APPENDIX B

THE CHERRY CREEK BASIN WATER QUALITY AUTHORITY
ROUTINE SAMPLING AND ANALYSIS PLAN/ QUALITY ASSURANCE PLAN
SAP/QAPP 2018

2018

The Cherry Creek Basin Water Quality Authority Routine Sampling and Analysis Plan/ Quality Assurance Project Plan

SAP | QAPP

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1. Introduction

The Cherry Creek Basin Water Quality Authority (Authority) was formally created in 1988 by the Colorado State Legislature by statute (see Colorado Revised Statues (C.R.S.) 25.8.5-101 et seq.). The Authority was created as a quasi-municipal corporation and political subdivision of the state, and is tasked with improving, protecting, and preserving the water quality of Cherry Creek and Cherry Creek Reservoir as well as achieving and maintaining state water quality standards for the reservoir and watershed. The Authority has the power to develop and implement plans and studies for water quality controls for the reservoir and watershed to achieve and maintain the water quality standards, and make recommendations regarding water quality projects and programs to achieve water quality standards. The Sampling and Analysis Plan (SAP) and Quality Assurance Project Plan (QAPP) includes long-term monitoring of nutrient levels within the reservoir and its tributaries, nutrient levels in precipitation and groundwater, and chlorophyll a levels within the reservoir. The overall goal of the monitoring program is to assess attainment of the water quality standards (including beneficial uses and the numeric criteria adopted to protect the uses) and to assess the effectiveness of the Authority's actions.

2. Purpose

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

- For the purpose of supporting and calibrating the reservoir and watershed water quality models, as anticipated by Regulation 72[1];

- For the purpose of meeting parameter-specific monitoring required of the Authority by Regulation 72 and additional non-specified monitoring determined by the Authority to be supportive of Authority goals;

[1] As future special studies are identified, the SAP/QAPP will be reviewed to determine if any modifications need to be made to support the new studies. In some instances, a short, stand-alone SAP may be more appropriate. "Special studies" are anticipated by Regulation 72, the Cherry Creek Reservoir Control Regulation, Section 72.8.4: "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; (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." The reservoir and watershed models qualify as special studies. A special study such as a side-by-side comparison of methods for cyanobacteria analysis, e.g., filtering vs. settling, would also require a separate special SAP.

- For the purpose of meeting nutrient Pollutant Reduction Facility (PRF) monitoring required of the Authority by Regulation 72;

- For the purpose of determining attainment of applicable water quality standards, as required of the Authority by Regulation 72; For the purpose of evaluating nutrient sources and transport, evaluating fate and transport of phosphorus, and calculating flow-weighted phosphorus concentrations, as required of the Authority by Regulation 72; and

- For the purpose of calculating flow-weighted nitrogen concentrations and evaluating the fate and transport of nitrogen, as well as calculating mass balances for both phosphorus and nitrogen inputs and losses from the reservoir, as determined by the Authority to be supportive of its goals, according to the 2010 expansion of Regulation 72 to consider all nutrients, and not just phosphorus.

3. Sampling Program Objectives

The Authority's long-term goals serve as assessment end-points for the reservoir and watershed (for example, protection of beneficial uses, and preservation and enhancement of water quality). The sampling program helps the Authority 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 *a* concentrations and collect other data (i.e., phytoplankton) related to the effect of chlorophyll *a* on beneficial uses;

- Determine the concentrations of phosphorus and nitrogen species in the reservoir and streams, and how it changes over time;

- Determine the annual flow-weighted phosphorus concentration and changes to the concentrations entering the reservoir from streams and precipitation and the phosphorus export from the reservoir via the outlet structure;

- Determine the effectiveness of pollutant removal by Pollutant Reduction Facilities, including the Reservoir Destratification System; and

- In collaboration with Leonard Rice Engineers, provide data for the Authority's Internet Data Portal.

The SAP/QAPP identifies field and laboratory protocols necessary to achieve high quality data. The 2018 SAP/QAPP is intended to build off of the 2016 and 2008 Sampling and Analysis Plans and Quality Assurance Work Plans and 2017 SAP modifications (GEI 2008, Tetra Tech 2016, Tetra Tech November 3, 2016) 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.

4. Regulation No. 72 Requirements

Regulation 72 states that 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.

- 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; and
- Monitoring of PRFs shall be implemented to determine inflow and outflow nutrient concentrations.

The Authority shall consult with the Colorado Water Quality Control Division (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. In addition, the Authority shall consult with the Division and other appropriate entities in development of any water quality investigative special studies.

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 (72.8).

Reporting requirements are also required under Regulation 72. The Authority shall submit an annual report on the activities to the Commission and Division by March 31 of each year (72.9).

The SAP/QAPP facilitates the above Regulation 72 requirements, and ensures a high quality, auditable, and well-documented monitoring program.

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 hardware,
- 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 the Authority's Board of Directors.

