Geotechnical
Environmental
Water Resources
Ecological

Cherry Creek Reservoir 2011 Water Year Aquatic Biological Nutrient Monitoring Study and Cottonwood Creek Pollutant Reduction Facilities Monitoring

Submitted to:
Cherry Creek Basin Water Quality Authority
R.S. Wells LLC
8390 East Crescent Parkway, Suite 500
Greenwood Village, CO 80111-2814

Submitted by:
GEI Consultants, Inc.
Ecological Division
4601 DTC Boulevard, Suite 900
Denver, CO 80237

March 2012
Project 062450

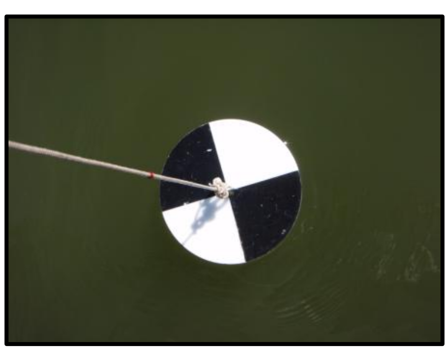


Table of Contents

List of Tables

List of Figures

List of Appendices

List of Acronyms & Abbreviations

ac-ft	acre-feet
ANOVA	analysis of variance
APHA	American Public Health Association
Authority	Cherry Creek Basin Water Quality Authority
CCBWQA	Cherry Creek Basin Water Quality Authority
CDOW	Colorado Division of Wildlife
CDPHE	Colorado Department of Public Health and Environment
CEC	Chadwick Ecological Consultants, Inc.
cfs	cubic feet per second
CPW	Colorado Parks and Wildlife
CWQCC	Colorado Water Quality Control Commission
DRCOG	Denver Regional Council of Governments
ed.(s)	editor(s)
ft	feet
GEI	GEI Consultants, Inc.
ha	hectare
JCHA	John C. Halepaska & Associates, Inc.
KAPA	Denver/Centennial Airport
km	kilometer
lb	pound
m	meter
mg	milligram
mg/L	milligrams/per liter
mL	milliliter
mo	month
mV	millivolt
ORP	oxidation reduction potential
PAR	photosynthetically active radiation
PRF	pollutant reduction facilities
Reservoir	Cherry Creek Reservoir
TDP	total dissolved phosphorus
TMAL	total maximum annual load
TMDL	total maximum daily load
TP	total phosphorus
TSS	total suspended solids
µg/L	micrograms per liter
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WY	water year
YOY	young-of-year
yr	year

Executive Summary

The purpose of this report is to present the 2011 water year (WY) data collected by GEI Consultants, Inc. (GEI), on behalf of the Cherry Creek Basin Water Quality Authority (Authority). The data were collected to evaluate Cherry Creek Reservoir (Reservoir) water quality with respect to standards and goals identified in the Cherry Creek Reservoir Control Regulation No. 72, selected water quality standards identified for the Reservoir in Regulation No. 38, and to evaluate the effectiveness of the Authority's pollutant reduction facilities (PRFs) on Cottonwood Creek. Additionally, this report provides analysis of trends observed in the long-term monitoring data collected on behalf of the Authority since 1987. The Authority with the approval of the Water Quality Control Division made the decision to switch their reporting to be consistent with a water year designation, (e.g., October to September), rather than the calendar year. Therefore, 2011 represents the first complete water year cycle with data presentations being based on the 12-month period from October 2010 to September 2011 (2011 WY). Historical data have been recalculated based on their respective water year for comparative purposes.

ES 1.1. Flow-weighted Phosphorus Concentrations and Loads

The total normalized inflow for Cherry Creek, Cottonwood Creek, and the ungaged surface water flow combined for the 2011 WY was 13,258 acre-feet per year (ac-ft/yr) and contributing a total of 8,009 pounds (lbs) of phosphorus. The combined stream flow-weighted total phosphorus concentration was 222 micrograms per liter (µg/L). The annual precipitation falling directly on the Reservoir accounted for 879 ac-ft of water and contributed 278 lbs of phosphorus, while the normalized alluvial inflow was 1,983 ac-ft/yr, and contributed 1,025 lbs of phosphorus to the Reservoir. These three primary sources of inflow—streams, precipitation, and alluvium—accounted for a total inflow of 16,120 ac-ft/yr to the Reservoir and contributing a total of 9,312 lbs of phosphorus to the Reservoir. The 2011 WY flow-weighted total phosphorus concentration for these sources of inflow was 212 µg/L which is slightly greater than the flow-weighted total phosphorus goal of 200 µg/L. The long-term (1992 to 2011) WY median flow-weighted total phosphorus concentration for the Reservoir is 205 µg/L. The total Reservoir outflow was 14,011 ac-ft/yr, exporting 4,113 lbs of phosphorus from the Reservoir with 2011 WY flow-weighted total phosphorus concentration of 108 µg/L. The long-term (1992 to 2011) WY median export flow-weighted total phosphorus concentration from the Reservoir is 99 µg/L.

ES 1.2. Total Phosphorus

Total phosphorus concentrations in the upper 3 m layer of the Reservoir ranged from 122 to 200 µg/L during the July to September sampling events, with a seasonal mean of 154 µg/L.

The long-term (1992 to 2011) seasonal median total phosphorus concentration for the Reservoir is 81 µg/L.

ES 1.3. Chlorophyll *a*

Chlorophyll *a* concentrations in the upper 3 m layer of the Reservoir ranged from 21.9 to 35.5 µg/L during the July to September sampling events, with a seasonal mean of 26.7 µg/L. The 2011 summer season represents a slight decrease in chlorophyll *a* levels observed last summer (31 µg/L), although beneficial algal productivity remains at a relatively high level, and highlights the propensity of algae to respond to optimal growing conditions. This is the second consecutive year when the seasonal mean chlorophyll *a* value has exceeded the site-specific standard of 18 µg/L. As a result, the Reservoir is not attaining the site-specific chlorophyll *a* standard.

Conditions leading up to the peak algal chlorophyll *a* level observed in late September began in mid-June when the Reservoir began showing evidence of internal phosphorus loading. During this time, chlorophyll *a* levels were approximately 15 µg/L and remained less than the site-specific standard. By late July, the internal phosphorus loading concentration peaked at 270 µg/L at the 7 m depth just above the sediment and combined with the effective mixing of the destratification system this mostly bioavailable form of phosphorus was immediately available to the phytoplankton assemblage. This condition resulted in a chlorophyll *a* level of 29.4 µg/L in early August when the phytoplankton assemblage was primarily comprised of dinoflagellates, diatoms, cyanobacteria, and green algae in terms of relative biovolume. In late August, the chlorophyll *a* concentration decreased slightly but cyanobacteria became the dominant algal type in terms of biovolume, followed by dinoflagellates, cryptomonads, and green algae.

The peak chlorophyll *a* concentration of 35.5 µg/L was observed in late September when dinoflagellates and diatoms were the dominant groups in terms of biovolume. At this time of the year there were no nuisance forms of cyanobacteria observed in the sample, yet the chlorophyll *a* concentration reached a peak in the Reservoir.

The brief period of cyanobacteria dominance during the 2011 summer is a unique condition for the Reservoir, but has been common during the past 3 years. Prior to the operation of the destratification system, cyanobacteria were often the dominant algal group throughout the late summer period often comprising between 40% and 80% of the annual algal density. However, during the past 3 years, cyanobacteria have comprised 1% (2009), 7% (2010), and 1.4% (2011) of the annual algal density. The observed shift in algal composition during the late summer season, combined with the low annual density of cyanobacteria is notable as it provides some initial results that validate the effectiveness of the destratification system at achieving one of the primary objectives—reducing suitable habitat conditions for cyanobacteria. Cyanobacteria are often associated with nuisance algal blooms, and can produce toxins that inhibit the growth of competing algae as well as inhibit grazing by zooplankton that rely on algae as a food source. In contrast, algal groups that were dominant in the Reservoir during the 2011 WY, such as the diatoms, green algae, dinoflagellates, and cryptomonads are the preferred food for zooplankton and some young-of-year (YOY) fish.

ES 1.4. Temperature and Dissolved Oxygen

The winter period for many front-range reservoirs is often a time of concern, because elevated algal growth combined with aquatic plant growth during the summer season, followed by mortality and microbial decomposition in the fall can create optimal conditions for reservoir anoxia during ice-covered periods. The flux of decaying organic matter into the bottom sediments can increase the oxygen demand during the fall and winter period. If the winter conditions are unusually cold and the lake becomes completely ice-covered for an extended period of time, the exchange of atmospheric oxygen is blocked and oxygen production via algae is diminished. These conditions combined with the continued oxygen consumption via decomposition and respiration may lead to anoxia and potentially a fish kill during the ice-covered period or even during spring turnover (aka, “winter kill”).

Dissolved oxygen profiles collected in late January, during ice-covered conditions, indicated the Reservoir was well oxygenated (~10 mg/L) and there were no indications of fish mortality during the ice-off period in mid-March. Following spring turnover and the startup of the aeration system, the Reservoir remained well mixed and oxygenated from March to early July 2011. On June 5th, the Reservoir began showing signs of brief thermal stratification lasting for approximately 6 days in early June, for 8 days in late-June, and 9 days in mid-July. The storm event on July 15th had a large effect on reservoir conditions, including dissolved oxygen conditions that were observed in data collected during the July 19th and August 2nd sampling events. During the mid-July sampling event, anoxic water conditions existed at the water/sediment interface, although the upper 3 m water layer remained well oxygenated at 7 mg/L.

During the 2011 WY a total of 68 vertical water column profiles were collected to evaluate the thermal and dissolved oxygen conditions in the Reservoir. Each profile was assessed for attainment of the Class 1 Warm Water table value standard (5 mg/L) for lakes and reservoirs that are greater than 5 m deep, and all 68 profiles showed the Reservoir was in attainment of the standard.

ES 1.5. Destratification System Effectiveness

The 2011 summer season represented the fourth full seasonal operation of the destratification system. The additional temperature monitoring continues to show that storm events greatly influence water temperatures and reservoir conditions, despite the constant mixing by the aeration system. However, based on the past 5 years of temperature monitoring data, the reservoir has shown a substantial reduction in the number of days it was thermally stratified during the summer season. Prior to the operation of the destratification system, the Reservoir was thermally stratified for approximately 60 days during the summer season, whereas during the 2011 WY, the Reservoir was thermally stratified for approximately 25 days. These results continue to support the observation that the destratification system has reduced the number of thermally stratified days by approximately 60% of pre-operating conditions.

To date, given the relative change in algal composition and the reduction in thermal stratification, the operation of the destratification system appears to be effective in attaining two of the key objectives that the system was designed to achieve—reduction of cyanobacteria habitat as well as thermal stratification. Low dissolved oxygen conditions still persist in the bottom waters at the sediment interface, which continues to facilitate internal nutrient loading.

ES 1.6. Pollutant Reduction Facility Effectiveness

The Cottonwood Creek Peoria Wetland PRF was effective in reducing the flow-weighted phosphorus concentration from 153 µg/L upstream to 131 µg/L downstream of the wetland system for a removal efficiency of approximately 14%. Further downstream, the Cottonwood Creek Perimeter Wetland PRF showed a slightly better efficiency (20%) as the flow-weighted phosphorus concentration decreased from 101 µg/L to 81 µg/L as flows passed through this PRF and into the Reservoir. Over the past few years the Cottonwood Creek Perimeter Wetland PRF has shown variable removal efficiencies, largely due to the accumulation of sediment and the variable flow conditions for each year. The current maintenance will remove the 15 years of accumulated sediment and ideally increase the phosphorus removal efficiencies. The Cottonwood Creek Stream Reclamation project has shown to be very effective in reducing the amount of suspended solids in the downstream reach, as well as being very effective in reducing the flow-weighted total phosphorus concentration. At the upstream end of the reclamation reach, the annual flow-weighted total phosphorus concentration was 131 µg/L, and at the downstream end it was 101 µg/L. Since the completion of the Cottonwood Creek Stream Reclamation, the combination of these three PRFs has effectively reduced the flow-weighted total phosphorus concentration entering the Reservoir, via Cottonwood Creek, from a pre-project WY average of 143 µg/L to a post-project WY average of approximately 75 µg/L.

1.0 Historical Perspective

An inter-governmental agreement was executed in 1985 by several local governmental entities within the Cherry Creek basin to form the Cherry Creek Basin Water Quality Authority (CCBWQA). This Authority was created for the purpose of coordinating and implementing the investigations necessary to maintain the quality of water resources of the Cherry Creek basin while allowing for further economic development. Based on a clean lakes water study (Denver Regional Council of Governments [DRCOG] 1984), the Colorado Water Quality Control Commission (CWQCC) set standards for phosphorus, and a total maximum daily load (TMDL) for phosphorus. The Reservoir was classified as Class 1 Warm Water for aquatic life, with an in-lake phosphorus standard of 35 micrograms per liter (µg/L) and seasonal mean chlorophyll *a* goal of 15 µg/L. Subsequently, a phosphorus TMDL was prepared for Cherry Creek Reservoir (Reservoir) allocating loads among point sources, background sources, and nonpoint sources within a net annual load of 14,270 pounds (lbs) total phosphorus.

The Cherry Creek Basin Master Plan (DRCOG 1985), approved by the CWQCC in 1985, was adopted in part as the "Regulations for Control of Water Quality in Cherry Creek Reservoir" (Section 4.2.0, 5C.C.R.3.8.11). An annual monitoring program (In-Situ, Inc. 1986, as amended, Advanced Sciences, Inc., 1994a and 1994b) was implemented at the end of April 1987 to assist in the assessment of several aspects of the Master Plan. These monitoring studies have included long-term monitoring of: 1) nutrient levels within the Reservoir and from tributary streams during base flows and storm flows; 2) nutrient levels in precipitation; and 3) chlorophyll *a* levels within the Reservoir.

In September 2000, following a hearing before the CWQCC, the standard for Cherry Creek Reservoir (Regulation #38) was changed to a seasonal July to September mean value of 15 µg/L of chlorophyll *a* to be met 9 out of 10 years, with an underlying total phosphorus goal of 40 µg/L, also as a July to September mean value. In addition, the limit for wastewater effluent phosphorus concentration was set at 50 µg/L, to be met as a 30-day mean value. In May 2001 at the CWQCC hearing, the Control Regulation (#72) was adopted for the Cherry Creek Reservoir, which maintained the annual allowable total phosphorus load (total maximum annual load [TMAL]) of 14,270 lbs/year as part of a phased TMDL for the Reservoir. During the March 2009 Rulemaking Hearing, Regulations 38 and 72 were again refined to reflect the most current feasibility-based chlorophyll *a* standard and flow-weighted inflow total phosphorus goal for Cherry Creek Reservoir. The current chlorophyll *a* standard is 18 µg/L with an exceedance frequency of once in 5 years. The control regulation changed from a phosphorus load-based TMAL to a flow-weighted concentration such that the annual flow-weighted total phosphorus concentration goal is 200 µg/L for all combined sources of inflow to the Reservoir.

From 1993 to 1998, Dr. John Jones of the University of Missouri contributed greatly to the Cherry Creek Reservoir annual monitoring program (Jones 1994 to 1999, 2001), and assisted with the transition of the program to Chadwick Ecological Consultants, Inc. (CEC) in 1994. Results of the aquatic biological and nutrient analyses have been summarized in annual monitoring reports (CEC 1995 to 2006). In 2006, CEC merged with GEI Consultants, Inc., and continues to perform the annual monitoring duties of Cherry Creek Reservoir (GEI 2007, GEI 2008b, GEI 2009, GEI 2010, GEI 2011). The present study was designed to continue the characterization of the relationships between nutrient loading (both in-lake and external) and Reservoir productivity. The specific objectives of this annual monitoring study include the following:

- Determine baseflow and stormflow concentrations for nitrogen and phosphorus fractions in tributary inflows, as well as concentrations in Cherry Creek Reservoir and the outflow.
- Determine the hydrological inflows and nutrient loads entering Cherry Creek Reservoir, including Reservoir exports. These data provide the necessary information to calculate flow-weighted nutrient concentrations for the Reservoir.
- Determine biological productivity in Cherry Creek Reservoir, as measured by algal biomass (chlorophyll *a* concentration) and algal densities. In addition, determine species composition of the algal and zooplankton assemblages.
- Evaluate relationships between the biological productivity and nutrient concentrations within Cherry Creek Reservoir and total inflows.
- Assess the effectiveness of pollutant reduction facilities (PRFs) on Cottonwood Creek to reduce phosphorus loads into the Reservoir.
- Assess the effectiveness of the destratification system in controlling nuisance algae and minimizing the potential for internal loading of phosphorus.

In 2010, the Authority changed the reporting year to be representative of the water year (WY, October to September) rather than the normal calendar year, thus the 2011 WY represents the first full year where annual comparisons have been completely switched to be representative of the water year. Tables and figures presenting historical data have been recalculated to appropriately reflect the water year summary values, although the 1992 WY only contains data from January 1992 to September 1992 due to the change in annual calculations. This 2011 WY report presents the water quality data collected from Cherry Creek Reservoir and its three primary tributaries, Cherry Creek, Shop Creek, and Cottonwood Creek, and provides comparisons for many parameters to the long-term monitoring data collected since 1987. The report also examines the nutrient removal efficiency of the CCBWQA PRFs as well as the Stream Reclamation Project located on Cottonwood Creek, and evaluates their effectiveness in reducing phosphorus loads to the Reservoir, and provides comparisons to historical data.

2.0 Study Area

Cherry Creek was impounded in 1950 by the U.S. Army Corps of Engineers (USACE) to protect the City of Denver from flash floods that may originate in the 995 square kilometers (385 square miles) drainage basin. The Reservoir has maintained a surface area of approximately 350 hectares (ha) (approximately 852 acres) since 1959. The Reservoir and surrounding state park has also become an important recreational site, providing activities that include fishing, boating, swimming, bicycling, bird watching, and hiking.

2.1 Sampling Sites

Sampling during the 2011 WY was routinely conducted at 10 sites, including three sites in Cherry Creek Reservoir, six sites on tributary streams, and one site on Cherry Creek downstream of the Reservoir (Figure 1). In addition to these routine monitoring sites, 10 transect sites (D1 to D10) were established from the approximate mid-point of the dam face extending perpendicular across the destratification zone in the Reservoir, as well as three continuous temperature logging sites near routine reservoir monitoring sites. The routine sampling sites are summarized below.

2.1.1 Cherry Creek Reservoir

CCR-1 This site is also called the Dam site, and was established in 1987. CCR-1 corresponds to the northwest area within the lake (Knowlton and Jones 1993). Sampling was discontinued at this site in 1996 following determination that this site exhibited similar characteristics to the other two sites in this polymictic Reservoir. 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 lake (Knowlton and Jones 1993).

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

2.1.2 Shop Creek

SC-3 This site was established on Shop Creek in 1990 upstream of the Perimeter Road and downstream of the Shop Creek detention pond and wetland system. In 1994, this site was moved just downstream of the Perimeter Road and again moved farther downstream to a location just upstream of its confluence with Cherry Creek in 1997. This site serves to monitor the water quality of Shop Creek as it joins Cherry Creek.

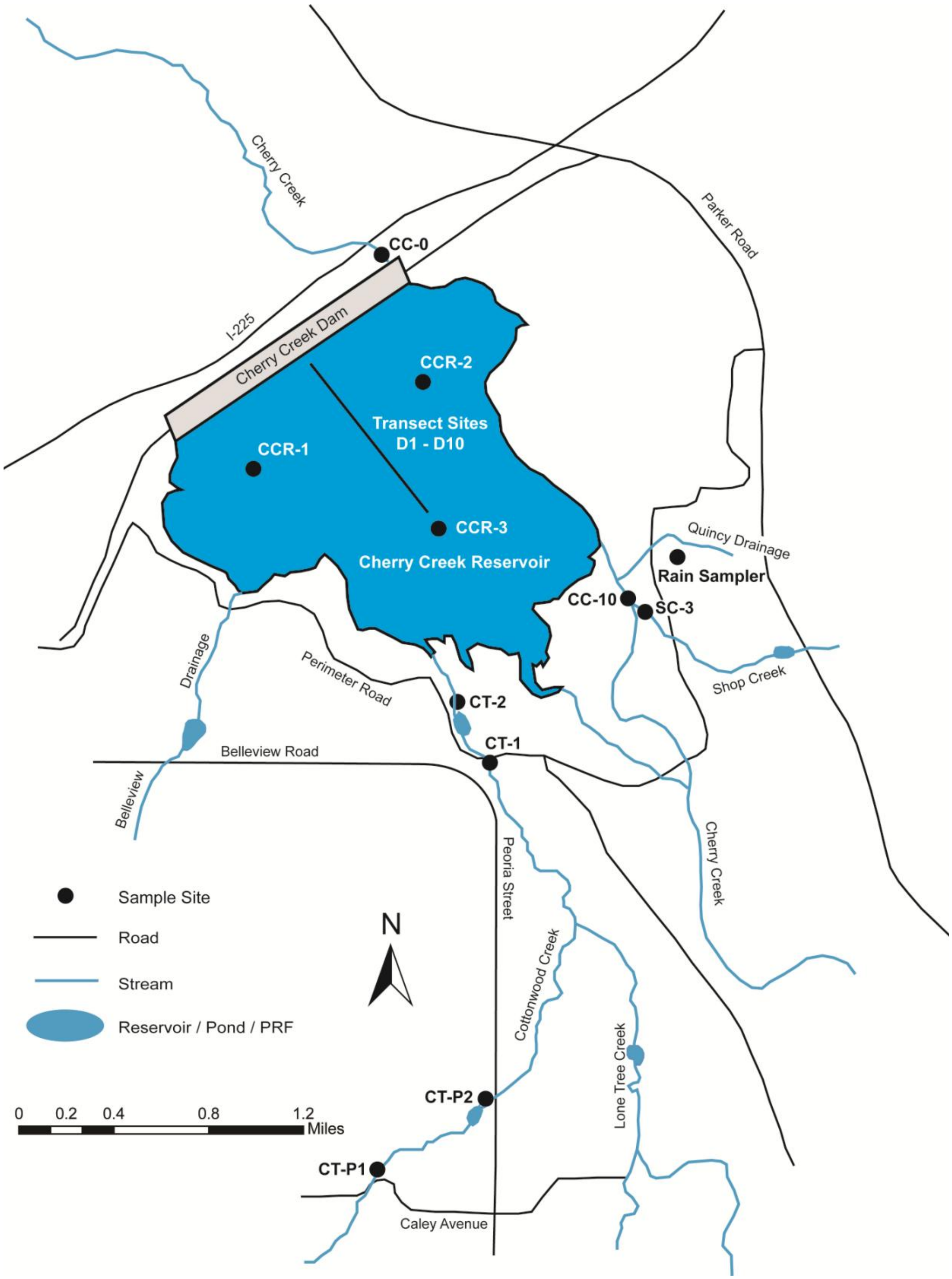


Figure 1: Sampling sites on Cherry Creek Reservoir and selected streams, 2011.

2.1.3 Cherry Creek

CC-10 This site was originally established in 1987 on Cherry Creek near the historic U.S. Geological Survey (USGS) Melvin gage, approximately 3.5 kilometers (km) upstream of the Reservoir (roughly due west of the intersection of Parker Road and Orchard Road). This location is in an area of Cherry Creek that frequently becomes dry during summer months as a result of the natural geomorphology and alluvial pumping for domestic water supply (John C. Halepaska & Associates, Inc. [JCHA] 1999 and 2000).

In 1995, this site was relocated farther downstream between the Perimeter Road and the Reservoir, approximately 800 meters (m) upstream of the Reservoir. This site was moved still farther downstream in 1996, just upstream of the confluence with Shop Creek and closer to the Reservoir. In 1999, it was moved below the confluence with Shop Creek to eliminate the effect of a stream crossing on the CC-10 hydrograph. Since 1995, Cherry Creek has been monitored in a reach with perennial flow, allowing for more accurate monitoring of water quality and surface flow in Cherry Creek before entering the Reservoir. Historically, this site has been referred to as CC or CC-I (i.e., CC-Inflow), but was renamed CC-10 in 1997 to place it in context with concurrent monitoring in Cherry Creek mainstem upstream of the Reservoir (JCHA 1999 to 2007).

CC-O This site was established in 1987 on Cherry Creek downstream of Cherry Creek Reservoir and upstream of the Hampden Avenue-Havana Street junction in the Kennedy Golf Course near the USGS gage. In 2007, Site CC-O (also identified as CC-Out @ I225) was relocated immediately downstream of the dam outlet structure and serves to monitor the water quality of the Reservoir outflow.

2.1.4 Cottonwood Creek

CT-P1 This site was established in 2002 and is located 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 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 stream reclamation project. This site is now approximately 200 m upstream of 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. Water quality samples are collected from the outlet structure as well. This site monitors the effectiveness of the PRF on Cottonwood Creek water quality and provides information on the stream before it enters the Reservoir.

3.0 Methods

3.1 Sampling Methodologies

Field sampling protocols and analytical methods used for monitoring the Reservoir and stream sites as outlined in the Cherry Creek Reservoir Sampling and Analysis Plan (GEI 2008a, Appendix A).

3.1.1 Reservoir Sampling

The general sampling schedule included regular sampling trips to the Reservoir at varying frequencies over the annual sampling period, as outlined below, with increased sampling frequency during the summer growing season (Table 1). A total of 15 reservoir sampling events were conducted during the 2011 WY. The December 2010 and February 2011 sampling events were not performed due to unsafe ice conditions. During each sampling event on the Reservoir, three main tasks were conducted, including: 1) determining water clarity, 2) collecting physicochemical depth profiles, and 3) collecting water samples for chemical and biological analyses.

Table 1: Sampling trips per sampling period.

Sampling Period	Frequency	Planned Trips/Period	Actual Trips/Period
Oct -- Apr	Monthly	7	5
May -- Sept	Bi-Monthly	10	10
	Total	**17**	**17**

3.1.1.1 Water Clarity

Transparency was determined using a Secchi disk and LI-COR quantum sensors (ambient and underwater). Detailed methods of both instruments can be found in the Sampling and Analysis Plan (Appendix A).

3.1.1.2 Profile Measurements

A Hydrolab MS5 Surveyor and Sonde was used for the collection of dissolved oxygen, temperature, conductivity, pH, and oxidation reduction potential (ORP) profile measurements from the surface to the bottom of the Reservoir.

3.1.1.3 Water Sampling

Water samples for nutrient, phytoplankton, zooplankton, chlorophyll *a*, and suspended solids analyses were collected at the three Reservoir sites. Data collected from each site during a single sampling event (i.e., three replicate samples), are averaged to provide a whole-reservoir mean estimate for each parameter. Sample event means are then used to calculate annual or seasonal mean values for key parameters such as chlorophyll *a* and total phosphorus and to facilitate comparison with regulatory standards and goals that apply to the Reservoir. Depending upon the distributional characteristics of each parameter, annual values may be compared to either the long-term mean or median value. Secchi depth and chlorophyll *a* are two parameters that reveal normal distributions, thus it is more appropriate to compare annual values with the long-term mean. Conversely, the total phosphorus data exhibit a log normal distribution; therefore it is more appropriate to compare annual values to the long-term median value. The Sampling and Analysis Plan (Appendix A) outlines the detailed methods used to collect lake water samples, as well as the laboratory methods in sample handling and preparation.

3.1.1.4 Fish Population Data

Historically, this monitoring study has also reviewed fish stocking and population data collected by the Colorado Parks and Wildlife (CPW). As part of their sampling schedule to reduce mortality to a walleye brood-stock population in Cherry Creek Reservoir, CDOW has sampled fish populations every 2 to 3 years in the past. The most recent fish population survey was conducted in 2011 by the CPW (personal communication with Harry Vermillion, CPW). Therefore, both the 2011 fish stocking and fish population sampling data are presented herein.

3.1.2 Stream Sampling

3.1.2.1 Base Flow Sampling

Base flow stream sampling was conducted on a monthly basis (12 events) in conjunction with the routine reservoir sampling trips to Cherry Creek Reservoir. This sampling was performed to characterize base flow conditions, which corresponds to the low-flow ambient samples collected in past studies. Monthly samples are assumed to be representative of non-storm, base flow periods.

3.1.2.2 Storm Sampling

Storm events sampled at the inflow sites on Cherry Creek, Cottonwood Creek, and Shop Creek characterize non-base flow conditions during the sampling season (Table 2). A detailed outline of storm sampling protocols can be found in the Sampling and Analysis Plan (Appendix A).

Table 2: Number of storm samples collected from tributary streams to Cherry Creek Reservoir, 2011 WY. See Appendix C for sample dates.

	Sites					
	CC-10	**SC-3**	**CT-P1**	**CT-P2**	**CT-1**	**CT-2**
Number of Storm Samples	6	5	6	6	6	6

3.1.3 Surface Hydrology

Pressure transducers attached to ISCO Series 6700 or 6712 flowmeters measured and recorded water levels (stage) at six sites on the three tributaries to Cherry Creek Reservoir (Figure 1). These flow meters are programmed to record water level data on 15-minute intervals year round. Streamflow (discharge) was estimated at sites CC-10, SC-3, CT-1, CT-P1 using stage-discharge relationships developed for each stream site. For sites CT-2 and CT-P2, where the flow meters are located inside the concrete outlet structure, multi-level orifice and weir equations were used to estimate discharge. Periodic stream discharge measurements were collected during a range of flow conditions using a Marsh McBirney Model 2000 flowmeter. For a complete description of streamflow determination, see Appendix D.

3.2 Laboratory Procedures

3.2.1 Nutrient Laboratory Analysis

Physicochemical and biological analyses from the Reservoir and stream water quality samples were performed by the GEI analytical laboratory (Table 3). Quality Assurance/ Quality Control protocols for the low level nutrient analyses were performed by the GEI Laboratory, with all results being reported in Appendix B.

3.2.2 Biological Laboratory Analysis

Biological analyses of the Reservoir phytoplankton samples were conducted by the Aquatic Analysts, Friday Harbor, Washington. Aquatic Analysts performed phytoplankton identification and enumeration and provided cell counts per unit volume (cells/mL) and taxa richness, while GEI performed the chlorophyll *a* concentrations (µg/L). Zooplankton samples were analyzed by Water's Edge Scientific LLC, Baraboo, Wisconsin. The methods for these analyses, with appropriate QA/QC procedures, are available from GEI.

Table 3: Parameter list, method number, and detection limits for chemical and biological analyses of water collected from Cherry Creek Reservoir and tributaries.

Parameter	Method	Detection Limit
Total Phosphorus	QC 10-115-01-4-U	2 µg/L
Total Dissolved Phosphorus	QC 10-115-01-4-U	2 µg/L
Soluble Reactive Phosphorus	QC 10-115-01-1-T	2 µg/L
Total Nitrogen	APHA 4500-N B (modified)	2 µg/L
Total Dissolved Nitrogen	APHA 4500-N B (modified)	2 µg/L
Ammonia	QC 10-107-06-3-D	3 µg/L
Nitrate and Nitrite	QC 10-107-04-1-B	2 µg/L
TSS	APHA 2540D	4 mg/L
TVSS	APHA 2540E	4 mg/L
Chlorophyll *a*	APHA 10200 H (modified)	0.1 µg/L

APHA = American Public Health Association, 1998.

3.3 Evaluation of Long-Term Trends in Cherry Creek Reservoir

Long-term seasonal trends were evaluated for Secchi depth, chlorophyll *a*, and total phosphorus using whole-lake mean values from 1987 to 2011 and linear regression analysis (described below). Additionally, 95% confidence intervals provided information on data dispersal around the mean annual values. These analyses were used to determine whether there was significant increasing or decreasing trends in Secchi depth, total phosphorus, and chlorophyll *a* levels over time.

Comparisons of biological and physical parameters for each site were conducted using SPSS 2006 or NCSS 2000 statistical software (Hintze 2001). Basic descriptive statistics were used to evaluate the distributional characteristics of the data, and to determine whether a variable required transformation to meet the basic assumptions of normality. Logarithmic transformations were used to increase the symmetry of the data about the mean, approximating a normal distribution. If the transformation did not improve normality, the untransformed data were used in subsequent analyses.

The least-squares linear regression was used to estimate slope, with analysis of variance (ANOVA) being used to determine if the slope was significantly different than zero. A probability of < 0.05 was used to indicate statistical significance. In the cases of the linear regressions, the R^2 value provided a measure of how well the variance is explained by the regression equation. R^2 values measure the proportion of total variation that is explained or accounted for by the fitted regression line; i.e., it is a measure of the strength of the relationship with the observed data.

4.0 Results and Discussion

4.1 Reservoir Water Quality

4.1.1 2011 WY Transparency

The whole-reservoir mean Secchi depth varied from 0.51 m in mid-October to 1.28 m in mid-May (Figure 2). The seasonal (July to September) whole-reservoir mean Secchi depth was 0.77 m (Figure 3). The depth at which 1% of photosynthetically active radiation (PAR) penetrated the water column (i.e., photic zone depth) ranged from 1.66 m in mid-April to a maximum depth 3.17 m in late May (Figure 2). The greatest level of chlorophyll *a* of 48.6 µg/L was observed in mid-October which is more representative of conditions during the 2010 summer growing season and also coincided with the poorest water clarity values.

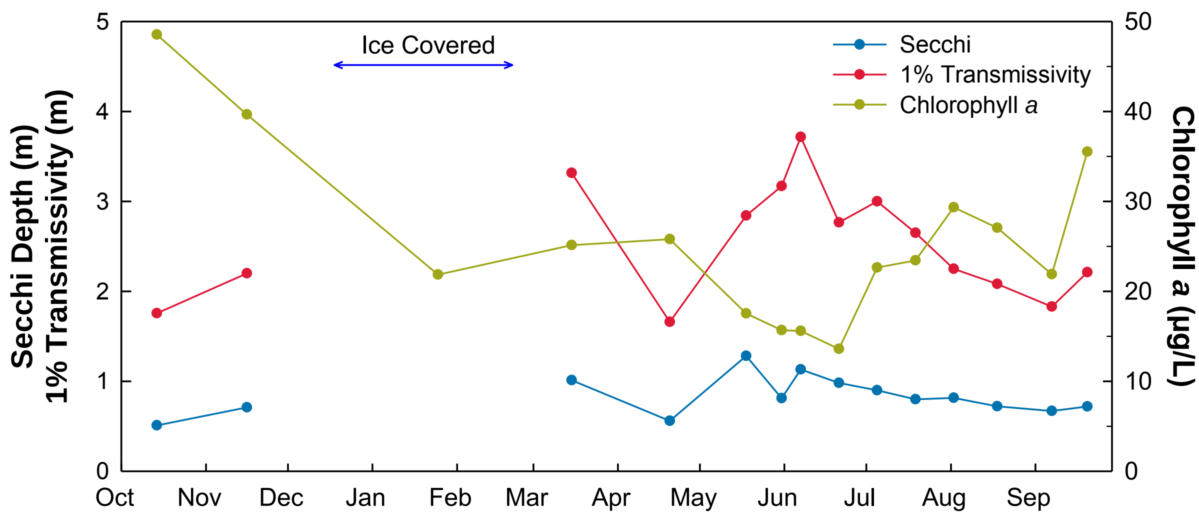


Figure 2: Patterns for mean whole-lake Secchi depth, 1% transmissivity, and chlorophyll *a* in Cherry Creek Reservoir, 2011 WY.

4.1.2 Long-Term Secchi Transparency Trends in Cherry Creek Reservoir

In general, seasonal mean (July to September) Secchi depths increased from 1987 to 1996, then decreased in 1997 at which time they have been relatively stable (Figure 3). The 2011 seasonal whole-reservoir mean Secchi depth, 0.77 m, which is less than the present long-term (1987-present) mean value of 0.97 m.

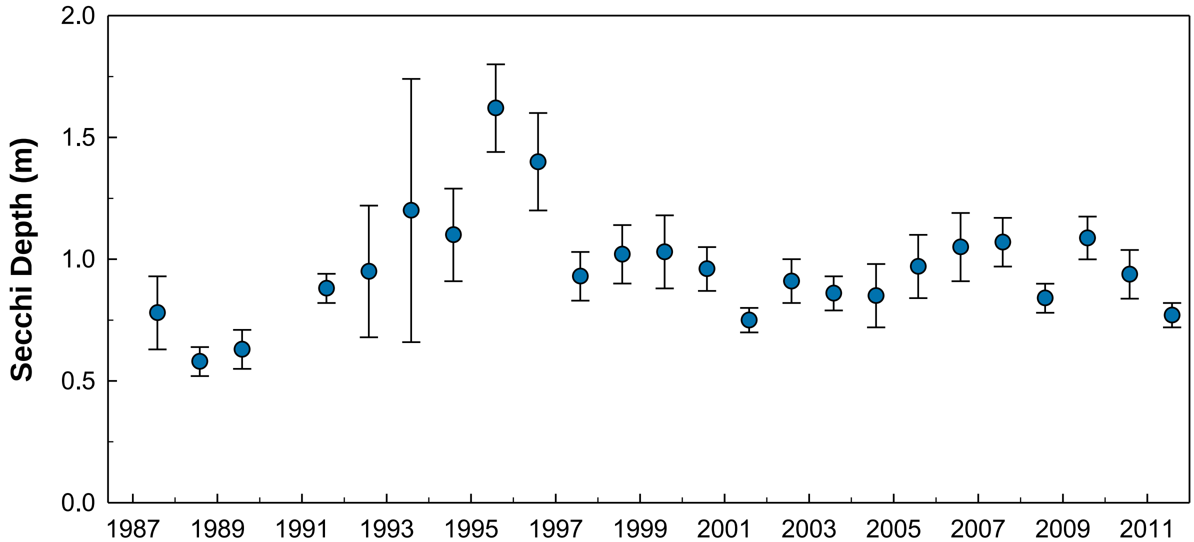


Figure 3: Whole-lake seasonal mean (July to September) Secchi depth (m) measured in Cherry Creek Reservoir. Error bars represent a 95% confidence interval for each mean.

4.1.3 2011 WY Temperature and Dissolved Oxygen

Analysis of past Cherry Creek Reservoir temperature profiles indicates that stratification typically occurs when there is greater than 2°C difference between the surface and bottom water temperatures (Jones 1998). Differences of less than 1°C between the surface and bottom waters indicate mixing (Jones 1998). This criterion is generally supported by the classical definition of a thermocline, as being the layer with the greatest rate of change in temperature or *d*t/*d*z greater than 1°C/m. However, given the relatively shallow nature of the Reservoir and the temperature-density relationships, the Reservoir can become stratified even though the greatest rate of change may be less than 1°C. Dissolved oxygen profiles are also used to evaluate periods of stratification when temperature differences are less than 1°C.

Under the current reservoir management regime, the physical location of the aeration heads in relation to the water column and bottom sediments (~ 0.75 m off of the bottom) has changed the location of the typical temperature-density boundary in the Reservoir and made the water temperatures more consistent. This boundary, as well as the oxygen boundary, typically align with the bubble plume rising upward from the aerators, thus density gradients can be established at this water level throughout the year. Using the above criteria, the multiple profiles and transect data for Cherry Creek Reservoir were evaluated for periods of potential stratification and low dissolved oxygen levels.

Water temperatures during routine profile measurements in Cherry Creek Reservoir ranged from 1.63°C at the surface in late January to 26.5°C at the surface in mid-July (Figure 4, Figure 6, and Figure 8). Temperature loggers were installed in late April and showed a well mixed Reservoir until early June. By the beginning of June, the Reservoir began showing signs of thermal stratification. During this time, the large pulses of inflow from the May storm events had subsided decreasing the inflow volume to the Reservoir. These lower inflow conditions created more hydrologically stable conditions in the Reservoir. During June, the dissolved oxygen concentrations generally remained greater than 5 milligrams per liter (mg/L) throughout the water column, except for the deeper 7 m layer and water/sediment interface where dissolved oxygen concentrations averaged 4 mg/L.

By the first sampling event in July, dissolved oxygen concentrations began decreasing at depths greater than 5 m with values less than the upper threshold (2 mg/L) conducive for internal loading at the 7 m layer. These conditions in the deep layers of the Reservoir may pose relatively little harm to the warm water biological community, because the mixed layer remained well oxygenated. However, deep water anoxia (< 2 mg/L) created favorable conditions for internal nutrient loading for several weeks during the summer period. In July, the deep layer anoxic conditions were affected by the periodic storm events culminating with the substantial inflow event on July 15th. These conditions were also likely exacerbated due to the periodic shut-down of the destratification system resulting from overheating during warm ambient conditions between July 4th and 23rd. On July 19th, low dissolved oxygen conditions (~2 mg/L) were observed at the 5 m layer. This decrease in dissolved oxygen in the deeper water layers resulted from the combination of cooler oxygen demanding storm water flowing into the Reservoir during peak sediment oxygen demand conditions as well as the lack of continuous mixing of the water column by the destratification system. The cooler water allowed the Reservoir to become thermally stratified as well as increased the oxygen demand in the bottom layers and thereby decreasing the dissolved oxygen concentrations in the Reservoir.

On August 2nd, dissolved oxygen profiles indicated that the water column had become completely mixed which had reduced the dissolved oxygen content in the upper photic zone too (Figure 5, Figure 7, and Figure 9) and made the water column more uniform with respect to dissolved oxygen content.

Reservoir profiles were also evaluated to determine the attainment of the dissolved oxygen standard. Over the course of the monitoring year, 68 vertical water column profiles were collected in the Reservoir. For each profile, the 1 m and 2 m dissolved oxygen values were averaged and evaluated for attainment of the Class 1 Warm Water table value standard (5 mg/L) for lakes and reservoirs that are greater than 5 m deep (CDPHE 2011). The Reservoir was in attainment of the dissolved oxygen standard for all 68 profiles; although the minimum average dissolved oxygen value was 5.5 mg/L which occurred at Site CCR-1 on August 2, 2011. During the July to September growing season, the average dissolved oxygen concentration of the upper layer was 7.2 mg/L for all vertical profiles.

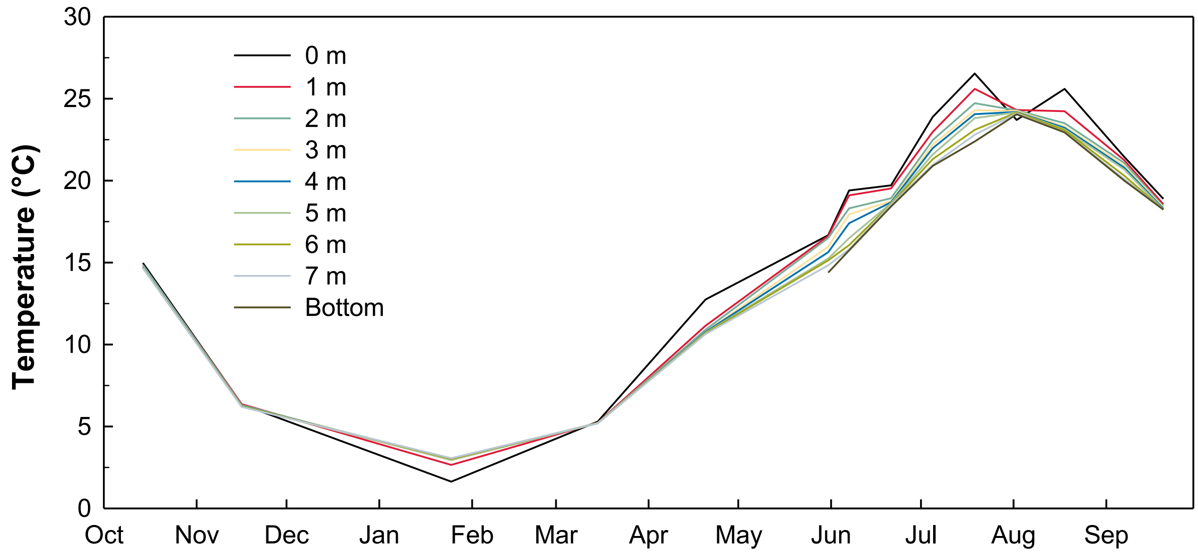


Figure 4: Temperature (°C) recorded at depth during routine monitoring at Site CCR-1 during the 2011 WY.

