Clear Creek / Standley Lake Watershed Agreement

2016 Annual Report

DRAFT

July 19, 2017

Clear Creek Watershed Annual Report – 2016

July 19, 2017

DRAFT

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 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

Prepared by:
Hydros Consulting Inc.
1628 Walnut Street
Boulder, CO 80302

Table of Contents

Cover photograph compliments of Eric Scott

List of Figures

List of Tables

List of Acronyms and Abbreviations

AF – Acre Feet

ANS – Aquatic Nuisance Species

AS - Autosampler

BMP – Best Management Practice

CC05 – Clear Creek Sampling Station: Clear Creek at Bakerville

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

CC40 – Clear Creek Sampling Station: Clear Creek near the junction of US-6 and I-70

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

CDWA – Church Ditch Water Authority

CFS –Cubic Feet per Second

Church – Church Ditch

Croke – Croke Canal

CY –Cubic Yard

DO – Dissolved Oxygen

EWM – Eurasian watermilfoil

fDOM – Fluorescent Dissolved Organic Matter

FHL – Farmers' High Line Canal

FRICO – Farmers' Reservoir and Irrigation Company

FT – Feet

IGA –Intergovernmental Agreement

I-70 – U.S. Interstate 70

KDPL – Kinnear Ditch Pipeline

LBS – Pounds

MGD – Millions of Gallons per Day

MS4 – Municipal Separate Storm Sewer System

N/A – Not Available

ORP – Oxidation/Reduction Potential

OWTS – Onsite Wastewater Treatment System

Reg. – Regulation

SL10 – Standley Lake Sampling Location Near Water Treatment Plant Intake

TIN – Total Inorganic Nitrogen

TN – Total Nitrogen

TP – Total Phosphorus

TSS – Total Suspended Solids

UCC – Upper Clear Creek

UCCWA – Upper Clear Creek Watershed Association

USGS – United States Geological Survey

UV – Ultraviolet

WQCC – Water Quality Control Commission

WWTF – Wastewater Treatment Facility

Executive Summary

I. Introduction

A. Purpose and Scope of Report

This annual report provides a review of 2016 water-quality efforts in the Clear Creek watershed. In 1993, the Clear Creek/Standley Lake Watershed Agreement (1993 Agreement, Appendix A) was signed by a contingent of governmental agencies and private corporations to address water-quality issues and concerns within the Clear Creek watershed – specifically as they affect the water quality of Standley Lake. This report fulfills the annual reporting obligations set forth in the 1993 Agreement. Water-quality data for 2016 are presented and compared to the recent conditions as represented by the previous five years of data (2011-2015).

B. Organization of the Report

Following this introductory section, this report is organized as follows:

- **Section II. Description of Standley Lake, Its Watershed, and Routine Monitoring** – An overview of the reservoir and its watershed, including maps and monitoring practices.
- **Section III. Activities and Accomplishments** – A summary of 2016 activities related to water-quality management and improvement in the Clear Creek Basin, canals, and Standley Lake.
- **Section IV. Upper Basin Water Flows and Water Quality** – A presentation of data collected from two 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. Canal Zone Flows and Water Quality**—A presentation of flows in the canals that flow into Standley Lake. This section also includes an analysis of changes in total nitrogen, total phosphorus, and total suspended solids concentrations observed across the length of the Farmers' Highline and Croke canals.
- **Section VI. Standley Lake Flows, Contents, and Loading –** A summary of 2016 inflow to Standley Lake, outflow from the lake, and lake storage. This section also includes an analysis of nutrient loading into and out of the lake, with consideration of total nitrogen and total phosphorus loads from each canal.
- **Section VII. Standley Lake Water Quality** - An analysis of lake water quality with a focus on total nitrogen, total phosphorus, chlorophyll *a,* dissolved oxygen, and clarity.
- **Section VIII. Conclusions** – A summary of findings from the report.

In addition, four appendices are included to provide additional background and detailed information:

- Appendix A. Clear Creek / Standley Lake Watershed Agreement;
- Appendix B. Upper Clear Creek / Standley Lake Watershed Water Quality Monitoring Plan;
- Appendix C. Clear Creek, Canal, and Standley Lake Water-Quality Monitoring Data for 2016; and
- Appendix D. Regulation 85 Water-Quality Monitoring Data--2016

II. Description of Standley Lake, Its Watershed, and Routine Monitoring

A broad description of Standley Lake and its watershed is provided in this section. The watershed is comprised of the Upper Basin and the Canal Zone. The Upper Basin is a portion of the larger Clear Creek watershed. The Canal Zone refers to the lands draining either directly to the lake or to the canals which flow into the reservoir. Routine monitoring activities for each area are also summarized.

A. Standley Lake

Standley Lake is an off-channel, municipal and agricultural reservoir located in Jefferson County, Colorado (Figure 1). This reservoir covers approximately 1,200 acres and has a storage capacity of 43,000 acre-feet (AF). It serves as a direct-use drinking water supply for over 250,000 consumers in the cities of Northglenn, Westminster, and Thornton. In addition, the reservoir supports recreational activities and provides water to farms located in Adams and Weld counties. It is owned and operated by the Farmers' Reservoir and Irrigation Company (FRICO).

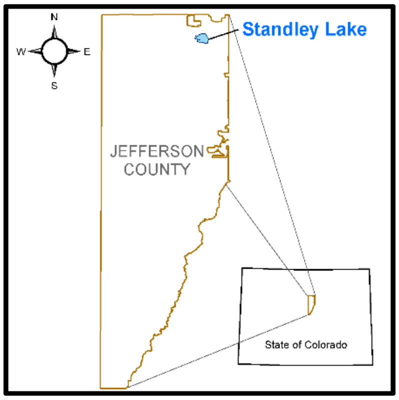


Figure 1. Location of Standley Lake

Through the Standley Lake Monitoring Program, the lake is monitored regularly during the ice-free period. Although the lake is sampled at multiple locations, the focus for this report is the deepest sampling location, SL10 (Figure 2). This location is approximately one-quarter mile south of the municipal supply intakes. Routine monitoring practices for Standley Lake are described in detail in the Upper Clear Creek/Standley Lake Watershed Water Quality Monitoring Program (Appendix B). Lake monitoring efforts at SL10 are summarized below:

- **Daily Profiles –**Standley Lake water quality is measured four times per day using an automated profiler (Figure 3). Measurements are taken every meter, from the surface to within 2 meters of the bottom. The profiler is equipped with a multi-probe sonde which provides readings of water temperature, dissolved oxygen, pH, conductivity, turbidity, oxidation/reduction potential (ORP), and chlorophyll *a* concentrations.
- **Water-Quality Sampling** – Grab samples are collected in the lake at three depths: the surface, the bottom of the photic zone (at two times the measured Secchi depth), and one meter from the bottom. Sampling occurs twice each month if the lake is not frozen. A wide range of constituents is measured, including nutrients, metals, algae, suspended solids, and field parameters.
- **Zooplankton Tows** – Zooplankton tows are conducted during each lake sampling event.
- **Invasive Species Monitoring** – Monitoring for zebra and quagga mussels is conducted during each lake sampling event. Monitoring for Eurasian watermilfoil is performed once per year.

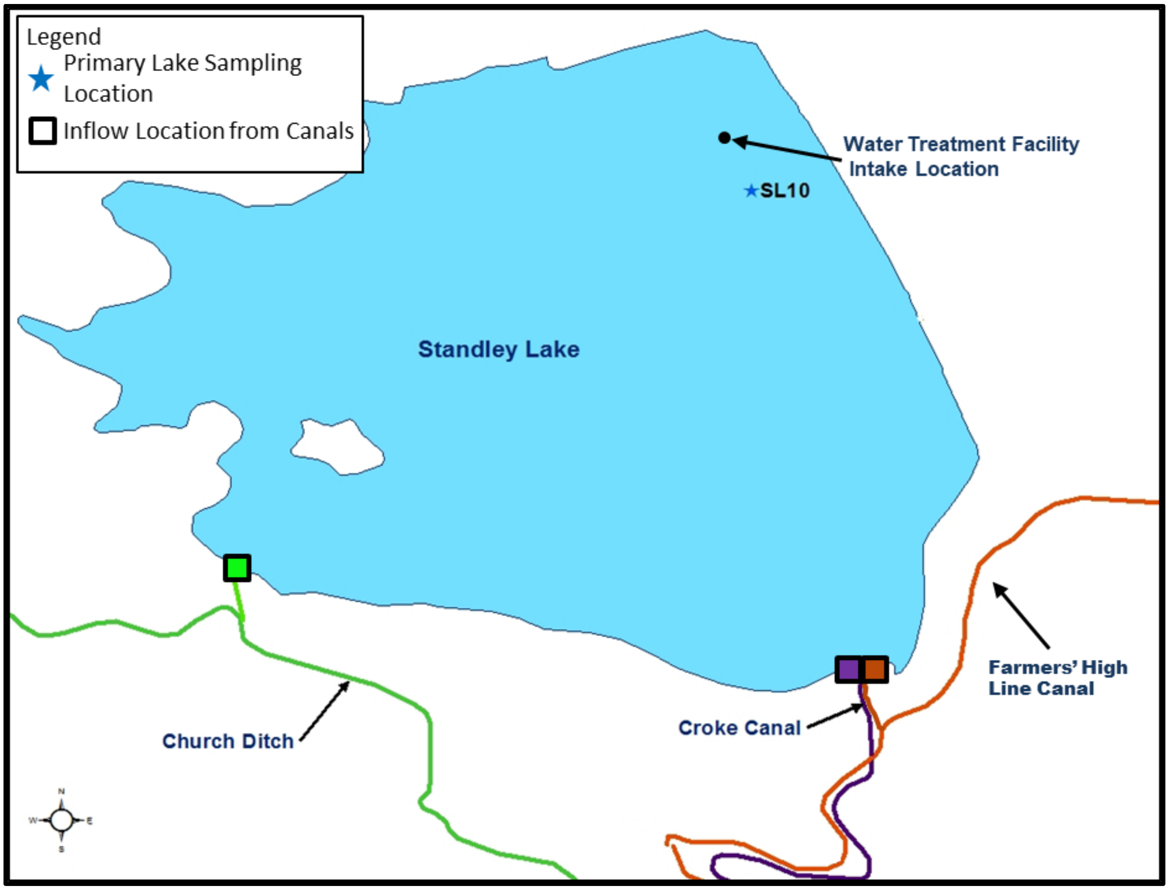


Figure 2. Standley Lake, Sampling Location SL10, and the Locations of Canal Inflows

Figure 3. Water-Quality Profiler at SL10

B. Description of the Watershed

The Clear Creek watershed is located west of Denver, Colorado, with headwaters at the Continental Divide (Figure 4). The watershed covers an area of 575 square miles; spanning elevations from nearly 14,000 feet (ft) to approximately 5,000 ft at the confluence with the South Platte River in north Denver. In addition to supplying drinking water to 350,000 residents in the watershed, Clear Creek provides water for recreational, agricultural, and industrial purposes.

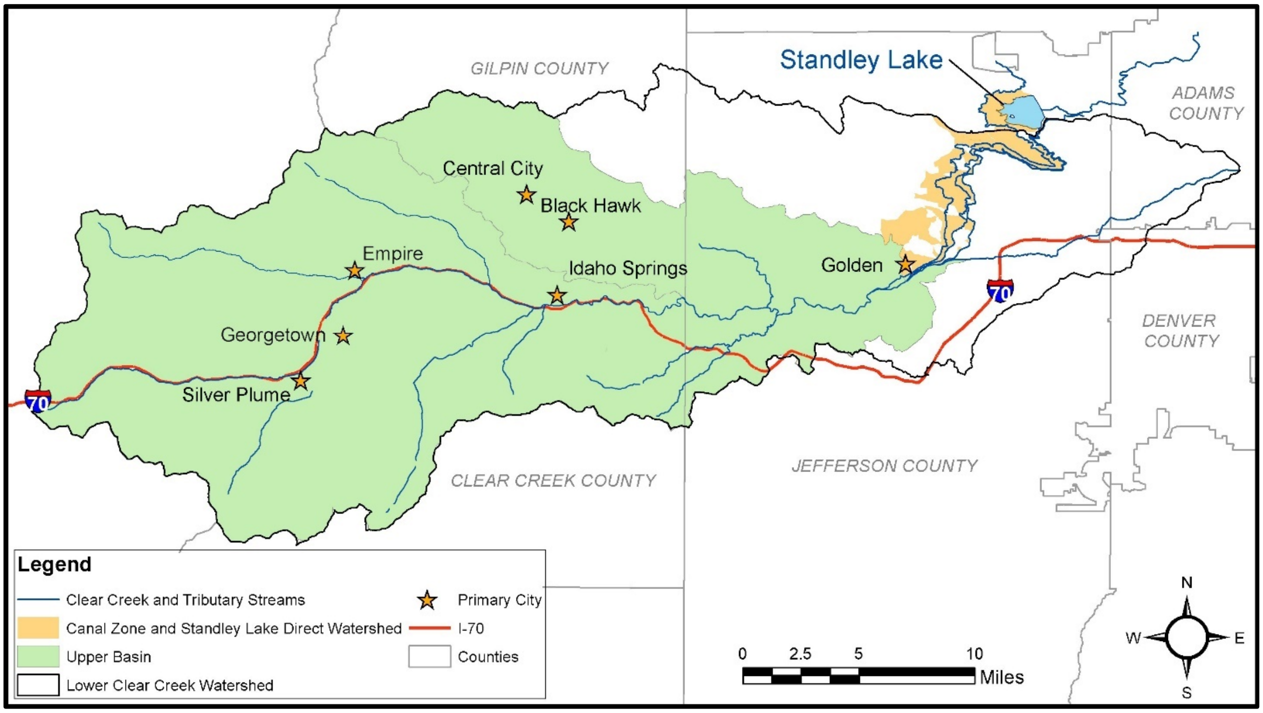


Figure 4. The Standley Lake Watershed, Upper Basin, Canal Zone, and Direct Watershed

The Upper Basin of the Clear Creek watershed is that portion of the watershed above the diversion points for the canals feeding Standley Lake. The Standley Lake watershed includes the Upper Basin of the Clear Creek watershed, the canals used to transport water from Clear Creek to the lake and their drainage areas (the Canal Zone), and a direct lake watershed. The following subsections describe the Upper Basin and the Canal Zone.

1. Upper Basin

The Upper Basin region of the Clear Creek watershed (Figure 4) is comprised of nearly 400 square miles upstream of the Croke Canal headgate. This region includes the upper portion of Clear Creek and its 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, Tucker Gulch, and Elk Creek. Numerous cities and 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) runs through the watershed.

This highly-utilized transportation corridor averages approximately 40,000 vehicles per day near Idaho Springs (CDOT 2015).

Water quality in the Upper Basin is affected by a variety of sources. Prominent amongst these are the nine wastewater treatment facilities (WWTFs) in the region which serve the local population and resorts (Figure 5). Additionally, the Upper Basin contains operating and abandoned mines and receives water from trans-basin diversions. Water quality in the Upper Basin may also be impacted by nonpoint sources of pollution, including numerous on-site wastewater treatment systems (OWTS), application of roadway deicers and traction sands, and residential and commercial stormwater runoff.

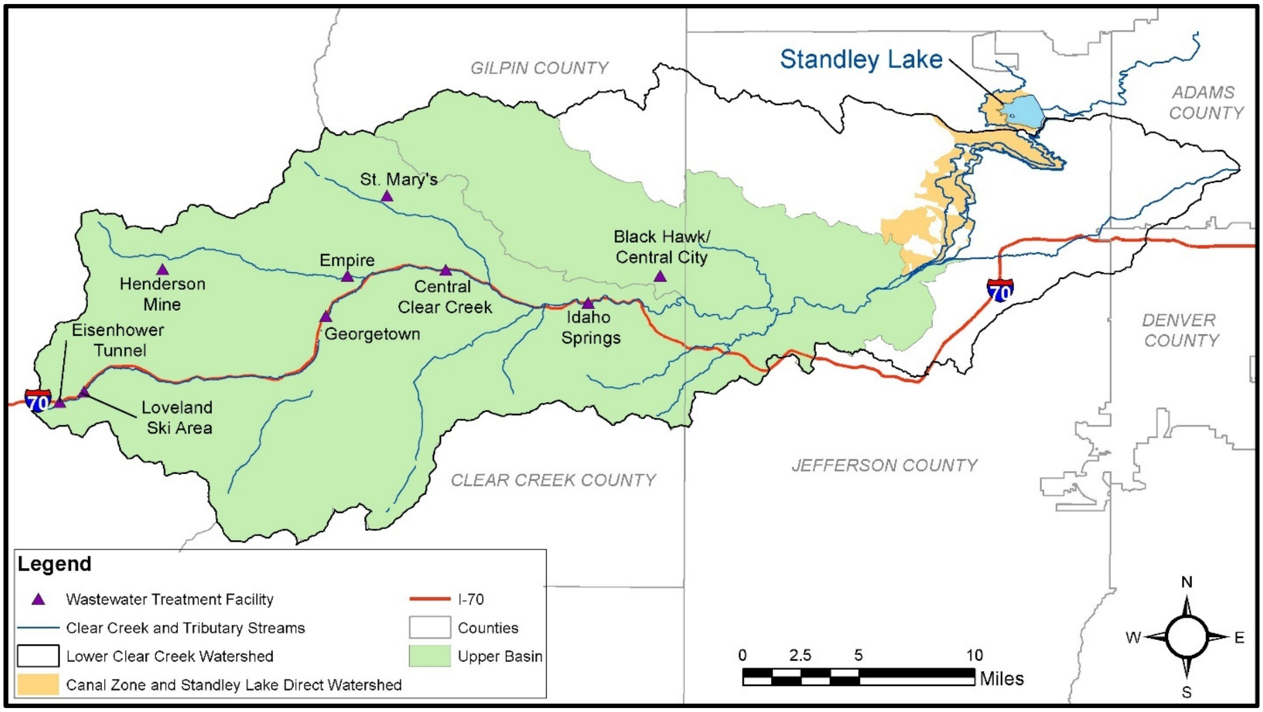


Figure 5. Wastewater Treatment Facilities in the Upper Basin

Flow measurements 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 6).

