Clear Creek / Standley Lake Watershed Agreement

2011 Annual Report

September 10, 2012

Clear Creek Watershed Annual Report – 2011

September 10, 2012

Submitted to the Water Quality Control Commission by:

Black Hawk/Central City Sanitation District
Central Clear Creek Sanitation District
Church Ditch Water Authority
City of Arvada
City of Black Hawk
City of Central
City of Golden
City of Idaho Springs
City of Northglenn
City of Thornton
City of Westminster
Clear Creek County
Clear Creek Skiing Corporation
Clear Creek Watershed Foundation
Climax Molybdenum Company/Henderson Operations
Colorado Department of Transportation
Farmers' High Line Canal and Reservoir Company
Farmers' Reservoir and Irrigation Company
Molson Coors Brewing Company
Gilpin County
Jefferson County
St. Mary's Glacier Water and Sanitation District
Town of Empire
Town of Georgetown
Town of Silver Plume
Upper Clear Creek Watershed Association

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Table of Contents

Recognition goes out to Mr. Vic Lucero for his 20 years of dedication as a member of the Standley Lake Water Quality Committee and for his contributions to improving water quality in the Clear Creek and South Platte watersheds. Mr. Lucero retired from the City of Thornton in 2011.

Cover photograph compliments of the City of Westminster

List of Figures

List of Tables

List of Acronyms and Abbreviations

BHCCSD – Black Hawk/Central City Sanitation District

BMP – Best management practice

BNR – Biological nutrient removal

CC26 – Clear Creek Sampling Station: Clear Creek at Lawson Gage

CC40 – Clear Creek Sampling Station: Clear Creek near Kermits (US-6 and I-70)

CC50 – Clear Creek Sampling Station: North Fork of Clear Creek at Mouth

CC60 – Clear Creek Sampling Station: Clear Creek at Church Ditch Headgate

CCAS26 – Clear Creek Autosampler Station: Clear Creek at Lawson Gage

CCAS59 – Clear Creek Autosampler Station: Clear Creek 2 Miles West of Highway 58/US6 in Golden

CCWF – Clear Creek Watershed Foundation

CDOT – Colorado Department of Transportation

CDPHE – Colorado Department of Public Health and Environment

Chl *a* – Chlorophyll *a*

Church – Church Ditch

Croke – Croke Canal

DEA – Drug Enforcement Administration

DO – Dissolved oxygen

EPA – U.S. Environmental Protection Agency

FHL – Farmers' High Line Canal and Reservoir Company

I-70 – U.S. Interstate 70

KDPL – Kinnear Ditch Pipeline

SCADA – Supervisory Control and Data Acquisition

SL10 – Standley Lake sampling location at WTP intake

TIN – Total inorganic nitrogen

TN – Total nitrogen

TOC – Total organic carbon

TP – Total phosphorus

TSS – Total suspended solids

UCCWA – Upper Clear Creek Watershed Association

USGS – United States Geological Survey

WWTP – Wastewater Treatment Plant

Executive Summary

ES-1. Introduction

Standley Lake is an off-channel, municipal and agricultural reservoir located in Jefferson County. This 41,000 acre-foot reservoir is a direct-use drinking water supply for over 250,000 consumers in the downstream cities of Northglenn, Westminster, and Thornton. In addition, the reservoir provides water to farms located in Adams and Weld counties and recreational opportunities. The Standley Lake watershed consists of the upper 400 square miles of the Clear Creek watershed (the Upper Basin) and lands draining into the three Clear Creek delivery canals (the Canal Zone), in addition to the lake's direct watershed. Figure ES-1 shows Standley Lake and the watershed.

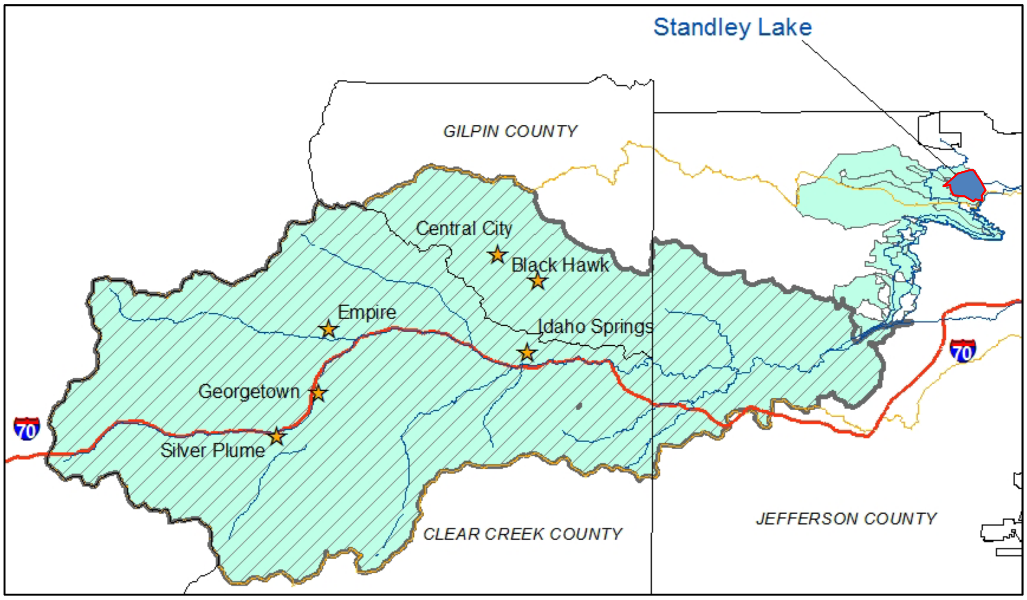


Figure ES-1. Standley Lake Watershed

The Upper Basin contains nine wastewater treatment plants (WWTPs) serving the local population and resorts. Additionally, the Upper Basin contains operating and orphaned mines, and trans-mountain diversions. The Upper Basin also includes nonpoint sources, including numerous onsite wastewater treatment systems (OWTS), application of roadway deicers and traction sands, and residential and commercial stormwater runoff.

In 1993, the Clear Creek/Standley Lake Watershed Agreement (1993 Agreement) was signed to address certain water-quality issues and concerns within the Clear Creek watershed – specifically as they affect the water quality of Standley Lake. In accordance with the annual reporting obligations set forth in the 1993 Agreement, this report presents an overview of watershed and lake monitoring, activities and accomplishments protective of water quality, and observed wastewater treatment plant, Clear Creek, and Standley Lake water quality in 2011.

ES-2. 2011 Monitoring Activities

Flow and water-quality samples are collected at numerous stations throughout the watershed and in the lake to monitor the concentrations and loading of nutrients, select metals, and other key constituents. Standley Lake is monitored throughout the year when ice is off the lake. Daily lake profiles are taken, and bi-monthly grab samples are also collected at three depths (at the surface, in the photic zone, and in the hypolimnion). A total of 67 grab samples were collected and analyzed in 2011.

Upper Basin and Canal Zone monitoring for water quality includes use of grab sampling and autosamplers. Recent years have seen a shift toward an increased use of autosamplers over grab sampling in the Upper Basin. The 24-hour composite samples collected by autosamplers provide a better measure of average water quality on the date of sampling, as compared to grab samples. In addition to collecting 24-hour ambient samples, the autosamplers are also used to collect specific storm-triggered event samples. A total of 228 samples were collected for water-quality analyses in the Upper Basin and Canal Zone in 2011. Table ES-1 summarizes sample counts in 2011 by sample type and area of the watershed.

Table ES-1. Number of Samples Collected and Number of Sampling Locations in the Upper Basin and in the Canal Zone, 2011

	Grab Samples		24-hour Ambient Auto-Samples		Storm Event-Triggered Auto-Samples	
	Number of Samples	Number of Locations	Number of Samples	Number of Locations	Number of Samples	Number of Locations
Upper Basin	43	16	56	4	15	3
Canal Zone	82	22	22	3	10	2

In 2011, Clear Creek water-quality monitoring costs for the City of Golden were approximately $20,000. The City of Golden also contributed $9,720 to fund the United States Geological Survey (USGS) stream gage on the West Fork of Clear Creek at Empire. UCCWA costs associated with the maintenance and monitoring the CC40 gage (Clear Creek near Kermit's, U.S. 6 and I-70) were $4,330. In addition, the Standley Lake Cities contributed $10,040 to fund operations of the USGS gages on Clear Creek at Lawson and Bakerville.

ES-3. 2011 Activities and Accomplishments

In 2011, members of the UCCWA, Standley Lake Cities, and all parties to the 1993 Agreement continued to work diligently to monitor, improve, and protect water quality. These efforts included:

- Upgrading WWTPs,
- Addressing illicit discharges, nonpoint sources and orphaned mines,
- Conducting public education and outreach, and
- Performing additional monitoring and investigations.

Highlights of this work are presented below. This is not a complete list, and additional important activities and details are presented in the main report.

Wastewater Treatment Plant Upgrades

- The Town of Georgetown completed an upgrade of its wastewater treatment plant.
- The Town of Silver Plume worked to reduce infiltration and inflow into its wastewater collection system in order to reduce flows into the Georgetown WWTP.
- The City of Idaho Springs completed $1.5 million in upgrades to its wastewater treatment facility, replacing outdated equipment.

Efforts to Control Illicit Discharges, Nonpoint Sources, and Orphaned Mines

- The City of Golden responded to 22 reports of illicit discharges (or potential discharges) to the storm sewer system, administered 23 stormwater-quality construction permits, and conducted 667 erosion and sediment control inspections.
- The City of Arvada conducted annual dry-weather screening inspections of 366 outfalls to identify potential sources of illicit discharges, conducted 1,036 erosion and sediment control inspections on active construction sites, inspected 3,720 inlets, jetted 14 miles of pipes, and removed over 182 tons of material from underground pipes and inlets.
- The Colorado Department of Transportation (CDOT) captured and removed sediment from highway runoff within the Upper Clear Creek Watershed, using 12 sediment basins on the east side of Berthoud Pass. CDOT also utilized more liquid deicer relative to traction sand and continued rock fall and fines control projects along I-70.
- The Clear Creek County Environmental Health Department issued 29 OWTS permits in 2011 and continued monitoring existing systems for failure.
- Following a March 2011 fire in the lower portion of Clear Creek canyon, the City of Golden installed a containment structure in Indian Gulch.
- Two remediation projects were completed on orphaned mines; Gilson Gulch and Upper Trail Creek. Follow-up monitoring continued at previously completed projects.

Public Education, Outreach, and Partnerships

- The Clear Creek Watershed Foundation (CCWF) organized and hosted the third annual Clear Creek Watershed Festival in September 2011. The event attracted over 800 participants and included more than 30 environmental education booths.
- The City of Golden contributed $7,903 to the Rooney Road Recycling Center, which provides critical recycling and disposal services of household chemicals and annually serves more than 3,000 Jefferson County residents.
- Clear Creek County continued development of its Household Hazardous Waste (HHW) collection program.
- The Drug Enforcement Administration (DEA) sponsored two National Pharmaceutical Take-Back Days in 2011. The City of Arvada collected 1,552 pounds of medications, the City of Golden collected 368 pounds, and the Standley Lake Cities collected 1,436 pounds.
- Over 1,100 students, teachers and parents from the water service areas of Thornton, Northglenn, and Westminster participated in the annual Youth Water Festival at Front Range Community College in Westminster.

Monitoring and Investigations

- The Standley Lake Cities continued with several programs to monitor and prevent aquatic nuisance species such as zebra and quagga mussels in Standley Lake. To combat the invasive aquatic plant Eurasian watermilfoil (*Myriophyllum spicatum*), 5,000 weevils (*Euhrychiopsis lecontei*) were stocked by the Standley Lake Cities in several watermilfoil beds in 2011.
- Sampling station CC50 (North Fork of Clear Creek) was upgraded in 2011 by the Standley Lake Cities to include a multi-probe sonde and a new conduit.
- A new multi-probe sonde instrument was installed by the Standley Lake Cities in the valve house at Standley Lake and connected to the SCADA system at the Westminster water treatment plants. This instrument allows both operations and water-quality staff to observe real-time data for the water coming from Standley Lake.
- The Standley Lake Cities conducted a Waterway Workshop and a special sampling event focused on the Croke Canal, providing valuable information toward understanding potential source areas for increases in nutrient concentrations along the Croke Canal.
- The Standley Lake Cities funded an update of the Clear Creek watershed hydrologic and water-quality model. The model now simulates nine years of record, making it a powerful tool for Standley Lake water-quality management support.

ES-4. 2011 Observed Flow and Water Quality Summary

Flow and water-quality records for 2011 were reviewed and compared to the previous five years of record (2006-2010) to assess conditions in 2011 in Clear Creek and in Standley Lake. The water-quality analysis focused on total suspended solids (TSS), total nitrogen (TN), and total phosphorus (TP). In addition, chlorophyll *a*, Secchi depth, and dissolved oxygen were assessed in the lake. In the Upper Clear Creek Basin, data analysis focused on results from CCAS59/CC60 located near the Canal diversion points, and CCAS26/CC26, located at Lawson. Water-quality analysis of Standley Lake focused on results from sampling location SL10. Select highlights of findings from these analyses are presented below.

2011 Runoff Flow Rates

Runoff flow rates and volumes in Clear Creek were higher in 2011 due to a deep winter snowpack. The peak flow rate in the Upper Basin at gaging station CC60 in 2011 was 45% percent higher and occurred approximately one month later than the average peak flow for 2006-2010. Additionally, the runoff volume was 39% higher than the preceding five-year average. The 2011 hydrograph is compared to previous years in Figure ES-2.

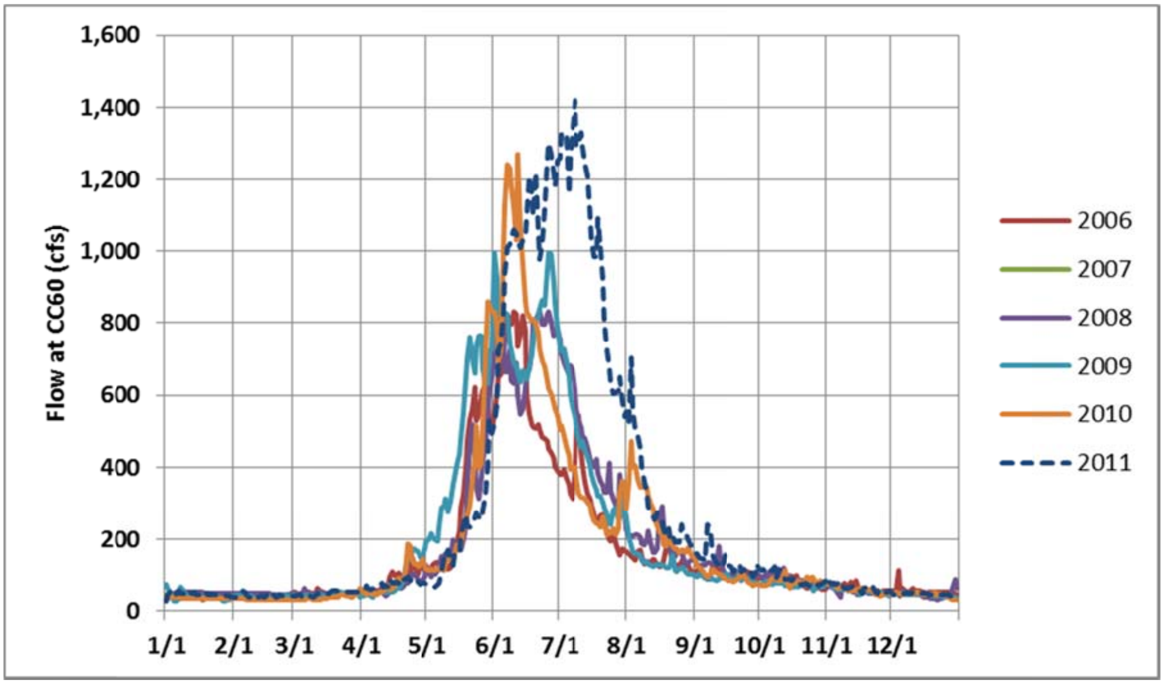


Figure ES-2. Annual Hydrographs for 2006-2011 in the Upper Basin (CC60)

WWTP Effluent Concentrations

The WWTPs in the Clear Creek watershed continued efforts in 2011 to reduce nutrient discharges. Table ES-2 presents a summary of 2011 TP and TN effluent data from the nine WWTPs in the watershed.

Table ES-2. Summary of Total Phosphorus and Total Nitrogen Concentrations in Wastewater Treatment Plant Effluents, 2011

	Total Phosphorus (mg/L)			Total Nitrogen (mg/L)		
WWTP	Min	Max	Average	Min	Max	Average
Loveland Ski Area	0.08	0.10	0.09	4.50	6.30	5.40
Georgetown	0.11	2.06	0.76	4.00	30.80†	12.70
Empire*	-	-	-	-	-	-
Central Clear Creek	0.13	1.84	0.70	4.60	32.60	16.10
St. Mary's	0.33	0.45	0.39	3.40	7.80	5.60
Idaho Springs	0.25	1.16	0.78	5.90	23.20	15.93
Black Hawk / Central City	0.07	0.18	0.13	3.10	7.20	4.79
Henderson Mine*	-	-	-	-	-	-
Eisenhower Tunnel	0.09	1.68	0.49	1.80	5.60	3.69

*No data provided for 2011.

†This maximum TN result is from a grab sample that does not correlate with the 24-hr composite sample results for TIN reported by Georgetown. Georgetown's average monthly DMR data are summarized in Appendix C.

TSS and Nutrients in Clear Creek

In 2011, observations of TSS, TP, and TN concentrations in Clear Creek reflected expected seasonal patterns and concentrations for the high runoff year. Figure ES-3 presents the combined set of observations from the CCAS59 and CC60, which are located on Clear Creek near the diversion points for the three main canals that bring water to Standley Lake. This figure shows TSS concentrations peaking in late May, corresponding to the rising limb of the hydrograph. TP concentrations generally track TSS concentrations. Figure ES-3 also shows 2011 TN concentrations following the typically observed pattern of higher concentrations in the winter and lower concentrations in the summer. The higher winter concentrations correspond to times of minimal runoff, and greater proportions of base flow, WWTP discharge, and possibly greater onsite wastewater treatment system influence.

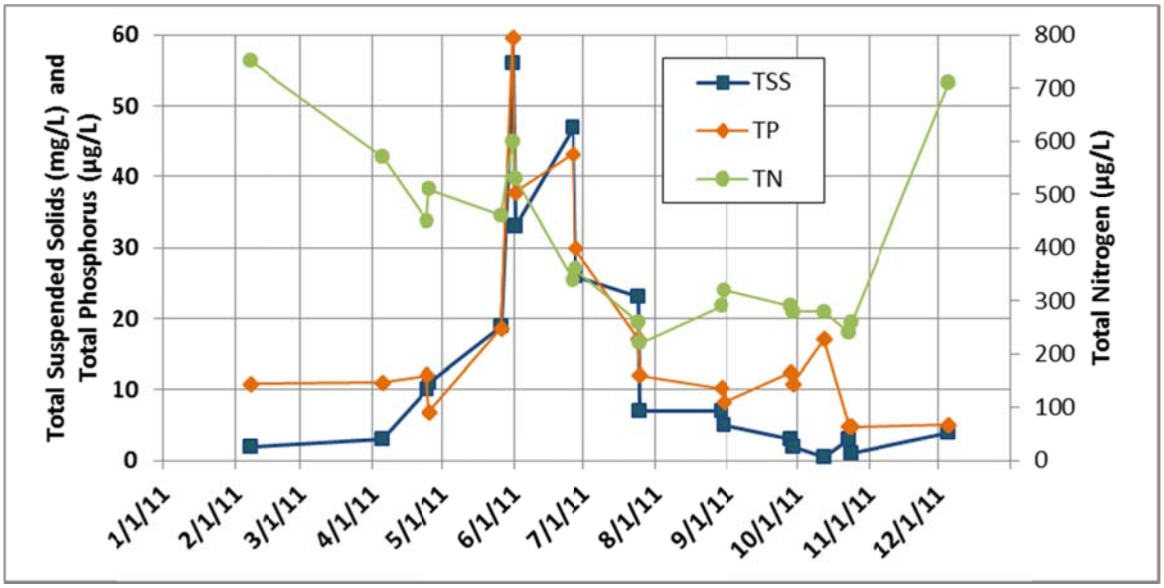


Figure ES-3. Total Suspended Solids and Nutrient Concentrations in the Upper Basin, as Measured by Grab Samples and 24-Hour Ambient Autosampler Data, 2011

The analysis of data indicates that 2011 loads of TSS, TP, and TN in Clear Creek were higher than the 2006-2010 average, largely due to the higher flow volumes. Average volume-weighted concentrations of TSS and TP were also higher in 2011 in Clear Creek, likely due to increased mobilization of solids by the higher flow rates. Additionally, as seen in previous years, TSS and TP concentrations increase in the lower half of the Upper Basin, particularly during the spring and early summer months. TN data do not show the same pattern. Volume-weighted concentrations of TN in 2011 were comparable to the preceding five-year average; and, as in previous years, spring/summer concentrations differences are not seen between the upper half of the basin and CCAS59/CC60.

Inflow and Loading into Standley Lake

The total inflow into Standley Lake in 2011 was 27% higher than the 2006-2010 average. Of the total 2011 inflow, 63% came through Farmers' High Line Canal. Figure ES-4 presents total annual inflow and outflow volumes for 2006-2011 as well as 2006-2010 averages.

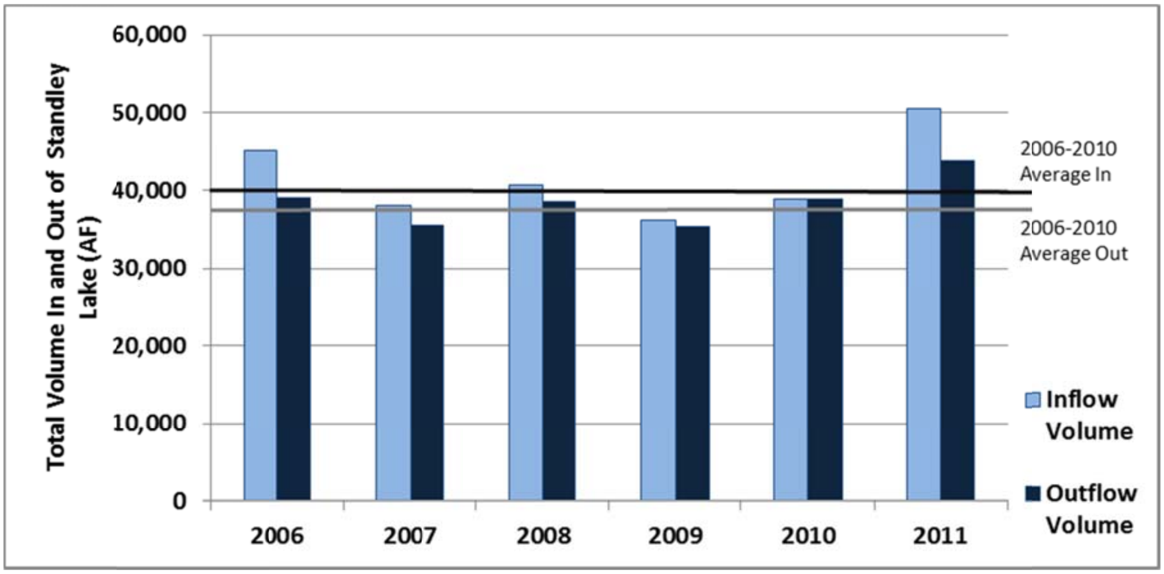


Figure ES-4. Total Annual Inflow and Outflow Volumes for Standley Lake, 2006-2011

Figure ES-5 presents total phosphorus loading into and out of Standley Lake for 2006-2011. TP loading into Standley Lake was 47% greater in 2011 than the 2006-2010 average. Farmers' High Line Canal, which is used more extensively than other canals during high Clear Creek runoff months, contributed 62% of the 2011 TP load. Although the TP loading to Standley Lake in 2011 was above average, the volume-weighted TP concentration of the inflow was 15% lower than the 2006-2010 average.

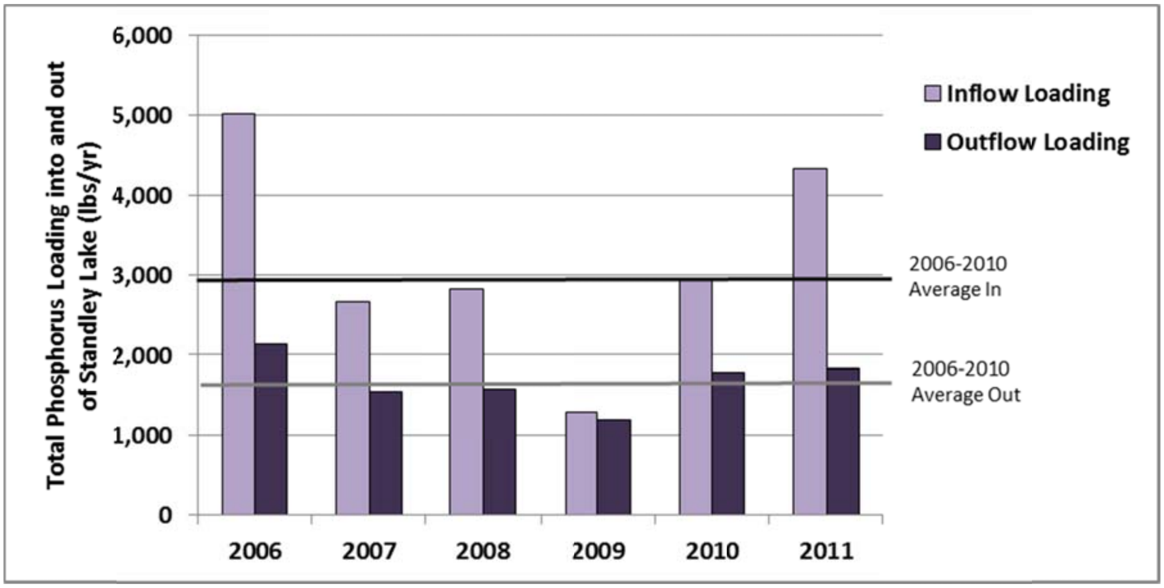


Figure ES-5. Total Phosphorus Loading into and out of Standley Lake, using Grab Samples and 24-Hour Ambient Autosampler Data, 2006-2011

Figure ES-6 presents total nitrogen loading into and out of Standley Lake for 2006-2011. TN loading was 31% higher in 2011 than the 2006-2010 average, with Farmers' High Line Canal delivering the majority of the load (55%). While loading was higher in 2011, the volume-weighted TN concentration into Standley Lake exhibited a 14% decrease from the average volume-weighted concentrations from 2006-2010.

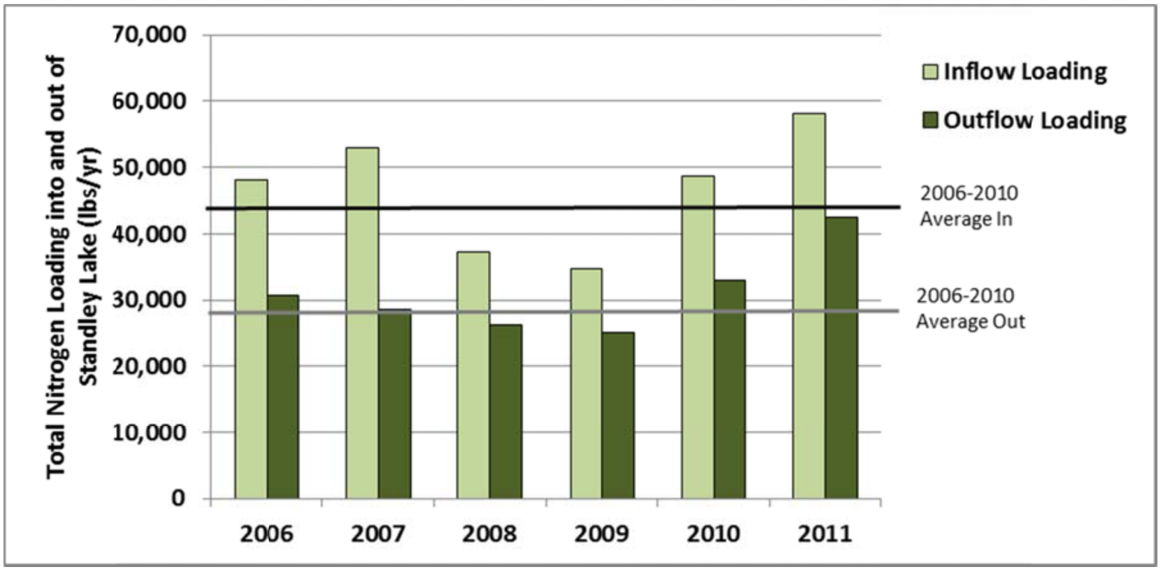


Figure ES-6. Total Nitrogen Loading into and out of Standley Lake, using Grab Samples and 24-Hour Ambient Autosampler Data, 2006-2011

Water Quality in Standley Lake

Standley Lake experienced good water quality in 2011, following typical seasonal patterns observed in previous years. Average in-lake concentrations of TSS were higher in 2011 than in recent years, reflecting the higher watershed TSS concentrations, though concentration ranges were comparable to previous years. Secchi depth and dissolved oxygen concentrations in 2011 also exhibited typical patterns and ranges. The total number of days of anoxia (<2mg/L dissolved oxygen) at the bottom of the reservoir in 2011 was 93, compared to 98 in 2010 and 84 for the 2006-2010 average.

Nutrient concentrations also followed typical seasonal patterns in 2011. As shown in Figure ES-7, TP concentrations near the top varied slightly but remained relatively constant throughout the year. At the bottom of the reservoir, release of ortho-phosphorus during stratification is apparent, peaking in September then falling again in October with turnover. Overall, 2011 TP concentrations were comparable to previous years. Similar photic zone and hypolimnion seasonal patterns are seen for TN (Figure ES-8), though TN concentrations in 2011 are higher than the average values from the preceding five years.