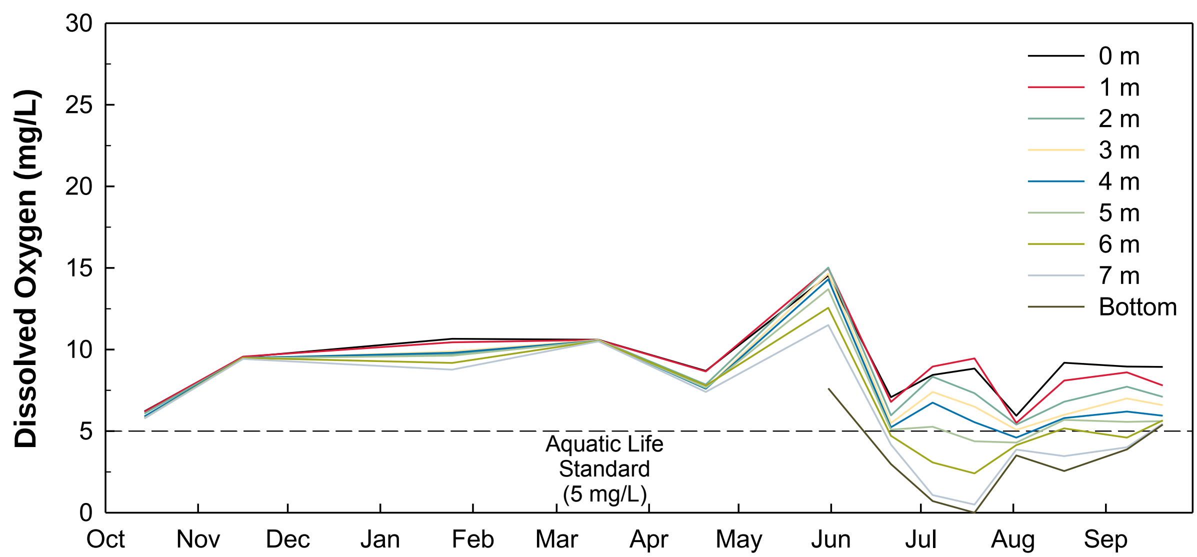


Figure 5: Dissolved oxygen (mg/L) recorded at depth during routine monitoring at Site CCR-1 during the 2011 WY. The dissolved oxygen basic standards table value for Class 1 warm water lakes and reservoirs is provided for comparison (5 mg/L).

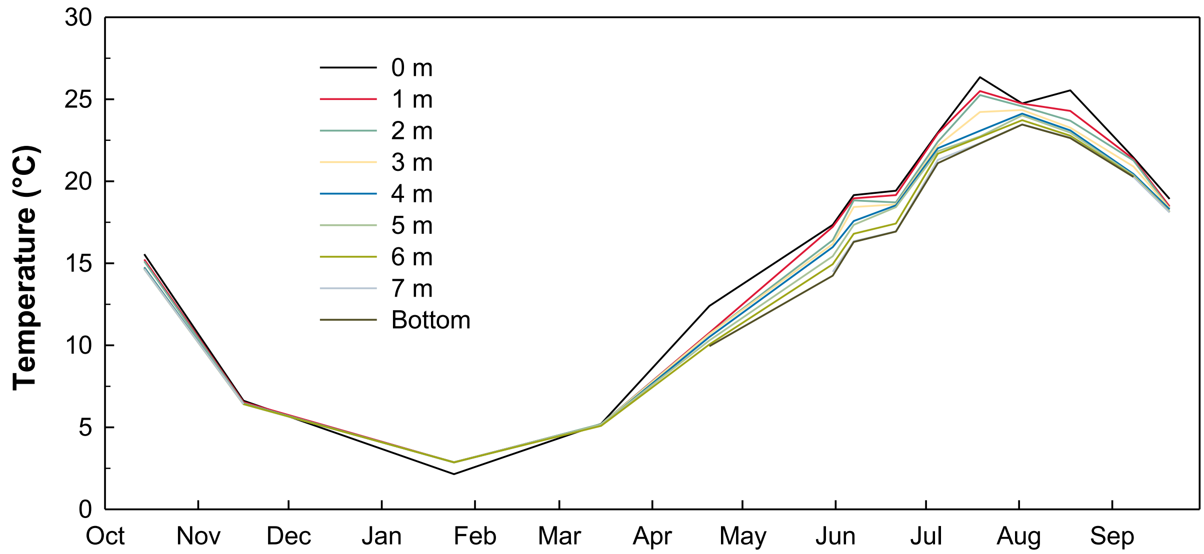


Figure 6: Temperature (°C) recorded at depth during routine monitoring at Site CCR-2 during the 2011 WY.

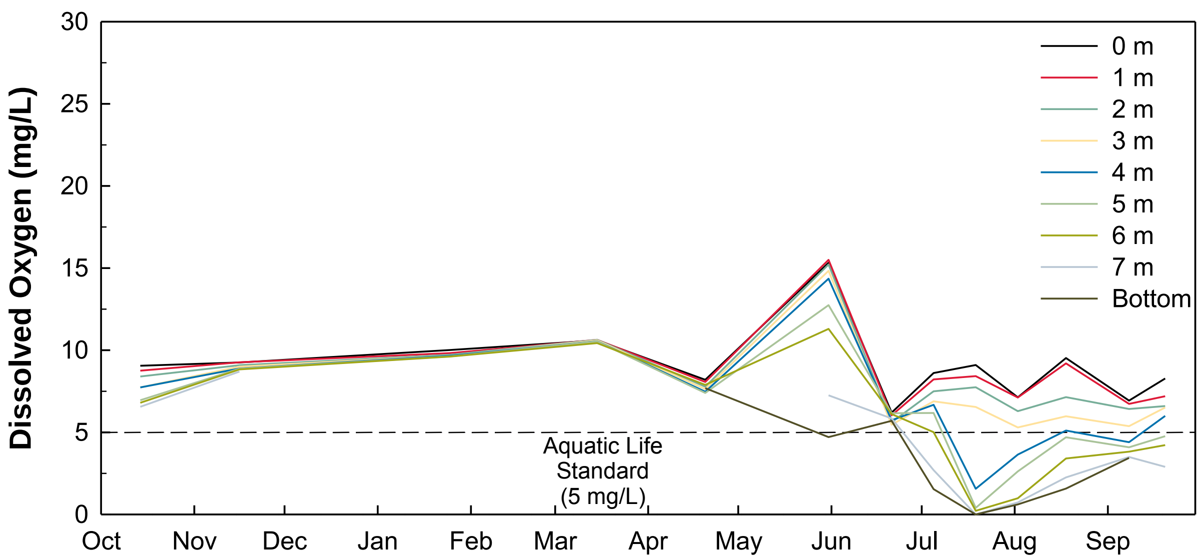


Figure 7: Dissolved oxygen (mg/L) recorded at depth during routine monitoring at Site CCR-2 during the 2011 WY. The dissolved oxygen basic standards table value for Class 1 warm water lakes and reservoirs is provided for comparison (5 mg/L).

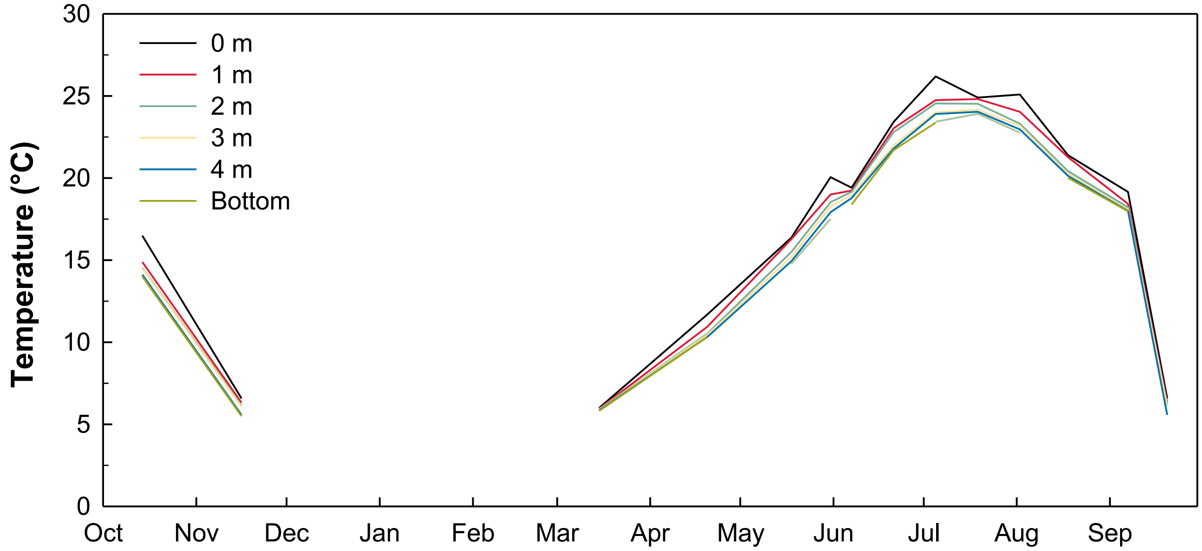


Figure 8: Temperature (°C) recorded at depth during routine monitoring at Site CCR-3 during the 2011 WY.

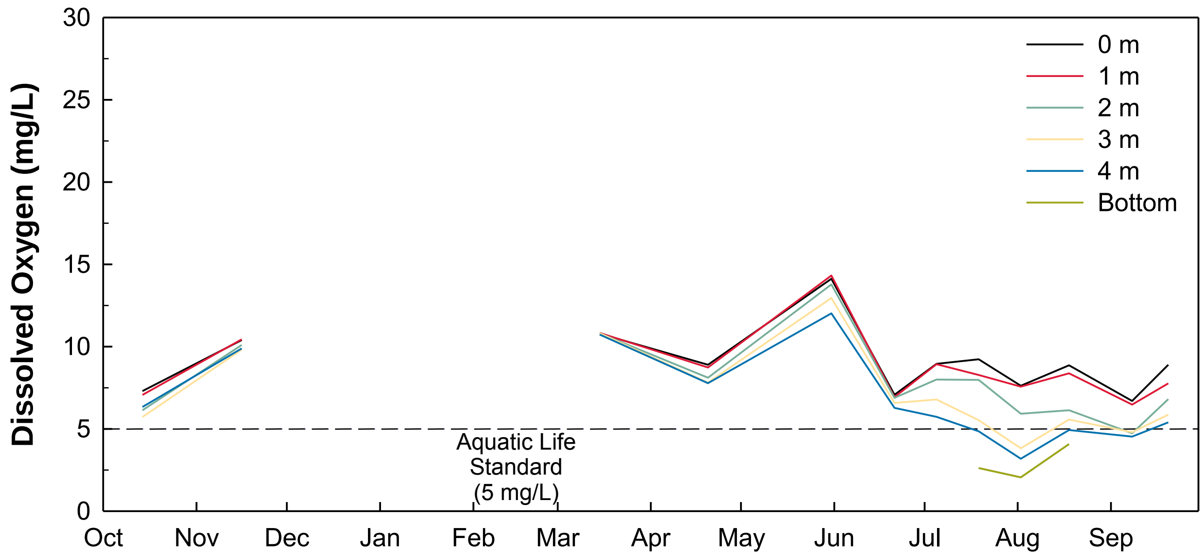


Figure 9: Dissolved oxygen (mg/L) recorded at depth during routine monitoring at Site CCR-3 during the 2011 WY. The dissolved oxygen basic standards table value for Class 1 warm water lakes and reservoirs is provided for comparison (5 mg/L).

4.1.3.1 Continuous Temperature Monitoring

In April 2011, temperature loggers were deployed for monitoring the efficiency of the destratification system at mixing the water column. From April through the beginning of June the temperature loggers revealed a very uniform water column temperature and it was not until early June before the Reservoir started showing signs of variation in water temperature (Figure 10, Figure 11, and Figure 12). Using the > 2°C difference criteria from the surface to the bottom, Cherry Creek Reservoir was evaluated for periods of stratification using the continuous temperature record at depths for all three Reservoir sites from April 21st to November 15th (Figure 10, Figure 11, and Figure 12). By July 25th the continuous temperature profiles indicated the Reservoir was more thermally consistent with little temperature variation from the surface to the bottom.

On June 5th, the Reservoir began showing signs of brief thermal stratification lasting for approximately 5 days in early June, for 3 days in mid-June, 8 days in late June, and 9 days in mid-July. Between these periods, storm events destratified the reservoir for a short periods. During these brief stratification periods, the deeper water layers of the Reservoir revealed low dissolved oxygen concentrations resulting from the higher sediment oxygen demand during the warmer summer conditions. These low dissolved oxygen levels persisted in the deeper waters throughout much of the summer period, despite the effectiveness of the destratification system at minimizing thermal stratification throughout the remainder of the summer. Within the Reservoir, thermally stratified conditions appear to be more closely linked to ambient weather conditions that either facilitate the onset of stratification or result in complete water column mixing, despite the evidence of the destratification system's effectiveness at circulating the upper water layers (0 to 6 m).

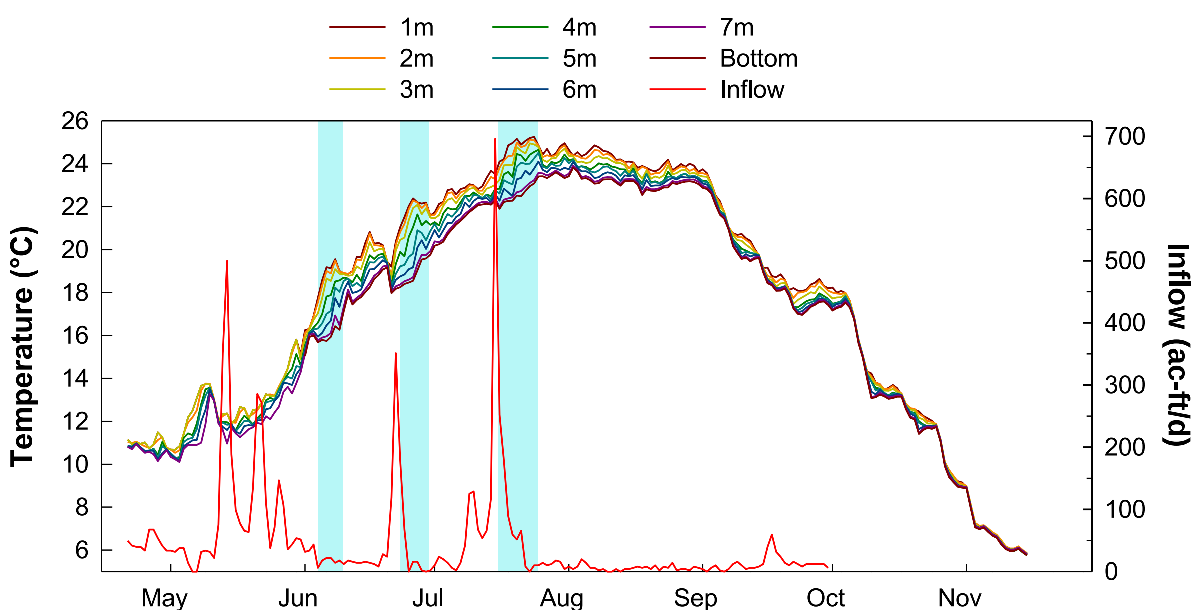


Figure 10: Daily mean temperature recorded at depth for Site CCR-1 based on 15-minute interval data collected by temperature loggers, with USACE inflow. Shaded areas denote periods of thermal stratification.

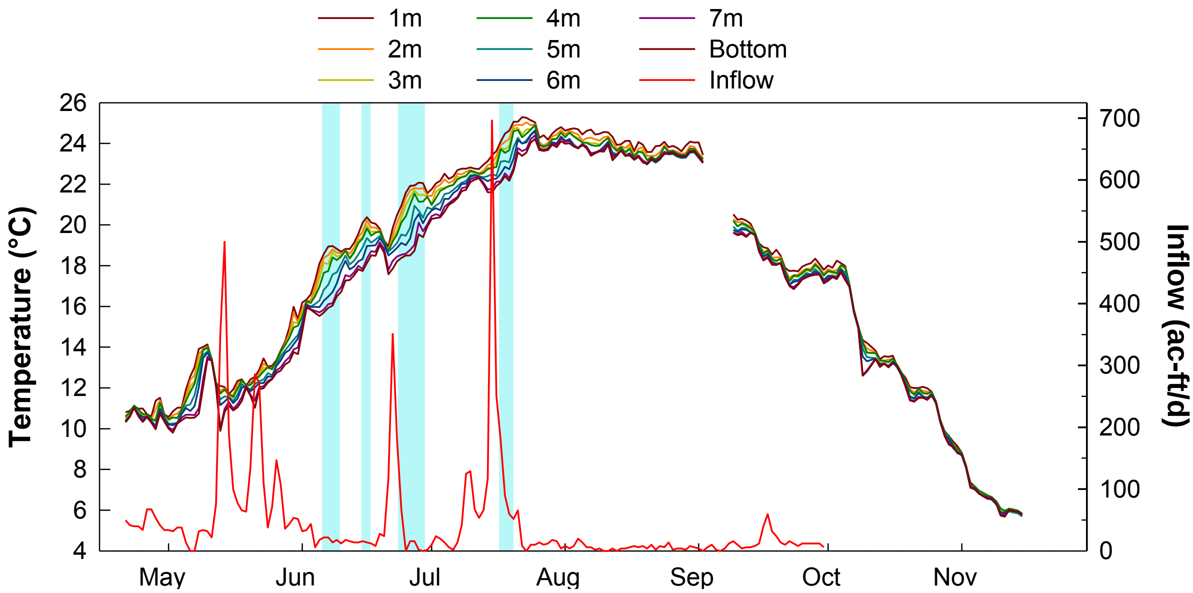


Figure 11: Daily mean temperature recorded at depth for Site CCR-2 based on 15-minute interval data collected by temperature loggers, with USACE inflow. Shaded areas denote periods of thermal stratification. Data gap resulted from retrieval and redeployment of array.

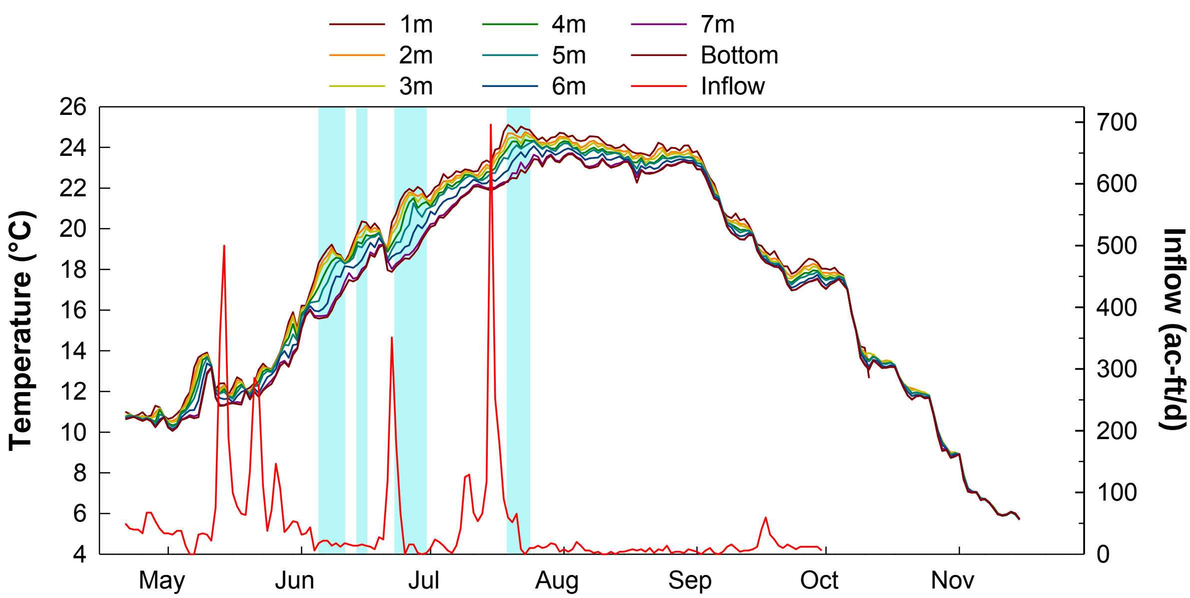


Figure 12: Daily mean temperature recorded at depth for Site CCR-3 based on 15-minute interval data collected by temperature loggers, with USACE inflow and KAPA precipitation. Shaded areas denote periods of thermal stratification.

4.1.3.2 Dissolved Oxygen and Oxidation-Reduction Potential Transect

The water quality transect was established in the Reservoir originating from approximately the mid-point of the dam and extending southward across the Reservoir, towards the inlet region (see Figure 1). As part of the destratification monitoring program, water column dissolved oxygen and oxidation reduction potential profiles were collected at ten locations along the transect and the nearby Site CCR-3 location, on three sample dates (Figure 13).

Oxidation reduction potential (ORP) measurements are used to quantify the exchange of electrons that occur during oxidation-reduction reactions (redox reactions), with electrical activity being reported in millivolts (mV), very similar to a pH probe. At the water-sediment boundary layer, microbial organisms facilitate the chemical reactions but do not actually oxidize or reduce the compounds. The redox reactions provide energy for microbial cells to carry out their metabolic processes (Wetzel 2001). The combination of microbial organisms and redox reactions are responsible for the breakdown of organic matter and development of anoxic conditions near the sediment boundary in lakes during the summer, and as a result soluble nutrients (nitrogen and phosphorus) are released as well as other forms of iron, manganese and sulfur.

In Cherry Creek Reservoir, the water column ORP measurements will often range between 100 to 300 mV depending upon the seasonal conditions. On any given date, the water column ORP conditions, from the surface waters down to approximately the 6 m layer, will be fairly uniform because there is sufficient dissolved oxygen in the water column to maintain compounds in their most oxidized state. However, when anoxic conditions exist at depths greater than 6 m or at the water-sediment interface, the redox potential will greatly decrease, often ranging from -200 to 0 mV, indicating conditions are favorable for internal phosphorus loading as well as other elemental releases. When reviewing ORP profile measurements (Figure 14), the occurrence of a sharp inflection point (i.e., low or negative values) in the profile indicates where conditions are favorable for redox reactions to occur.

During the first sample date on June 21st, the Reservoir was well oxygenated (5-7 mg/L DO) from the surface down to a depth of approximately 5 m. This pattern was consistent from Site D1 near the dam to Site D10, at which point the maximum Reservoir depth became shallower (4 to 5 m). The average dissolved oxygen concentration for the 1 m and 2 m depths along the transect was 6.4 mg/L indicating the Reservoir was in attainment of the dissolved oxygen standard. At the water-sediment interface the mean dissolved oxygen concentration was 3.7 mg/L (Figure 13 and Appendix B).

The July 19th transect profiles documented the extent of the anoxic zone as discussed above (Figure 13). The average dissolved oxygen concentration of the 1 m and 2 m layer values along the transect was 7.7 mg/L which indicated the Reservoir was in attainment of the standard, although the average concentration at the 4 m and 5 m layers was 5.2 mg/L and 2.6 mg/L, respectively. The dissolved oxygen concentration at the 7 m layer and at the water-sediment interface was 0.5 mg/L and 0.1 mg/L, respectively. Similarly, the oxidation-reduction potentials at the water/sediment interface revealed favorable conditions for a reducing environment (Figure 14).

The last transect profile was collected on August 18th and showed improvement in the dissolved oxygen concentrations in the Reservoir. The average concentration in the upper layer was 7.2 mg/L and in attainment of the standard, while the dissolved oxygen concentration in the 4 m and 5 m layers was 5.6 mg/L and 4.9 mg/L, respectively. The dissolved oxygen concentration at the 7 m layer and at the water-sediment interface was 3.3 mg/L and 3.0 mg/L, respectively. Dissolved oxygen concentrations in the Reservoir showed improvement over the previous month and indicated that the internal loading conditions had improved.

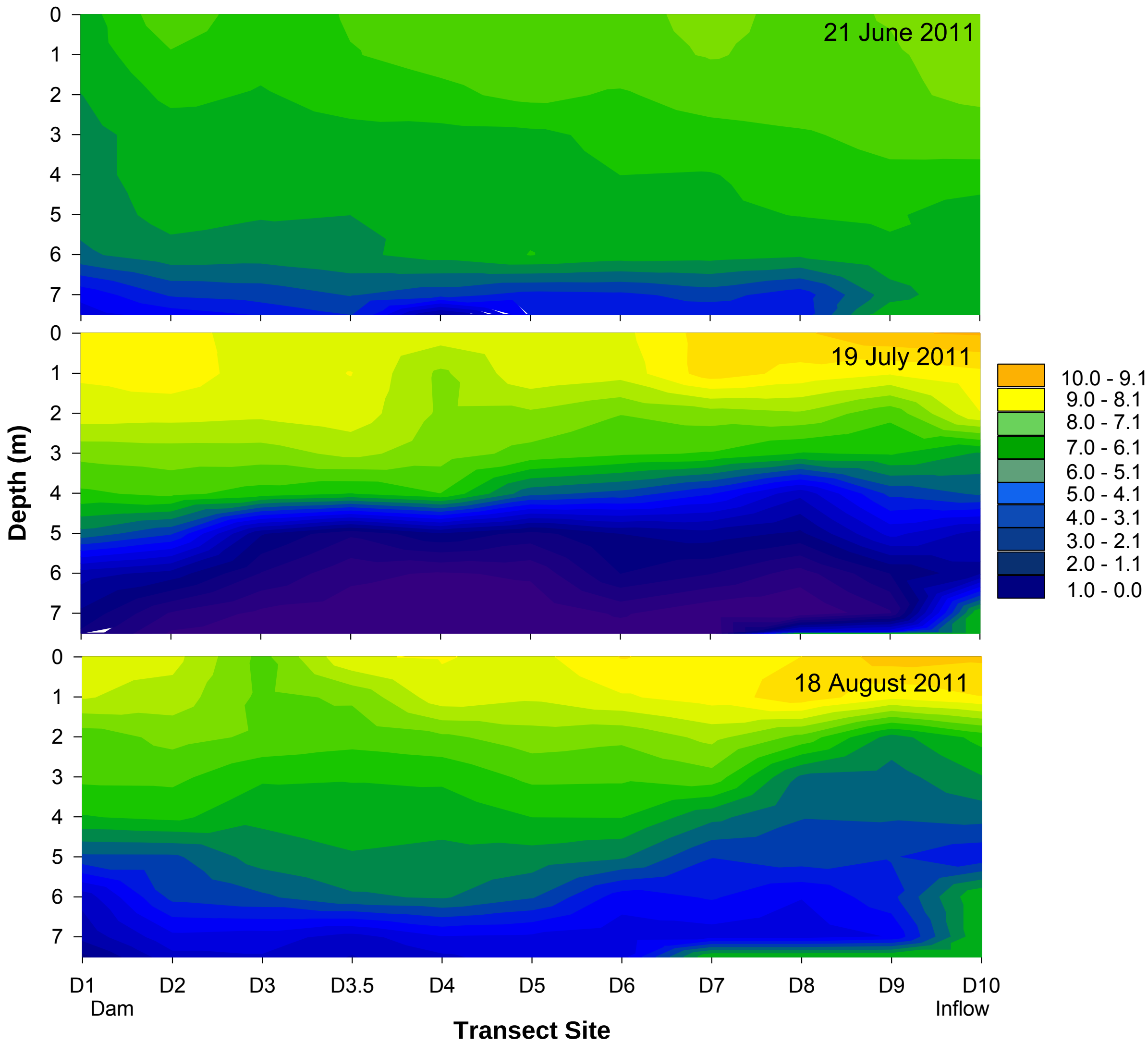


Figure 13: Dissolved oxygen conditions in Cherry Creek Reservoir for three dates based on transect profile data.

The oxidation-reduction potential profiles on June 21st also indicate that conditions were favorable for a reducing environment at the water-sediment interface (Figure 14). This interface acts as a barrier to the free exchange of soluble phosphorus between water and sediment, and when conditions are favorable (e.g., anoxic-reducing environment) phosphorus is released (i.e., internal load) at rates as much as 1,000 times faster than during well oxygenated conditions (Horne and Goldman 1994). Although the rate of exchange of nutrients (mainly phosphorus) at this interface remains unknown for Cherry Creek Reservoir, the internal loading component of the Reservoir has been estimated to account for approximately 25% of the cumulative total phosphorus load from 1992 to 2006 (Nürnberg and LaZerte 2008).

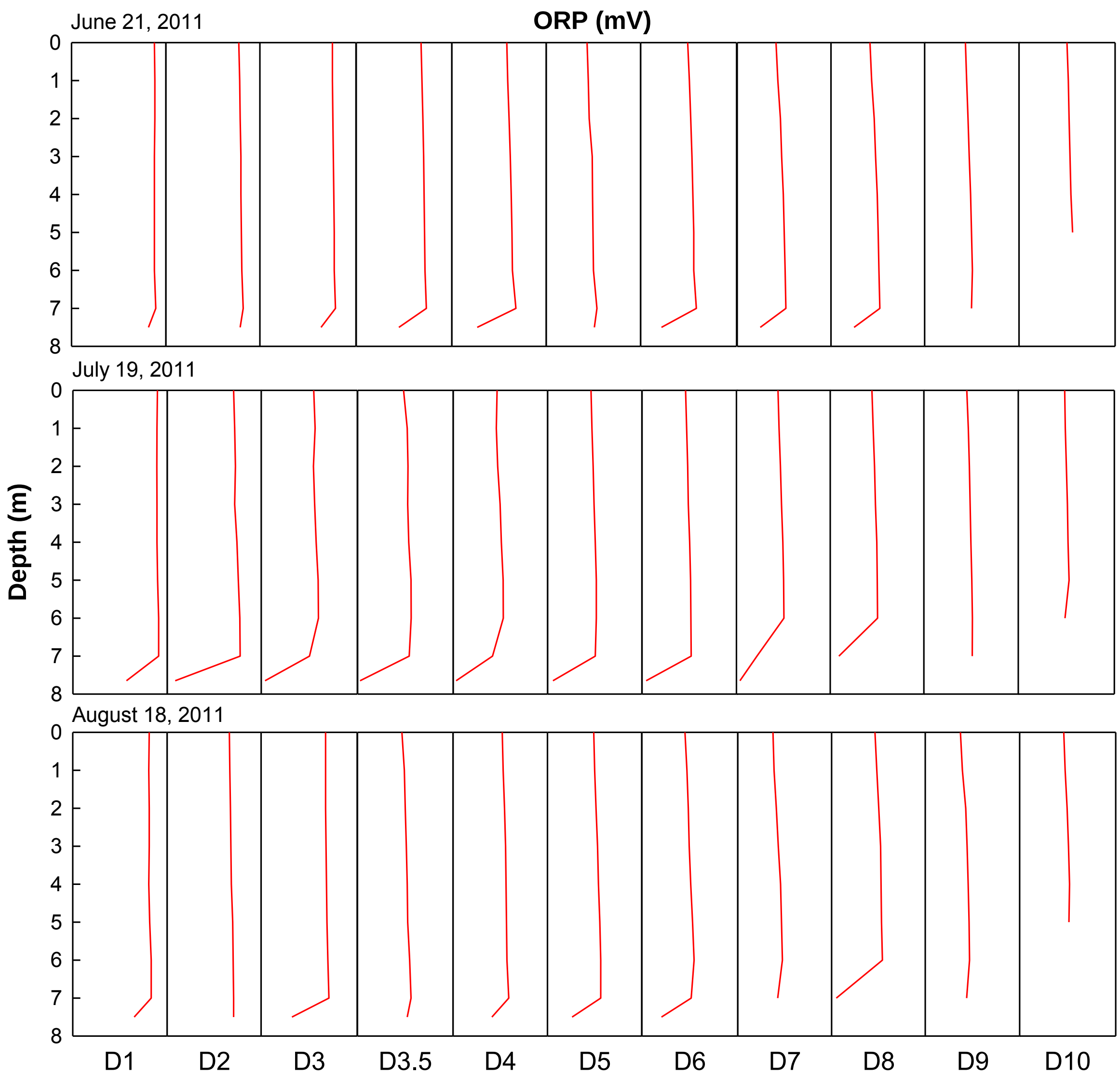


Figure 14: Oxidation reduction potentials in Cherry Creek Reservoir for three dates based on transect profile data. The ORP scales for each transect are all relative to each other within and among sampling events.

4.1.4 2011 WY Nutrients

Monitoring at Cherry Creek Reservoir has focused on the concentrations of phosphorus and nitrogen, because these inorganic nutrients are often the limiting factor in the growth of algae (Cole 1979; Horne and Goldman 1994; Wetzel 2001; Cooke et al. 1993). Excessive amounts of these nutrients in aquatic systems often result in algal blooms that create aesthetic problems as well as potentially unsuitable conditions for aquatic life.

During the 2011 WY, the photic zone mean concentration of total phosphorus ranged from 45 to 200 µg/L with an overall water year mean of 109 µg/L. The seasonal (July to September) photic zone concentrations ranged from 122 to 200 µg/L (Figure 15), with a seasonal mean of 154 µg/L. Reservoir internal loading contributed substantially to late summer phosphorus concentrations.

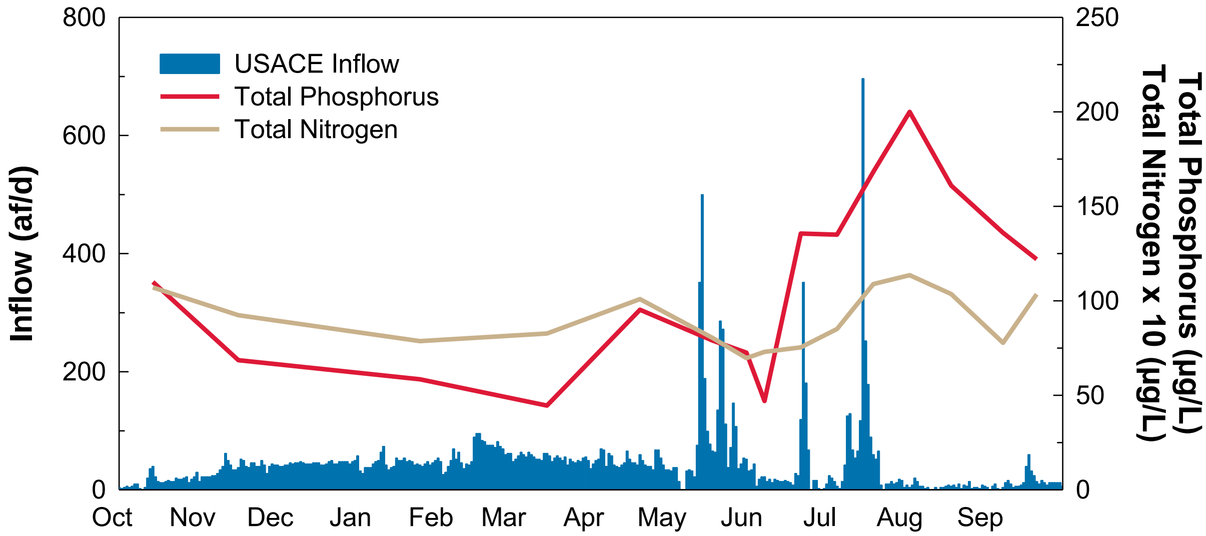


Figure 15: Annual pattern of photic zone total phosphorus, total nitrogen and USACE inflow in Cherry Creek Reservoir, 2011 WY.

Patterns in total phosphorus concentrations collected during profile sampling at Site CCR-2 showed a well-mixed Reservoir throughout the year (Figure 16). There was an extended period of nutrient release from bottom sediments from late May through late August as revealed by the pattern of increasing total phosphorus concentrations for 7 m layer as compared with concentrations observed at the same layers during the spring and late fall periods (Figure 16). The period of internal phosphorous loading shows a substantial increase in phosphorus at the 7 m depth, and a pattern of more consistent concentrations among the upper layers, though also elevated. This consistency within the upper layers is due to the upward diffusion of phosphorus from the sediment layer at approximately 7.5 m, and the eventual circulation within the upper layers by the aeration system. In terms of nutrient concentrations, the aeration system creates a well mixed layer from the surface down to approximately 6 m, which is slightly above the aerator heads (approximately 0.75 m above the sediment). During the July and August period, the soluble reactive phosphorus fraction in the 7 meter water layer accounted for approximately

47-69 percent of the total phosphorus content, also supporting evidence that phosphorus was being released from the sediment during that time.

Photic zone total nitrogen concentrations ranged from 697 to 1136 µg/L, with a WY average of 902 µg/L. During the July to September period, the photic zone total nitrogen concentration ranged from 778 to 1136 µg/L, with a mean concentration of 987 µg/L.

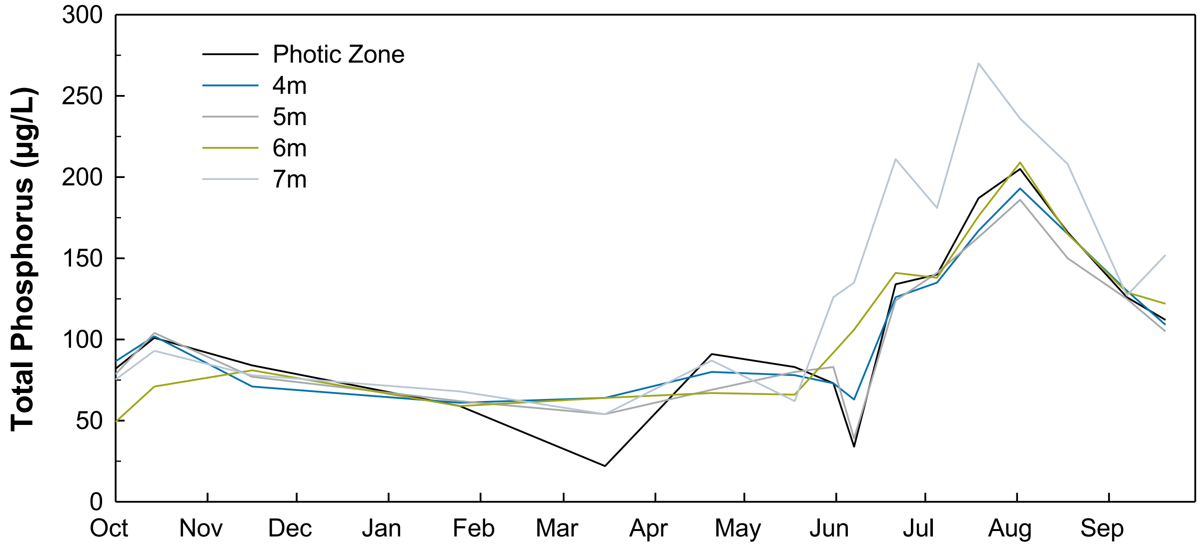


Figure 16: Total phosphorus concentrations recorded for the photic zone and at depth during routine monitoring during the 2011 WY.

4.1.5 Long-Term Phosphorus Trends in Cherry Creek Reservoir

In any long-term database, consistency in data analysis (i.e., analytical chemistry) is paramount, especially when evaluating long-term trends. Differences in methodologies or analytical laboratories may bias the data, which hinders the evaluation of potential trends. This is particularly evident in the total phosphorus and chlorophyll *a* database for Cherry Creek Reservoir. This database represents a variety of data produced by different analytical laboratories, and while the same standard method may have been utilized, subtle differences are apparent in the database. Over the monitoring period, analytical method detection limits varied and the precision of the analyses have increased with time. During the late 1990s, a transition from Metro Wastewater analytical services to GEI occurred, with the period from 1999 to 2011 representing the most consistent data processing methodologies. Furthermore, 1999 represents a time when a concerted effort started to implement best management practices throughout the basin, along with PRFs being established along Shop Creek and Cottonwood Creek to control storm flow and reduce the amount of phosphorus entering the Reservoir. Therefore, GEI also evaluated more recent trends in the data from 1999 through 2011.

Routine monitoring data collected since 1987 indicates a general increasing pattern in summer mean concentrations of total phosphorus (Figure 17). In 2011, the July to September mean concentration of total phosphorus was 154 µg/L. This value is significantly higher than last year's 101 µg/L concentration, and it is greater than the long-term median value of 84 µg/L (Table 4). Regression analyses performed on 1987 to 2011 seasonal mean TP data indicates a significant ($p < 0.01$) increasing trend.

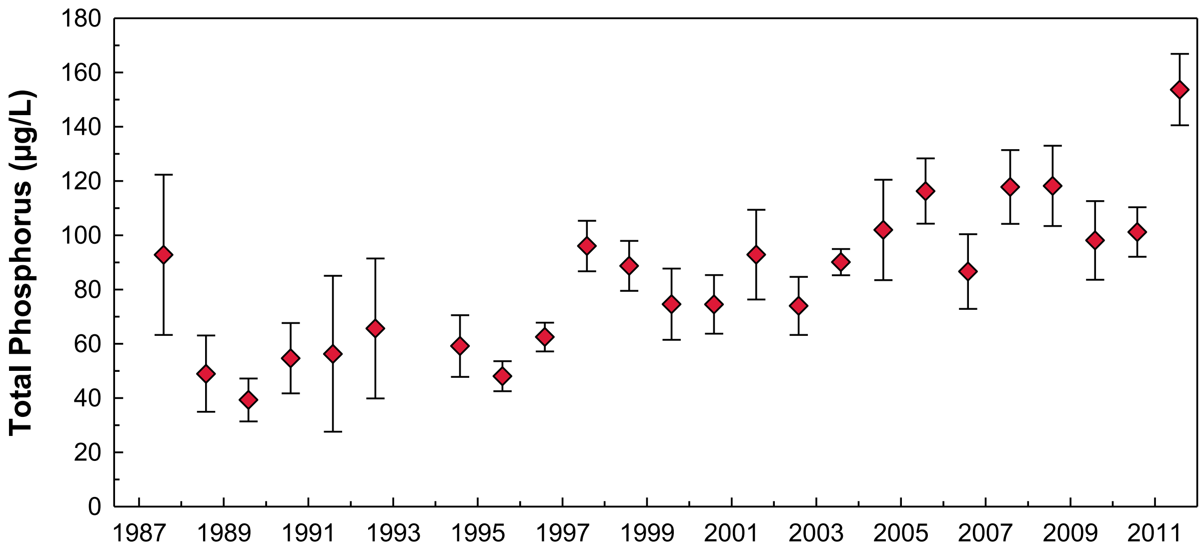


Figure 17: Seasonal mean (July to September) total phosphorus concentrations (µg/L) measured in Cherry Creek Reservoir, 1987 to 2011. Error bars represent a 95% confidence interval for each mean.

Table 4: Comparison of water year mean and July to September mean phosphorus, nitrogen, and chlorophyll *a* levels in Cherry Creek Reservoir, 1992 to 2011.

Year	Total Nitrogen (µg/L)		Total Phosphorus (µg/L)		Mean Chlorophyll *a* (µg/L)	
	WY	Jul-Sep	WY	Jul-Sep	WY	Jul-Sep
1988	902	1,053	52	49	21.8	31.8
1989	803	828	45	39	8.5	5.6
1990	600	--	58	55	2.3	8.6
1991	1,067	1,237	86	56	9.7	9.8
1992	931	970	52	66	12.2	17.4
1993	790	826	55	62	12.6	14.8
1994	1,134	1,144	53	59	11.4	15.4
1995	910	913	46	48	12.7	15.6
1996	889	944	35	62	13.4	18.2
1997	981	1,120	70	96	16.4	22.2
1998	763	880	77	89	18.4	26.6
1999	709	753	76	81	21.6	28.9
2000	774	802	80	81	22.3	25.1
2001	764	741	84	87	26.0	26.1
2002	825	858	70	74	21.7	18.8
2003	987	1,121	83	90	22.7	25.8
2004	929	977	85	102	19.1	18.4
2005	916	990	93	116	16.3	17.1

Table 4 (Cont.)