Upper Basin monitoring activities have been designed in order to evaluate the relative contributions of various nutrient sources, effectiveness of best management practices (BMPs), WWTF operational changes, and nutrient reductions from WWTF upgrades. The monitoring program has a strong emphasis on composite samples versus grab sampling. Composite samples are comprised of multiple sub-samples collected regularly over a pre-determined time period. Relative to grab samples, composite samples provide a more complete picture of water quality over the course of the sampling period. These composite samples are of two types: ambient and event. Ambient samples are collected on a periodic basis and are collected over a 24-hour period. Event samples are storm-triggered. Routine monitoring for the Upper Basin is described in detail in Appendix B.

The analyses described in the Upper Basin portion of this report are based on data from two key sampling areas (described in Table 1 and circled on Figure 6), selected based on their location and higher frequency of sampling. For this report, three important constituents are analyzed: total phosphorus (TP), total nitrogen (TN), and total suspended solids (TSS).

Table 1. Key Watershed Locations in the Upper Basin

General Area	Purpose	Station Name and Location	Station Type
Clear Creek main stem, downstream of the confluence with the West Fork, at the location of USGS* Lawson flow gage	Characterize water quality in the upper portion of the Upper Basin	CC26 – Clear Creek at Lawson Gage	Grab Sample Station
		CCAS26 -- Clear Creek at Lawson Gage	24-Hr Composite Autosampler
Clear Creek main stem, near the canal headgates, near Golden	Characterize water quality near the Clear Creek canal diversions to Standley Lake	CC60 – Clear Creek at Church Ditch Headgate	Grab Sample Station
		CCAS59 – Clear Creek 2 miles west of Highway 58/US6	24-Hr Composite Autosampler

*United States Geological Survey

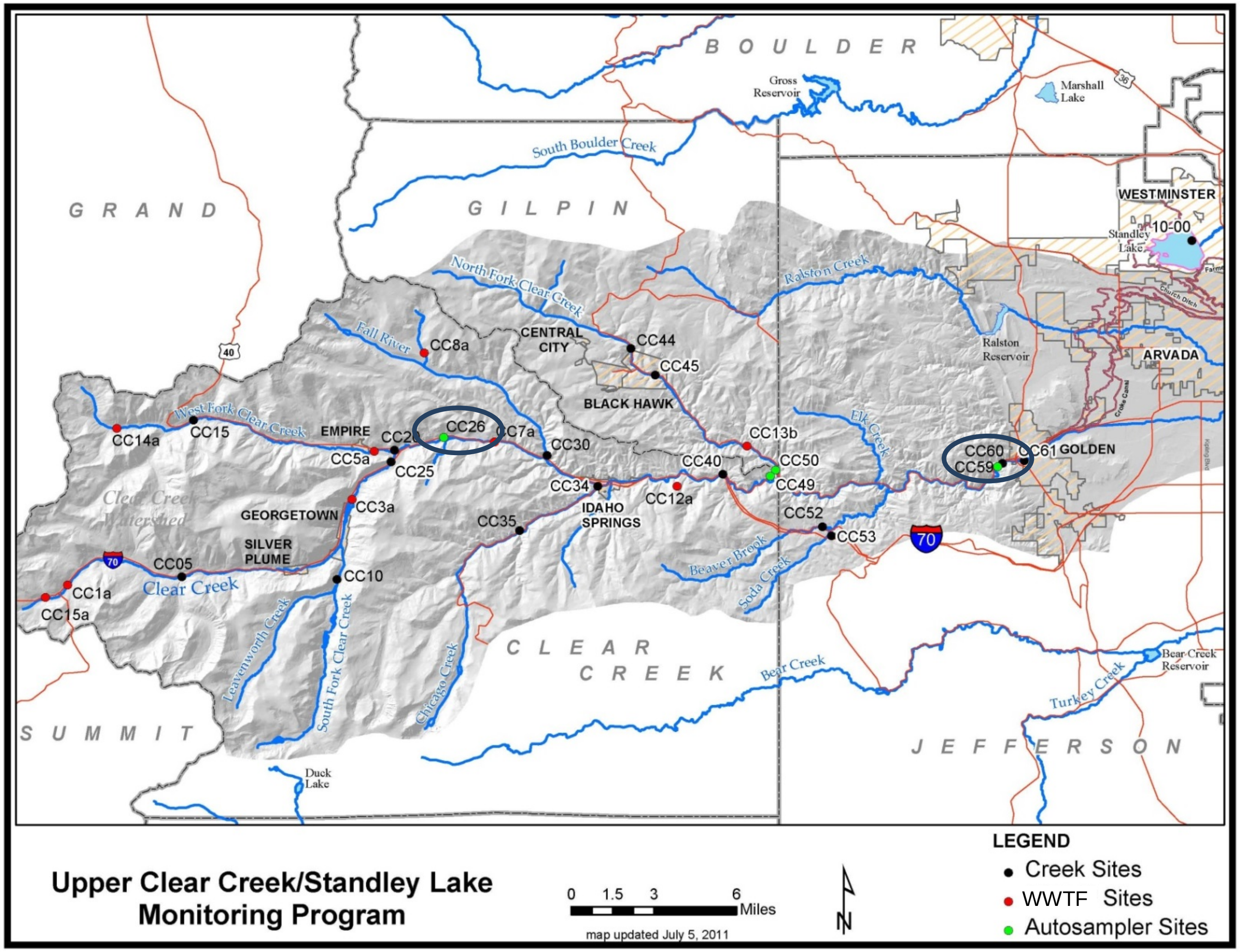


Figure 6. Upper Clear Creek Sampling Stations (Key locations for this report are circled)

2. Canal Zone

The Canal Zone contains the canals (and surrounding drainage areas) that divert water from Clear Creek into Standley Lake: Church Ditch (Church), Farmers' High Line Canal (FHL), and the Croke Canal (Croke) (Figure 7). The Kinnear Ditch Pipeline (KDPL) also contributes water to Standley Lake sourced from the Coal Creek, South Boulder Creek, and Fraser River basins. The canals are slow-flowing (low gradient), open and largely unlined ditches. In addition, they are subject to nonpoint-source loading from adjacent horse and cattle operations, agricultural operations, and residential properties (some with OWTSs). To protect Standley Lake water quality, a substantial percentage (~80%) of the direct runoff into the Clear Creek canals has been hydrologically disconnected from the canals since the 1990s.

To provide information for evaluation of the nutrient loadings from nonpoint sources in the Canal Zone, the three Clear Creek canals are sampled at the headgates where water is diverted, and at the inlets into the lake. The KDPL is sampled near the inlet into the lake. Figure 7 shows the inlet monitoring location for each canal (CCT4, CCT11, CCT27, and CCT22d). Routine monitoring for the Canal Zone is described in detail in Appendix B.

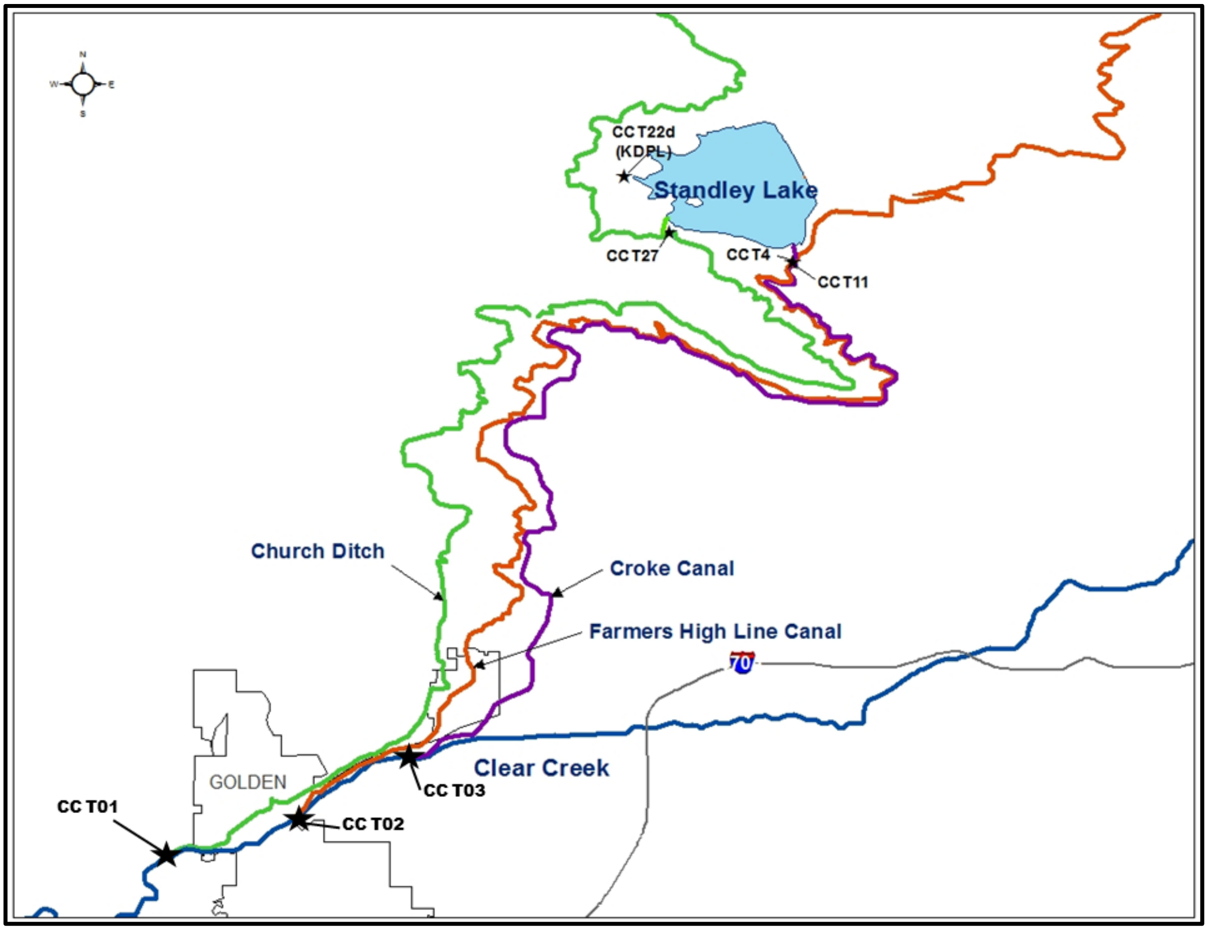


Figure 7. The Three Canals that Divert Water from Clear Creek to Standley Lake and Sampling Stations at the Lake Inflow Locations (Including KDPL)

III. Activities and Accomplishments

This section provides highlights of the efforts in 2016 to manage, enhance, and protect water quality in both the Clear Creek watershed and in Standley Lake. These activities were completed by a variety of interested groups and entities. The following groups of activities are described:

- Monitoring Activities;
- Canal Maintenance;
- Wastewater Treatment Facilities;
- Illicit Discharges and Emergency Response;
- Nonpoint Source Control, Stormwater Management and Remediation;
- General Public Education, Outreach, and Partnerships; and
- Other Activities.

A. Monitoring Activities

The routine collection of flow measurements and water-quality samples throughout the Upper Basin, the Canal Zone, and in Standley Lake is guided by the Upper Clear Creek / Standley Lake Watershed Water Quality Monitoring Program. Water-quality sample collection for this program in 2016 is summarized in Table 2. Samples were analyzed for a range of constituents, as described in the monitoring plan (Appendix B). Some of the funding used for flow and water-quality monitoring are listed in Table 3.

Table 2. Summary of 2016 Water-Quality Sample Collection

Sub-Region	Type of Sample	Number of Locations	Total Number of Samples Collected
Upper Basin	Grab Samples	17	47
	Ambient Composites	4	23
	Storm-triggered Composites	1	4
Canal Zone	Grab Samples	10	60
	Ambient Composites	2	14
	Storm-triggered Composites	0	0
	First Flush Composites	4	4
Standley Lake	Grab Samples	1 (3 depths)	60
	Vertical Profiles	1	Four Times Daily When Ice-Free, Every Meter

Table 3. Funding Resources for Flow and Water Quality Monitoring in 2016

Entity	Activity Funded	2016 Amount
Standley Lake Cities	Water-Quality Sampling and Analysis and Flow Gage Support at Bakerville (CC05) and Lawson (CC26)	$200,000+
Clear Creek County	Support gages: 1) on Leavenworth Creek, 2) at Berthoud Falls on the West Fork of Clear Creek, and 3) on Fall River.	$10,900
City of Golden	Water Quality Sampling and Analysis	n/a
	USGS gage on the West Fork of Clear Creek	$10,790
Upper Clear Creek Watershed Association (UCCWA)	Gage at CC40	$4,005

In 2016 a new second sampling station was installed at the CC59 location. The original CC59 monitoring site is located on Clear Creek in Golden, approximately 300 yards upstream of the Church Ditch headgate in Golden. The new CC59 sampling station is located approximately 100 ft upstream of the existing monitoring station. The City of Golden operates the original CC59 station, primarily for the collection of stormwater samples. The collection of ambient samples at this station was interfering with stormwater sampling. These ambient samples are considered a critical part of the Standley Lake watershed model. The new station was installed to allow for the continued collection of composite ambient samples at the CC59 location.


The new SLIGA CC59 Sampling Station

In 2016, Northglenn constructed a platform and box at the site and an Autosampler (AS) was installed. The monthly collection of ambient 24-hour composites using the SLIGA autosampler began in April 2016. In the spring of 2017, a sonde was installed and connected to a datalogger. The sonde, a YSI EXO2, measures depth, temperature, pH, ORP, turbidity and fluorescent dissolved organic matter (fDOM) data. These *in-situ* data will be collected on a seasonal basis as this site becomes very shallow in the late summer. The sonde will be removed when water depth at the site becomes too shallow.

B. Canal Maintenance

In 2016, the canals which supply water to Standley Lake received ongoing maintenance to enable the continued efficient delivery of high-quality water to Standley Lake and other water users.

1. Church Ditch Water Authority

Prior to the 2017 irrigation season, the Church Ditch Water Authority (CDWA) completed the construction of a new headworks structure with improved operational capabilities. This structure provides Church Ditch staff with better control of flows diverted from Clear Creek. It also provides the ability for remote access to gate controls. This capability simplifies flow adjustments and allows immediate shutdowns in the event of contamination in Clear Creek. The structure also allows for the removal of sediment from the diversion channel upstream of the headworks. This will reduce sedimentation from Clear Creek and help minimize ditch maintenance.

New Church ditch headworks structure.

CDWA continues to focus on maintenance of the ditch and associated easement. This maintenance includes vegetation removal, ditch shaping, and bank repair. Vegetation removal reduces the risk of blockages, increases ditch capacity, and decreases sedimentation from erosion. In 2016, approximately 16,000 ft of vegetation was removed along both sides of the ditch at a number of locations. Ditch shaping and bank repair are performed to increase ditch capacity, improve flow, and protect water quality by reducing erosion. Approximately 2,500 ft of the ditch was reshaped and cleaned in 2016 at several locations.

CDWA actively oversees any projects within the ditch easement or channel to ensure proper care is taken to maintain water quality by minimizing or eliminating erosion and stopping potential contaminants from entering the ditch. In 2016, such projects included the placement of two pedestrian bridges, one culvert ditch crossing, and multiple utility bores. Lastly, CDWA also replaced a number of user headgates—providing new headwalls, gates, and check pads where needed. These projects were completed by mixing native soil with bentonite and adding rip rap to provide bank stability.

Installation of new pedestrian bridge over Church ditch

2. Farmers' Highline Canal and Reservoir Company

Farmer's Highline Canal and Reservoir Company staff continued activities that support protection of or improvements to water quality. An example includes the installation of handrails at the Farmers' Highline Canal (FHL) headgate on Clear Creek to improve the safety of water-quality staff during sample collection. Other activities to enhance and maintain water quality include ditch maintenance, mowing, removal of sediment, and flushing.

3. Croke Canal

Activities on the Croke in 2016 performed by FRICO and the Standley Lake Operating Committee continued to support the protection of water quality. An example of one of these activities is a continuing process to address land uses with the potential to impact ditch water quality. In 2016, land uses identified as potentially impacting water quality included including horse boarding operations and equestrian access to the ditch road. In early 2017 a pedestrian bridge is expected to be installed to allow access across the Croke canal.