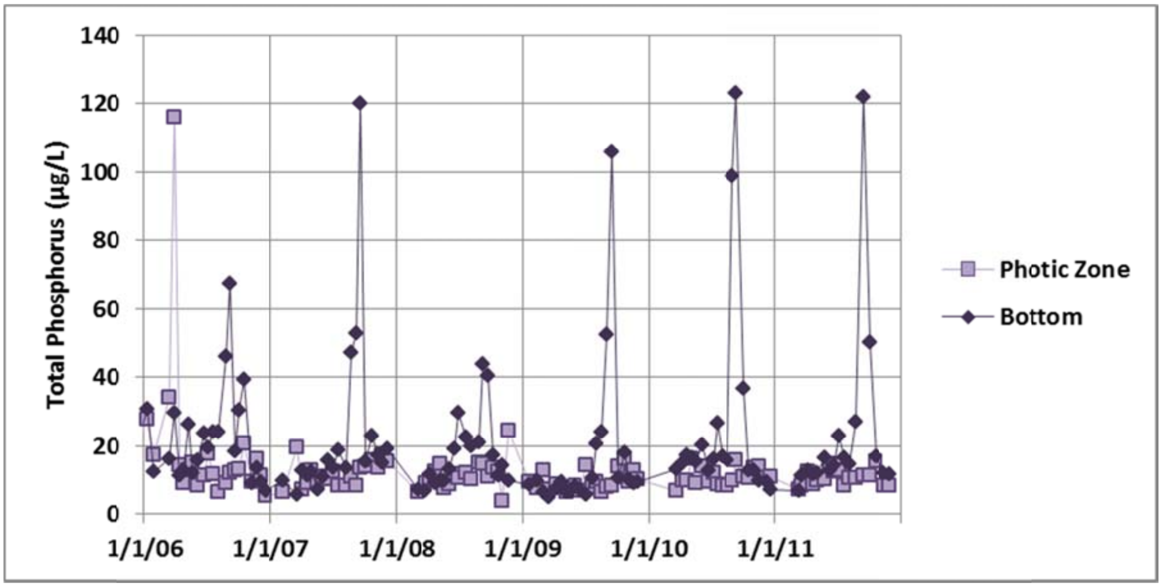


Figure ES-7. Total Phosphorus Concentrations in the Photic Zone and Bottom of Standley Lake, 2006-2011

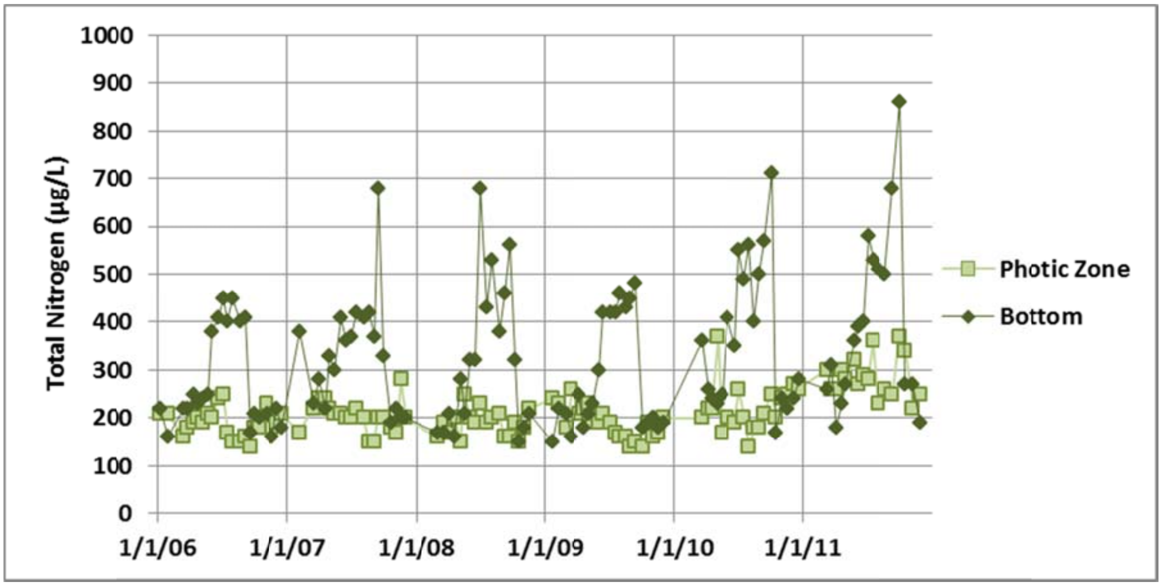


Figure ES-8. Total Nitrogen Concentrations in the Photic Zone and Hypolimnion of Standley Lake, 2006-2011

Chlorophyll *a* concentrations in Standley Lake in 2011 were low and followed the typical pattern of higher concentrations in the spring and late fall and lower concentrations in the summer. The average chlorophyll *a* concentration from March through November was 2.73 µg/L, which is well below the standard of 4 µg/L. This March through November average chlorophyll *a* concentration is the lowest observed in the previous five years, as shown in Figure ES-9.

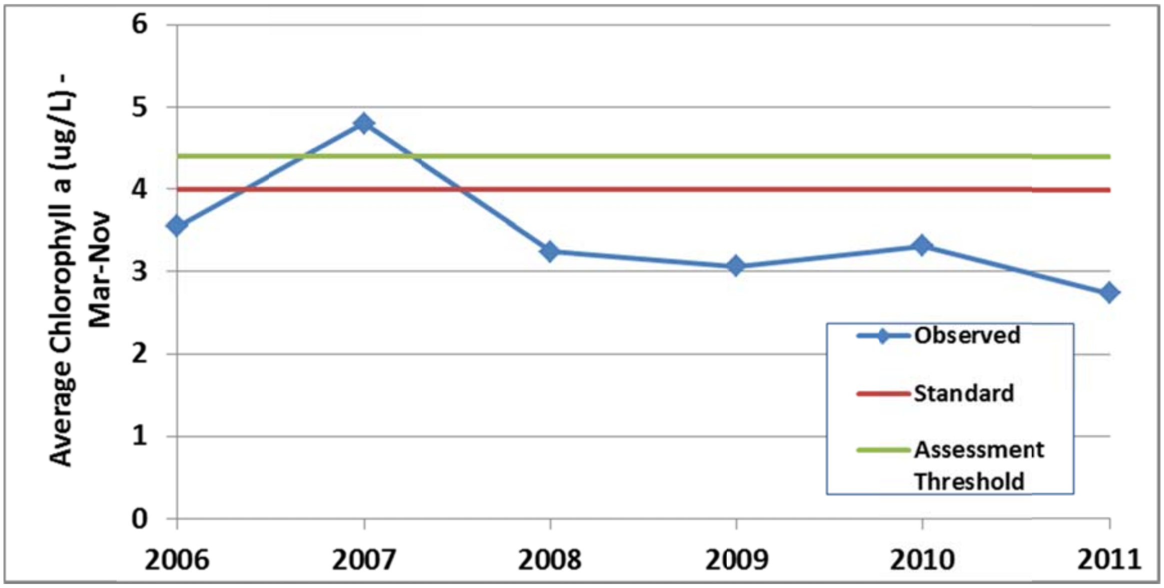


Figure ES-9. Observed Mean Chlorophyll *a* Concentrations (Mar-Nov) Compared with the Standard and the Assessment Threshold, 2006-2011

I. Introduction

Purpose and Scope of Report

In 1993, the Clear Creek/Standley Lake Watershed Agreement (1993 Agreement) was signed by a contingent of governmental agencies and private corporations to address certain water-quality issues and concerns within the Clear Creek watershed – specifically as they affect the water quality of Standley Lake. This report presents a review of 2011 water-quality efforts in the Clear Creek watershed, according to the annual reporting obligations set forth in the 1993 Agreement. In addition, 2011 water-quality data are presented and are often compared to the previous five years of data (2006-2010). The cooperative Water Quality Monitoring Program is the cornerstone of the 1993 Agreement (Appendix A).

Prior to 2009, a main focus for the signatories to the 1993 Agreement was to meet the 1993 narrative standard for Standley Lake which was described as:

> *The trophic status of Standley Lake shall be maintained as mesotrophic as measured by a combination of common indicator parameters such as total phosphorus, chlorophyll* a, *Secchi depth, and dissolved oxygen. Implementation of this narrative standard shall only be by Best Management Practices and controls implemented on a voluntary basis.*

During that period, numerous water-quality improvements were made in the watershed. In 2009, the Water Quality Control Commission adopted a numeric chlorophyll *a* standard for Standley Lake. A 4.0 µg/L chlorophyll *a* standard is now in place as a protective measure for this drinking water supply reservoir. The intention of the numeric standard is to control the contribution of algae to the formation of disinfection by-product precursors. In addition to the numeric standard, the Commission retained the first sentence of the narrative standard described above, which refers to maintaining mesotrophic conditions in the lake.

Clear Creek watershed spans 575 square miles from the headwaters near the Continental Divide to the South Platte River. The Standley Lake watershed consists of the upper 400 square miles of the Clear Creek watershed, lands draining into the three Clear Creek delivery canals, and the lake's direct watershed. For purposes of this report, the Standley Lake watershed geographic area is divided into three sub-regions:

- **The Upper Basin** – the Clear Creek watershed, from its headwaters to the Croke Canal headgate;
- **The Canal Zone** – the three canals delivering water from Clear Creek to Standley Lake, from the headgates to the lake, and their direct watersheds; and
- **Standley Lake** – the lake and its direct watershed.

Organization of the Report

Following this introductory Section, the report is organized as follows:

- **Section II. Description of the Lake, Watershed, and Routine Monitoring**– An overview of Standley Lake and its watershed, including maps and monitoring practices.
- **Section III. Activities and Accomplishments in 2011** – A summary of water-quality efforts in the Clear Creek Basin, including monitoring, wastewater treatment plants, illicit discharges, nonpoint source control, public education, outreach and partnerships, emergency response, planning, invasive species prevention and mitigation, and mine reclamation efforts.
- **Section IV. Upper Basin Water Quality** – A presentation of data collected from key locations in the Upper Basin, with a focus on nutrient concentrations and annual loading of total nitrogen, total phosphorus, and total suspended solids.
- **Section V. Inflow to Standley Lake –** A summary of 2011 inflow to Standley Lake, including timing of use of each canal.
- **Section VI. Standley Lake Water Quality** – An analysis of lake water quality with a focus on total nitrogen, total phosphorus, total suspended solids, chlorophyll *a,* dissolved oxygen, and Secchi depth.
- **Section VII. Conclusions** – A summary of findings from the report.

II. Description of the Lake, Watershed, and Routine Monitoring

This section presents an overview description of Standley Lake and its watershed (the Upper Basin and the Canal Zone). The discussion also includes a summary of routine monitoring activities.

Standley Lake Overview

Standley Lake is an off-channel, municipal and agricultural reservoir located in Jefferson County. This 41,000 acre-foot reservoir is a direct-use drinking water supply for over 250,000 consumers in the downstream cities of Northglenn, Westminster, and Thornton. In addition, the reservoir provides water to farms located in Adams and Weld counties and recreational opportunities. It is owned and operated by Farmers' Reservoir and Irrigation Company.

View from Standley Lake Shoreline Looking West

Through the Standley Lake Monitoring Program, the lake is frequently monitored throughout the year when ice is off the lake. The lake is sampled at multiple locations, but this report focuses on the results from the SL10 location (Figure 1). This location represents the deepest part of the lake and is the approximate location of the municipal supply intakes. Lake monitoring efforts can be summarized as follows:

Daily Profiles – Standley Lake water quality is measured every meter, from the surface to within 3 meters of the bottom, four times daily using an automated profiler. The profiler is equipped with a multi-probe sonde and provides readings of water temperature, dissolved oxygen, pH, conductivity, turbidity, oxidation reduction potential (ORP), and chlorophyll *a*.

Surface and Bottom Sampling – Grab samples are collected in the lake at the surface, the photic zone (two-times the Secchi Depth), and five feet from the bottom. Sampling occurs twice each month from March through November and is often extended during the winter if the lake is not frozen. Measurements and analyses include a large variety of constituents including nutrients, metals, algae, suspended solids, and various field parameters.

Zooplankton Tows – Zooplankton tows are taken throughout the summer months.

Invasive Species Monitoring – Monitoring focused on Eurasian watermilfoil and zebra and quagga mussels occurs every summer.

Routine monitoring for Standley Lake is described in detail in Appendix B.

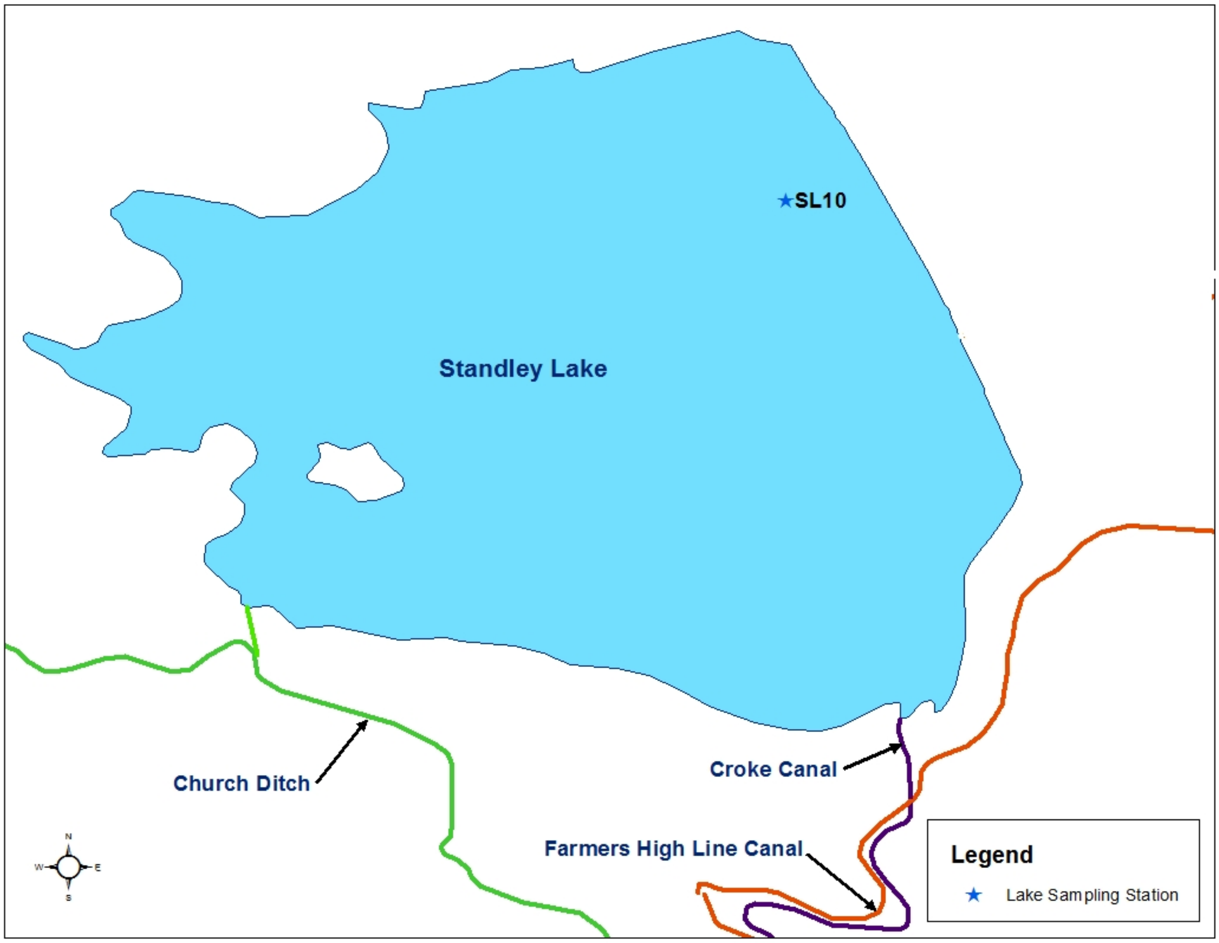


Figure 1. Standley Lake and the Sampling Station Location (SL10)

Description of the Watershed

The Clear Creek watershed is located west of Denver, Colorado, with its headwaters in the mountains up to the Continental Divide (Figure 2). The watershed covers an area of 575 square miles, beginning at an elevation of about 14,000 feet and descending to approximately 5,000 feet where it joins the South Platte River in north Denver. In addition to supplying drinking water to 350,000 people residing in the watershed, Clear Creek provides water for various recreational, agricultural, and industrial purposes.

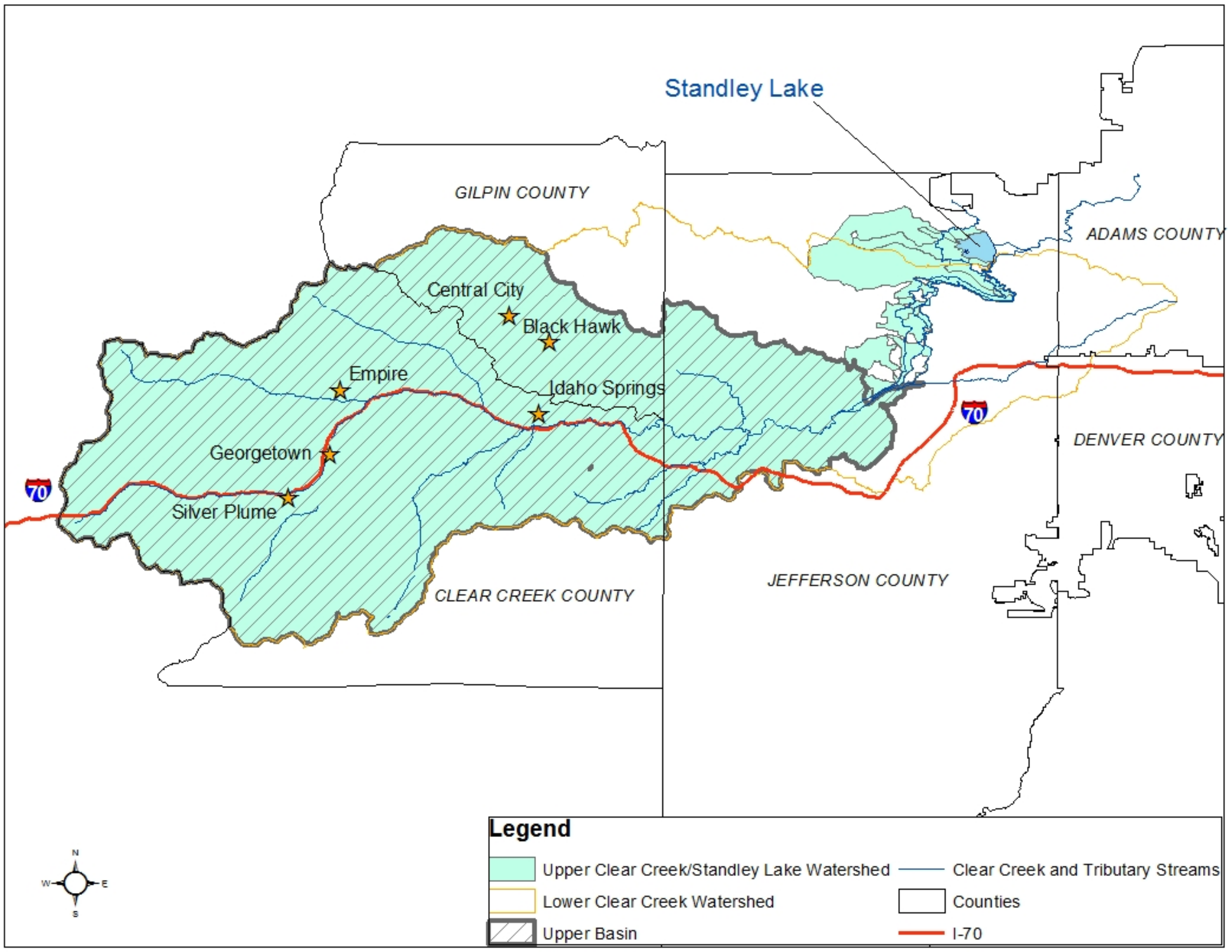


Figure 2. Clear Creek Watershed and the Upper Basin

The Standley Lake watershed includes the Upper Basin of Clear Creek, the canals used to transport water from Clear Creek to the lake (the Canal Zone), and a small direct watershed. The following subsections describe the Upper Basin and the Canal Zone.

Upper Basin

The Upper Basin region of the Clear Creek watershed includes the 400 square miles upstream of the Croke Canal headgate (Figure 2). This region includes the upper portion of Clear Creek and its various tributaries, the most prominent of these being the West Fork of Clear Creek, Leavenworth Creek, the South Fork of Clear Creek, Fall River, Chicago Creek, the North Fork of Clear Creek, Beaver Brook, Soda Creek, and Elk Creek. Numerous towns are scattered throughout this mountainous area including Idaho Springs, Black Hawk, Central City, Empire, Georgetown, and Silver Plume. Additionally, U.S. Interstate 70 (I-70), a highly-utilized corridor, runs through the watershed, providing access to towns and recreational areas.

Images from the Upper Basin of the Clear Creek Watershed

The Upper Basin contains nine wastewater treatment plants (WWTPs) serving the local population and resorts (Figure 3). Additionally, the Upper Basin contains operating and orphaned mines, and trans-mountain diversions. The Upper Basin also includes nonpoint sources, including numerous onsite wastewater treatment systems (OWTS), application of roadway deicers and traction sands, and residential and commercial stormwater runoff.

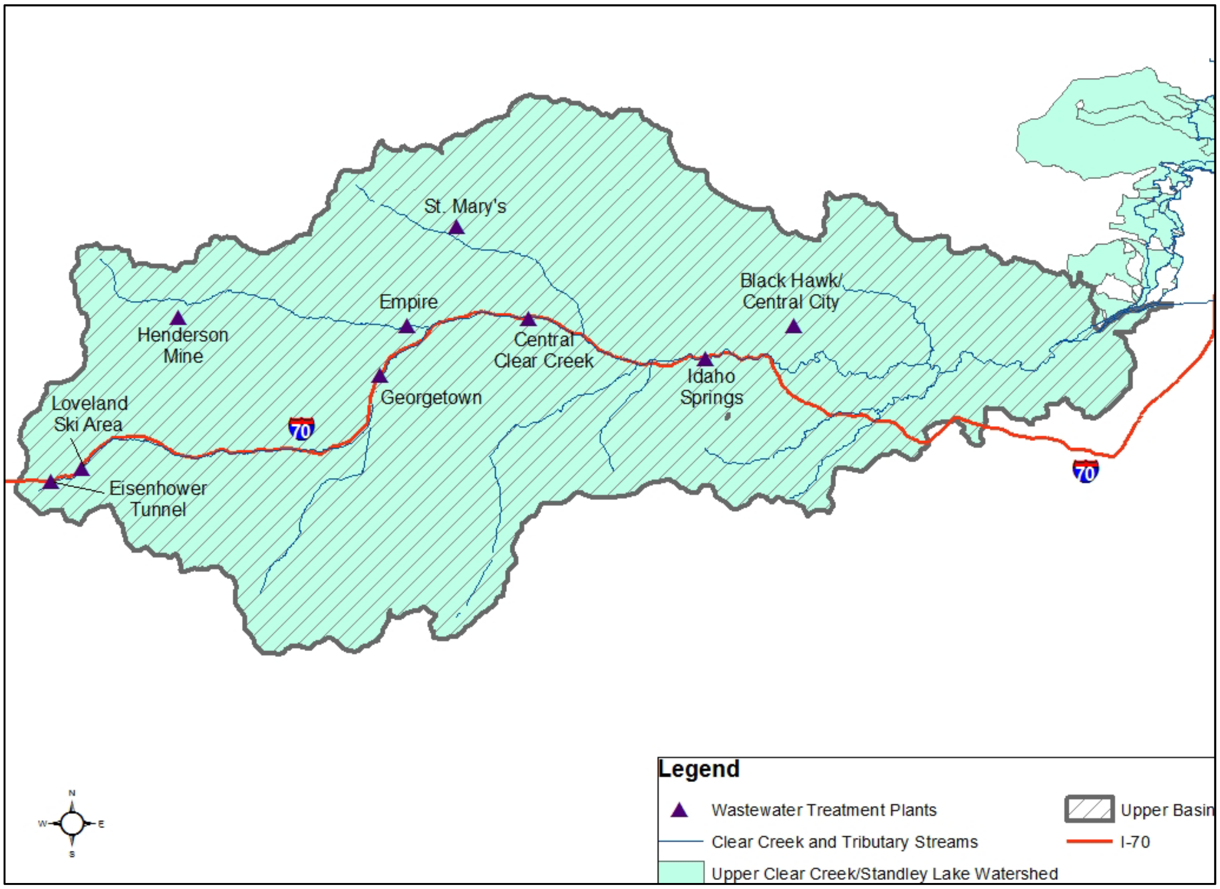


Figure 3. Wastewater Treatment Plants Located in the Upper Basin

Flow and water-quality samples are collected at numerous stations throughout the watershed to monitor the concentrations of nutrients, select metals, and other key constituents (Figure 4).

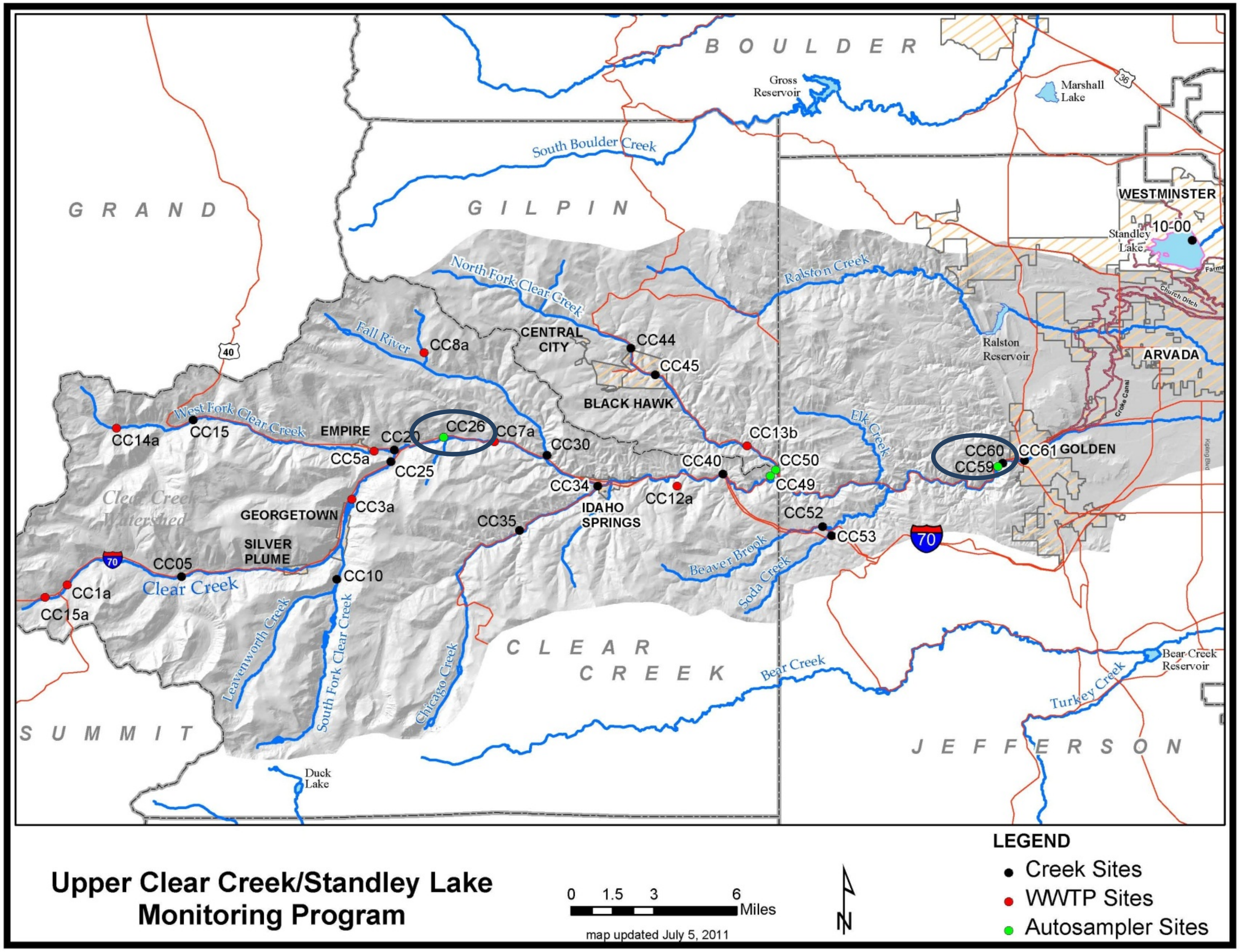


Figure 4. Upper Clear Creek Sampling Stations, Noting Key Locations for this Report

Upper Basin monitoring activities have been designed to evaluate relative contributions of various nutrient sources, effectiveness of BMPs, wastewater treatment plant operational changes, and nutrient reduction from treatment plant upgrades. Recent years have seen a shift toward an increased use of autosamplers over grab sampling in the Upper Basin. The 24-hour composite samples collected by autosamplers are a better measure of water quality on the date of sampling, as compared to grab samples. In addition to collecting 24-hour ambient samples, the autosamplers are also used to collect specific storm-triggered event samples. Routine monitoring for the Upper Basin is described in detail in Appendix B.

The analysis presented in the Upper Basin portion of this report is based on data from two key locations (Figure 4). These data include grab samples taken at sampling locations CC26 (Clear Creek at Lawson Gage) and CC60 (Clear Creek at Church Ditch Headgate), along with 24-hour composite samples from autosamplers CCAS26 (Clear Creek at Lawson Gage) and CCAS59 (Clear Creek 2 miles west of Highway 58/US6). These locations were selected to give a picture of water quality high in the Upper Basin and farther downstream. Because both grab sample data and autosampler data are available, these sites provide the most samples throughout the year. Data considered include total nitrogen (TN), total phosphorus (TP), and total suspended solids (TSS) concentrations.

Canal Zone

The Canal Zone is composed of three canals that divert water from Clear Creek into Standley Lake: Church Ditch, Farmers' High Line Canal (FHL), and Croke Canal (Figure 5). In addition to the three canals diverting water from Clear Creek, Kinnear Ditch Pipeline (KDPL) also contributes inflow to Standley Lake, delivering water from Coal Creek and the Boulder Diversion Canal. The canals are open, slow-flowing, largely unlined ditches that direct water to the reservoir through headgates. The canals may be subject to nonpoint source loading from adjacent horse and cattle operations, agricultural operations, and residential properties (some with onsite wastewater treatment systems). Note that a significant percentage (~80%) of the historical direct runoff drainage area into the canals has been reduced since the 1990s in order to protect Standley Lake water quality.

In order to provide information for evaluation of the nutrient loadings from nonpoint sources in the Canal Zone, the three canals are sampled at their headgates, where water is diverted from Clear Creek, and at the inlets into the lake. Routine monitoring for the Canal Zone is described in detail in Appendix B.