Year	Total Nitrogen (µg/L)		Total Phosphorus (µg/L)		Mean Chlorophyll *a* (µg/L)	
	WY	Jul-Sep	WY	Jul-Sep	WY	Jul-Sep
2006	874	914	96	87	13.7	14.7
2007	880	716	108	118	21.4	12.6
2008	795	800	92	118	15.8	16.6
2009	1,173	1,236	85	98	12.4	13.2
2010	925	974	92	101	23.6	31.0
2011	904	987	110	154	25.6	26.7
Mean	**884**	**947**	**74**	**83**	**16.6**	**19.2**
Median	**896**	**944**	**79**	**84**	**16.4**	**17.8**

4.1.6 2011 WY Chlorophyll a Levels

The annual pattern of chlorophyll *a* concentrations was quite variable with chlorophyll *a* less than 18 µg/L during the months of May and June, but considerably greater during late summer and fall 2010 (Figure 18). The conditions during the 2010 fall are indicative of the 2010 summer conditions and do not generally fit well into the water year hydrological regime. From October 2010 through September 2011, chlorophyll *a* concentrations ranged from 13.6 µg/L to 48.6 µg/L. Algal production is typically the lowest during the spring time of year, when the reservoir experiences flushing flows from spring runoff and seasonal storms. During the fall and winter, diatoms typically dominate the algal community and contribute to the increased chlorophyll *a* levels due to their larger chloroplast size and enhanced light capturing abilities of these algae. The July to September seasonal mean chlorophyll *a* level was 26.7 µg/L, with a peak seasonal reservoir mean concentration of 35.5 µg/L. The 2011 WY mean chlorophyll *a* concentration was 25.6 µg/L.

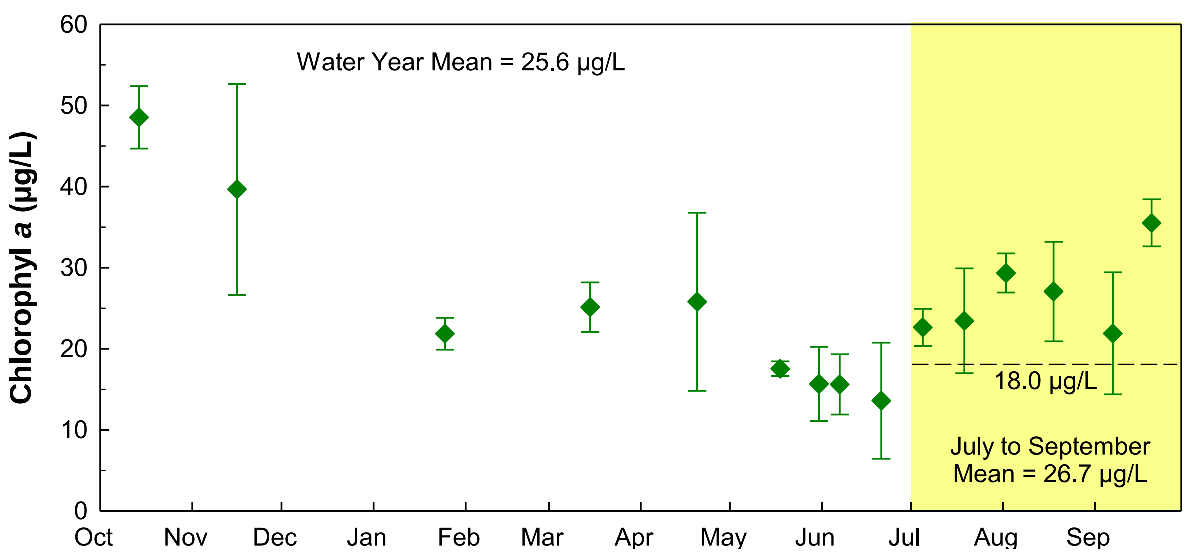


Figure 18: Concentration of chlorophyll *a* (µg/L) in Cherry Creek Reservoir, 2011 WY. Error bars represent a 95% confidence interval around each mean. Highlighted area denotes the seasonal period for the chlorophyll *a* standard.

4.1.7 Long-term Chlorophyll a Trends in Cherry Creek Reservoir

Since 1987, there is no significant trend in the seasonal mean chlorophyll *a* concentration (Figure 19). However, since 1999 there has been a steady decline in the seasonal mean chlorophyll *a* concentration, reaching a low level in 2007, and similarly again in 2009. However, the 2010 seasonal mean chlorophyll *a* concentration represented the highest seasonal level observed for the Reservoir since the Authority's monitoring program began, and highlights the propensity of algae to respond to optimal growing conditions. The 2011 seasonal mean chlorophyll level was not as high as 2010, but was considerably greater than the 18 µg/L chlorophyll *a* standard. The 2011 chlorophyll *a* conditions represent the second consecutive year when the Reservoir exceeded the seasonal chlorophyll standard, therefore the exceedance frequency (1 in 5 years) was also exceeded (Figure 19).

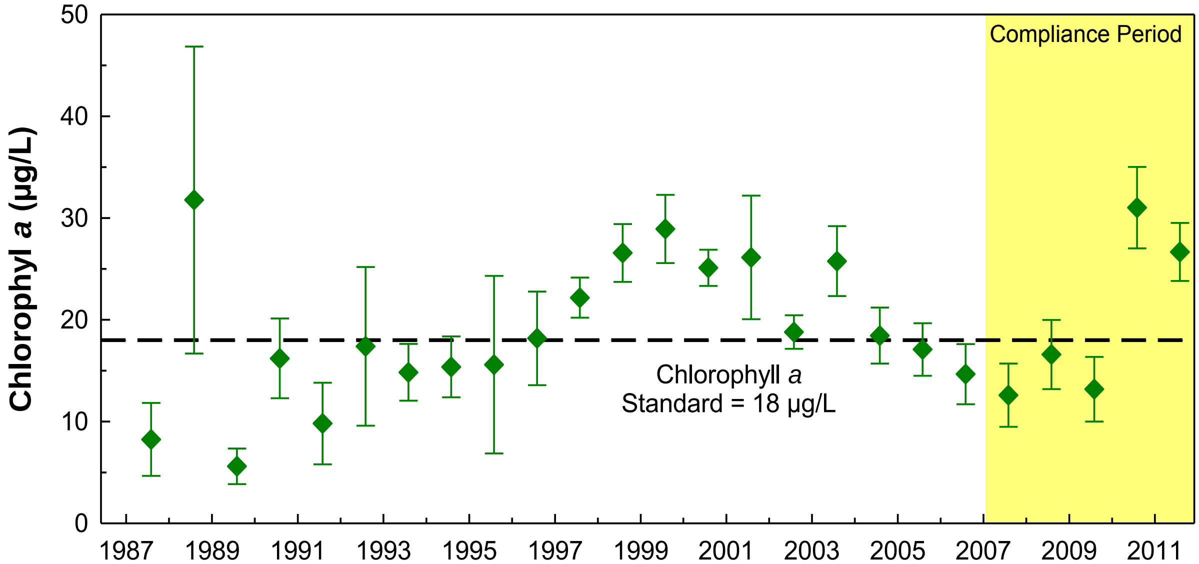


Figure 19: Seasonal mean (July to September) chlorophyll *a* concentrations measured in Cherry Creek Reservoir, 1987 to 2011. Error bars represent a 95% confidence interval around each mean.

4.2 Reservoir Biology

4.2.1 2011 WY Phytoplankton

Phytoplankton density in the photic zone ranged from 3,072 cells/mL on July 5th to 12,483 cells/mL on September 20th (Table 5). The number of algal taxa present in the Reservoir ranged from 11 on May 15th and 31st, to 24 on September 7th. Based on the water year, the assemblage was dominated in terms of density by diatoms (44%), with green algae and cryptomonads being the next most abundant taxonomic groups at 29% and 16%, respectively (Figure 20). Similar to 2010, the relative density of cyanobacteria (1.4%) was extremely low in 2011. Diatoms were relatively abundant throughout most of the year with exception to the month of February, when green algae dominated the algal assemblage in terms of density. Also, in July and August cryptomonads, green algae, and dinoflagellates increased in density.

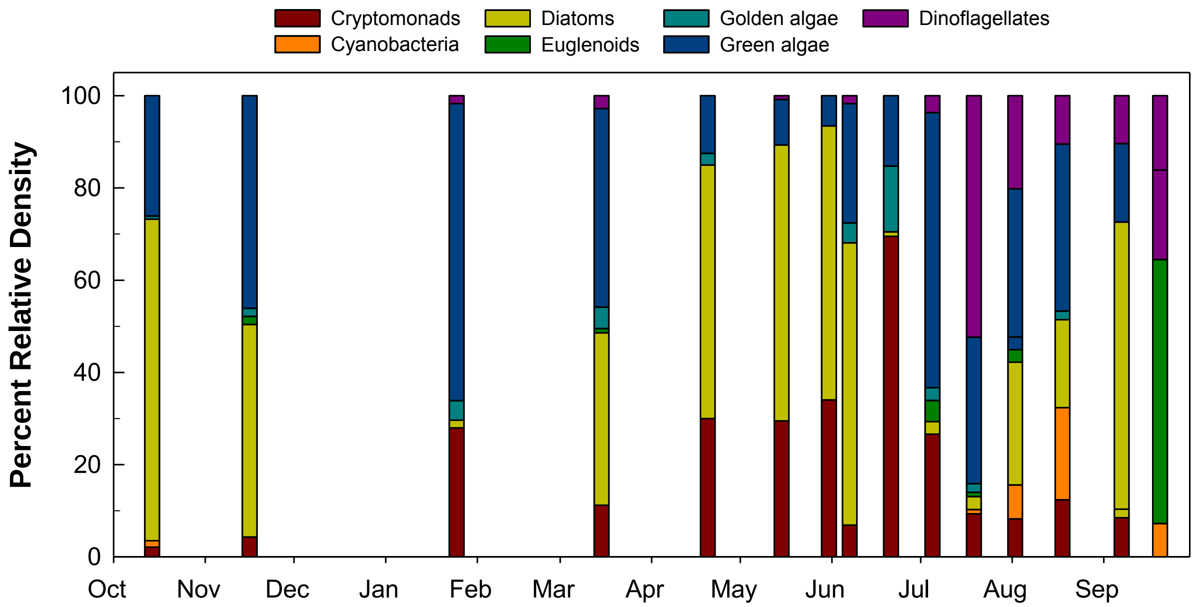


Figure 20: Percent relative density of algal groups by sample date in Cherry Creek Reservoir, 2011 WY.

When the size (i.e., biovolume) of each algae is considered, the diatoms were the most dominant algal group (50.6%) observed over the course of the year, followed by dinoflagellates (16%), then green algae (15%) and cryptomonads (11%) (Figure 21). The cyanobacteria only accounted for approximately 4% of the total algal biovolume. Patterns in algal biovolume show typical seasonal succession patterns of many temperate lakes and reservoirs with cryptomonads and diatoms being most abundant in the spring, cyanobacteria becoming evident in mid to late summer as well as dinoflagellates in late summer, then diatoms comprising most of the assemblage during the fall. These observed successional patterns of algal dominance are closely coupled with reservoir conditions such as cooler water temperature during the spring followed by the warmer water and longer photoperiod conditions of the summer and the cool down during the fall.

In the late winter, the flagellated cryptomonad algae (*Cryptomonas erosa*), the green algae (*Chlamydomonas* sp.) and the nonmotile green algae (*Scenedesmus* sp.) were abundant in terms of biovolume; although another cryptomonad (*Rhodomonas minuta*) and the nonmotile green algae (*Ankistrodesmus falcatus*) were the most dominant algae in terms of density. The diatoms and cryptomonads were the dominant algal groups in terms of density in the spring. Diatom dominance in the spring is common given the changing water temperature conditions and light typically occurring after ice off conditions. The cryptomonads (motile algae) also likely gain a competitive advantage in the spring given the constant mixing conditions of the destratification system. Similarly the dinoflagellates observed during late summer conditions may gain some preferential advantage of the constant mixing provided by the destratification system. The flagellated algae, which are motile and can vertically migrate through the water column to optimize production, represented 28% and 34% of the total assemblage in terms of WY density and biovolume, respectively.

Table 5: Density (cells/mL) of phytoplankton and total number of taxa collected from all three sites on Cherry Creek Reservoir 2011 WY.

Taxonomic Group	14-Oct	16-Nov	25-Jan	15-Mar	20-Apr	15-May	31-May	7-Jun
Diatoms								
Centrics	6,510	4,690	107	154	39	213	752	1,792
Pennates	134	90	--	1,896	2,527	2,011	5,412	2,313
Green Algae	2,483	4,781	4,080	2,358	583	366	677	1,735
Cyanobacteria	134	--	--	--	--	--	--	--
Golden Algae	67	180	268	256	117			289
Euglenoid	--	180	--	51	--	--	--	--
Dinoflagellate	--	--	107	154	--	30	--	116
Cryptomonads	201	451	1772	615	1400	1097	3,533	463
Total Density	**9,529**	**10,372**	**6,334**	**5,484**	**4,666**	**3,717**	**10,374**	**6,708**
Total Taxa	**23**	**16**	**15**	**21**	**14**	**11**	**11**	**16**
Taxonomic Group	**21-Jun**	**5-Jul**	**19-Jul**	**2-Aug**	**18-Aug**	**7-Sep**	**20-Sep**	**--**
Diatoms								--
Centrics	30	56	125	852	552	1,779	7047	--
Pennates	--	28	--	63	61	318	101	--
Green Algae	484	1,832	1,420	1,104	1,166	572	2,416	--
Cyanobacteria	--	--	42	252	644	64	--	--
Golden Algae	454	85	84	95	--	--	--	--
Euglenoid	--	141	42	95	61	--	--	--
Dinoflagellate	--	113	2,339	694	337	349	2,013	--
Cryptomonads	2,210	817	418	284	399	286	906	--
Total Density	**3,178**	**3,072**	**4,470**	**3,439**	**3,220**	**3,368**	**12,483**	**--**
Total Taxa	**15**	**22**	**18**	**21**	**21**	**24**	**14**	**--**

In the Rocky Mountain region, cryptomonads appear to prefer colder water (Kugrens and Clay 2003) which explains their dominance in late winter and spring. Cryptomonads also prefer moderate turbulence when they are circulated through the water column and mixed with higher nutrient rich waters (Reynolds 1984). During the fall, the diatoms became the more dominant algal group. Cyanobacteria were again very rare in terms of annual density (1.3%), although this group did have a small mid-August bloom when they comprised approximately 20% of the total density. This mid-August cyanobacteria bloom was primarily comprised of *Aphanizomenon flos-aquae*, a filamentous nitrogen fixing cyanobacterium whose trichome is composed of many individual cells to form one physiological entity (Komárek et al. 2003) which explains their larger biovolume relative to their density. A key aspect in the algal successional patterns is that cyanobacteria were only dominant during a few weeks in mid to late August. Twenty days after this cyanobacteria bloom was observed on August 18th, this group comprised less than 2% of the assemblage in terms of density and less than 6% in terms of biovolume. Historically, cyanobacteria were the most dominant group throughout much of the summer period and often extending into the fall.

The relative density and biovolume of algae is largely a response to bottom-up factors that promote growth such as inorganic nutrients, light, temperature, and pH which are closely coupled with top-downs factors such as predation (i.e., zooplankton grazing), life history traits (i.e., cyst production) and outflow (Pollingher 1987). The bottom-up factors were clearly evident during the summer season when internal phosphorus loading occurred and phosphorus was quickly mixed throughout the water column by the destratification system. Following the mid-July storm event, the Reservoir was likely "flushed" of the non-motile green algae or diatoms, either by direct outflow or the sudden changes in reservoir conditions (i.e., lower temperature and lower light due to sediment influx) that were less conducive to their growth. This resetting of the assemblage in late July provided a competitive edge to the dinoflagellate (*Glenodinium* sp.) that dominated the assemblage in terms of density and biovolume. The dinoflagellates along with the cyanobacteria (e.g., *Aphanizomenon flos-aquae* and *Anabaena flos-aquae)* typically dominate late summer algal assemblages (Whitton and Potts 2000, James et al. 1992, Padisák 1985, Konopka and Brock 1978, Pollingher 1987). The constant mixing by the destratification system also enhances the bottom-up factors by providing a soluble phosphorus-rich photic zone environment which allows algae to maximize their production during the summer. However, the sudden decline of cyanobacteria in early August is likely a result of reduced internal phosphorus loading at this time combined with the efficient mixing of the destratification system. The constant mixing reduces the favorable habitat for the non-motile cyanobacteria. One of the primary objectives of the destratification system was to reduce the favorable habitat conditions for cyanobacteria (AMEC 2005) and given their low relative abundance during the past few years, the system appears to be effective with respect to this goal. Interestingly, the constant mixing by destratification system also appears to have provided more suitable habitat for flagellated algae. These algae are motile and typically move up and down in the water column to maximize production while minimizing grazing pressure.

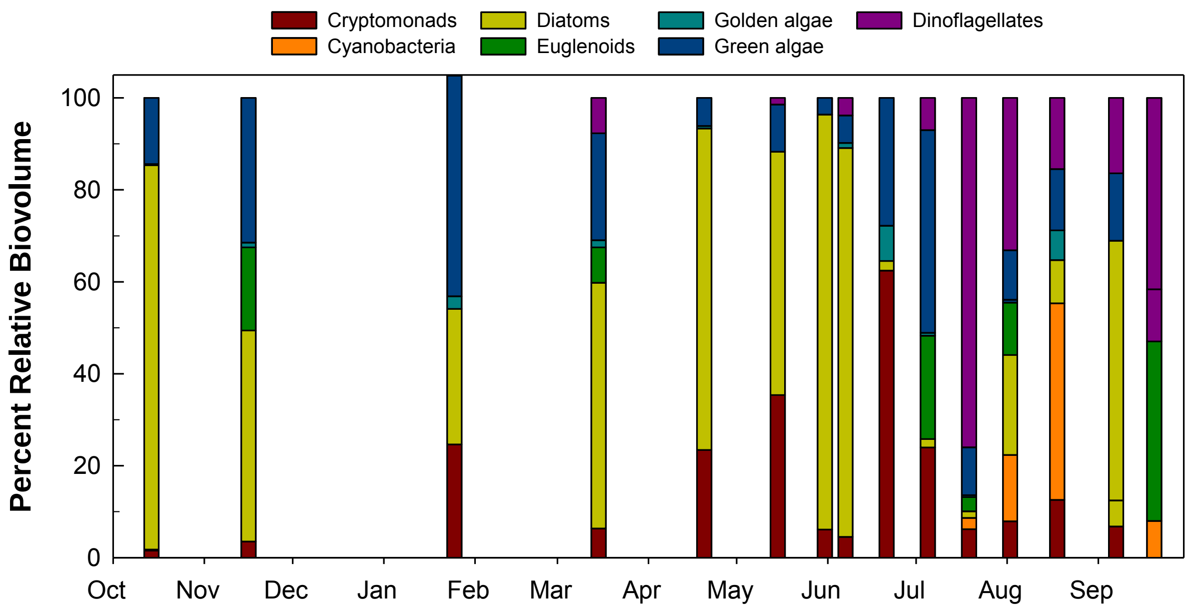


Figure 21: Percent relative biovolume of algal groups by sample date in Cherry Creek Reservoir, 2011 WY.

In the event of reduced top-down pressure such as low zooplankton grazing, the algal assemblage can maximize their relative density given constraints of the bottom-up factors. It is unclear whether the zooplankton population was able to effectively control the algal population during the summer 2011 conditions. It is possible, that given the large gizzard shad (forage fish) population in the Reservoir, these fish could be exerting a heavy grazing pressure on the zooplankton population such that algae growth remained unchecked during their peak growing period. Communities dominated by large zooplankton populations tend to show reduced algal biomass yields as these herbivores effectively reduce the number of algae in the water column (Sarnelle 1992, Mazumder 1994, Mazumder and Lean 1994). However, this relationship can be affected by the relative biomass (e.g., size) of the individual algae. For example, if the algal assemblage is dominated by filamentous or colonial cyanobacteria, zooplankton will preferentially graze on more palatable and preferred algae such as diatoms, cyptomonads, and green algae (Vanni and Temte 1990).

In 2011, the Reservoir exhibited extremely high chlorophyll levels at various periods throughout the year. In early and late fall, the high chlorophyll levels of 49 µg/L and 40 µg/L were associated with an abundance of *Ankistrodesmus falcatus* (green algae) and *Rhodomonas minuta* (cryptomonad). Both algae provide optimal or near optimal food resources for zooplankton (Stemberger and Gilbert 1985, Sarnelle 1993, Kilham et al. 1997). The high summer 2011 levels that ranged from 21.9 µg/L to 35.5 µg/L were associated with a variety of algae. In July, the green algae, cryptomonads, and dinoflagellates contributed to the high levels of chlorophyll *a*, whereas in August, the green algae, diatoms and cyanobacteria were associated with the chlorophyll *a* levels. The highest summer chlorophyll *a* concentration of 35.5 µg/L was primarily due to dinoflagellates, with both diatoms and green algae contributing to the high level. As discussed earlier, cyanobacteria were not associated with the summer maximum chlorophyll *a* concentration. This is a unique condition for the Reservoir, because historically the peak chlorophyll *a* concentration was associated with cyanobacteria.

4.2.2 Long-Term Phytoplankton

Historically, the cyanobacteria have been the most abundant algae in the Reservoir, especially during the late summer season. One of the primary objectives of the destratification system was to reduce the suitable habitat conditions for cyanobacteria by vertical mixing which would disrupt the ability of cyanobacteria to efficiently grow in the upper water layers. Historically, the nuisance chlorophyll *a* levels (i.e., > 30 mg/L) during the summer have always been associated with cyanobacteria blooms. However, during the past 3 years the reservoir has exhibited a shift in the algal species composition such that cyanobacteria have been a very small component of the assemblage (Figure 22). Prior to the operation of the destratification system, cyanobacteria represented between 40 and 80 percent of assemblage in terms of density (cells/mL). During the first season of operation in 2008, green algae and cyanobacteria were still the dominant types of algae, with cyanobacteria dominating the summer assemblage. However, since 2009, the cyanobacteria population has been greatly reduced, representing between 1 and 7 percent of the algal assemblage in terms of density (Figure 22). Cryptomonads, diatoms, and green algae have become the dominant algal types, all of which are a better food source for zooplankton and fish.

This shift in algal composition is notable as it provides some initial results that validate the effectiveness of the destratification system at achieving one of the primary objectives—reducing suitable habitat conditions for cyanobacteria. The destratification system's efficient vertical mixing allows the more beneficial algal types (e.g., cryptomonads, diatoms, and green algae) a competitive advantage over cyanobacteria, in terms of nutrient and light resources. However, as a consequence of the efficient mixing, the relatively constant supply of soluble reactive phosphorus to algal community allows the beneficial cells to maximize their productivity. As a result, the reservoir exhibited extremely high chlorophyll *a* levels in 2011 which exceeded the chlorophyll threshold of 18 µg/L. This greater productivity in the Reservoir has also resulted in the exceedance of the chlorophyll *a* standard, despite being associated with more beneficial types of algae in terms of zooplankton and fish food resources.

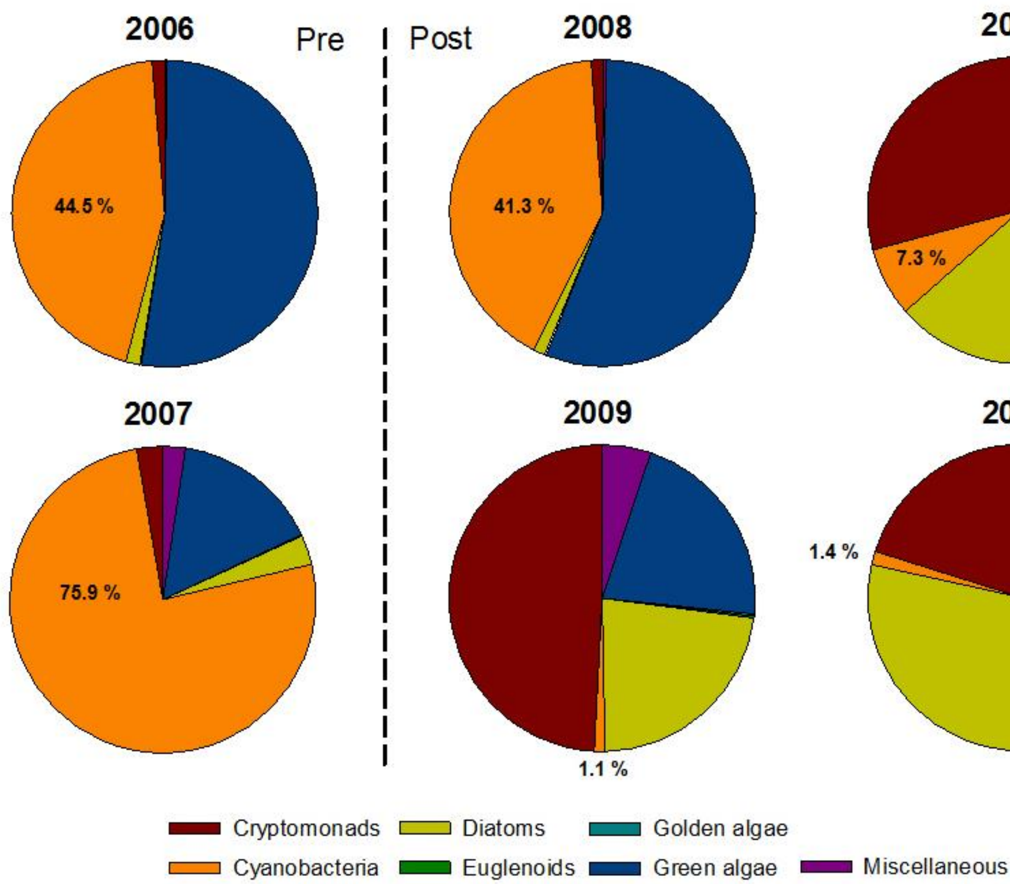


Figure 22: Percent algal density of major taxonomic groups in Cherry Creek Reservoir, pre- and post-operation of the destratification system. For comparative purposes, diagrams are based on the calendar year composition rather than water year.

4.2.3 2011 Zooplankton

Zooplankton density ranged from 166 organisms/L to 1,410 organisms/L which occurred shortly after ice-off conditions in mid-March to mid-April, respectively. A total of nine zooplankton crustacean species—six cladocerans and three copepods with immature copepodids and nauplius—and six species of rotifers were collected during the 13 sampling events (Appendix C). There was only one relatively smaller cladoceran (*Bosmina longirostris*) that was collected during all 13 sampling events, while all three copepods (*Diacyclops thomasi*, *Mesocyclops edax, Skistodiaptomus pallidus*) were collected during 12 of the 13 sampling events. The other five cladoceran taxa, mainly larger daphnia, were observed to occur over shorter time periods (i.e., 2–8 weeks). The immature copepods (copepodids and nauplius) were observed during all 13 sampling events too. *Bosmina longirostris* have been found to be the dominant cladoceran in other eutrophic lakes (Harman et al. 1995).

During the spring sampling events, rotifers comprised between 43% and 91% of the total zooplankton density, while during the summer months this group comprised approximately

10% of the zooplankton density. Cladocera were relatively abundant in mid-April, and then again during the summer months of late June through August both cladocerans and copepods comprised the majority of the zooplankton assemblage in roughly equal percentages. The total density of zooplankton generally follows the pattern of chlorophyll *a* concentration (Figure 23); however there is no statistical correlation between the zooplankton density and chlorophyll *a* (surrogate for algal biomass). Similarly, there was no correlation between zooplankton density and algal density or algal biomass.

Ideally, the pattern between zooplankton density and chlorophyll *a* (algal biomass) should be inversely related, as herbivorous zooplankton could theoretically affect algal biomass via grazing pressure, provided planktivorous fish are not suppressing the zooplankton populations (Harman et al 1995). However, in Cherry Creek Reservoir, the increased abundance of gizzard shad has likely increased the grazing pressure on the zooplankton assemblage, thereby reducing the zooplankton density and reducing their ability to effectively control the algal assemblage.

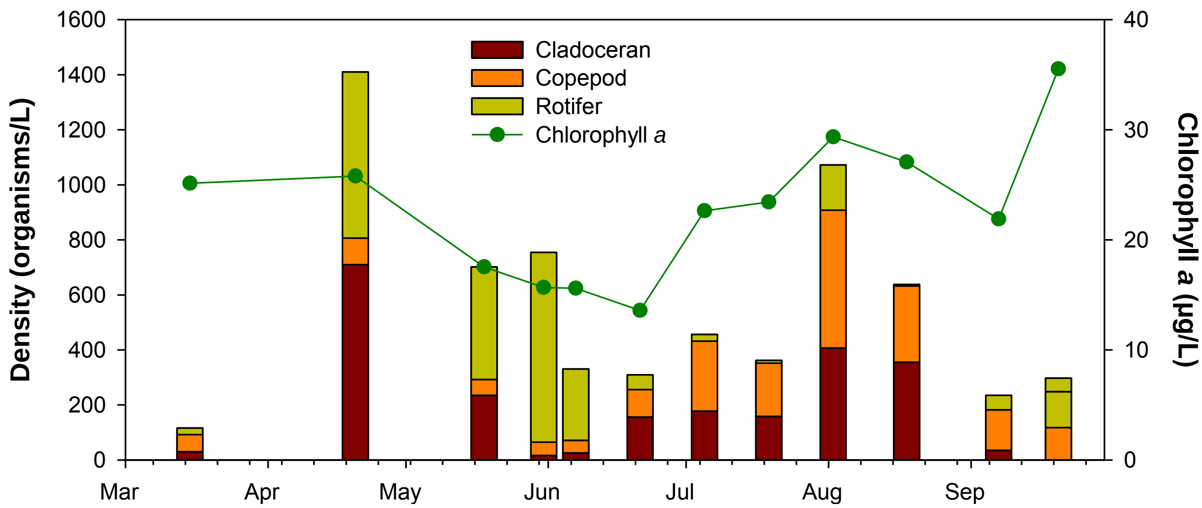


Figure 23: Total density of zooplankton groups and chlorophyll *a* concentration by sample date in Cherry Creek Reservoir, 2011.

4.2.4 2011 Fish Stocking and Populations

Historically, the fish assemblage has been composed of many species that represent a variety of trophic levels, which include omnivores, insectivores, zooplanktivores, and piscivores. Fish can exert a strong influence on the structure and productivity of phytoplankton and zooplankton assemblage through food web pathways between different levels (phytoplankton, zooplankton, and fish) of the aquatic ecosystem (Carpenter et al. 1985). In addition, these trophic dynamics can affect the variability, distribution, and ratios of limiting nutrients, such as phosphorus and nitrogen (Vanni et al. 1996). Mechanisms that may possibly result because of fish predation include decreased herbivory by zooplankton when fish are abundant, modification of nutrient recycling rates by herbivorous zooplankton as fish abundance varies, and nutrient recycling by fish (Vanni and Layne 1996).

Stocking data from the Colorado Division of Wildlife (CDOW) shows that 11 species and 3 hybrids have been stocked in Cherry Creek Reservoir from 1985 to 2011 (Appendix E). The three stocked hybrids have been the wiper (striped bass × white bass), the tiger musky (northern pike × muskellunge), and a trout hybrid (rainbow × cutthroat trout). Of these 14 stocked fish taxa, rainbow trout and walleye have been stocked every year. In 2011, the CPW stocked approximately 22,200 catchable rainbow trout (*Oncorhynchus mykiss*) and 200 Snake River cutthroat (*Oncorhynchus clarkii*), and approximately 4,000 subcatchable rainbow trout. CPW also stocked warm water species that included approximately 9,500 channel catfish (*Ictalurus punctatus*), 97,400 black crappie (*Pomoxis nigromaculatus*), and 4 million walleye (*Sander vitreus*). All of the warm water fish were subcatchable size fish.

CPW performed a fish population survey on September 8th 2011, and observed that 56% of the fish collected were gizzard shad (*Dorosoma cepedianum*), while walleye and white sucker (*Catostomus commersonii*) comprised the majority of the remaining individuals collected, 16% and 15% respectively. In 2008, CPW observed that gizzard shad only comprised 20% of the fish collected, thus over the 3 years the gizzard shad population has increased at least 2.5 fold. In contrast, the walleye have decreased 2.5 fold from 41% to 16% of the fish collected. This is one of the relationships in food web dynamics between the beneficial algae, zooplankton, forage fish and predatory fish that should be evaluated in the future to fully understand the effects of the destratification system on reservoir ecology.

4.3 Stream Water Quality

4.3.1 2011 WY Phosphorus Concentrations in Streams

The median annual total phosphorus concentration for base flow conditions ranged from 37 μg/L at SC-1 to 226 μg/L at CC-10 (Table 6). At most stream sites, the median seasonal (July to September) base flow concentration was similar to the annual median concentration. The seasonal median concentration of total phosphorus ranged from 42 μg/L at Site SC-3 to 272 μg/L at Site CC-10. At most stream sites, the storm flow TP concentration was greater than concentrations during base flow conditions. The annual median storm flow concentration ranged from 113 μg/L at Site CT-2 to 409 μg/L at Site CC-10.

Table 6: Comparison of median base flow and median storm flow concentrations of total phosphorus (TP) and total suspended solids (TSS) in tributaries to Cherry Creek Reservoir, 2011 WY.

Stream, Site	Base Flow				Storm Flow	
	Summer		Annual		Annual	
	TP (µg/L)	TSS (mg/L)	TP (µg/L)	TSS (mg/L)	TP (µg/L)	TSS (mg/L)
Cherry Creek						
CC-10	272	22	226	11	409	116
CC-O	245	15	92	18	--	--
Cottonwood Creek						
CT-1	52	14	66	30	141	44
CT-2	56	18	56	23	113	34
CT-P1	96	21	40	12	232	114
CT-P2	70	15	43	12	213	47
Shop Creek						
SC-3	42	10	37	32	142	26

4.3.2 Long-Term Trends in Phosphorus Concentrations in Cherry Creek Reservoir Tributaries

Long-term patterns (1995-2011) in total phosphorus and soluble reactive phosphorus concentrations were evaluated for the three main tributary sites (CC-10, SC-3, and CT-2) to Cherry Creek Reservoir, for both base flow and storm flow conditions. The long-term median annual base flow total phosphorus concentration for Cherry Creek (CC-10) and Shop Creek (SC-3) are 214 µg/L and 91 µg/L, respectively (Table 7), with storm flow concentrations being approximately 65-85% greater (Table 8). In Cottonwood Creek (CT-2), the long-term median annual base flow total phosphorus concentration is 76 µg/L; however, the long-term median storm flow concentration is approximately 170% greater. Soluble reactive phosphorus fractions for base flows in Cherry Creek and Shop Creek were approximately 77% and 75%, respectively, of the total phosphorus concentrations, while soluble reactive phosphorus fractions in Cottonwood Creek (CT-2) have been approximately 16% of total phosphorus concentrations.

Table 7: Comparison of base flow median WY total phosphorus and soluble reactive phosphorus concentrations for sites CC-10, SC-3, and CT-2 from 1995 to 2011.

Water Year	CC-10		SC-3		CT-2	
	TP (µg/L)	SRP (µg/L)	TP (µg/L)	SRP (µg/L)	TP (µg/L)	SRP (µg/L)
1995	218	169	85	75	--	--
1996	145[a]	153[a]	77	68	97	77
1997	176	170	91	71	108	64
1998	291	231	80	76	108	66
1999	258	200	93	60	94	39
2000	247	195	156	134	83	24
2001	239	168	173	116	84	22
2002	191	144	160	125	69	13
2003	213	158	81	59	83	13
2004	214	164	139	105	92	8
2005	200	163	142	76	66	10
2006	162	134	101	59	67	7
2007	217	160	103	47	65	11
2008	200	143	49	27	69	5
2009	176	129	58	23	50	6
2010	217	168	74	30	61	7
2011	226	165	46	25	56	7
Median	**214**	**164**	**91**	**68**	**76**	**12**

[a] Results for total phosphorus and soluble reactive phosphorus are obtained independently and are within the 10% analytical error rate for all data used to calculate the median annual value.

Table 8: Comparison of storm flow median WY total phosphorus and soluble reactive phosphorus concentrations for sites CC-10, SC-3, and CT-2 from 1995 to 2011.

Water Year	CC-10		SC-3		CT-2	
	TP (µg/L)	SRP (µg/L)	TP (µg/L)	SRP (µg/L)	TP (µg/L)	SRP (µg/L)
1995	181	161	122	95	--	--
1996	323	270	132	85	336	160
1997	402	316	175	74	391	221
1998	378	277	155	124	314	108
1999	348	247	141	112	118	58
2000	673	274	407	166	277	93
2001	293[a]	172[a]	227	84	209	33
2002	251	171	207	110	175	21
2003	365	171	197	134	204	35
2004	285	237	208	100	208	35
2005	354	187	190	129	175	26
2006	477	221	161	122	259	74
2007	366	195	167	78	230	27
2008	271	207	175	101	79	14
2009	378	180	111	80	78	24
2010	307	178	130	101	97	24
2011	409	197	142	56	113	29
Median	**354**	**197**	**167**	**101**	**206**	**34**

Base flow total phosphorus and soluble reactive phosphorus concentrations revealed no trends over time at both sites CC-10 and SC-3 (Figures 24 through 27). However, at Site CT-2, both the total phosphorus and soluble reactive phosphorus concentrations reveal a significant ($p < 0.05$) decreasing trend (Figure 28 and Figure 29) during base flow conditions. The observed decreasing trend and greatly reduced variability in soluble reactive phosphorus concentrations at Site CT-2 from 1995 to 2011 is the result of the effectiveness of the PRFs near the Perimeter Road and Peoria Street, along with the stream reclamation project along Cottonwood Creek. There is a seasonal pattern in phosphorus concentration at all sites, which is not specifically addressed in the trend analysis.

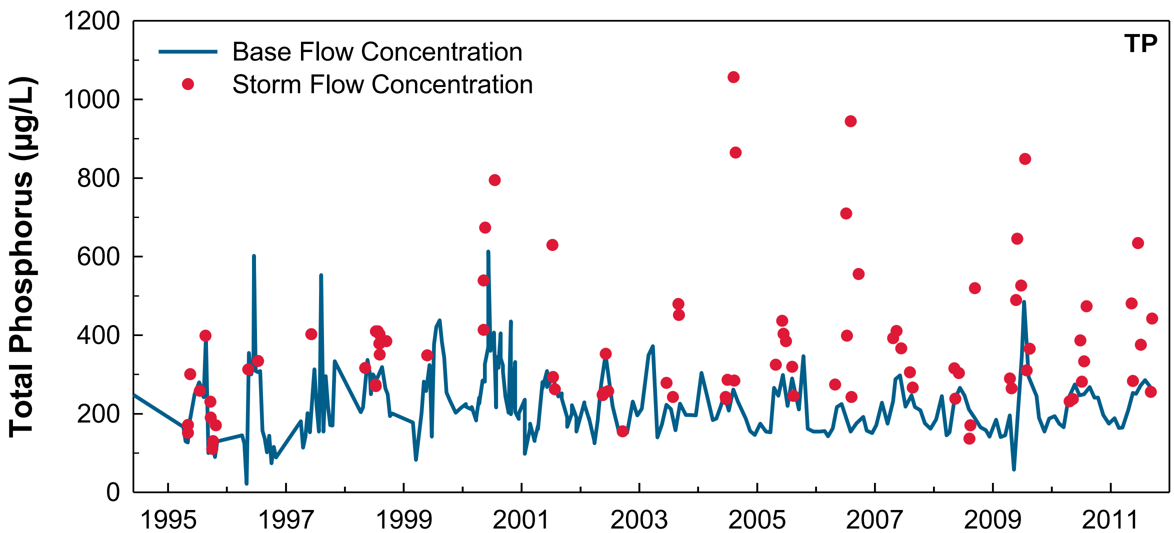


Figure 24: Base flow and storm flow total phosphorus concentrations measured in Site CC-10, 1994 to 2011.

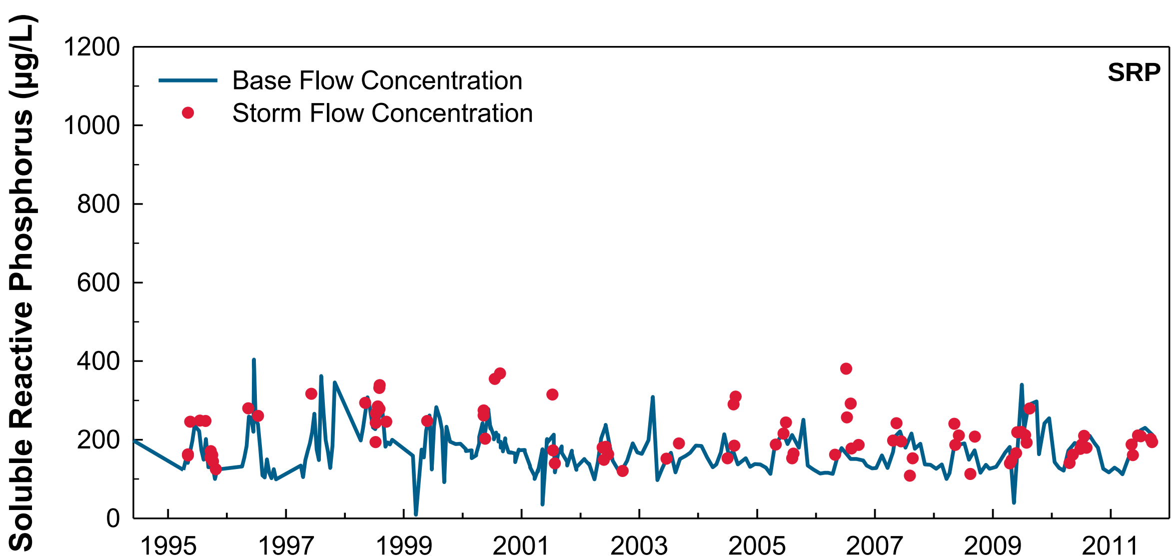


Figure 25: Base flow and storm flow soluble reactive phosphorus concentrations measured in Site CC-10, 1994 to 2011.

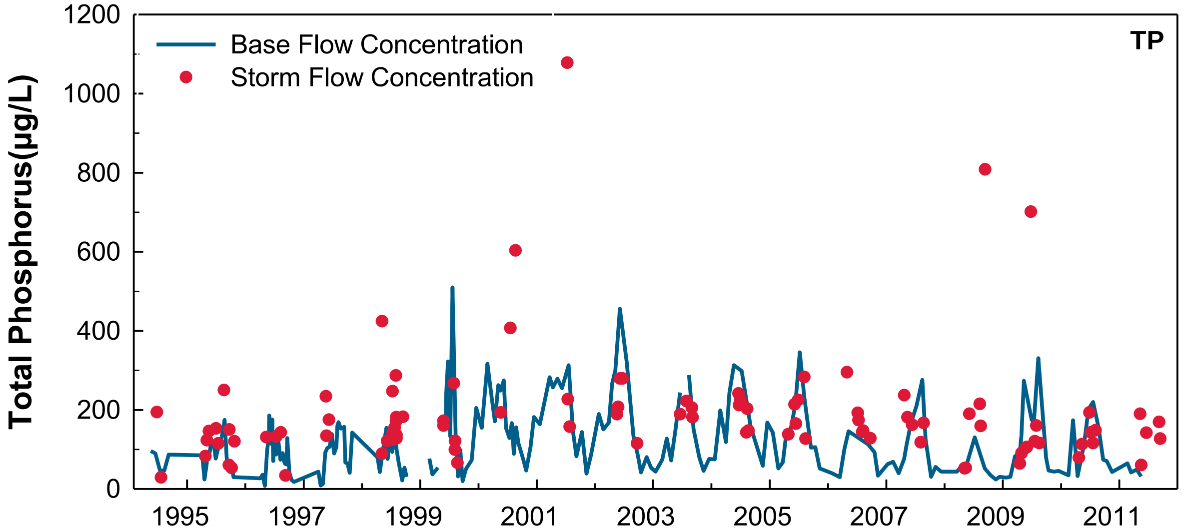


Figure 26: Base flow and storm flow total phosphorus concentrations measured in Site SC-3, 1994 to 2011.