6. Timeline

Sampling and data collection shall be implemented per Regulation 72. The Cherry Creek Basin is subject to the hearing timelines of the Cherry Creek Reservoir Control Regulation (Regulation 72), statewide water quality standards (Regulation 31), Cherry Creek water quality standards (Regulation 38), statewide water quality standards assessment (Regulation 93), and other regulations (Regulation 22, 43, 61, 85). As these regulations change, the SAP/QAPP may need to be revisited and may change. The next Water Quality Control Commission (Commission) Triennial Review Informational Hearing for Regulation 72 will be held in May 2018. 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

Regulation Number	2018	2019	2020	2021	2022	2023	2024
#38 (Water Quality Standards Regulation)	**ISH[1] 10/9/2018**	**IFH[2] 11/12/2019**	**RMH[3] 6/2020**				
#72 (Cherry Creek Reservoir Control Regulation)	**TRIH[4] 5/7/2018**			**TRIH ~5/2021[5]**	**RMH[6] (date & year TBD)[7]**		**TRIH ~5/2024[5]**
#93 (List of Impaired Waters)		**RMH[8] 12/9/2019**		**RMH[8] 12/2021**		**RMH[8] 12/2023**	

[1] Issues Scoping Hearing (ISH) to provide an early identification of the possible need for revisions to the South Platte River basin water quality classifications and standards

[2] Issues Formulation Hearing (IFH) to identify potential revisions to the South Platte River basin water quality classifications and standards, for consideration in a June 2020 rulemaking hearing.

[3] Rulemaking Hearing (RMH) to consider revisions to the South Platte basin water quality classifications and standards, to address issues identified in the November 2019 Issues Formulation Hearing.

[4] Triennial Review Informational Hearing to consider the possible need for revisions to the Cherry Creek Reservoir Control Regulation. Any actual revisions would be considered in a subsequent rulemaking hearing.

[5] This date assumes that the Commission found at the previous TRIH there was no need to schedule full rulemaking hearing prior to the next TRIH.

[6] Rulemaking Hearing (RMH) to consider adoption of revisions to the Cherry Creek Reservoir Control Regulation.

[7] This date (and year) assumes that the Commission found at the previous TRIH there was a need to schedule full rulemaking hearing to consider adoption of changes to the regulation. Alternately, the Commission could schedule a TRIH for 2024.

[8] Rulemaking Hearing to consider revisions to Colorado's Section 303(d) List of Impaired Waters and Monitoring and Evaluation List.

7. Project Description

The Authority has been collecting water quality data since 1994. The data has provided an extensive site-specific data set for Cherry Creek Reservoir and its tributaries. This SAP/QAPP has been designed to better define water quality conditions and to gain a better understanding of changes of nutrients in the reservoir and its tributaries and the effectiveness of PRGs. 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 Cherry Creek mainstem (Figure 1). Data from many of these monitoring sites are used to assess the effectiveness of several of the Authority's PRFs (Figure 2).

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 located 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.

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.

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 is 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 back-flow 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 was located 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 will be established in 2018 in a reach of Piney Creek upstream of the confluence with Cherry Creek, and downstream of the Piney Creek Stream Reclamation Project.

7.1.2.4. McMurdo 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.

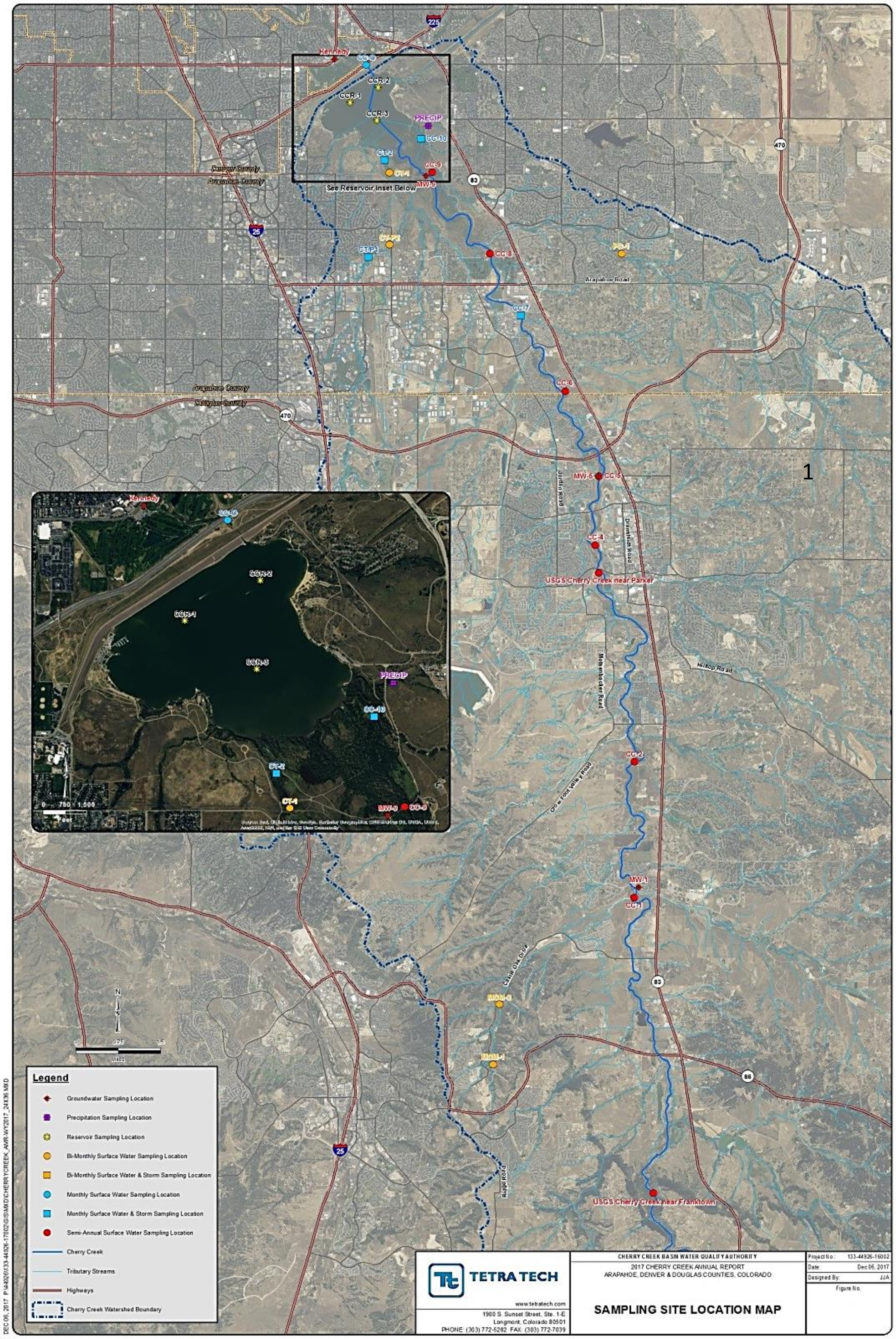
MW-5 This alluvial well monitor has been sampled since 1994, and is located immediately downgradient of the confluence with Newlin Gulch. This site is located where Pine Lane crosses Cherry Creek, approximately 0.65 km west of Parker Road.