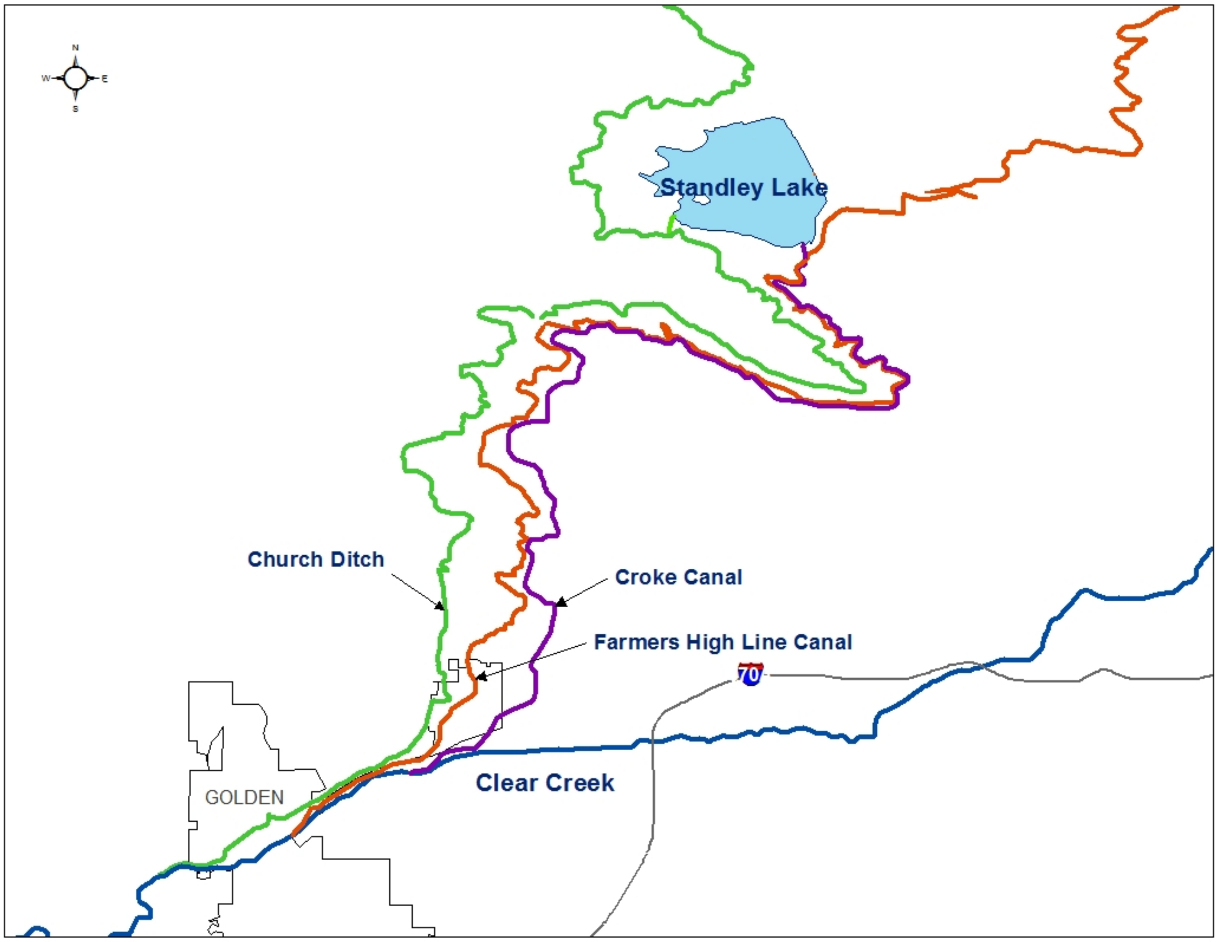


Figure 5. Standley Lake and the Three Canals Diverting Water from Clear Creek

III. Activities and Accomplishments in 2011

In 2011, entities with the potential to impact water quality continued efforts to improve and protect the quality of water in the Clear Creek watershed and the reservoir itself. This section provides a summary of 2011 activities and accomplishments in the following areas:

- Monitoring,
- Wastewater treatment plants,
- Illicit discharges,
- Nonpoint source control,
- Public education, outreach and partnerships,
- Emergency response,
- Planning,
- Invasive species prevention and mitigation, and
- Mine reclamation efforts.

Monitoring Activities

Through the Upper Clear Creek/Standley Lake Watershed Water Quality Monitoring Program (Appendix B), flow and water-quality samples are routinely collected and analyzed throughout the Upper Basin, the Canal Zone, and in Standley Lake. An overview of the program was provided in Section II and a listing of the monitoring data for 2011 can be found in Appendix C. Additional details for 2011 monitoring are provided below along with other monitoring-related highlights for the year.

Upper Basin and Canal Zone Water Quality Sampling

Sampling in the Upper Basin is performed through a combination of grab samples at 16 locations and autosamplers that collect 48-hour ambient samples as well as storm-event-triggered samples at four locations (Figure 4). A total of 43 grab samples were collected in 2011 (photo below, left). Autosamplers collected 56 ambient samples and 15 event samples (photo below, right).

Grab Sampling on Clear Creek (left); Autosampler Collection on Clear Creek (right)

The Canal Zone Monitoring Program also uses a combination of grab sampling and autosamplers along each of the Canals and at the inflow points into Standley Lake. A total of 82 grab samples were collected in 2011 at 22 stations. Autosamplers collected 22 ambient samples at 3 stations and 10 storm-event samples at 2 stations.

Standley Lake Water Quality Sampling

On Standley Lake, daily lake profiles are taken (photo below, left). Bi-monthly grab samples (photo below, right) are also collected at a three depths (at the surface, in the photic zone, and in the hypolimnion). All profiles and samples are taken at sampling station SL10. A total of 67 grab samples were collected and analyzed in 2011.

Standley Lake Monitoring: Automatic Lake Profiler on Standley Lake (left); Grab Sampling on Standley Lake (right)

2011 Flow and Water Quality Monitoring Costs

In 2011, Clear Creek water-quality monitoring costs for the City of Golden were approximately $20,000. The City of Golden also contributed $9,720 to fund the United States Geological Survey (USGS) stream gage on the West Fork of Clear Creek at Empire. UCCWA costs associated with the maintenance and monitoring the CC40 gage (Clear Creek near Kermit's, U.S. 6 and I-70) were $4,330. In addition, the Standley Lake Cities contributed $10,040 to fund operations of the USGS gages on Clear Creek at Lawson and Bakerville.

CC50 Upgrade

Sample station CC50 (North Fork of Clear Creek) was upgraded in 2011 by the Standley Lake Cities to include a multi-probe sonde and a new conduit. The instrumentation is now the same as all the other sample stations and improves the overall operations and maintenance of the system.

Real-time Monitoring of Water Treatment Plant Influent

A new multi-probe sonde instrument was installed by the Standley Lake Cities in the valve house at Standley Lake and is connected to the SCADA system at the Westminster water treatment plants.

This instrument allows both operations and water quality staff to observe real-time data for the water coming from Standley Lake. This helps operators fine tune treatment and serves as an early warning system of significant changes in water quality, which can be important for a direct-use reservoir.

CC59 Data Summary Report

The City of Golden provides funding for a data summary report for ambient and event-triggered autosampler samples collected each year at CC59. Data collected for the monitoring program provides downstream water users with information about trends in sediment-related nutrient and metal concentrations and loadings. Data collected during storm event monitoring in 2011 and in prior years shows that storm events transport significant amounts of nutrients, indicative of the effects of nonpoint sources of erosion and urban runoff. The study, conducted by Clear Creek Consultants, found notable differences between loading estimates when storm event triggered results are included in calculations and when they are not. Effects of storm events on loading calculations are further discussed in Sections IV and VI of this report.

Wastewater Treatment Plants

There are nine wastewater treatment plants in the Upper Basin (Figure 3). Following is a brief discussion to highlight 2011 activities at several individual plants.

Eisenhower Tunnel WWTP

The Colorado Department of Transportation (CDOT) now holds a single permit with Colorado Department of Public Health and Environment (CDPHE) for the Eisenhower-Johnson Memorial Tunnel. CDPHE has combined the WWTP and subterranean discharge permit for groundwater seepage, which accounts for up to 90% of total flow out of the tunnel, into one industrial discharge permit.

Georgetown WWTP

The Town of Georgetown completed the upgrade of its wastewater treatment plant. It came online in September 2011, and a new discharge permit for the plant went into effect June 1, 2011. Treatment facility improvements included headworks improvements, implementation of an Integrated Fixed-Film Activated Sludge biological treatment process (IFAS), secondary clarifier, tertiary filtration (sand filters), chemical storage and feed systems, aerated biosolids storage and handling, a new facility operations building, facility electrical and control systems, and site landscaping.

Georgetown's nutrient discharge in 2011 averaged 8.74 mg/L for ammonia-N, 5.37 mg/L for total inorganic nitrogen (TIN), and 0.59 mg/L for TP. The plant removed an average of 85% of both TSS and biological oxygen demand.

The Town of Silver Plume continued work to reduce infiltration and inflow into its wastewater collection system, rehabilitating 70% of its sewer collection lines in 2011. This project is designed to reduce flows into the Georgetown WWTP.

Idaho Springs WWTP

The City of Idaho Springs completed $1.5 million in upgrades to its wastewater treatment facility in July 2011. As part of the upgrades, the following new equipment was installed: two high speed turbo blowers, two motive pumps, stainless steel jet headers, a grit separator, grit classifier, effluent equalization basin floating decanter (tied in to take first minute of decant), updated Supervisory Control and Data Acquisition (SCADA) and alarm systems, an influent flow meter, and effluent decant valves. More lab space was added, allowing for an increase in daily process control testing, as well as digester pump piping to the headworks. Many process changes were required during construction in the first part of 2011, resulting in temporary marginal treatment. Once completed, the facility only experienced a few minor equipment failures.

Standard Operating Procedures were developed for the upgraded facility, along with a new detailed computerized preventive maintenance program that will keep the equipment running throughout its life with minimal premature failures. The goal of the upgrades was to replace outdated equipment and improve treatment and water quality to all downstream users including biological TIN and TP removal. It is anticipated that the facility will consistently meet TIN of less than 8.0 mg/L and TP of less than 0.8 mg/L.

The Idaho Springs wastewater treatment plant had one monitoring violation for failing to collect an *E. coli* sample on the discharge within the required time frame due to a temporary failure of the disinfection system. Overall, however, the plant operated well below its State-permitted discharge limits in 2011. Its annual averages for nutrient discharge were 5.38 mg/L ammonia-N, 1.00 mg/L nitrate-N and 0.87 mg/L TP.

Black Hawk/Central City Sanitation District WWTP

Black Hawk/Central City Sanitation District (BHCCSD) continued to achieve excellent nutrient removal in its wastewater treatment plant effluent. The District's WWTP is considered a Level 4 treatment plant and employs enhanced biological nutrient removal (BNR) treatment plus filtration and ultraviolet (UV) disinfection.

The concentration of TP measured in the effluent ranged from 0.03 mg/L to 1.10 mg/L during 2011. TIN concentrations ranged from 1.75 mg/L to 9.85 mg/L. A brief increase in TP concentrations was observed in the WWTP effluent during late September 2011. The District believes the isolated increase in TP and TIN concentration was related to roadway construction activities.

In general, the BHCCSD WWTP effluent TP and TIN concentrations were similar to concentrations observed during 2010. The District continues to operate its enhanced BNR treatment plant and remove nutrients to very low levels as an ongoing component in its efforts to protect water quality in Clear Creek.

Observed WWTP Effluent Concentrations

The WWTPs in the Upper Basin of the Clear Creek watershed continued efforts in 2011 to reduce nutrient discharges. Effluent nutrient data, presented herein, are representative of end of pipe samples. Nutrient reporting was not required in NPDES permits prior to and including 2011. TP and TN concentrations measured for each WWTP in 2006-2011 are presented in Figures 6-11. Note that the sampling frequency varied by WWTP and over the course of the year.

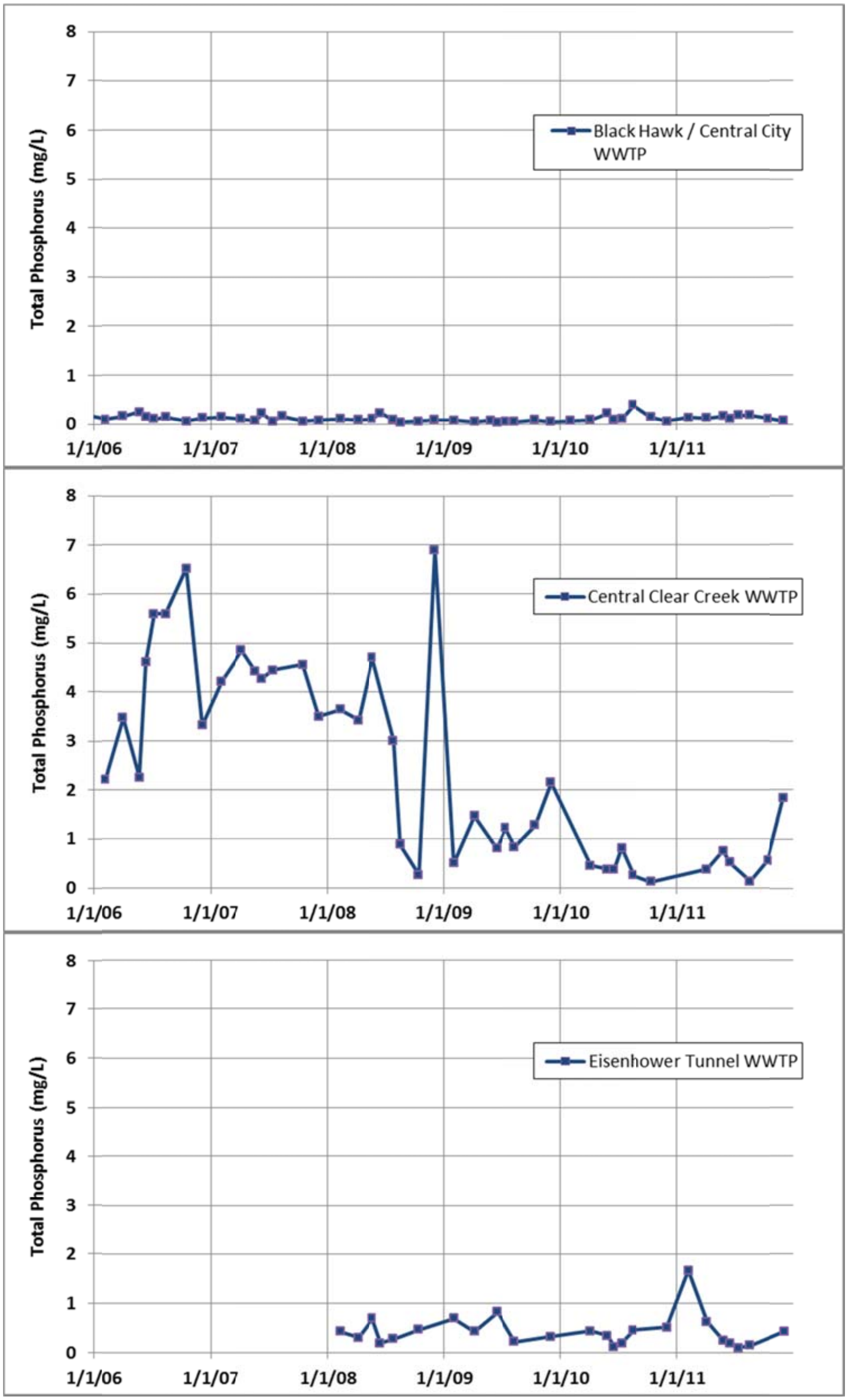


Figure 6. Effluent TP Concentrations (2006-2011) for Black Hawk/Central City, CCC, and Eisenhower Tunnel

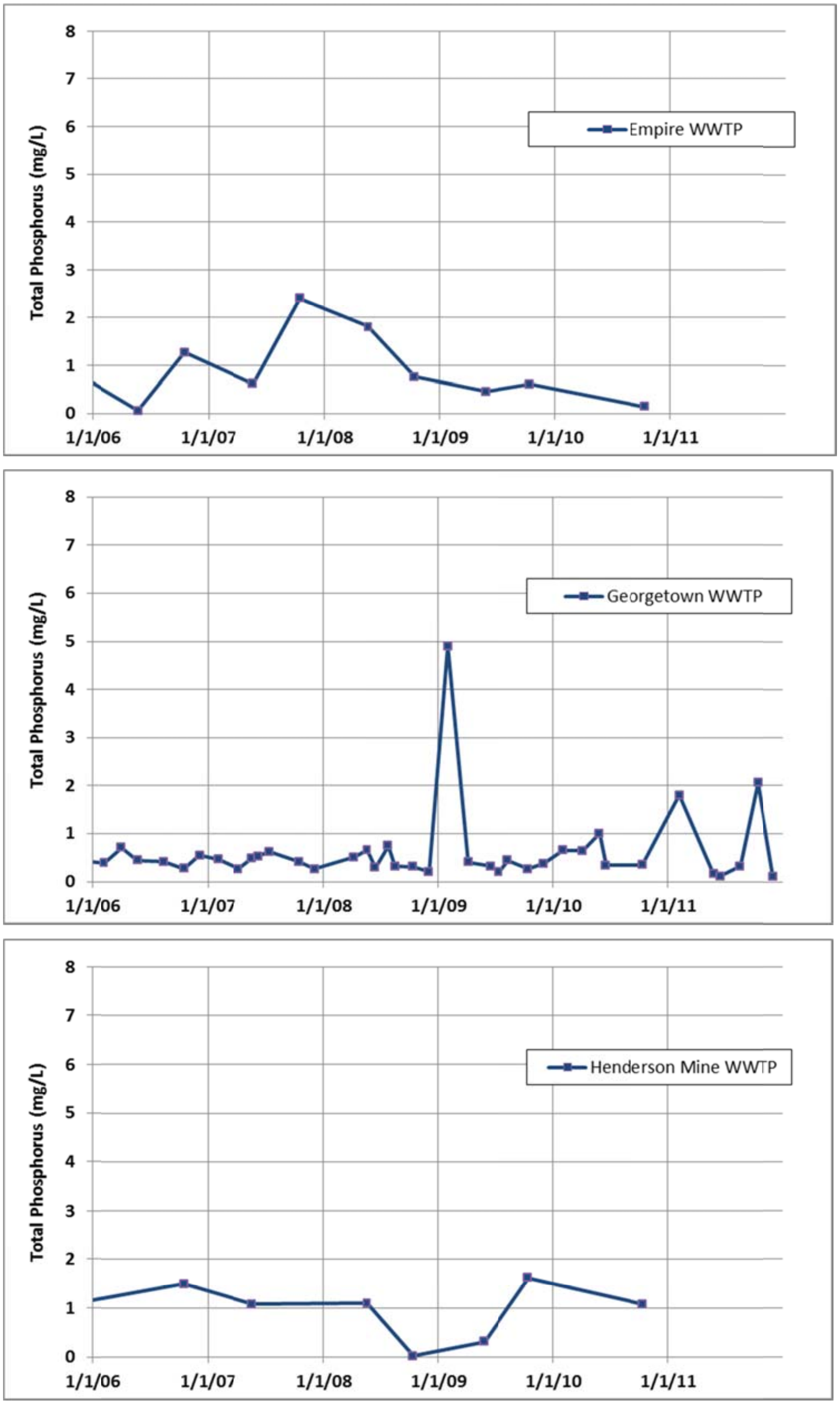


Figure 7. Effluent TP Concentrations (2006-2011) for Empire, Georgetown, and Henderson Mine

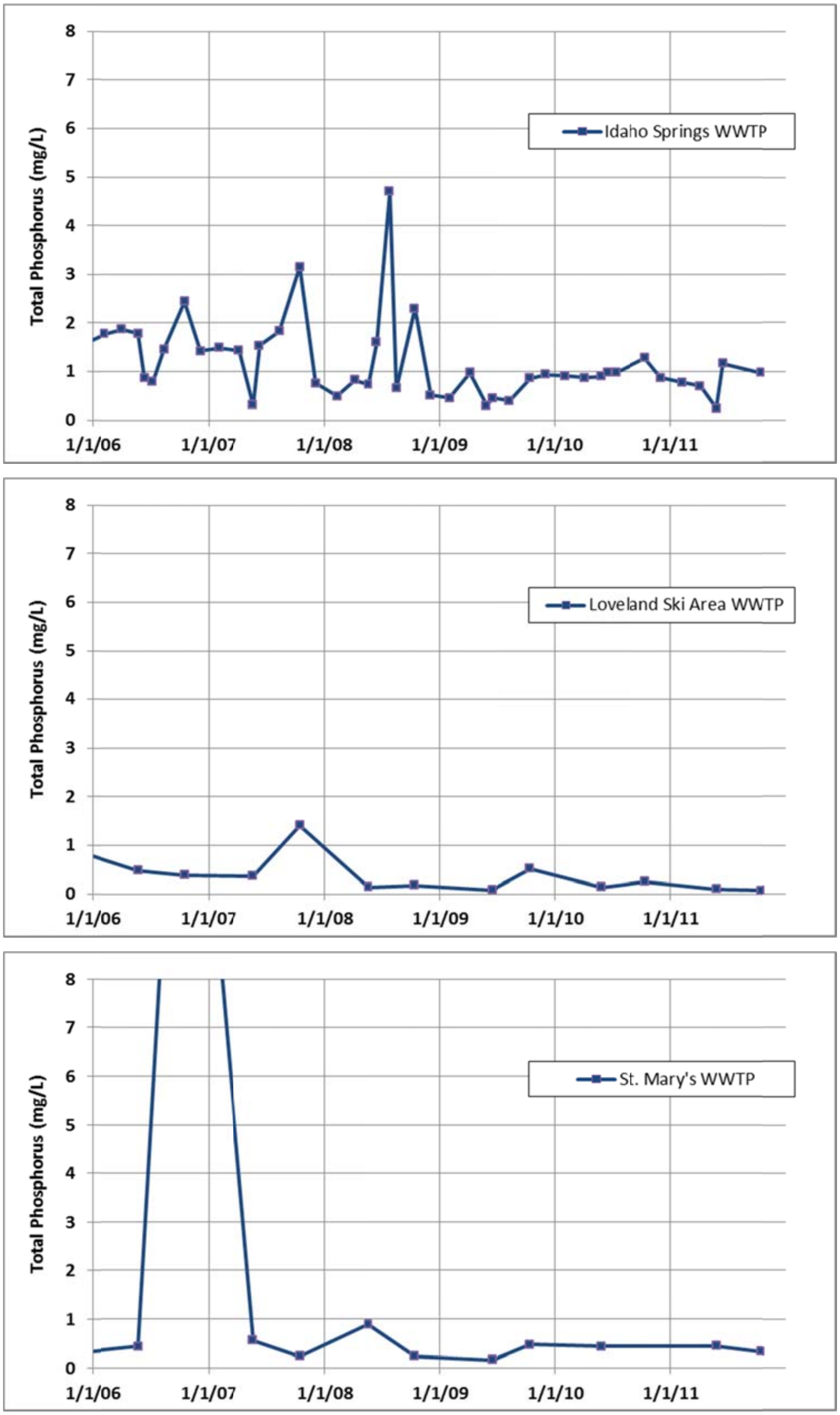
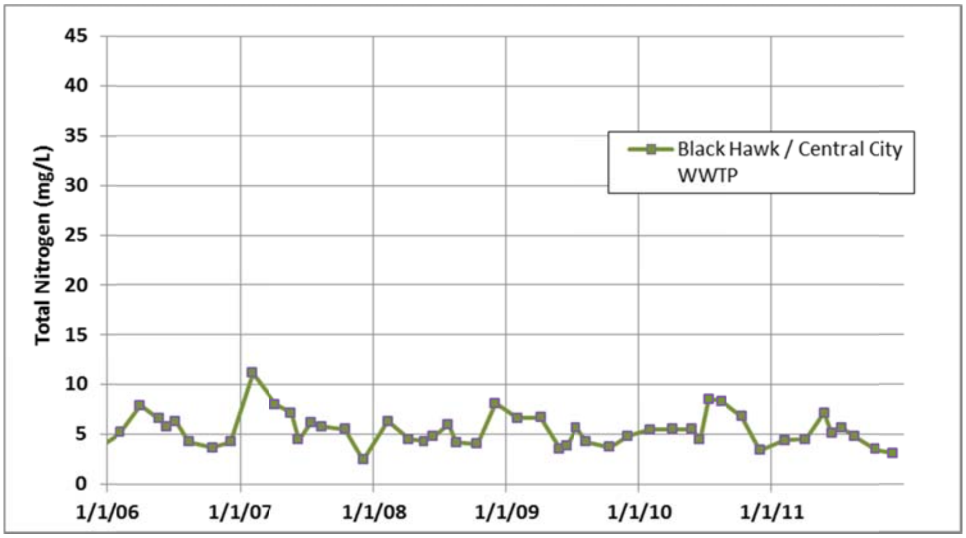
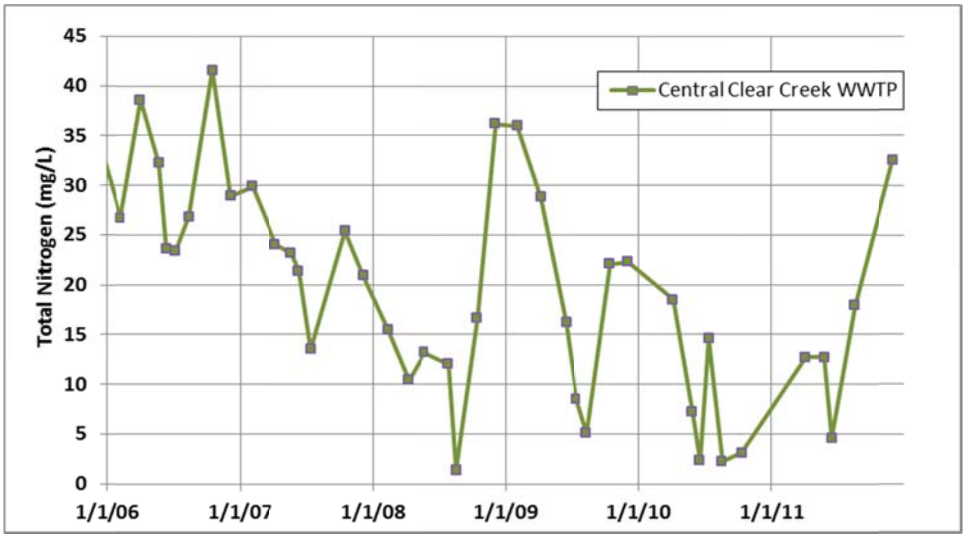


Figure 8. Effluent TP Concentrations (2006-2011) for Idaho Springs, Loveland Ski Area, and St. Mary's





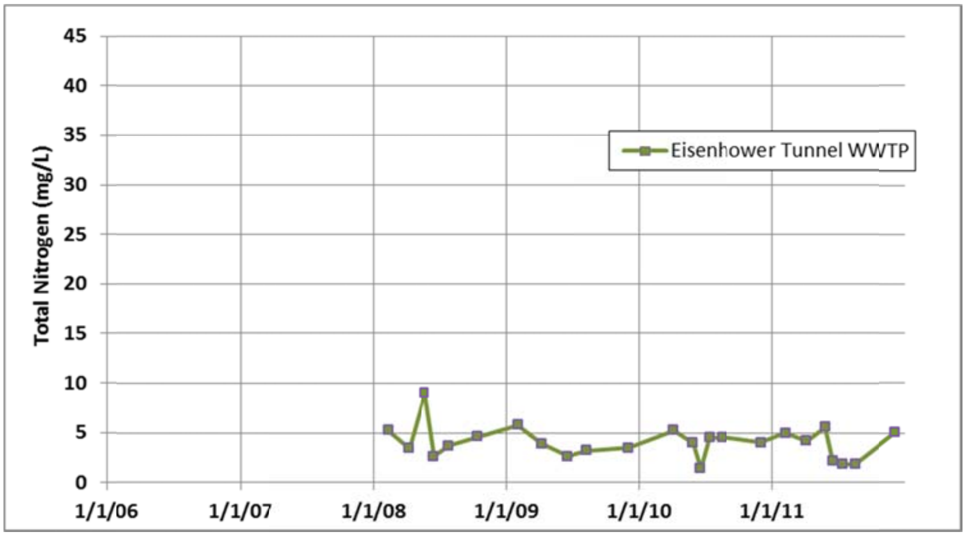


Figure 9. Effluent TN Concentrations (2006-2011) for Black Hawk/Central City, CCC, and Eisenhower Tunnel

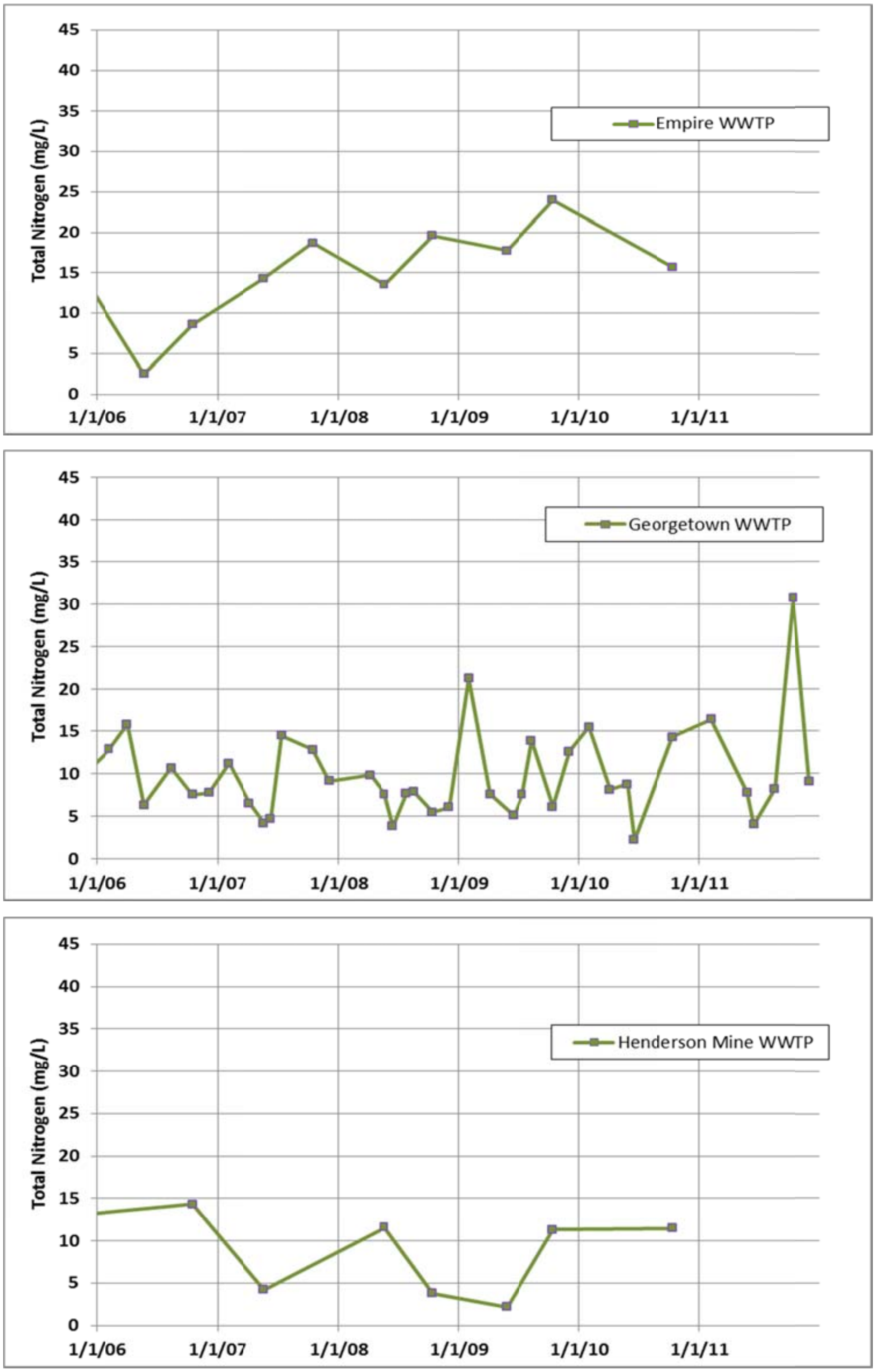
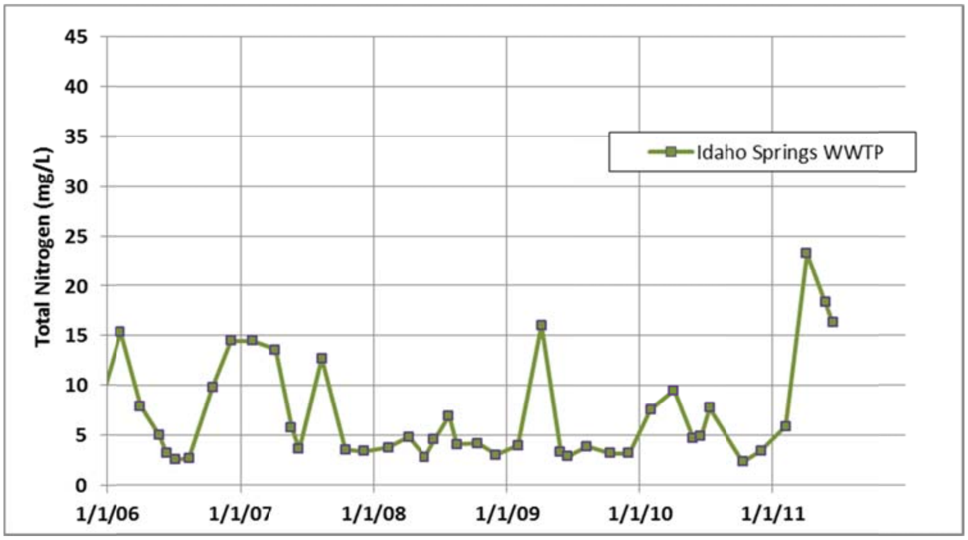
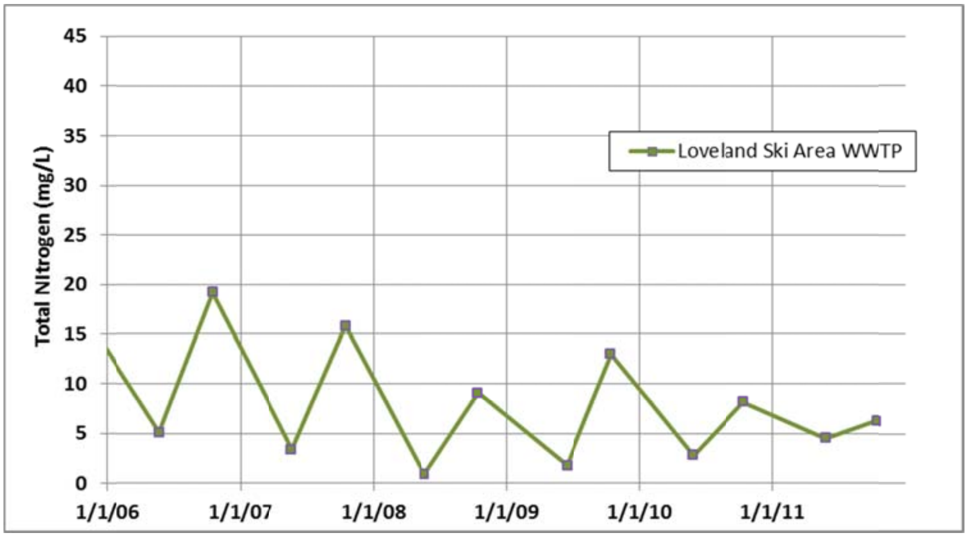


Figure 10. Effluent TN Concentrations (2006-2011) for Empire, Georgetown, and Henderson Mine

Note: The maximum 2011 TN result presented for the Georgetown WWTP is a grab sample that does not correlate with the 24-hr composite sample results for TIN reported by Georgetown. Georgetown's average monthly DMR data are summarized in Appendix C.