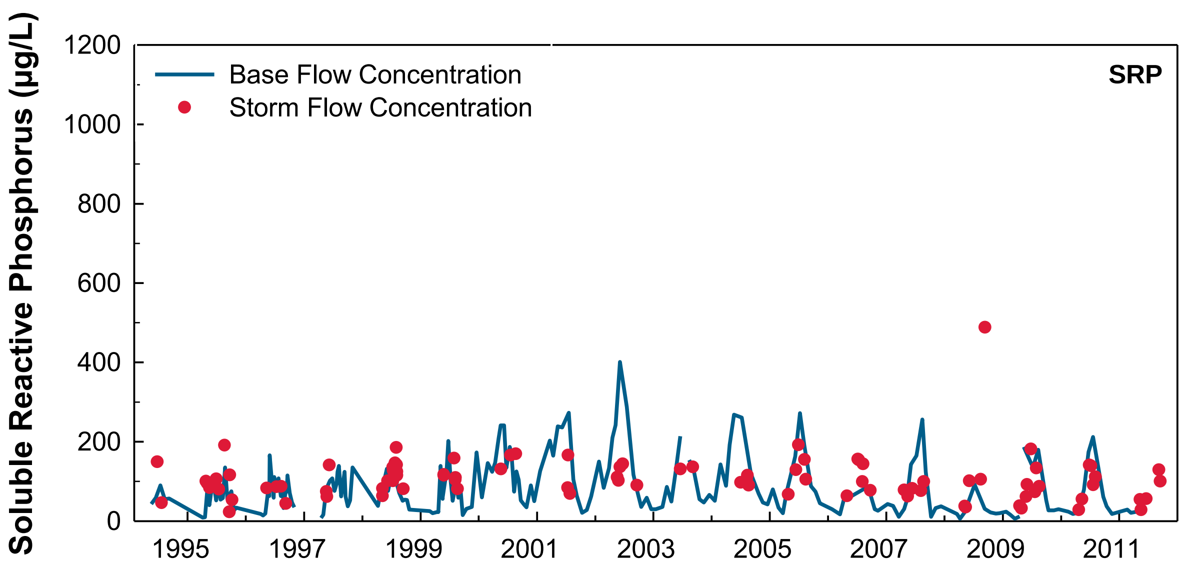


Figure 27: Base flow and storm flow soluble reactive phosphorus concentrations measured in Site SC-3, 1994 to 2011.

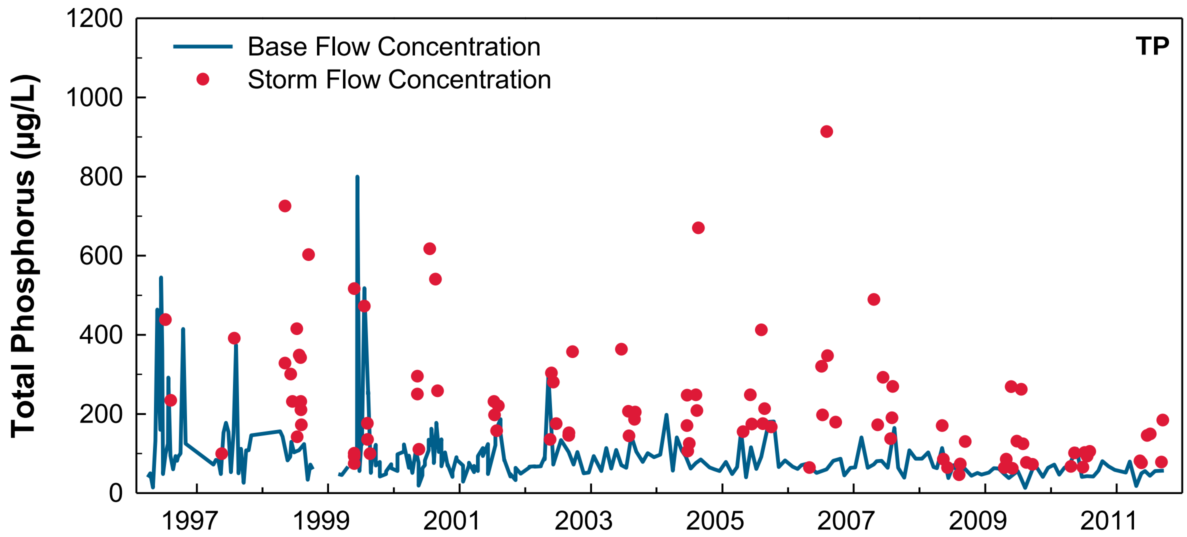


Figure 28: Base flow and storm flow total phosphorus concentrations measured in Site CT-2, 1996 to 2011.

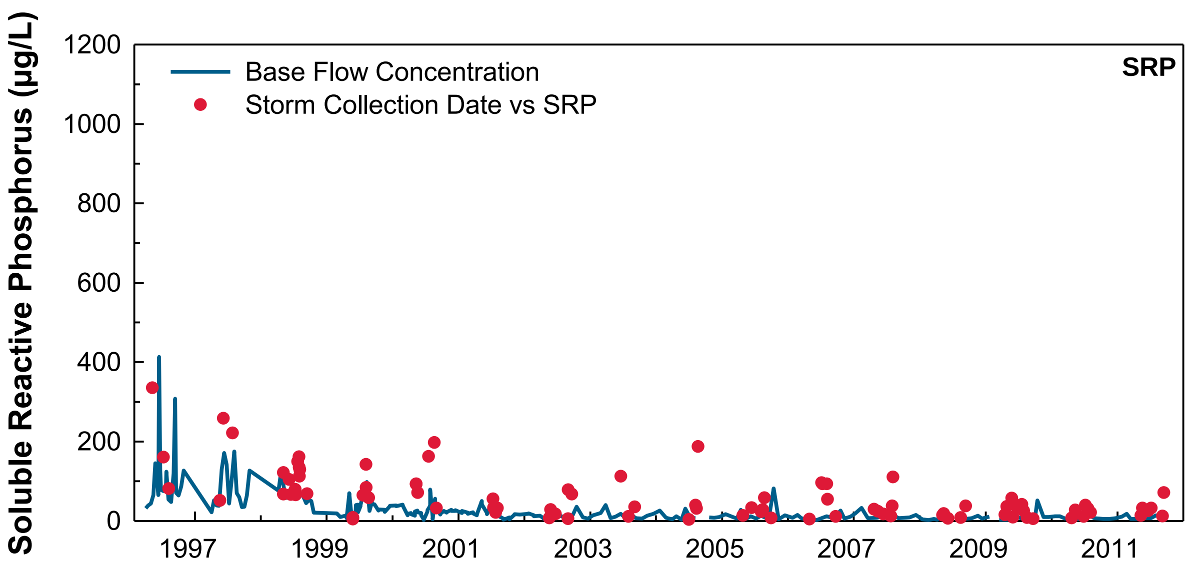


Figure 29: Base flow and storm flow soluble reactive phosphorus concentrations measured in Site CT-2, 1996 to 2011.

4.3.3 Long-Term Trends in Phosphorus Concentrations in Cherry Creek Reservoir Alluvium

Alluvial phosphorus data were obtained from Halepaska & Associates for Site MW-9, and are used to estimate the alluvial phosphorus load component, as summarized in Appendix D (JCHA 2001 through 2010). Given the ability of alluvium to filter out particulates, total dissolved phosphorus was used as a surrogate to total phosphorus. Alluvial total dissolved phosphorus concentrations show a slight, but significant ($p < 0.05$), increasing trend over time (1994 to 2011) at Site MW-9 (Figure 30).

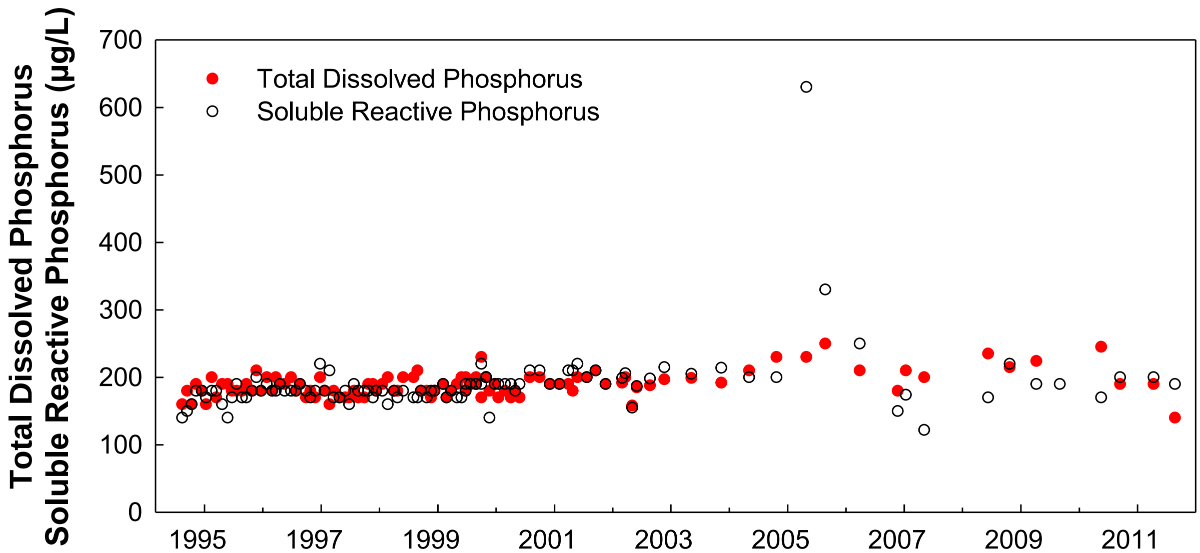


Figure 30: Total dissolved phosphorus and soluble reactive phosphorus concentrations measured at Site MW-9, 1994 to 2011.

4.4 Reservoir Phosphorus Loads and Export

Nutrients that limit or enhance algal growth in Cherry Creek Reservoir have many sources, both within the Reservoir (internal loading) or from outside the Reservoir (external loading). The direct release of nutrients from sediment, fish and plankton excrement, and the decay of organic matter are all internal sources of nutrients in a reservoir (Horne and Goldman 1994). However, the release of phosphorus from sediment during anoxic water conditions is the most substantial component of internal loading and is approximately 2,000 pounds per year in Cherry Creek Reservoir (Nürnberg and LaZerte 2008). Other studies evaluating internal loading from the sediments suggest lower estimates of internal phosphorus loading ranging between 810 lbs/yr and 1,590 lbs/yr (AMEC et al. 2005).

External sources of nutrients include flow from streams, direct precipitation and the alluvium, which carry nutrients from soil erosion, agricultural and residential runoff, treated wastewater, and airborne particulates. While both phosphorus and nitrogen are potentially important, past studies have concluded that Cherry Creek Reservoir was generally phosphorus limited

(DRCOG 1985). However, a more recent nutrient enrichment study by Lewis et al. (2004) indicated that nitrogen was often the primary limiting nutrient in Cherry Creek Reservoir during the growing season.

Phosphorus (unlike nitrogen) does not have a gas phase. Thus, phosphorus concentrations cannot be reduced by interactions with the atmosphere or gases within the water column. For these reasons, efforts in past years and during the present study have focused on phosphorus loading and flow-weighted phosphorus concentrations. Total phosphorus loads were determined for several primary sources, including the tributary streams Cherry Creek, Shop Creek, and Cottonwood Creek, as well as from precipitation and alluvium, as summarized in Appendix D. The flow-weighted concentrations simply represent the relationship between the total annual phosphorus load divided by total annual flow at a site.

4.4.1 Phosphorus Load from Tributary Streams

Monthly base flow phosphorus concentrations, along with the annual storm flow median concentration were applied to their respective flow to estimate loads for each stream site. Stream flows that were greater than the 90th percentile of all flows measured during the respective year and for that site were categorized as storm flows. The greatest proportion (79%) of the normalized total phosphorus load to the Reservoir was from Cherry Creek mainstem flows (7,237 lbs). Because Cherry Creek is monitored downstream of Shop Creek, the 117 lbs (<1%) contributed by Shop Creek has been subtracted from the normalized total load calculated for Site CC-10. Cottonwood Creek accounted for 7% of the phosphorus load, or 653 lbs. During the 2011 WY, the total phosphorus load to Cherry Creek Reservoir from tributary streams was 8,009 lbs and includes no ungaged residual phosphorus load (Table 9).

4.4.2 Phosphorus Export from Reservoir Outflow

The total outflow from Cherry Creek Reservoir as measured by the USACE was 14,010 acre-feet in 2011 (Appendix D). Monthly total phosphorus data collected from Site CC-O near the dam outlet was used to estimate the phosphorus export (4,032 lbs/yr) leaving the Reservoir in 2011 (Table 9).

Table 9: Normalized phosphorus loads and export (lbs/year) for Cherry Creek Reservoir, 1992 to 2011 WY.

Water Year	Cherry Creek Load	Cottonwood Creek Load	Stream & Ungaged Residual Load	Cherry Creek Alluvial Load	Direct Precipitation Load	External Load	Cherry Creek Export	Net External Load
1992*	3,007	344	3,700	750	350	4,800	1,376	3,424
1993	1,534	233	1,854	1,026	305	3,185	995	2,190
1994	2,524	169	2,788	876	264	3,929	1,016	2,912
1995	2,081	1,400	3,989	996	592	5,576	1,377	4,200
1996	2,587	602	3,287	941	343	4,571	1,418	3,153
1997	2,159	622	2,894	1,008	436	4,338	1,140	3,198
1998	10,107	1,827	12,203	1,033	437	13,673	4,100	9,572
1999	10,606	1,279	14,950	1,033	526	16,508	6,363	10,145
2000	11,822	1,384	13,206	1,034	358	14,598	4,113	10,485
2001	6,293	2,108	8,647	1,033	397	10,077	5,524	4,553
2002	2,098	443	2,540	916	295	3,751	1,971	1,781
2003	6,215	1,055	7,894	1,033	445	9,372	4,774	4,598
2004	4,316	1,643	5,983	1,034	369	7,386	2,682	4,703
2005	8,770	1,351	10,121	1,033	372	11,526	3,964	7,562
2006	3,580	1,230	4,810	1,033	340	6,184	3,251	2,932
2007	15,999	2,075	18,209	1,033	369	19,611	7,891	11,721
2008	7,263	833	8,096	1,016	276	9,388	4,785	4,603
2009	13,608	937	14,607	1,033	424	16,063	9,483	6,581
2010	12,065	1,039	13,104	1,003	389	14,496	7,880	6,616
2011	7,354	655	8,009	1,025	278	9,312	4,113	5,179
Median	**6,254**	**1,047**	**7,951**	**1,029**	**369**	**9,341**	**4,032**	**4,600**

* 1992 WY totals are calculated using January through September data.

4.4.3 Phosphorus Load from Precipitation

During the 2011 WY, a total of 12.4 inches of precipitation was recorded at the KAPA meteorological station located at Centennial Airport (as of 30 September 2011). When scaled to the areal extent of the Reservoir (852 acres), precipitation accounted for a total of 878 acre-feet of inflow to the Reservoir. The long-term (1995 to 2005) median total phosphorus concentration of 116 µg/L was used to calculate the 2011 WY total phosphorus load of 277 lbs/yr. This long-term median TP concentration represents a combination of dry fall and precipitation as measured near the Reservoir. The long-term median total phosphorus load from precipitation events collected from 1992 to 2011 is 369 lbs (Table 9).

4.4.4 Phosphorus Load from Alluvium

In 2011, the alluvial inflow constant of 2,000 was reduced during the normalization process to account for an imbalance of flows in August. Extremely low flows reported by the USACE for August 2011 substantially reduced the measured stream flows to ZERO for sites CC-10 and CT-2, and reduced alluvial flows during the normalization process to 1,983 ac-ft/yr (see Appendix D). The long-term (1994 to 2006) median total dissolved phosphorus concentration of alluvial flows from Site MW-9 is 190 µg/L. The alluvial phosphorus load to the Reservoir was estimated to be 1,025 lbs in 2011 (Table 9).

4.4.5 Mass Balance/Net Loading of Phosphorus to the Reservoir

The USACE calculates daily inflow to Cherry Creek Reservoir as a function of change in storage (i.e., reservoir volume) based on: 1) changes in reservoir level; 2) measured outflow; 3) precipitation; and 4) evaporation. This method for calculating reservoir volume accounts for groundwater inflow via alluvium, but does not directly quantify the flow. GEI monitors surface water inflow to the Reservoir using gaged stations on the three main surface inflows, Cherry Creek, Cottonwood Creek, and Shop Creek. Given the differences in the two methods for determining inflow, combined with the potential for unmonitored multiple Cherry Creek channels in the wetlands adjacent to the Reservoir, unmonitored surface flow (i.e., Belleview and Quincy drainages), and the potential for the USACE calculations to underestimate dam leakage (Lewis and Saunders 2002), an exact match between USACE and GEI calculated inflows is not expected.

During the 2011 WY, the USACE calculated inflow was 16,120 ac-ft/yr, while GEI calculated stream inflow was 15,065 ac-ft/yr (Appendix D). To compare these two inflow values, the USACE inflow was adjusted for precipitation (879 ac-ft/yr) and alluvial inflows (1,983 ac-ft/yr), which resulted in an adjusted USACE inflow of 13,241 ac-ft/yr. The difference between the adjusted USACE inflow and the GEI stream inflow was 1,823 acre-feet of water. This water volume difference was reapportioned between Cherry Creek (74%), Cottonwood Creek (26%), and Ungaged Inflow (0%). Flow-weighted total phosphorus concentrations for Cherry Creek and Cottonwood Creek were used to calculate the combined reapportioned load of 1,055 lbs.

Following the water balance normalization process, flow from the two tributary streams accounted for a total phosphorus load of 8,009 lbs to the Reservoir during the 2011 WY (Figure 31). The alluvial inflow contributed 1,025 lbs of phosphorus, with precipitation events contributing 278 lbs to the Reservoir. The total external load of phosphorus to the Reservoir in 2011 was 9,312 lbs (Figure 31).

The Reservoir outflow phosphorus load was estimated to be 4,113 lbs. The flow-weighted total phosphorus concentration for all external sources of inflow to the Reservoir is 212 µg/L and the flow-weighted export concentration for the Reservoir is 108 µg/L (Table 10). The difference of 104 µg/L was retained by the Reservoir. The net external phosphorus load to the Reservoir was 4,806 lbs during the 2011 WY.

Table 10: Flow-weighted phosphorus concentrations (µg/L) for Cherry Creek Reservoir, 1992 to 2011 WY.

Water Year	Cherry Creek Flow-weighted Concentration	Cottonwood Creek Flow-weighted Concentration	Inflow Flow-weighted Concentration	Outflow Flow-weighted Concentration
1992	268	172	220	95
1993	251	189	199	91
1994	247	88	196	77
1995	190	203	179	63
1996	234	331	211	89
1997	266	184	201	89
1998	282	176	238	81
1999	271	134	235	101
2000	312	159	265	83
2001	257	130	198	127
2002	221	88	171	107
2003	287	138	229	140
2004	247	157	201	96
2005	247	120	208	78
2006	231	132	187	115
2007	295	149	254	115
2008	205	84	177	104
2009	276	62	218	148
2010	239	78	200	115
2011	263	81	212	108
Median	**254**	**136**	**205**	**99**

The effectiveness of the Authority's efforts in reducing flow-weighted phosphorus concentrations entering the Reservoir is illustrated by the concentrations observed along Cottonwood Creek (Table 10). During the past few years, the effectiveness of the Cottonwood Reclamation Project combined with the effectiveness of sediment removal at the Peoria Pond appear to have greatly reduced the amount of phosphorus mobilized within this system. At the most upstream monitoring location (CT-P1), the annual flow-weighted total phosphorus concentration was 153 µg/L. The phosphorus level in Cottonwood Creek flow was greatly reduced by the Cottonwood Creek Peoria Wetland System, and was further reduced through the stream restoration reach before the flow entered the Perimeter Pond PRF. The normalized flow-weighted concentration of 81 µg/L at Site CT-2 is still on the low end of the observed inflow concentrations for Cottonwood Creek since 1992.

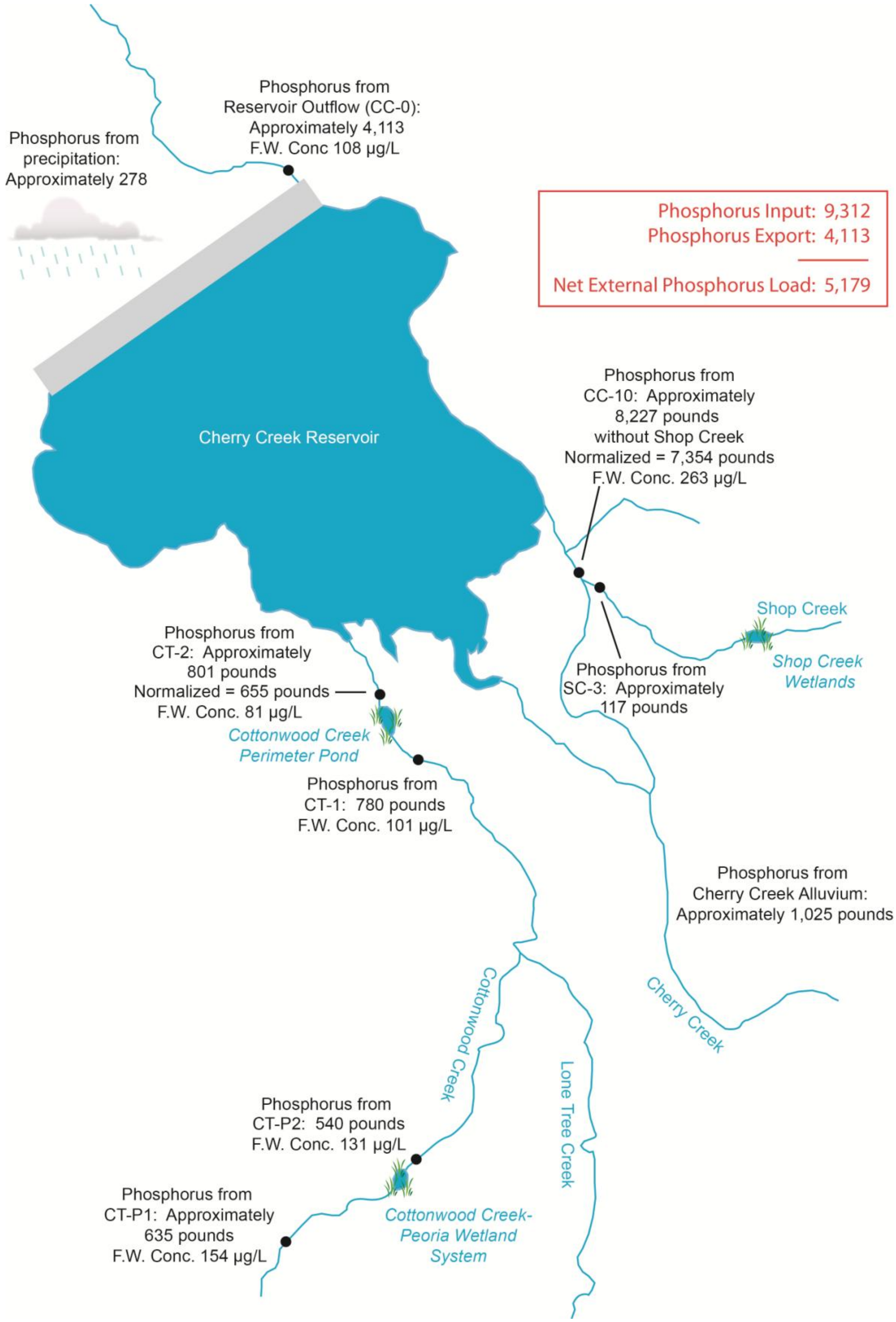


Figure 31: Mass balance diagram of phosphorus loading in Cherry Creek Reservoir, 2011 WY.

4.5 Effectiveness of Pollutant Reduction Facilities

4.5.1 Cottonwood Creek Peoria Pond

The effectiveness of the Cottonwood Creek Peoria Pond is gaged by monitoring the concentrations of phosphorus and TSS, and the flow-weighted phosphorus concentrations upstream and downstream of the facility. Notably, the loads and flows used to evaluate the effectiveness of the PRF are not affected by the "normalization" of GEI inflow to USACE inflow values for Cherry Creek Reservoir.

This PRF continues to be effective in reducing the amount of total suspended solids and total phosphorus as stream flow passes through this system. The total suspended solids were reduced by approximately 38% in 2011, with the long-term average showing a 20% reduction. The flow-weighted total phosphorus concentration upstream and downstream of the PRF was 153 µg/L and 131 µg/L, respectively, which indicates a high efficiency in removing phosphorus from flow (Table 11). Over the life of the project, the PRF shows approximately a 14% reduction in the flow-weighted total phosphorus concentration at the downstream site.

Table 11: Historical total phosphorus and total suspended solids concentrations and total phosphorus loads upstream and downstream of the Cottonwood Creek – Peoria Pond, 2002 to 2011 WY.

Parameter	Water Year	Sampling Sites		Difference	Percent Change Downstream
		CT-P1	CT-P2		
Mean Total Suspended Solids (mg/L)	2002	81	74	-7	-9
	2003	30	33	3	10
	2004	104	51	-53	-51
	2005	50	53	3	6
	2006	13	13	0	0
	2007	78	41	-37	-47
	2008*	36	34	-2	-6
	2009	48	27	-21	-44
	2010	34	26	-8	-24
	2011	48	30	-18	-38
	Mean	**52**	**38**	**-14**	**-20**
Flow-weighted Total Phosphorus Concentration (µg/L)	2002	142	118	-24	-17
	2003	117	109	-8	-7
	2004	132	132	0	0
	2005	129	119	-10	-8
	2006	146	140	-6	-4
	2007	156	120	-36	-23
	2008*	128	92	-36	-28
	2009	114	83	-31	-27
	2010	106	96	-10	-9
	2011	153	131	-22	-14
	Mean	**132**	**114**	**-18**	**-14**

* Eight months of operation.

4.5.2 Cottonwood Creek Perimeter Pond

The effectiveness of the Cottonwood Creek storm water Perimeter Pond in reducing phosphorus loads to the Reservoir is similarly gaged by comparing data from sites upstream and downstream of the PRF (Table 12). In 2011, this PRF continues to be variable in its removal efficiency of both total suspended solids and total phosphorus. During the 2010 WY the PRF was not effective, while in 2011 it again showed some effectiveness in removing both suspended sediment and total phosphorus. As of January 2012, this PRF is currently being renovated for sediment removal and maintenance. In 2011, the mean concentration of TSS decreased from 48 mg/L upstream to 30 mg/L downstream of the PRF (Table 12). The flow-weighted total phosphorus concentration also decreased downstream of the PRF by 20%, with the flow-weighted concentration entering the Reservoir from Cottonwood Creek being 81 µg/L.

Since the completion of the Cottonwood Creek Reclamation Project in 2008, the flow-weighted total phosphorus concentrations at both sites CT-1 and CT-2 have decreased by approximately 40 and 45%, respectively. Similar reductions have occurred in the suspended solids concentrations at these sites. Prior to the reclamation project, the mean flow-weighted total phosphorus concentration for Cottonwood Creek was 142 µg/L, whereas the flow-weighted concentration has been less than 81 µg/L for the past 3 years. The decrease in suspended solids and total phosphorus concentrations is likely attributed to the relocation of Cottonwood Creek into a wide, shallow channel that slows the velocity of the water and dissipates the hydraulic energy of the flows, reducing the erosion potential through this reach. In addition, the redesigned drop structures along Cottonwood Creek have reduced the erosion potential that has historically occurred within this reach. These data continue to support the Authority's premise that stream stabilization/reclamation provides a water quality benefit to the Cherry Creek Watershed and Reservoir by reducing the amount of suspended solids and phosphorus due to stream bank erosion.

Table 12: Historical total phosphorus and total suspended solids concentrations and total phosphorus loads upstream and downstream of the Cottonwood Creek Perimeter Pond, 1997 to 2011 WY.

Parameter	Water Year	Sampling Sites		Difference	Percent Change Downstream
		CT-1	CT-2		
Average Total Suspended Solids (mg/L)	1997	207	87	-120	-58
	1998	311	129	-182	-59
	1999	267	68	-199	-75
	2000	96	64	-32	-33
	2001	79	43	-36	-46
	2002	150	86	-64	-43
	2003	83	58	-25	-30
	2004	156	128	-28	-18
	2005	123	65	-58	-47
	2006	31	20	-11	-35
	2007	93	64	-29	-31
	2008*	31	59	28	90
	2009	31	32	1	3
	2010	33	33	0	0
	2011	48	30	-18	-38
	Mean	**116**	**64**	**-52**	**-28**
Flow-weighted Total Phosphorus Concentration (µg/L)	1997	485	183	-302	-62
	1998	311	176	-135	-43
	1999	143	129	-14	-10
	2000	266	161	-105	-39
	2001	163	146	-17	-10
	2002	124	105	-19	-15
	2003	193	124	-69	-36
	2004	194	149	-45	-23
	2005	141	120	-21	-15
	2006	165	135	-30	-18
	2007	170	148	-22	-13
	2008*	87	86	-1	-1
	2009	70	61	-9	-13
	2010	77	77	0	0
	2011	101	81	-20	-20
	Mean	**179**	**125**	**-54**	**-21**

* Nine months of operation.

5.0 References

Advanced Sciences, Inc. 1994a. *Cherry Creek Basin, Annual Water-Quality Monitoring Report, 1993 Water Year*. Project No. 8970. Prepared for the Cherry Creek Basin Water Quality Authority.

Advanced Sciences, Inc. 1994b. 1993 Cherry Creek Basin Water Quality Authority Contract: Project 8790. Exhibits A through H (amended).

AMEC, Earth and Environmental, Inc., Alex Horne Associates, and Hydrosphere Resource Consultants, Inc. 2005. *Cherry Creek Reservoir Destratification*. Feasibility report prepared for the Cherry Creek Basin Water Quality Authority.

American Public Health Association (APHA). 1998. *Standard Methods for the Examination of Water and Wastewater*, 20th Edition. Prepared and published jointly by the American Public Health Association, American Water Works Association, and Water Pollution Control Federation, Washington, DC.

Carpenter, S. R., J. F. Kitchell, and J. R. Hodgson. 1985. Cascading trophic interactions and lake productivity. *Bioscience* 35:634-639.

Chadwick Ecological Consultants, Inc.(CEC). 1995. *Cherry Creek Reservoir Annual Aquatic Biological and Nutrient Monitoring Study, 1994*. Prepared for the Cherry Creek Basin Water Quality Authority.

Chadwick Ecological Consultants, Inc. (CEC). 1996. *Cherry Creek Reservoir Annual Aquatic Biological and Nutrient Monitoring Study, 1995*. Prepared for the Cherry Creek Basin Water Quality Authority.

Chadwick Ecological Consultants, Inc. (CEC). 1997. *Cherry Creek Reservoir Annual Aquatic Biological and Nutrient Monitoring Study, 1996*. Prepared for the Cherry Creek Basin Water Quality Authority.

Chadwick Ecological Consultants, Inc. (CEC). 1998a. *Analysis of Phosphorus Loads to Cherry Creek Reservoir*. Prepared for the Cherry Creek Basin Water Quality Authority.

Chadwick Ecological Consultants, Inc. (CEC). 1998b. *Cherry Creek Reservoir Annual Aquatic Biological and Nutrient Monitoring Study, 1997*. Prepared for the Cherry Creek Basin Water Quality Authority.

Chadwick Ecological Consultants, Inc. (CEC). 1999. *Cherry Creek Reservoir 1998 Annual Aquatic Biological and Nutrient Monitoring Study*. Prepared for the Cherry Creek Basin Water Quality Authority.

Chadwick Ecological Consultants, Inc. (CEC). 2000. *Cherry Creek Reservoir 1999 Annual Aquatic Biological and Nutrient Monitoring Study*. Prepared for the Cherry Creek Basin Water Quality Authority.

Chadwick Ecological Consultants, Inc. (CEC). 2001. *Cherry Creek Reservoir 2000 Annual Aquatic Biological and Nutrient Monitoring Study*. Prepared for the Cherry Creek Basin Water Quality Authority.

Chadwick Ecological Consultants, Inc. (CEC). 2002. *Cherry Creek Reservoir 2001 Annual Aquatic Biological and Nutrient Monitoring Study*. Prepared for the Cherry Creek Basin Water Quality Authority.

Chadwick Ecological Consultants, Inc. (CEC). 2003a. *Cherry Creek Reservoir 2002 Annual Aquatic Biological and Nutrient Monitoring Study and Cottonwood Creek Phosphorus Reduction Facility Monitoring*. Prepared for the Cherry Creek Basin Water Quality Authority.

Chadwick Ecological Consultants, Inc. (CEC). 2004. *Cherry Creek Reservoir 2003 Annual Aquatic Biological and Nutrient Monitoring Study and Cottonwood Creek Phosphorus Reduction Facility Monitoring*. Prepared for the Cherry Creek Basin Water Quality Authority.

Chadwick Ecological Consultants, Inc. (CEC). 2005. *Cherry Creek Reservoir 2004 Annual Aquatic Biological and Nutrient Monitoring Study and Cottonwood Creek Phosphorus Reduction Facility Monitoring*. Prepared for the Cherry Creek Basin Water Quality Authority.

Chadwick Ecological Consultants, Inc. (CEC). 2006. *Cherry Creek Reservoir 2005 Annual Aquatic Biological and Nutrient Monitoring Study and Cottonwood Creek Phosphorus Reduction Facility Monitoring*. Prepared for the Cherry Creek Basin Water Quality Authority.

Cole, G. A. 1979. *Textbook of Limnology*, 2nd Edition. The C.V. Mosby Company, St. Louis, MO.

Colorado Department of Public Health and Environment (CDPHE). 2011. *Section 303(d) Listing Methodology: 2012 Listing Cycle.* Water Quality Control Division, Denver, CO.

Cooke, D. C., E. B. Welch, S. A. Peterson, and P.R. Newroth. 1993. *Restoration & Management of Lakes & Reservoirs*, 2nd Edition. Lewis Publishers, Boca Raton, FL.

Denver Regional Council of Governments (DRCOG). 1984. *Cherry Creek Reservoir Clean Lakes Study*. Denver Regional Council of Governments, Denver, CO.

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

GEI Consultants, Inc. (GEI). 2007. *Cherry Creek Reservoir 2006 Annual Aquatic Biological and Nutrient Monitoring Study and Cottonwood Creek Phosphorus Reduction Facility Monitoring*. Prepared for the Cherry Creek Basin Water Quality Authority.

GEI Consultants, Inc. (GEI). 2008a. *Cherry Creek Reservoir Aquatic Biological and Nutrient Sampling and Laboratory Analyses, Sampling, Analysis, and Quality Assurance Work Plan. April 2008.* Prepared for the Cherry Creek Basin Water Quality Authority.

GEI Consultants, Inc. (GEI). 2008b. *Cherry Creek Reservoir 2007 Annual Aquatic Biological and Nutrient Monitoring Study and Cottonwood Creek Phosphorus Reduction Facility Monitoring*. Prepared for the Cherry Creek Basin Water Quality Authority.

GEI Consultants, Inc. (GEI). 2009. *Cherry Creek Reservoir 2008 Annual Aquatic Biological and Nutrient Monitoring Study and Cottonwood Creek Phosphorus Reduction Facility Monitoring*. Prepared for the Cherry Creek Basin Water Quality Authority.

GEI Consultants, Inc. (GEI). 2010. *Cherry Creek Reservoir 2009 Annual Aquatic Biological and Nutrient Monitoring Study and Cottonwood Creek Phosphorus Reduction Facility Monitoring*. Prepared for the Cherry Creek Basin Water Quality Authority.

GEI Consultants, Inc. (GEI). 2011. *Cherry Creek Reservoir 2010 Annual Aquatic Biological and Nutrient Monitoring Study and Cottonwood Creek Phosphorus Reduction Facility Monitoring*. Prepared for the Cherry Creek Basin Water Quality Authority.

Harman, C. D., D. R. Bayne, and M. S. West. 1995. Zooplankton trophic state relationships in four Alabama-Georgia reservoirs. *Lake and Reservoir Management*, 11:4 299-309.

Hintze, J. L. 2001. NCSS and PASS. Number Cruncher Statistical Systems, Kaysville, UT.

Horne, A. J. and C. R. Goldman. 1994. *Limnology*. McGraw-Hill Company, NY.

In-Situ, Inc. 1986 (as amended). *Cherry Creek Reservoir and Cherry Creek Basin Monitoring Program, Southeastern Denver Metropolitan Area, Colorado: Proposal No. 4405*. Prepared for the Cherry Creek Basin Authority, December 3 (with later modifications).

James, W. F., W. D. Taylor, J. W. Barko. 1992. Production and vertical migration of *Ceratium hirundinella* in relation to phosphorus availability in Eau Galle Reservoir, Wisconsin. *Canadian Journal of Fisheries and Aquatic Sciences* 49:694-700.

John C. Halepaska & Associates, Inc. (JCHA). 1999. *1998 Annual Report, Phase I Baseline Water Quality Data Collection Study for the Upper Cherry Creek Basin*. Prepared for the Cherry Creek Basin Water Quality Authority, Project No. 5601:6.

John C. Halepaska & Associates, Inc. (JCHA). 2000. *1999 Annual Report, Phase I Baseline Water Quality Data Collection Study for the Upper Cherry Creek Basin*. Prepared for the Cherry Creek Basin Water Quality Authority.

John C. Halepaska & Associates, Inc. (JCHA). 2001. *2000 Annual Report, Baseline Water Quality Data Collection Study for the Upper Cherry Creek Basin*. Prepared for the Cherry Creek Basin Water Quality Authority.

John C. Halepaska & Associates, Inc. (JCHA). 2002. *2001 Annual Report, Baseline Water Quality Data Collection Study for the Upper Cherry Creek Basin*. Prepared for the Cherry Creek Basin Water Quality Authority.

John C. Halepaska & Associates, Inc. (JCHA). 2003. *2002 Annual Report, Baseline Water Quality Data Collection Study for the Upper Cherry Creek Basin*. Prepared for the Cherry Creek Basin Water Quality Authority.

John C. Halepaska & Associates, Inc. (JCHA). 2004. *2003 Annual Report, Baseline Water Quality Data Collection Study for the Upper Cherry Creek Basin*. Prepared for the Cherry Creek Basin Water Quality Authority.

John C. Halepaska & Associates, Inc. (JCHA). 2005. *2004 Annual Report, Baseline Water Quality Data Collection Study for the Upper Cherry Creek Basin*. Prepared for the Cherry Creek Basin Water Quality Authority.

John C. Halepaska & Associates, Inc. (JCHA). 2006. *2005 Annual Report, Baseline Water Quality Data Collection Study for the Upper Cherry Creek Basin*. Prepared for the Cherry Creek Basin Water Quality Authority.

John C. Halepaska & Associates, Inc. (JCHA). 2007. *2006 Annual Report, Baseline Water Quality Data Collection Study for the Upper Cherry Creek Basin*. Prepared for the Cherry Creek Basin Water Quality Authority.

John C. Halepaska & Associates, Inc. (JCHA). 2008. *2007 Annual Report, Baseline Water Quality Data Collection Study for the Upper Cherry Creek Basin*. Prepared for the Cherry Creek Basin Water Quality Authority.

John C. Halepaska & Associates, Inc. (JCHA). 2009. *2008 Annual Report, Baseline Water Quality Data Collection Study for the Upper Cherry Creek Basin*. Prepared for the Cherry Creek Basin Water Quality Authority.

John C. Halepaska & Associates, Inc. (JCHA). 2010. *2009 Annual Report, Baseline Water Quality Data Collection Study for the Upper Cherry Creek Basin*. Prepared for the Cherry Creek Basin Water Quality Authority.

Jones, J. R. 1994. *Report on Cherry Creek Reservoir, Summer 1993*. Report to Cherry Creek Basin Water Quality Authority.

Jones, J. R. 1995. *Report on Cherry Creek Reservoir, Summer 1994*. Report to Cherry Creek Basin Water Quality Authority.

Jones, J. R. 1996. *Report on Cherry Creek Reservoir, 1995 Sampling Season*. Report to Cherry Creek Basin Water Quality Authority.

Jones, J. R. 1997. *Report on Cherry Creek Reservoir, 1996 Sampling Season*. Report to Cherry Creek Basin Water Quality Authority.

Jones, J. R. 1998. *Report on Cherry Creek Reservoir, 1997 Sampling Season*. Report to Cherry Creek Basin Water Quality Authority.

Jones, J. R. 1999. *Report on Cherry Creek Reservoir, 1998 Sampling Season*. Report to Cherry Creek Basin Water Quality Authority.

Jones, J. R. 2001. *Report on Cherry Creek Reservoir, 1992-2001 and Historical Data*. Report to Cherry Creek Basin Water Quality Authority.

Kilham, S. S., D. A. Kreeger, C. E. Goulden, and S. G. Lynn. 1997. Effects of nutrient limitation on biochemical constituents of *Ankistrodesmus falcatus*. *Freshwater Biology* 38:591-596.

Konopka, A. and T. D. Brock. 1978. Effect of temperature on blue-green algae (Cyanobacteria) in Lake Mendota. *Applied and Environmental Microbiology* 36:572-576.

Knowlton, M. R., and J. R. Jones. 1993. *Limnological Investigations of Cherry Creek Lake*. Final report to Cherry Creek Basin Water Quality Authority.

Komárek, J., H. Kling, and J. Komáaková. 2003. Filamentous Cyanobacteria. Pp 117-196 *in* Wehr, J. D. and R. G. Sheath (eds.). *Freshwater Algae of North America: Ecology and Classification.* Academic Press, Burlington, MA.

Kugrens, P. and B. L. Clay. 2003. Cryptomonads. Pp. 715-755 *in* Wehr, J. D. and R. G. Sheath (eds.). *Freshwater Algae of North America: Ecology and Classification.* Academic Press, Burlington, MA.

Lewis, W. M., and J. F. Saunders. 2002. *Review and Analysis of Hydrologic Information on cherry Creek Watershed and Cherry Creek Reservoir*. Prepared for the Cherry Creek Basin Water Quality Authority.

Lewis, W. M., J. F. Saunders, and J. H. McCutchan. 2004. *Studies of Phytoplankton Response to Nutrient Enrichment in Cherry Creek Reservoir, Colorado.* Prepared for Colorado Department of Public Health and Environment, Water Quality Control Division.

Lewis, W. M., J. H. McCutchan, and J. F. Saunders. 2005. *Estimation of Groundwater Flow into Cherry Creek Reservoir and its Relationship to the Phosphorous Budget of the Reservoir*. Prepared for the Cherry Creek Basin Water Quality Authority.

Mazumder, A. 1994. Phosphorus-chlorophyll relationships under contrasting zooplankton community structure: potential mechanisms. *Canadian Journal of Fisheries and Aquatic Sciences* 51:401-407.