4. City of Arvada

In 2016, the City of Arvada continued restoring and improving waterways that were impacted by the historic flooding of September 2013. A significant amount of funding and man-hours were dedicated to assisting Jefferson County, CDOT, Urban Drainage, and ditch operation companies. This assistance supported the repair and replacement of diversion control structures and erosion control systems along Leyden Creek, Ralston Creek, Church Ditch, Farmers' Highline Canal and the Croke Canal.

C. Wastewater Treatment Facilities

As described in Section II, nine wastewater treatment facilities are located in the Upper Basin (Figure 5). The following sub-sections provide a brief discussion of key activities at two of the three largest WWTFs in the basin. At the end of this section, effluent nutrient concentrations from 2011 to 2016 are presented for each of the WWTFs that are subject to Regulation 85.

1. Idaho Springs WWTF

The City of Idaho Springs completed installation of an ultraviolet (UV) disinfection system in 2016 at the city's WWTF. The city no longer uses gaseous chlorine and sulfur dioxide for disinfection; however, liquid chlorine and sodium bisulfite are onsite for emergency backup. Facility upgrades continued with the commencement of the engineering phase to install an on-site dewatering facility for sludge produced by the aerobic digester. The project is tentatively scheduled for completion in late 2017.

2. Georgetown WWTF

Under a longstanding agreement, Silver Plume's wastewater is treated at the Georgetown WWTF. In 2016, both towns continued work to locate and resolve infiltration and inflow issues.

3. Observed WWTF Effluent Concentrations

In 2012, the Water Quality Control Commission (WQCC) adopted Regulation 85 (CDPHE 2012), the Nutrients Management Control Regulation, which establishes numeric standards for nutrient concentrations in WWTF effluent (Table 4). WWTFs are not required to meet the discharge limits set in the regulation if they have a design capacity of less than or equal to 1.0 MGD or if they are owned by a disadvantaged community. Of the nine WWTFs in the watershed, only Black Hawk / Central City Sanitation District facility (with a design hydraulic capacity of 2.0 MGD) is subject to Regulation 85.

Table 4. Regulation 85 Limitations, Existing Facilities, for TP and TIN

Constituent	Units	Median (50th Percentile)	95th Percentile
Total Phosphorus	mg/L as P	1.0	2.5
Total Inorganic Nitrogen	mg/L as N	15	20

The WQCC, through Regulation 85, also requires all WWTFs to sample and report effluent nutrient concentrations. For minor dischargers (less than 1 MGD), sampling is required once every two months at a minimum. For major WWTF dischargers (greater than 1 MGD), monthly sampling is required. With the exception of only the Black Hawk / Central City Sanitation District, all of the WWTFs in the watershed are classified as minor dischargers. Sampling under Regulation 85 began in April of 2013. Prior to this, periodic effluent sampling for nutrients was conducted as part of the

Upper Clear Creek (UCC) Monitoring Program. Nutrient analysis of samples from the WWTFs was discontinued with the implementation of Regulation 85. Data from the UCC Monitoring Program and data collected to meet Regulation 85 requirements represent end-of-pipe concentrations and are generated by different laboratories, in some cases, using different methods.

TP and TN concentrations measured for each WWTF subject to Regulation 85[1] in 2011-2016 are presented in Figure 8 through Figure 13. These figures show observations from both the UCC Monitoring Program (through early 2013) and Regulation 85 sampling (2013 to present). Note that the sampling frequency varied by WWTF and over the course of the year. Data collected as part of the UCC Monitoring Program are depicted with filled data points, and data collected as part of Regulation 85 are depicted with hollow data points. For context, the average daily flow for each facility is provided on the figure.

---

[1] In previous reports, this section included figures for the Eisenhower Tunnel and Henderson Mine WWTFs. These facilities are not subject to Regulation 85 and no additional data has been provided for this report since 2013. Readers with interest in these facilities are referred to previous reports (e.g. Hydros [2016]).

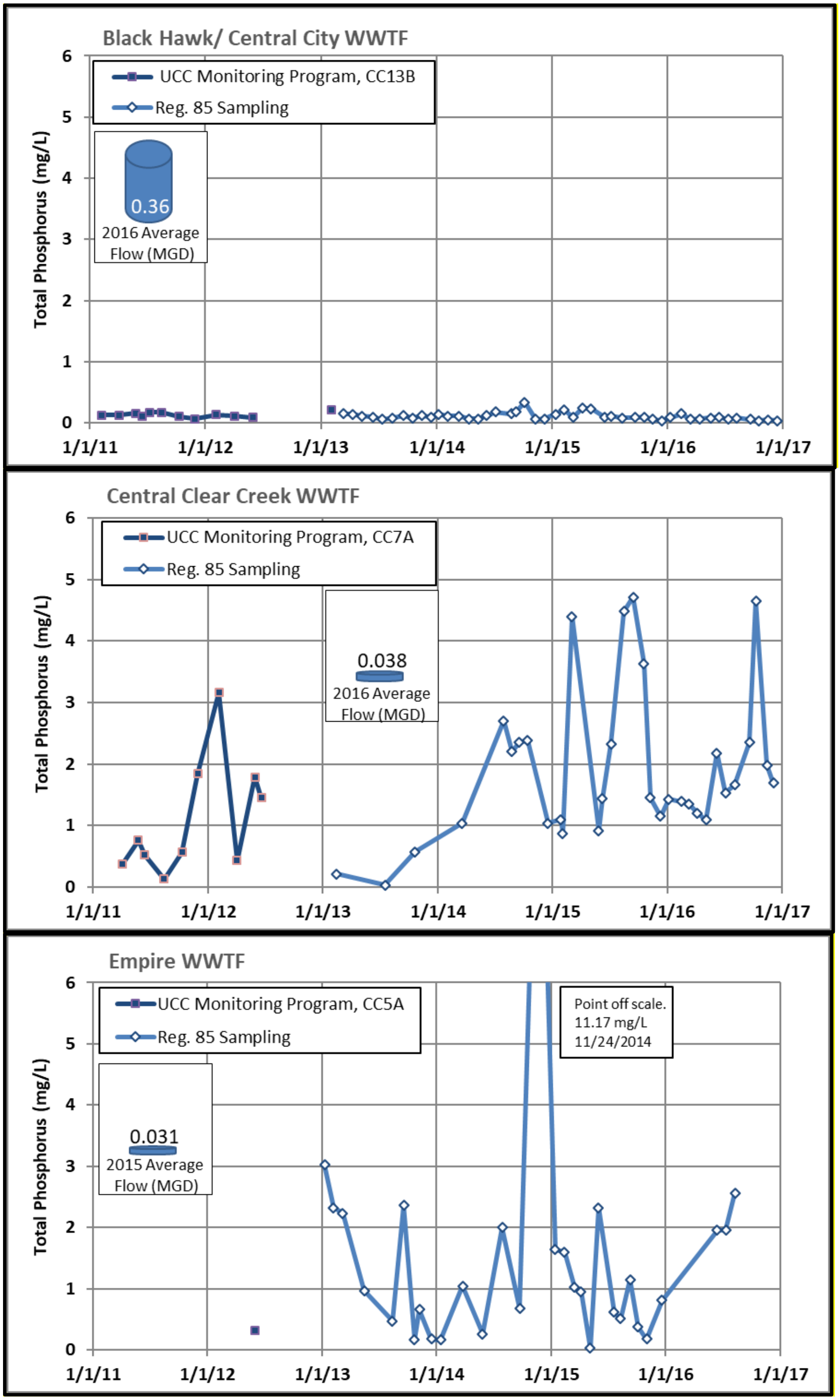


Figure 8. Effluent TP Concentrations (2011-2016) for Black Hawk/Central City, Central Clear Creek, and Empire WWTFs

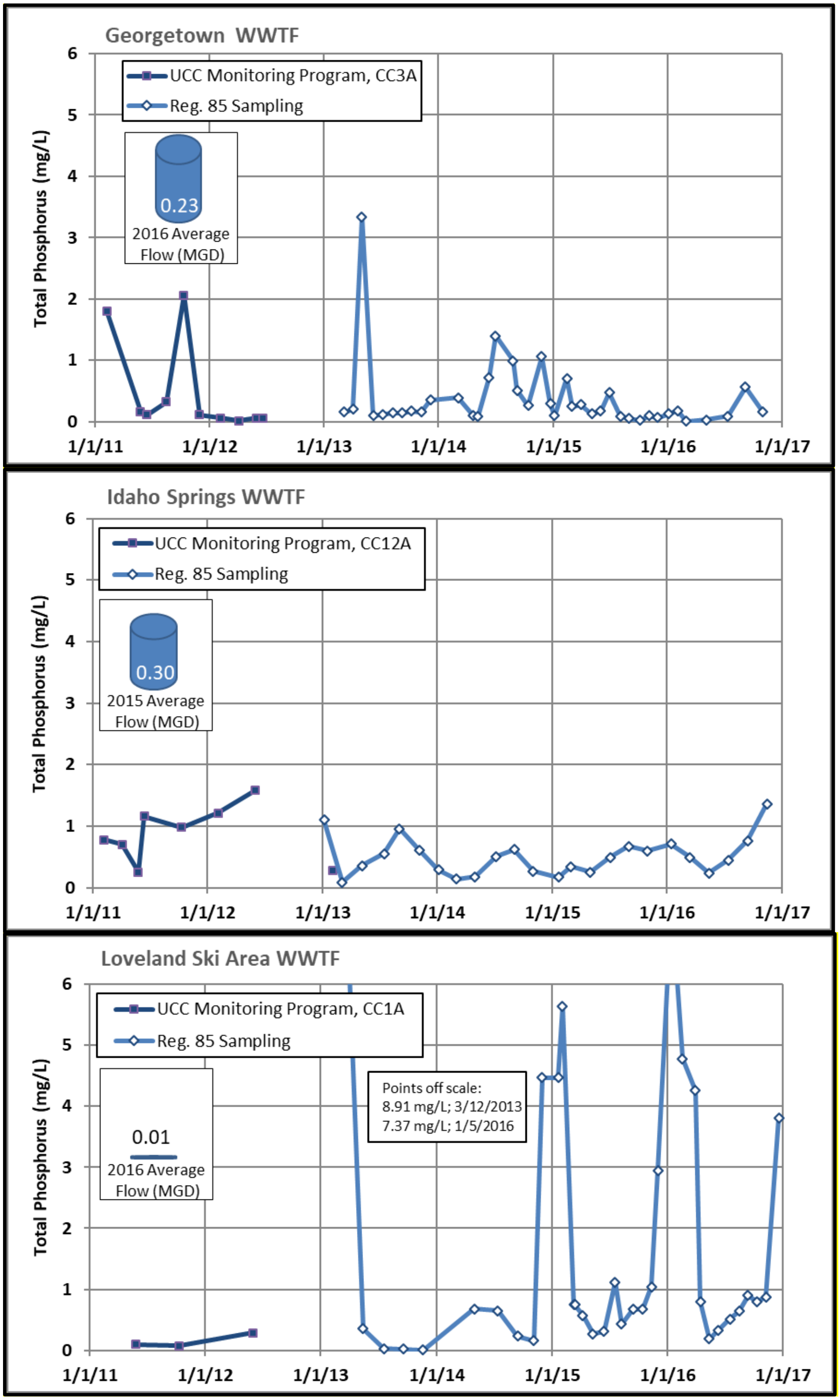


Figure 9. Effluent TP Concentrations (2011-2016) for Georgetown, Idaho Springs and Loveland Ski Area WWTFs

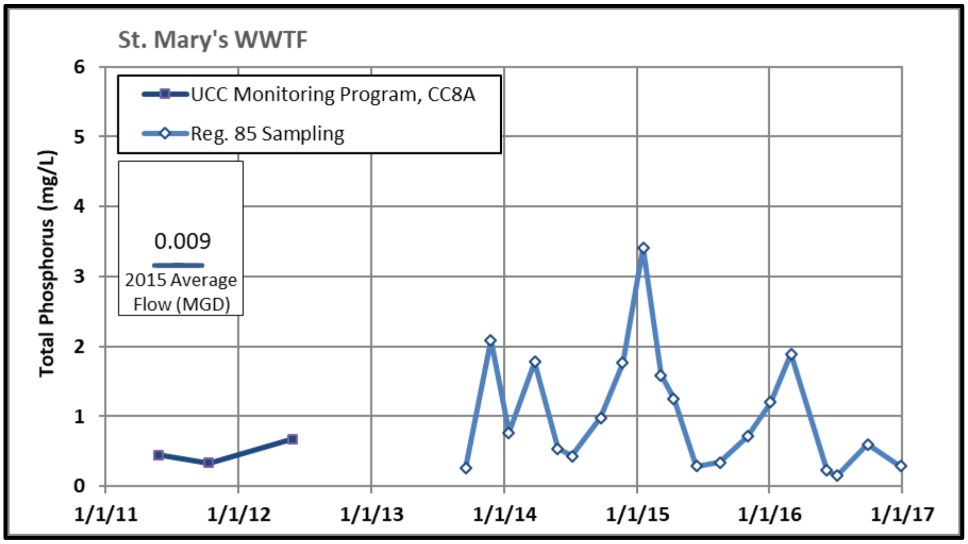


Figure 10. Effluent TP Concentrations (2011-2016) for St. Mary's WWTF

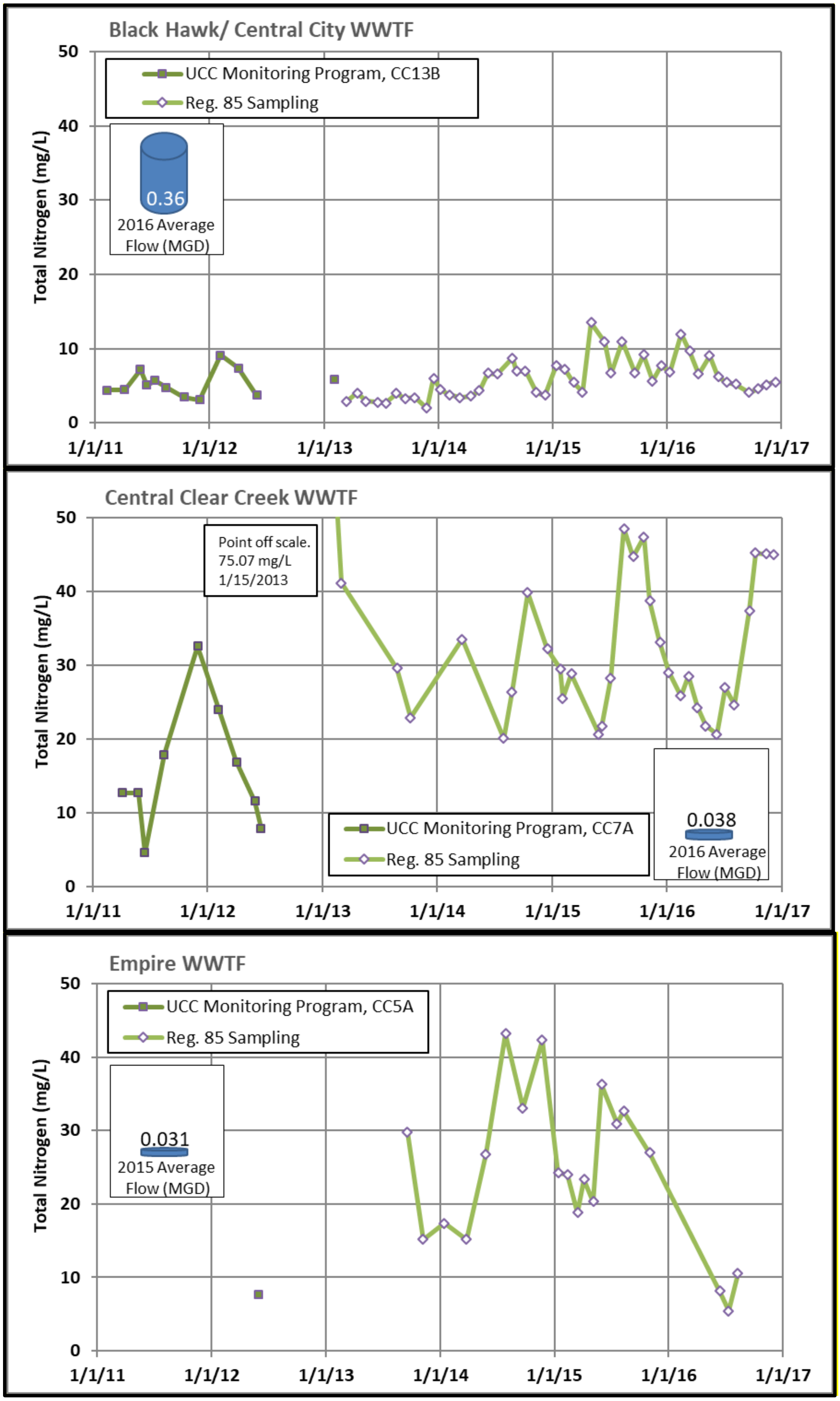
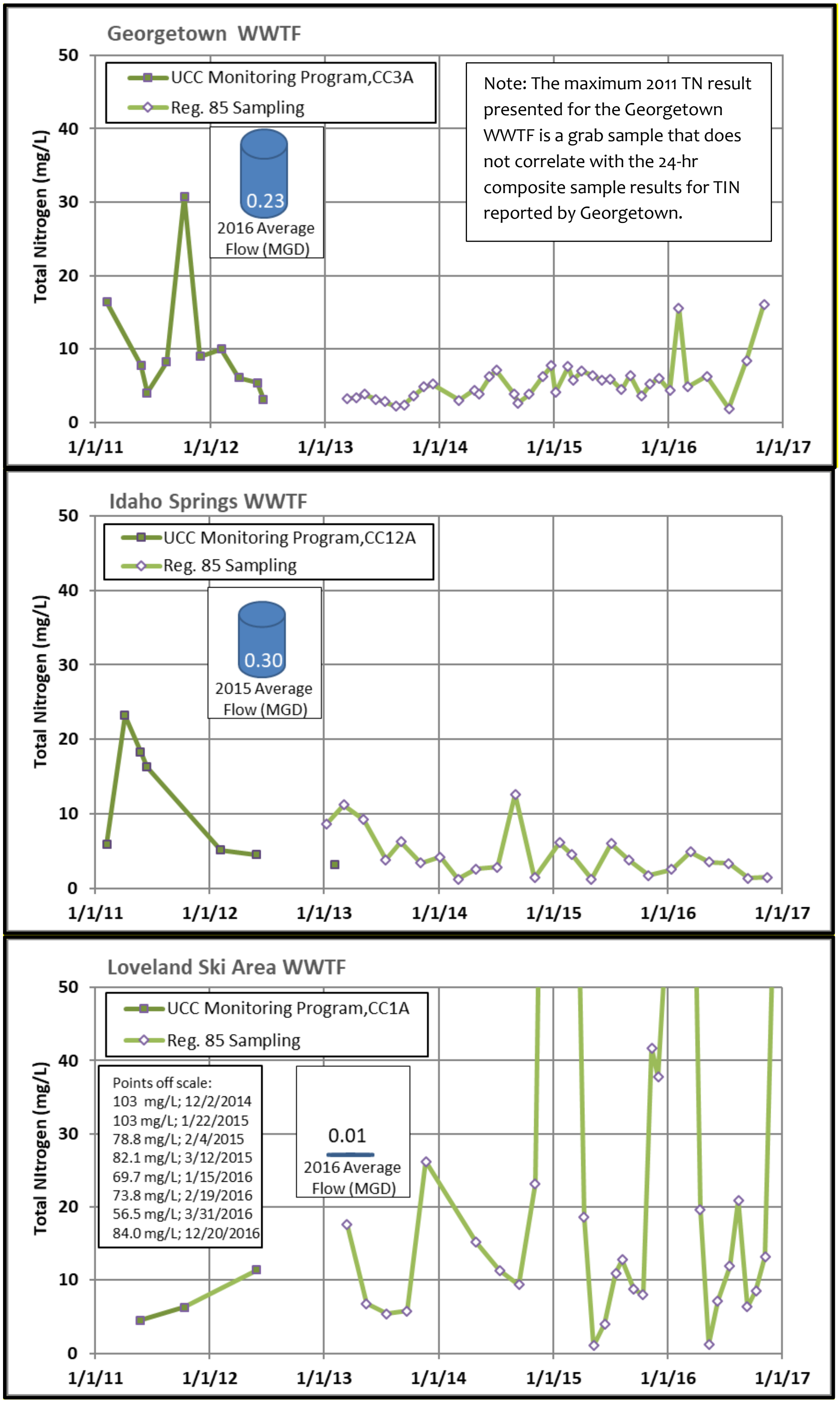