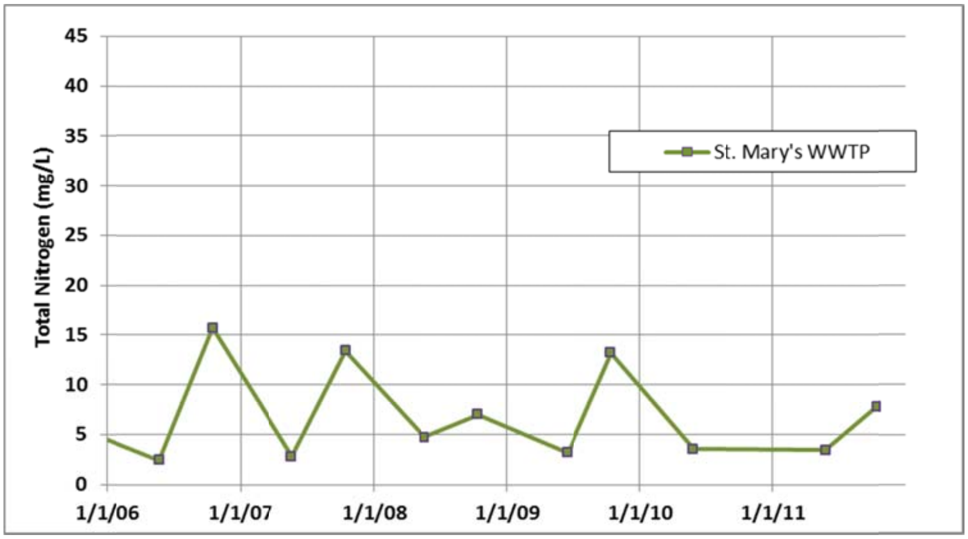


Figure 11. Effluent TN Concentrations (2006-2011) for Idaho Springs, Loveland Ski Area, and St. Mary's

Illicit Discharges

The municipalities in the Upper Basin made efforts in 2011 to detect and reduce illicit discharges into the water system. Highlighted below are a few particular achievements by the City of Golden and the City of Arvada.

The City of Golden responded to 22 reports of discharges (or potential discharges) to the storm sewer system, issuing two written warnings, 11 verbal warnings, and billing one party for clean-up costs.

The City of Arvada continued annual dry-weather screening inspections of outfalls to identify potential sources of illicit discharges. In 2011, 366 outfalls were inspected with 19 outfalls requiring maintenance ranging from concrete work to debris clean-up. Another key element of the 2011 work was the illicit discharge detection and elimination program, with the City of Arvada responding to over 55 complaints from citizens and City of Arvada field staff. A total of 11 written and 21 verbal warnings were issued. In three instances, a professional environmental clean-up firm was contracted to remediate the situation.

Nonpoint Source and Stormwater Control

Clear Creek watershed entities and Canal Zone stakeholders took steps to reduce nonpoint source water contamination. This included efforts such as conducting erosion and sediment control inspections and reducing sediment input from highway runoff. Described below are highlights of these endeavors.

Management of Sediment from Highway Activities

The Colorado Department of Transportation (CDOT) continues to capture and remove sediment from highway runoff within the Upper Clear Creek Watershed. Specifically, twelve sediment basins on the east side of Berthoud Pass (U.S. 40) serve to capture sand. The sand is removed and placed as capping on mine tailings areas in Empire, on the east side of Main Street. CDOT continues to look for new sites for sand disposal and supports research for traction sand reuse.

CDOT continued to utilize more liquid deicer relative to traction sand. This reduces the amount of winter traction sand entering the creek. CDOT Maintenance now trains new members in order to ensure that only sufficient, not excessive, deicer (of any kind) is used. Training is the best management practice (BMP) for minimizing deicer usage.

CDOT continued its rock fall control projects along I-70, just west of Georgetown. As part of these projects, CDOT removed both large boulders and fine material from the west-bound side ditches. The boulders would not reach Clear Creek, but fine particles can.

In November 2010, construction began on a safety project along SH119, south of Black Hawk. This CDOT project involves straightening a curve just south of Black Hawk, building a bridge, and widening two to four lanes (with a median) for about one-third of a mile south of Main Street. As part of this project, CDOT is restoring a full mile of North Clear Creek and building a sediment basin to catch sand used on the highway. Both actions are intended to improve water quality in both North Clear Creek and the main stem of Clear Creek. Removal of winter traction sand helps to control nutrients from nonpoint sources. The basin also has a valve that can be closed to contain potentially hazardous spills in this section of the roadway.

Erosion and Sediment Control in Urban Areas

The City of Golden administered 23 stormwater quality construction permits, conducted 667 erosion and sediment control inspections, issued 173 written notifications of violation and 93 verbal notifications of violation, and used performance security for corrections at one site. The Stormwater Maintenance Program conducted 165 inspections of permanent water-quality BMPs and sent 143 letters requesting maintenance to land owners, with subsequent 100% compliance.

A major component of Arvada's Stormwater Program is the erosion and sediment control efforts focused on construction sites. In 2011, 1,036 erosion and sediment control inspections were conducted on 79 active construction sites. A testament to the compliance focus of this program is that there were 15 notices of violation with notices of compliance not being awarded until sites met runoff control requirements. Additionally, 34 warnings were issued to notify developers that further enforcement action may be taken if the sites remained in noncompliance.

The City of Arvada also carried out inspection and enforcement related to post-construction, permanent BMPs. In 2011, a total of 84 permanent stormwater BMPs on 74 developments were inspected. After inspection, corresponding reports that identified noncompliant issues needing to be addressed were sent to owners.

Onsite Wastewater Treatment Systems

The Clear Creek County Environmental Health Department issued 29 Onsite Wastewater Treatment System permits in 2011 and continued monitoring existing systems for failure. None of the permits were issued to correct failures.

Reductions in Stormwater Flows to Delivery Canals

For nearly two decades, Arvada has strived to improve stormwater quality to the canals feeding Standley Lake by returning flows into natural drainage ways and by developing a comprehensive Stormwater Program. 2011 marked one of the first years in which no new areas were returned to their natural drainage ways. Historically, 12,700 acres that are now within or flow through Arvada drained into the canals; today there are only 2,500 acres, an 80% reduction.

Stormwater System Maintenance

The City of Arvada's storm system maintenance staff inspected 3,720 inlets (cleaning 1,589 of them), jetted 14 miles of pipes, and removed over 182 tons of material from underground pipes and inlets.

Runoff Control from Urban Facilities

To reduce pollution from City operations, all Arvada facilities with Runoff Control Plans were inspected twice in 2011. Over 20 staff from multiple operations attended training focused on:

- Potential facility-specific pollutant sources,
- Potential activity-specific pollutant sources, and
- Spill response procedures.

Post-Fire Stormwater Mitigation

Following a March 2011 fire in the lower portion of Clear Creek canyon, the City of Golden installed a containment structure and BMPs in Indian Gulch prior to discharge into Clear Creek. Monitoring above and below the structure indicated no contamination from the fire. The structure will remain in place through 2012.

Public Education, Outreach, and Partnerships

Entities in the watershed and lake managers continued efforts to educate the public regarding water quality and watershed protection, maintained programs to prevent hazardous household wastes from entering the water system, and created partnerships to further enhance the tradition of responsible watershed stewardship. This section presents specific 2011 activities and programs.

Stormwater Pollution Prevention

The City of Arvada continued its on-going education of contractors, City personnel, citizens, and students. The goal of the program is to ensure that the public is aware that City storm drains flow directly to waterways and that certain activities can contaminate those waterways. The City provided the public with various resources to increase awareness, such as adopt-a-street and trail programs, storm drain marking, household hazardous chemical disposal and recycling, and brochures and demonstrations that focused on preventing stormwater pollution.

The City of Golden continued to manage and support the City of Golden Stormwater Program. Public education activities included distributing educational materials and attending public events.

General Public Education and Outreach

Throughout 2011, the Clear Creek Watershed Foundation (CCWF) continued its tradition of public education and outreach concerning watersheds, water quality, environmental restoration, and mining history. CCWF attended and presented at numerous meetings and conferences. Additionally, CCWF supported public and school tours of the Clear Creek Watershed Exhibit in the Idaho Springs Visitor Center, provided elementary school classroom presentations, and maintained and updated its informational website.

CCWF organized and hosted the third annual Clear Creek Watershed Festival in September 2011. The event was a success, with over 800 participants and more than 30 environmental education booths.

Recycling and Disposal of Household Chemicals and Hazardous Waste

In 2011, the City of Golden contributed $7,903 to the Rooney Road Recycling Center. The City actively participates as a member of the Board of Managers for the Rooney Road Recycling Center Authority. This facility provides critical recycling and disposal services of household chemicals and annually serves more than 3,000 Jefferson County residents. Less than 1% of all materials collected at the facility are deposited in landfills. In addition to household chemicals, the recycling center also recycles residential and commercial green wastes. In 2011, over 80,000 cubic yards of green waste from over 27,000 customers was collected and recycled. The City has also been an active founding member of the Rooney Road Recycling Center Foundation. The foundation was created to help secure additional funding for the Rooney Road Recycling Center Authority to further augment the number of residents served by the chemical recycling and disposal aspect of the facility.

Clear Creek County continued development of its Household Hazardous Waste (HHW) collection program. Staff training began in 2011 toward the goal of making HHW collection a more frequent event at the Transfer Station, located at 1531 Soda Creek Road, Idaho Springs. The Transfer Station accepts various sorts of materials and offers an extensive recycling program.

Pharmaceutical Disposal

The Drug Enforcement Administration (DEA) sponsored two National Pharmaceutical Take-Back Days in 2011. These nationwide events provided a unified opportunity for the public to surrender expired, unwanted, or unused pharmaceutical controlled substances and other medications to law enforcement officers for destruction. The DEA's efforts bring national focus to the issues of pharmaceutical substance abuse and the hazards associated with contamination of our water systems with prescription drugs. DEA efforts also provide a secure outlet for disposal that will protect our water resources. In 2011, the City of Arvada collected 1,552 pounds of medications, the City of Golden collected 368 pounds, and the Standley Lake Cities collected 1,436 pounds.

Industrial Water Use Reporting

Molson Coors started a program that will strengthen its focus on corporate responsibility through partnerships with the United Nations CEO Water Mandate, Beverage Industry Environmental Roundtable (BIER), and other agencies that report water use. The goal of this program is to make the public aware of water use by Molson Coors and efforts underway to decrease the amount of water used globally at all of its breweries, including the United Kingdom, Canada, China and India. A large portion of this program is based on the success that has been achieved within the Clear Creek watershed.

Molson Coors reports water use, efficiencies and program improvements to several reporting groups including the Dow Jones Sustainability Index and the Water Disclosure Project. Both of these groups allow for external reporting of water use.

Water Education for Elementary School Students

In May 2011, fourth and fifth graders from the Standley Lake Cities converged to learn about a variety of Colorado water topics. Students from the water service areas of Thornton, Northglenn, and Westminster participated in the annual Youth Water Festival at Front Range Community College in Westminster. Over 1,100 students, teachers and parents attended the event, which offered a day of fun and educational workshops featuring active learning and hands-on activities. The Festival's workshops were designed to teach students about water conservation, water chemistry, the water cycle, local water supplies, water treatment, Colorado water law, aquatic wildlife, ecology and more.

Youth Water Festival Held by the Standley Lake Cities, 2011

Emergency Response

In order to promptly and effectively notify downstream users of water from Clear Creek of any potential contamination from an upstream source, Clear Creek County uses the Code Red emergency call-down system. The Clear Creek Office of Emergency Management Director continues to update and maintain the database for the call lists. The system applies to incidents/spills into Clear Creek and tributaries leading into Clear Creek that occur in Clear Creek County.

Based on a review of the Code Red database for 2011, the Clear Creek Office of Emergency Management reported five launches which were initiated by Clear Creek County Dispatch for three incidents with two follow-up notifications. One call was launched by the City of Golden Dispatch.

In 2011, a supplemental procedure was developed to activate the call-down system in incidents where no public safety official may be present. The need came to light in February 2011, when a CDOT contractor's work near the Eisenhower Tunnel resulted in a discharge of styrene into the headwaters of Clear Creek, impacting the Loveland Ski Area in particular. CDPHE was notified, but downstream users, other than the ski area, were not. Impacted waters were treated until monitoring demonstrated that the water was clean. Through 2011, UCCWA and the County continued to work with CDPHE to resolve concerns about notification timing.

Planning Activities

Several entities took valuable planning steps in 2011 to preserve and improve the quality of water in Clear Creek and Standley Lake. Notable planning endeavors are described below.

Upper Basin 208 Management

The Upper Clear Creek Watershed Association (UCCWA), consisting of 18 members, is the designated 208 management agency for the Upper Basin responsible for testing, monitoring, overseeing, and reporting water quality and water resource issues through the upper portion of the Clear Creek Watershed. In that capacity, UCCWA reviewed and commented on seven referrals; two referrals were for the Colorado Department of Public Health and Environment (CDPHE); four were for a county government; and one was for the US Forest Service. In addition, UCCWA reviewed and commented on five mining applications made to the Division of Reclamation Mining and Safety.

Sediment Management, Erosion Control, and Spill Containment

A study is being conducted by CDOT to address sediment management from roadway maintenance activities and natural erosion into Clear Creek. This Sediment Control Action Plan (SCAP) study will first focus on the section of I-70 between the Eisenhower Tunnel and below Idaho Springs. Recommendations will be provided as part this effort. Because representatives from the Upper Clear Creek Watershed Association (UCCWA) expressed concern about fuel spills as another significant threat to water quality, options will be considered for spill containment.

I-70 Corridor Project

The Colorado Department of Transportation (CDOT), along with the Federal Highway Administration, is managing the I-70 Corridor Project. The first project related to the I-70 Corridor Programmatic Environmental Impact Statement (PEIS) within the Clear Creek watershed has begun. The Environmental Assessment (EA) for the Twin Tunnels project, and National Environmental Policy Act (NEPA) clearance for a smaller project on CR314 (both east of Idaho Springs) include public participation. Members of UCCWA are represented on the Project Leadership Team and in the Stream and Wetland Ecological Enhancement Program (SWEEP) and A Landscape Level Inventory of Valued Ecosystems (ALIVE) committees. These committees focus on aquatic resources, wetlands, water quality, and wildlife concerns.

The area to be impacted extends east from Idaho Springs to Hidden Valley on both sides of Clear Creek, and east to the base of Floyd Hill on the north side. Construction on CR314 (“Frontage Road”) is anticipated to begin in summer/fall of 2012. The Twin Tunnels EA, which assesses potential impacts from adding one eastbound lane from Idaho Springs to the base of Floyd Hill, including widening the eastbound tunnel, is anticipated to be completed in summer/fall of 2012.

Intergovernmental Agreement for Managing Water Quality

The Standley Lake Cities renewed the Water Quality Cost-Sharing Intergovernmental Agreement (IGA). This IGA provides the mechanism for jointly sharing the costs related to pursuing water quality protection efforts for the Standley Lake water supply.

Incorporating Water Quality Factors into Ditch Operations

A meeting was held in August 2011 with both water-quality and water-quantity staff from the Standley Lake Cities. Although it is implicitly understood that water *quantity* trumps water *quality*, the meeting included an effective dialogue about when it might be advantageous, from a water-quality perspective, to prevent some water from reaching Standley Lake by closing canal headgates. Such scenarios include spills or accidents in Clear Creek, mine blowouts, or large storms in the watershed that have the potential to add significant amounts of nutrients and sediments to the lake.

Nutrient Loads in the Canal Zone

The Standley Lake Cities continued efforts to develop an improved understanding of the water-quality dynamics in the Canal Zone between Clear Creek and Standley Lake. In 2011, the Standley Lake Cities conducted a Waterway Workshop and a special sampling event focused on the Croke Canal. Increases in nutrient concentrations in this canal have been observed. The Waterway Workshop was held on March 3, 2011. The workshop brought together key personnel with knowledge of the system, including ditch riders, operators, samplers, and water-quality and flow managers for a productive discussion and information exchange. This group developed a mapped list of potential nutrient source areas along the Croke Canal.

Based on information gathered at this meeting, a special sampling event was designed. This sampling event, targeting Croke Canal water quality during flowing conditions, was completed on March 30, 2011. Samples were collected at 11 locations from upstream to downstream over a period of several hours.

This reconnaissance sampling provided valuable information toward an improved understanding of potential source areas for observed increases in nutrient concentrations along the Croke Canal. The investigation is ongoing, and findings will be used to support informed operational decision-making to protect the water quality in Standley Lake.

Clear Creek Watershed Model Updates

In 2011, the Standley Lake Cities funded an update of the Clear Creek watershed hydrologic and water-quality model. The Clear Creek watershed model is an application of a process-based watershed modeling software package, WARMF -- Watershed Assessment Risk Management Framework. This model simulates the processes of snowpack development, rainfall-runoff response, surface and sub-surface flow into channelized flow, point and nonpoint nutrient sources, as well as transport, transformation, and decay of chemical constituents.

The work in 2011 included updating the model with meteorological inputs, flow records, and water-quality records through 2010. Flow and water-quality simulation results were compared to observations. By keeping the model updated, the Standley Lake Cities continue to gain insights into system behavior and track changes in watershed loading through the detailed data workups required for model development. The model now simulates nine years of record, making it a powerful tool for Standley Lake water-quality management support.

Invasive Species Prevention and Mitigation

Aquatic Nuisance Species Prevention Measures

The Standley Lake Cities continued with several programs in 2011 to monitor or prevent aquatic nuisance species in Standley Lake. Park rangers consistently make efforts to inspect, tag, and quarantine boats. Lake samples are analyzed for the presence of Quagga and Zebra mussel veligers. Substrate samplers are examined for the presence of aquatic nuisance species, and a shoreline survey is conducted annually to look for invasive species.

Eurasian Watermilfoil Mitigation

To combat the invasive aquatic plant Eurasian watermilfoil (*Myriophyllum spicatum*), 5,000 weevils (*Euhrychiopsis lecontei*) were stocked by the Standley Lake Cities in several watermilfoil beds in 2011. Enviroscience, Inc. reported 500 stems/m^2 in 2006; a 2011 survey showed only 26 stems/m^2. Success is further indicated by the wider spectrum of plant species now present in areas once predominated by milfoil, as well as evident weevil damage in all stocked sites.

Mine Reclamation Efforts

The Clear Creek Watershed Foundation is a driving force in Orphan Mine Remediation within the watershed, working in cooperation with the Environmental Protection Agency (EPA), the CDPHE, the US Forest Service, local governments and property owners. CCWF's ambitious agenda is funded primarily through government grants, and Molson Coors Brewing Company contributed $30,000 to CCWF in 2011 for continued support of orphaned mine restoration.

In 2011, two remediation projects were completed; Gilson Gulch and Upper Trail Creek, both near Idaho Springs. Additionally, follow-up monitoring continues at previously completed projects.

Other Activities

Hidden Valley Water Treatment Plant

In 2011, the City of Black Hawk began work for construction of a new raw water intake and infiltration gallery at the Hidden Valley Water Treatment Plant along Clear Creek near Idaho Springs. The new intake will replace the existing tee screen that extends into the creek with a flat plate screen flush with the bank of the creek. The new infiltration gallery will be located under the channel of the creek.

Green Lake

The City of Black Hawk, along with Clear Creek County, has been operating Green Lake which receives water delivery by way of Vidler Tunnel and Leavenworth Creek, a tributary to Clear Creek. The County and the City purchased additional materials to begin replacing the old pipeline from the Leavenworth headgate.

Georgetown Lake

Black Hawk continues to work with the Town of Georgetown to upgrade the existing Georgetown Lake Dam outlet. The existing outlet gate will be automated to control the storage and release of both Georgetown's and Black Hawk's water rights.

Georgetown Dam Spillway, which Feeds Directly into Clear Creek

IV. Upper Basin Water Quality

The previous Section highlighted particular activities and accomplishments of various groups focused on improving and protecting water quality. This Section presents an analysis of 2011 observed water-quality data in the Upper Basin. Constituents presented include discharge, TSS, TP, and TN. The analysis is based on grab samples data collected at sampling stations CC26 (Clear Creek at Lawson Gage) and CC60 (Clear Creek at Church Ditch Headgate), as well as the closely collocated autosampler data, CCAS26 (Clear Creek at Lawson Gage) and CCAS59 (Clear Creek 2 miles west of Highway 58/US-6). CC26 and CCAS26 provide information on water quality in the upper half of the Upper Basin, while CC60 and CCAS59 provide data at the bottom of the Upper Basin near Golden. Figure 4 in Section II shows the locations of these key sampling stations.

Discharge

2011 hydrographs for the Upper Basin are presented in Figure 12, compiled from mean daily flow rates recorded at sampling stations CC26 and CC60. As seen in the plot, in 2011 flow began increasing sharply by the end of May as snows began to melt. Flow rates remained high through June and July, reaching the highest 2011 rates (1,440 cfs at CC26, and 1,420 cfs at CC60) on July 8. Flow rates decreased quickly in July, with the snowmelt hydrograph largely complete in August. Several storm events are also apparent as spikes in the hydrograph record between July and September.

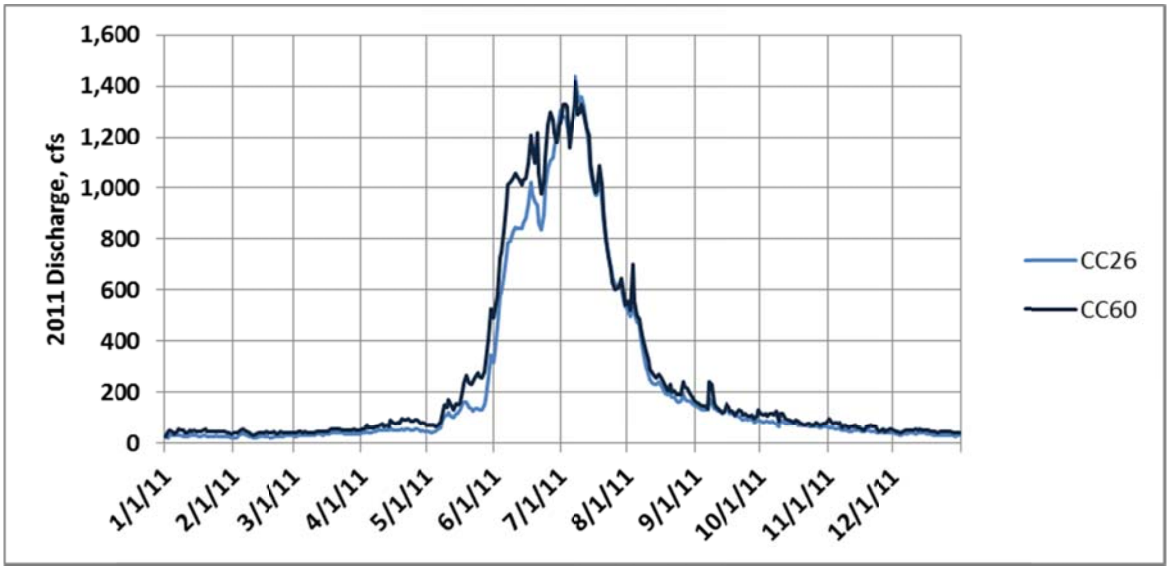


Figure 12. 2011 Hydrograph for the Upper Basin (CC26, CC60)

This runoff pattern of yearly snowmelt domination of the hydrograph is typical, but runoff volumes and timing in 2011 were not typical. Due to unusually high snowfall in the winter of 2010/2011, the total annual flow at CC60, as shown in Figure 13, was 39% higher in 2011 than the average total annual flow from 2006-2010.

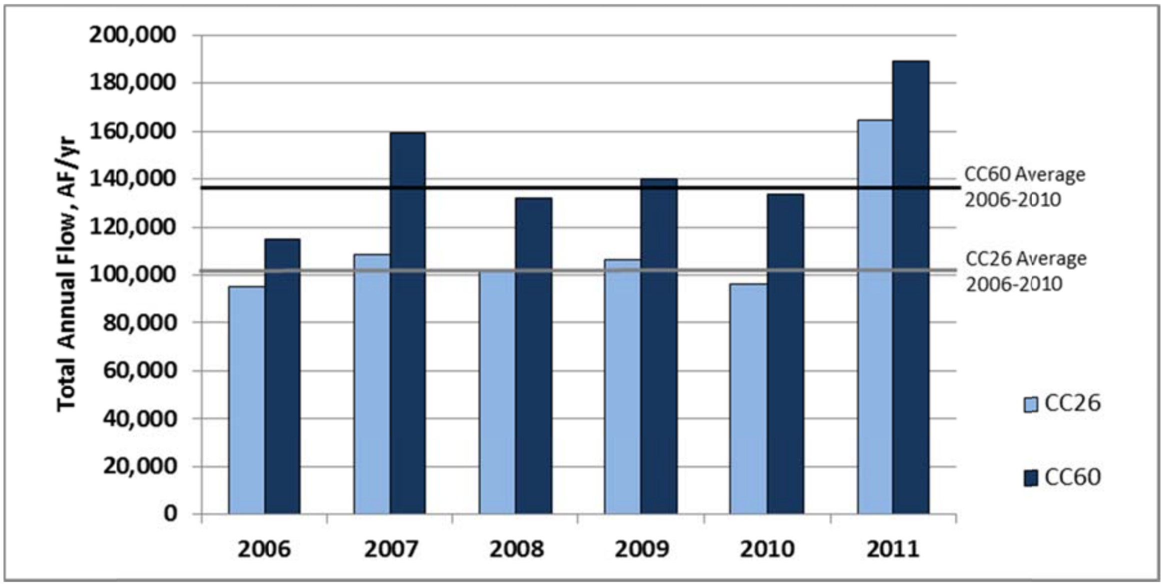


Figure 13. Total Annual Flow in the Upper Basin, 2006-2011

Correspondingly, the peak flow rate at CC60 in 2011 was 45% percent higher than the average peak flow rate for 2006-2010. Additionally, the 2011 peak flow occurred approximately one month later (in July) than the peak flows of previous years, which occurred in mid-June. This higher peak and longer-duration snowmelt period are apparent in the overlaid CC60 hydrographs for 2006-2010 in Figure 14.

