new	39°36'08.2"N	104°46'18.5"W
McMurdo Gulch	MCM-1	39°23'19.54"N	104°48'53.63"W
McMurdo Gulch	MCM-2	39°24'16.60"N	104°48'46.01"W
Precipitation	PRECIP	39°38'12.40"N	104°50'8.47"W
Groundwater	MW-1	39°26'07.50"N	104°45'59.80"W
Groundwater	MW-5	39°32'39.10"N	104°46'46.88"W
Groundwater	MW-9	39°37'25.00"N	104°50'11.20"W
Groundwater	MW-Kennedy	39°39'15.80"N	104°52'0.20"W

13. APPENDIX B –Abandoned Sampling Sites

Historical Reservoir Sites (Abandoned)

D-1 to D-10 These sites were a series of transect profile locations that started near the dam face (D1) and continued across the Reservoir to CCR-3. The transect corresponded to Transect D of the Destratification Feasibility Report (AMEC 2005). The D transects were discontinued in 2016 when the destratification system was not in operation. Data analyses also demonstrated that D transect data was statistically similar to the profile data collected at CCR-1, CCR-2, and CCR-3 (which continues to be collected by Authority).

Historical Surface Water Sites (Abandoned)

CC-3 This site was located 1 mile south of West Parker Road. It is no longer used as a water quality sampling location.

CC-7 This was the original CC-7 site, located ¾ mile south of Arapahoe Road. It was abandoned in 2000 due to development.

CC-10A This site was established in 1999 on an intermittent channel of Cherry Creek. CC-10A is active during spring runoff and some precipitation events. Flow measurements at this site were used to provide additional data on total inflows into the Reservoir. This site has not been monitored since 2001.

SC-1 This site was established in 1987, immediately east of Parker Road on Shop Creek. Originally, SC-1 monitored phosphorous levels prior to the confluence with Cherry Creek. From 1990 through 2001, this site monitored water quality upstream of the Shop Creek detention pond/wetland PRF. This site has not been monitored since 2001.

SC-2 This site was established in 1990 and was located west of Parker Road at the outlet from the Shop Creek detention pond. This site monitored the water quality as it left the detention pond. This site has not been monitored since 2001.

SC-3 This site is located 35 m upstream of its confluence with Cherry Creek and was used to monitor the water quality of Shop Creek before it joins Cherry Creek. Sampling ceased at this site in 2013 because flow and total phosphorus loads were less than one percent of the total annual flow-weighted load entering the reservoir.

QD-1 This site was established in 1996 on Quincy Drainage, above of the Perimeter Road wetlands, which were constructed in 1990 just downstream of the outlet for the Quincy Road/Parker Road stormwater drain. This site monitored water quality of the Quincy Drainage upstream of the wetlands and a new PRF, consisting of a water quality/berm system, established in late 1995, downstream of the Perimeter Road. This site has not been monitored since 2001.

BD-1 This site was established in mid-1996 at the suggestion of State Parks personnel and is used to monitor the inflow to an old stock pond on this drainage near Belleview Avenue. This site has not been monitored since 2001.

BD-2 This site was established in mid-1996 at the suggestion of State Parks personnel and is used to monitor this drainage as it crosses the Perimeter Road before entering the Reservoir. This site monitors the nutrient removal abilities of the historic stock pond and natural wetland system. This sites have not been monitored since 2001.

Historical Groundwater Sites (Abandoned)

MW-2 This alluvial well monitor was 1994 - 2016 and was located downstream of the Pinery's wastewater treatment plant. This site was located approximately 0.85 km upstream of Stroh Road. The site was discontinued in 2017 due to statistical evaluations that demonstrated the similarity of the groundwater to the proximate surface water station that continues to operate.

MW-3c This alluvial well monitor was sampled 2012-2016 and was located near the KOA tower approximately 0.49 km southwest of the Parker Road and Twentymile Road intersection. The original alluvial well MW-3 was abandoned in 2009 and replaced by MW-3b which was then abandoned in 2010. This site was discontinued in 2017 due to statistical evaluations that demonstrated the similarity of the groundwater to the proximate surface water station that continues to operate.

MW-4b This site was located downstream of Sulphur Gulch, and was abandoned in 2002 due to development.

MW-6 This alluvial well monitor was sampled 1994 -2016 and was located downgradient of Parker's North AWT plant. This site was located approximately 1.38 km downstream of Cottonwood Drive and approximately 0.41 km west of Parker Road. This site was discontinued in 2017 due to statistical evaluations of the 22-year record that demonstrated the similarity of the groundwater to the proximate surface water station that continues to operate.

MW-7 This site was located south of Arapahoe Road near EcoPark, and it was abandoned in 2000 due to development.

MW-7a Site MW-7a was established in 2013 as part of monitoring for the Eco-Park Reclamation Project. This alluvial well was sampled from 2013 - 2016 and was located at the downstream boundary of Cherry Creek Valley Ecological Park (EcoPark). This site was approximately 1.7 km upstream of Arapahoe Road. This site was discontinued in 2017 due to statistical evaluations that demonstrated the similarity of the groundwater quality to the proximate surface water station that continues to operate.

MW-8 This site was the Arapahoe Deem production well, located north of Arapahoe Road. It was abandoned as a sampling site in 2000 due to development.

14. APPENDIX C – Changes from Previous SAP

1. In 2018, at site CT-1, 15-minute level data and flow measurements were collected in order to update the stage discharge relationship and report flows. This was added in order to provide the data to ACWWA.
2. In 2019, the Real -Time water quality monitoring probes were removed from sites CC-10 and CT-2. This equipment was not ideal for continuous deployment in stream sites with variable water levels and required a significant effort and cost to maintain They were replaced with thermistors to record temperature on a 15-min time interval.
3. In 2019, TOC and DOC analyses were added back for the two sites just upstream of the reservoir at CT-2 and CC-10. This was completed at the request of the reservoir modeler.
4. In 2019, continuous DO monitoring loggers were installed in Cherry Creek Reservoir at the buoy near CCR-2. These were installed at the request of the reservoir modeler.
5. In 2019, an additional probe for Chl-α/ Phycocyanin (Blue green algae) will be added to the sonde for profiling of these parameters.
6. In 2020, at site CT-P2, 15-minute level data and flow measurements were collected in order to update the stage discharge relationship and report flows. In addition, both CT-P2 and CT-1 were sampled monthly during base flows and included in the storm sampling program in order to evaluate the various sections of the Cottonwood treatment train in more detail.
7. In 2021, the sample collection of TOC/ DOC at the profile sites (4-7m) at CCR-2 will be removed from the SAP and will just be continued at the CCR-2 (0-3m) composite site. This data was being collecting by request of the modeler and sufficient data has been collected at this point.
8. In 2021, analysis for TDS components (Chloride, Sulfate, Magnesium, Sodium, Calcium, and Alkalinity) will be added to the monitoring program for 2021 to see what components are affecting these values and if a relationship between the values in the surface water and Reservoir can been seen. These analyses will be completed at the stream sites CT-P1, CT-2 and CC-10 and to the CCR-2 sites from the top (0-3m) and bottom (7m) during the March and September monitoring events.
9. In 2022, Soils sampling collection and analysis methods were added for consistency when evaluating the potential for phosphorus immobilization of stream restoration projects and to help inform the efficiency of phosphorus removal during sediment removal from PRF ponds.