MW-9 This alluvial well monitor has been sampled since 1994, and is located 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.

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



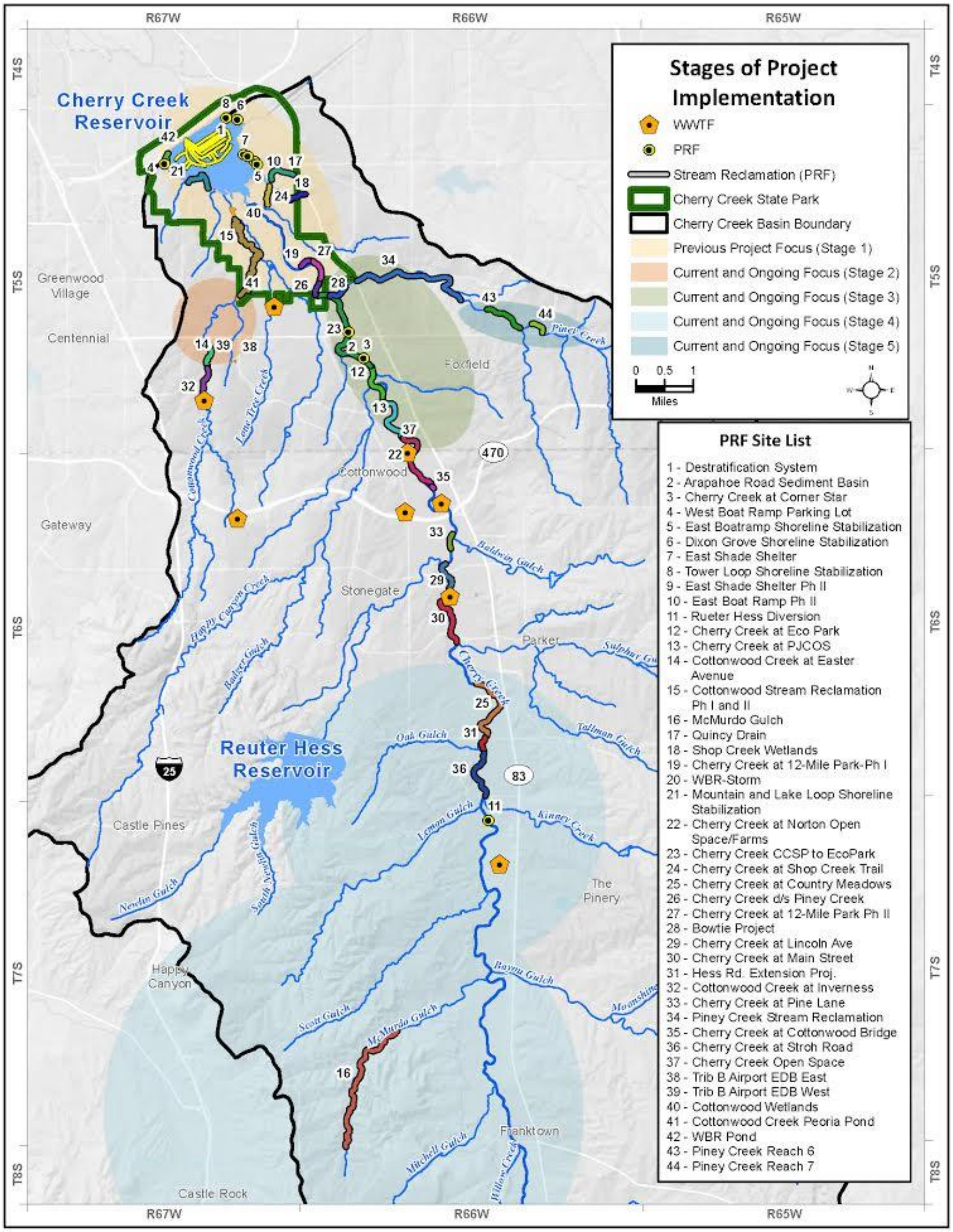


Figure 2: Pollutant Reduction Facility (PRF) Sites Located Throughout the Cherry Creek Watershed.