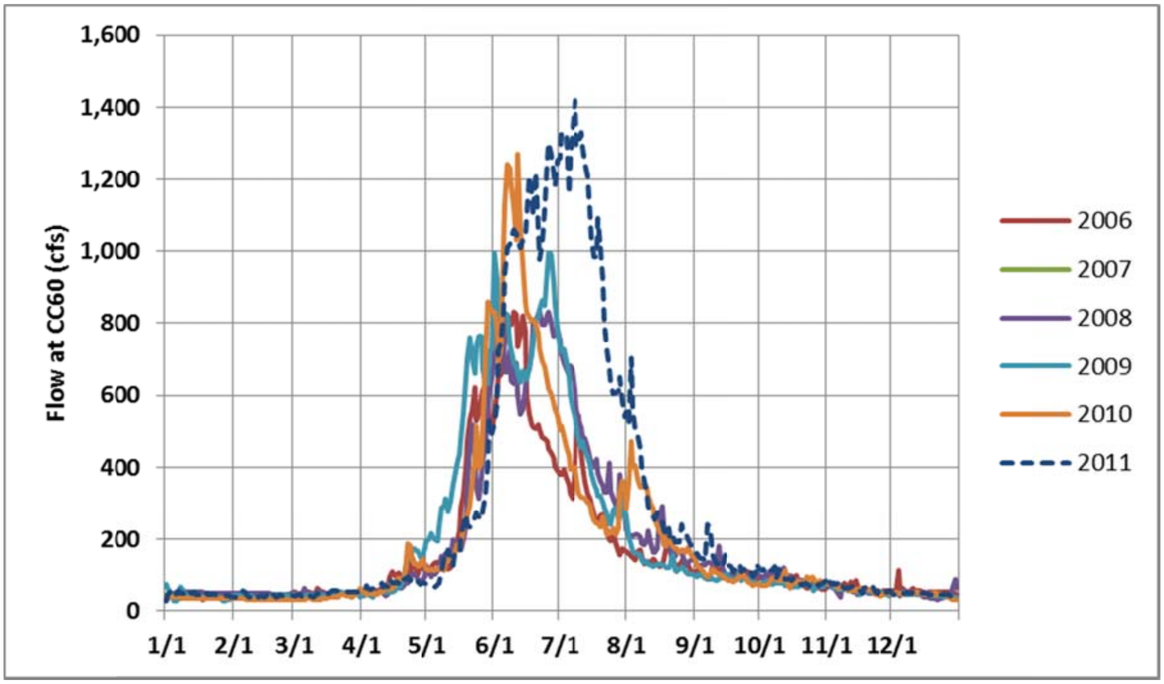


Figure 14. Annual Hydrographs for 2006-2011 in the Upper Basin (CC60)

Total Suspended Solids

TSS concentrations for 2011, shown in Figure 15, increased with the snowmelt hydrograph, reaching a peak concentration of 56 mg/L at CCAS59 on 5/31/11 and remaining high through June, followed by a decrease through the end of the year. As seen in the figure, there is a pattern of increasing TSS concentrations between CC26 and CC60, particularly in the summer months.

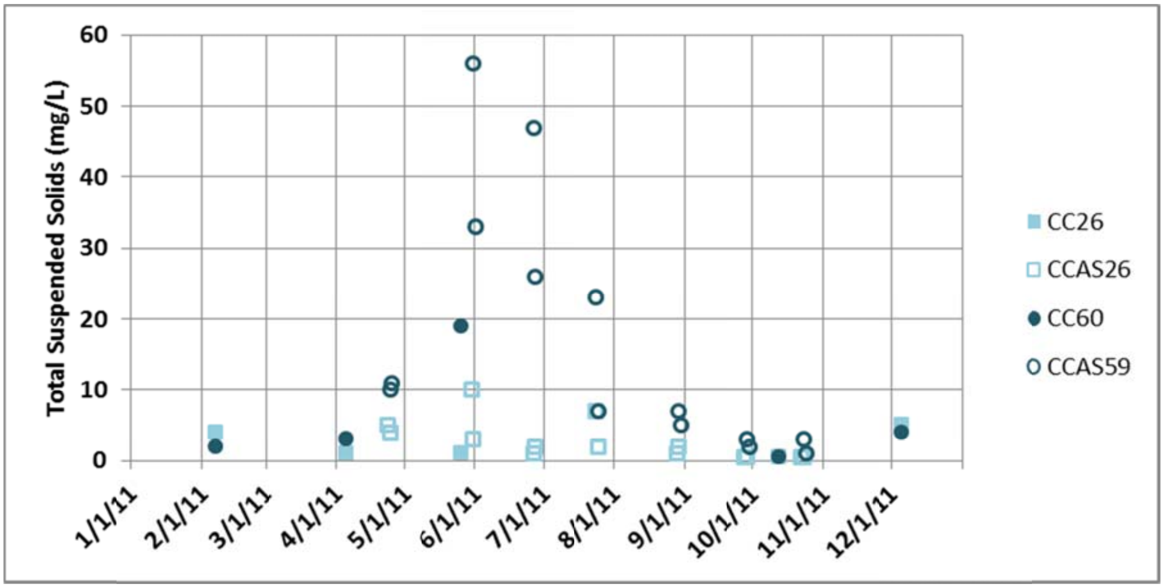


Figure 15. Total Suspended Solids Concentrations in the Upper Basin, as Measured by Grab Samples and 24-Hour Ambient Autosampler Data, 2011

TSS concentrations in the Upper Basin for 2011 are compared in Figure 16 to the concentrations from previous years. 2011 TSS concentrations follow the same seasonal pattern observed in previous years. The highest concentration in 2011 was 23% lower than the 2006-2010 average peak concentration, although that five-year average is heavily influenced by the high concentrations detected in 2006. Those high TSS values in 2006 were collected by composite autosamplers, but CC26 exhibited one grab sample result in 2006 greater than 50 mg/l in the same season. At this time it is not clear what caused these 2006 elevated values. Interestingly, those same elevated values in 2006 do not correspond to comparably-elevated nutrient concentrations. Excluding these 2006 values, the 2011 peak TSS concentration was 50% higher than the 2007-2010 average peak concentrations. Relative to 2010, the peak TSS concentration in 2011 was twice as high. These higher peak TSS concentrations in 2011 are likely attributable to greater mobilization of solids by the higher flow rates in 2011.

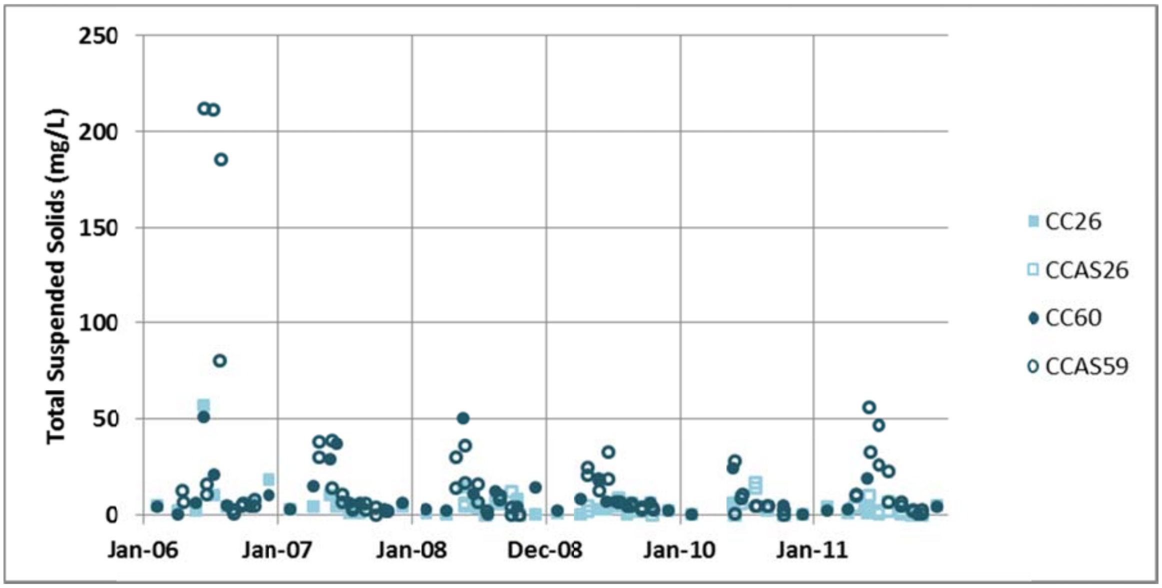


Figure 16. Total Suspended Solids Concentrations in the Upper Basin, as Measured by Grab Samples and 24-Hour Ambient Autosampler Data, 2006-2011

Average monthly concentrations of TSS at CCAS59/CC60 for 2011 and previous years (2006-2010) are shown in Table 1. For TSS, a comparison to monthly concentrations from 2007 through 2010 is also included, recognizing the uncharacteristically high TSS observations in 2006. Overall, TSS concentrations were higher in 2011, particularly for June and July.

Table 1. Total Suspended Solids Monthly Average Concentrations in the Upper Basin at CCAS59/CC60

Month	2011 TSS Concentrations (mg/L)	2006-2010 Average TSS (mg/L)	% Change in 2011 (Relative to 2006-2010)	2007-2010 Average TSS (mg/L)	% Change in 2011 (Relative to 2007-2010)
February	2.0	2.5	-20%	2.1	-6%
April	6.8	13.3	-49%	17.0	-60%
May	37.5	23.2	62%	27.4	37%
June	35.3	24.6	44%	15.5	128%
July	15.0	21.6	-30%	4.6	226%
August	6.0	5.8	3%	6.7	-10%
September	2.5	3.4	-26%	2.7	-6%
October	1.3	3.6	-66%	3.2	-61%
December	4.0	6.5	-38%	5.6	-29%

The TSS loading in the Upper Basin at CCAS59/CC60 in 2011 was 89% higher than the 2006-2010 average, as shown in Figure 17. The 2011 TSS loading was 128% higher than the 2007-2010 average. Through examination of the volume-weighted concentrations, however, as shown in Figure 18, 2011 saw only 32% increase at CCAS59/CC60 from the 2006-2010 average. Again, this relative result is strongly influenced by the 2006 elevated TSS observations. Excluding 2006, the 2011 volume-weighted average concentration was 73% higher than the 2007-2010 average. The volume-weighted average concentration is computed as the total load divided by the total flow volume for each year.

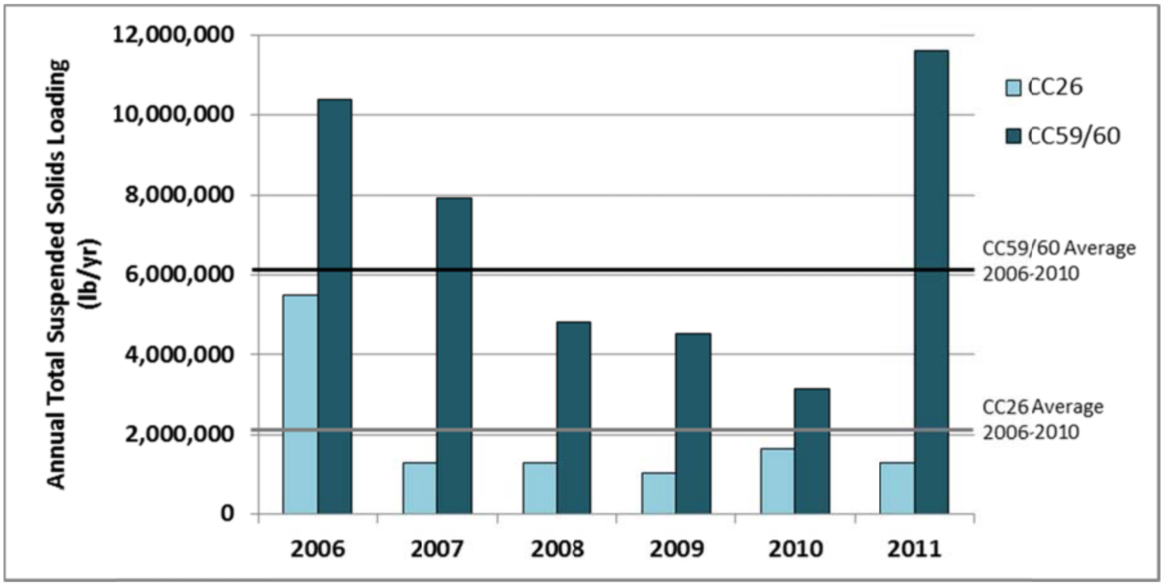


Figure 17. Annual Loads for Total Suspended Solids in the Upper Basin, using Grab Samples and 24-Hour Ambient Autosampler Data, 2006-2011

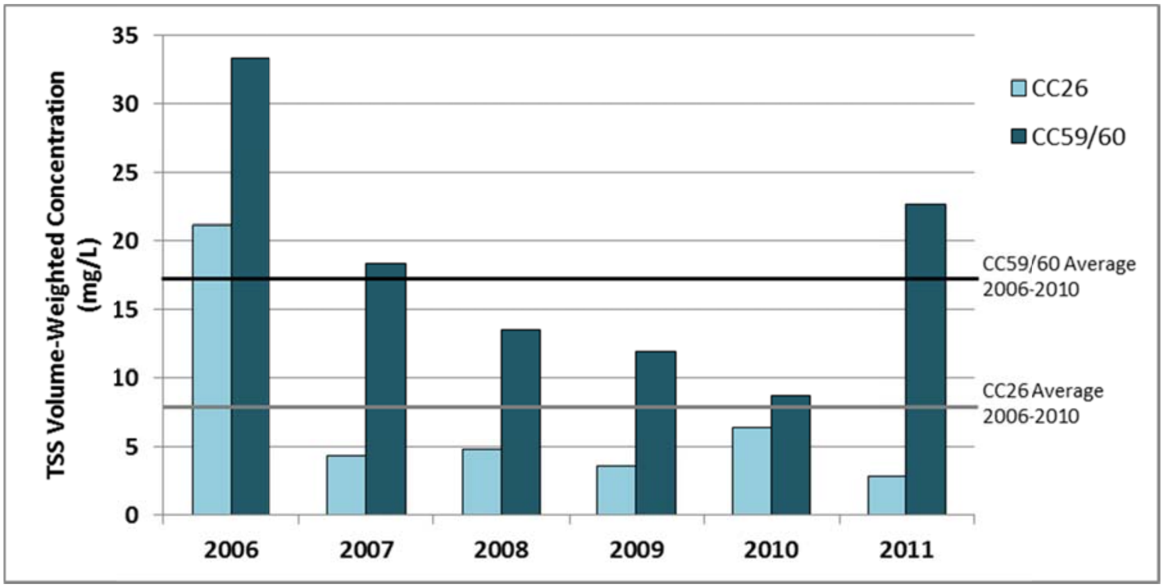


Figure 18. Volume-Weighted Concentration for Total Suspended Solids in the Upper Basin, using Grab Samples and 24-Hour Ambient Autosampler Data, 2006-2011

Total Phosphorus

Total phosphorus concentrations in the Upper Basin for 2011 are presented in Figure 19. The plot shows the ambient sampling program data (combined data from grab samples at CC26 and CC60, as well as 24-hour composite autosamples from CCAS26 and CCAS59).

Note that the ambient autosampler at CCAS26 picked up unusually high TP concentrations on 6/26/11 and 6/27/11, higher by an order-of-magnitude than typically observed. This could correspond to a specific occurrence, or this may be indicative of a collection or analysis error. At this point, there is no basis to exclude these two results collected on consecutive days. The results showed consistent ortho-phosphorus to TP concentration ratios, but there is no indication of a storm event or other specific cause. Further, TSS concentrations were not unusually high in the same samples, and the autosampler stations downstream (CCAS49, CCAS59) did not detect these unusually high TP concentrations in samples collected on the same days. Based on all of this information, these results have been kept in the dataset, but are evaluated here with caution.

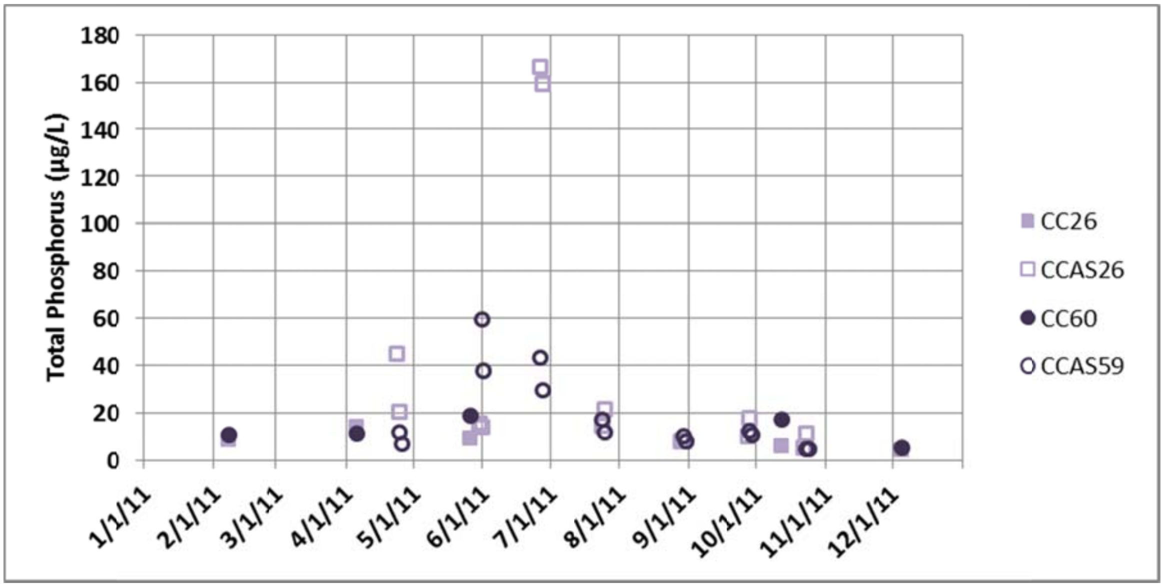


Figure 19. Total Phosphorus Concentrations in the Upper Basin, as Measured by Grab Samples and 24-Hour Composite Autosampler Data, 2011

As compared to previous years, shown in the 2006-2011 time-series in Figure 20, TP concentrations in the Upper Basin followed relatively consistent seasonal patterns. With the exclusion of the high values detected by CCAS26 for 6/26/11 and 6/27/11, the peak TP concentration in the Upper Basin in 2011 was comparable to peak concentrations in 2006, 2008, and 2010.

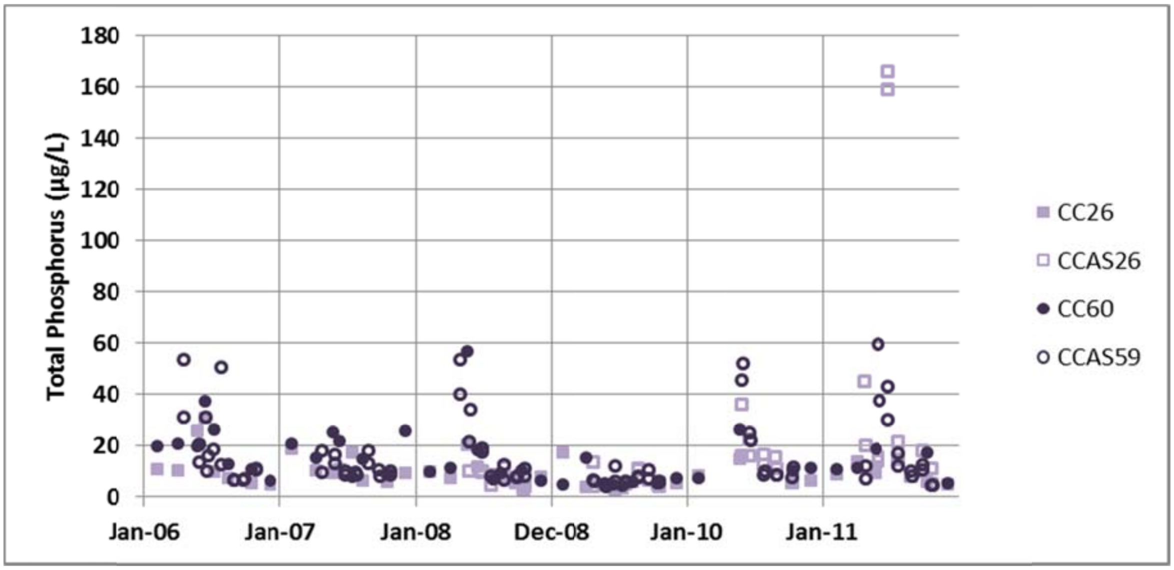


Figure 20. Total Phosphorus Concentrations in the Upper Basin, as Measured by Grab Samples and 24-Hour Ambient Autosampler Data, 2006-2011

As seen in Figure 20, concentrations generally increased into the summer and across the watershed (between CC26 and CC60). This seasonal pattern is typical for TP in the Upper Basin, and the increases in TP correspond roughly to the seasonal increases in TSS discussed above. Figure 21 shows TP concentrations plotted as a function of TSS concentrations at CC26 and CCAS59/CC60 for 2011. The pattern indicates a strong relationship between the two parameters at TSS concentrations greater than 10 mg/L ($R^2 = 0.94$). Phosphorus is often associated with solids in natural systems.

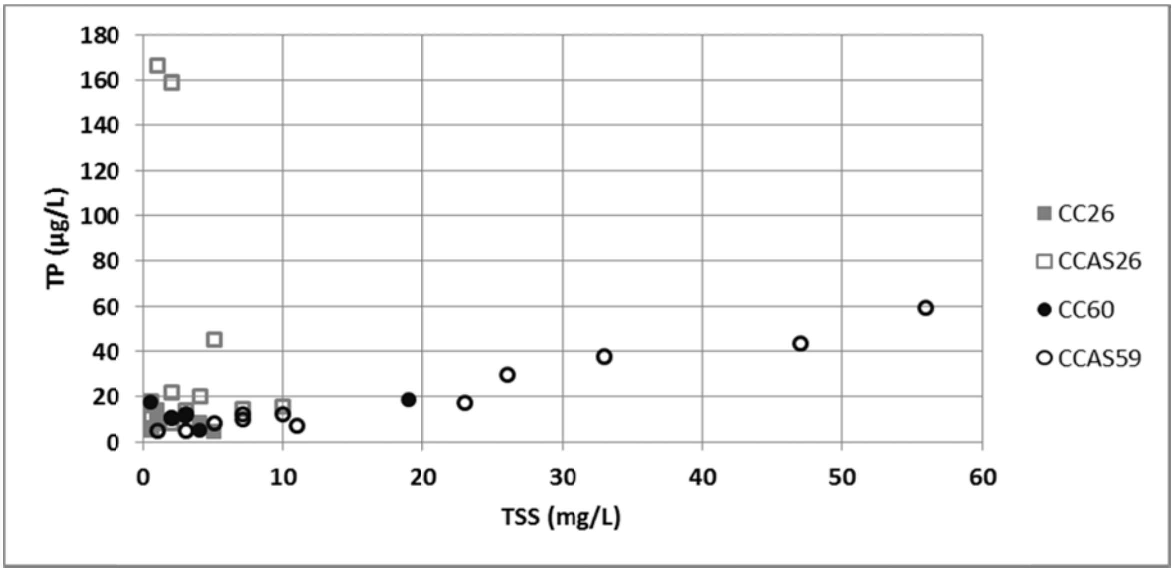


Figure 21. Relationship between Total Phosphorus and Total Suspended Solids at CC26 and CCAS59/CC60 in 2011

Table 2 provides a comparison of monthly average TP concentrations at CCAS59/CC60 in 2011 and previous years. As seen for TSS and TN, May and June 2011 exhibited higher relative TP concentrations (of 56% and 82% above the monthly averages of previous years). The June results should be considered recognizing possible uncertainty around the two very high results in 2011.

Table 2. Total Phosphorus Monthly Average Concentrations in the Upper Basin at CCAS59/CC60

Month	2011 Average TP (µg/L)	2006-2011 TP (µg/L)	% Change in 2011
February	10.8	12.3	-12%
April	10.2	20.6	-50%
May	39.1	25.0	56%
June	37.0	20.3	82%
July	14.6	11.3	29%
August	9.2	9.9	-7%
September	11.7	8.2	42%
October	11.0	8.9	22%
December	5.1	11.2	-54%

The 2011 TP load in the Upper Basin at CCAS59/CC60, shown in Figure 22, was double the average load for 2006-2010. This is likely due to the high discharge seen in 2011 and the correspondingly high TSS load. As demonstrated by the volume-weighted concentration, shown in Figure 23, 2011 exhibited a 45% increase in average volume-weighted phosphorus concentration at CC59/60, as compared to the average for 2006-2010, and a 6% increase from 2010 concentrations. Both the load and volume-weighted concentrations for TP show more than a 30% increase (52% for TP loading and 32% for volume-weighted concentration) between CC26 and CC60, indicating increased concentration loads coming into Clear Creek between these two locations. This pattern also matches the general pattern observed for TSS.

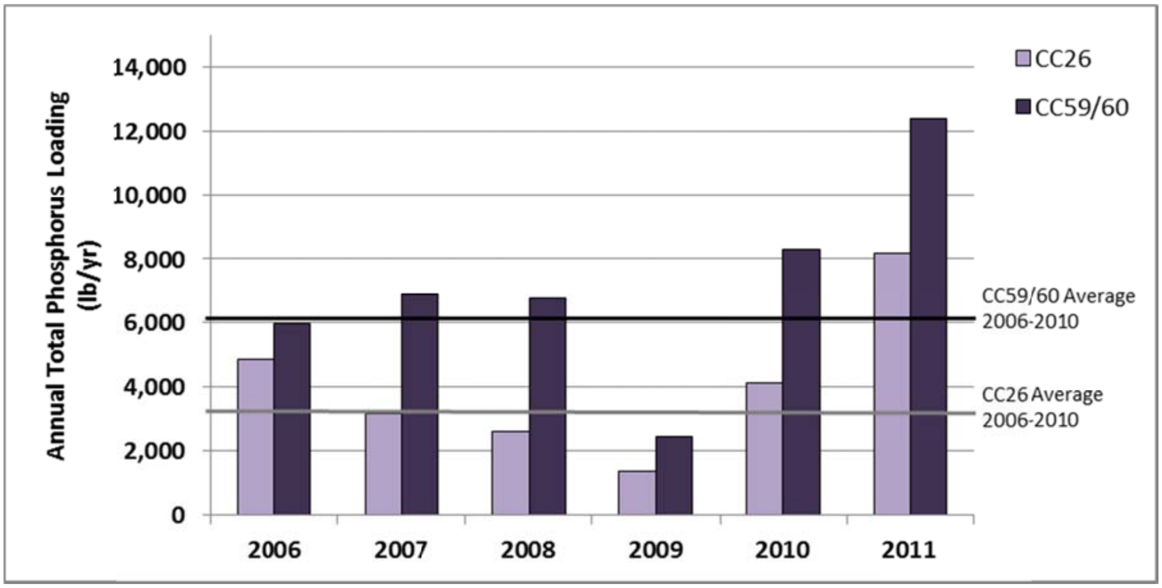


Figure 22. Annual Loads for Total Phosphorus in the Upper Basin, using Grab Samples and 24-Hour Ambient Autosampler Data, 2006-2011

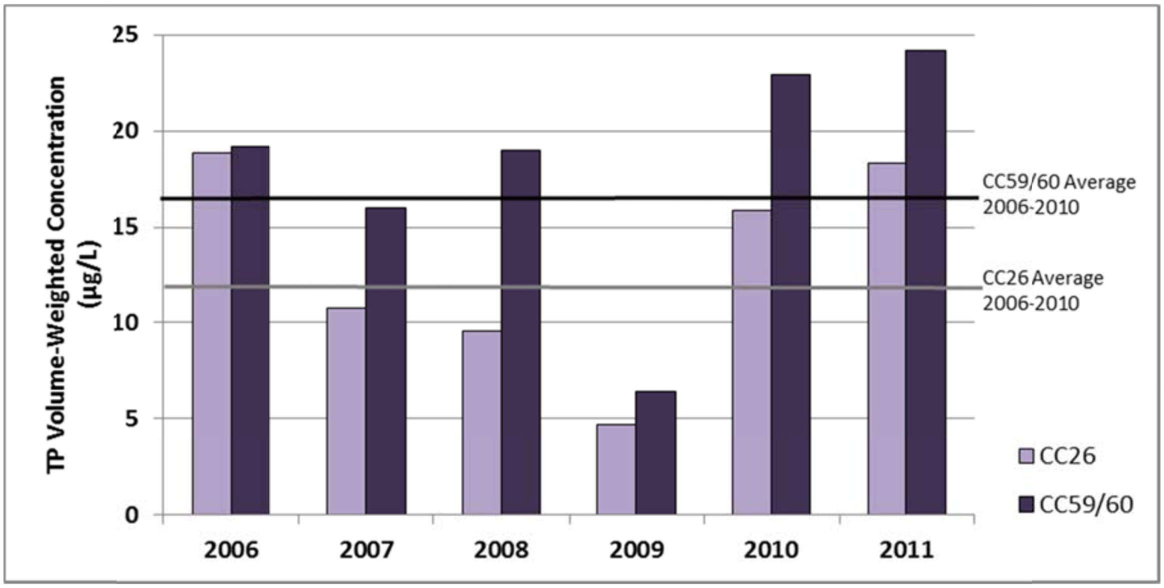


Figure 23. Volume-Weighted Concentration for Total Phosphorus in the Upper Basin, using Grab Samples and 24-Hour Ambient Autosampler Data, 2006-2011

Total Nitrogen

TN concentrations in the Upper Basin for 2011 are presented in Figure 24. The time-series presents the combined ambient sampling dataset (grab samples and 24-hour composite autosamples). The monitoring program has moved increasingly toward using autosamplers in recent years, especially in the summer months. As seen in Figure 24, concentrations were higher in the winter and lower in the summer months, with the lowest concentration samples collected July 24.

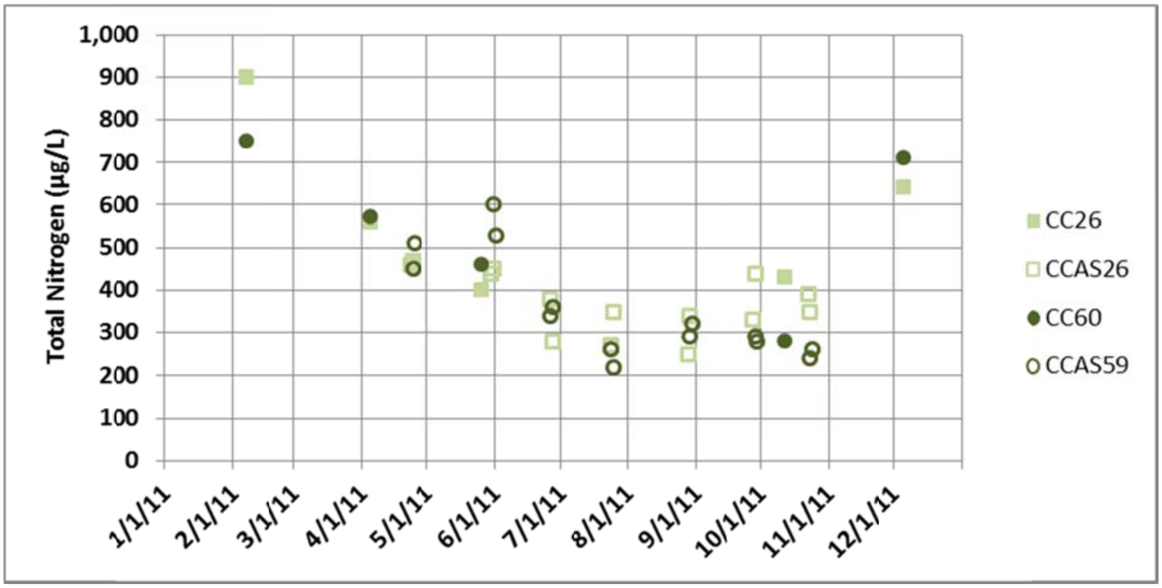


Figure 24. 2011 Total Nitrogen Concentrations in the Upper Basin as Measured by Grab Samples and 24-Hour Composite Autosampler Data

TN concentrations for 2011 in the Upper Basin followed a consistent pattern, as compared with previous years. The 2006-2011 time-series, presented in Figure 25, clearly shows the repeated annual pattern of higher concentrations in the winter and lower concentrations in the summer. The higher winter concentrations correspond to times of minimal runoff, and greater proportions of base flow, WWTP discharge, and possibly greater onsite wastewater treatment system influence.