Mazumder, A. and D. R. S. Lean. 1994. Consumer dependent responses of lake ecosystems to nutrient loading. *Journal of Plankton Research* 16:1567-1580.

Nürnberg, G., and LaZerte, B. 2008. *Cherry Creek Reservoir Model and Proposed Chlorophyll Standard*. Prepared for the Cherry Creek Basin Water Quality Authority.

Padisák, J. 1985. Population dynamics of the freshwater dinoflagellate *Ceratium hirundinella* in the largest shallow lake of Central Europe, Lake Balaton, Hungary. *Freshwater Biology* 15:43-52.

Pollingher, U. 1987. Freshwater ecosystems, *in* Taylor, F. J. R. (ed.). *The Biology of Dinoflagellates.* Blackwell Science, Malden, MA.

Reynolds, C. S. 1984. Phytoplankton periodicity: The interactions of form, function, and environmental variability. *Freshwater Biology* 14:111-142.

Sarnelle, O. 1992. Nutrient enrichment and grazer effects on phytoplankton in lakes. *Ecology* 73:51-56.

Sarnelle, O. 1993. Herbivore effects on phytoplankton succession in a eutrophic lake. *Ecological Monographs* 63:129-149.

SPSS, 2006. SPSS 15.0 for Windows. Release 15.0.0 (6 Sep 2006).

Stemberger, R. S., and J. J. Gilbert. 1985. Body size, food concentration and population growth in planktonic rotifers. *Ecology* 66:1151-1159.

Vanni, M. J., and J. Temte. 1990. Seasonal patterns of grazing and nutrient limitation of phytoplankton in a eutrophic lake. *Limnology and Oceanography* 35:697-709.

Vanni, M. J., and C. D. Layne. 1996. Nutrient recycling and herbivory as mechanisms in the top-down effect of fish on algae in lakes. *Ecology* 78:21-40.

Vanni, M. J., C. D. Layne, and S. E. Arnott. 1996. Top-down trophic interactions in lakes: effects of fish on nutrient dynamics. *Ecology* 78:1-20.

Wetzel, R. G. 2001. *Limnology*, 3rd Edition. Academic Press, San Diego, CA.

Whitton, B. A. and M. Potts (eds.). 2000. *The Ecology of Cyanobacteria: Their diversity in time and Space*. Kluwer Academic, Boston, MA.

Appendix A

Cherry Creek Reservoir Sampling and Analysis Plan

GEI Consultants

Geotechnical
Water Resources
Environmental and
Ecological Services

Cherry Creek Reservoir Aquatic Biological and Nutrient Sampling and Laboratory Analysis Sampling, Analysis, and Quality Assurance Work Plan

Submitted to:
Cherry Creek Basin Water Quality Authority
R.S. Wells LLC
8390 East Crescent Parkway, Suite 500
Greenwood Village, CO 80111

Submitted by:
GEI Consultants, Inc.
Ecological Division
5575 South Sycamore Street, Suite 101
Littleton, CO 80120

April 2008
Project 062450

Table of Contents

List of Tables

List of Figures

1.0 Introduction

An inter-governmental agreement was executed in 1985 by several local governmental entities within the Cherry Creek basin to form the Cherry Creek Basin Water Quality Authority (Authority). The Authority, initially created by an intergovernmental agreement, was specially authorized by legislation adopted in 1988. The Authority develops and implements the means to protect the water quality of Cherry Creek Basin and Reservoir. Following legislation in 2001, the Board was reconstituted to include Arapahoe and Douglas County, seven municipalities (Aurora, Castle Rock, Centennial, Foxfield, Greenwood Village, Lone Tree, and Parker), one member representing the seven special districts (Arapahoe, Cottonwood, Inverness, Meridian, Parker, Pinery, and Stonegate Village), and seven citizens appointed by the governor. The Authority was created for the purpose of coordinating and implementing the investigations necessary to protect and to preserve the quality of water resources of the Cherry Creek basin while allowing for further economic development.

The Cherry Creek Basin Master Plan (DRCOG 1985), approved by the Colorado Water Quality Control Commission (CWQCC) in 1985, was adopted in part as the "Regulations for Control of Water Quality in Cherry Creek Reservoir" (Section 4.2.0, 5C.C.R.3.8.11). An annual monitoring program was implemented at the end of April 1987 to assist in the assessment of several aspects of the Master Plan. These monitoring studies have included long-term monitoring of 1) nutrient levels within the reservoir and from tributary streams during base flows and storm flows, 2) nutrient levels in precipitation, and 3) chlorophyll *a* levels within the reservoir. This monitoring program has been modified over the years in response to changes in the Control Regulation, various research goals, and suggestions from outside reviewers, including input from the Water Quality Control Division (WQCD).

2.0 Project Description

The Authority has prepared this Sampling, Analysis, and Quality Assurance Work Plan (Sampling and Analysis Plan) for aquatic biological nutrient analyses to be conducted on Cherry Creek Reservoir and selected off-lake sampling sites in 2008. This Sampling and Analysis Plan identifies field and laboratory protocols necessary to achieve quality data designed to help characterize the potential relationships between nutrient loading (both in-lake and external) and reservoir productivity. The specific objectives of the Sampling and Analysis Plan study are:

1. Determine the concentrations of selected nutrients, primarily phosphorus and nitrogen species, in Cherry Creek Reservoir as well as in various streams flowing into the reservoir and measure nutrients in the reservoir outflow.

2. Determine the annual phosphorus load entering Cherry Creek Reservoir from streams and precipitation and the phosphorus export from the reservoir via the outlet structure.

3. Determine biological productivity in Cherry Creek Reservoir, as measured by chlorophyll *a* concentrations and algal densities.

4. Provide data on the effectiveness of pollutant removal from Pollutant Removal Facilities (PRF) constructed by the Authority.

5. Provide data on the effectiveness of the destratification system at mixing the reservoir water column.

This Sampling and Analysis Plan presents the proposed 2008 sampling and analyses requirements for Cherry Creek Reservoir and includes discussions of: 1) project organization and responsibilities; 2) quality assurance objectives for the measurement of data in terms of accuracy, representativeness, comparability, and completeness; 3) field sampling and sample preservation procedures; 4) laboratory processing and analytical procedures; and 5) guidelines for data verification and reporting, quality control checks, corrective actions, and quality assurance reporting.

3.0 Project Organization and Responsibilities

All personnel involved in the investigation and in the generation of data are implicitly a part of the overall project and quality assurance program. Certain individuals have specifically delegated responsibilities, as described below.

3.1 Project Manager

Steven Canton is the Project Manager who 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 review all work products.
- Evaluate impacts on project objectives and the need for corrective actions based on quality control checks.
- Review and update of this Sampling and Analysis Plan as needed.

3.2 Quality Assurance Manager

Craig Wolf is the Quality Assurance Manager who is responsible for the aquatic biological and field sampling portions of the study 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 central file, which contains or indicates the location of all documents relating to this project.
- Coordinate with the Authority, the WQCD, and the Authority's other consultants to ensure compliance with the Cherry Creek Reservoir Control Regulation No. 72.

3.3 Analytical and Biological Laboratory Managers

Suzanne Pargee is the Analytical Laboratory Manager who 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.

GEI subcontracts the phytoplankton identification and enumeration to the University of Colorado, Center for Limnology. This Center for Limnology 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.

3.4 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.

4.0 Aquatic Biological and Nutrient Sampling

4.1 Reservoir Monitoring Sites

Sampling would be conducted at sites established during past sampling efforts, as modified herein (see Figure 1 for location of all sites).

4.1.1 Cherry Creek Reservoir

CCR-1 This site is also called the Dam site, and was established in 1987. CCR-1 corresponds to the northwest area within the lake (Knowlton and Jones, 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 lake (Knowlton and Jones, 1993).

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

4.2 Stream Monitoring Sites

4.2.1 Cherry Creek

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 Shop Creek.

CC-O In 2007, this site was relocated further upstream on Cherry Creek to a location approximately 75 m downstream of the reservoir outflow gates. Site CC-O (i.e., CC-Outflow) provides data to evaluate the water quality of the Reservoir outlet.

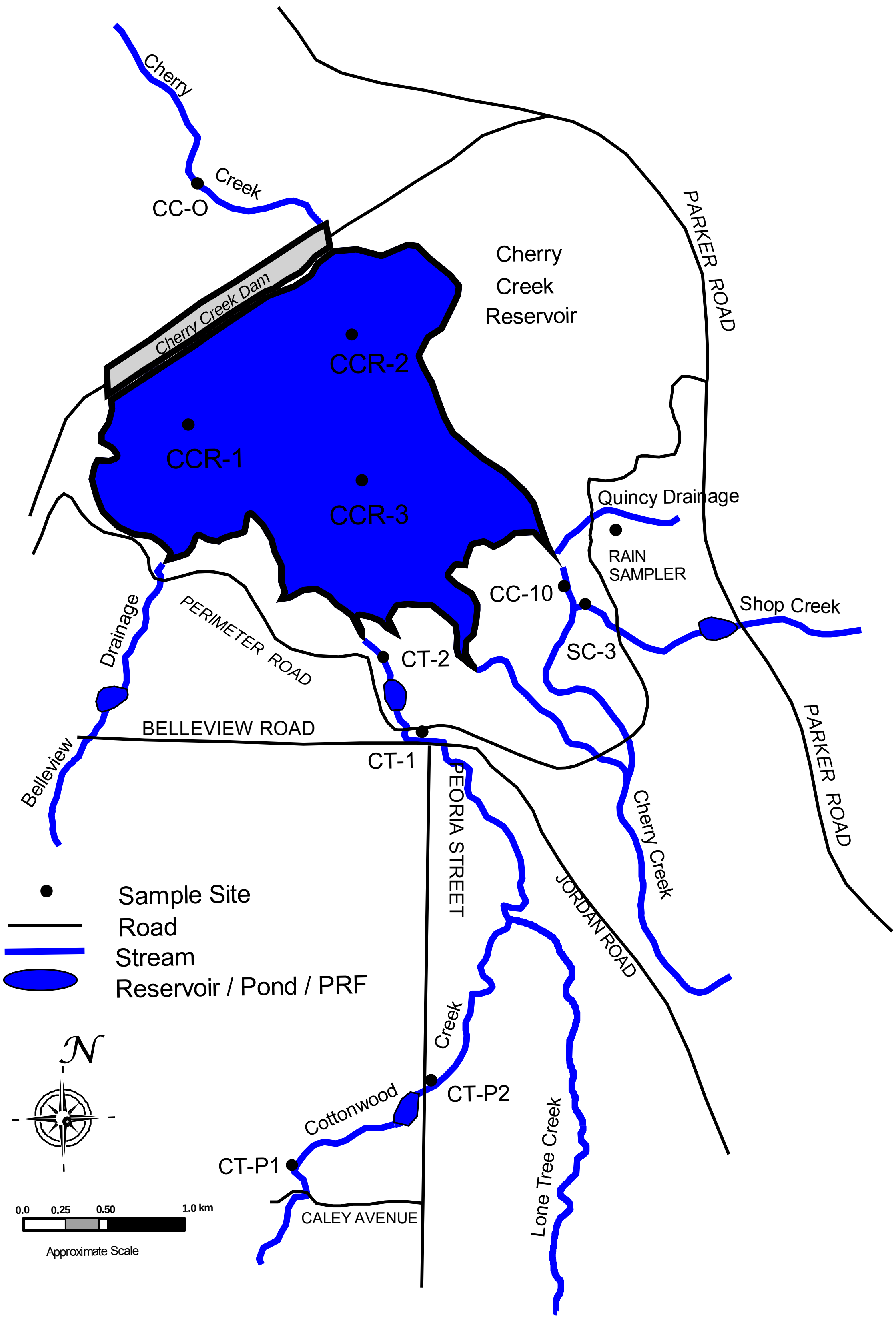


Figure 1: Sampling sites on Cherry Creek Reservoir and selected streams.

4.2.2 Cottonwood Creek

CT-2 This site is contained within the outflow weir structure for the Perimeter Pond PRF, upstream of Cherry Creek Reservoir. This site is included in the reservoir portion of the effort because the data is used to estimate phosphorus loads to the Reservoir from Cottonwood Creek. This site is also used to evaluate the performance of the Perimeter Pond PRF.

4.3 PRF Monitoring Sites

4.3.1 Shop Creek

SC-3 This site is located 35 m upstream of its confluence with Cherry Creek, and is used to monitor the water quality of Shop Creek before it joins Cherry Creek.

4.3.2 Cottonwood Creek

CT-P1 This site is located just north of where Caley Avenue crosses Cottonwood Creek, and west of Peoria Street. This site is used to monitor the water quality of Cottonwood Creek before it enters the Peoria Pond PRF.

CT-P2 This site is located at the outfall of the Peoria Pond PRF, on the west side of Peoria Street. The ISCO stormwater sampler and pressure transducer is located inside the outlet structure. This site is used to evaluate the performance of the PRF on water quality.

CT-1 This site is located 250 m upstream of the Cherry Creek Park Perimeter Road. The Cottonwood Creek Phase II Project will require the relocation of this site in 2008. Note that Site CT-2 is included in the reservoir monitoring requirements.

4.3.3 Precipitation Sampling Site

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.

4.4 Analyte List

The sampling and analyses shall be conducted in accordance with the methods and detection limits provided in Table 1.

Table 1: Standard methods for sample analysis.

Parameter	Abbreviation	Analytical Method*	Recommended Hold Times	Detection Limit
Physicochemical				
Total Nitrogen	TN	4500-N B (modified)	< 24 hrs before digestion; < 7 days after digestion	2 µg/L
Total Dissolved Nitrogen	TDN	4500-N B (modified)	48 hrs	2 µg/L
Nitrate/Nitrite Nitrogen	NO_3+NO_2	4500-NO31	48 hrs	2 µg/L
Ammonium Ion Nitrogen	NH_4	QuickChem 10-107-06	24 hrs	3 µg/L
Total Phosphorus	TP	4500-P G	< 24 hrs before digestion	2 µg/L
Total Dissolved Phosphorus	TDP	4500-P G	48 hrs	2 µg/L
Soluble Reactive Phosphorus	SRP	4500-P G	48 hrs	2 µg/L
Total Suspended Solids	TSS	2540 D	7 days	4 mg/L
Total Volatile Suspended Solids	TVSS	2540 E	7 days	4 mg/L
Biological				
Chlorophyll *a*	Chl	10200 H (modified)	< 24 hrs before filtration	0.1 µg/L
Phytoplankton	--	Standard methods	NA	NA

* Analytical Methods are from American Public Health Association (APHA) 2005, unless otherwise noted.

4.5 Sampling Schedule

4.5.1 Reservoir Sampling

The Reservoir monitoring program includes collecting water quality data from three locations within the Reservoir, CCR-1, CCR-2, and CCR-3, as well as three stream sites, CC-10, CT-2 and CC-O that are important for characterizing the hydrological and mass balance budgets for the Reservoir. The Reservoir sampling schedule generally consists of monthly sampling from January to April and from October to December, with bimonthly reservoir samples collected from May to September (Table 2). Sampling during the winter months (November – February) will depend on ice conditions and safety concerns. The tributary inflow/outflow sites are sampled on a monthly basis from January to December and represent base flow conditions during each month. The sampling schedule for the reservoir and streams sites is summarized below:

Table 2: Cherry Creek reservoir and tributary inflow/outflow sampling.

	Sampling Period	Frequency	Trips/Period
Reservoir Sites CCR-1, CCR-2, and CCR-3	Jan – April	Monthly	4
	May – Sept	Bi-monthly	10
	Oct – Dec	Monthly	3
		Total	**17**
Stream Sites CC-10, CT-2, and CC-O	Jan – Dec	Monthly	12
		Total	**12**

4.5.2 PRF Sampling

The PRF sampling is conducted on a monthly basis, often concurrent with the regular reservoir sampling trips, to represent base flow conditions during each month (Table 3). These samples correspond to the low-flow ambient samples collected during earlier studies.

Table 3: PRF sampling.

Stream Sites CT-P1, CT-P2, CT-1, SC-3	Sampling Period	Frequency	Trips/Period
	Jan – Dec	Monthly	12
		Total	**12**

4.5.3 Storm Flow Sampling

To characterize storm flows, six stream sites are sampled during storm events (i.e., S-3, CC-10, CT-1, CT-2, CT-P1, and CT-P2). Automated samplers collect sequential storm flow samples when a threshold stream level is exceeded for each site. Storm samples are not collected at Site CC-O downstream of the reservoir, unless the Army Corps of Engineers (Corps) alerts the Consultant to an outflow event that could be tied to a storm-related inflow. Up to five storm events shall be collected over the summer for Cherry Creek (Site CC-10) and on Shop Creek (Site S-3). Up to seven storm events shall be collected at the four sites on Cottonwood Creek (CT-1, CT-2, CT-P1, and CT-P2). The actual number of storm events for which samples are obtained will be subject to weather patterns. The recommended storm sampling period is April through September to attempt to capture some of the late spring snowmelt events as well as the summer "monsoon" season.

4.5.4 Precipitation Sampling

Precipitation samples are to be collected after substantial rainfall events, defined as 0.5 inches or more. The sampler shall be inspected weekly and emptied of any accumulations of insignificant precipitation and the collector (inverted trash can lid) cleaned. This procedure is required to minimize small amounts of precipitation contaminating the sample between larger precipitation events.

4.6 Field Methodologies

4.6.1 Reservoir Sampling

4.6.1.1 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 to the nearest tenth of a meter. 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 Licor-1400 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.

4.6.1.2 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 YSI 600XL Multiparameter Sonde. The sonde shall be calibrated at the GEI Laboratory 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.

4.6.1.3 Continuous Temperature Monitoring

The effectiveness of the destratification system at mixing the entire water column would be evaluated by deploying Onset HOBO® Water Temp Pro data loggers at three locations in the Reservoir (CCR-1, CCR-2, and CCR-3). At each site, temperature loggers would be deployed at 1 m increments, including the 0.5 m and bottom depths and configured to collect 15-minute interval temperature data.

The temperature arrays would be deployed using the State Park's buoy system, beginning in March/April and operated through October, with periodic downloading of data to minimize potential loss of data. This deployment schedule would overlap with the proposed operational schedule of the destratification system.

In addition to the temperature loggers at the three monitoring sites, GEI will also perform three monthly ORP profiles during the July to September period at up to ten sample locations along a single transect through the deep-water zone. The sample locations and transect will be consistent with locations previously established by AMEC during their destratification feasibility study. Measurements of ORP will be performed from the waters surface to the sediment interface using the YSI 600XL Multiparameter Sonde.

4.6.1.4 Water Samples

A primary task of the monitoring program is to characterize the chemical and biological constituents of the upper 3m layers of the reservoir. This layer represents the most active layer for algal 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, 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. Three 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.

At Site CCR-2, profile water samples are also collected on one-meter increments, starting from 4 m and continuing down to the 7 m depth. Given the recent lowering of the reservoir level by the USACE, in preparation for a 100-year flood event, the 7 m sample often represents a bottom water sample at Site CCR-2. This sample is collected as close to the water/sediment interface as possible, without 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 as below:

Table 4: Number of reservoir samples collected.

Reservoir Site	Upper 3m 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**

4.6.2 Water Quality Analyses

1. Nutrient analyses shall be performed on all reservoir water samples.
2. Chlorophyll analyses shall be performed on all photic zone composite samples.
3. Phytoplankton analyses shall be performed on all photic zone composite samples.

See Table 1 for the list of analytes, laboratory methods, and detection limits.

4.7 Stream Sampling

One sample shall be collected from each stream site on a monthly basis, when there is sufficient flow. Samples shall be collected as mid-stream mid-depth grab sample using a 5-gallon container. Two one-liter aliquots are collected from this grab sample and stored on ice, until transferred to the GEI laboratory for chemical analyses (Table 5).

4.7.1 Automatic Sampler

Each stream sampling station upstream of the reservoir also contains an Authority-owned ISCO flow meter and sampling device. The flow meter is a pressure transducer that measures stream water level. 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.

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. GEI monitors inflow to the Reservoir using gaging stations on Cherry Creek, Cottonwood Creek, and Shop Creek (the three main surface inflows) 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 GEI calculated inflows is not expected. Therefore, GEI normalizes their streamflow data to match the USACE computed inflow value.

4.7.2 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 Sites S-3, CC-10, CT-1, CT-2, CT-P1, and CT-P2. Following the storm event, water collected by the automatic samplers is combined (timed composite) into a clean 5-gallon container, with two 1-liter 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. During the seasons in which no storm samples are collected, the storm samplers are disabled.

4.8 Precipitation Sampling

After each substantial storm, the sample bottle shall be removed, stored on ice, and transferred to the laboratory for analysis of phosphorus and nitrogen fractions. 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 substantial storm events.

5.0 Laboratory Procedures

5.1 Chemical Laboratory Analysis

Chemical analyses for the water collected in the study (Table 1) will be conducted by a qualified laboratory. Water samples will be analyzed for the parameters listed in Table 5.

Table 5: List of Analytes performed on each type of sample.

Parameter	Reservoir Photic Zone Composite	Reservoir 1 m Interval	Stream Base Flow	Stream Storm Flow	Rain Fall
Physicochemical					
Total Nitrogen	X	X	X	X	X
Total Dissolved Nitrogen	X	X	X	X	X
Nitrate/Nitrite Nitrogen	X	X	X	X	X
Ammonium Ion Nitrogen	X	X	X	X	X
Total Phosphorus	X	X	X	X	X
Total Dissolved Phosphorus	X	X	X	X	X
Soluble Reactive Phosphorus	X	X	X	X	X
Total Suspended Solids	--	--	X	X	--
Total Volatile Suspended Solids	--	--	X	X	--
Biological					
Chlorophyll *a*	X	--	--	--	--
Phytoplankton	X	--	--	--	--

5.2 Biological Laboratory Analysis

Biological analyses for the samples collected in the study, include chlorophyll *a*, phytoplankton identification and enumeration. The methods of these analyses, with appropriate QA/QC procedures shall be in accordance with the methods provided in Table 1. Chlorophyll *a* samples are analyzed by the GEI Analytical Laboratory, while phytoplankton samples are analyzed by the University of Colorado, Center for Limnology.

5.3 Laboratory Quality Assurance/Quality Control Protocols

Analytical 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 and ammonia. If parameters are not in agreement samples are reanalyzed.

6.0 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. At least 10 percent of 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 a 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.

Data shall be summarized and provided to the Authority's Technical Advisory Committee on a monthly basis and presented in an annual report.

7.0 References

American Public Health Association. 2005. *Standard Methods for Examination of Water and Wastewater*, 20th Edition. American Public Health Association, Washington, DC.

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.R., and A.J. Horne. 1983. *Limnology*. McGraw-Hill Company, NY.

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

Knowlton, M.R., and J.R. Jones. 1993. *Limnological Investigations of Cherry Creek Lake*. Final report to Cherry Creek Basin Water Quality Authority.

Appendix B

2011 WY Reservoir Water Quality Data

CCR-1 GEI Water Chemistry Data									
Analytical Detection Limits		**2**	**2**	**2**	**2**	**2**	**2**	**3**	**0.1**
Sample Date	**Sample Name/ Location**	**Total Phosphorous µg/L**	**Total Dissolved Phosphorous µg/L**	**Ortho-phosphate µg/L**	**Total Nitrogen µg/L**	**Total Dissolved Nitrogen µg/L**	**Nitrate+ Nitrite µg/L**	**Ammonia µg/L**	**Average Chlorophyll *a* (mg/m^3)**
10/14/2010	CCR-1 Photic	118	21	12	1,168	607	14	126	45.1
11/16/2010	CCR-1 Photic	28	16	3	916	515	--	9	44.4
1/25/2011	CCR-1 Photic	58	13	4	767	417	3	8	19.9
3/15/2011	CCR-1 Photic	55	8	4	875	432	--	9	23.6
4/20/2011	CCR-1 Photic	98	19	6	1,002	601	--	42	35.7
5/18/2011	CCR-1 Photic	69	32	23	852	523	17	28	16.7
5/31/2011	CCR-1 Photic	71	14	6	787	494	--	13	20.2
6/7/2011	CCR-1 Photic	55	14	4	699	462	--	11	19.4
6/21/2011	CCR-1 Photic	134	74	65	716	512	5	65	8.7
7/5/2011	CCR-1 Photic	128	52	41	821	533	--	22	20.8
7/19/2011	CCR-1 Photic	174	51	44	957	506	--	12	21.2
8/2/2011	CCR-1 Photic	200	87	83	1,178	614	--	42	27.0
8/18/2011	CCR-1 Photic	151	80	65	915	514	--	16	20.8
9/7/2011	CCR-1 Photic	141	60	42	836	521	--	66	22.4
9/20/2011	CCR-1 Photic	123	19	9	1,088	557	--	16	38.4

-- Denotes result less than method detection limit.

CCR-2 GEI Water Chemistry Data									
Analytical Detection Limits		**2**	**2**	**2**	**2**	**2**	**2**	**3**	**0.1**
Sample Date	**Sample Name/ Location**	**Total Phosphorous µg/L**	**Total Dissolved Phosphorous µg/L**	**Ortho-phosphate µg/L**	**Total Nitrogen µg/L**	**Total Dissolved Nitrogen µg/L**	**Nitrate+ Nitrite µg/L**	**Ammonia µg/L**	**Average Chlorophyll *a* (mg/m^3)**
10/14/2010	CCR-2 Photic	101	12	5	1,019	460	--	17	51.9
10/14/2010	CCR-2 4m	102	4	5	977	445	3	23	
10/14/2010	CCR-2 5m	104	6	4	1,214	438	2	23	
10/14/2010	CCR-2 6m	71	10	4	884	456	6	51	
10/14/2010	CCR-2 7m	93	10	5	927	504	8	81	
11/16/2010	CCR-2 Photic	84	14	--	893	519	--	8	48.1
11/16/2010	CCR-2 4m	71	11	--	896	512	--	7	
11/16/2010	CCR-2 5m	77	11	--	906	491	--	8	
11/16/2010	CCR-2 6m	81	12	--	926	496	--	7	
11/16/2010	CCR-2 7m	78	10	--	921	506	--	8	
1/25/2011	CCR-2 Photic	59	11	5	806	450	32	15	23.2
1/25/2011	CCR-2 4m	61	10	2	818	453	33	10	
1/25/2011	CCR-2 5m	62	11	4	857	438	34	7	
1/25/2011	CCR-2 6m	59	10	4	818	442	31	9	
1/25/2011	CCR-2 7m	68	23	3	846	435	33	11	
3/15/2011	CCR-2 Photic	22	10	4	825	424	--	13	26.7
3/15/2011	CCR-2 4m	64	12	5	777	422	--	9	
3/15/2011	CCR-2 5m	54	11	5	817	409	--	9	
3/15/2011	CCR-2 6m	64	12	5	809	492	--	8	
3/15/2011	CCR-2 7m	54	8	4	858	404	--	9	
4/20/2011	CCR-2 Photic	91	19	8	954	556	--	32	25.5
4/20/2011	CCR-2 4m	80	14	8	851	488	--	31	
4/20/2011	CCR-2 5m	69	9	7	854	472	--	29	
4/20/2011	CCR-2 6m	67	11	5	828	458	--	30	
4/20/2011	CCR-2 7m	87	15	6	1053	492	--	30	
5/18/2011	CCR-2 Photic	83	33	25	786	511	40	37	17.9

CCR-2 GEI Water Chemistry Data									
Analytical Detection Limits		2	2	2	2	2	2	3	0.1
Sample Date	Sample Name/ Location	Total Phosphorous µg/L	Total Dissolved Phosphorous µg/L	Ortho-phosphate µg/L	Total Nitrogen µg/L	Total Dissolved Nitrogen µg/L	Nitrate+ Nitrite µg/L	Ammonia µg/L	Average Chlorophyll *a* (mg/m^3)
5/18/2011	CCR-2 4m	78	37	24	793	532	37	29	
5/18/2011	CCR-2 5m	80	27	24	830	500	35	27	
5/18/2011	CCR-2 6m	66	24	22	712	490	29	26	
5/18/2011	CCR-2 7m	62	33	26	708	519	33	45	
5/31/2011	CCR-2 Photic	73	13	5	550	533	--	12	12.4
5/31/2011	CCR-2 4m	73	14	3	750	467	--	9	
5/31/2011	CCR-2 5m	83	16	6	838	459	--	11	
5/31/2011	CCR-2 6m	92	21	13	775	459	--	23	
5/31/2011	CCR-2 7m	126	53	45	820	520	9	77	
6/7/2011	CCR-2 Photic	34	13	5	720	505	--	11	14.3
6/7/2011	CCR-2 4m	63	13	3	593	428	--	6	
6/7/2011	CCR-2 5m	39	14	7	673	464	--	6	
6/7/2011	CCR-2 6m	106	31	25	681	441	--	7	
6/7/2011	CCR-2 7m	135	79	76	695	480	2	64	
6/21/2011	CCR-2 Photic	134	81	75	754	600	5	90	11.4
6/21/2011	CCR-2 4m	126	67	62	679	542	17	42	
6/21/2011	CCR-2 5m	124	67	59	697	517	25	42	
6/21/2011	CCR-2 6m	141	71	60	749	517	39	48	
6/21/2011	CCR-2 7m	211	106	96	883	620	114	69	
7/5/2011	CCR-2 Photic	140	57	46	936	572	2	36	22.4
7/5/2011	CCR-2 4m	135	54	46	766	434	--	12	
7/5/2011	CCR-2 5m	141	57	46	764	446	--	13	
7/5/2011	CCR-2 6m	138	67	57	721	455	--	11	
7/5/2011	CCR-2 7m	181	100	88	753	450	--	17	
7/19/2011	CCR-2 Photic	187	51	43	1,231	641	--	18	30.0
7/19/2011	CCR-2 4m	167	87	84	787	461	--	10	

CCR-2 GEI Water Chemistry Data									
Analytical Detection Limits		**2**	**2**	**2**	**2**	**2**	**2**	**3**	**0.1**
Sample Date	**Sample Name/ Location**	**Total Phosphorous µg/L**	**Total Dissolved Phosphorous µg/L**	**Ortho-phosphate µg/L**	**Total Nitrogen µg/L**	**Total Dissolved Nitrogen µg/L**	**Nitrate+ Nitrite µg/L**	**Ammonia µg/L**	**Average Chlorophyll *a* (mg/m^3)**
7/19/2011	CCR-2 5m	163	108	107	750	474	--	13	
7/19/2011	CCR-2 6m	176	106	103	716	472	--	9	
7/19/2011	CCR-2 7m	270	187	187	786	516	--	67	
8/2/2011	CCR-2 Photic	205	87	77	1,158	565	--	33	31.0
8/2/2011	CCR-2 4m	193	104	97	877	517	--	88	
8/2/2011	CCR-2 5m	186	106	105	900	553	--	114	
8/2/2011	CCR-2 6m	209	148	140	861	567	--	180	
8/2/2011	CCR-2 7m	236	162	159	884	555	--	166	
8/18/2011	CCR-2 Photic	166	73	61	1,151	610	--	27	29.9
8/18/2011	CCR-2 4m	165	89	76	838	499	--	51	
8/18/2011	CCR-2 5m	150	92	80	836	530	--	69	
8/18/2011	CCR-2 6m	165	100	86	859	549	--	97	
8/18/2011	CCR-2 7m	208	103	98	1,010	579	--	158	
9/7/2011	CCR-2 Photic	126	62	48	804	548	--	76	15.0
9/7/2011	CCR-2 4m	130	65	48	802	464	--	77	
9/7/2011	CCR-2 5m	125	64	48	769	441	--	77	
9/7/2011	CCR-2 6m	129	63	48	768	535	--	79	
9/7/2011	CCR-2 7m	127	63	48	814	426	--	75	
9/20/2011	CCR-2 Photic	112	19	10	988	525	--	14	33.3
9/20/2011	CCR-2 4m	109	24	14	823	474	--	14	
9/20/2011	CCR-2 5m	105	32	25	852	492	2	49	
9/20/2011	CCR-2 6m	122	38	32	865	507	5	80	
9/20/2011	CCR-2 7m	152	53	44	893	563	--	121	

CCR-3 GEI Water Chemistry Data									
Analytical Detection Limits		**2**	**2**	**2**	**2**	**2**	**2**	**3**	**0.1**
Sample Date	**Sample Name/ Location**	**Total Phosphorous µg/L**	**Total Dissolved Phosphorous µg/L**	**Ortho-phosphate µg/L**	**Total Nitrogen µg/L**	**Total Dissolved Nitrogen µg/L**	**Nitrate+ Nitrite µg/L**	**Ammonia µg/L**	**Average Chlorophyll *a* (mg/m^3)**
10/14/2010	CCR-3 Photic	111	10	4	1,025	489	11	90	48.7
11/16/2010	CCR-3 Photic	94	12	--	964	511	--	7	26.6
3/15/2011	CCR-3 Photic	57	12	4	781	419	--	9	22.6
4/20/2011	CCR-3 Photic	97	8	7	1,070	471	--	43	16.3
5/18/2011	CCR-3 Photic	85	35	28	773	543	45	55	18.2
5/31/2011	CCR-3 Photic	74	16	5	754	665	--	19	14.5
6/7/2011	CCR-3 Photic	52	11	3	772	494	--	10	13.2
6/21/2011	CCR-3 Photic	139	73	63	792	449	8	28	20.8
7/5/2011	CCR-3 Photic	137	52	40	795	483	--	10	24.8
7/19/2011	CCR-3 Photic	144	47	41	1,080	640	--	18	19.2
8/2/2011	CCR-3 Photic	195	88	77	1,071	535	--	23	30.1
8/18/2011	CCR-3 Photic	166	85	67	1,041	586	--	29	30.5
9/7/2011	CCR-3 Photic	141	60	45	693	394	--	41	28.3
9/20/2011	CCR-3 Photic	131	22	9	1,030	512	--	14	35.0

-- Denotes result less than MDL.

Site CCR-1 Small Tables

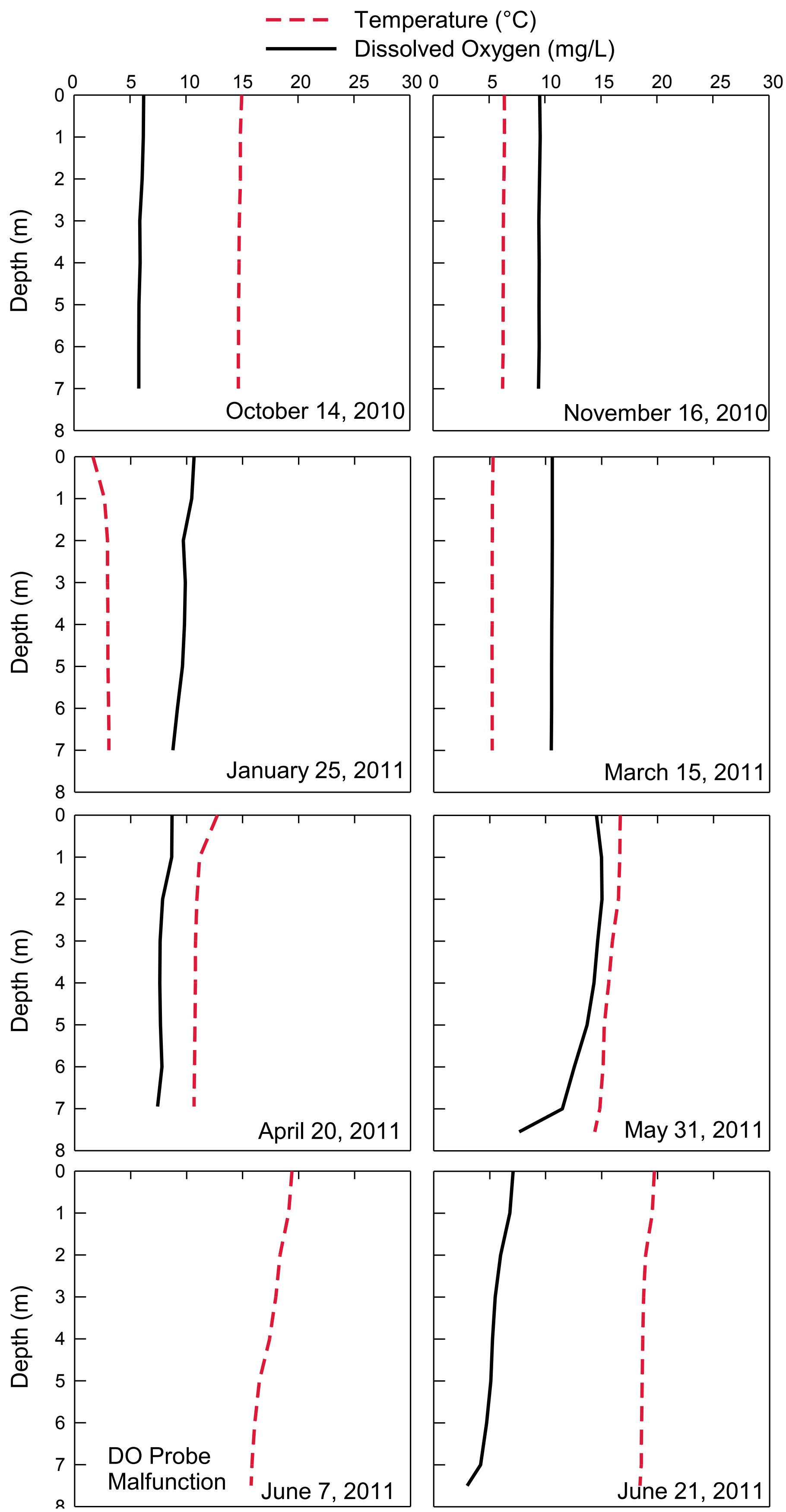
Sample Date	Depth	Temperature	Conductivity	Dissolved Oxygen	pH	ORP	1% Transmittance	Secchi Disk
10/14/2010	0	14.98	902	6.22	7.96	285		
	1	14.85	902	6.19	8.01	282		
	2	14.86	902	6.08	8.00	280		
	3	14.75	902	5.88	7.99	278		
	4	14.73	902	5.90	8.00	276		
	5	14.69	903	5.80	7.99	275		
	6	14.68	903	5.78	7.99	273		
	7	14.68	903	5.78	7.99	272		
	--						1.80	0.50
11/16/2010	0	6.35	900	9.54	8.30	180		
	1	6.36	900	9.57	8.17	179		
	2	6.31	900	9.51	8.12	178		
	3	6.27	899	9.45	8.10	178		
	4	6.26	899	9.48	8.09	177		
	5	6.23	899	9.47	8.10	177		
	6	6.24	899	9.49	8.09	177		
	7	6.19	899	9.43	8.09	177		
	--						2.25	0.75
1/25/2011	0	1.63	975	10.66	7.60	361		
	1	2.65	965	10.45	7.61	361		
	2	2.94	964	9.70	7.54	364		
	3	2.94	965	9.88	7.60	364		
	4	2.97	966	9.80	7.60	365		
	5	2.96	967	9.63	7.60	366		
	6	3.02	967	9.18	7.56	363		
	7	3.06	968	8.77	7.50	365		
	--						ICE	ICE
3/15/2011	0	5.29	941	10.60	7.72	163		
	1	5.23	941	10.59	7.85	163		
	2	5.22	941	10.59	7.80	163		
	3	5.21	942	10.58	7.80	163		
	4	5.20	942	10.55	7.80	163		
	5	5.20	942	10.54	7.78	162		
	6	5.21	942	10.54	7.79	162		
	7	5.20	942	10.51	7.81	162		
	--						3.45	1.15
4/20/2011	0	12.75	977	8.69	7.95	181		
	1	11.15	974	8.66	7.88	180		
	2	10.90	973	7.86	7.75	182		
	3	10.78	975	7.63	7.74	182		
	4	10.77	975	7.60	7.75	182		
	5	10.73	974	7.66	7.76	181		
	6	10.69	972	7.79	7.79	180		
	6.95	10.64	973	7.40	7.72	181		
	--						1.57	0.57

Sample Date	Depth	Temperature	Conductivity	Dissolved Oxygen	pH	ORP	1% Transmittance	Secchi Disk
5/31/2011	0	16.67	992	14.54	8.11	201		
	1	16.63	992	14.99	8.16	201		
	2	16.50	992	15.03	8.16	202		
	3	15.97	990	14.65	8.12	204		
	4	15.64	990	14.31	8.12	204		
	5	15.25	991	13.70	8.04	206		
	6	15.14	992	12.56	8.00	208		
	7	14.84	993	11.50	7.85	211		
	7.55	14.39	997	7.63	7.57	217		
	--						3.31	0.84
6/7/2011	0	19.41	1,092	*	8.09	241		
	1	19.11	1,093	*	8.14	240		
	2	18.32	1,090	*	8.12	240		
	3	17.95	1,095	*	8.07	241		
	4	17.40	1,096	*	7.91	246		
	5	16.49	1,100	*	7.65	252		
	6	16.07	1,100	*	7.55	255		
	7	15.82	1,103	*	7.39	260		
	7.5	15.75	1,103	*	7.32	256		
	--						3.60	1.25
6/21/2011	0	19.72	1,003	7.08	7.99	134		
	1	19.53	1,003	6.79	7.89	135		
	2	18.93	1,002	5.97	7.80	139		
	3	18.75	1,004	5.49	7.78	140		
	4	18.68	1,003	5.24	7.76	142		
	5	18.63	1,003	5.09	7.75	143		
	6	18.58	1,002	4.72	7.71	145		
	7	18.54	1,001	4.18	7.67	147		
	7.5	18.43	998	2.98	7.57	145		
	--						3.00	1.05
7/5/2011	0	23.89	1,197	8.45	8.48	229		
	1	22.98	1,192	8.96	8.46	226		
	2	22.48	1,194	8.34	8.34	227		
	3	22.19	1,195	7.40	8.24	228		
	4	21.98	1,195	6.75	8.14	230		
	5	21.61	1,194	5.27	7.94	234		
	6	21.32	1,194	3.08	7.76	238		
	7	20.97	1,194	1.08	7.62	239		
	7.45	20.91	1,194	0.72	7.61	118		
	--						3.25	0.95
7/19/2011	0	26.54	939	8.84	8.28	111		
	1	25.61	935	9.46	8.31	111		
	2	24.73	938	7.33	8.12	117		
	3	24.29	938	6.50	8.04	119		
	4	24.06	939	5.55	7.93	122		
	5	23.82	939	4.38	7.78	126		
	6	23.10	939	2.42	7.51	133		
	7	22.80	938	0.50	7.29	138		
	7.45	22.40	944	0.00	7.06	-186		
	--						2.50	0.95

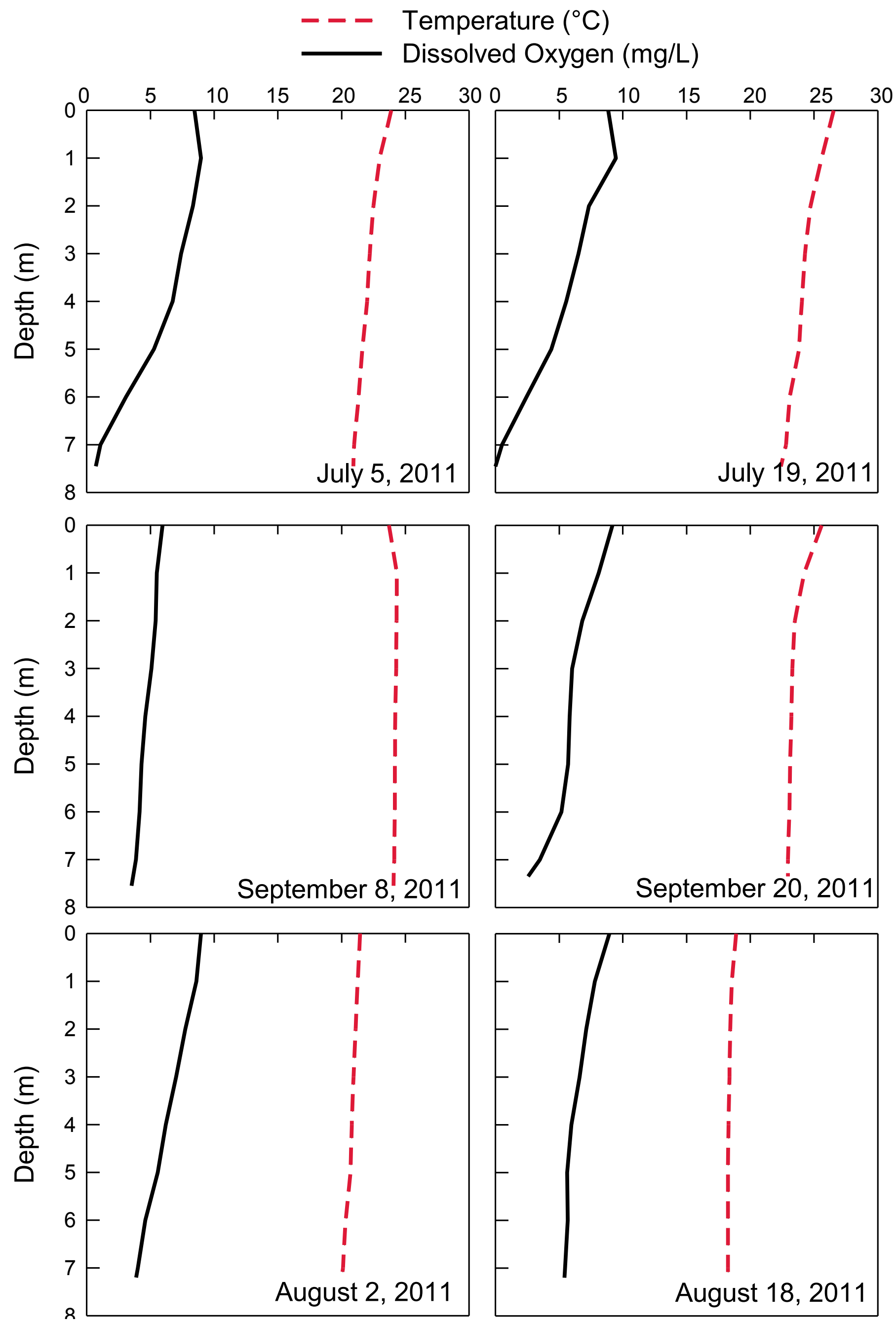
Sample Date	Depth	Temperature	Conductivity	Dissolved Oxygen	pH	ORP	1% Transmittance	Secchi Disk
8/02/2011	0	23.71	962	5.95	8.04	292		
	1	24.32	962	5.50	8.02	293		
	2	24.29	962	5.41	8.01	293		
	3	24.26	963	5.08	7.97	294		
	4	24.19	963	4.60	7.94	295		
	5	24.17	963	4.30	7.89	295		
	6	24.16	963	4.15	7.87	296		
	7	24.11	964	3.87	7.86	295		
	7.55	24.05	964	3.52	7.83	168		
	--						2.25	0.90
8/18/2011	0	25.60	965	9.19	8.48	114		
	1	24.24	962	8.10	8.37	116		
	2	23.50	963	6.81	8.28	119		
	3	23.31	964	6.01	8.21	121		
	4	23.23	964	5.81	8.19	122		
	5	23.14	965	5.69	8.18	123		
	6	23.08	965	5.17	8.14	124		
	7	22.95	969	3.47	8.01	127		
	7.35	22.95	969	2.56	7.98	129		
	--						2.25	0.77
9/8/2011**	0	21.45	960	8.96	8.36	231		
	1	21.25	961	8.60	8.39	227		
	2	21.08	960	7.73	8.33	227		
	3	20.92	961	7.01	8.28	226		
	4	20.79	961	6.20	8.23	225		
	5	20.68	962	5.57	8.18	225		
	6	20.30	962	4.60	8.10	226		
	7	20.09	963	4.02	8.05	226		
	7.2	20.00	963	3.88	8.04	220		
	--						1.79	0.64
9/20/2011	0	18.89	1,013	8.94	8.26	342		
	1	18.56	1,013	7.80	8.19	338		
	2	18.43	1,014	7.11	8.15	337		
	3	18.37	1,015	6.59	8.10	335		
	4	18.29	1,016	5.95	8.05	334		
	5	18.24	1,016	5.62	8.02	332		
	6	18.24	1,017	5.66	8.02	329		
	7	18.24	1,017	5.46	8.00	326		
	7.2	18.24	1,017	5.41	8.00	317		
	--						2.25	0.73

* Denotes a dissolved oxygen probe malfunction.
** Denotes water collected on 9/7/11 and parameters measured on 9/8/11 (1% Transmittance and Secchi disk measured 9/7/11).