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 Pot'l	x				x	
1% Transmittance	x				x	
Secchi disk	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 Phosphorus		x	x	x	x	x
Total Dissolved P		x	x	x	x	
Orthophosphate as P		x	x	x	x	
Total Organic Carbon			x	x	x	
Dissolved Organic			x	x	x	
Total Volatile Suspended		x	x		x	
Total Suspended Solids		x	x		x	
Chlorophyll *a*		x	x		x	
Phytoplankton			x		x	
Zooplankton			x		x	

[1]As safety 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
	5 sites (CC-0, CC-10, CC-7-EcoPark, CT-1, CT-2)	**5 sites** (CT-P1, CT-P2, MCM-1, MCM-2, PC-1)	**4 sites** (CC-10, CC-7-EcoPark, CT-2, CT-P1)	**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 Pot'l					x
Water Level, Continuous (15-minute interval)			x		x **(MW-9 only)**
Discharge, Rating Curve			x		
Inorganics					
Total Nitrogen	x		x		
Ammonia as N	x		x	x	x
Nitrate+Nitrite as N	x		x	x	x
Nitrate as N				x	x
Nitrite as N				x	x
Total Phosphorus	x		x	x	
Total Dissolved Phosphorus	x		x	x	x
Orthophosphate as P	x		x	x	x
Chloride					x
Sulfate					x
Organics					
Total Organic Carbon					x **(MW-9 only)**
Dissolved Organic Carbon					x **(MW-9 only)**
Total Volatile Suspended Solids	x		x		
Total Suspended Solids	x		x		

Note that the Total and Dissolved Organic Carbon samples collected at CCR-1, CCR-2, CCR-3, and MW-9, and the water levels at MW-9, are being collected at the request of the Authority's Reservoir Modeler as input for the model. These parameters will be reviewed and perhaps discontinued when this SAP/QAPP is next updated.

7.3. Authority Roles and Participation

The Authority 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/QAPP, as more specifically identified in Exhibit A, the "2018 Sampling and Analysis Program - Scope of Work". 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 contact with the project's progress;
- Regularly review the project schedule and budget, and review all work products; and
- Evaluate impacts on project 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 the Authority, the WQCD, and the Authority's other consultants to ensure compliance with the Cherry Creek Reservoir Control Regulation 72.

7.4.3. Analytical and Biological Laboratory Managers

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 Analytical Laboratory Manager, and the Authority. 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 quality control records for samples delivered 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 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 reading 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 disk 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 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 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 benthos.

7.5.1.3. Continuous Temperature Monitoring

Continuous temperature monitoring to document the water column profile shall be performed at one location in the Reservoir, 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.

The temperature arrays shall be deployed using the State Park’s buoy system, beginning in March/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, and 1 m, 2 m, and 3 m depths is 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. Four one-liter aliquots 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. 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	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-2, CC-10, and CC-7 EcoPark, , CC-O. Samples shall be collected as mid-stream mid-depth grab samples using a 5-gallon container. Two one-liter aliquots are collected from this grab sample and stored on ice, until transferred to the laboratory for chemical analyses.

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; CT-P2, CT-1, MCM-1, MCM-2, and PC-1. Samples shall be collected as mid-stream mid-depth grab samples using a 5-gallon container. Two one-liter aliquots are collected from this grab sample and stored on ice, until transferred to the laboratory for chemical analyses.

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 storm levels. When the threshold is reached, the ISCO collects a sample every 15 minutes for approximately 2.5 hours (i.e., a timed composite) or until the water recedes below the threshold level. This sampling procedure occurs at CT-P1, CT-2, CC-10, and CC-7 EcoPark. Following the storm event, water collected by the automatic samplers is combined (timed composite) into a clean 5-gallon container, with two 1 liter (L) aliquots collected 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. Rating curves are developed for each sampling site by measuring stream discharge (ft^3/sec) with a Marsh McBirney Model # 2000 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. These data are downloaded on a monthly basis to minimize the risk of data loss due to power failure or ISCO failure. 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 the Authority 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. It is anticipated that the pressure transducer and bubbler systems will be operated in parallel through at least part of WY2018 at CC-10 and CT-2 to ensure comparable data are generated by the CF bubbler systems.]

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. The Authority 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, the Authority normalizes their streamflow data to match the USACE computed inflow value.

7.5.3. Watershed Surface Water Sampling

The Cherry Creek mainstem monitoring was initiated in 1994. The monitoring includes semiannual 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:

- Nitrite + Nitrate
- Nitrite
- Nitrate
- Ammonia
- Total dissolved phosphorus
- Total phosphorus
- Soluble reactive phosphorus (AKA Orthophosphate)

7.5.4. 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:

- Nitrite + Nitrate
- Nitrite
- Nitrate
- Ammonia
- Total dissolved phosphorus
- Soluble reactive phosphorus (AKA Orthophosphate)
- Chloride
- Sulfate

7.5.5. Precipitation Sampling

After each of the seven monitored storm events, the sample bottle shall be removed, stored on ice, and transferred to the laboratory for analysis of total phosphorus and total nitrogen. The sampler shall be inspected and cleaned of any accumulations of unimportant precipitation 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.