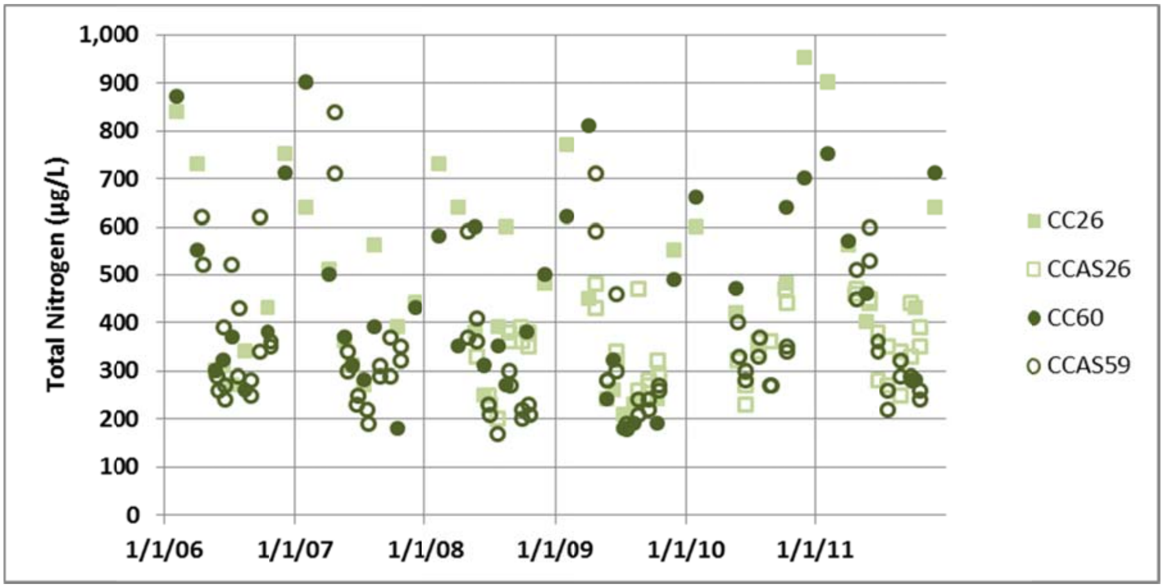


Figure 25. Total Nitrogen Concentrations in the Upper Basin as Measured by Grab Samples and 24-Hour Composite Autosampler Data, 2006-2011

Table 3 provides a comparison of monthly average TN concentrations in 2011 at CCAS59 and CC60 with monthly average concentrations for 2006-2010. From this table, it is apparent that the differences were greatest in May and June. 2011 saw notably higher concentrations in May and June (43% and 36% higher, respectively) relative to the 2006-2010 average monthly concentrations. This may be related to the delayed timing of the runoff peak and corresponding annual snowmelt water quality. Overall, however, the annual volume-weighted average concentrations of TN were similar to previous years, as discussed below.

Table 3. Total Nitrogen Monthly Average Concentrations in the Upper Basin at CCAS59/CC60

Month	2011 TN (µg/L)	2006-2010 Average TN (µg/L)	% Change in 2011
February	750	726	3%
April	525	572	-8%
May	530	371	43%
June	410	301	36%
July	240	285	-16%
August	305	273	-12%
September	285	313	-9%
October	265	329	-19%
December	710	566	25%

TN loading in the Upper Basin was 46% higher in 2011 than the average annual TN loading for 2006-2010 (Figure 26). This is largely attributable to the higher discharge rates tied to greater snowpack (28% higher runoff volume in 2011). This loading pattern is apparent at both CC26 and CC60.

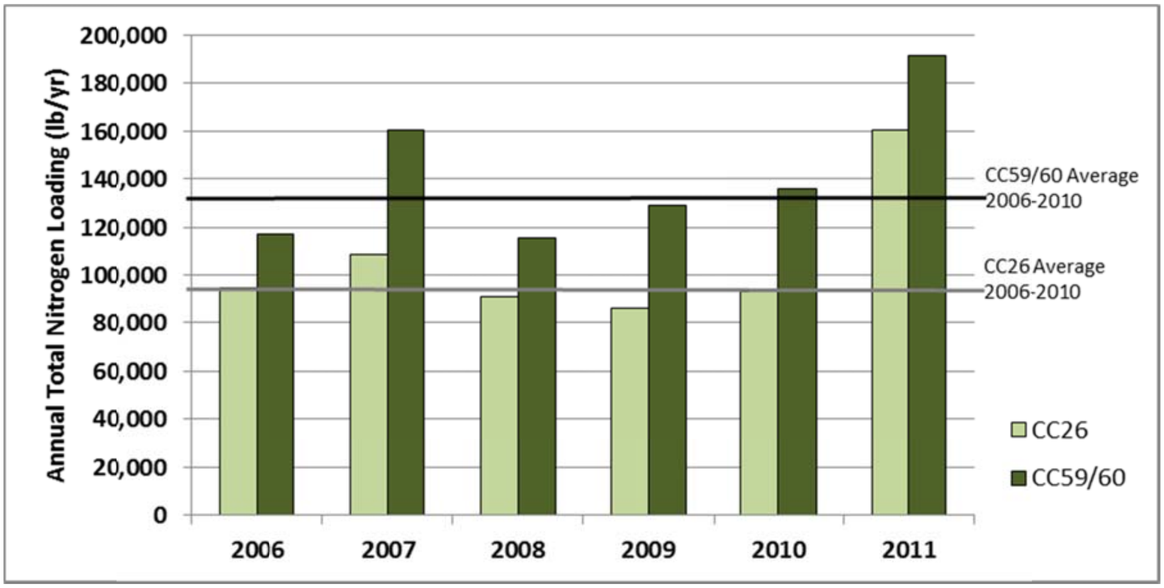


Figure 26. Annual Total Nitrogen Loading in the Upper Basin, using Grab Samples and 24-Hour Ambient Autosampler Data, 2006-2011

As depicted in Figure 27, the volume-weighted concentrations of TN in the Upper Basin were comparable to (5% higher than) the average concentrations of 2006-2010. Further, volume-weighted concentrations at CC26 were only slightly lower than those at CC60. This is different than that observed for TSS and TP, where the load observed at CC60 was significantly higher than at CC26.

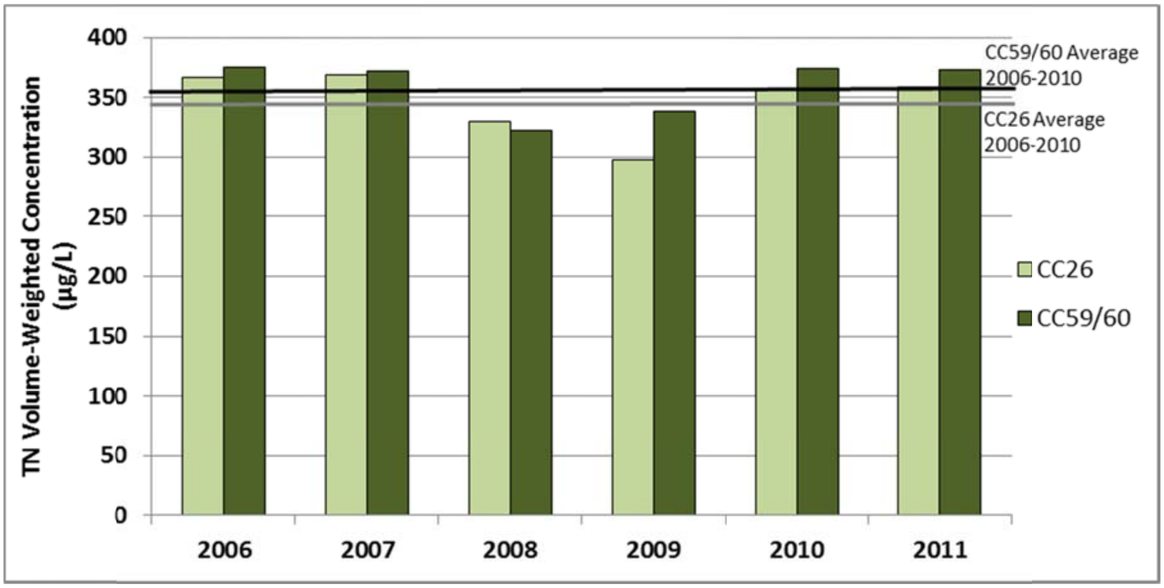


Figure 27. Volume-Weighted Concentration for Total Nitrogen in the Upper Basin, using Grab Samples and 24-Hour Ambient Autosampler Data, 2006-2011

Effects of Storm Events on Loading

An analysis was conducted to look at the relative importance of stormwater events on nutrient and TSS loading at key locations in Clear Creek. Loading calculations presented above and presented in previous annual reports focus on ambient conditions. Storm events are not included in these data, and therefore are not considered in these annual loading estimates. In 2011, one storm event was collected at CCAS59 on 9/7/11. On that date, TSS concentrations were 134 mg/L, and TP and TN concentrations were 92 and 1,800 µg/L, respectively. Loads for the month of September were calculated with and without this event, assuming the storm sample represents a 24-hour storm event response. Figure 28 shows the difference in estimated monthly loading at CCAS59/CC60 with and without inclusion of this event for the month of September for TN, TP, and TSS.

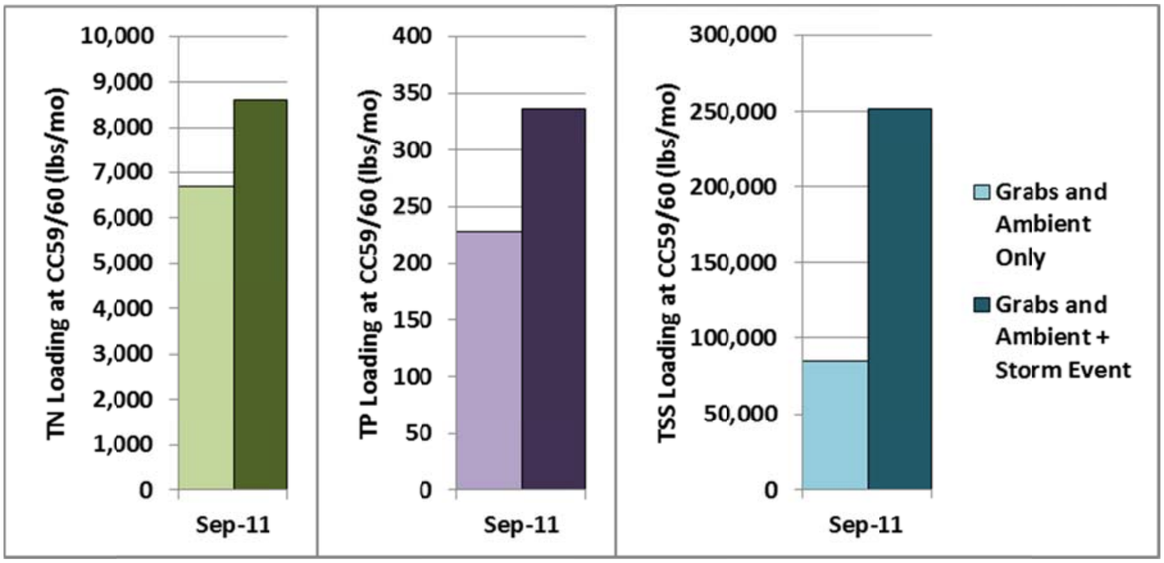


Figure 28. Total Nitrogen, Total Phosphorus, and Total Suspended Solids Loading in September 2011, with and without the 9/7/11 Event

Storm events can significantly increase the total loading calculations. This finding agrees with the findings of Clear Creek Consultants in a study based on CCAS59 (funded by the City of Golden, noted in Section III). A comparison of nutrient loading with and without available storm event data is presented in Figure 29 for TN, TP, and TSS in 2010. The year 2010 is presented because it is the year with the greatest number of storm events sampled (6 events)[1]. Storm event concentrations were assumed in each case to represent concentrations for the full day of the sampling date. Annual loads increase for TN, TP, and TSS, with the largest increases shown for TP and TSS.

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[1] Zero storm events were collected in 2006; 1 event was collected in 2007; 5 events were collected in 2008; 5 events were collected in 2009; 6 events were collected in 2010; and one event was collected in 2011.

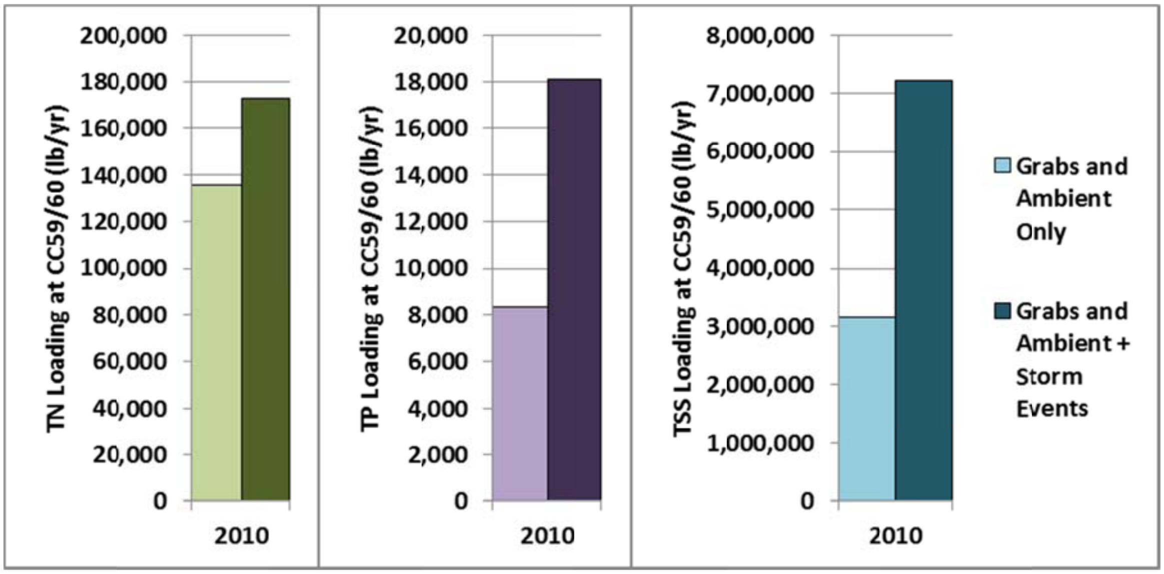

Figure 29. Total Nitrogen, Total Phosphorus, and Total Suspended Solids Loading in the Upper Basin (CCAS59/CC60), with and without Storm Events, 2010

V. Standley Lake Inflow, Outflow, and Volume

The previous section examined water-quality data in the Upper Basin. This section will describe inflow into the lake from the Canal Zone, outflows from the lake, and lake contents. Inflow to Standley Lake comes through four managed sources: Church Ditch, Croke Canal, and FHL Canal, as shown previously in Figure 5, and through the Kinnear Ditch Pipeline (KDPL). Figure 30 presents hydrographs for each of these sources in 2011, indicating delivery periods. The Croke Canal generally delivers water to the lake in the November to April timeframe. In 2011, an additional 4,490 AF were delivered to the lake in June.

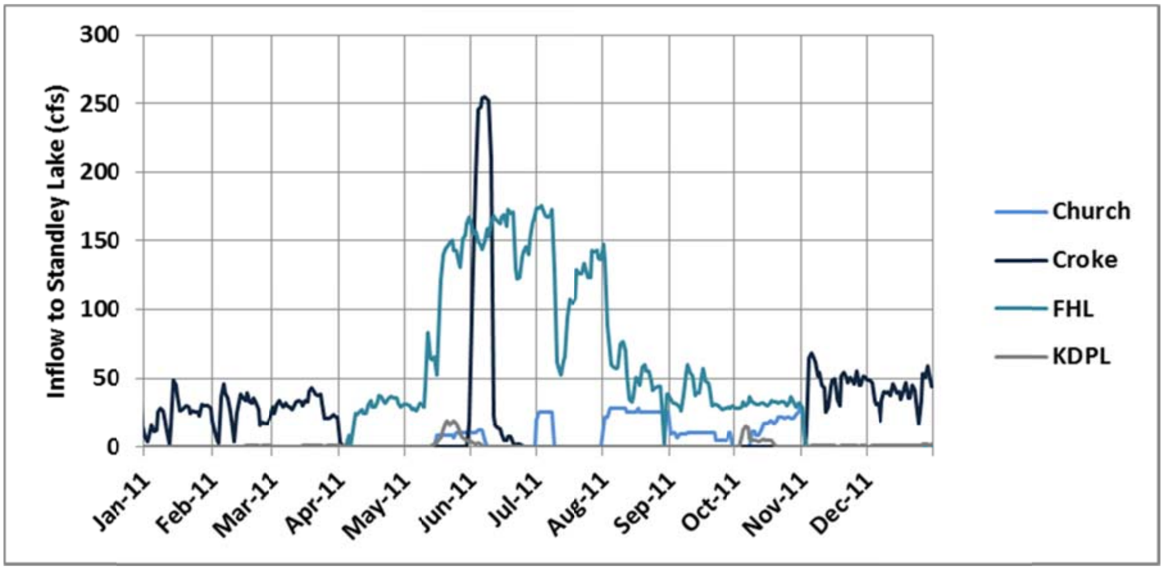

Figure 30. Inflow Hydrograph into Standley Lake, 2011

Figure 31 presents the total annual inflow volumes from each source into the lake for 2006-2011, and Figure 32 presents the total inflow and outflow volumes. The total inflow in 2011 was 27% higher than the 2006-2010 average. Of the total 2011 inflow, 63% came through FHL.

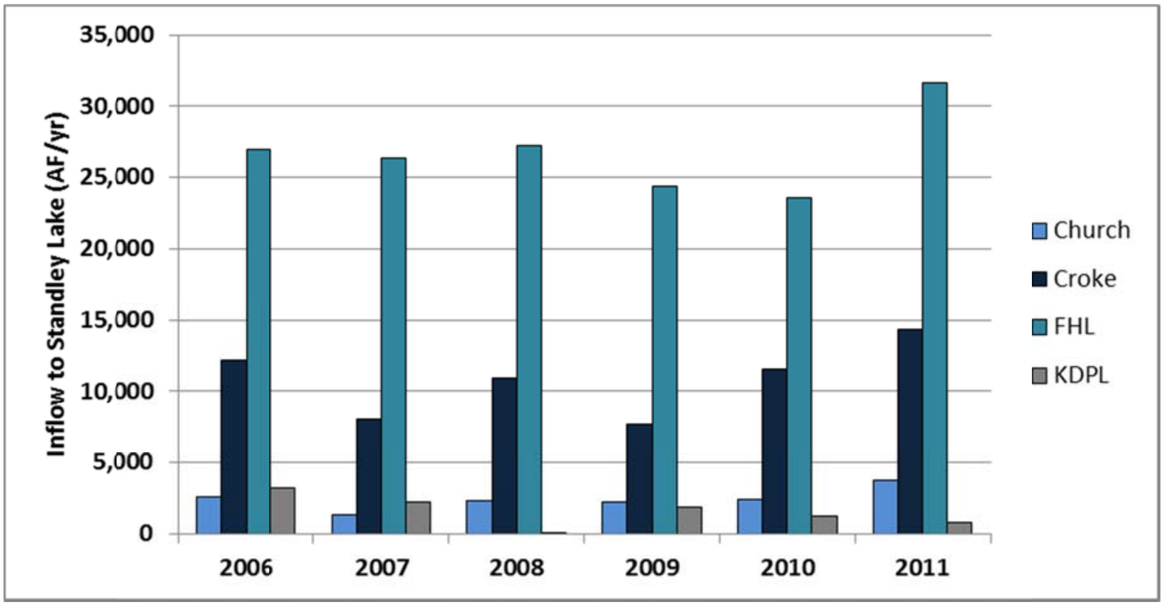

Figure 31. Annual Inflow to Standley Lake by Source, 2006-2011

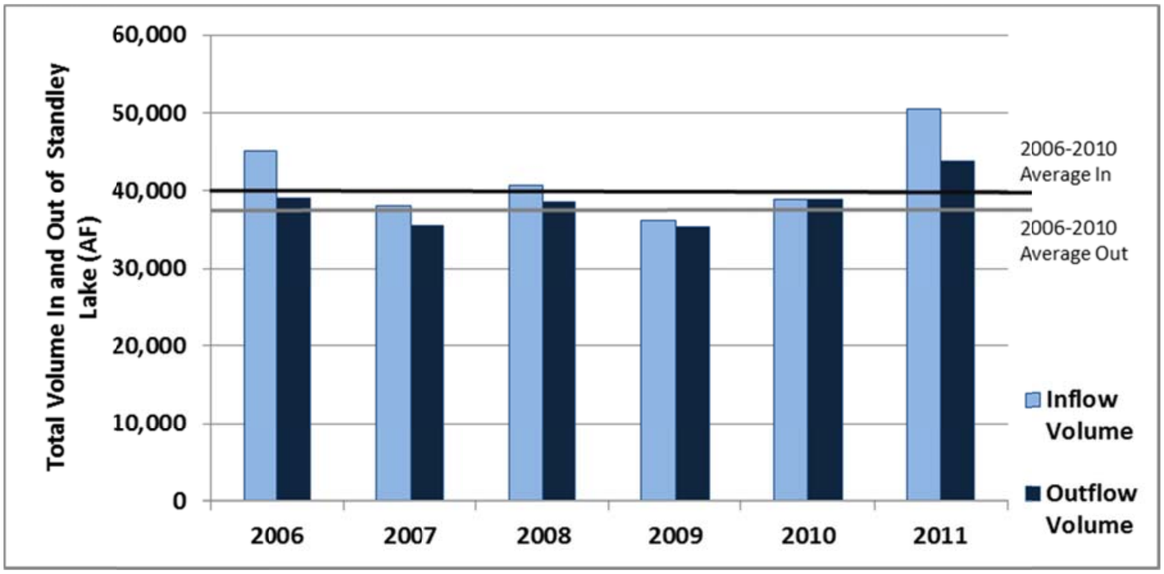

Figure 32. Total Annual Inflow and Outflow Volumes for Standley Lake, 2006-2011

The volume of Standley Lake for 2011 and previous years is presented in Figure 33, as calculated from gage height measurements and elevation-area-volume data. Reflecting operations and the heavy snowpack of the preceding winter, the lake quickly filled in spring 2011. In 2011, the lake went from 76% full to 98% full in 33 days. The maximum capacity was reached in mid-June 2011, later by approximately one month than the fill date for 2009 and 2010, when the lake reached capacity in mid-May. The average lake volume in 2011 was 5% lower than the annual 2006-2010 average.

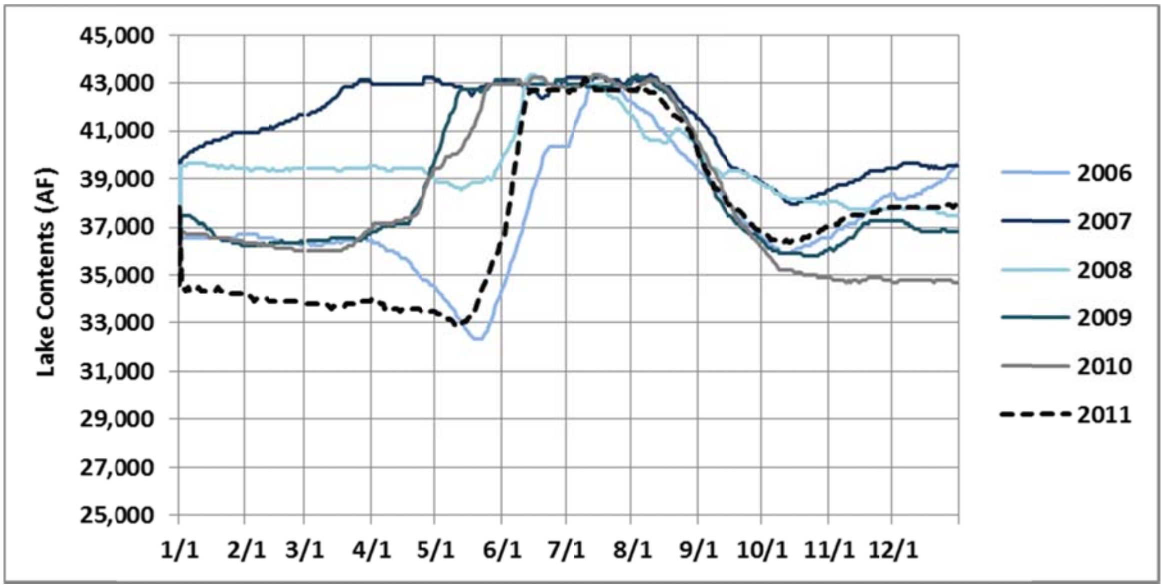

Figure 33. Standley Lake Contents, 2006-2011

VI. Loading Into and Out of Standley Lake

Water quality in the Upper Basin for 2011 is analyzed and discussed in Section IV, and lake inflows, outflows, and contents are presented in Section V. This section describes TSS, TP, and TN loading into and out of the lake.

Total Suspended Solids

Total suspended solids loading into Standley Lake is shown in Figure 34 for each inflow structure. The overall TSS loading (from all sources combined), as shown in Figure 35, was 92% higher than the 2006-2010 average. This increase was greatest for FHL and Croke, responsible for 65% and 32% of the 2011 loading, respectively. FHL is typically operated in the summer and Croke also delivered water in June 2011. This is the period when the exceptionally high runoff and higher TSS concentrations of 2011 occurred in the Upper Basin.

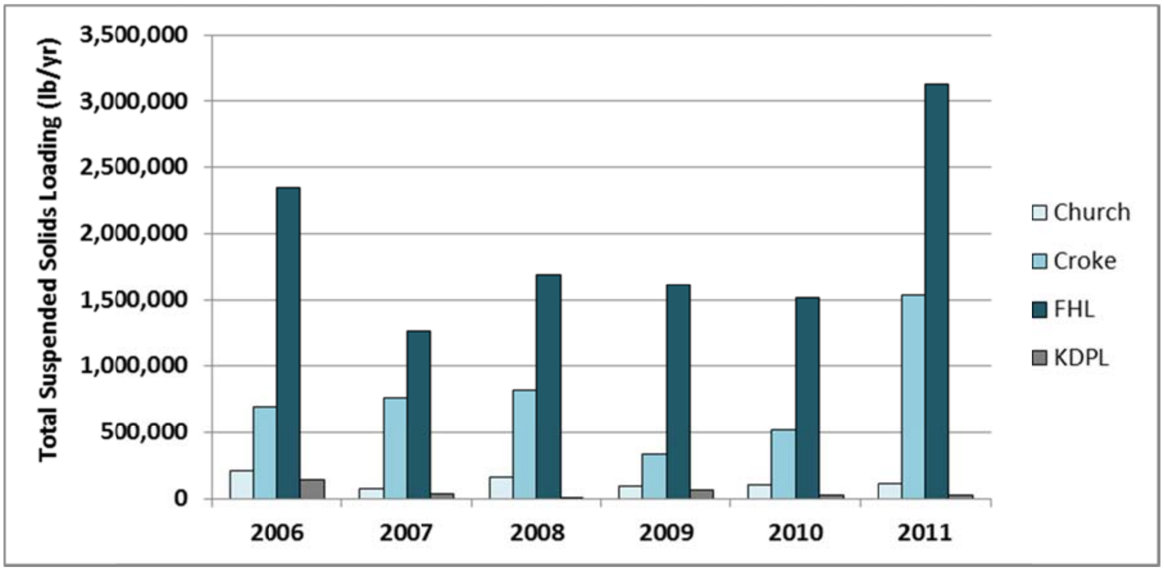

Figure 34. Annual Loading of Total Suspended Solids into Standley Lake by Source, using Grab Samples and 24-Hour Ambient Autosampler Data, 2006-2011

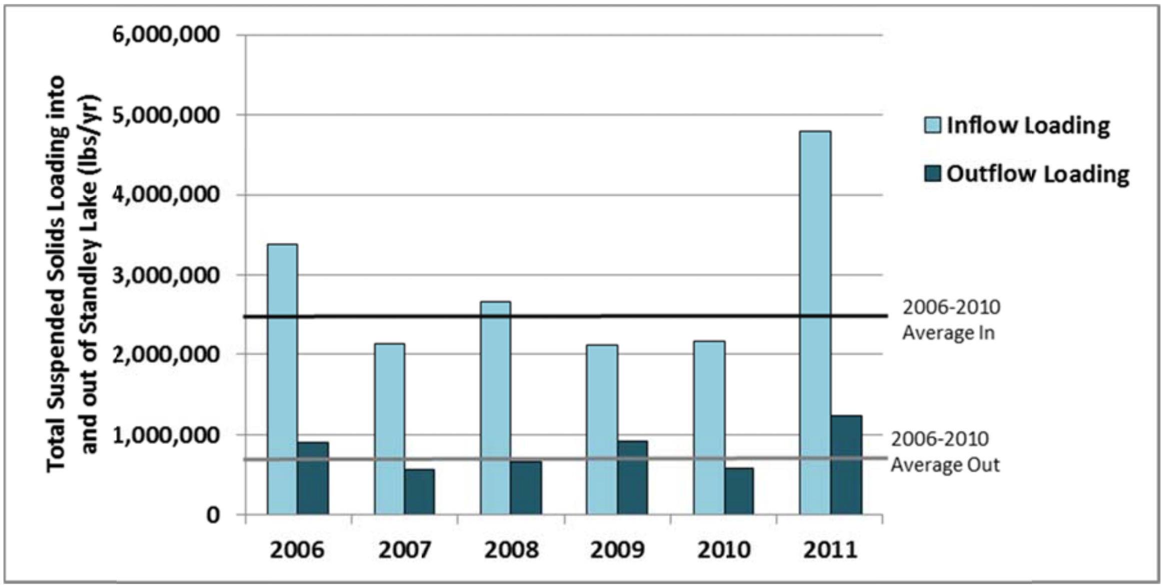

Figure 35. Total Suspended Solids Loading into and out of Standley Lake, using Grab Samples and 24-Hour Ambient Autosampler Data, 2006-2011

In addition to an increase in TSS loading to the lake, there was an increase in the volume-weighted average TSS concentration into the lake of 24% in 2011 over the 2006-2011 average (Figure 36). This is likely attributable to the timing of canal operations (FHL and Croke) relative to the period of higher TSS concentrations in the Upper Basin. As discussed in Section IV, the Upper Basin also experienced increased volume-weighted TSS concentrations in 2011.