Figure 11. Effluent TN Concentrations (2011-2016) for Black Hawk/Central City, Central Clear Creek, and Empire WWTFs



Note: The maximum 2011 TN result presented for the Georgetown WWTF is a grab sample that does not correlate with the 24-hr composite sample results for TIN reported by Georgetown.

Points off scale:
103 mg/L; 12/2/2014
103 mg/L; 1/22/2015
78.8 mg/L; 2/4/2015
82.1 mg/L; 3/12/2015
69.7 mg/L; 1/15/2016
73.8 mg/L; 2/19/2016
56.5 mg/L; 3/31/2016
84.0 mg/L; 12/20/2016

Figure 12. Effluent TN Concentrations (2011-2016) for Georgetown, Idaho Springs and Loveland Ski Area WWTFs

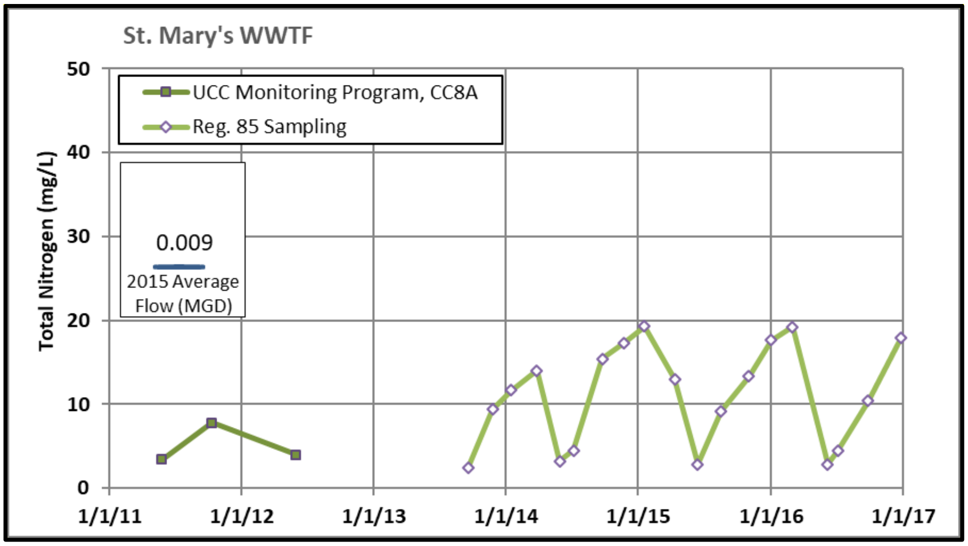


Figure 13. Effluent TN Concentrations (2011-2016) for St. Mary's WWTF

D. Illicit Discharges and Emergency Response

Limitation and control of illicit discharges and the timely response to unexpected upstream releases are key to controlling the potential effects of these incidents on in-stream and reservoir water quality. Programs to address these issues continue to be effective and are a focus of stakeholders.

1. Illicit Discharges

The City of Golden responded to 54 reports of illicit discharges or potential discharges to the storm sewer system in 2016. This resulted in the issuance of eight written and 16 verbal warnings. In three cases, clean-up costs were levied. Jefferson County inspected nine reports of illicit discharges, each of which resulted in enforcement actions. The county maintains a comprehensive storm sewer outfall map. This map is maintained to enable the tracing and investigation of illicit discharges and illegal dumping. The Illicit Discharge Detection and Elimination Program of the City of Arvada issued eight written Notices of Violation. The city's vacuum trucks were often used to conduct clean-ups. This was necessary where the responsible party was not identified or was unable to clean up the spill. In addition, Arvada conducted dry-weather screenings of outfalls. These outfall inspections help identify and eliminate potential sources of illicit discharges. Further, these are used to evaluate the condition of outfalls and identify those in need of repair. Outfalls found to be in need of repair are listed on a maintenance schedule.

2. Emergency Response

Clear Creek County uses the Code Red Emergency Call-Down System. This system is used to promptly and effectively notify downstream users of Clear Creek water of any potential contamination from an upstream source. The Clear Creek Office of Emergency Management continues to maintain and update the call lists database. The system applies to incidents / spills into Clear Creek and its tributaries that occur in Clear Creek County.

In 2016, the dispatch centers of Clear Creek County, the City of Golden, and Jefferson County launched nine calls for incidents within their respective jurisdictions that impacted Clear Creek. Clear Creek County launched a total of three calls; one in response to a raw sewage leak and two related to traffic accidents.

E. Nonpoint Source Control, Stormwater Management, and Remediation

Additional efforts to reduce pollutant and nutrient loading to Clear Creek are discussed in this section. The sources in the previous two sections, WWTFs and illicit discharges, are types of point sources. The sources in this section are primarily non-point sources, including stormwater and erosion. It also includes OWTS monitoring and regulation and the remediation of abandoned mines. The following subsections provide selected highlights of such activities in 2016.

1. Erosion and Sediment Control

City of Golden: The City of Golden operates under a Municipal Separate Storm Sewer System (MS4) permit and is designated a Qualifying Local Program by the Water Quality Control Division. Under this permit and designation, the City ensures that erosion and sediment controls are implemented on construction sites. In 2016, the City of Golden administered 33 stormwater-quality construction permits and conducted 542 erosion and sediment control inspections. These inspections resulted in 112 written and 85 verbal notifications of violations. Two stop-work orders were issued and at two sites performance security for corrections was used.

The Stormwater Maintenance Program of the City of Golden performs yearly inspections on all private systems requiring routine cleaning and maintenance. In 2016, 288 inspections were conducted resulting in 194 maintenance request letters sent to land owners. In addition, municipal inlets are inspected and cleaned twice each year by the city's Stormwater Division. This aggressive schedule helps increase the efficiency of system operation and improves the quality of stormwater released to the creek. Stormwater conveyance system improvements have included sumped manholes and sediment traps. The sumped manholes allow for the settling of solids in stormwater. These sumps are cleaned twice each year, yielding an average of one cubic yard (CY) per cleaning. In addition to the reconfigured channel and sediment trap in Tucker Gulch, the City has also installed sediment traps in ponds and at outfalls. In 2016, sediment traps removed and captured 403 CY of debris that would have otherwise been released to Clear Creek.

Jefferson County: The MS4 permit program of Jefferson County includes construction site runoff control, cost-construction site runoff control, and pollution prevention/good housekeeping. Each control program is supplemented by a corresponding inspection program. The county maintains a small-site erosion control manual that explains the basic principles of erosion control and illustrates techniques to control sediment from small development sites.

City of Arvada: The City of Arvada's MS4 Program includes a concentrated effort to ensure that erosion and sediment controls are implemented on construction sites. In 2016, 1,473 erosion and sediment control inspections were conducted on 146 active construction sites. These inspections resulted in 32 notices of violation. For two builders building inspections were made contingent on the demonstration of compliance.

A second key component of Arvada's stormwater program is the inspection and enforcement of permanent stormwater BMPs. Examples of these include detention and retention ponds, swales, and underground proprietary devices. In 2016, 13 new permanent BMPs were added to the 194 BMPs previously implemented since the program began. The city inspected 58 permanent BMPs in 2016. Inspections are followed by reports identifying areas of non-compliance to be addressed. These reports are sent to owners of the stormwater conveyance.

Arvada's Wastewater Division is responsible for storm sewer maintenance under the MS4 permit. In 2016, the Wastewater Division inspected 3,036 inlets and manholes, of which 818 required maintenance and cleaning. Crews also cleaned 8,064 ft of storm sewer pipe resulting in the removal of 230,580 pounds (lbs) of debris from the system. Projects to improve stormwater drainage were completed at nine locations.

Pollution prevention is an ongoing component of the City of Arvada's stormwater protection efforts. All City of Arvada facilities with runoff control plans are inspected twice annually. Employee training on pollution prevention for municipal operations is conducted routinely. The training focus is two-fold: 1) preventing and mitigating any potential contamination sources from city facilities, and 2) spill response procedures specific to work in the field. Arvada's spill response hotline is answered after-hours by personnel at the water treatment plant, who then dispatch on-call staff to respond to the spill.

Clear Creek County: As part of the county's efforts to control the releases of sediment to Clear Creek, permits are required for BMPs and floodplain development. The purpose of these permits is to monitor BMP performance and ensure environmental and public safety. In 2016, the county issued six permits for floodplain development and finalized four. In addition, 13 BMP permits were issued and five finalized.

Colorado Department of Transportation: A major focus of CDOT projects is the control and capture of sediment from highway maintenance activities. During construction of these projects, attention is paid to control of erosion and sediment.

In 2016, the eastbound Peak Period Shoulder Lane Project on I-70 was substantially completed. The project includes permanent sediment control facilities (BMPs) that represent a significant improvement relative to pre-project conditions. Also, the US 6 Acceleration Lane Project was completed in 2016. This project created a formal chain-down station at the eastbound on-ramp from US 6 to I-70 near the headwaters of Clear Creek. Water-quality BMPs were included at the ramp and chain station areas to address the high rates of sand usage at this location.

2. Onsite Wastewater Treatment Systems

In 2016, Clear Creek County implemented the final phase of new regulations for OWTS (also known as septic systems). Under the new regulations, operating permits are required for any OWTS that that is designed to provide higher level treatment. The permit verifies that the mechanical and/or electrical components of the system are operating as designed. In 2016, seven operating permits were issued, 19 standard treatment permits, 10 repair or alteration permits, and 115 use permits were issued.

3. Remediation

The Clear Creek Watershed Foundation (CCWF) completed the Middle North Empire Creek Restoration Project in 2016. This was the second of three phases to address sources of contamination to North Empire Creek. North Empire Creek drains into the West Fork of Clear Creek near the Town of Empire

The project included four primary components. In the first, the large (0.5 acre) Gold Dirt mine waste pile was reshaped and revegetated. Second, Equator mine waste pile was removed to a repository. Third, a fluvial fan containing highly mineralized material was removed to a repository. The completion of these three activities allowed the channel of North Empire Creek to be restored.

Gold Dirt Mine Waste Pile (left). Restored Channel of North Empire Creek (right)

F. General Public Education, Outreach and Partnerships

Outreach activities, primarily through festivals, seminars, and public meetings, are a key component of educating the public about the protection of water quality.

1. General Public Education and Outreach

Clear Creek Watershed Foundation: The CCWF organized and hosted the eighth annual Clear Creek Watershed Festival in September 2016. This popular event is held at Courtney Riley Cooper Park located along the banks of Clear Creek in central Idaho Springs. The event and creek-side venue provide the opportunity for watershed stakeholders to share their message and educate participants.

City of Golden: The Stormwater Program of the City of Golden continues its public education campaign by distributing educational materials and attending or hosting public events. Events in 2016 included the Water-Wise Seminar and Greener Golden. At these events, Golden distributes Garden-in-a-Box kits to encourage the planting of water-conserving landscapes.

Jefferson County: Jefferson County residents, and visitors to the watershed, had opportunities to learn about and be involved in programs that promote water quality and environmental stewardship. These opportunities were made available as part of the county's Public Education and Outreach and Public Participation and Involvement programs. The Jefferson County MS4 and floodplain programs continue to participate in a number of public events to reach diverse audiences.

City of Arvada: Public education and outreach continues to be a major component of Arvada's Stormwater Program. Education for contractors, city personnel, citizens, and students is provided by the city on an on-going basis. This ensures that the public is aware that city storm drains flow directly to waterways and that certain activities can contaminate those waterways. The city provides the public with various resources to increase their awareness, such as the adopt-a-street or trail program, storm drain marking, household hazardous chemical disposal and recycling, and brochures and demonstrations that are focused on preventing stormwater pollution. In 2016, city stormwater and environmental education staff had a booth at two festivals and spoke one-on-one to attendees about issues concerning water quality.

Hydroscape at City of Arvada's Stormwater Division Booth at Trails Day

2. Recycling and Disposal of Household Chemicals and Hazardous Waste

Rooney Road Recycling Center: This facility provides critical recycling and disposal services for household hazardous waste and electronics. In 2016, the facility collected more than 604,000 lbs of household hazardous waste. Support and participation with the Rooney Road facility are provided by both Jefferson County and the City of Golden.

Clear Creek County: The Clear Creek County Transfer Station and Recycling Center continues to support efforts to protect the watershed. In 2016, three one-day household hazardous waste collection days were held. The year-round collection of household paint, through the PaintCare Program, collected 25 4'x4'x4' Gaylord boxes of paint. Approximately 685 CY of screened compost from the transfer station were put to beneficial use in the county. Compost is offered for sale to the public and at a low or no cost for reclamation projects in the county. In 2016, the transfer station received 3,690,980 lbs of household trash, construction material, furniture, tires, appliances, and rubble. Residents recycled 871,520 lbs of metals, glass, plastic, cardboard, paper, and electronics.

3. Pharmaceutical Disposal

Prescription drug take-back events are an important way of ensuring that unused prescription drugs are not disposed of in landfills or sanitary sewers, thus preventing them from reaching Colorado's waterways. The City of Arvada and Arvada Police Department hosted a prescription drug take-back event at City Hall on April 7th, 2016 and recovered 2,875 lbs of prescription drugs. Also in 2016, the Idaho Springs Police Department held its first ever drug collection in event in cooperation with the Clear Creek Sheriff's Department.

G. Other Activities

The following section provides a description of various water-quality related activities that occurred in the watershed in 2016.

1. Standley Lake Infrastructure and Standley Lake Park

The Standley Lake Operating Committee, working with FRICO, continued to address water resources and water-quality issues along the Croke ditch and in Standley Lake itself. To that end, the following accomplishments were completed

The inlet conduits and associated piping of the Standley Lake facilities were shut down and inspected in the fall of 2016. This was done to help ensure the continued reliable delivery of water from the lake to water treatment facilities. A second shut down was necessary to inspect the 102-inch lines on the upper and lower intakes. These shutdowns required the City of Westminster to use the Standley Lake Bypass Line. This line bypasses the lake, routing water directly from the canals feeding Standley Lake to the water treatment facilities. During this time, water was delivered to the City of Northglenn by diverting water from the Semper pipeline into the FHL canal. To help keep Standley Lake free of aquatic nuisance species (ANS), all boats and equipment were sprayed for ANS prior to launching and diving.