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	10-107-04-4-B*	< 24 hrs before digestion; < 7 days after digestion	2 µg/L
Nitrate/Nitrite Nitrogen	NO_3+NO_2	10-107-04-1-C	48 hrs	2 µg/L
Ammonium Ion Nitrogen	NH_4	10-107-06-2-A	24 hrs	3 µg/L
Total Phosphorus	TP	10-115-01-4-B*	< 24 hrs before digestion	2 µg/L
Total Dissolved Phosphorus	TDP	10-115-01-4-B	48 hrs	2 µg/L
Soluble Reactive Phosphorus	SRP	10-115-01-1-T	48 hrs	2 µg/L
Total Suspended Solids	TSS	SM 2540D	7 days	4 mg/L
Total Volatile Suspended Solids	TVSS	SM 2540 E	7 days	4 mg/L
Total Organic Carbon	TOC	SM 5310 B	28 days	0.16 mg/L
Dissolved Organic Carbon	DOC	SM 5310 B	28 days	
Chloride	Cl	EPA 300.0/SW846 9056	28 days	0.1 mg/L
Sulfate	SO_4	EPA 300.0/SW846 9056	28 days	0.1 mg/L
Biological				
Chlorophyll *a*	Chl	SM 10200 H	< 24 hrs before filtration	0.1 µg/L
Phytoplankton	--	SM 10200 B.2.a SM 10200 C.2 SM 10200 .D.2 SM 10200 E.4 SM 10200 F.2.c	NA	NA
Zooplankton	--	SM 10200 B.2.B SM 10200 C.4 SM 10200 D.4 SM 10200 E.4 SM 10200 .G	NA	NA

* 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.

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

7.6.1. Biological Laboratory Analysis

Biological analyses for the samples collected in the study, include chlorophyll a, 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.

7.7. Laboratory Quality Assurance/Quality Control Protocols

Analytical laboratory equipment calibrations are performed every time new standards are prepared (minimum of once per week). 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 are >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 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.

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 the Authority upon request.

9. Data Validation and Usability

All field data and chain-of-custody (COC) forms will be reviewed the Field Team Leader for 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 with method detection limits. 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 proof reading 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 insure 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 provide the monitoring data to Leonard Rick Engineers (LRE) in the specific template format used for data upload to the Authority's Data Portal. Contractor will work with LRE to reconcile any inconsistent values (such as parameter names, monitoring location IDs, and units) prior to data upload. The Authority'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.*

American Public Health Association. (20th Edition American Public Health Association). *Standard Methods for Examination of Water and Wastewater.* Washington DC: 1985.

Cheryl C. Harrelson, C. P. (1994). *Stream channel reference sites: an illustrated guide to field technique.* Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station 61 p.: Gen Tech. Rep. RM-245.

Denver Regional Council of Governments. (1985). *Cherry Creek Basin Water Quality Management Master Plan.* Prepared in Cooperation with Counties, Municipalities, and Water and Sanitation Districts in the Cherry Creek Basin and Colorado Department of Health.

Goldman, C. a. (1983). *Limnology.* NY: McGraw-Hill Company.

Knowlton, M. a. (1993). *Limnological Investigations of Cherry Creek Lake.* Final report to Cherry Creek Basin Water Quality Authority.

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	PC-1	39°36'23.21"N	104°48'52.02"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 has not been monitored since 2001.

<u>Historical Groundwater Sites (Abandoned)</u>

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.

Exhibit A - 2018 Sampling & Analysis Program - Scope of Work

The 2018 program continues to thoughtfully address the sampling program objectives (based on the "2018 Routine Sampling and Analysis Plan (SAP)/Quality Assurance Project Plan (QAPP)" ("2018 SAP") and regulatory requirements while providing program efficiencies and meeting the following programmatic goals:

- Assuring technically defensible data are collected in the field and generated by the laboratories.
- Collaborating with the Authority members and staff to ensure that the monitoring programs support the technical and regulatory requirements of all users as cost-effective as possible.
- Providing guidance on water quality and limnology issues as they relate to the data, science, and monitoring program.

The 2018 scope of work is broken into three main programmatic categories, with a variety of tasks to support the program goals, as follows;

I. **Sampling and Analysis Program**

Task 1 – Reservoir Sampling and Monitoring

Task 2 – Watershed Sampling and Monitoring

Task 3 – Continuous Water Quality Monitoring Upgrades and Communications for Authority Website

II. **Technical Support**

Task 4 – Annual Report and Graphical Updates

Task 5 – SAP Refinements

Task 6 - Optional Services

III. **Database Support**

Task 7 – Monthly Database Management

I. SAMPLING AND ANALYSIS PROGRAM

TASK 1. RESERVOIR SAMPLING AND MONITORING

The Cherry Creek Reservoir monitoring program contains the following major elements:

- Routine Vertical Profiling and Nutrient/Biological Sampling
- Precipitation Gage Maintenance and Sampling

The 2018 sampling frequency, based on Table 2 of the 2018 SAP, is as follows assuming a March 2018 sampling start date:

1. CCR-1, CCR-2 and CCR-3 will be profiled and sampled once per month March, April, and October, ice-conditions permitting (assumes three (3) site visits in 2018).
2. CCR-1, CCR-2 and CCR-3 will be profiled and sampled twice per month from May through September (ten visits).
3. Precipitation gage will be inspected weekly during storm sampling season and precipitation samples will be collected and analyzed following seven (7) storm events from April through October.