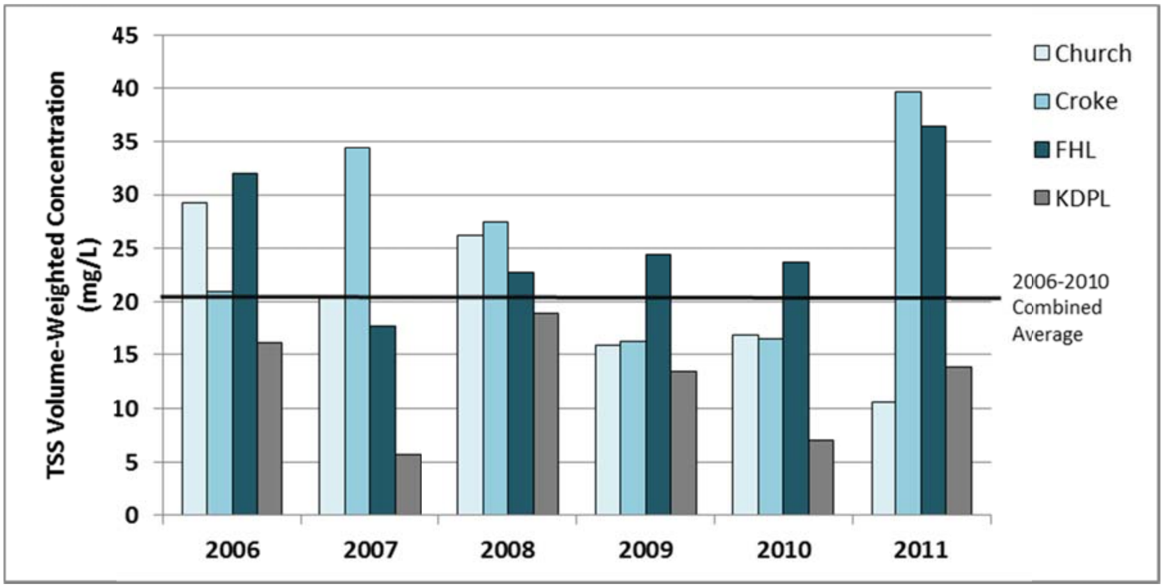

Figure 36. Volume-Weighted Concentrations for Total Suspended Solids into Standley Lake, using Grab Samples and 24-Hour Ambient Autosampler Data, 2006-2011

Total Phosphorus

The 2011 TP load into Standley Lake is pictured for each source in Figure 37. Figure 38 presents the total TP loading into and out of Standley Lake for 2006-2011. TP loading into the lake was 47% greater in 2011 than the 2006-2010 average. With more frequent and extensive use than the other canals during the spring and summer months of high runoff (when TP concentrations are higher in the Upper Basin), FHL contributed 62% of the 2011 TP loading.

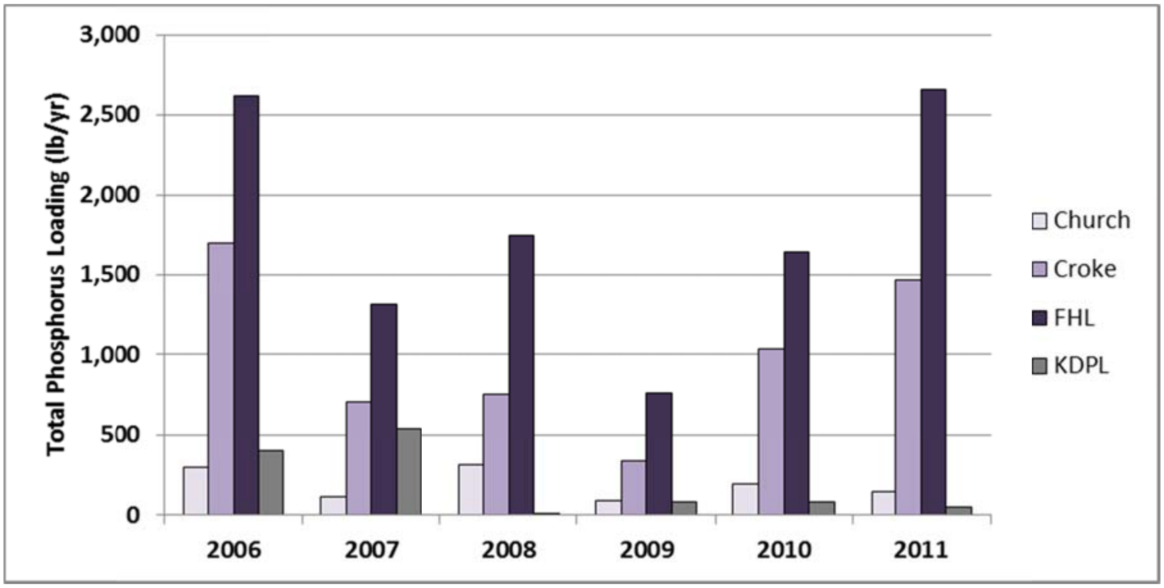

Figure 37. Total Phosphorus Loading into Standley Lake by Canal, using Grab Samples and 24-Hour Ambient Autosampler Data, 2006-2011

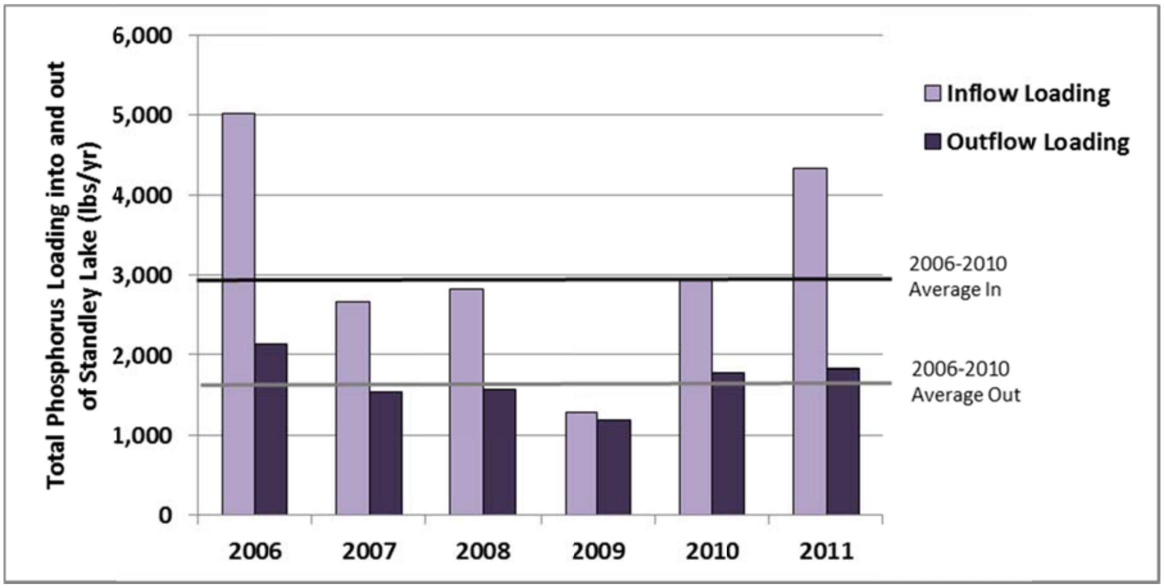

Figure 38. Total Phosphorus Loading into and out of Standley Lake, using Grab Samples and 24-Hour Ambient Autosampler Data, 2006-2011

Although the TP loading in 2011 was 47% greater than the 2006-2010 average, the volume-weighted concentration, as seen in Figure 39, was actually 15% lower in 2011 than the average concentration of previous years' inflows.

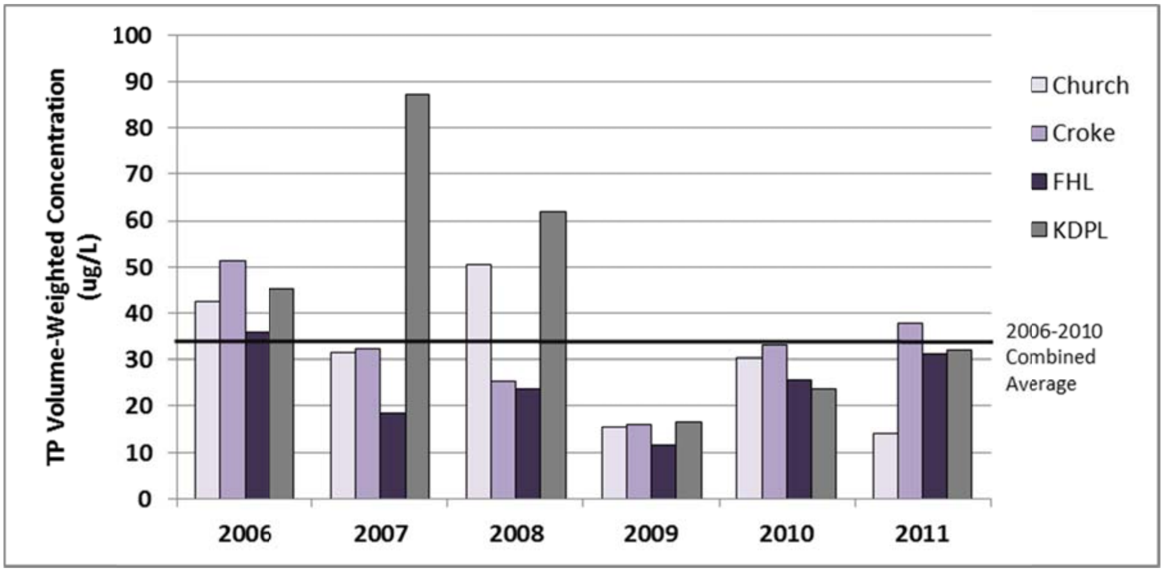

Figure 39. Total Phosphorus Volume-Weighted Concentration into Standley Lake, using Grab Samples and 24-Hour Ambient Autosampler Data, 2006-2011

Total Nitrogen

Total nitrogen loading for 2006-2011 is shown in Figure 40 for each of the four canals, incorporating grab sample data and ambient autosampler data collected at the canal headgates. Figure 41 presents the combined TN loading into and out of Standley Lake for 2006-2011. TN loading was 31% higher in 2011 than the 2006-2010 average, with FHL contributing 55% of the 2011 load. Relative canal loading patterns in 2011 were similar to previous years, showing the most through FHL, followed by the Croke, Church, and KDPL.

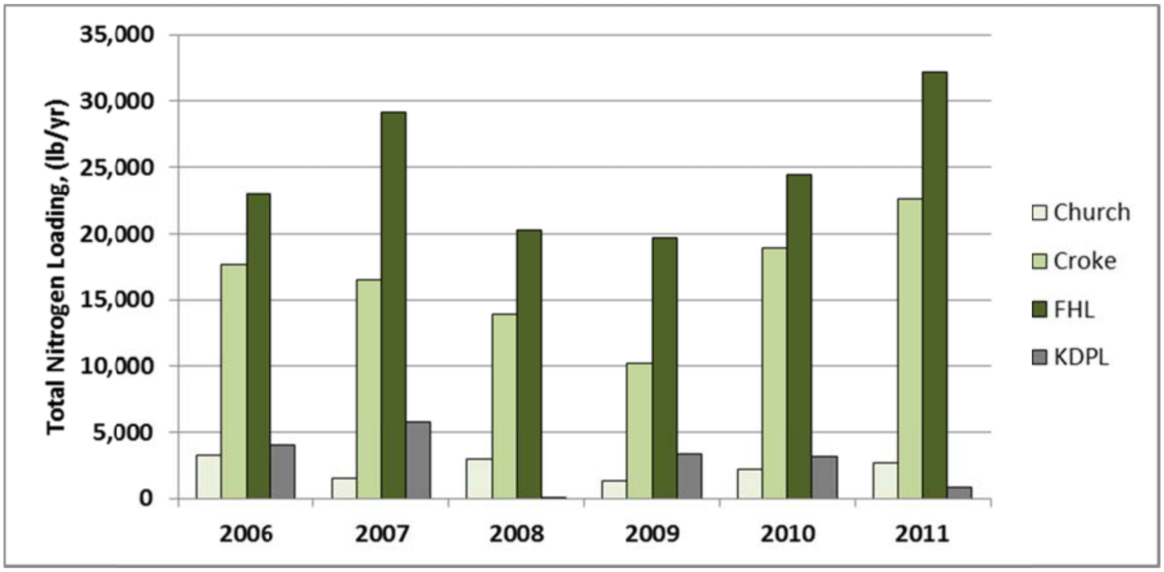

Figure 40. Total Nitrogen Loading into Standley Lake by Canal, using Grab Samples and 24-Hour Ambient Autosampler Data, 2006-2011

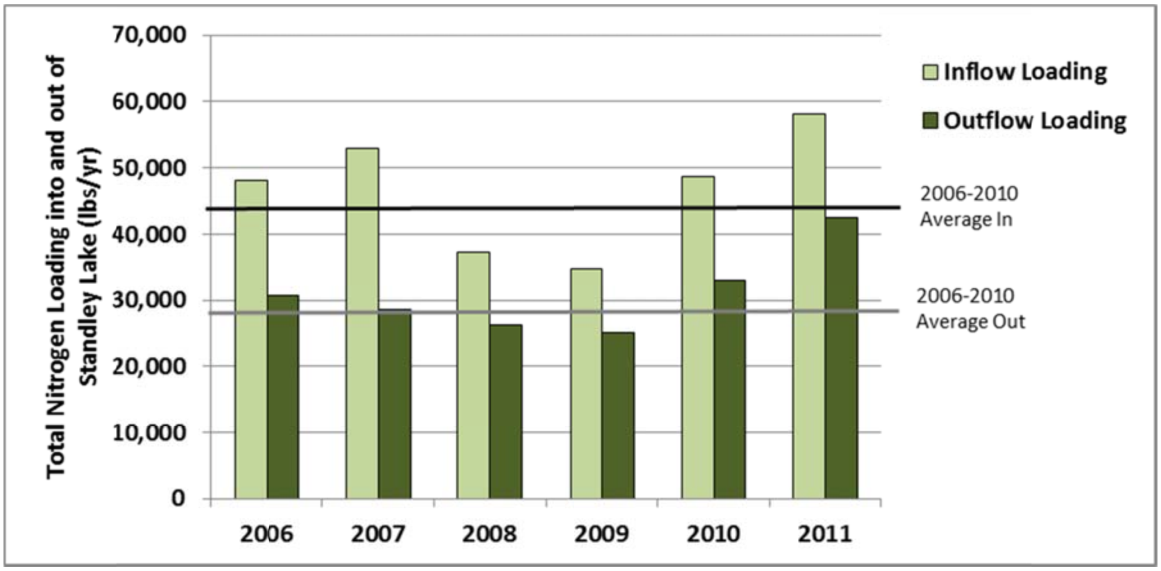

Figure 41. Total Nitrogen Loading into and out of Standley Lake, using Grab Samples and 24-Hour Ambient Autosampler Data, 2006-2011

Although TN loading into Standley Lake was 31% higher in 2011 than in previous years, the volume-weighted TN concentration (Figure 42) reflected a 14% decrease from the average concentration over

2006-2010. This indicates that the increased loading is associated largely with the increased volume of water moved through the canals (27% higher than the 2006-2010 average).

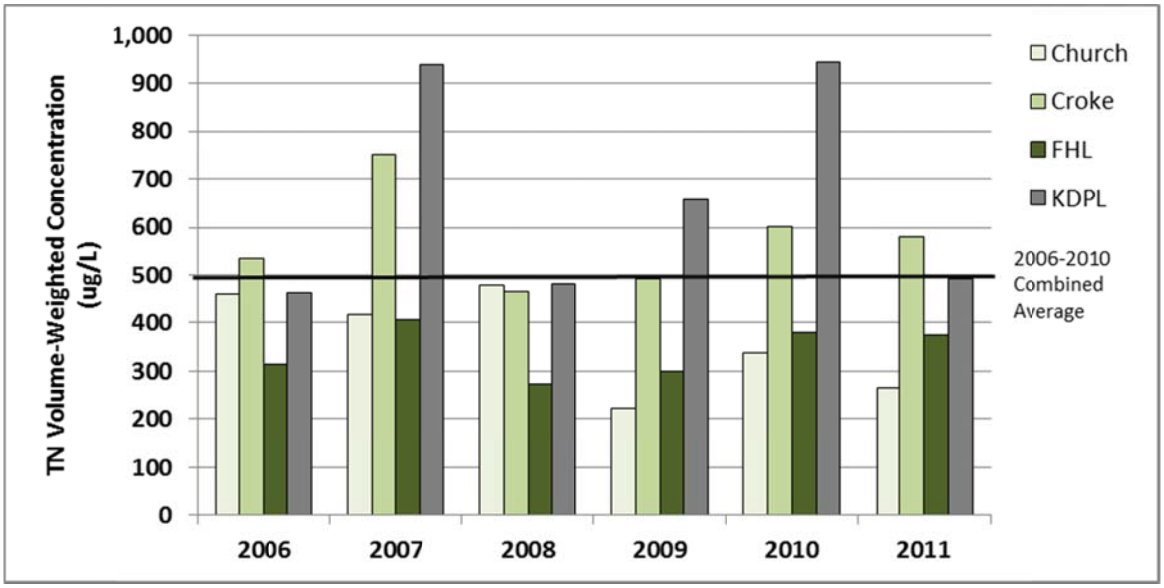

Figure 42. Total Nitrogen Volume-Weighted Concentration, using Grab Samples and 24-Hour Ambient Autosampler Data, 2006-2011

Effects of Storm Events on Nutrient Loading

Nutrient and TSS loads, presented above, were calculated using concentrations from grab sample data and ambient autosampler data at each of the inflows to Standley Lake. Daily concentrations were filled using a mid-point step function between the available sample data. A total of 320 grab samples and 87 ambient autosamples from the individual inflows were considered in 2011. Although the monitoring program collects some storm event samples, these events were not used in calculating nutrient loading. To evaluate the effect of storm events on loading, TN, TP, and TSS loads from FHL for 2011 were calculated with and without storm events included. Storm event samples were assumed to represent conditions for a 24-hour period. Figure 43 shows the TN, TP and TSS loadings from FHL in 2011 with and without storm events considered. Data were collected for 9 storm events at FHL in 2011. As seen from similar analysis conducted for the Upper Basin (Section IV), storm events can have a measurable impact on loading estimates into the reservoir.

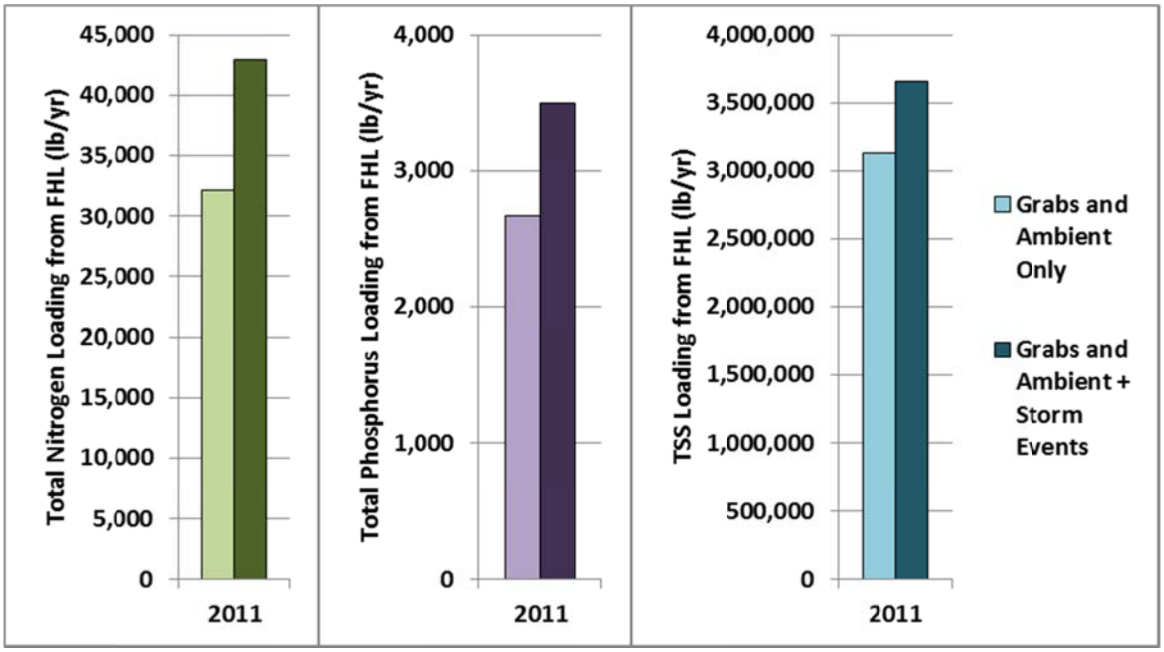

Figure 43. Total Nitrogen, Total Phosphorus, and Total Suspended Solids Loading from Farmers' High Line Canal into Standley Lake, with and without Storm Events

VII. Standley Lake Water Quality

Total Suspended Solids

Total suspended solids concentrations are shown in Figure 44, as measured by grab samples near the top and bottom of the lake for March through November 2011. The photic zone and hypolimnetic solids concentrations were similar through the early part of the year, diverging from June through September as the lake stratified. The average TSS concentrations were 78% and 20% higher, respectively, in the photic zone and in the hypolimnion, as compared to the 2006-2010 averages (Figure 45). As discussed in Section IV, average TSS concentrations were higher in the Upper Basin in 2011 than in previous years for May and June, which was also reflected in the inflow TSS concentrations from the Canal Zone. This increase may be a result of the high runoff and corresponding increased flow in Clear Creek.

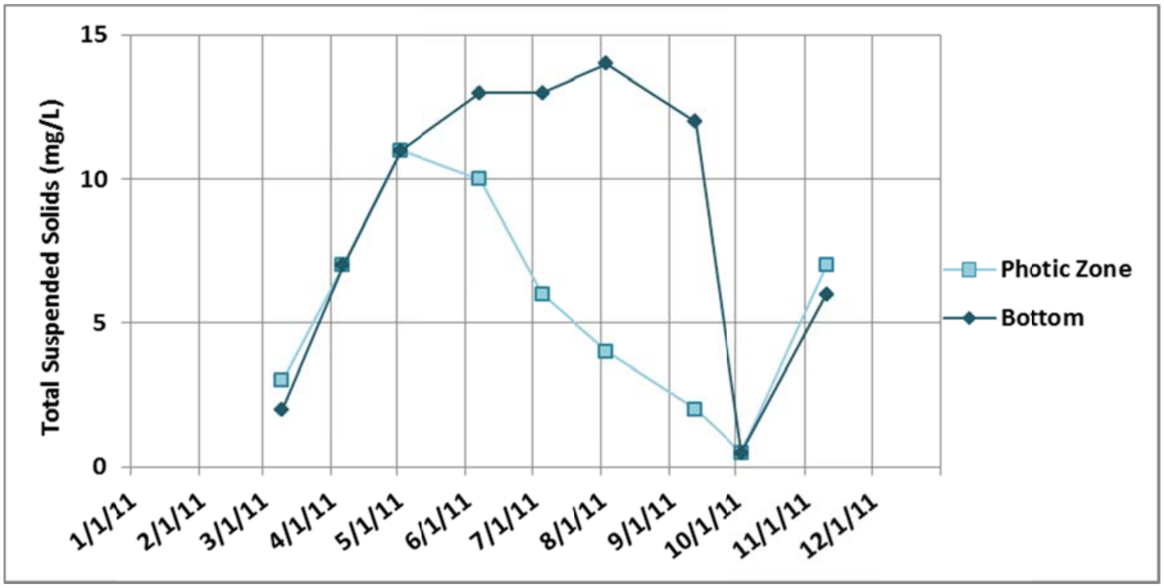

Figure 44. Total Suspended Solids Concentrations near the Top and Bottom of Standley Lake, March-November 2011

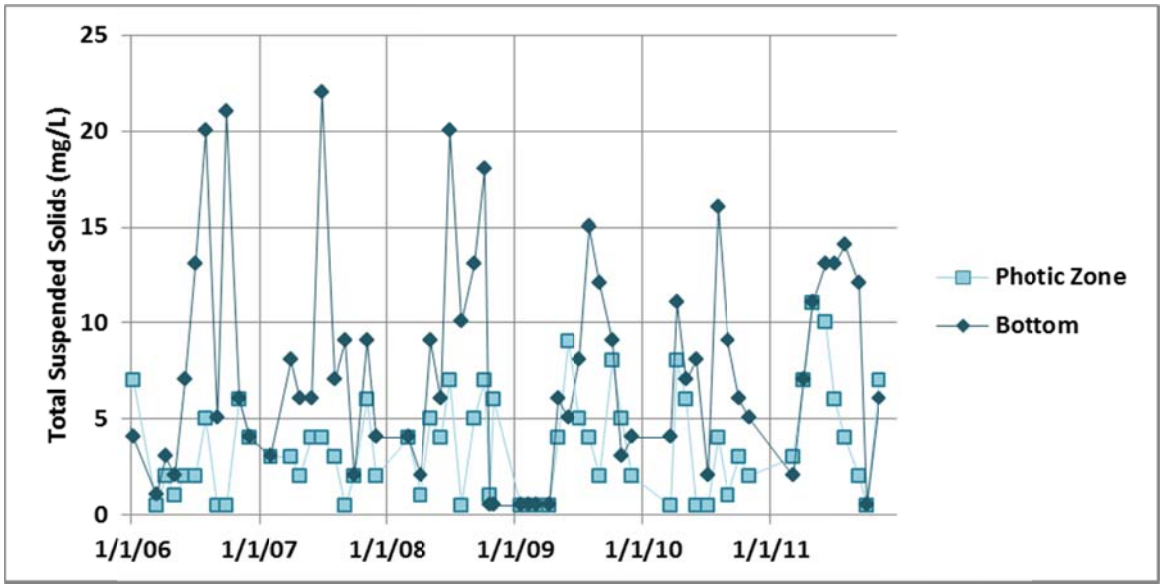

Figure 45. Total Suspended Solids Concentrations near the Top and Bottom of Standley Lake, 2006-2011

Total Phosphorus

Total phosphorus concentrations near the top (in the photic zone) and near the bottom of the lake are shown in Figure 46 for March through November 2011. TP concentrations near the top varied slightly but remained relatively constant throughout the season. At the bottom of the reservoir, the effects of decreasing DO in the hypolimnion during stratification are apparent in release of ortho-phosphorus, initiating with low dissolved oxygen conditions as early as July and peaking in September, before falling again in October with turnover. When compared with previous years, as shown in Figure 47 this pattern and concentration range in the lake are fairly typical of what has been observed in the photic zone and hypolimnion over the previous years. Overall, the average 2011 TP concentration was 14% lower in the photic zone, and 9% higher in the hypolimnion, as compared to the 2006-2010 averages.

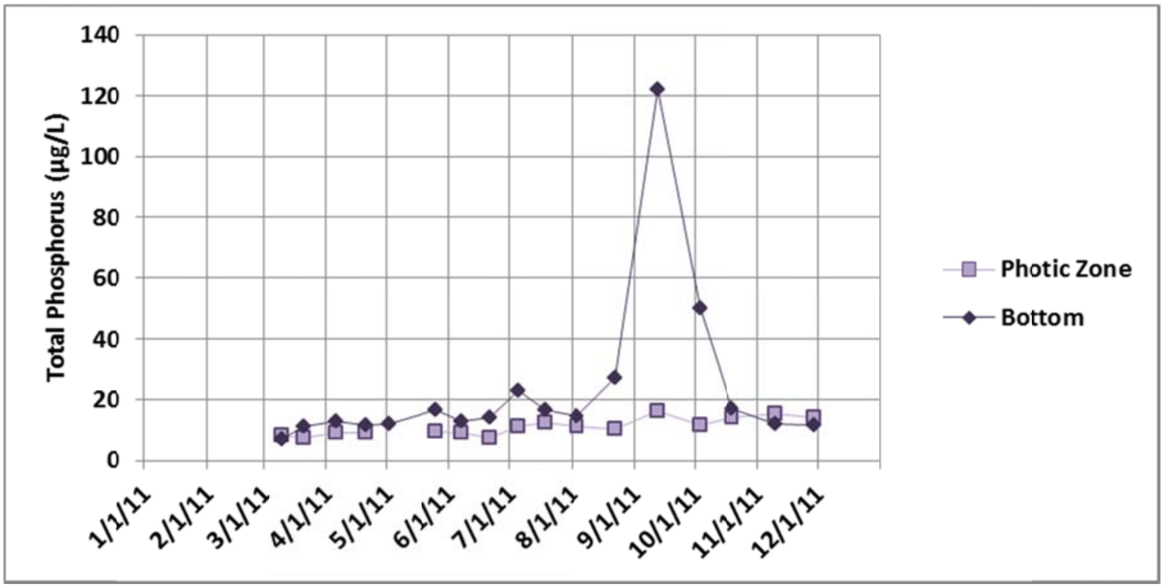

Figure 46. Total Phosphorus Concentrations in the Photic Zone and Bottom of Standley Lake, March-November 2011

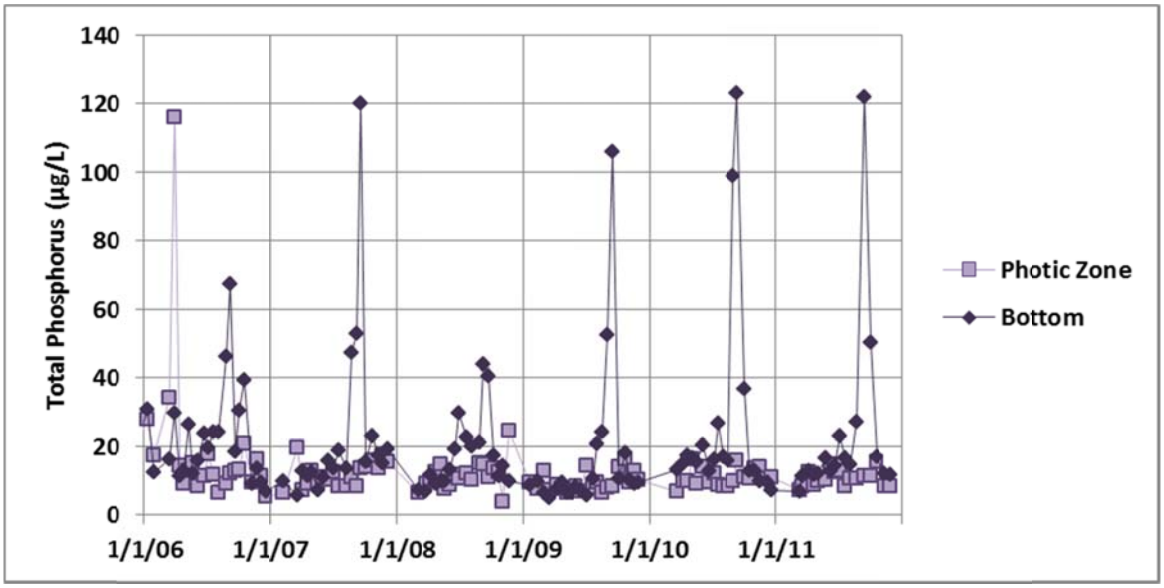

Figure 47. Total Phosphorus Concentrations in the Photic Zone and Bottom of Standley Lake, 2006-2011

Total Nitrogen

TN concentrations for 2011 in the lake are presented in Figure 48, as measured by grab samples taken near the top (in the photic zone) and near the bottom. The nitrogen content near the bottom increases through the summer, corresponding to sediment release of nutrients with the decrease in dissolved oxygen in the hypolimnion during stratification. In contrast, the concentrations near the top vary less and are consistently below the volume-weighted TN concentrations of the inflow (428 µg/L).