The popularity of Standley Lake as a regional amenity was demonstrated by a 15-20% increase in visitation in 2016. Improvements to Standley Lake Park include the ongoing trail work for the Refuge-to-Refuge trail. Maintenance to the park included control measures for noxious species; both terrestrial and aquatic. Goats were used to mitigate noxious weeds in various areas of the park. Additionally, approximately 1,600 inspections were conducted on watercraft to control the spread of ANS.

2. City of Arvada Water Discharge Permit Management

As part of efforts to maintain and improve water quality, Arvada is committed to responsibly managing water discharges so as to not degrade downstream water quality. Two examples of this commitment are described in the following.

In 2016, Arvada made routine annual discharges of residual treated drinking water from the Arvada Water Treatment Plant. These routine annual discharges occur after the plant is shut down in the fall and remaining water is discharged to Ralston Creek. Water is discharged under a general discharge permit and is analyzed prior to discharge to ensure it meets all stream standards.

The City also obtained a new subterranean dewatering permit. This permit allows the operation of a system to dewater the foundation of the newly constructed Transit Hub. A sampling well and pump system have been installed on site to allow Arvada to conduct monitoring necessary for permit compliance.

3. Clear Creek County Wildfire Protection Plan and Wildfire Mitigation Grant Program

The Clear Creek County Office of Emergency Management continued work on community wildfire mitigation. The Echo Hills Wildfire Mitigation Project is ongoing. Work completed in 2016, or slated for completion in 2017, includes wildfire reduction measures on over 30 acres of County Right-of-Way and the creation of defensible space and hazardous fuels reduction around homes on approximately 23 properties covering 57 acres.

4. Source Water Protection Plans

Both Idaho Springs and Black Hawk worked on developing Source Water Protection Plans. The plan for Idaho Springs was successfully adopted. It is anticipated that Black Hawk's plan will be adopted in 2017.

5. Aquatic Invasive Species Management

Eurasian Watermilfoil - Eurasian watermilfoil (EWM; *Myriophyllum spicatum L)* is a non-native, noxious aquatic weed that grows rapidly at depths of up to 35 ft. EWM can grow into dense mats that severely interfere with recreation and can provide a substrate for blue-green algae growth. Blue-green algae blooms can ultimately cause taste and odor events in drinking water supplies. EWM was first observed in Standley Lake in 1998 and positively identified in 2000. EWM weevils, an herbivorous insect specialized to EWM, have been stocked on the west side of the lake on five occasions since 2002. When an adequate weevil population is sustained, the weevils may be able to control the spread of the milfoil. A substantial decrease in milfoil densities has been observed since the weevil stocking program. Additional contributors to EMW density declines include other insects, reservoir drawdown, and competition from native plants.

Eurasian watermilfoil near Control Site (Location M1, see Figure 14) in 2002

The 2016 EWM survey was performed on August 22, 2016. This marked the third consecutive year that the survey was performed[2] by City of Westminster personnel. Each of the ten sample sites (Figure 14) was surveyed using an electronic depth finder to identify the densest part of the weed bed. A one-square meter (m^2) sample was collected at each location using a 1-meter wide rake. The vegetation samples were then returned to the lab for identification and enumeration. A subsample of 25 randomly chosen milfoil stems were selected for examination. A dissecting scope (40x magnification) was used to evaluate insect populations, insect damage to plants, and disease.

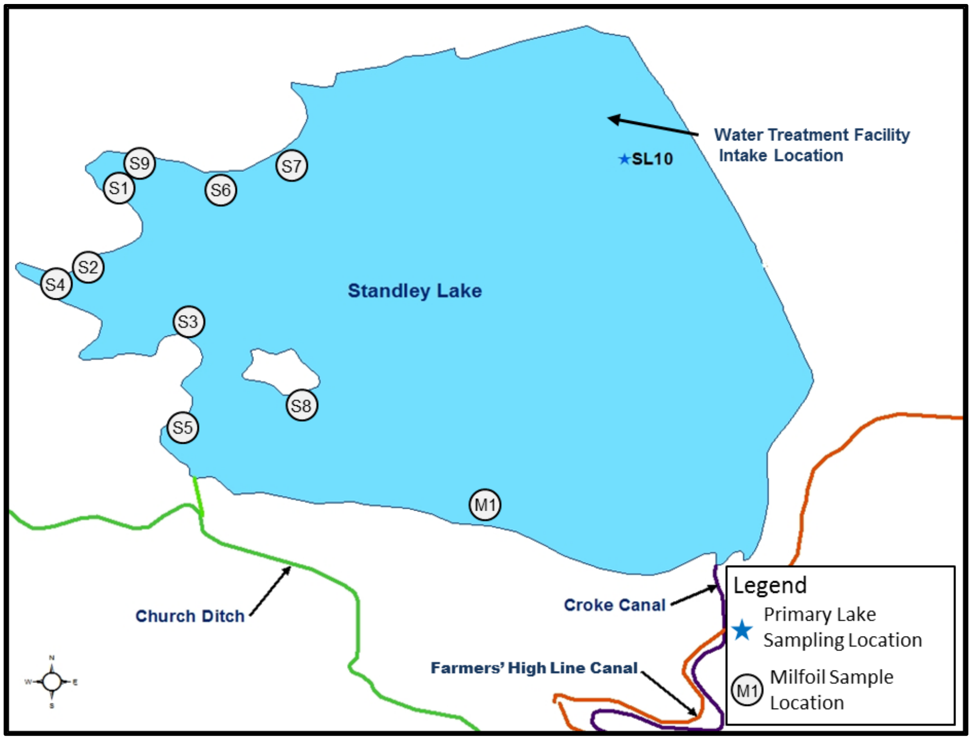


Figure 14. Milfoil Sample Locations

In 2016, average milfoil densities were 72.4 stems/m^2 (Figure 15). These densities are higher than the 2011 to 2015 average of 49.6 stems/m^2. The period from 2011 through 2016 has shown variability in milfoil density, however, it appears that densities have reached a semi-stable condition with an average density around a level of approximately 50 stems/m^2. The 2016 densities are on the higher end of conditions observed in the post-2011 period. The highest densities of EWM in 2016 were recorded at locations S8 and S9 (Figure 16), with densities greater than 100 stems/m^2. The remaining sites all had lower densities of EWM, ranging from 20 to 80 stems/m^2.

---

[2] As discussed in previous reports (e.g. Hydros [2016]), the plant survey underwent a change in methodologies in 2014. Prior to that time, sampling was performed by divers and focused on EWM weevils. Beginning in 2014, the survey method began using a rake for sample collection. The effect of the change in sampling methodologies on milfoil densities is uncertain, given the lack of a direct comparison. However, the milfoil densities measured in the 2014-2016 period (rake method) are consistent with milfoil densities measured in the preceding years (diver method).

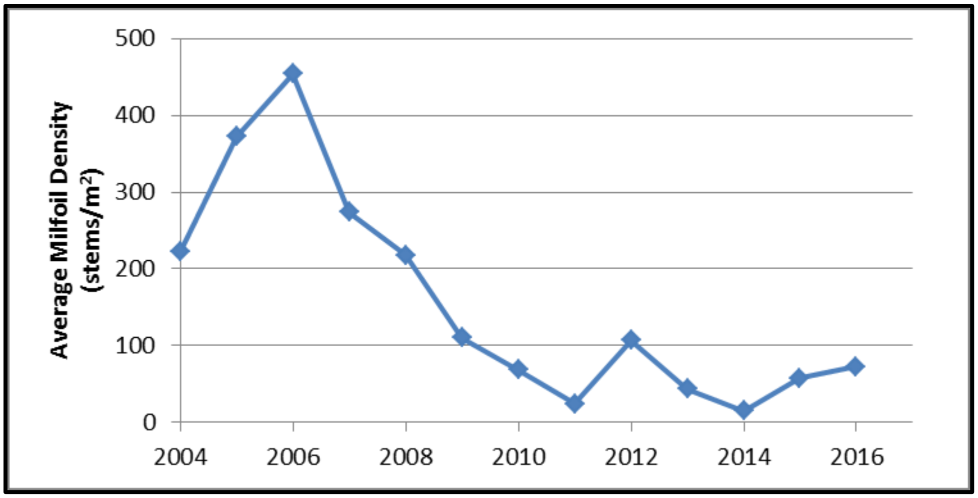


Figure 15. Average Milfoil Densities in Standley Lake (2004-2016) [pre-2014 data from Enviroscience (2013)]

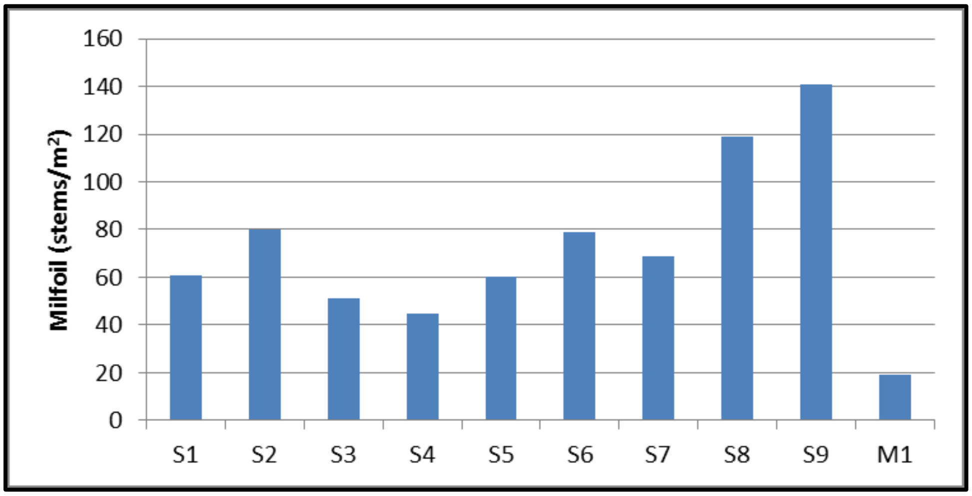


Figure 16. Milfoil Densities by Site, 2016

Weevil stocking appears to have played a significant role in the long-term decrease in EWM based on the observed relationship between weevil populations, EMW density, and plant damage. Many of the sites had strong evidence of weevil damage to EWM. Sites S2, S4, and S7 each had more than 70% of the EWM with weevil damage (Figure 17). However, other factors are likely contributing to the long-term decrease in EWM. Competition from other aquatic vegetation for the limited pool of available nutrients, minerals, and light provides an additional control on milfoil populations. This is shown in Figure 18 which provides a comparison of the abundance, expressed as a percentage of the total plant population, of milfoil at each sample site. The 2016 sampling showed an increased abundance of milfoil (average of 87% for all sites), relative to the 2015 (64%) and 2014 (51%) sampling events. The past three years have been a period of high water storage with minimal drawdown (discussed further in Section VI A). This may be a factor in the increasing abundance of EMW.

In summary, average EWM densities in Standley have decreased nearly 90% from peak densities in 2006. Since 2011, EMW densities have remained far lower than the peaks. From 2011 to 2016, the average EMW density has been around 50 stems/m^2. The maintenance of these lower EWM densities results from multiple controlling factors including EWM weevils, other herbivorous insects, and competition from other aquatic vegetation.

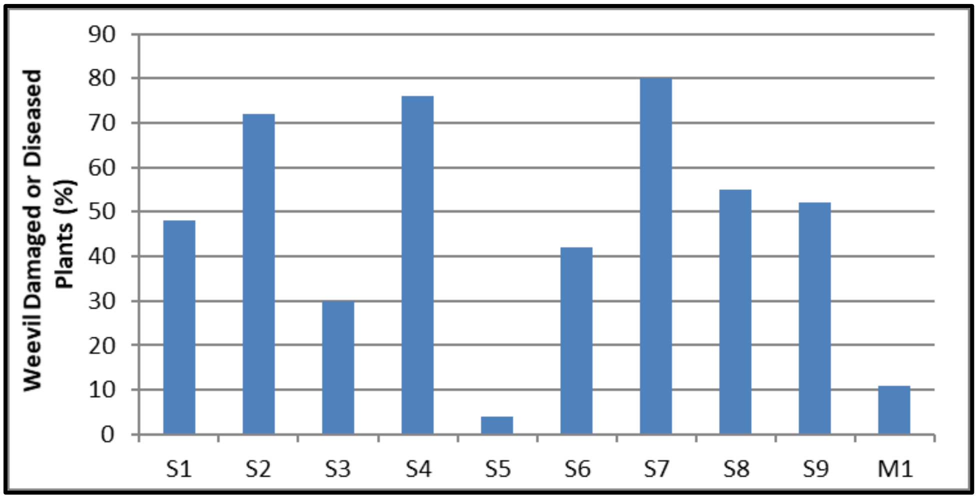


Figure 17. Weevil Damaged or Diseased Plants by Site, 2016

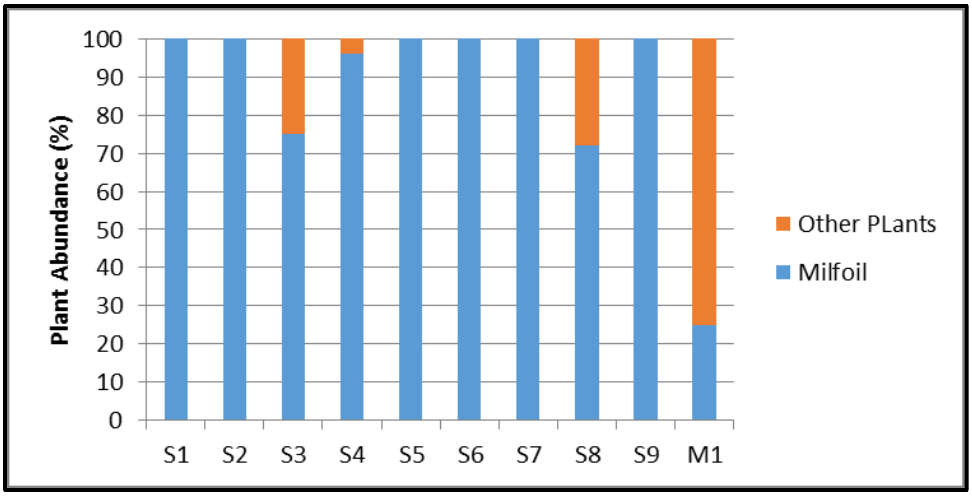


Figure 18. Relative Milfoil Abundance in Standley Lake in 2016

Zebra and Quagga Mussels - Zebra and quagga mussels are non-native, aquatic invasive species. They can be introduced to new water bodies by the unintentional transfer of organisms from an infested water body, often via boats or fishing bait. These mussels cause serious damage to the ecosystem and require costly control procedures for drinking water treatment facilities. Both zebra and quagga veligers (zebra or quagga mussel larvae) were discovered in a few of Colorado's lakes in 2008. Prevention is key to protecting Standley Lake from aquatic mussel infestation. An intensive boat inspection and decontamination program was initiated in 2008 to protect the lake from new invasive species. Additionally, no live aquatic baits are allowed in the reservoir.

Monitoring for these mussels in Standley Lake includes three methods: zooplankton tows, substrate samplers, and shoreline surveys. Standley Lake is monitored for aquatic mussels every two weeks using the zooplankton tow procedure. The tows are performed at the lake inlets, SL-10 (Figure 2), and the boat ramp/outlet area. Several invasive species have a planktonic life stage, and sampling with the plankton nets can provide early warning of infestation. In addition, substrate samplers, constructed and monitored by Colorado Parks and Wildlife, are placed throughout the lake. Substrate samplers are made up of a float, rope, plastic plates, and an anchor weight. A plate is located every 10 ft from the surface to the bottom of the lake. The plates and ropes are checked periodically for aquatic mussel growth. A plate or rope that feels like sand paper will be scraped and examined under the microscope for veligers. Shoreline surveys are performed when the water level is at the lowest for the year. A shoreline survey consists of walking the shoreline in teams looking for adult mussels attached to any hard substrate. Sampling tows, substrate samplers, and shoreline surveys from 2016 show that Standley Lake continues to be free of zebra and quagga mussels.

IV. Upper Basin Flows and Water Quality

The previous section provided highlights of the activities and accomplishments undertaken by interested entities to manage, enhance, and protect the water quality of the Clear Creek watershed. This section describes an analysis of water-quality data in the Upper Basin in 2016. Constituents included in this analysis are discharge (flow), total suspended solids, total phosphorus, and total nitrogen. The analysis is based on data from two sampling locations CC26 (Clear Creek at Lawson Gage) and CC59/60 (Clear Creek at Church Ditch headgate) (Figure 6). The data from each location include both grab samples and composite samples. Grab samples represent the conditions at a single point of time. Composite samples, comprised of multiple samples collected over 24 hours represent the conditions occurring over the entire collection period. The data presentation and discussion in this section focus on ambient (non-event samples). However, loading estimates are presented both including and excluding the event samples (e.g. storm event samples).