During the recreational boating season, Contractor will utilize a boat rented from the Cherry Creek Marina (or other suitable boat for reservoir sampling) to perform the sampling and profiling. Contractor will coordinate during the year with Colorado Parks and Wildlife (CPW) staff on buoy placement and sampling schedule. When on open water, Contractor staff will adhere to CPW's Boating Statutes and Regulations and operate under Contractor's Safe Work Practice for Working Over or Near Water (SWP 5-6). Equipment calibration will be verified and documented in the field prior to use. Contractor will utilize the Authority-owned HOBO® Water Temp Pro data loggers (and associated hardware and software) specified in the 2018 SAP and the Authority negotiated access to the State Park's buoy system for the seasonal deployment of these sensors. The number of samples that Contractor assumes will be collected during the 2018 sampling season (March 1 – December 31) for laboratory analyses per analyte is provided in Tables 1 and 2 below, and in the 2018 SAP (as reduced herein by 2 months sampling assuming a March 1 start).

In Contractor's commitment to the Authority to produce defensible data, the frequency of the field duplicate and blank sample collection is 15% per sampling event. Field QA/QC samples shall be collected at each sampling event and any issues detected through the collection of these field QA/QC samples will be isolated to the samples only collected during the associated event. Due to the manner in which the zooplankton, phytoplankton, and rain (storm) event samples are collected or analyzed, field duplicate or field blank samples will not be generated from these monitoring program aspects. As part of the QA/QC protocol, Contractor shall establish a split sample program to document and quantify potential lab variability and comparability issues. For example, in WY2016 some analytical laboratories were changed, therefore nutrient and chl-*a* samples were split between IEH Analytical and GEI Consultants to understand lab variability and data comparability.

The reservoir sampling parameters and 2018 laboratory analyses will be performed at the frequency indicated in Table 1, assuming a March 1 start date. An expedited turn-around time (4-6 weeks) will be utilized for phytoplankton and zooplankton enumeration during the crucial late spring through early fall months. Physical parameters will be collected in the field at the required frequencies in accordance with the 2018 SAP, Table 2 (i.e., temperature, conductivity, pH, dissolved oxygen, oxidation/reduction potential, Secchi disk, 1% transmittance, and continuous temperature at station CCR-2 vertical profiles). The thermistor string will be installed at CCR-2, and data uploaded monthly, May through September.

WORK PRODUCTS: *Reservoir water quality monitoring and laboratory analyses conducted March 2018 through December 2018, including routine vertical profiling and nutrient/biological sampling, and precipitation gage maintenance and sampling.*

TABLE 1. RESERVOIR SAMPLING PARAMETERS AND 2018 TOTAL LABORATORY ANALYSES (Mar-Dec)

Analyte	Monthly Nutrient-Biological Samples (Photic Zone)		Monthly Nutrient Profile (4m-7m)	Bi-monthly Sonde & Nutrient Samples (May- Sept)	Subtotal	Field QA/QC	Total Number of Samples (Mar – Dec)
	CCR-1, CCR-3	CCR-2	CCR-2	CCR-1, CCR-2, CCR-3			
Inorganics							
Total Nitrogen	20	10	40	30	100	15	**115**
Total Dissolved Nitrogen	20	10	40	30	100	15	**115**
Ammonia as N	20	10	40	30	100	15	**115**
Nitrate + Nitrite as N	20	10	40	30	100	15	**115**
Total Phosphorus	20	10	40	30	100	15	**115**
Total Dissolved Phosphorus	20	10	40	30	100	15	**115**
Orthophosphate as P	20	10	40	30	100	15	**115**
Organics							
Total Organic Carbon		10	40	30	80	12	**92**
Dissolved Organic Carbon		10	40	30	80	12	**92**
Total Volatile Suspended Solids	20	10		15	45	7	**52**
Total Suspended Solids	20	10		15	45	7	**52**
Biological							
Chlorophyll *a*	20	10		15	45	7	**52**
Phytoplankton		10		5	15	0	**15**
Zooplankton		10		5	15	0	**15**

Table 2. Annual Rain Gage Sampling Parameters

Analyte	Total Number of Samples (April thru October)
Total Nitrogen	7
Total Phosphorus	7

TASK 2. WATERSHED SAMPLING AND MONITORING

The Authority conducts a watershed-wide water quality monitoring program to evaluate the location, timing, and magnitude of nutrient load sources to the Reservoir. The surface water and groundwater monitoring program contains the following elements:

- Routine Surface Water Sampling, including PRF Pollutant Reduction Effectiveness Sampling
- Storm Event Sampling
- Groundwater Sampling

A major objective of the monitoring program is to collect nutrient and TSS data to monitor the effectiveness of the existing PRFs in reducing nutrient loading to the Reservoir. Additionally, the storm event and routine surface water data assists the TAC in targeting remaining non-point source nutrient loading areas for mitigation, not to mention, watershed modeling. The sampling frequency and analytes are summarized in Table 3 and based on the 2018 SAP (as reduced herein by 2 months sampling assuming a March 1 start).

1. Ten (10) surface water sampling stations throughout the Cherry Creek Basin will be sampled on a monthly or every other month basis (10 site visits, March through December).

2. Four (4) surface water sites would be equipped with automatic (ISCO) samplers and pre-programmed to collect storm water samples during up to seven (7) storm events between May and October (Four (4) visits: mobilization, demobilization and seven {7} storm events).
3. Nine (9) additional surface water sampling stations throughout the Cherry Creek Basin will be sampled twice per year (in addition to those monthly site visits at surface water stations).
4. Four (4) alluvial groundwater monitoring wells along Cherry Creek will be sampled twice per year (2 site visits).