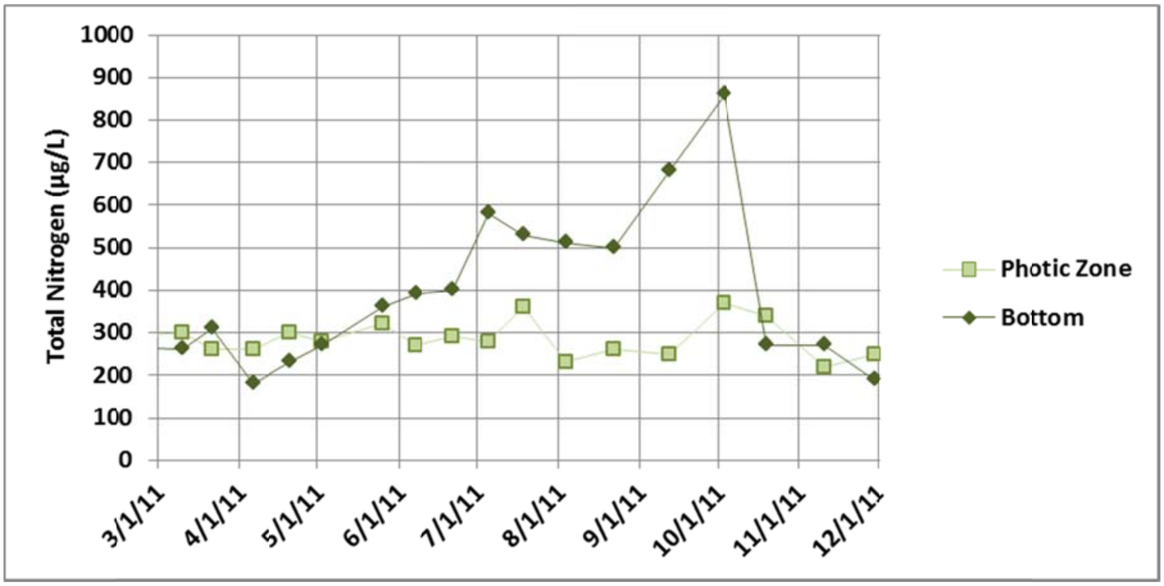

Figure 48. Total Nitrogen Concentrations in the Photic Zone and Hypolimnion of Standley Lake, March-November 2011

The average annual TN concentrations for 2011 were 285 µg/L and 399 µg/L, respectively, for the photic zone and hypolimnion. This was an increase of 43% in the photic zone and 27% in the hypolimnion from the 2006-2010 averages. Figure 49 presents TN concentrations in the lake for 2006-2011, clearly showing the higher 2011 TN concentrations, particularly in the photic zone. As presented in Section IV, the Upper Basin saw only a slight increase in average TN concentrations, but did experience high concentrations in the months of May and June with the runoff signal when high volumes of water were diverted from Clear Creek to Standley Lake. Total nitrogen loading into Standley Lake was highest in 2011, as compared to the previous five years.

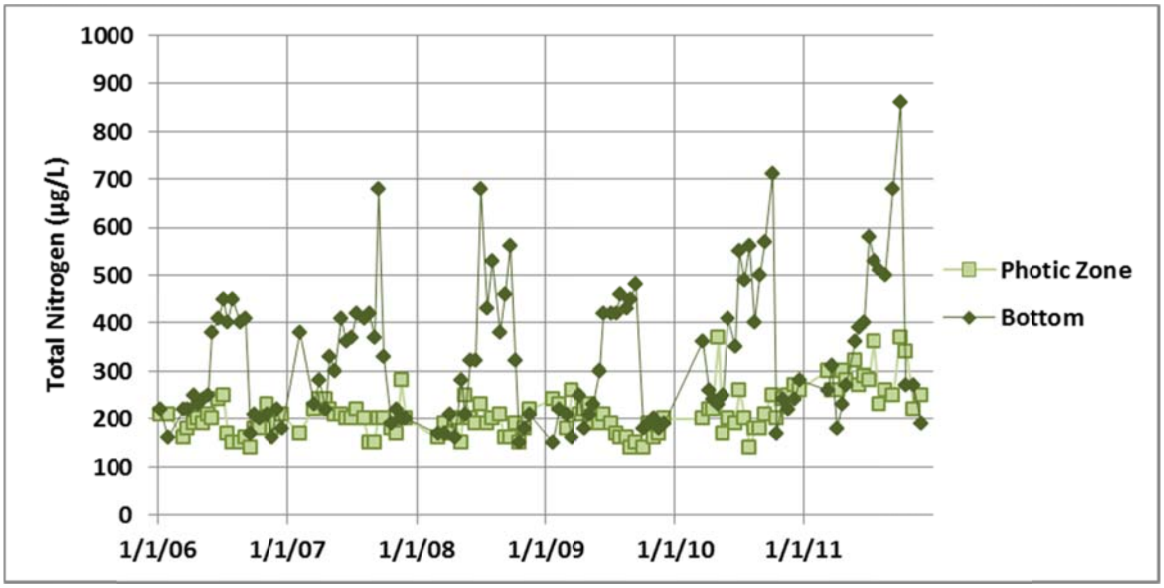

Figure 49. Total Nitrogen Concentrations in the Photic Zone and Hypolimnion of Standley Lake, 2006-2011

Chlorophyll *a*

Chlorophyll *a* concentrations for the period 2006-2011 are shown in Figure 50. The typical pattern of low chlorophyll *a* in the summer and higher measurements in the spring and late fall period was observed. Concentrations during the summer of 2011 were noticeably lower than in previous years although late year (October through December) concentrations were not as low as those measured in 2009. Food web dynamics, energized by an increased loading of carbon during this high runoff year, are a likely cause for this result. An isopleth for chlorophyll *a* is displayed in Figure 51. Low concentrations are evident throughout the entire depth of the reservoir until late September, when chlorophyll *a* exceeded 5 µg/L for a short period and then declined. The lake turned over on October 7, 2011, and chlorophyll *a* concentrations increased in response to mixing of the high nutrient concentrations at the bottom of the reservoir (Figure 45 and 47) with the epilimnion.

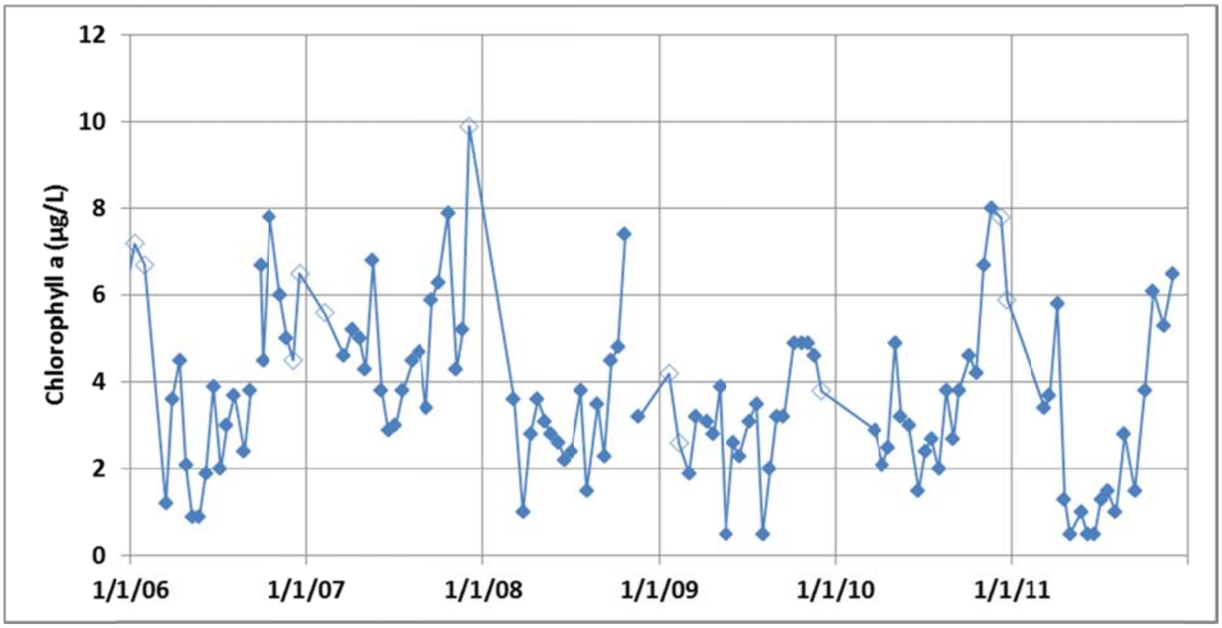

Figure 50. Chlorophyll *a* Concentrations in Standley Lake, 2006-2011.
Hollow symbols indicate chlorophyll *a* results collected in December, January, and February.

The chlorophyll *a* standard for Standley Lake was met in 2011 (Figure 52). The standard requires four out of five years having a nine-month average below 4.0 µg/L (for the five-year period of 2007-2011), based on grab samples taken in the lake. An assessment threshold of 4.4 µg/L is used, calculated using the annual arithmetic mean. The March-November average concentration for 2011 was 2.73 µg/L. This value is well below the standard and is the lowest observed average since 1999.

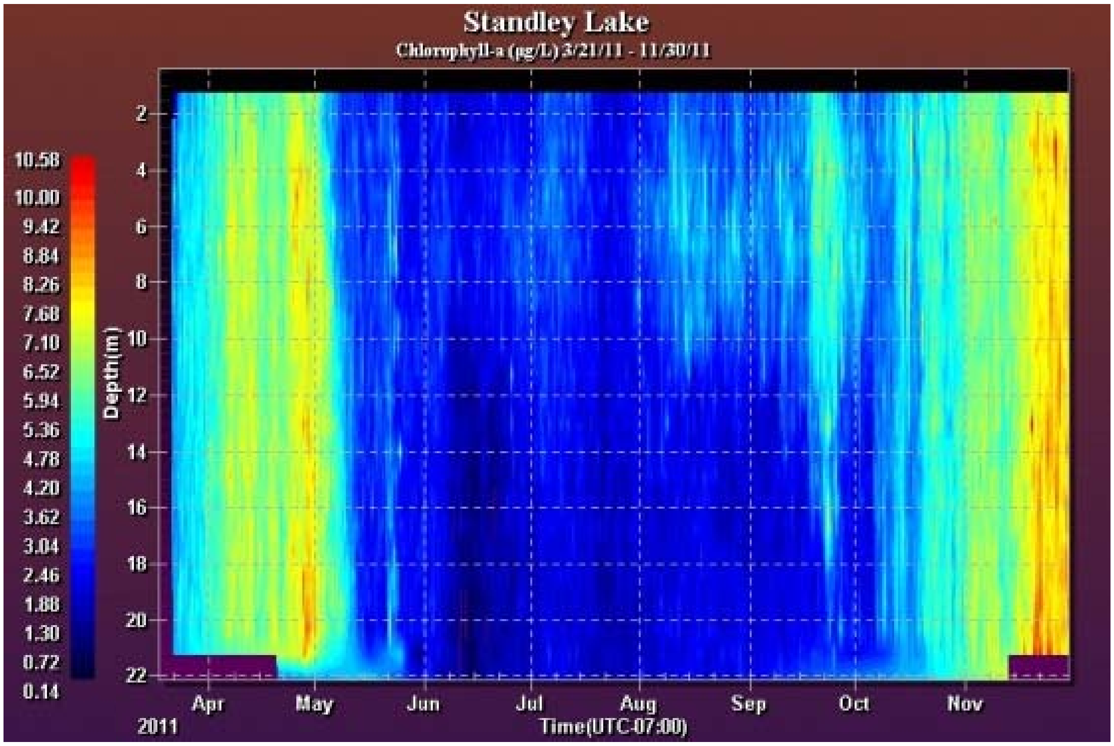

Figure 51. Isopleth of Chlorophyll *a* Concentrations in Standley Lake, 2011

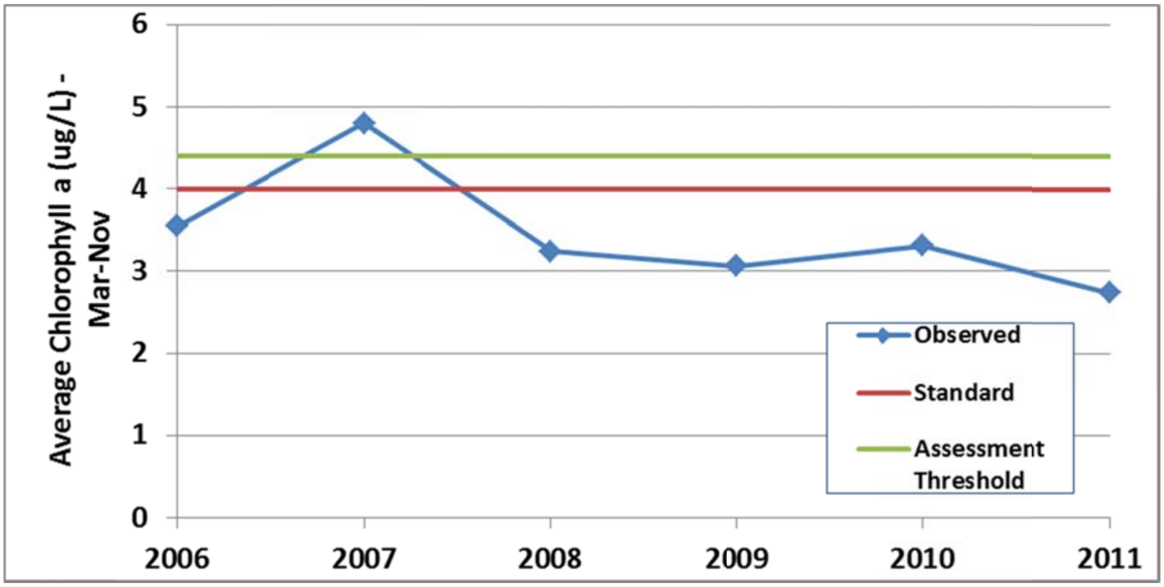

Figure 52. Observed Mean Chlorophyll *a* Concentrations (Mar-Nov) Compared with the Standard and the Assessment Threshold, 2006-2011

Figure 53 presents the seasonal pattern for total algae count and chlorophyll *a* concentrations in the lake. Both dropped through the summer months and peaked in November when nutrient concentrations generally increase following turnover, as is typical for Standley Lake.

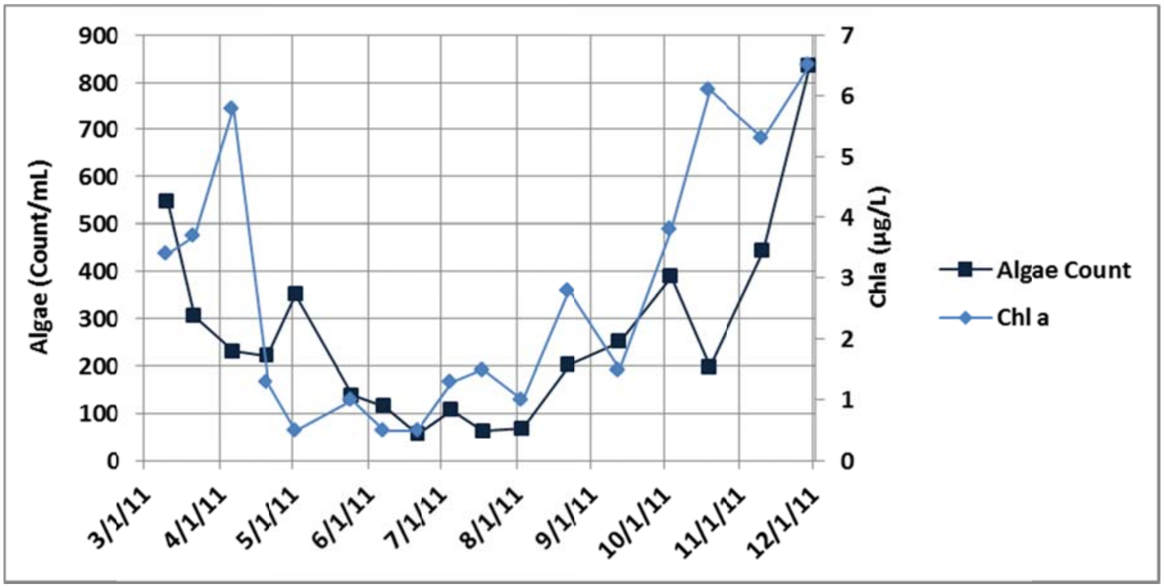

Figure 53. Algae Count and Chlorophyll *a* Concentrations in the Photic Zone (Twice the Secchi Depth) in Standley Lake for March-November 2011

Secchi Depth

Secchi depth, a measure of clarity, is determined by lowering a black-and-white painted disk vertically from the surface until the pattern is no longer visible. The Secchi reading is a combined measure of scattering and absorption of light in the upper portion of the water column, including the effects of algae, non-algal organic particulate matter, inorganic suspended solids, dissolved organic matter, and the water itself. 2011 data exhibit the pattern typically observed in Standley Lake of greater Secchi depths in summertime and shallower observations in spring and late fall, as seen in Figure 54. Although there are no readings greater than 5 meters for June through September, 2011, (which is not the case for 2006-2010), the summer period of greater clarity is longer. Clarity in Standley Lake in 2011 was 4 meters in early October. Typical early October Secchi depths are in the 2-3 meter range. The lowest Secchi depth reading for 2006-2011 (1.4 m) occurs shortly afterwards on October 19, 2011. This coincides with an increase in chlorophyll *a* from 3.8 to 6.1 µg/L, responding to nutrient concentration increases following lake turnover.

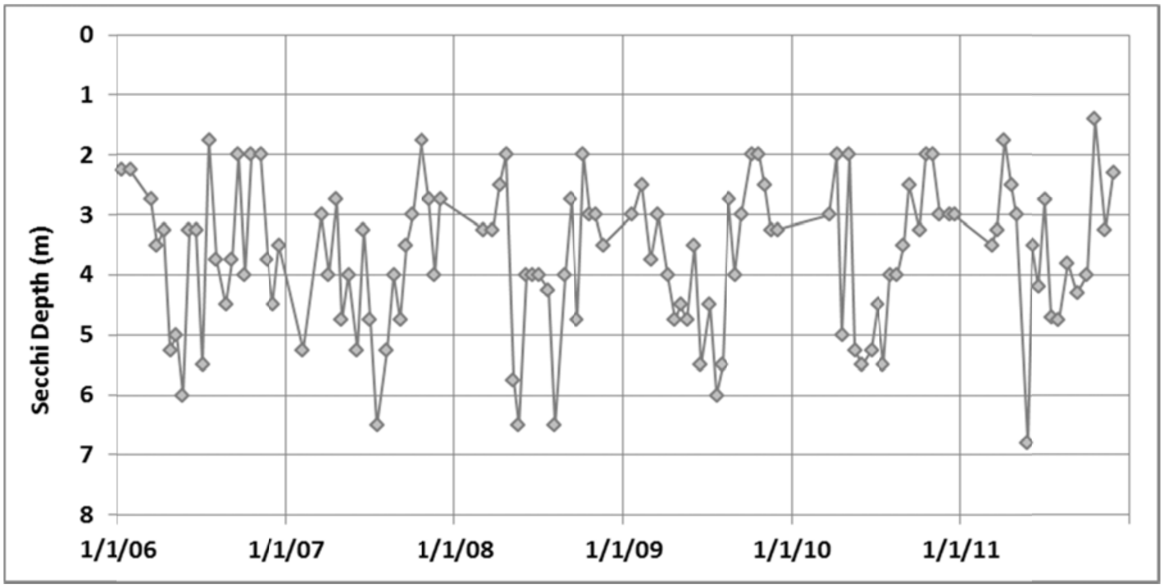

Figure 54. Secchi Depth in Standley Lake, 2006-2011

Although the Secchi depth patterns generally follows the chlorophyll *a* pattern (with the deepest Secchi depths during times of the lowest chlorophyll *a* concentrations), suspended solids appear to be important as well. One would expect to see greater clarity in a year with very low chlorophyll *a* concentrations. In 2011, the overall slight decrease in average clarity in 2011 may be related to the increase in TSS concentration in the photic zone (Figure 45). The increased TSS concentrations in the photic zone coincide with increased TSS loading to the lake (presented in Section V) and increases in TSS concentrations in the Upper Basin (presented in Section IV).

Dissolved Oxygen

Dissolved oxygen (DO) concentrations are important from both an aquatic life and a drinking water treatment standpoint. Standley Lake was on the State's Monitoring and Evaluation (M&E) list for low DO from an aquatic life perspective in 2010. This listing was based on low DO in the metalimnion. In 2011, the DO standard was revised so that concentrations in the top 0.5 – 2.0 meters of the reservoir are considered. Due to this revision, Standley Lake is now deemed to be in attainment of the DO standard and does not appear on the 2012 M&E list.

From a drinking water treatment standpoint, low DO, particularly at the sediment-water interface, is of most concern. Low DO concentrations can result in releases of nutrients (phosphorus and ammonia) and some metals (manganese and iron) from the sediments. These releases can lead to increases in treatment costs and the potential for taste and odor events.

Standley Lake experiences anoxia (DO < 2 mg/L) in the hypolimnion on an annual basis. This is typical for stratified reservoirs with a small hypolimnion and low level withdrawals, such as Standley Lake. In 2011, DO near the bottom of the lake exhibited a large seasonal fluctuation, as hypolimnetic DO decreased, reaching anoxic conditions through August and September. Turnover occurred in

October 2011. Figure 55 shows an isopleth of DO concentrations throughout the lake for March-November 2011. These conditions are similar to those occurring in 2006-2010 (Figure 56).

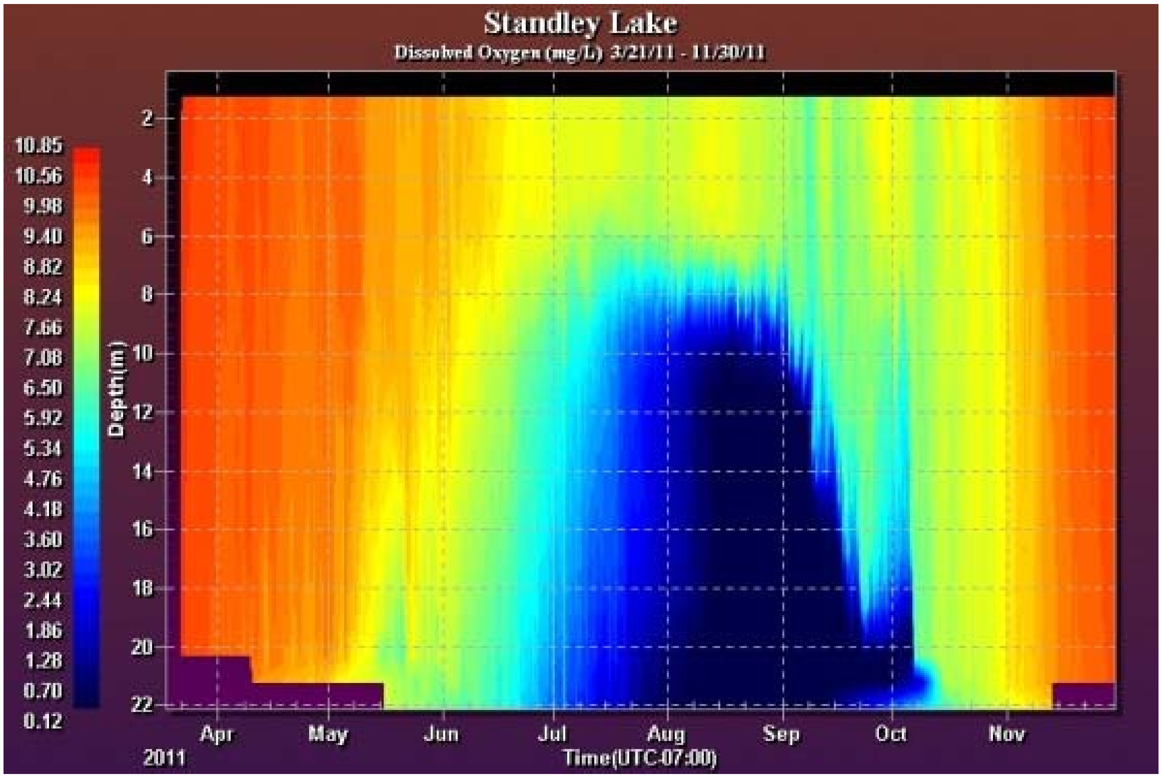

Figure 55. Dissolved Oxygen Concentrations in Standley Lake, March-November 2011

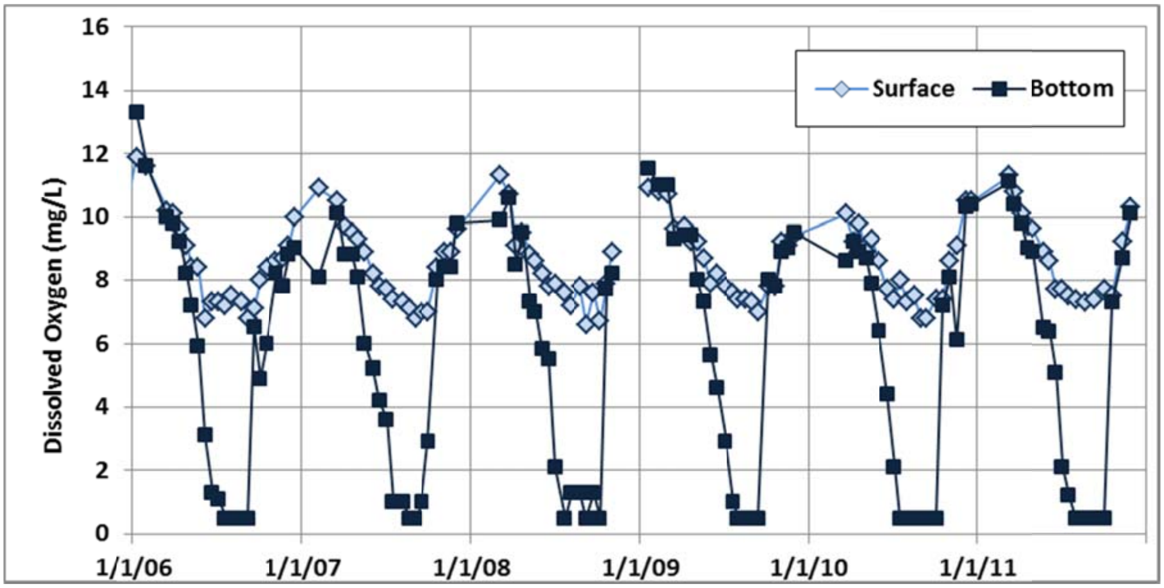

Figure 56. Dissolved Oxygen Concentrations at the Surface and near the Bottom of Standley Lake, 2006-2011

Although anoxia occurs at the bottom of Standley Lake each year during the summer, the duration of anoxia can very year-to-year. The anoxic period for 2011 was similar to that in 2010 but higher than the 2006-2010 average of 84 days (Figure 57).

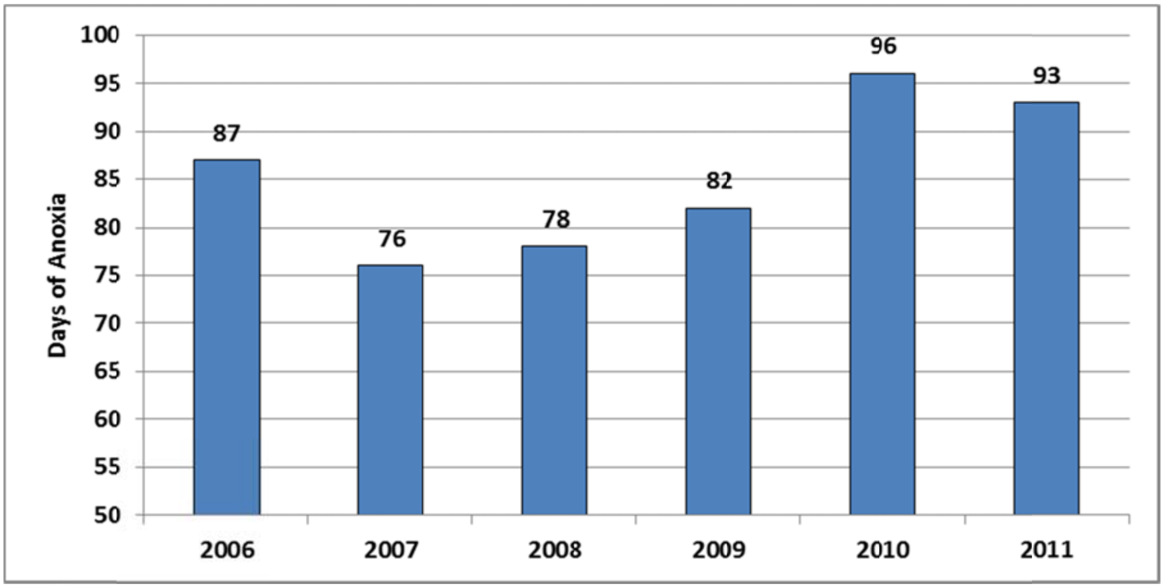

Figure 57. Days of Anoxia (DO < 2.0 mg/L), 2006-2011

VIII. Conclusions

In 2011, members of the UCCWA, Standley Lake Cities, and all parties to the 1993 Agreement continued to work diligently to monitor, improve, and protect water quality. These efforts included upgrading monitoring locations, upgrading WWTPs, addressing illicit discharges and nonpoint sources, conducting public education and outreach, and supporting mine reclamation efforts. Additionally, members engaged in numerous planning efforts to support improvement and protection of Clear Creek and Standley Lake into the future.

For the Clear Creek/Standley Lake watershed, 2011 was a year characterized by high snowmelt runoff volumes, with flow rates peaking in July, a month later than typically observed. The runoff volume was 39% higher than the previous 5-year average, and the peak flow rate was 45% higher. Loads of TSS, TP, and TN in Clear Creek and into Standley Lake were higher in 2011 than the average of 2006-2010 due to the higher volumes. Average volume-weighted concentrations of TSS and TP were also higher in 2011 in Clear Creek, likely due to increased mobilization of solids by the higher flow rates. Volume-weighted concentrations of TN in 2011, however, were generally comparable to the average of the preceding five years.

In 2011, Standley Lake water quality was good, with the lake following typical seasonal patterns observed in previous years. In-lake concentrations of TSS were higher in 2011 than the 2006-2010 average. This is expected to be a direct reflection of the increased TSS concentrations observed in Clear Creek where water is diverted to canals feeding Standley Lake. TN concentrations were generally higher than the previous five-year average values, particularly in the photic zone, while TP averages were closer to recent five-year values. Both Secchi depths and dissolved oxygen concentrations exhibited typical patterns and ranges over the year. The March through November average chlorophyll *a* concentration in Standley Lake in 2011 was 2.73 µg/L, which is the lowest value observed since 1999 and well below the 4.0 µg/L standard.