Water quality in the upper portion of the Upper Basin is represented by location CC26. This station is located on the main stem of Clear Creek (Figure 6) between Georgetown and Idaho Springs. This location includes samples from stations CC26 (grab) and CCAS26 (autosampler). Water quality in the lower portion of the Upper Basin is represented by location CC59/60. This station is located on the main stem of Clear Creek. It is just upstream of the headgates of the Croke and FHL canals which feed Standley Lake (Figure 6). This location includes samples from stations CC60 (grab) and CCAS59 (autosampler).

A. Discharge

The annual hydrographs for Upper Basin location (CC26) exhibited twin peaks in flows—one higher peak in early June followed by a secondary peak in late June (Figure 19). The mid-June decrease in flows appears to have been driven by a period of low temperature in the upper portion of the basin; the low temperatures would have decreased the rate of snow melt. The overall pattern--rising in early April and steeply increasing mid-May, coinciding with snowmelt runoff, was consistent with past years. The annual hydrograph at the lower location (CC60) demonstrated patterns consistent with both the twin-peak in flows and the overall patterns. At both locations, peak annual flow rates occurred in early June and the falling limb of the snowmelt hydrograph extended through the summer punctuated by a few increases in stream flow associated with precipitation events.

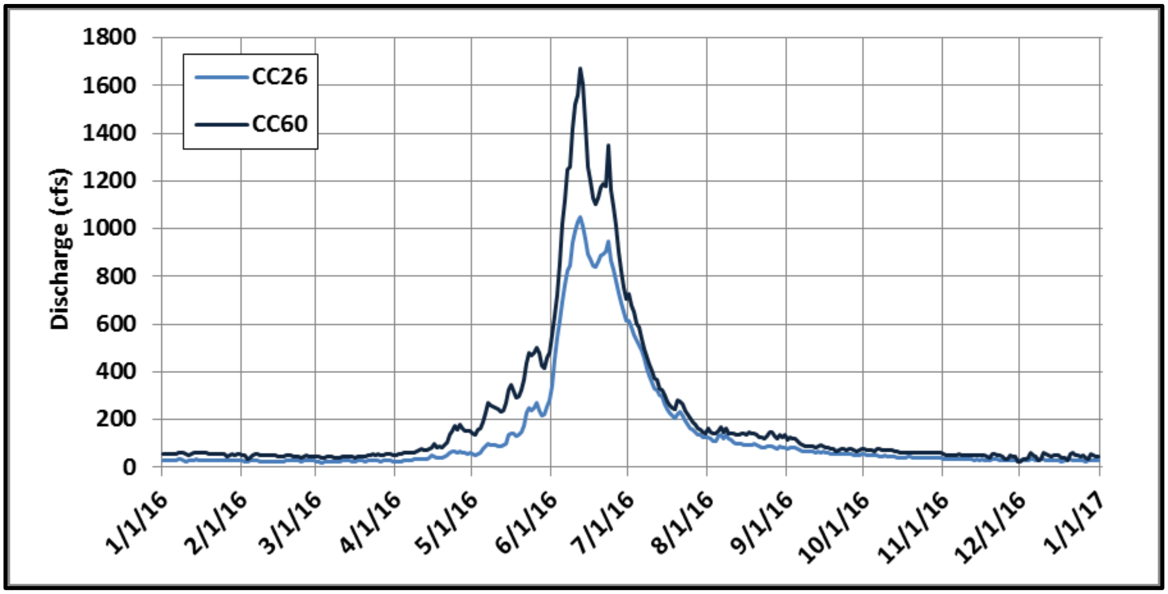


Figure 19. 2016 Clear Creek Hydrographs (CC26, CC60)

Total annual flows at the upper station (CC26) of 98,860 AF were below (-14%) the 2011-2015 average of 114,634 AF. Annual flows at the lower station (CC60) of 146,029 AF were also lower (-9%) than the 2011-2015 average of 160,691 AF. Compared to the longer-term average however, flows at CC60 were slightly (5%) above the average (1975-2015, 139,334 AF). This reflects the higher than normal flows in recent years. Total annual flow volumes (in AF per year) for 2011-2016 are presented in Figure 20, which also includes the 2011-2015 average flow volume at each location for reference.

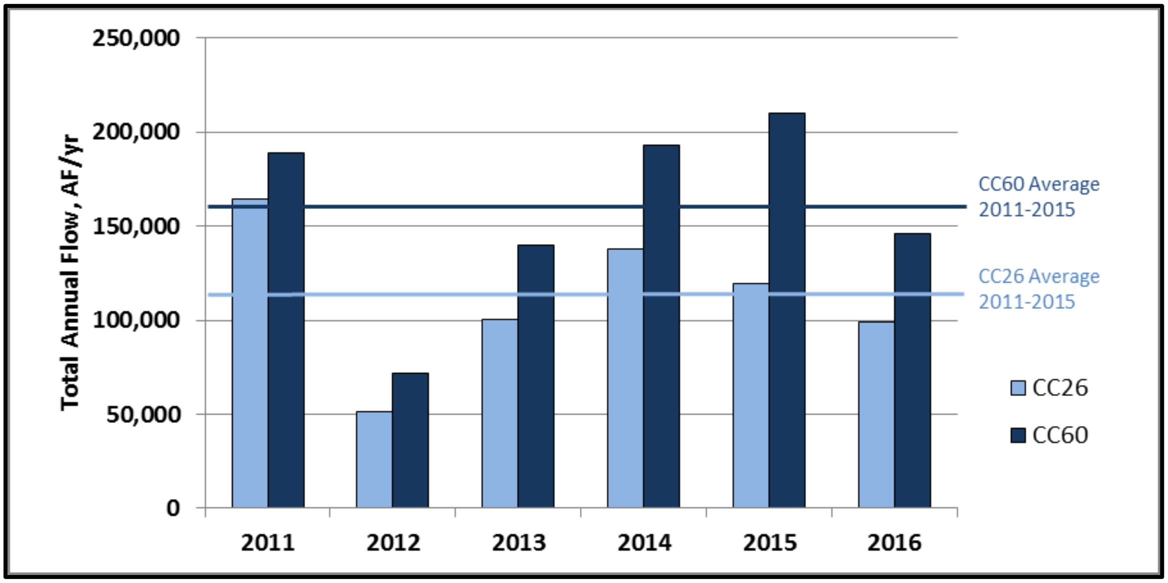


Figure 20. Total Annual Flow in Clear Creek at CC26 and CC60, 2011-2016

Hydrographs from CC60 for 2011-2016 are shown in Figure 21. The timing, patterns, and magnitude of flows in 2016 are generally consistent with those of previous years.

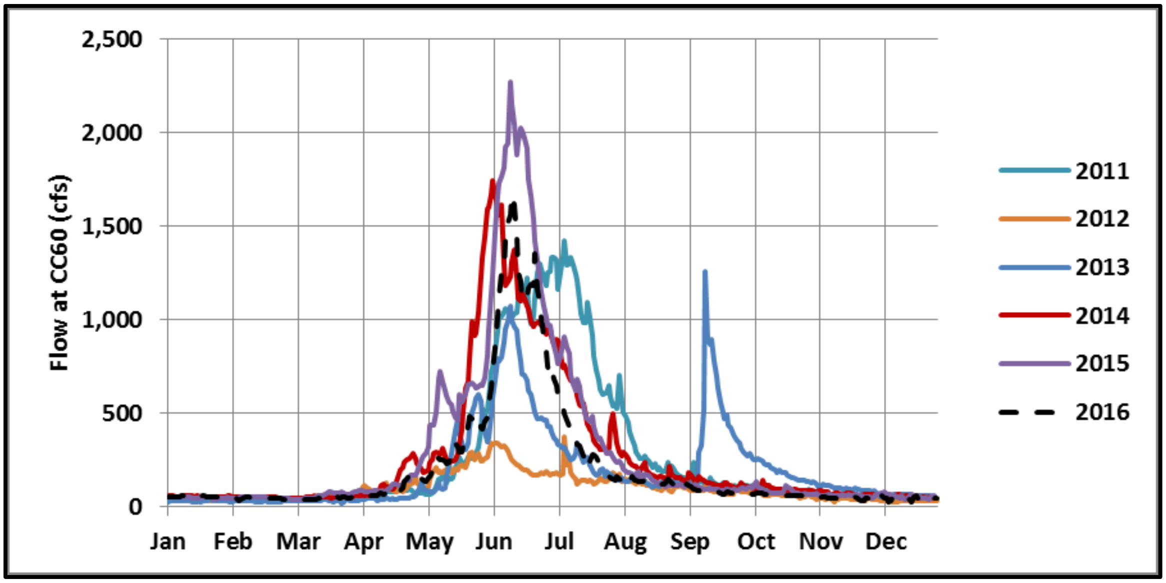


Figure 21. Annual Clear Creek Hydrographs for 2011-2016 (CC60)

B. Total Suspended Solids

Total suspended solids concentrations in 2016 from grab samples and ambient composites from at CC59/60 and CC26 are displayed in Figure 22. The highest TSS concentration (39 mg/L) was measured at the lower station (CCAS59) on August 30, 2016. The maximum observed TSS (6 mg/L) for the upper portion of the basin (CCAS26) was observed on June 27, 2016. Changes in land use, increased anthropogenic disturbance, and decreases in forest cover tend all contribute to increased TSS concentrations at the lower station.

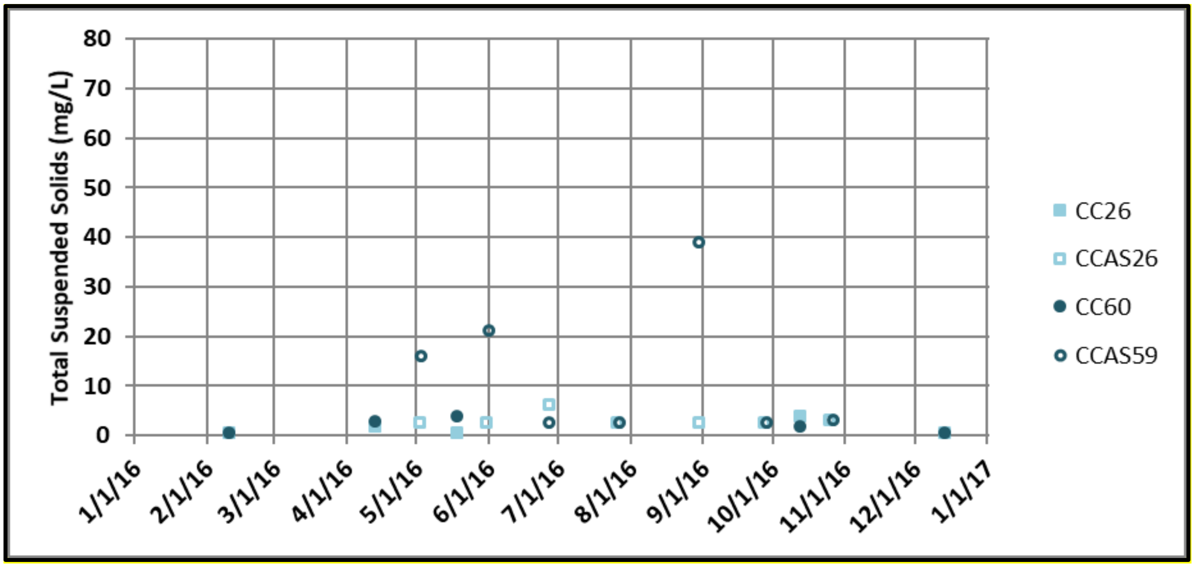


Figure 22. Total Suspended Solids Concentrations (Non-Event) in the Upper Basin, 2016

Non-storm-event TSS sample results in the Upper Basin over the last six years are presented in Figure 23. In this figure, and subsequent related figures for TP and TN, the November to March period is highlighted in grey. This is done to emphasize the seasonality of the observed water quality patterns. A general pattern of higher concentrations at the lower location (CC59/60) is apparent. Peak TSS concentrations at both CC59/60 and CC26 were consistent with peak concentrations observed in previous years.

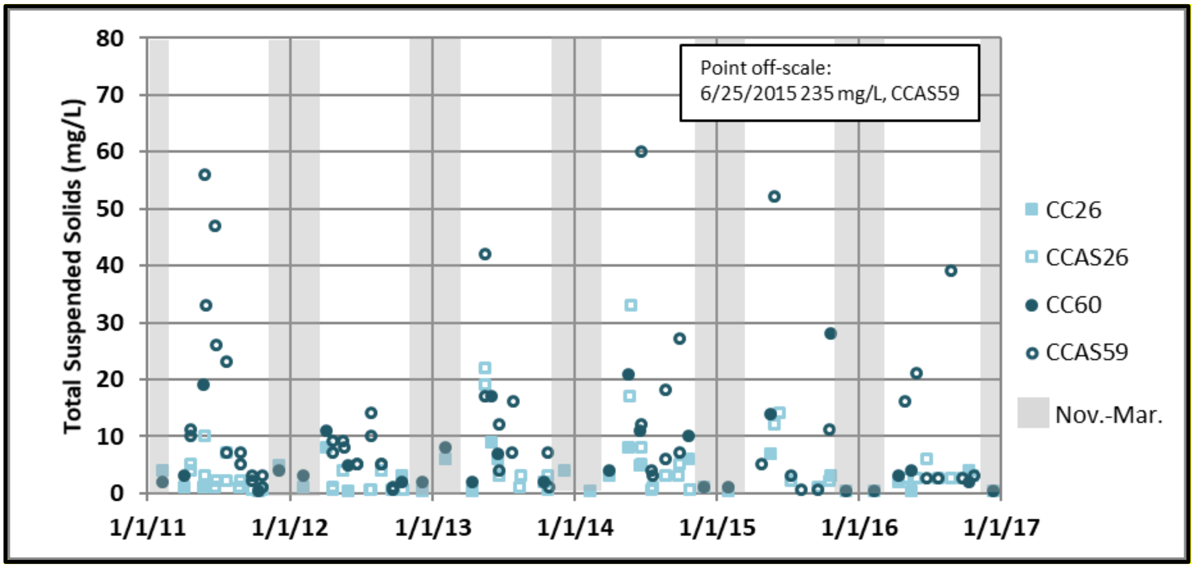


Figure 23. Total Suspended Solids Concentrations (Non-Event) in the Upper Basin, 2011-2016

Average monthly TSS concentrations in the lower portion of the basin in 2016 are compared to the average and range of previous years (2011-2015) in Table 5. Monthly concentrations in 2016 were generally lower than averages of the previous five years; May and June showed the largest magnitude differences (May 11.1 mg/L and June 25.8 mg/L below respective five-year averages).

Table 5. Monthly Average Total Suspended Solids Concentrations (Non-Event) in the Upper Basin at CC59/60

Month	2016 TSS Concentrations (mg/L)	2011-2015 Average and Range of TSS (mg/L)	% Difference -- 2016 Versus 2011-2015 Average
February	0.5*	3.5 (1.0-8)	-86%
April	3.0*	6.9 (2.0-11)	-56%
May	10.0	21.2 (5.0-56)	-53%
June	11.8	37.6 (4.0-235)	-69%
July	2.5*	9.7 (3.0-23)	-74%
October	2.5	6.6 (0.5-2.8)	-62%

* "Average" based on only one observed value.

One possible explanation for these decreases in concentration in May and June is that the sampling dates may have missed the peak concentrations during snowmelt. The samples collected in May and early June occurred on the rising shoulder of the flow peak (Figure 24). The samples collected in late June occurred between the peaks of flow. If patterns observed in previous years were followed, it is likely that higher TSS concentrations may have occurred in early- to mid-June during the period of sharply rising flows.

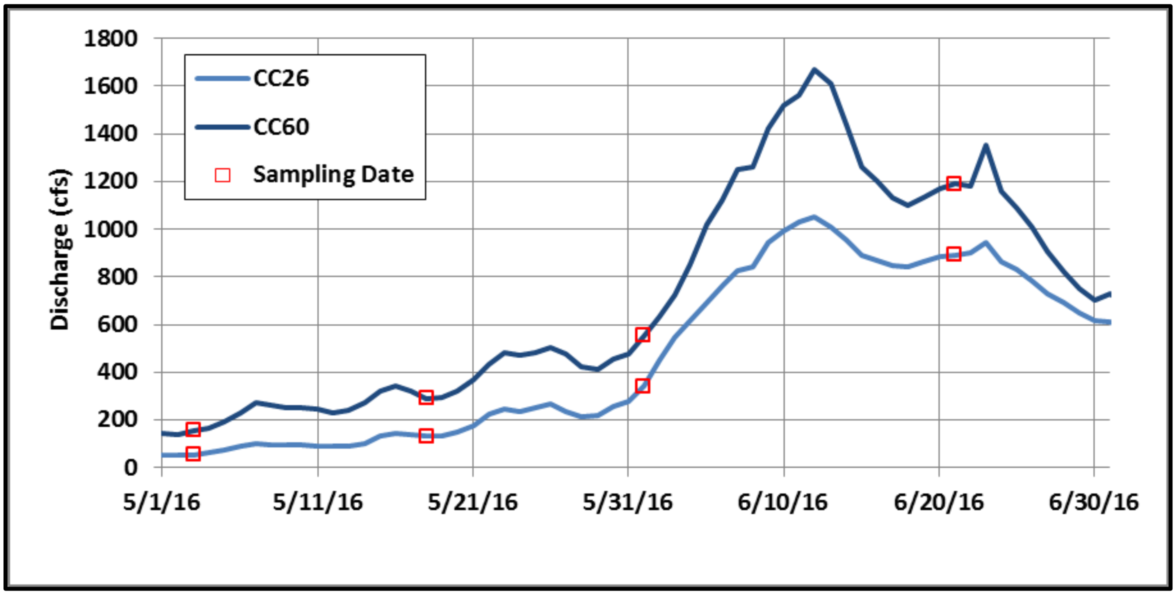


Figure 24. Sampling Dates for CC26 and CC60 in 2016 and Daily Streamflow Values

An analysis was performed of the longer-term record (2005-2016) of TSS concentrations in the Upper Basin. This analysis did not show evident patterns in TSS concentrations in the Upper Basin at either the CC26 or the CC59/60 locations.