CCR-1


Temperature (°C)
Dissolved Oxygen (mg/L)
0 5 10 15 20 25 30
Depth (m)
October 14, 2010
November 16, 2010
January 25, 2011
March 15, 2011
April 20, 2011
May 31, 2011
DO Probe Malfunction
June 7, 2011
June 21, 2011

CCR-1


Temperature (°C)
Dissolved Oxygen (mg/L)
0 5 10 15 20 25 30
Depth (m)
0 1 2 3 4 5 6 7 8
July 5, 2011
July 19, 2011
September 8, 2011
September 20, 2011
August 2, 2011
August 18, 2011

CCR-2 Small Tables

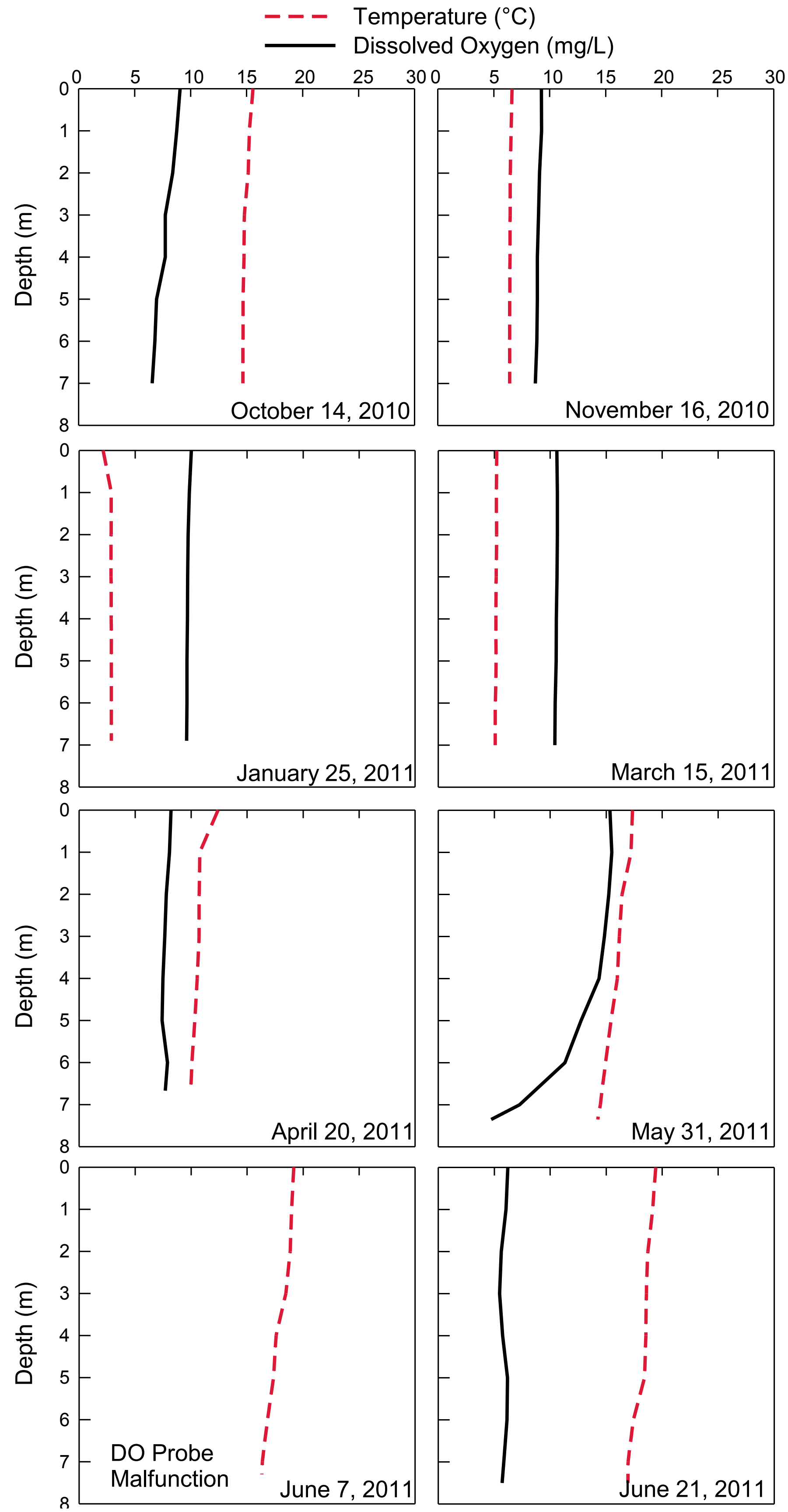
Sample Date	Depth	Temperature	Conductivity	Dissolved Oxygen	pH	ORP	1% Transmittance	Secchi Disk
10/14/2010	0	15.56	897	9.06	8.32	242		
	1	15.24	898	8.76	8.33	243		
	2	15.13	898	8.40	8.28	244		
	3	14.78	898	7.74	8.21	245		
	4	14.75	899	7.74	8.19	245		
	5	14.68	900	6.96	8.13	247		
	6	14.66	900	6.80	8.11	247		
	7	14.66	902	6.56	8.09	247		
	--						1.72	0.53
11/16/2010	0	6.62	899	9.26	8.06	192		
	1	6.53	899	9.27	8.06	191		
	2	6.46	899	9.09	8.04	191		
	3	6.44	899	9.00	8.03	191		
	4	6.43	899	8.89	8.02	191		
	5	6.41	899	8.88	8.03	190		
	6	6.42	899	8.84	8.02	190		
	7	6.42	899	8.71	8.01	190		
	--						2.10	0.73
1/25/2011	0	2.14**	959**	10.02**	7.74**	274**		
	1	2.86	965	9.83	7.71	278		
	2	2.85	965	9.73	7.71	282		
	3	2.85	965	9.68	7.72	287		
	4	2.86	965	9.67	7.72	290		
	5	2.87	965	9.63	7.72	292		
	6	2.86	965	9.62	7.72	294		
	6.9	2.87	965	9.60	7.72	295		
	--						ICE	ICE
3/15/2011	0	5.21	939	10.60	7.91	169		
	1	5.17	939	10.64	7.91	168		
	2	5.19	939	10.64	7.91	168		
	3	5.15	939	10.61	7.90	168		
	4	5.12	940	10.55	7.90	168		
	5	5.15	940	10.54	7.90	168		
	6	5.08	940	10.44	7.89	168		
	7	5.08	940	10.41	7.89	168		
	--						3.25	1.02
4/20/2011	0	12.40	975	8.20	7.89	218		
	1	10.77	973	8.07	7.84	219		
	2	10.70	973	7.78	7.81	219		
	3	10.70	971	7.64	7.78	219		
	4	10.52	974	7.48	7.75	219		
	5	10.31	972	7.40	7.74	219		
	6	10.06	970	7.89	7.81	216		
	6.67	9.95	972	7.69	7.75	217		
	--						1.75	0.56

Sample Date	Depth	Temperature	Conductivity	Dissolved Oxygen	pH	ORP	1% Transmittance	Secchi Disk
5/31/2011	0	17.35	993	15.33	8.17	181		
	1	17.23	991	15.50	8.19	181		
	2	16.42	991	15.23	8.16	182		
	3	16.18	990	14.84	8.22	182		
	4	15.99	990	14.36	8.24	183		
	5	15.44	993	12.75	8.02	187		
	6	14.95	992	11.31	7.88	189		
	7	14.48	997	7.26	7.34	199		
	7.35	14.25	1,001	4.72	7.23	201		
	--						3.20	0.75
6/7/2011	0	19.16	1,092	*	8.24	233		
	1	18.96	1,092	*	8.16	232		
	2	18.84	1,093	*	8.14	232		
	3	18.44	1,092	*	8.12	232		
	4	17.58	1,097	*	8.02	235		
	5	17.35	1,099	*	7.95	236		
	6	16.81	1,104	*	7.73	242		
	7	16.35	1,106	*	7.50	248		
	7.3	16.30	1,107	*	7.49	242		
	--						3.75	1.10
6/21/2011	0	19.43	1,003	6.20	7.82	142		
	1	19.16	1,003	6.04	7.84	142		
	2	18.72	1,002	5.62	7.81	145		
	3	18.59	1,004	5.47	7.81	145		
	4	18.54	994	5.74	7.81	144		
	5	18.43	975	6.17	7.87	143		
	6	17.43	899	6.12	7.83	146		
	7	16.95	856	5.85	7.77	149		
	7.5	16.94	853	5.70	7.58	65		
	--						2.65	0.95
7/5/2011	0	22.97	1,197	8.62	8.43	215		
	1	22.92	1,195	8.23	8.40	212		
	2	22.42	1,195	7.51	8.29	213		
	3	22.17	1,196	6.89	8.22	214		
	4	22.02	1,195	6.68	8.20	214		
	5	21.84	1,196	6.18	8.15	215		
	6	21.68	1,196	5.02	8.00	218		
	7	21.30	1,196	2.70	7.73	225		
	7.4	21.10	1,196	1.55	7.64	179		
	--						3.05	0.90
7/19/2011	0	26.35	938	9.10	8.31	122		
	1	25.51	934	8.43	8.17	124		
	2	25.26	936	7.75	8.16	128		
	3	24.23	937	6.55	8.03	132		
	4	23.08	934	1.57	7.40	147		
	5	22.74	930	0.41	7.29	149		
	6	22.70	928	0.23	7.27	149		
	7	22.33	922	0.00	7.21	-141		
	7.4	22.30	921	0.00	7.20	-153		
	--						2.85	0.75

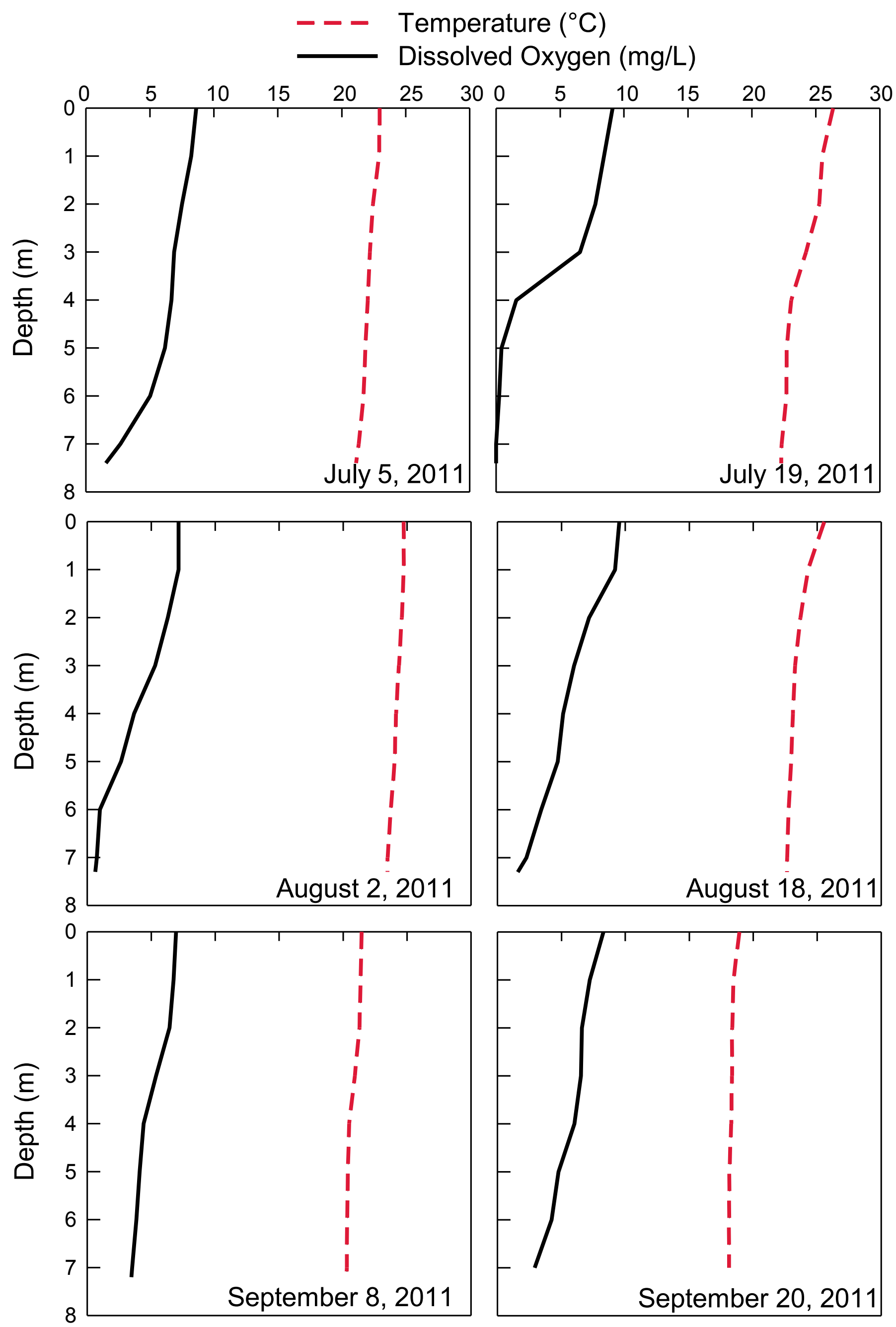
Sample Date	Depth	Temperature	Conductivity	Dissolved Oxygen	pH	ORP	1% Transmittance	Secchi Disk
8/2/2011	0	24.75	962	7.14	8.16	173		
	1	24.74	962	7.13	8.15	182		
	2	24.57	962	6.29	8.08	189		
	3	24.35	963	5.30	7.96	197		
	4	24.13	965	3.65	7.79	203		
	5	24.02	966	2.63	7.69	206		
	6	23.73	967	0.99	7.50	211		
	7	23.47	970	0.74	7.46	212		
	7.3	23.46	970	0.62	7.46	183		
	--						2.05	0.75
8/18/2010	0	25.55	964	9.53	8.49	120		
	1	24.29	962	9.20	8.46	121		
	2	23.69	962	7.15	8.32	124		
	3	23.27	965	5.98	8.23	127		
	4	23.1	965	5.12	8.15	129		
	5	22.97	966	4.70	8.12	131		
	6	22.78	969	3.42	8.03	134		
	7	22.66	972	2.26	7.95	136		
	7.3	22.64	973	1.58	7.87	110		
	--						1.95	0.65
9/8/2011***	0	21.45	963	6.94	8.30	232		
	1	21.36	962	6.74	8.28	229		
	2	21.27	962	6.43	8.26	228		
	3	20.90	962	5.38	8.16	228		
	4	20.45	962	4.40	8.10	228		
	5	20.37	963	4.09	8.07	228		
	6	20.30	963	3.83	8.05	228		
	7	20.27	964	3.51	8.03	227		
	7.2	20.27	964	3.45	8.02	214		
	--						1.90	0.70
9/20/2011	0	18.93	1014	8.28	8.26	253		
	1	18.47	1014	7.20	8.80	254		
	2	18.36	1016	6.60	8.14	255		
	3	18.35	1015	6.52	8.13	255		
	4	18.29	1015	6.01	8.08	255		
	5	18.16	1017	4.77	7.97	257		
	6	18.12	1018	4.23	7.90	259		
	7	18.11	1020	2.90	7.79	253		
	--						2.29	0.75

* Denotes a dissolved oxygen probe malfunction.
** Denotes value obtained from within the ice layer (approximately 22 cm thick).
*** Denotes water collected on 9/7/11 and parameters measured on 9/8/11 (1% Transmittance and Secchi disk measured 9/7/11).

CCR-2


Temperature (°C)
Dissolved Oxygen (mg/L)
Depth (m)
0 5 10 15 20 25 30
0 1 2 3 4 5 6 7 8
October 14, 2010
November 16, 2010
January 25, 2011
March 15, 2011
April 20, 2011
May 31, 2011
June 7, 2011
DO Probe Malfunction
June 21, 2011

CCR-2


Temperature (°C)
Dissolved Oxygen (mg/L)
Depth (m)
0
5
10
15
20
25
30
0
1
2
3
4
5
6
7
8
July 5, 2011
July 19, 2011
August 2, 2011
August 18, 2011
September 8, 2011
September 20, 2011

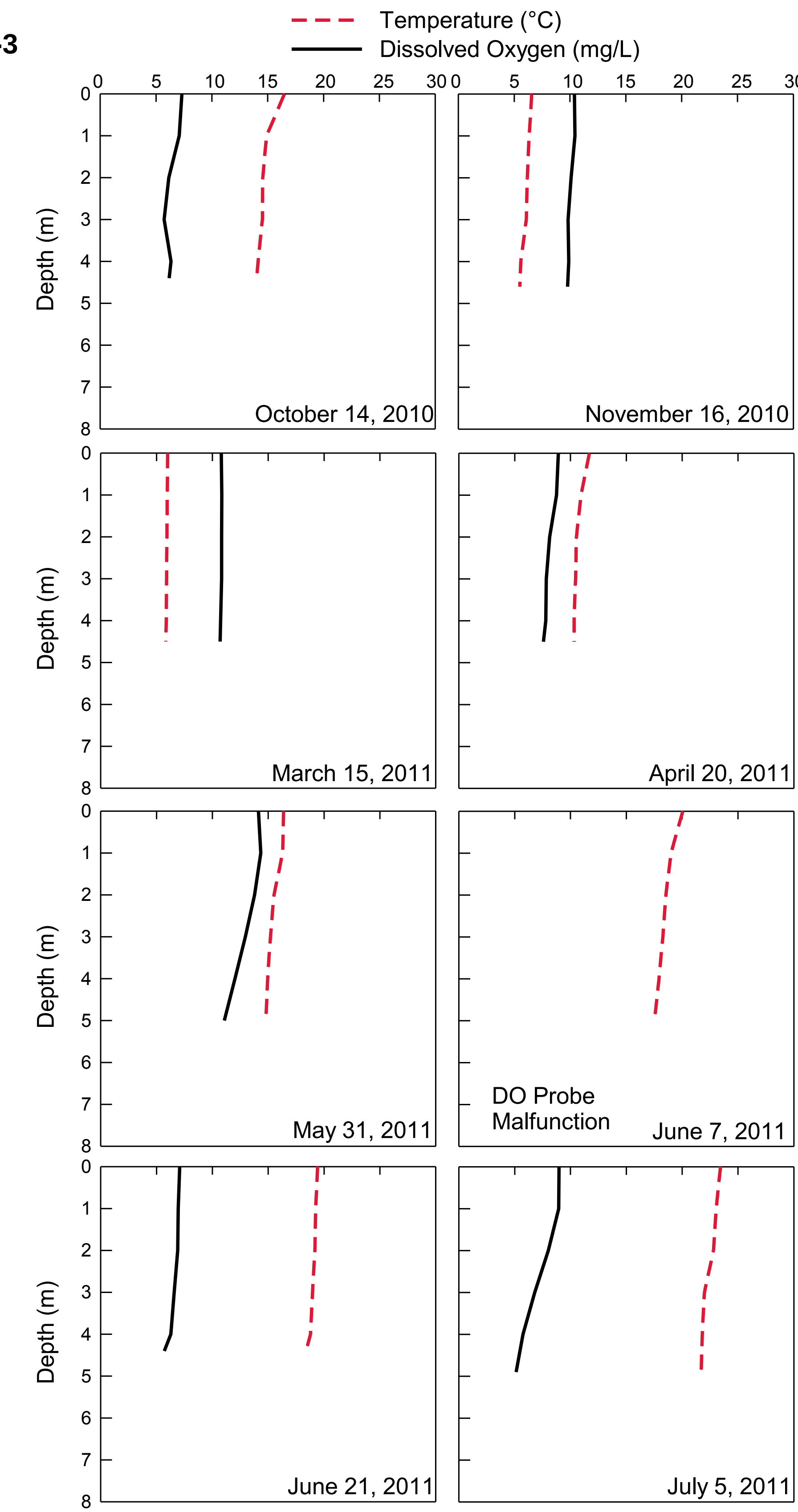
CCR-3 Small Tables

Sample Date	Depth	Temperature	Conductivity	Dissolved Oxygen	pH	ORP	1% Transmittance	Secchi Disk
10/14/2010	0	16.49	901	7.31	8.08	236		
	1	14.89	902	7.07	8.09	237		
	2	14.54	903	6.14	7.94	241		
	3	14.51	906	5.73	7.91	243		
	4	14.13	919	6.34	7.98	241		
	4.4	14.01	923	6.17	7.95	242		
	--						1.75	0.50
11/16/2010	0	6.57	899	10.40	8.26	195		
	1	6.32	899	10.45	8.24	194		
	2	6.16	898	10.10	8.18	194		
	3	6.07	899	9.83	8.14	195		
	4	5.57	905	9.89	8.13	196		
	4.6	5.49	907	9.79	8.11	196		
	--						2.25	0.65
3/15/2011	0	6.00	945	10.79	8.01	168		
	1	5.95	944	10.84	8.01	168		
	2	5.92	944	10.82	8.00	167		
	3	5.89	944	10.82	8.01	167		
	4	5.86	943	10.74	8.00	167		
	4.5	5.82	943	10.69	7.99	167		
	--						3.25	0.87
4/20/2011	0	11.70	971	8.90	7.98	222		
	1	10.95	971	8.74	7.95	222		
	2	10.53	971	8.12	7.84	224		
	3	10.46	972	7.82	7.81	225		
	4	10.33	972	7.78	7.79	224		
	4.5	10.33	972	7.57	7.78	225		
	--						1.80	0.55
5/31/2011	0	16.37	992	14.13	8.06	151		
	1	16.28	992	14.33	8.07	151		
	2	15.51	991	13.78	7.99	153		
	3	15.19	989	12.96	7.96	155		
	4	14.94	990	12.03	7.89	158		
	5	14.78	992	11.07	7.81	160		
	--						3.00	0.85
6/7/2011	0	20.06	1,099	*	8.16	238		
	1	19.01	1,095	*	8.18	238		
	2	18.54	1,093	*	8.17	238		
	3	18.28	1,093	*	8.15	238		
	4	17.93	1,095	*	8.09	239		
	5	17.52	1,120	*	7.87	244		
	--						3.80	1.05
6/21/2011	0	19.42	1,001	7.08	7.93	110		
	1	19.24	1,000	6.94	7.95	113		
	2	19.16	998	6.89	7.94	115		
	3	18.96	996	6.58	7.91	117		
	4	18.78	995	6.28	7.88	119		
	4.4	18.39	975	5.70	7.80	123		
	--						2.65	0.95

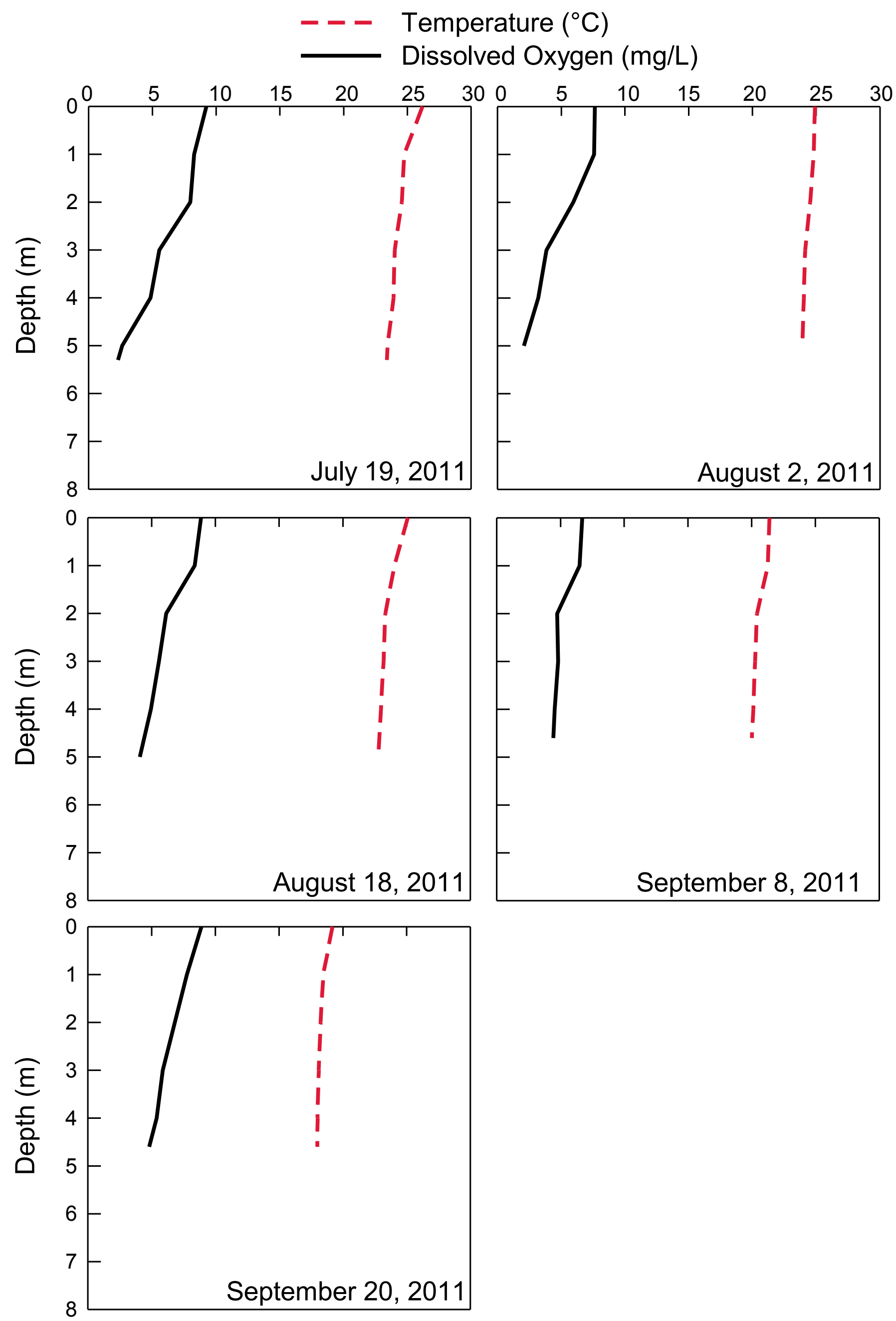
Sample Date	Depth	Temperature	Conductivity	Dissolved Oxygen	pH	ORP	1% Transmittance	Secchi Disk
7/5/2011	0	23.43	1,198	8.96	8.48	213		
	1	23.04	1,198	8.94	8.47	210		
	2	22.80	1,193	8.00	8.31	211		
	3	22.00	1,196	6.79	8.22	214		
	4	21.80	1,198	5.74	8.13	216		
	4.9	21.71	1,198	5.12	8.06	209		
	--						2.70	0.85
7/19/2011	0	26.19	934	9.24	8.32	78		
	1	24.75	936	8.28	8.25	82		
	2	24.55	935	7.98	8.20	88		
	3	24.00	939	5.54	7.95	95		
	4	23.90	940	4.86	7.89	98		
	5	23.44	941	2.63	7.59	105		
	5.3	23.38	941	2.30	7.56	80		
	--						2.60	0.70
8/2/2011	0	24.90	962	7.63	8.22	171		
	1	24.82	960	7.57	8.19	177		
	2	24.53	962	5.93	8.01	186		
	3	24.15	964	3.83	7.80	195		
	4	24.04	965	3.19	7.73	198		
	5	23.92	966	2.06	7.61	198		
	--						2.45	0.80
8/18/2011	0	25.09	963	8.87	8.49	92		
	1	24.04	962	8.38	8.44	95		
	2	23.32	964	6.14	8.25	99		
	3	23.19	964	5.57	8.20	102		
	4	22.97	967	4.94	8.15	104		
	5	22.77	968	4.08	8.08	103		
	--						2.05	0.75
9/8/2011**	0	21.40	965	6.70	8.28	234		
	1	21.27	963	6.48	8.27	231		
	2	20.43	963	4.74	8.14	232		
	3	20.27	963	4.81	8.14	231		
	4	20.14	964	4.54	8.11	230		
	4.6	20.02	966	4.43	8.09	229		
	--						1.80	0.67
9/20/2011	0	19.16	1,014	8.91	8.33	227		
	1	18.44	1,014	7.77	8.28	228		
	2	18.23	1,015	6.82	8.18	229		
	3	18.09	1,017	5.87	8.10	231		
	4	18.00	1,018	5.40	8.03	232		
	4.6	17.98	1,018	4.81	8.01	232		
	--						2.10	0.68

* Denotes a dissolved oxygen probe malfunction.
** Denotes water collected on 9/7/11 and parameters measured on 9/8/11 (1% Transmittance and Secchi disk measured 9/7/11).

CCR-3


Temperature (°C)
Dissolved Oxygen (mg/L)
0 5 10 15 20 25 30
Depth (m)
0 1 2 3 4 5 6 7 8
October 14, 2010
November 16, 2010
March 15, 2011
April 20, 2011
May 31, 2011
DO Probe Malfunction
June 7, 2011
June 21, 2011
July 5, 2011

CCR-3


Temperature (°C)
Dissolved Oxygen (mg/L)
0 5 10 15 20 25 30
Depth (m)
0 1 2 3 4 5 6 7 8
July 19, 2011
August 2, 2011
August 18, 2011
September 8, 2011
September 20, 2011

Cherry Creek Transect ORP Data

Collection Date	Depth	Transect ORP (mV)										
		D1	D2	D3	D3.5	D4	D5	D6	D7	D8	D9	D10
6/21/2011	0	193	170	166	149	128	95	112	108	91	94	110
	1	194	172	166	151	130	98	113	112	95	97	113
	2	194	173	167	153	133	100	116	115	101	100	115
	3	193	175	168	155	136	107	118	118	104	103	117
	4	193	175	169	156	138	108	120	120	108	106	119
	5	193	176	170	157	140	109	122	122	110	108	--
	6	193	177	170	158	141	110	123	122	112	110	--
	7	196	180	173	161	149	118	129	128	114	108	--
	Bottom	179	173	140	98	59	112	97	48	54	--	123

Collection Date	Depth	Transect ORP (mV)										
		D1	D2	D3	D3.5	D4	D5	D6	D7	D8	D9	D10
7/19/2011	0	314	204	114	76	67	64	62	54	55	59	78
	1	312	211	122	98	62	70	68	61	62	68	82
	2	311	215	112	103	70	77	74	69	70	75	88
	3	312	211	119	101	85	83	78	75	76	79	95
	4	312	225	128	107	93	90	86	84	84	84	98
	5	315	233	140	121	104	97	92	88	87	89	105
	6	322	242	142	122	105	97	93	90	89	93	--
	7	322	244	88	110	39	90	95	-75	-147	92	--
	Bottom	126	-152	-178	-186	-183	-168	-175	-178	--	--	80

Collection Date	Depth	Transect ORP (mV)										
		D1	D2	D3	D3.5	D4	D5	D6	D7	D8	D9	D10
8/18/2011	0	162	132	134	93	104	98	90	75	92	74	92
	1	161	133	134	98	106	100	94	77	96	78	95
	2	162	134	134	100	109	103	97	82	100	85	99
	3	162	135	135	102	111	106	99	86	104	88	102
	4	161	136	136	104	112	108	102	91	105	90	104
	5	163	139	137	105	113	111	106	93	106	92	--
	6	166	140	139	109	114	113	109	95	108	93	--
	7	166	141	141	112	118	113	103	--	--	--	--
	Bottom	130	141	64	104	82	52	41	85	10	87	103

Cherry Creek Transect DO Data

Collection Date	Depth	Dissolved Oxygen (mg/L)										
		D1	D2	D3	D3.5	D4	D5	D6	D7	D8	D9	D10
6/21/2011	0	5.78	6.70	6.13	6.44	6.51	6.67	6.69	6.90	6.70	6.82	7.08
	1	5.76	6.35	6.12	6.38	6.53	6.63	6.69	6.82	6.72	6.76	6.94
	2	5.59	6.10	5.96	6.16	6.30	6.51	6.34	6.62	6.70	6.72	6.89
	3	5.47	5.79	5.84	5.89	5.87	5.90	6.12	6.22	6.34	6.55	6.58
	4	5.47	5.79	5.70	5.80	5.78	5.85	6.00	5.98	6.15	6.30	6.28
	5	5.34	5.75	5.63	5.60	5.62	5.91	5.90	5.94	6.01	6.07	--
	6	5.12	5.44	5.37	5.52	5.74	6.01	5.81	5.77	5.66	5.90	--
	7	3.70	4.44	4.56	4.82	4.55	4.24	4.29	4.56	4.17	5.40	--
	Bottom	3.37	3.62	4.02	4.33	1.75	4.01	4.14	4.00	4.12	--	5.70

Collection Date	Depth	Dissolved Oxygen (mg/L)										
		D1	D2	D3	D3.5	D4	D5	D6	D7	D8	D9	D10
7/19/2011	0	8.10	8.09	7.89	7.71	7.80	7.63	7.88	8.59	8.72	9.16	9.24
	1	8.05	8.23	7.80	8.01	7.11	7.89	7.74	8.60	8.27	8.02	8.28
	2	7.83	7.77	7.69	7.84	7.13	7.12	6.81	6.99	7.13	6.50	7.98
	3	6.92	7.00	7.01	7.31	6.99	6.67	6.46	6.37	5.97	6.04	5.54
	4	6.32	6.51	6.23	5.98	6.39	4.92	4.65	4.04	2.90	4.50	4.86
	5	5.05	4.44	2.04	1.26	1.94	1.43	2.00	2.22	1.90	3.32	2.63
	6	2.58	2.22	1.17	0.50	0.35	0.47	1.60	1.21	0.60	1.59	--
	7	1.91	0.74	0.29	0.18	0.09	0.10	0.45	0.04	0.00	0.72	--
	Bottom	1.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	--	--	2.30

Collection Date	Depth	Dissolved Oxygen (mg/L)										
		D1	D2	D3	D3.5	D4	D5	D6	D7	D8	D9	D10
8/18/2011	0	7.72	7.74	6.66	7.97	8.03	7.85	8.42	8.23	8.40	9.00	8.87
	1	7.63	7.42	6.70	6.86	7.85	7.66	7.95	8.17	8.65	8.08	8.38
	2	6.55	6.93	6.73	6.56	6.71	7.01	6.88	7.32	6.67	5.43	6.14
	3	6.49	6.50	6.06	6.03	6.08	6.49	6.47	6.64	5.11	5.02	5.57
	4	5.97	6.10	5.68	5.81	5.74	6.00	6.01	5.31	4.81	4.84	4.94
	5	4.70	4.71	5.40	5.56	5.49	5.43	5.24	4.41	4.63	4.42	--
	6	2.94	4.51	4.72	5.14	5.24	4.83	3.78	4.04	3.61	4.27	--
	7	2.52	3.48	3.39	3.01	3.55	3.50	3.36	3.39	3.39	--	--
	Bottom	1.88	3.06	3.16	2.77	3.12	3.42	3.40	--	--	3.61	4.08

Appendix C

2011 WY Stream Water Quality and Precipitation Data

CC-10 C&A Water Chemistry Data										
Analytical Detection Limits		2	2	2	2	2	2	3	4	4
Sample Date	**Sample Name/ Location**	**Total Phosphorous µg/L**	**Total Dissolved Phosphorous µg/L**	**Ortho-phosphate µg/L**	**Total Nitrogen µg/L**	**Total Dissolved Nitrogen µg/L**	**Nitrate+ Nitrite µg/L**	**Ammonia µg/L**	**TSS mg/L**	**TVSS mg/L**
1/15/2008	CC-10	186	137	126	1,831	1,639	1,332	55	20.6	
2/19/2008	CC-10	245	149	137	1,768	1,599	1,078	189	45.8	5
3/19/2008	CC-10	145	101	100	1,346	1,128	692	50	19.4	
4/7/2008	CC-10	153	124	115	1,521	1,444	1,077	80	17.4	
5/6/2008	CC-10	234	193	185	1,177	1,061	631	42	28.4	5.4
6/10/2008	CC-10	266	192	188	975	880	533	45	24.7	4.8
7/8/2008	CC-10	247	198	191	814	721	432	79	11.4	
8/5/2008	CC-10	211	148	149	717	688	284	48	23.3	6
9/9/2008	CC-10	190	166	173	878	766	467	31	4	
10/16/2008	CC-10	166	119	116	871	772	469	34	11.8	
11/18/2008	CC-10	158	122	136	920	797	513	24	36.4	5.6
12/11/2008	CC-10	142	118	126	1,408	1,390	730	45	14.6	
5/7/2008	CC-10 storm	315	246	240	1,347	1,373	715	131	62	9
5/13/2008	CC-10 storm	238	191	186	1,382	1,188	698	48	41.8	7.4
6/5/2008	CC-10 storm	303	224	210	1,384	1,140	580	80	36.5	7
8/9/2008	CC-10 storm	136			875				31.2	7.2
8/15/2008	CC-10 storm	170	137	112	1,123	996	590	96	21.6	5.8
9/12/2008	CC-10 storm	519	213	207	2,272	1,350	817	113	139.3	19

CC-O at I-225 C&A Water Chemistry Data										
Analytical Detection Limits		2	2	2	2	2	2	3	4	4
Sample Date	Sample Name/ Location	Total Phosphorous µg/L	Total Dissolved Phosphorous µg/L	Ortho- phosphate µg/L	Total Nitrogen µg/L	Total Dissolved Nitrogen µg/L	Nitrate+ Nitrite µg/L	Ammonia µg/L	TSS mg/L	TVSS mg/L
1/15/2008	CC-Out at I225	59	27	15	929	711	134	98	6.8	
2/19/2008	CC-Out at I225	82	11	9	980	694	154	72	7	
3/19/2008	CC-Out at I225	68	18	8	1,085	541		10	8.6	5
4/7/2008	CC-Out at I225	80	14	5	840	435		8	8.4	
5/6/2008	CC-Out at I225	233	34	25	914	508	3	13	19	7.8
6/10/2008	CC-Out at I225	101	59	54	722	577	6	66	14.7	5.7
8/5/2008	CC-Out at I225	170	90	84	754	570	18	114	25	5.3
9/24/2008	CC-Out at I225	75	18	16	808	520	3	31	29	7.6
10/16/2008	CC-Out at I225	79	17	14	759	423		16	24.7	6.5
11/18/2008	CC-Out at I225	75	17	9	671	418	2	7	24.4	5.8
12/11/2008	CC-Out at I225	61	8	6	741	506		13	9.8	4.8