Table 3. 2018 Stream and Groundwater Sampling Parameters & Total Laboratory Analyses (Mar-Dec)

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	Subtotal	Field Dups, Splits & Blanks	Total Number of Samples (Mar-Dec)
	5 sites CC-0, CC-7, CC-10, CT-1, CT-2	5 sites (CT-P1, CT-P2, MCM-1, MCM-2, PC-1)	4 sites (CC-10, CT-1, CT-2, CC-7	9 sites (USGS Cherry Creek near Franktown gage location, USGS Cherry Creek near Parker gage location, CC-1, CC-2, CC-4, CC-5, CC-6, CC-8, CC-9)	4 sites MW-1, MW-5, MW-9, Kennedy			
Inorganics								
Total Nitrogen	50	25	28	18	8	129	19	**148**
Ammonia as N	50	25	28	18	8	129	19	**148**
Nitrate + Nitrite as N	50	25	28	18	8	129	19	**148**
Total Phosphorus	50	25	28	18	8	129	19	**148**
Total Dissolved Phosphorus	50	25	28	18	8	129	19	**148**
Orthophosphate as P	50	25	28	18	8	129	19	**148**
Chloride					8	8	1	**9**
Sulfate					8	8	1	**9**
Organics								
Total Organic Carbon					8	8	1	**9**
Dissolved Organic Carbon					8	8	1	**9**
Total Volatile Suspended Solids	50	25	28			103	15	**118**
Total Suspended Solids	50	25	28			103	15	**118**

Contractor either owns or rents the equipment specified in the 2018 SAP to perform the watershed sampling[1]. Equipment calibration will be verified and documented in the field prior to use. The Authority owned ISCO® samplers will be deployed to perform the storm event sampling.

Contractor will collect the bi-annual Cherry Creek samples from upstream to downstream. The bi-annual events will coincide with the monthly surface water sampling events so two "snapshots" of the watershed quality are captured annually. The bi- annual groundwater sampling events would be timed to coincide with the bi-annual surface water sampling events to characterize non-point source contributions at the time of the surface water events.

For groundwater monitoring, approximately three-casing volumes will be evacuated (purged) from each well prior to the collection of groundwater samples. The purges water will be disposed of on the ground surface at a location adjacent to the well prior to sampling.

For surface water monitoring, Contractor will maintain accurate stage-discharge relationships at the ISCO equipped sites, in addition to the new Sutron Accubar Constant Flow (CF) bubbler systems installed in 2017 at CT-2 and CC-10 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 through at least part of WY2018 at CC-10 and CT-2 to ensure comparable data are generated by the CF bubbler systems, while bolstering the data record (including during storm flow conditions) and evaluate efficiencies to the monitoring program using real-time data to reduce the physical monitoring efforts at the ISCO sites. Pricing shall presume that flows will be manually gaged at the four (4) ISCO equipped sites four (4) times per year for calibration and validation purposes, with the caveat that Contractor's ability to safely enter the streams and gage flows under very high flows may be limited. However, based on prior data collection, under the majority of flow conditions, field staff are typically able to safely access the streams at the four (4) ISCO equipped sites to manually measure flows.

The number of samples that Contractor will collect during the 2018 contract period (March – December) for laboratory analysis for each analyte is provided in Table 3. Physical parameters will also be collected in the field at the required frequencies in accordance with the 2018 SAP, Table 3 (i.e., temperature, conductivity, pH, continuous water level measurements, and discharge). Similar to the 2017 program, Contractor will implement the following refinements, as identified in the 2018 SAP (Table 3) to the surface water and groundwater analytes: TN (diss) is omitted from the analytical suite for all surface water and groundwater samples based on the strong statistical relationship between total nitrogen and total dissolved nitrogen at these sites; Two groundwater sites (MW-2 and MW-7a) are omitted from the sampling based on statistical analyses of data and similar character of surface water and alluvial groundwater quality at these sites; Chloride and sulfate are omitted from the surface water program but maintained in the biannual groundwater monitoring program due to similar character of surface water and alluvial groundwater quality at these sites; Five surface water sites (CT-P1, CT-P2, MCM-1, MCM-2, and PC-1) are identified for sampling every other month; Four stormwater ISCO sites (CC-7 (Ecopark), CC-10, CT-1, and CT-2) are identified for characterizing stormwater from seven (7) rainfall events.

The frequency of the field duplicate and blank sample collection will be 15% of the samples collected. Due to the manner in which the rain (storm) event samples are collected, field duplicate or field blank samples will not be generated from the ISCO (storm event) samples.

WORK PRODUCTS: *Surface water, groundwater, stormwater, and PRF water quality monitoring and* *laboratory analyses, March 2018 through December 2018.*

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[1] Marsh-McBirney flow meter, pH, conductivity, temperature, DO meter, tape measure, coolers, calibration solutions, bailer, peristaltic pump or submersible, gloves, toolkit, bailing wire, camera.

TASK 3. CONTINUOUS WATER QUALITY MONITORING AND COMMUNICATIONS FOR AUTHORITY'S WEBSITE

Contractor will install, operate, troubleshoot, and maintain continuous water quality monitoring probes and communications hardware at stations at CC-10 (Cherry Creek upstream of Reservoir), CT-2 (Cottonwood Creek upstream of Reservoir) and PC- 1 (Piney Creek near confluence with Cherry Creek). The 15-minute data will be transmitted to Sutron's Hydromet Cloud and directed to the Authority's website for real-time graphical assessment of water quality and flow data.by all interested parties. The continuous monitoring will support assessments of the hydrological and water quality conditions of creeks in the Cherry Creek basin during time periods other than when monthly surface water sampling events occur. Interested parties will also be able to review water data via continuous monitoring stations near real-time on the Authority's website.