Loads were calculated using daily flows and concentration data, from samples collected as part of the Upper Clear Creek/Standley Lake Watershed Water Quality Monitoring Program. A mid-point step function was used to fill in daily concentrations between available sample data. Annual loads are then calculated as the sum of individual daily loads. Non-storm-event TSS loading at CC26 and CC59/60 was calculated for 2016 and compared to estimates from 2011-2015 (Figure 25). At both locations, loads were lower than all other years except for 2012.

Volume-weighted concentrations were computed at the two key locations for the past six years (Figure 26). They were calculated by summing the annual load and dividing by the annual flow volume. Volume-weighted concentrations were lower than concentrations calculated for the past five years. This result is expected given that loadings were low but flows volumes were only slightly below average.

In summary, the TSS concentrations and loads in 2016 were lower than those typically observed. It appears possible that sampling in 2016 missed peak TSS concentrations during snowmelt. Both the upstream and downstream station showed similar seasonal patterns in TSS loading and concentrations.

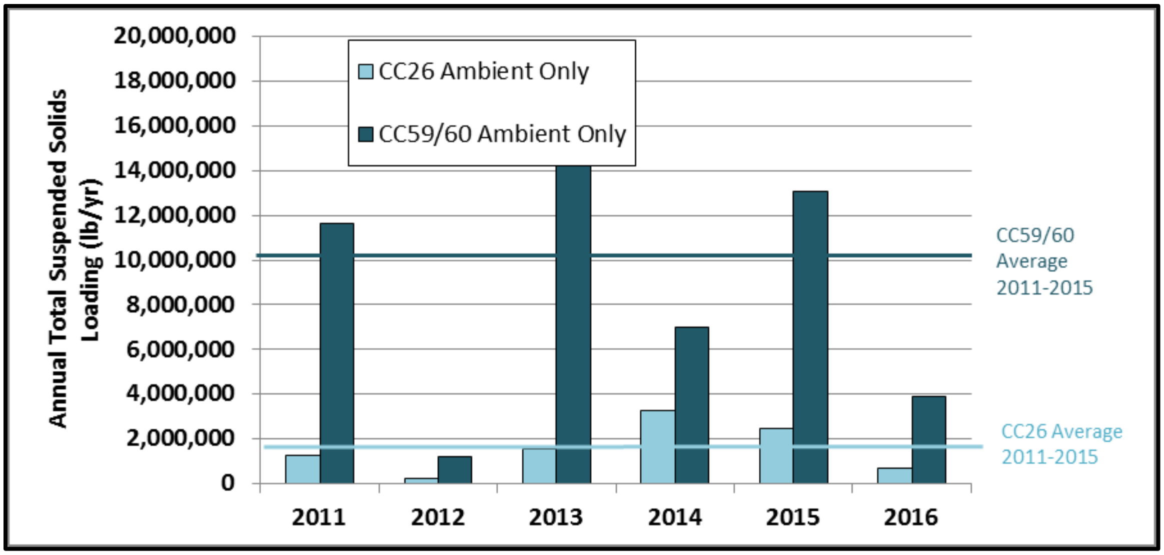


Figure 25. Total Suspended Solids Loading Estimates in the Upper Basin, 2011-2016

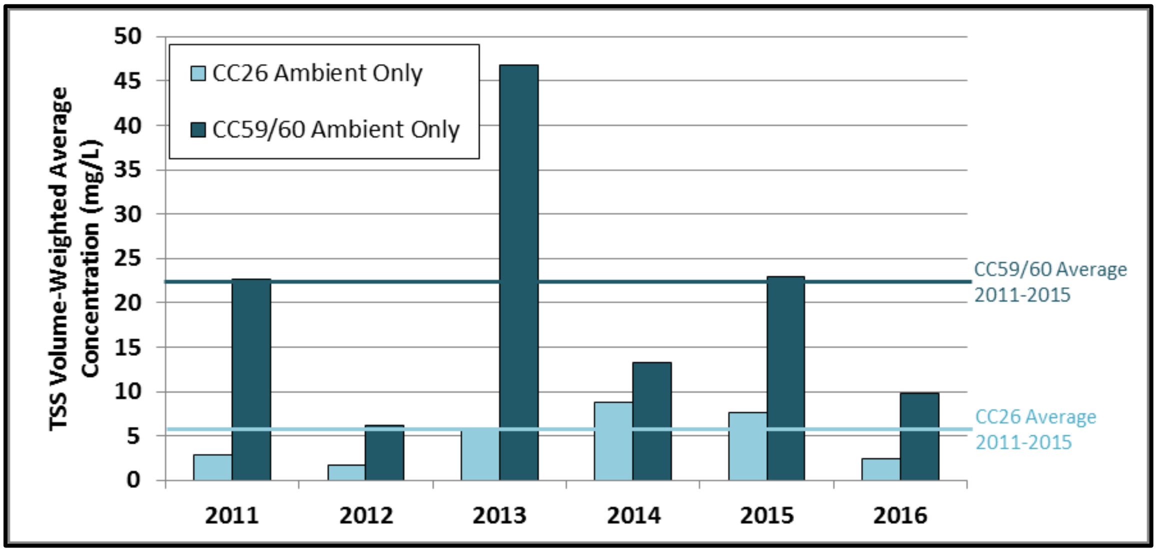


Figure 26. Total Suspended Solids Volume-Weighted Concentration Estimates in the Upper Basin, 2011-2016

C. Total Phosphorus

Total phosphorus concentrations from grab samples and ambient composites in the Upper Basin are displayed in Figure 27. At CC60 concentrations show a slight increase in May relative to the remainder of the year. At CC26, and for most of the year at CC60, TP concentrations show little variation and are typically around 10 µg/L. The maximum measured concentration of 26.6 µg/L occurred on June 1, 2016 at CC60.

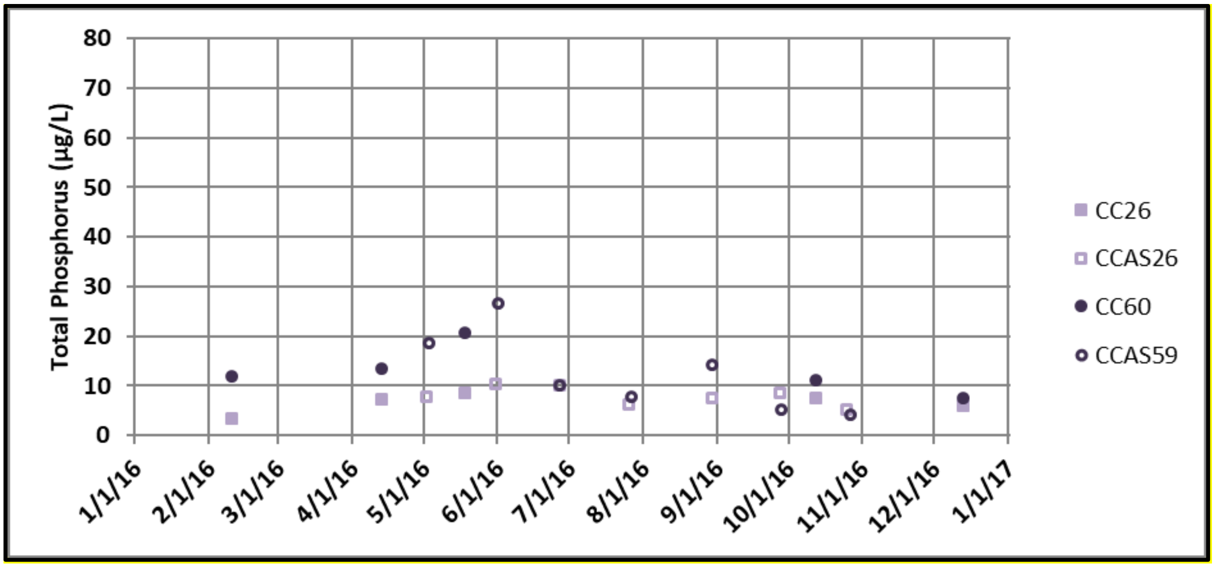


Figure 27. Total Phosphorus Concentrations (Non-Event) in the Upper Basin, 2016

Typically TP concentrations at both stations show a substantial increase during the snowmelt period. However in 2016, as can be seen in Figure 28, this pattern was not as strong as obseved in past years. As discussed for TSS, this may be explained by the timing of sample collection 2016. Conceptually, TP concentrations are closely linked with TSS due to particle-associated transport. The similarity in concentration patterns for TSS and TP in 2016 are consistent with this understanding.

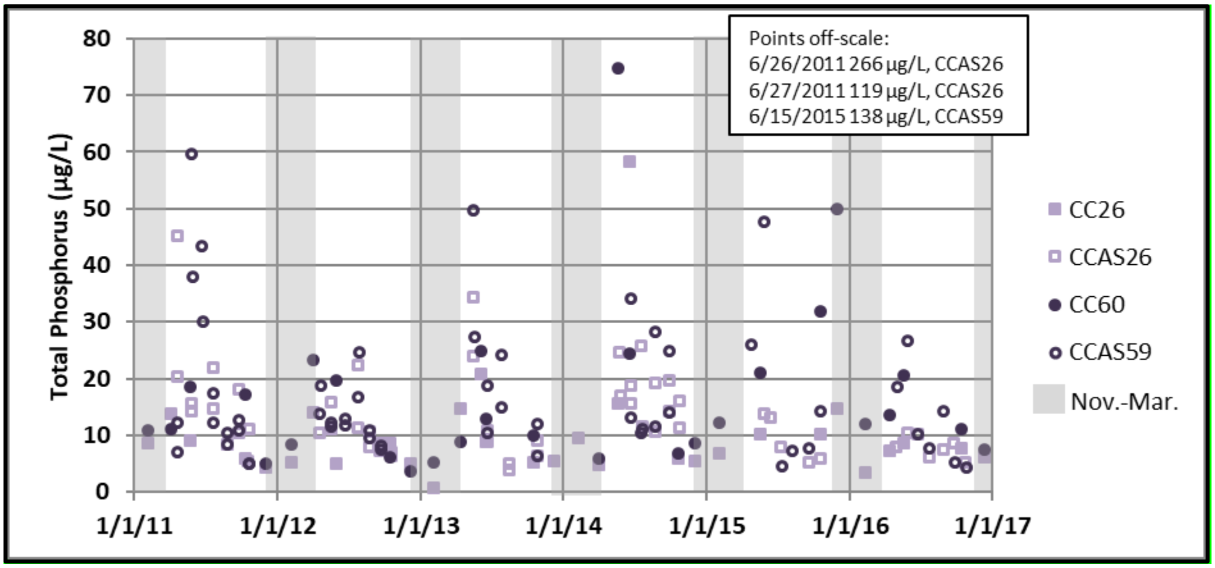


Figure 28. Total Phosphorus Concentrations (Non-Event) in the Upper Basin, 2011-2016

Monthly average TP concentrations for 2016 and the 2011-2015 average and range are shown in Table 6. In general, 2016 monthly TP concentrations are relatively consistent throughout the year. These concentrations are generally lower than the average 2011 to 2015 concentrations.

Table 6. Monthly Average Total Phosphorus Concentrations (Non-Event) in the Upper Basin at CC59/60

Month	2016 Average TP (µg/L)	2011-2015 Average and Range of TP (µg/L)	% Difference -- 2016 Versus 2011-2015 Average
February	12.0*	9.2 (5.3-12.3)	31%
April	13.5*	14.0 (5.9-25.8)	-3%
May	19.5	32.7 (11.5-74.7)	-40%
June	18.4	32.8 (10.3-138)	-44%
July	7.7*	15 (4.5-24.5)	-49%
October	7.7	11.6 (4.8-31.9)	-34%

*"Average" based on only one observed value

An analysis was performed of the longer-term record (2005-2016) of TP concentrations in the Upper Basin. This analysis did not show evident patterns in TP concentrations in the Upper Basin at either the CC26 or the CC59/60 locations.

Non-storm-event TP loading at CC26 and CC59/60 was calculated for 2016 and compared to estimates from 2011-2015 (Figure 29). Loads in 2016 were lower than the 2011-2015 average. This decrease in loading is expected given the decrease in concentrations observed relative to previous years.

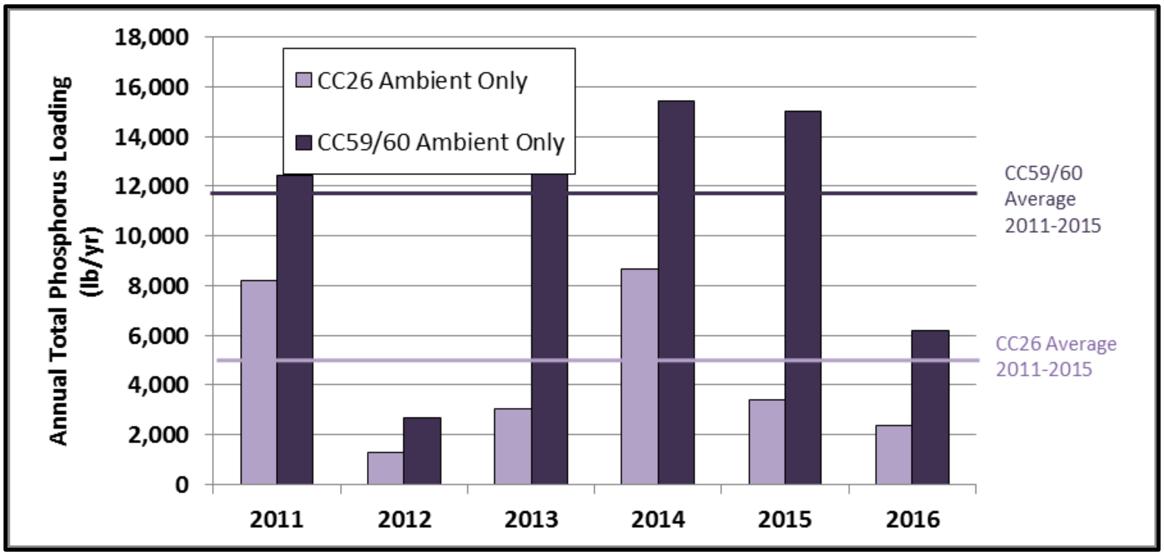


Figure 29. Annual Total Phosphorus Loading Estimates in the Upper Basin, 2011-2016

Volume-weighted concentrations (annual load divided by annual volume) of TP at CC26 and CC59/60 are presented in Figure 30 for 2011-2016. In 2016, volume-weighted concentrations at CC59/60 were lower than the average of the previous five years.

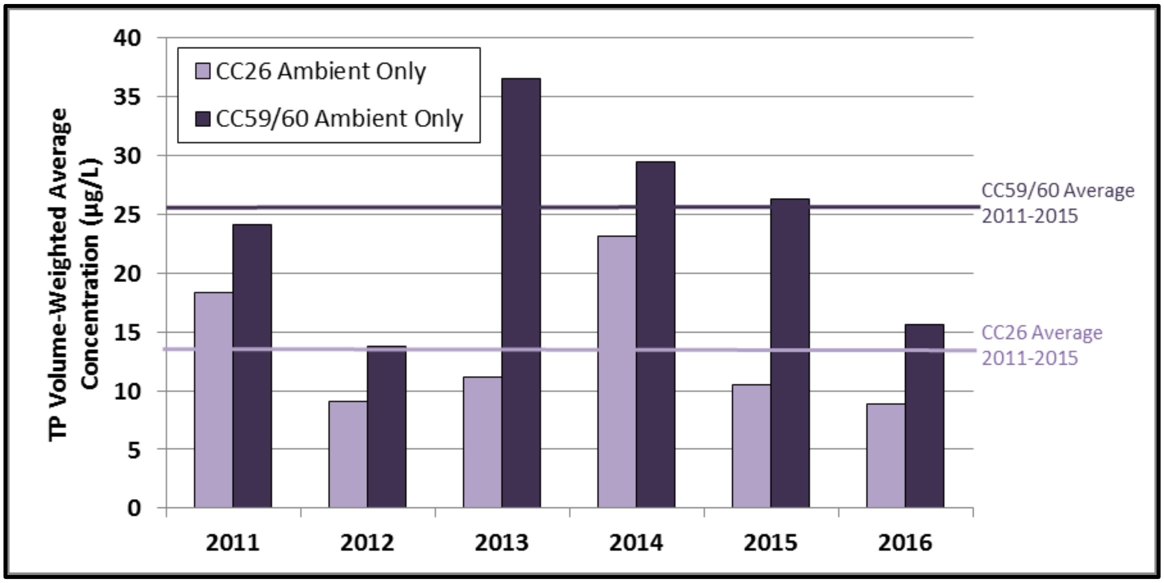


Figure 30. Volume-Weighted Total Phosphorus Concentration Estimates in the Upper Basin, 2011-2016

In summary, TP concentrations in 2016 were lower than average. These lower concentrations are reflected in the loading and volume-weighted average concentrations. As discussed for TSS, it appears that these low TP concentrations may be the result of sample timing rather than a reflection of an actual large decrease in TP concentrations. Concentrations of TP in Clear Creek at both the upstream and downstream stations are typically below the relevant water-quality standard.