CT-1 C&A Water Chemistry Data										
Analytical Detection Limits		2	2	2	2	2	2	3	4	4
Sample Date	**Sample Name/ Location**	**Total Phosphorous µg/L**	**Total Dissolved Phosphorous µg/L**	**Ortho-phosphate µg/L**	**Total Nitrogen µg/L**	**Total Dissolved Nitrogen µg/L**	**Nitrate+ Nitrite µg/L**	**Ammonia µg/L**	**TSS mg/L**	**TVSS mg/L**
1/15/2008	CT-1	88	10	4	5,377	4,860	3,828	496	43	6.8
2/19/2008	CT-1	99	8	2	3,832	3,963	2,682	774	32.6	5.8
3/19/2008	CT-1	56	11	9	3,853	3,889	3,403	198	6.6	
4/7/2008	CT-1	52	10	5	3,796	3,944	3,315	374	29.8	4.4
6/10/2008	CT-1	44	19	14	1,155	1,032	462	20	27.5	9
7/8/2008	CT-1	71	28	20	814	735	260	22	20.4	5
8/5/2008	CT-1	53	22	17	704	611	122	15	19.8	4.7
9/9/2008	CT-1	47	7	7	2,393	2,039	1,620	6	13.1	4
10/16/2008	CT-1	42	12	9	2,629	2,408	2,281	25	13	4
11/18/2008	CT-1	43	20	18	2,904	2,761	2,195	52	31.4	5
12/11/2008	CT-1	53	12	6	3,277	2,967	1,720	75	25.4	5
8/9/2008	CT-1 storm	56			893				31.4	7.4
8/15/2008	CT-1 storm	56	10	4	1,134	925	368	15	40	7
9/12/2008	CT-1 storm	146	44	39	1,635	1,203	704	245	87.5	20.5

CT-2 C&A Water Chemistry Data										
Analytical Detection Limits		2	2	2	2	2	2	3	4	4
Sample Date	**Sample Name/ Location**	**Total Phosphorous µg/L**	**Total Dissolved Phosphorous µg/L**	**Ortho-phosphate µg/L**	**Total Nitrogen µg/L**	**Total Dissolved Nitrogen µg/L**	**Nitrate+ Nitrite µg/L**	**Ammonia µg/L**	**TSS mg/L**	**TVSS mg/L**
1/15/2008	CT-2	87	8	4	5,346	4,922	3,774	460	28.4	5
2/19/2008	CT-2	103	6	2	4,314	3,833	2,619	827	35.4	6
3/19/2008	CT-2	66	8	5	3,528	3,179	2,619	164	42	6.6
4/7/2008	CT-2	63	10	3	4,850	4,505	3,816	433	32.8	6.2
5/6/2008	CT-2	114	20	14	2,491	2,285	1,650	77	158	15.6
6/10/2008	CT-2	38	10	2	1,039	844	208	107	40.2	7
7/8/2008	CT-2	71	9		925	615	44	28	29.5	7.9
8/5/2008	CT-2	50	12	7	428	337	10	13	27.7	6.2
9/9/2008	CT-2	62	45	5	2,139	1,762	1,362	14	37.2	6.7
10/16/2008	CT-2	44	7	7	2,382	2,406	1,920	38	29	6.3
11/18/2008	CT-2	51	12	13	2,568	2,288	1,948	30	44.6	8.8
12/11/2008	CT-2	47	44	6	3,137	2,817	1,618	64	18.2	4.2
5/7/2008	CT-2 storm	170	18	14	1,590	1,504	1,043	102	231.3	24
5/13/2008	CT-2 storm	85	20	18	1,488	1,358	794	81	90.2	14.6
6/5/2008	CT-2 storm	64	16	6	1,261	851	212	87	52	14
8/9/2008	CT-2 storm	46			831				31	8.6
8/15/2008	CT-2 storm	73	13	8	986	776	212	19	39.2	8
9/12/2008	CT-2 storm	130	26	37	1,644	1,200	650	196	43.5	14

CT-P1 C&A Water Chemistry Data										
Analytical Detection Limits		2	2	2	2	2	2	3	4	4
Sample Date	**Sample Name/ Location**	**Total Phosphorous µg/L**	**Total Dissolved Phosphorous µg/L**	**Ortho-phosphate µg/L**	**Total Nitrogen µg/L**	**Total Dissolved Nitrogen µg/L**	**Nitrate+ Nitrite µg/L**	**Ammonia µg/L**	**TSS mg/L**	**TVSS mg/L**
1/15/2008	CT-P1	40	25	18	2,478	2,152	842	356	9	
2/19/2008	CT-P1	29	11	4	1,316	1,230	771	26	6.2	
3/19/2008	CT-P1	28	5	5	905	634	282	27	8	
4/7/2008	CT-P1	42	8	4	738	585	133	31	12.8	
5/6/2008	CT-P1	155	22	15	838	718	208	50	8.6	
6/10/2008	CT-P1	88	21	14	997	843	332	77	21.5	8
7/8/2008	CT-P1	162	40	25	1,368	907	242	72	43.1	11.3
8/5/2008	CT-P1	141	44	24	1,143	969	350	76	30	7
9/9/2008	CT-P1	115	9	6	1,271	606	121	8	27.8	11.4
10/16/2008	CT-P1	38	10	8	937	801	446	32	8	
11/18/2008	CT-P1	19	5	7	1,095	981	487	69	9.6	
12/11/2008	CT-P1	58	4	2	1,566	1,226	575	29	26.6	7.4
5/7/2008	CT-P1 storm	142	35	29	1,427	1,489	626	365	94	18
5/13/2008	CT-P1 storm	57	36	28	1,201	1,228	569	214	31.8	10
6/5/2008	CT-P1 storm	116	17	8	1,456	887	293	167	103	23
8/9/2008	CT-P1 storm	137			1,500				33.4	14.2
8/15/2008	CT-P1 storm	293	78	62	1,611	1,069	462	139	110.6	19
9/12/2008	CT-P1 storm	154	84	85	1,321	992	453	347	82.5	21.5

CT-P2 C&A Water Chemistry Data										
Analytical Detection Limits		2	2	2	2	2	2	3	4	4
Sample Date	**Sample Name/ Location**	**Total Phosphorous µg/L**	**Total Dissolved Phosphorous µg/L**	**Ortho-phosphate µg/L**	**Total Nitrogen µg/L**	**Total Dissolved Nitrogen µg/L**	**Nitrate+ Nitrite µg/L**	**Ammonia µg/L**	**TSS mg/L**	**TVSS mg/L**
1/15/2008	CT-P2	29	12	9	2,391	1,400	1,211	214	17.6	
2/19/2008	CT-P2	33	12	8	1,519	1,397	931	32	6.6	
3/19/2008	CT-P2	47	15	11	1,198	932	581	21	10.6	
4/7/2008	CT-P2	60	11	6	1,220	1,057	388	203	166.8	12.6
5/6/2008	CT-P2	40	28	22	1,497	1,408	450	88	9.4	
6/10/2008	CT-P2	40	20	15	1,338	1,205	676	111	23	7
7/8/2008	CT-P2	65	27	17	1,256	1,069	504	67	24.6	9.5
8/5/2008	CT-P2	83	29	19	1,244	1,122	631	37	19.8	5
9/9/2008	CT-P2	76	12	7	1,384	897	450	14	22.4	8.2
10/16/2008	CT-P2	34	10	9	1,418	1,250	871	52	24	6.3
11/18/2008	CT-P2	38	4	9	1,400	1,270	813	55	27.2	5.2
12/11/2008	CT-P2	32	8	7	1,382	1,262	483	42	20.6	7
5/7/2008	CT-P2 storm	109	44	41	1,252	1,270	506	240	61	12.5
5/13/2008	CT-P2 storm	53	35	31	1,116	1,065	522	148	18.4	6.6
6/5/2008	CT-P2 storm	135	59	44	1,415	1,125	446	154	55	17
8/9/2008	CT-P2 storm	144			1,571				26	9
8/15/2008	CT-P2 storm	122	58	44	1,295	983	317	120	26	8
9/12/2008	CT-P2 storm	238	69	65	1,901	1,348	737	315	76.5	21.5

SC-3 C&A Water Chemistry Data										
Analytical Detection Limits		2	2	2	2	2	2	3	4	4
Sample Date	**Sample Name/ Location**	**Total Phosphorous µg/L**	**Total Dissolved Phosphorous µg/L**	**Ortho-phosphate µg/L**	**Total Nitrogen µg/L**	**Total Dissolved Nitrogen µg/L**	**Nitrate+ Nitrite µg/L**	**Ammonia µg/L**	**TSS mg/L**	**TVSS mg/L**
3/19/2008	SC-3	44	19	18	1,503	1,243	1,021	20	17.4	
4/7/2008	SC-3	53	9	6	522	375	125	9	60	5.6
5/6/2008	SC-3	45	27	22	386	359	45	11	9	
7/8/2008	SC-3	131	109	92	616	535	42	15	25.5	6.9
9/9/2008	SC-3	52	38	31	287	273	10	5	7.2	
10/16/2008	SC-3	35	22	22	288	270	62	5		
11/18/2008	SC-3	24	19	19	585	546	368	7	11	
12/11/2008	SC-3	31	18	20	2,346	2,218	1,298	72	9.2	4
5/7/2008	SC-3 storm	52	37	37	574	546	138	19	21	6
5/13/2008	SC-3 storm	53	40	35	1,332	1,245	909	4	11.2	5.2
6/5/2008	SC-3 storm	190	109	101	854	654	168	33	46.5	8
8/9/2008	SC-3 storm	215			2,408				18.6	4.6
8/15/2008	SC-3 storm	159	125	105	1,243	1,107	628	107	14	4.4
9/12/2008	SC-3 storm	808	541	488	5,188	3,964	3,199	90	111	28.5

Rain Gauge C&A Water Chemistry Data								
Analytical Detection Limits		2	2	2	2	2	2	3
Sample Date	Sample Name/ Location	Total Phosphorous µg/L	Total Dissolved Phosphorous µg/L	Ortho-phosphate µg/L	Total Nitrogen µg/L	Total Dissolved Nitrogen µg/L	Nitrate+ Nitrite µg/L	Ammonia µg/L
5/7/2008	Rain Gauge storm	76	26	23	1,350	1,189	442	565
5/13/2008	Rain Gauge storm	26	8	8	1,143	1,098	378	630
8/15/2008	Rain Gauge storm	43	6	6	649	565	240	250
9/12/2008	Rain Gauge storm	24	10	5	360	218	89	136

GEI Water Chemistry Data

Site/ Sample Date	Total Phosphorus (µg/L)	Total Dissolved Phosphorus (µg/L)	Orthophosphate (µg/L)	Total Nitrogen (µg/L)	Total Dissolved Nitrogen (µg/L)	Nitrate+ Nitrite (µg/L)	Ammonia (µg/L)	Total Suspended Solids (mg/L)	Total Volatile Suspended Solids (mg/L)
Analytical Detection Limits	**2**	**2**	**2**	**2**	**2**	**2**	**3**	**4**	**4**
CC-10									
1/21/2009	185	130	131	2,091	1,614	946	64	31	4
2/17/2009	141	104	96	1,262	1,189	908	25	21	4
3/17/2009	145	104	110	1,219	1,162	788	31	13	
4/16/2009	196	132	119	946	867	463	28	58	8
5/12/2009	58	47	39	349	309	13	5	64	9
6/30/2009	348	246	230	1,354	1,202	792	40	50	6
7/14/2009	485	240	225	1,528	1,037	619	47	168	19
8/11/2009	294	176	188	1,230	940	569		54	7
9/29/2009	245	186	186	1,339	1,226	977	14	21	
10/14/2009	190	158	163	1,262	1,276	973	13	13	4
11/17/2009	155	133	140	1,266	1,336	1,010	25	36	4
12/16/2009	188	152	147	1,520	1,398	1,137	69	12	
CC-10 Storm									
4/17/2009	289	137	139	1,413	1,186	685	59	211	14
4/28/2009	264	161	147	1,158	956	499	65	83	8
5/26/2009	489	162	165	1,750	952	511	30	171	18
6/1/2009	391	208	218	1,239	1,151	645	61	133	14
6/26/2009	526	245	219	1,490	854	271		153	17
7/21/2009	848	227	211	1,693	1,071	635	35	896	108
7/30/2009	310	227	192	1,385	1,198	861	29	55	10
8/18/2009	365	156	167	2,119	1,300	900	36	147	18
CC-Out @ I225									
1/21/2009	83	33	19	1,032	761	93	65	11	4
2/17/2009	62	16	6	987	597	4	24	14	6
3/17/2009	75	6	5	852	440		10	14	6
4/16/2009	91	8	5	747	416			31	10
4/21/2009	82	18	11	1,065	600	10	32	12	5
4/22/2009	83	17	13	754	457	5	9	12	5
5/12/2009	82	54	50	753	601	50	101	11	4
5/29/2009	77	12	5	776	502		26	20	7
6/30/2009	350	236	223	1,226	873	19	391	32	8
7/14/2009	200	121	106	1,091	755	23	194	24	6
8/11/2009	83	84	77	1,043	657	11	122	40	9
9/29/2009	101	29	29	804	582	75	104	23	5
10/14/2009	58	18	7	668	450	3	16	13	6
11/17/2009	67	19	7	789	387		34	21	5
12/16/2009	81	20	14	924	533	74	23	6	

GEI Water Chemistry Data									
Analytical Detection Limits	2	2	2	2	2	2	3	4	4
Site/ Sample Date	Total Phosphorus (µg/L)	Total Dissolved Phosphorus (µg/L)	Orthophosphate (µg/L)	Total Nitrogen (µg/L)	Total Dissolved Nitrogen (µg/L)	Nitrate+ Nitrite (µg/L)	Ammonia (µg/L)	Total Suspended Solids (mg/L)	Total Volatile Suspended Solids (mg/L)
CT-1									
1/21/2009	102	29	29	2,761	2,600	2,241	27	26	4
2/17/2009	75	22	25	2,639	2,389	2,014	23	47	9
3/17/2009	79	17	14	2,202	1,897	1,526	17	45	7
4/16/2009	78	35	30	1,860	1,704	1,269	49	29	7
5/12/2009	36	9	11	736	606	228	10	13	5
6/30/2009	39	25	17	645	557	56	26	21	5
7/14/2009	46	20	7	1,139	996	468	31	22	7
8/11/2009	66	10	6	1,154	884	347	31	21	5
9/29/2009	47	13	13	1,552	1,385	966	15	13	
10/14/2009	53	16	7	2,190	2,039	1,671	19	21	
11/17/2009	79	21	15	1,400	1,125	786	48	57	8
12/16/2009	95	23	22	1,995	1,690	1,134	209	51	7
CT-1 Storm									
4/17/2009	47	27	25	1,071	956	1,051	79	38	8
4/28/2009	82	44	35	978	868	362	44	20	5
5/26/2009	218	75	74	1,231	889	400	80	58	8
6/1/2009	74	17	11	1,197	912	359	76	38	9
6/26/2009	117	42	31	1,271	881	353		25	7
7/21/2009	176	71	58	1,455	1,049	502	74	86	23
7/30/2009	97	46	35	1,425	1,117	620	64	26	7
8/18/2009	101	6	6	1,921	1,120	613	51	41	9
9/21/2009	57	17	16	1,408	1,266	834		20	
CT-2									
1/21/2009	52	13	11	3,288	2,957	2,560	20	57	7
2/17/2009	63	12		3,207	2,829	2,385	17	45	10
3/17/2009	62	9	3	2,844	2,643	1,978	24	36	6
4/16/2009	48	10	3	2,352	2,089	1,488	46	37	7
5/12/2009	38	11	3	888	724	154	14	24	6
6/30/2009	56	16	9	828	687	31	52	10	
7/14/2009	42	18	7	1,062	933	414	24	18	6
8/11/2009	13	11	5	1,002	718	215	19	19	6
9/29/2009	71	6	3	1,739	1,440	977	15	34	7
10/14/2009	65	12	5	2,155	1,978	1,550	23	30	5
11/17/2009	41	15	10	1,283	1,177	752	76	27	6
12/16/2009	64	15	10	2,057	1,792	1,208	195	31	5
CT-2 Storm									
4/17/2009	64	21	15	2,190	2,022	1,380	81	36	8
4/28/2009	85	47	36	988	824	388	42	20	5
5/26/2009	178	54	57	1,205	855	375	108	56	8
6/1/2009	62	16	9	1,170	959	330	118	31	9
6/26/2009	131	39	33	1,391	1,018	430		32	8
7/21/2009	168	66	41	1,534	1,097	493	81	50	9
7/30/2009	78	32	25	1,454	1,142	638	65	23	7
8/18/2009	77	10	8	1,745	1,143	602	22	29	9
9/21/2009	72	7	5	1,282	1,203	686		32	6

GEI Water Chemistry Data									
Analytical Detection Limits	**2**	**2**	**2**	**2**	**2**	**2**	**3**	**4**	**4**
Site/ Sample Date	**Total Phosphorus (µg/L)**	**Total Dissolved Phosphorus (µg/L)**	**Orthophosphate (µg/L)**	**Total Nitrogen (µg/L)**	**Total Dissolved Nitrogen (µg/L)**	**Nitrate+ Nitrite (µg/L)**	**Ammonia (µg/L)**	**Total Suspended Solids (mg/L)**	**Total Volatile Suspended Solids (mg/L)**
CT-P1									
1/21/2009	8	5	6	1,103	1,109	701	23	4	
2/17/2009	21	8	6	971	899	507	52	10	
3/17/2009	29	9	7	802	706	294	55	10	
5/12/2009	38	18	11	933	831	372	41	13	4
6/30/2009	87	40	28	1,015	851	279	76	26	6
7/14/2009	113	32	20	1,150	830	293	34	28	8
8/11/2009	104	30	20	1,256	649	268	10	17	7
9/29/2009	79	48	42	1,009	838	491	39	11	
10/14/2009	35	11	6	990	879	500	14	14	5
11/17/2009	29	20	14	1,048	994	672	50	14	5
12/16/2009	13	5	7	1,252	1,157	904	45	4	
CT-P1 Storm									
4/17/2009	185	18	15	1,509	1,061	364	183	124	18
5/26/2009	259	74	72	1,278	565	236	63	55	8
6/1/2009	115	37	30	1,368	1,048	496	125	36	8
6/26/2009	419	55	54	2,062	1,276	564		183	31
7/21/2009	402	163	147	1,660	876	366	70	252	27
7/30/2009	178	91	72	1,315	924	381	110	31	9
8/18/2009	159	34	30	1,722	921	451	69	50	15
9/21/2009	152	36	29	1,264	892	364		30	8
CT-P2									
1/21/2009	16	7	6	1,315	1,282	939	23	7	
2/17/2009	47	6	5	1,204	1,055	694	30	36	7
3/17/2009	19	6	5	1,086	879	496	32	11	
4/16/2009	27	6	5	891	743	302	27	17	5
5/12/2009	37	15	9	1,176	1,035	702	27	11	
6/30/2009	75	39	31	1,274	1,149	626	66	19	5
7/14/2009	99	20	18	1,182	855	399	13	21	5
8/11/2009	75	15	8	1,366	958	639	14	15	6
9/29/2009	66	30	28	1,350	1,180	834	31	13	
10/14/2009	53	12	7	1,343	1,268	857	39	40	9
11/17/2009	31	19	13	1,095	1,039	774	33	23	5
12/16/2009	50	6	8	1,685	1,485	1,256	45	37	7
CT-P2 Storm									
4/17/2009	122	39	33	1,422	1,184	490	155	41	7
4/28/2009	106	52	47	1,017	828	388	75	23	5
5/26/2009	217	102	100	1,203	843	357	68	36	6
6/1/2009	88	31	23	1,325	1,033	487	94	18	5
6/26/2009	213	98	82	1,385	932	361		38	11
7/21/2009	309	141	124	1,452	864	395	80	106	25
7/30/2009	133	81	59	1,256	963	461	88	21	8
8/18/2009	67	44	41	1,739	1,025	496	81	25	13
9/21/2009	115	56	49	1,160	946	402		27	7

GEI Water Chemistry Data									
Analytical Detection Limits	**2**	**2**	**2**	**2**	**2**	**2**	**3**	**4**	**4**
Site/ Sample Date	**Total Phosphorus (µg/L)**	**Total Dissolved Phosphorus (µg/L)**	**Orthophosphate (µg/L)**	**Total Nitrogen (µg/L)**	**Total Dissolved Nitrogen (µg/L)**	**Nitrate+ Nitrite (µg/L)**	**Ammonia (µg/L)**	**Total Suspended Solids (mg/L)**	**Total Volatile Suspended Solids (mg/L)**
SC-3									
1/21/2009	29	26	24	2,149	2,113	2,010	12	6	
2/17/2009	31	25	16	2,411	2,348	2,169	12	23	
3/17/2009	83	9	6	733	441	127	7	82	10
4/16/2009	36	14	12	372	281	19	8	15	5
5/12/2009	274	182	187	1,311	1,123	1,139	31	7	
6/30/2009	175	158	143	484	435	64	59	9	
7/14/2009	171	155	143	400	347	56	16	18	7
8/11/2009	331	208	180	1,595	1,251	627	71	58	9
9/29/2009	79	35	53	357	238	36	4	9	
10/14/2009	47	31	27	751	673	475	11	15	6
11/17/2009	44	32	27	1,242	958	801	24	5	
12/16/2009	46	34	30	2,588	2,488	2,417	49		
SC-3 Storm									
4/17/2009	64	43	38	1,604	1,524	1,065	56	12	
4/28/2009	58	37	32	779	719	500	14	22	4
5/26/2009	104	67	61	926	788	472	18	14	
6/1/2009	106	89	92	411	339	36	43	17	6
6/26/2009	701	193	181	1,586	630	220		260	34
7/21/2009	120	87	73	881	786	470	20	24	7
7/30/2009	160	146	133	547	478	144	31	7	
8/18/2009	116	89	87	1,653	1,251	849	36	19	6
Rain Gauge									
4/17/2009	37	25	25	1,635	1,616	396	1,076		
5/26/2009	130	49	51	2,581	1,693	627	1,888		
6/26/2009	341	125	108	2,689	1,335	367			
7/21/2009	398	371	209	2,844	1,858	286	1,351		
7/30/2009	154	72	62	2,229	1,642	591	988		
8/18/2009	263	164	147	2,726	1,621	542	999		

GEI Water Chemistry Data									
Analytical Detection Limits	**2**	**2**	**2**	**2**	**2**	**2**	**3**	**4**	**4**
Site/ Sample Date	**Total Phosphorus (µg/L)**	**Total Dissolved Phosphorus (µg/L)**	**Ortho-phosphate (µg/L)**	**Total Nitrogen (µg/L)**	**Total Dissolved Nitrogen (µg/L)**	**Nitrate+ Nitrite (µg/L)**	**Ammonia (µg/L)**	**Total Suspended Solids (mg/L)**	**Total Volatile Suspended Solids (mg/L)**
CC-10									
1/19/2010	194	138	143	1,784	1,655	1,282	200	28	4
2/16/2010	175	121	128	1,855	1,773	1,437	37	18	--
3/16/2010	166	126	121	1,445	1,310	1,005	27	19	--
4/14/2010	239	180	172	1,080	967	606	14	33	7
5/24/2010	275	201	192	1,098	986	627	39	44	5
6/22/2010	247	187	187	1,084	1,050	739	32	27	5
7/20/2010	250	192	192	971	855	567	39	19	--
8/24/2010	268	218	210	928	854	294	55	15	4
9/22/2010	241	182	192	614	544	256	55	13	5
CC-10 Storm									
4/22/2010	231	150	140	1,540	1,354	987	66	42	6
5/12/2010	237	164	161	1,375	1,101	641	113	93	6
6/28/2010	386	201	176	1,445	1,088	669	51	100	10
7/7/2010	281	179	187	1,227	974	625	46	70	9
7/21/2010	333	191	209	1,696	1,209	572	37	107	22
8/5/2010	473	171	179	1,465	1,036	737	32	197	17
CC-Out @ I225									
1/19/2010	82	55	48	1,006	834	223	208	7	--
2/16/2010	144	113	107	1,243	1,065	150	459	7	--
3/16/2010	92	55	49	972	791	190	188	9	--
4/14/2010	93	15	7	868	423	--	--	18	8
5/24/2010	95	54	44	694	456	7	30	13	5
6/22/2010	278	184	171	999	757	10	410	28	8
7/6/2010	298	188	182	1,109	816	127	180	22	8
7/20/2010	316	268	259	1,079	930	29	487	8	4
8/10/2010	127	58	42	1,033	626	15	80	19	5
8/24/2010	121	39	29	1,023	669	12	62	21	6
9/8/2010	129	45	36	1,424	1,038	297	189	26	5
9/22/2010	86	40	36	1,267	1,045	171	318	17	6

GEI Water Chemistry Data									
Analytical Detection Limits	**2**	**2**	**2**	**2**	**2**	**2**	**3**	**4**	**4**
Site/ Sample Date	**Total Phosphorus (µg/L)**	**Total Dissolved Phosphorus (µg/L)**	**Ortho-phosphate (µg/L)**	**Total Nitrogen (µg/L)**	**Total Dissolved Nitrogen (µg/L)**	**Nitrate+ Nitrite (µg/L)**	**Ammonia (µg/L)**	**Total Suspended Solids (mg/L)**	**Total Volatile Suspended Solids (mg/L)**
CT-1									
1/19/2010	84	30	21	1,866	1,721	971	139	38	5
2/16/2010	55	28	21	1,680	1,547	726	362	15	--
3/16/2010	89	18	11	1,490	1,218	715	153	32	5
4/14/2010	56	11	3	1,212	1,032	330	5	28	5
5/24/2010	53	15	9	1,562	1,392	621	64	19	5
6/22/2010	35	17	12	934	842	194	49	12	--
7/20/2010	58	29	20	971	863	235	48	13	--
8/24/2010	57	24	13	1,386	1,222	479	30	23	5
9/22/2010	63	16	9	1,711	1,524	973	40	30	8
CT-1 Storm									
4/22/2010	75	18	10	1,471	1,246	690	106	20	5
5/12/2010	111	38	34	1,897	1,569	900	147	21	--
6/28/2010	72	15	13	1,076	836	294	48	12	--
7/7/2010	65	36	28	818	672	192	41	22	11
7/21/2010	146	40	34	2,334	1,745	798	90	72	26
8/5/2010	246	44	22	1,776	1,270	663	14	100	18
CT-2									
1/19/2010	72	22	12	2,030	1,877	1,026	128	35	5
2/16/2010	47	19	12	1,962	1,791	826	434	15	4
3/16/2010	64	12	6	1,422	1,211	652	81	20	5
4/14/2010	72	10	5	972	732	153	--	41	8
5/24/2010	112	11	4	1,516	1,156	410	94	71	12
6/22/2010	41	13	6	907	802	114	50	13	--
7/20/2010	43	27	17	1,022	782	114	51	10	--
8/24/2010	42	18	7	1,316	1,178	316	52	13	4
9/22/2010	57	10	6	1,603	1,096	759	59	34	10
CT-2 Storm									
4/22/2010	67	16	7	1,452	1,235	670	114	16	5
5/12/2010	101	34	27	2,187	1,971	1,108	193	26	5
6/28/2010	65	23	11	1,117	952	341	53	12	4
7/7/2010	102	52	39	829	630	133	14	29	11
7/21/2010	93	35	31	2,491	2,060	1,013	247	42	25
8/5/2010	105	32	21	1,600	1,215	764	55	127	30

GEI Water Chemistry Data									
Analytical Detection Limits	**2**	**2**	**2**	**2**	**2**	**2**	**3**	**4**	**4**
Site/ Sample Date	**Total Phosphorus (µg/L)**	**Total Dissolved Phosphorus (µg/L)**	**Ortho-phosphate (µg/L)**	**Total Nitrogen (µg/L)**	**Total Dissolved Nitrogen (µg/L)**	**Nitrate+ Nitrite (µg/L)**	**Ammonia (µg/L)**	**Total Suspended Solids (mg/L)**	**Total Volatile Suspended Solids (mg/L)**
CT-P1									
1/19/2010	24	10	6	1,312	1,233	855	44	7	--
2/16/2010	15	8	7	1,314	1,225	929	28	4	--
3/16/2010	46	10	4	1,510	1,255	820	67	8	--
4/14/2010	39	10	5	855	710	119	--	8	4
5/24/2010	53	8	3	878	701	201	82	17	5
6/22/2010	83	22	18	1,066	926	324	87	23	6
7/20/2010	86	28	40	1,120	928	428	92	17	--
8/24/2010	96	54	45	1,199	1,036	371	94	22	5
9/22/2010	81	14	9	1,167	884	343	80	22	9
CT-P1 Storm									
4/22/2010	401	56	52	1,459	934	392	249	234	26
5/12/2010	112	11	8	1,196	1,103	414	221	23	5
6/28/2010	138	52	29	1,356	1,059	376	158	27	5
7/7/2010	146	58	48	1,133	795	328	26	38	8
7/21/2010	209	19	15	2,285	1,229	491	78	91	28
8/5/2010	318	30	18	1,607	846	361	19	32	9
CT-P2									
1/19/2010	30	11	7	1,485	1,411	1,102	38	15	--
2/16/2010	18	8	6	1,661	1,555	1,215	30	5	--
3/16/2010	42	8	3	1,385	1,145	692	64	7	--
4/14/2010	53	11	7	971	880	426	--	22	7
5/24/2010	55	7	3	1,174	966	494	56	35	7
6/22/2010	54	25	20	1,306	1,197	654	80	10	--
7/20/2010	58	38	34	1,416	1,179	658	121	8	4
8/24/2010	93	48	38	1,598	1,446	802	135	20	5
9/22/2010	86	10	6	1,432	1,129	622	75	21	6
CT-P2 Storm									
4/22/2010	158	44	34	1,653	1,324	618	242	42	10
5/12/2010	138	25	20	1,725	1,369	520	257	42	8
6/28/2010	192	58	37	1,615	1,176	558	113	29	7
7/7/2010	109	56	48	1,243	1,010	506	59	27	10
7/21/2010	110	43	40	2,313	1,555	667	155	39	13
8/5/2010	213	59	46	1,512	863	445	63	48	14

GEI Water Chemistry Data									
Analytical Detection Limits	**2**	**2**	**2**	**2**	**2**	**2**	**3**	**4**	**4**
Site/ Sample Date	**Total Phosphorus (µg/L)**	**Total Dissolved Phosphorus (µg/L)**	**Ortho-phosphate (µg/L)**	**Total Nitrogen (µg/L)**	**Total Dissolved Nitrogen (µg/L)**	**Nitrate+ Nitrite (µg/L)**	**Ammonia (µg/L)**	**Total Suspended Solids (mg/L)**	**Total Volatile Suspended Solids (mg/L)**
SC-3									
2/16/2010	35	28	24	3,958	3,611	3,414	19	4	--
3/16/2010	174	30	18	3,281	2,645	2,495	6	10	6
4/14/2010	33	22	21	344	292	7	--	5	--
5/24/2010	113	91	79	538	480	33	38	8	4
6/22/2010	203	183	174	401	387	11	9	6	--
7/20/2010	220	210	212	425	332	--	8	--	--
8/24/2010	155	135	132	453	446	--	8	41	--
9/22/2010	74	57	61	310	280	--	28	8	--
SC-3 Storm									
4/22/2010	79	42	28	1,899	1,684	1,198	31	17	5
5/12/2010	113	65	55	1,866	1,678	1,147	135	15	--
6/28/2010	193	170	141	688	597	189	63	8	--
7/7/2010	143	136	139	366	353	74	13	16	6
7/21/2010	116	91	91	1,323	1,097	611	23	5	8
8/5/2010	148	109	111	759	624	324	21	14	5
Rain Gauge									
6/28/2010	155	102	71	1,947	1,664	514	734	12	9
7/21/2010	1,482	529	551	8,522	7,787	922	2,044	--	--
8/5/2010	34	19	16	1,095	981	464	439	--	--

GEI Water Chemistry Data									
Analytical Detection Limits	**2**	**2**	**2**	**2**	**2**	**2**	**3**	**4**	**4**
Site/Sample Date	**Total Phosphorus (µg/L)**	**Total Dissolved Phosphorus (µg/L)**	**Ortho-phosphate (µg/L)**	**Total Nitrogen (µg/L)**	**Total Dissolved Nitrogen (µg/L)**	**Nitrate+ Nitrite (µg/L)**	**Ammonia (µg/L)**	**Total Suspended Solids (mg/L)**	**Total Volatile Suspended Solids (mg/L)**
CC-10									
10/14/2010	241	181	180	739	641	353	47	15	5
11/16/2010	197	130	126	1,663	1,522	1,151	41	27	--
12/21/2010	175	115	117	1,506	1,413	1,191	29	31	9
1/25/2011	189	126	129	1,902	1,774	1,519	54	28	--
2/21/2011	164	131	121	2,043	1,859	1,492	54	56	6
3/15/2011	165	114	112	1,442	1,313	990	32	31	5
4/20/2011	210	144	152	1,802	1,609	983	56	31	5
5/18/2011	253	173	178	1,617	1,505	1,153	76	17	4
6/7/2011	251	196	197	818	772	491	45	15	--
7/5/2011	272	218	224	663	602	322	45	11	--
8/2/2011	286	227	230	841	740	385	62	14	--
9/20/2011	259	215	211	713	672	450	50	8	--
CC-10 Storm									
5/11/2011	480	187	187	1,985	1,434	732	273	195	24
5/19/2011	283	165	160	1,541	1,404	952	91	65	10
6/20/2011	634	227	210	1,996	1,331	786	58	240	28
7/7/2011	375	210	208	1,681	1,370	754	40	73	16
9/7/2011	255	224	201	620	550	339	25	7	--
9/15/2011	442	183	193	1,593	1,124	754	46	158	21
CC-Out @ I225									
10/14/2010	127	11	7	1,092	563	16	165	32	11
11/16/2010	86	13	--	936	489	--	9	22	8
12/21/2010	66	13	2	834	482	96	6	15	9
1/25/2011	54	10	5	745	459	34	19	7	4
2/21/2011	63	22	3	884	547	112	23	9	--
3/15/2011	61	13	5	799	421	--	10	9	5
4/20/2011	82	17	7	855	517	--	31	20	6
5/18/2011	97	42	38	773	668	64	114	50	6
6/22/2011	166	88	77	989	701	11	134	24	6
7/20/2011	245	167	164	756	495	8	47	11	--
8/2/2011	254	166	160	995	572	45	76	15	7
9/7/2011	143	64	50	881	468	7	80	38	9

GEI Water Chemistry Data									
Analytical Detection Limits	**2**	**2**	**2**	**2**	**2**	**2**	**3**	**4**	**4**
Site/Sample Date	**Total Phosphorus (µg/L)**	**Total Dissolved Phosphorus (µg/L)**	**Ortho-phosphate (µg/L)**	**Total Nitrogen (µg/L)**	**Total Dissolved Nitrogen (µg/L)**	**Nitrate+ Nitrite (µg/L)**	**Ammonia (µg/L)**	**Total Suspended Solids (mg/L)**	**Total Volatile Suspended Solids (mg/L)**
CT-1									
10/14/2010	73	12	7	1,454	1,196	764	36	35	7
11/16/2010	98	9	--	2,225	1,990	1,369	90	64	9
12/21/2010	79	24	17	1,839	1,579	1,210	90	37	4
1/25/2011	83	11	5	2,101	1,743	1,228	129	51	6
2/21/2011	79	17	9	1,133	911	380	50	27	4
3/15/2011	30	21	16	786	596	84	24	22	4
4/20/2011	50	15	5	1,300	909	194	23	32	6
5/18/2011	58	17	15	1,156	945	416	71	26	4
6/7/2011	44	20	12	747	655	64	29	10	--
7/5/2011	52	26	20	684	607	20	40	14	--
8/2/2011	50	17	12	1,013	811	215	71	14	5
9/20/2011	148	16	7	1,167	785	340	29	75	9
CT-1 Storm									
5/11/2011	111	32	23	1,829	1,491	624	194	51	13
5/19/2011	72	34	32	1,173	1,039	535	84	16	--
6/20/2011	251	59	48	1,395	1,007	433	72	86	11
7/7/2011	179	48	35	1,728	1,291	499	31	52	12
9/7/2011	75	13	6	1,371	1,110	658	40	37	8
9/15/2011	171	68	63	1,680	1,297	806	75	34	10
CT-2									
10/14/2010	81	8	5	1,479	1,124	671	34	37	8
11/16/2010	68	9	5	1,882	1,682	1,134	81	32	5
12/21/2010	59	16	7	2,024	1,830	1,418	84	26	7
1/25/2011	55	16	11	1,821	1,864	1,062	174	21	4
2/21/2011	52	17	18	1,164	879	341	48	27	5
3/15/2011	80	8	5	849	605	57	24	42	7
4/20/2011	18	2	5	979	779	123	16	17	5
5/18/2011	50	12	9	1,035	878	311	89	19	--
6/7/2011	56	14	7	715	688	35	86	20	7
7/5/2011	44	11	7	762	598	11	62	12	4
8/2/2011	56	19	14	970	785	81	118	18	4
9/20/2011	57	13	6	916	748	194	16	27	6
CT-2 Storm									
5/11/2011	81	25	13	1,817	1,476	555	135	25	11
5/19/2011	76	49	32	1,430	1,293	682	94	20	5
6/20/2011	145	34	25	1,511	1,037	355	102	41	8
7/7/2011	149	46	32	1,487	1,018	361	10	24	12
9/7/2011	78	21	12	1,072	875	396	40	34	6
9/15/2011	184	77	71	1,800	1,387	881	79	42	9

GEI Water Chemistry Data									
Analytical Detection Limits	**2**	**2**	**2**	**2**	**2**	**2**	**3**	**4**	**4**
Site/Sample Date	**Total Phosphorus (µg/L)**	**Total Dissolved Phosphorus (µg/L)**	**Ortho-phosphate (µg/L)**	**Total Nitrogen (µg/L)**	**Total Dissolved Nitrogen (µg/L)**	**Nitrate+ Nitrite (µg/L)**	**Ammonia (µg/L)**	**Total Suspended Solids (mg/L)**	**Total Volatile Suspended Solids (mg/L)**
CT-P1									
10/14/2010	70	20	11	1,337	910	459	77	15	5
11/16/2010	37	9	--	1,027	896	467	51	5	--
12/21/2010	23	8	5	912	807	488	39	5	--
1/25/2011	18	5	6	1,104	1,039	713	31	5	--
2/21/2011	26	16	6	928	812	486	34	5	--
3/15/2011	41	9	4	910	705	248	42	8	--
4/20/2011	20	4	5	1,016	859	162	26	12	5
5/18/2011	51	24	24	1,100	958	427	117	13	--
6/7/2011	39	19	14	930	811	258	67	21	5
7/5/2011	96	32	25	1,218	935	278	91	20	6
8/2/2011	102	31	23	1,074	752	265	60	21	6
9/20/2011	77	16	6	1,194	694	277	15	21	7
CT-P1 Storm									
5/11/2011	362	67	59	1,840	1,119	333	305	169	30
5/19/2011	52	52	44	1,517	1,255	478	267	76	12
6/20/2011	463	40	28	1,720	945	440	49	226	33
7/7/2011	331	52	11	1,851	1,055	374	23	152	24
9/7/2011	130	25	11	1,431	1,010	557	64	27	9
9/15/2011	133	40	35	1,165	772	403	73	57	12
CT-P2									
10/14/2010	70	10	11	1,388	1,116	718	73	26	7
11/16/2010	36	6	4	1,295	1,211	778	50	12	--
12/21/2010	14	8	5	1,183	1,090	832	34	7	--
1/25/2011	22	5	7	1,441	1,352	1,091	21	10	--
2/21/2011	33	9	4	1,347	1,043	721	46	69	8
3/15/2011	80	8	5	1,009	876	425	36	41	6
4/20/2011	47	17	4	1,103	362	263	33	11	4
5/18/2011	39	18	18	1,263	1,164	656	122	10	--
6/7/2011	36	11	5	944	864	395	35	9	--
7/5/2011	61	32	25	1,212	1,049	479	90	8	--
8/2/2011	76	23	17	1,371	1,127	637	87	18	5
9/20/2011	70	21	9	1,259	907	520	23	15	6
CT-P2 Storm									
5/11/2011	256	82	73	2,233	1,627	536	358	80	18
5/19/2011	110	53	34	1,464	1,258	610	196	38	10
6/20/2011	261	49	43	1,612	1,078	516	78	88	17
7/7/2011	228	42	41	1,797	1,191	454	57	56	14
9/7/2011	197	47	26	1,700	1,136	531	83	33	9
9/15/2011	142	74	69	1,275	962	498	88	17	5

GEI Water Chemistry Data									
Analytical Detection Limits	**2**	**2**	**2**	**2**	**2**	**2**	**3**	**4**	**4**
Site/Sample Date	**Total Phosphorus (µg/L)**	**Total Dissolved Phosphorus (µg/L)**	**Ortho-phosphate (µg/L)**	**Total Nitrogen (µg/L)**	**Total Dissolved Nitrogen (µg/L)**	**Nitrate+ Nitrite (µg/L)**	**Ammonia (µg/L)**	**Total Suspended Solids (mg/L)**	**Total Volatile Suspended Solids (mg/L)**
SC-3									
10/14/2010	71	41	37	560	392	138	29	12	--
11/16/2010	43	19	18	718	667	403	11	7	--
2/21/2011	65	34	29	1,526	1,379	1,112	44	18	--
3/15/2011	42	26	21	1,135	1,061	790	19	11	--
4/20/2011	49	31	24	444	266	29	23	9	--
5/18/2011	32	33	25	264	239	8	12	--	--
SC-3 Storm									
5/11/2011	190	62	54	2,275	1,854	1,192	150	78	12
5/19/2011	60	36	28	1,280	1,179	885	44	9	--
6/20/2011	142	72	56	1,181	905	403	11	31	6
9/7/2011	169	154	129	838	684	240	16	8	--
9/15/2011	127	100	100	824	696	465	13	21	8

-- Denotes result less than MDL.

Appendix D

2011 WY Streamflow, Rainfall, Phosphorus Loading Calculations and Final Inflow and Load Data Normalized to the U.S. Army Corps of Engineers Inflow Data

D.1 Streamflow Determination

Water levels (stage) were monitored on 15-minute intervals using ISCO Model 6700 and 6712 flowmeters, with each unit being calibrated on a monthly basis using in situ staff gage measurements. Stage-discharge data were collected for sites CC-10, SC-3, CT-P1, CT-P2, and CT-1 by measuring stream discharge (ft^3/sec) with a Marsh McBirney Model 2000 flowmeter, and recording the water level at the staff gage and ISCO flowmeter (Table D-1).

Stage-discharge data collected in 2010 were combined with data collected during previous years to develop rating curves for each site, as long as historical data reflected no major changes to the streambed morphology, transducer, or staff gage. For example, if the transducer or staff gage was relocated or reset, then only the data collected post-change would be combined with the 2010 data.

Rating curves were developed for CC-10, SC-3, CT-P1, and CT-1 by fitting a nonlinear regression model to the data (Table D-2). For sites CC-10, SC-3, and CT-P1 a two-stage rating curve was developed to more accurately estimate flows at these sites. A multi-level weir equation is used to estimate flows at both the CT-P2 and CT-2 sites located in the outlet structure for each pond. The weir equations for Site CT-P2 and Site CT-2 (Table D-2) were provided by Muller Engineering (unpublished data, 2004).

While water levels for Cherry Creek, Shop Creek, and Cottonwood Creek are monitored on a fairly continuous basis, there were periods of time when daily mean flows were estimated due to a dead battery, pressure transducer malfunction, icing, or flooding (Table D-3). To estimate mean daily water levels for periods of missing data, stage relationships were evaluated among nearby sites, with the best-fit linear regression model being used to estimate the missing level data. In 2010, Site CC-10 contained one water level data gap at the first part of the year. In 2010, Site CC-10 revealed no strong relations with any of the GEI monitored stream sites. Therefore a model was developed with the USGS Cherry Creek Gage near Parker (#393109104464500), using data from January 20, 2010 to March 8, 2010, to estimate periods of missing levels for CC-10 in January and early February.

Table D-1: Stage-discharge data used to develop rating curves for sites CC-10, SC-3, CT-P1, CT-P2, and CT-1 in 2011.