Continuous water quality (i.e., pH, temperature, EC, turbidity) monitoring equipment will be installed at the three monitoring stations, CT-2, CC-10, and PC-1, to compliment continuous flow data. Data measured by flow and water quality equipment will be programmed for cellular activation to the Sutron data collection platform (DCP) at 15-minute intervals. Sutron Hydromet Cloud will supportstorage of the real time data and facilitate displays of data in graphical format that can be linked to the Authority's website, providing easy access of real-time flow and water quality data to the Authority and its stakeholders. The transmission of flow and water quality data to the website supports the approach of making data readily available and accessible to all users, communicating information and promoting data transparency.

An important feature regarding continuous monitoring is utilizing the strong statistical relationships between flow and turbidity evaluated in 2017 to predict TP concentrations ($R^2 = 0.90$). The continuous monitoring will also facilitate evaluating long-term (seasonal) and short-term (storm events) flow and water quality changes in these selected creeks and pair this water quality data with continuous flow data. In the future, Contractor should anticipate the use of continuous monitoring to reduce field resources to conduct stormwater monitoring in the basin.

WORK PRODUCTS*: Installation and operation of continuous water quality monitoring hardware. Coordination with website administrator to receive transmitted data for posting on Authority's website.*

II. TECHNICAL SUPPORT

Tasks 4-6 support the technical data evaluations and reporting aspects of the 2018 water monitoring program.

TASK 4. ANNUAL MONITORING REPORT AND MONTHLY GRAPHICAL UPDATES

Contractor will develop the annual monitoring report, including executive summary, in coordination with the Authority and its consultant team to support the Regulation #72 reporting requirements. All draft and final work products will be prepared on schedule, with a December 31st delivery of the draft Monitoring Report deliverable that includes an executive summary. Contractor will coordinate with Leonard Rice Engineers (LRE) and the consultant team in addressing comments and finalizing the report for approval by the TAC and inclusion in the Annual Report to the WQCC no later than March 15th. Contractor will support development of the Annual Report documentation, including graphics useful for presentation to the WQCC and other audiences. The report will include documentation of compliance (or determination of noncompliance) with the applicable Regulation 38 water quality standards (chlorophyll *a*, dissolved oxygen, and pH), using Water Quality Control Commission and Water Quality Control Division assessment methods. This documentation is required by Regulation 72.

Contractor will develop graphical representations for Authority meetings using the on-line Database Portal, supported by other statistical software and MS-Excel analyses, as appropriate.

WORK PRODUCTS*: Draft and final “Annual Monitoring Report”, water quality standards compliance documentation, and graphical updates for Authority meetings.*

TASK 5. SAMPLING AND ANALYSIS PLAN REFINEMENTS

In coordination with consultants' and modeling team, Contractor will identify monitoring program efficiencies and needs based on watershed and reservoir modeling outputs. Contractor and the modeling and consultant team will be meeting in mid-2018 to evaluate monitoring needs as it relates to modeling outputs. Modeling outputs may suggest that monitoring can be reduced in some locations or that monitoring is needed in others. Based on these 2018 discussions, changes to the 2018 SAP may be warranted. If modifications to the SAP are prudent, Contractor will propose a streamlined review process, including proposed redline changes to the SAP based on consultant recommendations. The proposed changes will go before the TAC and Board for review and approval.

WORK PRODUCTS: *Two meetings with modeling team to understand opportunities for SAP refinements and scientific and technical basis for proposed refinements. Redline and final version of the SAP modifications.*

TASK 6. OTHER SERVICES

From time to time there may be other water quality activities, tasks, or technical support that arise that were not contemplated during the annual planning and budgeting cycle. On an as needed basis, as authorized by the Authority and its Manager, Contractor will provide optional services related to water quality in the watershed and reservoir. Contractor does not need to budget for this Task, as any other services provided will be approved through a contract change order process with rates based on the Contractors' annually authorized rate schedule.

WORK PRODUCTS: *As requested on an as-needed basis.*

III. DATABASE SUPPORT

Task 7 is specific to database management, supporting the Authority's official data record.

TASK 7. MONTHLY DATABASE MANAGEMENT

The on-line database tool developed by LRE, known as the Cherry Creek Basin Water Quality Data Portal, consolidates over 30 years of data from the reservoir and watershed, is password protected and available on the Authority's website. Data in MS Excel is uploaded into Google worksheets on to the Drupal™ website used by members of the Authority, consultants, and outside entities for data evaluation and review.

Water quality data analyzed by laboratories and checked by Contractor will be transmitted to the on-line database on a monthly basis including field and laboratory data from each month's sampling events. Contractor will conduct QC and validation on all lab data and streamflow data, utilizing very efficient programs that automate much of the QC checks to meet specific project specific QAPP objectives, coupled with physical laboratory report reviews. The QC programs including the following:

- Compare field to lab pH.
- Compare field specific conductance to lab specific conductance (and to TDS).
- Compare metal fractions to ensure dissolved < total recoverable < total (this could easily be modified to compare the sum of the various nutrient analyses to the "total" concentration).

- Compare results to regulatory limits to flag exceedances.
- Checks on holding times.
- For field duplicates, calculate RPDs or control limits for values < 5x PQL and identify anomalous values.
- Identify values > 10x values detected in blanks.

***WORK PRODUCTS**: Monthly data management, data pre-processing, validation, and reporting.*