Site	Year	Date	Staff Gage Level (ft)	Transducer Level (ft)	Discharge (cfs)
CC-10	2004	27-May-04	1.09	1.463	3.10
CC-10	2004	22-Jun-04	2.50	2.493	24.45
CC-10	2004	23-Jun-04	1.54	1.530	8.65
CC-10	2004	24-Aug-04	2.47	2.472	23.93
CC-10	2005	01-Apr-05	2.39	2.531	20.11
CC-10	2005	14-Apr-05	4.84	4.890	142.89
CC-10	2005	25-Apr-05	4.05	4.093	91.76
CC-10	2005	02-May-05	2.63	2.630	40.14
CC-10	2005	19-May-05	1.68	1.612	14.27
CC-10	2005	26-May-05	1.40	1.422	8.79
CC-10	2005	01-Jun-05	1.47	1.469	17.86
CC-10	2005	16-Aug-05	0.81	0.808	3.60
CC-10	2005	13-Oct-05	2.41	2.418	29.81
CC-10	2006	20-Apr-06	1.40	1.391	10.92
CC-10	2006	13-Jun-06	0.56	0.567	2.05
CC-10	2006	12-Jul-06	1.56	1.482	23.62
CC-10	2006	08-Aug-06	0.55	0.550	5.18
CC-10	2006	27-Dec-06	1.27	1.230	20.51
CC-10	2007	13-Mar-07	4.27	4.317	93.87
CC-10	2007	10-May-07	3.10	3.100	62.15
CC-10	2007	26-Jul-07	0.61	0.621	1.63
CC-10	2007	9-Aug-07	1.32	1.306	11.11
CC-10	2007	13-Nov-07	1.70	1.692	6.27
CC-10	2008	19-Feb-08	2.50	2.470	31.14
CC-10	2008	27-Mar-08	1.98	1.980	25.65
CC-10	2008	26-Jun-08	0.64	0.617	2.79
CC-10	2008	15-Aug-08	0.87	0.864	5.92
CC-10	2008	11-Dec-08	1.36	1.387	21.28
CC-10	2009	22-Jan-09	1.27	--	21.53
CC-10	2009	24-Mar-09	1.18	1.126	17.98
CC-10	2009	23-Jun-09	1.80	1.767	19.25
CC-10	2009	08-Dec-09	1.79	1.802	11.11
CC-10	2009	18-Aug-09	2.48	2.470	38.79
CC-10	2009	20-Nov-09	2.12	2.081	27.89
CC-10	2010	26-Jan-10	1.76	1.733	21.03
CC-10	2010	15-Apr-10	2.15	2.136	28.03
CC-10	2010	29-Jun-10	0.91	0.889	6.10
CC-10	2010	10-Aug-10	1.58	1.566	21.51
CC-10	2010	8-Sep-10	0.42	0.468	1.77

Site	Year	Date	Staff Gage Level (ft)	Transducer Level (ft)	Discharge (cfs)
CC-10	2011	1-Mar-11	1.76	1.767	21.17
CC-10	2011	31-Mar-11	1.52	1.656	22.81
CC-10	2011	27-Apr-11	1.48	1.414	18.63
CC-10	2011	11-May-11	2.35	2.485	29.56
CC-10	2011	4-Aug-11	1.15	1.153	5.36
CC-10	2011	27-Sep-11	0.78	0.662	1.88
SC-3	2009	24-Mar-09	0.18	0.021	0.13
SC-3	2009	26-May-09	1.04	1.014	6.29
SC-3	2009	18-Aug-09	0.75	0.684	1.29
SC-3	2009	20-Nov-09	0.30	0.376	0.11
SC-3	2010	29-Jun-10	0.26	0.237	0.08
SC-3	2010	10-Aug-10	0.35	0.349	0.75
SC-3	2011	04/27/2011	0.29	0.316	0.14
SC-3	2011	05/11/2011	1.10	1.000	5.28
CT-P1	2009	26-May-09	2.29	2.286	21.80
CT-P1	2009	23-Jun-09	1.42	1.401	1.27
CT-P1	2009	12-Aug-09	1.38	1.375	0.82
CT-P1	2009	18-Aug-09	2.00	1.916	12.43
CT-P1	2009	20-Nov-09	1.64	1.634	1.79
CT-P1	2010	26-Jan-10	1.50	1.497	0.78
CT-P1	2010	20-Apr-10	1.51	1.511	1.15
CT-P1	2010	29-Jun-10	1.57	1.582	1.79
CT-P1	2010	10-Aug-10	1.72	1.704	3.29
CT-P1	2010	8-Sep-10	1.48	1.446	0.57
CT-P1	2011	1-Mar-11	1.46	1.463	0.57
CT-P1	2011	31-Mar-11	1.50	1.483	0.84
CT-P1	2011	27-Apr-11	1.65	1.639	2.97
CT-P1	2011	11-May-11	2.45	2.423	31.15
CT-P1	2011	26-May-11	1.64	1.632	2.23
CT-P1	2011	20-Jun-11	3.00	3.360	64.62
CT-P1	2011	4-Aug-11	1.50	1.502	0.62
CT-P1	2011	27-Sep-11	1.50	1.542	0.61
CT-1	2011	1-Mar-11	0.40	0.378	1.53
CT-1	2011	31-Mar-11	0.40	0.420	2.29
CT-1	2011	27-Apr-11	0.58	0.579	6.34
CT-1	2011	11-May-11	0.80	0.814	15.69
CT-1	2011	20-Jun-11	1.80	1.637	119.77
CT-1	2011	4-Aug-11	1.06	1.060	1.31
CT-1	2011	27-Sep-11	1.02	1.013	1.41

Table D-2: Discharge (Q, cfs) and stage height (H, ft) relationships for all sites. Rating curves are developed for sites CC-10, SC-3, CT-P1, and CT-1, while multi-level orifice and weir equations are used for sites CT-P2, and CT-2.

Site	Stage Interval	Discharge Equations	R^2
CC-10	< 1.0	Q = EXP((H+0.3113)/0.7788)	0.76
	> 1.0	Q = EXP((H+9.9361)/2.8567)-40.0351	0.90
SC-3	< 0.25	Q = EXP((H-0.6651)/0.1984)	0.90
	0.25 – 1.2	Q = EXP((H-0.3871)/0.3723)-0.5803	0.94
	> 1.2	Q = (H-0.2915)/0.1376)	0.88
CT-P1		Q = EXP((H+0.5924)/0.8212)-11.8991	0.99
CT-P2	< 0.60	Q = (3.3)*(1)*(H)^(1.5)	
	0.61 - 1.09	Q = (0.60)*(0.50)*((2*32.2*(H_{adj}))^(0.5)	
	1.10 - 1.99	Q = (0.60)*(0.50)*((2*32.2*(H_{adj}))^(0.5))+((3.33)*(1)*(H-1.0)^(1.5)	
	2.00 - 2.59	Q = (0.60)*(0.50)(2*32.2*(H_{adj}))^(0.5)+((0.60)*(0.50)*((2*32.2*(H_{adj}-1.0))^(0.5))+((3.33) *(1)*(H-2.0)^(1.5)	
	2.60 - 2.99	Q = (0.60)*(0.50)(2*32.2*(H_{adj}))^(0.5)+((0.60)*(0.50)*((2*32.2*(H_{adj}-1.0))^(0.5))+((0.60) *(0.50)*(H_{adj}-2.0)^(0.5)	
	3.00 - 3.59	Q = (0.60)*(0.50)(2*32.2*(H_{adj}))^(0.5)+((0.60)*(0.50)*((2*32.2*(H_{adj}-1.0))^(0.5))+((0.60) *(0.50)*(H_{adj}-2.0)^(0.5))+((3.3)*(1)*(H-3.0)^(1.5)	
	3.60 - 3.99	Q = (0.60)*(0.50)(2*32.2*(H_{adj}))^(0.5)+((0.60)*(0.50)*((2*32.2*(H_{adj}-1.0))^(0.5))+((0.60) *(0.50)*(H_{adj}-2.0)^(0.5))+((0.60)*(0.50)*(2*32.2*(H_{adj}-3.0)^(0.5)	
	4.00 - 4.49	Q = (0.60)*(0.50)(2*32.2*(H_{adj}))^(0.5)+((0.60)*(0.50)*((2*32.2*(H_{adj}-1.0))^(0.5))+((0.60) *(0.50)*(H_{adj}-2.0)^(0.5))+((0.60)*(0.50)*(2*32.2*(H_{adj}-3.0)^(0.5))+((3.3)(1)(H-4.0))^ (1.5)	
	4.50 - 5.19	Q = (0.60)*(0.50)(2*32.2*(H_{adj}))^(0.5)+((0.60)*(0.50)*((2*32.2*(H_{adj}-1.0))^(0.5))+((0.60) *(0.50)*(H_{adj}-2.0)^(0.5))+((0.60)*(0.50)*(2*32.2*(H_{adj}-3.0)^(0.5))+((0.60)(0.50)(2* 32.2*H_{adj}-4.0))^(0.5)	
	5.20 - 6.80	Q = (0.60)*(0.50)(2*32.2*(H_{adj}))^(0.5)+((0.60)*(0.50)*((2*32.2*(H_{adj}-1.0))^(0.5))+((0.60) *(0.50)*(H_{adj}-2.0)^(0.5))+((0.60)*(0.50)*(2*32.2*(H_{adj}-3.0)^(0.5))+((0.60)(0.50)(2* 32.2*H_{adj}-4.0))^(0.5))+((3.3)(1)(H-5.2)^(1.5)	
CT-1	1 Oct to 20 Feb	Q = EXP((-0.0768+SQRT((0.0768^2)-(4*0.0339*(0.4992-H))))/(2*0.0339))	0.97
CT-1	21 Feb to 30 Sep	Q = EXP((H+1.822)/0.7336)-19.6997	0.99
CT-2	< 0.95	Q = ((3.3)*(2)*(H)^(1.5))	
	0.95 - 1.35	Q = ((7.2)+(3.3)*(2)*(H)^(1.5))	
	> 1.35	Q = ((7.2)+(3.3)*(2)*(H)^(1.5))+((3.3)*(2)*(H-1.0)^(1.5))+((3.3)*(2)*(H-0.50)^(1.5))	

H_{adj} = Mean daily level - 0.25 ft

Table D-3: Equations used to estimate missing daily mean data and percent of annual data estimated.

Site	Equations	R^2	Percent of Annual Data Estimated
CC-10, Oct to Dec	CC-10 Level = 3.7483*(Parker Level) -12.185	0.93	7%
CC10, Jul to Sep	CC-10 Level 3.0153*(Parker Level) - 9.2532	0.72	5%
SC-3, May to Sep	SC-3 Level = 0.3718*(CC-10 Level) - 0.2339	0.53	23%
CT-P1, Oct to Sep	CT-P1 Level = 0.2294(CT-P2 Level) + 1.3837	0.87	7%
CT-P2	Interpolated		3%
CT-1, Oct to Sep	CT-1 Level = 0.1403*(CT-P2 Level) + 0.5484	0.82	11%
CT-2, Oct to Sep	CT-2 Level = 0.3452*(CT-P2 Level) + 0.4368	0.84	5%

D.2 Phosphorus Loading

The USACE 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. GEI monitors stream inflows to the reservoir using gaging stations on Cherry Creek, Cottonwood Creek, and Shop Creek (the three main surface inflows) to provide a daily surface inflow record. Given the differences in the two methods for determining inflow, combined with the potential of unmonitored surface flows that may result in greater seepage through the adjacent wetlands during storm events, an exact match between USACE and GEI calculated inflows is not expected.

In an effort to maintain a seasonality component in phosphorus loads and exports for the reservoir, the normalization process was performed on monthly data. Loads attributed to stream inflow, reservoir outflow, precipitation and the alluvium were still calculated on a daily basis, using the daily inflow records and respective concentration data, but summed to create a monthly inflow value. In the case of the alluvial inflow constant, the annual value was divided by the number of days in the year to create a daily value, and then summed to create a monthly value, with no seasonal dynamics. The monthly precipitation and alluvial inflow values are subtracted from the monthly USACE inflow value to create an Adjusted USACE Inflow. The monthly GEI stream flow (CC-10 and CT-2 flow) is subtracted from the Adjusted USACE Inflow to determine the quantity of flow that needs to be redistributed proportionally among the two primary surface inflow streams (Cherry Creek and Cottonwood Creek). If the monthly Redistributed Inflow is greater than 1,000 acre-feet, then the first 1,000 acre-feet is redistributed proportionally to the stream sites, with the remainder being placed in an Ungaged Flow category. This category represents unmonitored flow that may be attributed to wetland seepage, stream bank storage, or ungaged surface flows during the respective month. Once the redistributed inflows are apportioned to the stream sites, monthly loads are computed using their respective flow-weighted phosphorus concentrations and identified as "Normalized" to the USACE inflow. The alluvial load is based on the long-term median phosphorus concentration for MW-9 (1995-2006, 190 µg/L). Notably, flow and loads for sites upstream of CT-2 or on Shop Creek are not normalized. Only the unadjusted flow and load data was used to evaluate the effectiveness of the PRFs on Cottonwood Creek.

D.3 Tributary Streams

Once the water year flow record for each stream site was finalized, the mean daily flows were categorized as either base flow or storm flow events. If the mean daily flow was greater than the 90th percentile annual value (Table D-4), then the flow was categorized as storm flow. Flows less than the 90th percentile were categorized as base flows.

Table D-4: Threshold flow value used to categorize base flows and storm flows in 2011.

Site	90th Percentile (cfs)
CC-10	24.22
SC-3	0.76
CT-1	6.87
CT-2	4.56
CT-P1	4.08
CT-P2	3.25

For all streams, total phosphorus concentrations were determined for base flow samples collected on a monthly basis, and for storm flow samples collected at irregular intervals throughout the year (Appendix C). For each inflow site, the monthly base flow TP concentration (Table D-5) was applied to the daily base flows during that month, while the annual median storm flow TP concentration was applied to storm flows (Equation 1). Daily loadings were then summed to obtain estimates of monthly and water year phosphorus loading for each stream site (Table D-6).

EQUATION 1:

$$L_{day} = \mu g/L \times Q_{in} \times \frac{86400 sec}{day} \times \frac{28.3169 L}{ft^3} \times \frac{2.205 \times 10^{-9} lbs}{\mu g}$$

where:

L_{day} = pounds per day phosphorus loading,

$\mu g/L$ = total phosphorus concentration of base flow or storm flow

Q_{in} = mean daily flow in ft^3/sec.

Table D-5: Monthly base flow TP concentrations (µg/L) and median annual storm flow TP concentration (µg/L) applied to respective flows in 2011.

Month	CC-O	CC-10	SC-3	CT-P1	CT-P2	CT-1	CT-2
October 2010	127	241	71	70	70	73	81
November 2010	86	197	43	37	36	98	68
December 2010	66	175	50	23	14	79	59
January 2011	54	189	58	18	22	83	55
February 2011	63	164	65	26	33	79	52
Marc 2011h	61	165	42	41	80	30	80
April 2011	82	210	49	20	47	50	18
May 2011	97	253	32	51	39	58	50
June 2011	166	251	154	39	36	44	56
July 2011	245	272	143	96	61	52	44
August 2011	254	286	145	102	76	50	56
September 2011	143	259	87	77	70	148	57
Water Year storm flow median	--	409	142	232	213	141	113

D.4 Reservoir Outflow

The USACE monitors flows through the outlets gates on a regular interval and provides GEI with estimates of daily outflow for the reservoir. GEI monitors water quality of the outflow at a site located approximately 75 m downstream of the concrete outflow structure at the base of the dam (CC-O @ I-225). The monthly total phosphorus concentration collected from this site was applied to the USACE outflow to estimate the 2011 WY export load (Equation 1).

D.5 Precipitation

Precipitation data collected at Denver/Centennial Airport (KAPA) was used to estimate phosphorus loading due to precipitation in 2011 (Appendix D), with the basic premise that precipitation generally falls evenly across the reservoir, although rain showers in the Cherry Creek Reservoir area can be localized. Calculation of the phosphorus load into Cherry Creek Reservoir from precipitation was based on the long-term median phosphorus concentration (1987 to 2005) and Equation 2.

EQUATION 2:

$$L_{precip} = \frac{PR}{12in} \times A_{res} \times \frac{43650ft^2}{acre} \times \frac{\mu g}{L} \times \frac{28.3169L}{ft^3} \times \frac{2.205 \times 10^{-9} lbs}{\mu g}$$

where:

L_{precip} = pounds of phosphorus from precipitation,

PR = rainfall precipitation in inches,

A_{res} = surface area of the reservoir (852 ac), and

µg/L = 116 µg/L, long-term median TP concentration.

D.6 Alluvium

The alluvial water component remains one of the unmonitored sources of inflow to the reservoir. The annual flow is relatively constant given the boundaries of the alluvium in relation to the reservoir, with the majority of the alluvial water monitored at MW-9 flowing beneath the reservoir and under the dam, because the dam is not grounded on bedrock.

In 2005, Lewis et al. evaluated the ground water contribution and its relationship to the phosphorus budget to the reservoir. They observed a zone of high alluvial seepage located in the southeastern margin of the reservoir that covered approximately 1.5 acres and extended further into the reservoir to an approximate depth of 2 feet. At depths greater than 2 feet the composition of the sediment changed from one of coarse sand to one of high organic matter and carbonate content which greatly limited alluvial seepage. Lewis et al. used three different methods to derive the alluvial water component of 2,200 ac-ft/yr; direct measurements of alluvial inflow which included seepage estimates from the adjacent wetlands (submerged seepage meters and piezometers), ionic mass balance, and water budget balances.

Based on this study, and analysis of long-term residual inflow estimates, the 2011 alluvial component was defined as a constant source of water to the reservoir that accounted for 1,437 ac-ft/yr with no seasonal fluctuations. The long-term (1994-2005) median total dissolved phosphorus concentration for MW-9 (190 µg/L) was used to estimate the alluvial load component (Equation 3).

EQUATION 3:

$$L_{alluvium} = \mu g/L \ (\ Q_{alluvium} \ (\ \frac{2.205 \ H \ 10^{-9} \ lbs}{\mu g} \ (\ \frac{1,233,482 \ L}{Ac\text{-}ft}$$

where:

$L_{alluvium}$ = alluvial phosphorus loading in pounds per year

µg/L = 190 µg/L, long-term median TDP concentration

$Q_{alluvium}$ = alluvial inflow in ac-ft

D.7 Redistributed Inflows

During the 2011 WY, the repartitioning of the alluvial inflow component created a "Redistributed Inflow" category that is comprised of flows that are currently unaccounted for given the current monitoring regime. The majority of these flows are likely the result of bank full flooding that occurs along Cherry Creek, upstream of Site CC-10, which eventually enters the reservoir as seepage from the wetland area. Other flows in this category include unmonitored inflows from the Belleview and Quincy drainages, and surface inflows around the margin of the reservoir. The monthly "Redistributed Inflow" is calculated as presented below (Equation 4, Table D-6), and is either a positive or negative value depending on the monthly balance.

EQUATION 4:

Redistributed Inflow = (USACE Inflow - Precipitation - Alluvial Inflow) - GEI Stream Inflow

If the value is positive, then the inflow or load is added proportionally to Cherry Creek and Cottonwood Creek inflows. If the value is negative, the inflow or load value is subtracted proportionally from Cherry Creek and Cottonwood Creek inflows.

In the case when the redistributed inflow or load results in a negative monthly balance for a stream, the inflow or load for that stream is set to ZERO, with the remaining balance being subtracted from the other stream site. In the rare case when the redistributed inflow or load results in negative monthly balances for both streams, then the inflow or load for each stream is set to ZERO, with the remaining balance being subtracted from the monthly alluvial values.

Additionally, when the redistributed inflow is greater than 1,000 ac-ft/mo, the first 1,000 acre-feet will be redistributed among the two streams, and the remainder will be placed into an "Ungaged Inflow" category. The reasoning behind this category is if the redistributed inflow is truly this great, then the current inflow monitoring regime should be reevaluated to address such occurrences.

Table D-6: Unadjusted monthly flow and load data and the final normalized flow and load.

Month	Unadjusted Flow (ac-ft/mo)									Normalized Flow (ac-ft/mo)		
	USACE Inflow	USACE Outflow	CC-10	SC-3	CT-P1	CT-P2	CT-1	CT-2	Precip	Alluvium	CC-10	CT-2
October 2010	442	637	234	4	107	95	217	203	46	170	121	105
November 2010	1,101	851	750	5	67	77	191	183	24	164	734	179
December 2010	1,388	1,212	1,085	19	16	52	145	166	1	170	1,056	162
January 2011	1,406	1,399	1,072	25	47	67	163	181	20	170	1,041	176
February 2011	1,732	1,630	1,242	38	76	87	114	204	18	153	1,341	220
March 2011	1,668	1,922	1,287	6	35	56	59	211	11	170	1,278	210
April 2011	1,460	1,269	940	9	103	101	171	211	70	164	1,001	225
May 2011	3,045	1,612	1,779	80	433	350	561	723	258	170	1,860	756
June 2011	1,137	913	883	107	168	127	374	373	111	164	605	256
July 2011	2,182	1,803	1,423	33	330	322	578	735	227	170	1,177	608
August 2011	180	186	409	2	23	50	95	188	28	153	0	0
September 2011	379	577	311	29	119	132	161	271	65	164	80	70
Water Year Total	**16,120**	**14,011**	**11,415**	**357**	**1,524**	**1,516**	**2,829**	**3,649**	**879**	**1,983**	**10,294**	**2,967**
Month	**Unadjusted Total Phosphorus Load (lbs/mo)**									**Normalized Load (lbs/mo)**		
	USACE Inflow	**USACE Outflow (CC-O)**	**CC-10**	**SC-3**	**CT-P1**	**CT-P2**	**CT-1**	**CT-2**	**Precip**	**Alluvium**	**CC-10**	**CT-2**
October 2010	--	220	153	1	30	26	46	46	15	88	79	24
November 2010	--	199	402	1	12	12	53	35	8	85	393	34
December 2010	--	218	517	5	1	2	31	27	0	88	503	26
January 2011	--	205	551	4	2	4	37	27	6	88	535	26
February 2011	--	279	1,040	12	11	16	24	30	6	79	1,122	33
March 2011	--	319	642	1	4	12	5	46	3	88	638	46
April 2011	--	283	537	2	29	28	31	13	22	85	571	14
May 2011	--	425	1,742	28	238	175	186	200	82	88	1,821	209
June 2011	--	412	753	42	65	45	96	85	35	85	517	59
July 2011	--	1,201	1,353	13	187	164	194	203	72	88	1,119	168
August 2011	--	128	318	1	6	10	13	29	9	79	0	0
September 2011	--	224	219	7	50	46	64	60	20	85	56	16
Water Year Total	**--**	**4,113**	**8,227**	**117**	**635**	**540**	**780**	**801**	**278**	**1,025**	**7,354**	**655**

Table D-7: Calculation of the monthly redistributed inflow and load values and the apportioning of these data to sites CC-10 and CT-2.

Month	Adjusted USACE Inflow (USACE Precip Alluvium)	GEI Inflow CC-10 +CT-2 (ac-ft/mo)	Redistributed Inflow (ac-ft/mo)	CC-10 Percent of GEI Inflow	CT-2 Percent of GEI Inflow	CC-10 Redistributed Flow (ac-ft/mo)	CT-2 Redistributed Flow (ac-ft/mo)	Ungaged Residual Flow (ac-ft/mo)	Redistributed Load (lbs/mo)	CC-10 Redistributed Load (lbs/mo)	CT-2 Redistributed Load (lbs/mo)	Ungaged Residual Load (lbs/mo)
October 2010	226	437	-211	54%	46%	-113	-98	0	-96	-74	-22	0
November 2010	912	933	-20	80%	20%	-16	-4	0	-10	-9	-1	0
December 2010	1,218	1,252	-34	87%	13%	-29	-5	0	-15	-14	-1	0
January 2011	1,217	1,253	-36	86%	14%	-31	-5	0	-17	-16	-1	0
February 2011	1,560	1,446	115	86%	14%	99	16	0	85	82	3	0
March 2011	1,488	1,498	-10	86%	14%	-9	-1	0	-4	-4	0	0
April 2011	1,225	1,151	74	82%	18%	60	14	0	35	34	1	0
May 2011	2,616	2,502	114	71%	29%	81	33	0	88	79	9	0
June 2011	861	1,256	-395	70%	30%	-278	-117	0	-262	-236	-26	0
July 2011	1,785	2,158	-374	66%	34%	-246	-128	0	-269	-234	-35	0
August 2011	-17	597	-614	69%	31%	-409	-188	0	-347	-318	-29	0
September 2011	150	582	-432	53%	47%	-231	-201	0	-207	-163	-44	0
Water Year Total	**13,241**	**15,065**	**-1,823**	**74%**	**26%**	**-1,122**	**-684**	**0**	**-1,019**	**-873**	**-146**	**0**

Appendix E

2011 WY Biological Data

Table E-1: Quantity and size of fish stocked in Cherry Creek Reservoir, 1985 to 1995.

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Black crappie											
Size (inches)	5	--	--	--	--	--	--	--	--	--	--
Number	7,234	--	--	--	--	--	--	--	--	--	--
Blue catfish											
Size (inches)	--	--	--	--	--	--	--	3	--	3	--
Number	--	--	--	--	--	--	--	9,000	--	21,000	--
Bluegill											
Size (inches)	--	1	0.2	--	--	--	--	--	--	--	--
Number	--	111,968	70,000	--	--	--	--	--	--	--	--
Channel catfish											
Size (inches)	2 to 8	4	4	3	3	3.5	3	4	4	4	4
Number	116,784	25,594	25,600	16,000	10,316	25,599	13,500	13,500	13,500	23,625	18,900
Cutthroat trout											
Size (inches)	--	6	--	--	--	--	--	--	--	9	--
Number	--	52,228	--	--	--	--	--	--	--	9,089	--
Flathead catfish											
Size (inches)	--	--	--	--	--	--	--	--	--	1	--
Number	--	--	--	--	--	--	--	--	--	148	--
Largemouth bass											
Size (inches)	--	--	5	5	6	--	--	--	--	--	--
Number	--	--	10,000	10,000	8,993	--	--	--	--	--	--
Rainbow trout											
Size (inches)	8 to 12	2 to 18	2 to 26	9.5	8 to 22	9 to 15	9 to 10	9.5	9.5	9 to 18	9 to 20
Number	75,753	414,136	129,715	293,931	79,919	74,986	79,571	101,656	92,601	62,615	139,242
Tiger musky											
Size (inches)	--	5.5	7	8	--	8	5 to 8	7	9	8	8
Number	--	4,723	4,000	4,500	--	2,001	6,500	4,940	4,500	900	4,500
Walleye											
Size (inches)	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Number	2,346,000	1,734,000	1,760,000	1,760,000	1,352,000	1,400,000	1,300,000	2,600,000	2,600,000	2,600,000	2,600,000
Wiper											
Size (inches)	--	0.2	--	--	0.2	1	1	10	1	1 to 4	1
Number	--	80,000	--	--	99,000	8,996	9,000	15,520	9,003	26,177	4,500
Yellow perch											
Size (inches)	2	--	--	--	--	--	--	--	--	--	--
Number	90,160	--	--	--	--	--	--	--	--	--	--

Table E-2: Quantity and size of fish stocked in Cherry Creek Reservoir, 1996 to 2006.

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Black crappie											
Size (inches)	--	--	--	--	--	--	--	--	--	--	2.5
Number	--	--	--	--	--	--	--	--	--	--	300
Channel catfish											
Size (inches)	3	3	4	3.5	4.1	3.5	--	2.5	2.5	2.2	2.8
Number	8,100	13,500	7,425	13,500	13,500	13,500	--	33,669	13,500	14	13,500
Cutthroat trout											
Size (inches)	9.5	3 to 9	--	--	--	--	--	--	--	--	--
Number	85,802	22,907	--	--	--	--	--	--	--	--	--
Largemouth bass											
Size (inches)	--	--	--	--	--	--	--	--	--	--	2.1
Number	--	--	--	--	--	--	--	--	--	--	195
Northern pike											
Size (inches)	--	--	--	--	--	--	--	--	--	--	--
Number	--	--	--	--	46	--	--	--	--	--	--
Rainbow × cutthroat hybrid											
Size (inches)	--	--	--	--	--	--	--	--	--	--	10.6
Number	--	--	--	--	5,600	--	--	--	--	--	7,895
Rainbow trout											
Size (inches)	4 to 22	10 to 24	11	10 to 19	--	10 to 19	10	10.5	10.5	10.4	10.8
Number	163,007	74,525	59,560	32,729	--	23,065	13,900	30,111	43,553	43,248	47,150
Snake River cutthroat											
Size (inches)	--	--	--	--	--	--	--	--	--	--	16.1
Number	--	--	--	--	--	--	--	--	--	--	204
Tiger musky											
Size (inches)	7	6	7	7	8	7	7	--	--	--	--
Number	3,500	4,500	4,000	3,000	4,086	4,000	4,000	--	--	--	--
Walleye											
Size (inches)	0.2	0.2	1.5	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.2
Number	3,202,940	2,600,000	40,000	2,400,000	2,400,000	2,400,000	2,519,660	4,136,709	2,874,100	2,579,939	2,788,825
Wiper											
Size (inches)	1	1	1.3	1.3	--	--	--	--	--	0.2	2.1
Number	8,938	9,000	9,000	9,000	--	--	--	--	--	200,000	5,000

Table E-3: Quantity and size of fish stocked in Cherry Creek Reservoir, 2007 to 2011.

	2007	2008	2009	2010	2011
Black crappie					
Size (inches)	--	--	1.4	--	1.1 to 1.2
Number	--	--	5,000	--	97,399
Channel catfish					
Size (inches)	3	--	3.3	2.7	3.4
Number	9,360	--	3,780	13,500	9,450
Cutthroat trout					
Size (inches)	--	--	--	12.5 to 14.7	15.1
Number	--	--	--	1,562	200
Rainbow × cutthroat trout					
Size (inches)	--	9.7	--	--	--
Number	--	4,001	--	--	--
Rainbow trout					
Size (inches)	10	10.1	4.8	9.6 to 17.7	10.1 to 10.9
Number	37,709	11,588	12,287	11,038	28,029
Size (inches)	12	--	10.2	9.8 to 10.2	10.6
Number	4,800	--	29,759	39,200	1,737
Size (inches)	--	--	13.6	--	--
Number	--	--	109	--	--
Walleye					
Size (inches)	0.3	0.2	0.2	0.2 to 1.1	0.2
Number	4,300,000	3,992,572	4,012,800	4,264,512	4,001,400
Size (inches)	1	--	1.3	--	--
Number	7,998	--	14,998	--	--
Wiper					
Size (inches)	1.5	--	--	1.6	--
Number	4,600	--	--	8,000	--

Table E-4: 2011 Cherry Creek Reservoir phytoplankton.

	2011														
	14-Oct	16-Nov	25-Jan	15-Mar	20-Apr	15-May	31-May	7-Jun	21-Jun	5-Jul	19-Jul	2-Aug	18-Aug	7-Sep	20-Sep
Bacillariophyta															
Centrales															
Coscinodiscus sp.	67	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cyclotella meneghiniana	134	180	--	--	--	--	--	--	--	28	--	95	92	95	--
Cyclotella stelligera	3,087	--	--	--	--	--	--	--	--	--	42	--	--	127	--
Stephanodiscus astraea minutula	3,154	--	--	51	--	--	--	116	30	--	84	442	123	381	1,107
Stephanodiscus hantzschii	--	4,510	--	--	--	--	--	--	--	28	--	284	337	1,112	5,940
Stephanodiscus niagarae	67	--	--	--	--	--	150	58	--	--	--	--	--	32	--
Synedra radians	--	--	107	103	39	213	601	1,619	--	--	--	32	--	--	--
Synedra ulna	--	--	--	--	--	--	--	--	--	--	--	--	--	32	--
Pennate															
Amphora ovalis	--	--	--	--	--	--	--	--	--	--	--	--	--	32	--
Asterionella formosa	--	--	--	1,691	2,411	2,011	5,412	2,313	--	--	--	--	--	64	--
Fragilaria construens	--	--	--	--	--	--	--	--	--	28	--	--	--	--	--
Melosira ambigua	--	--	--	--	--	--	--	--	--	--	--	32	--	--	--
Melosira granulata	134	90	--	--	--	--	--	--	--	--	--	--	31	32	101
Navicula anglica	--	--	--	--	--	--	--	--	--	--	--	--	--	32	--
Navicula cascadensis	--	--	--	--	--	--	--	--	--	--	--	--	--	32	--
Navicula decussis	--	--	--	--	--	--	--	--	--	--	--	--	--	32	--
Navicula minuscula	--	--	--	--	39	--	--	--	--	--	--	--	--	--	--
Navicula sp.	--	--	--	--	78	--	--	--	--	--	--	--	--	--	--
Nitzschia acicularis	--	--	--	154	--	--	--	--	--	--	--	32	31	64	--
Nitzschia capitellata	--	--	--	51	--	--	--	--	--	--	--	--	--	--	--
Nitzschia palea	--	--	--	--	--	--	--	--	--	--	--	--	--	32	--
Chlorophyta															
Ankistrodesmus falcatus	537	1,714	1,289	308	--	--	75	1,272	30	141	459	568	337	191	503
Chlamydomonas sp.	134	--	322	103	--	--	--	--	30	620	292	95	153	191	403
Chodatella wratislawiensis	--	--	322	51	--	--	--	--	--	--	--	--	--	--	--
Cosmarium sp.	--	--	--	--	--	--	--	--	30	--	--	--	--	--	--
Crucigenia crucifera	--	--	--	--	--	--	--	--	--	--	--	--	61	--	--
Crucigenia quadrata	134	992	537	615	78	91	75	58	30	197	167	95	31	--	403
Crucigenia tetrapedia	134	90	--	--	--	--	--	--	--	56	--	--	61	--	--
Gloeocystis ampla	--	--	--	51	--	--	--	--	--	--	--	--	--	--	--
Oocystis lacustris	--	--	--	--	--	30	150	173	61	56	42	--	--	64	--
Oocystis pusilla	67	180	--	51	117	91	150	--	30	141	84	95	61	--	--
Pediastrum boryanum	67	--	--	--	39	91	--	58	--	85	--	--	--	--	--
Pediastrum duplex	--	--	--	--	--	--	--	--	--	--	42	--	--	--	--
Pediastrum tetras	67	--	--	51	--	--	--	--	--	56	--	--	--	--	--
Scenedesmus abundans	470	541	483	308	117	--	75	--	30	56	84	--	61	64	--
Scenedesmus acuminatus	67	--	591	308	--	30	--	--	--	28	42	95	92	--	--
Scenedesmus quadricauda	268	1,082	268	461	156	--	150	116	61	310	167	126	245	32	604
Schroderia sp.	--	--	54	--	--	--	--	--	--	--	--	--	--	--	--
Selenastrum minutum	201	180	215	51	--	--	--	--	--	--	42	--	--	--	201
Sphaerocystis schroeteri	--	--	--	--	--	--	--	--	--	--	--	--	--	32	101
Staurastrum gracile	--	--	--	--	--	30	--	--	--	--	--	--	--	--	--
Tetraedron minimum	201	--	--	--	78	--	--	58	182	85	--	32	61	--	101
Tetraedron regulare	--	--	--	--	--	--	--	--	--	--	--	--	--	--	101
Tetrastrum staurogeniaforme	134	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Chrysophyta															
Chrysococcus rufescens	67	90	215	256	39	--	--	--	30	--	--	--	--	--	--
Dinobryon sertularia	--	--	--	--	--	--	--	58	--	--	--	--	--	--	--
Kephyrion littorale	--	90	--	--	78	--	--	58	303	56	84	95	--	--	--
Kephyrion sp.	--	--	54	--	--	--	--	173	121	28	--	--	--	--	--
Cyanobacteria															
Anabaena flos-aquae	--	--	--	--	--	--	--	--	--	--	--	95	552	64	--
Aphanizomenon flos-aquae	--	--	--	--	--	--	--	--	--	--	42	158	92	--	--
Aphanothece sp.	134	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Euglenophycota															
Euglena sp.	--	--	--	--	--	--	--	--	--	28	--	--	--	--	--
Trachelomonas crebea	--	90	--	--	--	--	--	--	--	--	--	--	--	--	--
Trachelomonas hispida	--	--	--	51	--	--	--	--	--	113	--	32	--	--	--
Trachelomonas scabra	--	90	--	--	--	--	--	--	--	--	42	63	61	--	--
Pyrrophycophyta															
Glenodinium sp.	--	--	107	154	--	30	--	116	--	113	2,339	694	337	349	2,013
Cryptophyta															
Cryptomonas erosa	67	90	322	154	816	1,006	376	173	545	507	251	221	368	191	503
Rhodomonas minuta	134	361	1,450	461	583	91	3,157	289	1,665	310	167	63	31	95	403
Total Density (cells/mL)	9,530	10,373	6,335	5,484	4,666	3,718	10,373	6,707	3,178	3,072	4,468	3,438	3,221	3,367	12,483
Total Taxa	23	16	15	21	14	11	11	16	15	22	18	21	21	24	14

Table E-5: Reservoir mean phytoplankton density (cells/mL) and number of taxa in Cherry Creek Reservoir, 1984 to 2011.

	1984	1985	1986	1987	1988	1989	1991	1992	1993	1994	1995	1996
Blue-Green Algae												
Density	71,780	66,496	99,316	168,259	155,180	273,175	307,691	77,516	15,708	10,015	18,194	16,599
Taxa	7	7	6	18	24	24	14	16	7	3	7	9
Green Algae												
Density	5,864	11,760	25,595	11,985	19,177	55,415	18,688	41,899	1,198	314	355	738
Taxa	11	10	13	58	76	66	46	48	16	2	11	11
Diatoms												
Density	1,776	3,863	5,428	10,677	12,880	9,311	4,160	1,243	946	194	2,189	2,354
Taxa	6	4	7	34	30	31	21	11	15	2	15	13
Golden-Brown Algae												
Density	--	7	125	469	56	505	821	93	158	3	63	249
Taxa	--	1	1	6	4	7	5	4	1	1	2	4
Euglenoids												
Density	514	135	208	251	276	108	89	23	231	196	304	409
Taxa	2	1	1	9	9	6	3	5	2	1	2	3
Dinoflagellates												
Density	--	13	19	19	83	28	23	54	--	31	5	21
Taxa	--	1	1	2	4	3	2	2	--	1	2	4
Cryptomonads												
Density	1,513	718	1,113	1,090	2,689	1,689	628	529	332	450	919	1,104
Taxa	2	3	3	6	4	5	2	3	1	1	1	1
Miscellaneous												
Density	--	--	--	--	--	--	--	--	--	--	--	--
Taxa	--	--	--	--	--	--	--	--	--	--	--	--
Total Density (cells/ml)	81,447	82,992	131,804	192,750	190,341	340,231	329,773	121,357	18,573	11,203	22,029	21,474
Total Number of Taxa	28	27	32	133	151	142	93	89	42	11	40	45

Table E-5: Reservoir mean phytoplankton density (cells/mL) and number of taxa in Cherry Creek Reservoir, 1984 to 2011 (cont.)

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Blue-Green Algae												
Density	19,716	44,951	15,263	164,290	148,691	941	54,114	165,677	79,154	665,696	1,266,765	1,124,197
Taxa	10	11	8	19	12	3	21	27	19	19	21	19
Green Algae												
Density	2,461	1,809	898	43,881	33,217	1,973	55,190	56,236	189,777	1,358,248	563,344	1,531,579
Taxa	18	18	18	71	56	27	70	75	66	63	63	67
Diatoms												
Density	1,109	628	838	12,019	5,256	978	2,026	1,720	3,610	32,036	60,127	27,681
Taxa	8	18	16	34	22	24	22	26	24	21	21	17
Golden-Brown Algae												
Density	227	56	--	391	1,346	34	44	57	335	542	2,380	6,270
Taxa	2	2	--	14	13	3	5	5	4	5	3	3
Euglenoids												
Density	838	698	1,252	126	91	22	308	24	39	1,549	1,303	259
Taxa	3	3	1	6	4	3	9	11	8	10	10	11
Dinoflagellates												
Density	--	18	45	80	157	193	20	57	60	330	595	722
Taxa	--	2	2	8	6	5	3	5	6	5	5	3
Cryptomonads												
Density	1,487	1,393	559	2,472	2,851	355	3,282	3,158	3,293	40,511	61,037	35,962
Taxa	1	1	1	4	6	4	8	8	9	12	9	11
Miscellaneous												
Density	--	--	--	1,923	5,714	15	1,294	164	2,014	4,855	73,435	53,330
Taxa	--	--	--	1	1	1	3	6	6	6	7	8
Total Density (cells/ml)	25,838	49,553	18,855	225,182	197,323	4,511	116,278	227,093	278,282	2,103,767	2,028,986	2,780,000
Total Number of Taxa	39	55	46	157	120	70	141	164	142	141	139	139

Table E-5: Reservoir mean phytoplankton density (cells/mL) and number of taxa in Cherry Creek Reservoir, 1984 to 2011 (cont.)

	2009	2010	2011	Long-term
Blue-Green Algae				
Density	332	4,177	1,136	**71,780**
Taxa	3	6	3	**11**
Green Algae				
Density	10,733	19,202	26,055	**19,177**
Taxa	20	22	23	**27**
Diatoms				
Density	11,609	13,975	39,654	**3,863**
Taxa	25	30	21	**21**
Golden-Brown Algae				
Density	246	587	1,895	**246**
Taxa	4	3	4	**4**
Euglenoids				
Density	83	272	570	**251**
Taxa	3	4	4	**4**
Dinoflagellates				
Density	4,497	2,556	6,253	**56**
Taxa	4	3	1	**3**
Cryptomonads				
Density	22,277	16,794	14,850	**1,513**
Taxa	2	2	2	**3**
Miscellaneous				
Density	--	--	--	**2,014**
Taxa	--	--	--	**6**
Total Density (cells/ml)	49,777	57,563	90,413	**116,278**
Total Number of Taxa	61	70	58	**70**

Table E-6: 2011 Cherry Creek Reservoir zooplankton.

	2011											
	15-Mar	20-Apr	15-May	31-May	7-Jun	21-Jun	5-Jul	19-Jul	2-Aug	18-Aug	7-Sep	20-Sep
Cladocera												
Bosmina longirostris	30	683	127	13	22	153	175	158	360	226	34	109
Daphnia galeata mendotae	--	28	108	3.1	3.2	3.1	2.6	--	--	--	--	--
Daphnia lumholtzi	--	--	--	--	--	--	--	--	--	116	0.2	--
Daphnia parvula	--	--	--	--	--	--	--	--	47	11	0.7	8.4
Diaphanosoma leuchtenbergianum	--	--	--	--	--	--	--	--	--	1.7	--	--
Copepod												
Diacyclops thomasi	13	22	0.9	2.8	3.4	6.3	0.2	0.2	0.5	0.6	--	0.1
Immature instar (copepodid)	19	67	52	26	11	13	21	6.6	60	89	22	19
Mesocyclops edax	--	3.4	0.9	2.1	3.2	7.7	4.0	0.9	1.7	23	1.2	0.7
Nauplius	29	0.9	4.3	17	28	70	221	173	333	136	117	104
Skistodiaptomus pallidus	0.7	3.4	--	0.3	0.3	2.6	8.3	13	106	30	6.2	6.9
Rotifer												
Asplanchna sp.	23	--	--	--	0.7	11	2.9	--	126	--	11	--
Brachionus angularis	--	--	--	--	--	--	--	7.1	36	4.2	40	49
Brachionus calyciflorus	1.0	--	--	--	--	--	--	--	--	--	--	--
Brachionus urceolaris	--	--	--	--	--	--	--	--	--	--	1.7	--
Keratella cochlearis	--	603	410	690	259	40	21	1.4	2	--	--	0.8
Keratella quadrata	--	--	--	--	--	1.4	--	1.4	--	--	--	--
Total Concentration (#/L)	116	1,410	702	755	330	309	457	362	1,072	638	235	297
Total Number of Taxa	7	8	7	8	9	10	9	9	10	10	10	9