D. Total Nitrogen

Ambient total nitrogen concentrations observed in the Upper Basin for 2016 based on grab and composite sample data are presented in Figure 31. Data from both stations follow the same general seasonal pattern, with lower concentrations during the summer months, and higher concentrations during the winter and early spring. This pattern is the inverse of the pattern for TSS and TP; indicating that the mechanisms of nitrogen loading are different. The maximum non-storm-event concentration observed at CC26 of 460 µg/L was observed on February 10, 2016. The maximum concentration of 650 µg/L at CC60 was observed on February 10, 2016.

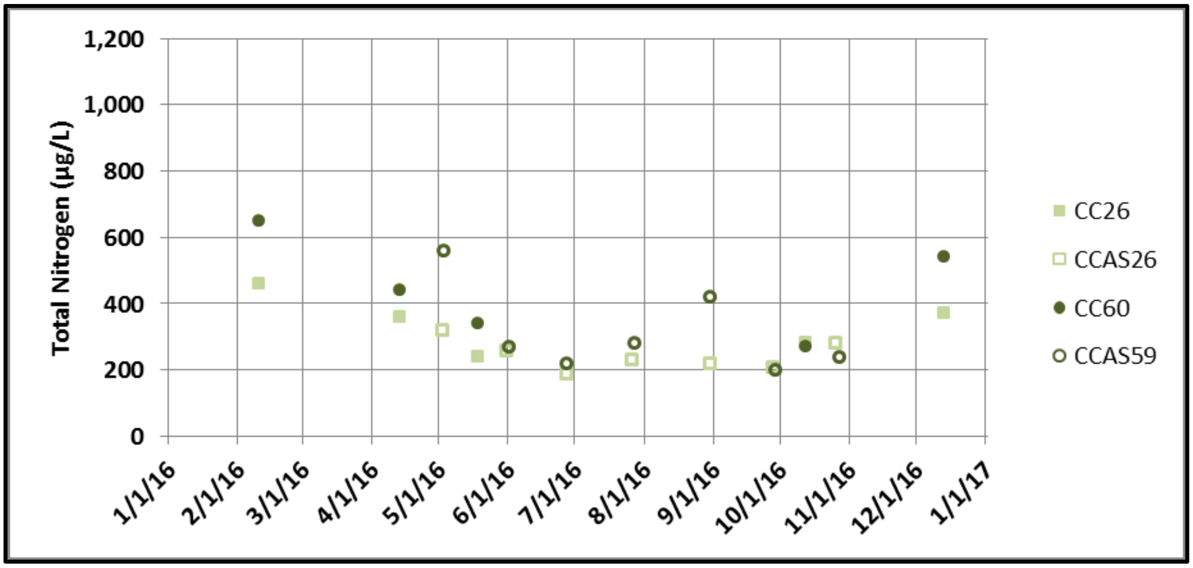


Figure 31. Total Nitrogen Concentrations (Non-Event) in the Upper Basin, 2016

A temporal pattern of lower TN concentrations in summer and higher concentrations during the winter low-flow period (typically November to March) winter was observed in the 2016. This pattern is ambient TN concentration data is consistent with previous years (Figure 32). This pattern is driven by the dilution of sources during periods of higher flow.

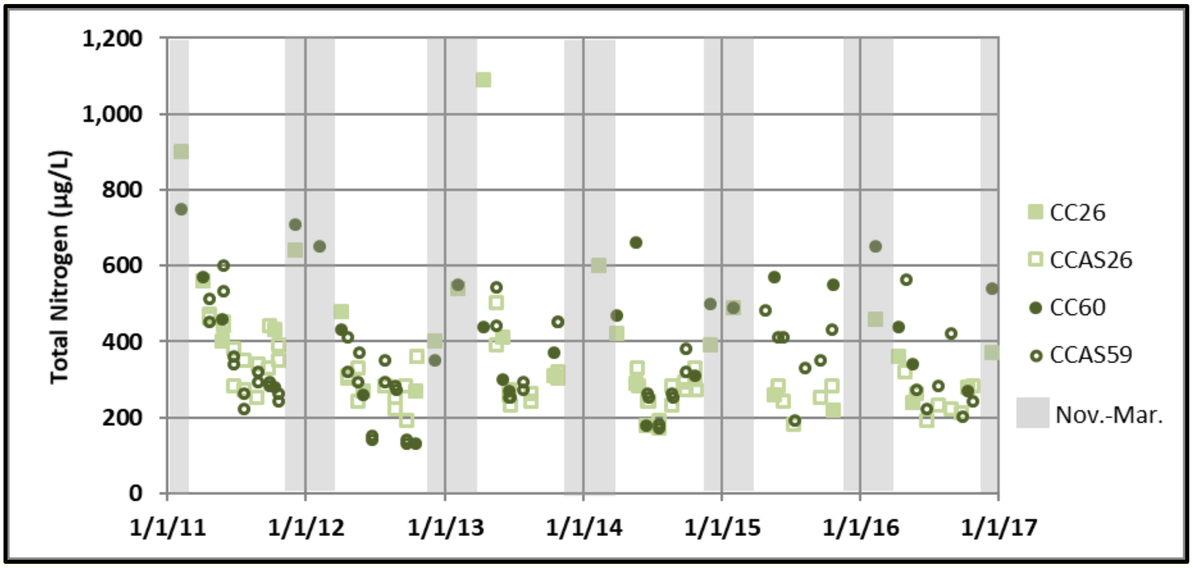


Figure 32. Total Nitrogen Concentrations (Non-Event) in the Upper Basin, 2011-2016

A comparison of monthly average TN concentrations at CC59/60 for 2016 and the 2011-2015 average is provided in Table 7. These non-storm-event results for TN from 2016 are all within observed ranges from the previous five years. Further, monthly 2016 concentrations are generally similar to the monthly averages from 2011 to 2015.

Table 7. Monthly Average Total Nitrogen Concentrations (Non-Event) in the Upper Basin at CC59/60

Month	2016 TN (µg/L)	2011-2015 Average and Range of TN (µg/L)	% Difference -- 2016 Versus 2011-2015 Average
February	650*	610 (490-750)	7%
April	440*	453 (320-570)	-3%
May	450	466 (260-660)	-3%
June	245	293 (140-530)	-16%
July	280*	247 (170-350)	14%
October	255	345 (130-550)	-26%

*Average based on one observed value

Analysis of the long-term record (2005-2016) did not result in any evident patterns in TN concentrations in the Lower Basin at CC59/60. However, in the Upper Basin (CC26) there appears to be a continued pattern of sustained lower TN concentrations for the period of 2012-2016 when compared to the 2005-2011 period (Figure 33). As discussed in the 2015 Standley Lake Report (Hydros 2016), it is likely that this decrease is the integrated result of facility upgrades at the Georgetown WWTF, process improvements at other facilities, and the diverse range of other watershed activities undertaken to improve water quality in the Clear Creek basin.

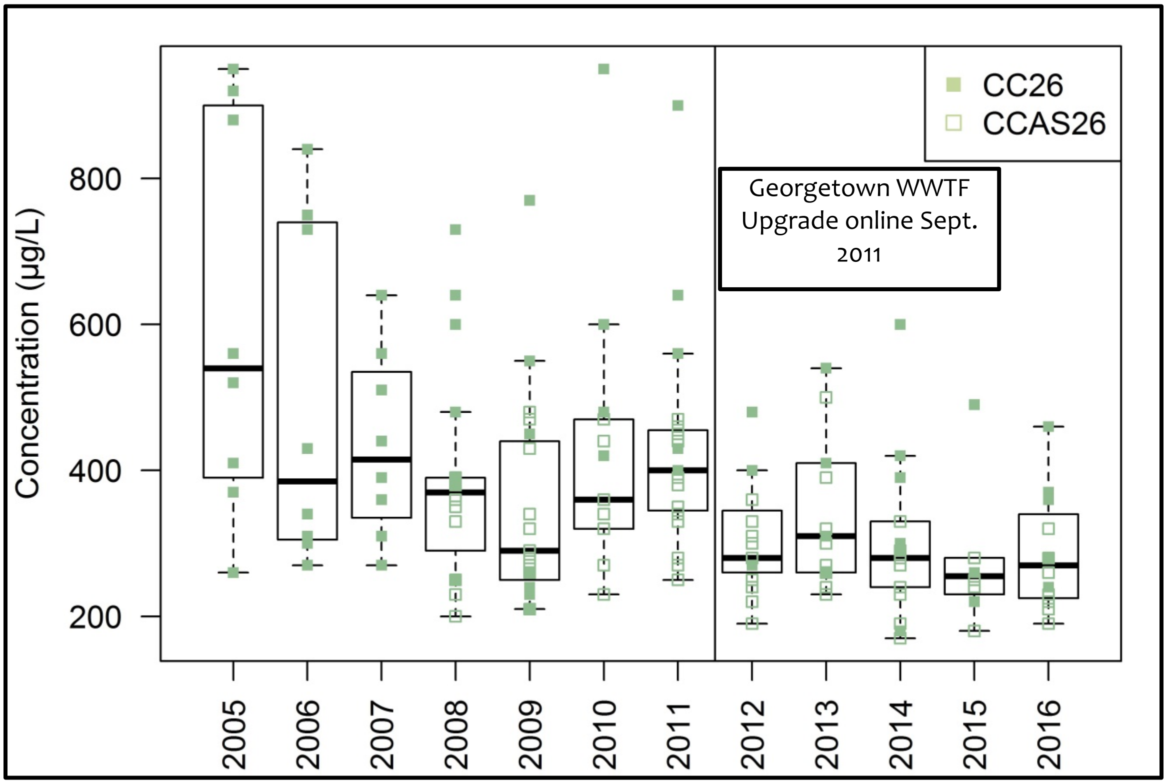


Figure 33. Total Nitrogen Concentrations at CC26 for the period of 2005-2016

Loading at both CC59/60 and CC26 are lower than the average of the past five years (Figure 34). This decrease in loads is driven by the combined effect of slightly lower flows and lower concentrations.

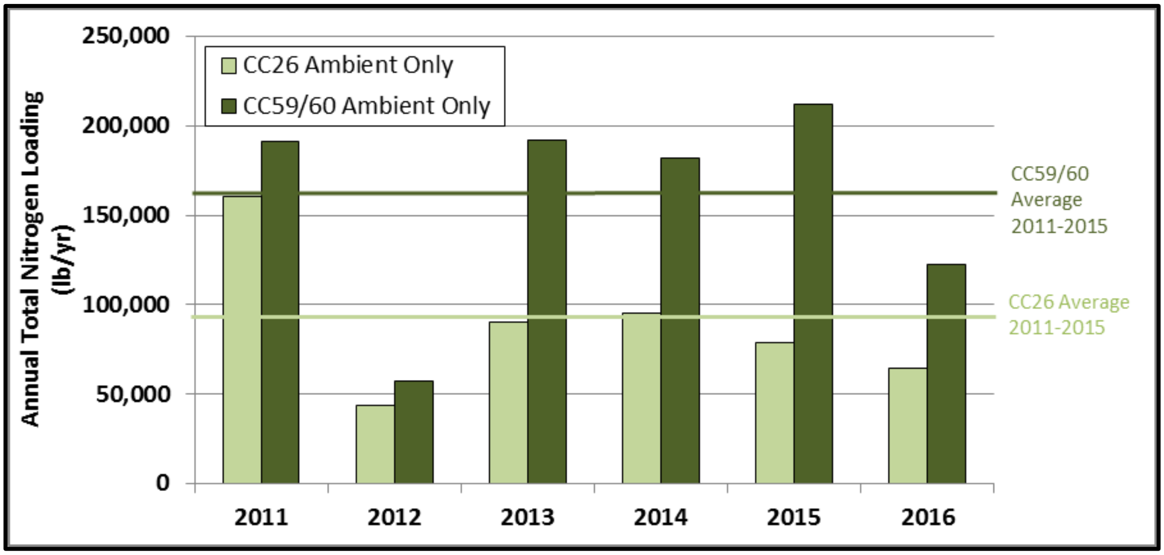


Figure 34. Total Nitrogen Loading Estimates in the Upper Basin, 2011-2016

Volume-weighted concentrations (annual load divided by annual volume) of TN at CC26 and CC59/60 are presented in Figure 35 for 2011-2016. Volume weighted concentrations of TN at both stations are slightly below the averages of the previous five years.

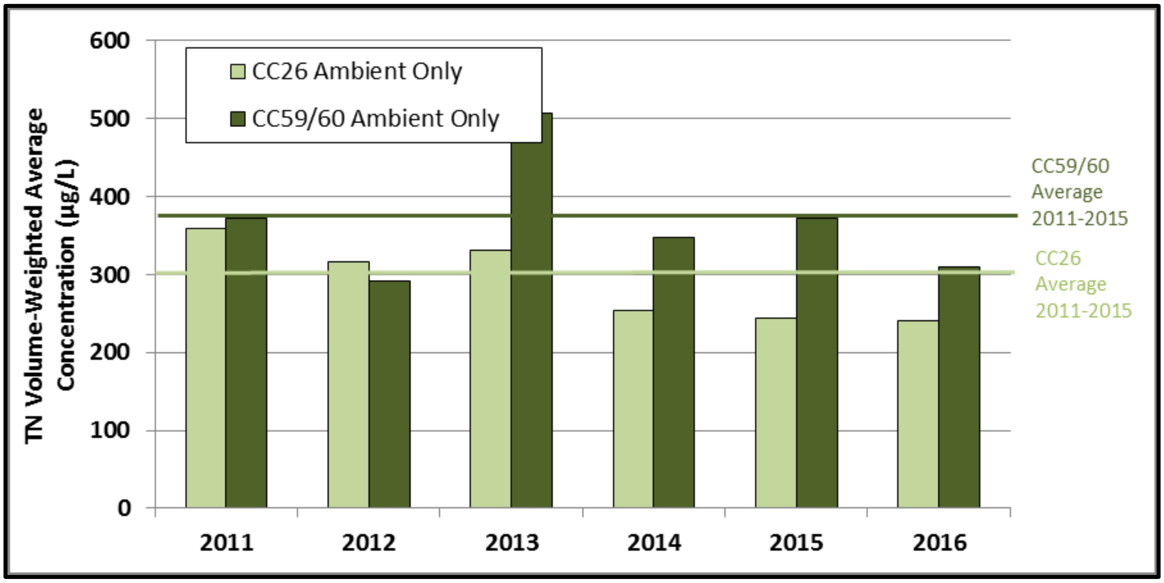


Figure 35. Volume-Weighted Total Nitrogen Concentration Estimates in the Upper Basin, 2011-2016

In summary, TN concentration patterns in 2016 were similar for the upstream (CC26) and downstream (CC60) locations; this is in contrast to the observations for TSS and TP. Concentrations of TN in the Upper Basin were generally consistent with those observed in the previous five years.

However, the loading estimates for 2016 were lower than most of the previous years. This decrease in loading is consistent with the decrease in volume-weighted concentrations of TN in 2016. All observed concentrations of TN in Clear Creek from ambient samples were below the relevant water-quality standard for both the upstream and downstream stations.

E. Effects of Storm Events on Loading

The loading calculation results described earlier in this section include grab samples and ambient composite data. These types of samples, which are taken at regular intervals, are not intended to capture the water-quality response to storm events. It is widely recognized, however, that precipitation events can result in substantial changes to water quality. As such, since 2006 event-triggered sampling has been conducted and this was continued in 2016 at station CCAS59. For the event-triggered samples, the storm-event concentrations were assumed to represent concentrations for the full day of the composite sample, though runoff events can cover longer or shorter periods.

In July and August 2016, four event-triggered samples were collected at CCAS59. The effects of these storms on loading estimates are presented in Table 8 and Figure 36. Incorporating these event samples into the loading calculations increases the annual loads of TN (8%), TP (30%), and TSS (45%). The effects are even more apparent loading estimates for the individual months (Table 8).

The effects of a single storm event are exemplified by the August 30, 2016 event. This single-day event is estimated to have contributed 6,952 lbs of TN, 921 lbs of TP and 816,218 lbs of TSS of loading. These amounts represent a substantial fraction of the annual loading (TN: 6%, TP: 15%, TSS: 21%); and represents a substantial fraction of the loading differences seen in Figure 36. The large loading estimates for August 30, 2016 are the result of the high concentrations measured on this date (TN: 10,650 µg/L; TP 1,370 µg/L and TSS: 1,240 mg/L). While not all storm events have such high concentrations, and correspondingly large impact on annual totals, this event demonstrates the importance of understanding the effects of storm events on water quality. The comparison of the effects of storm events on a year-to-year basis is not straight forward. The effects of storm events on loading estimates is highly depending on the number of storm events captured by sampling and by the concentrations observed during each individual event.

Table 8. Effect of Storm Events on Annual and Monthly Loading at CC59/60

Time Period	Increase in TN Loading with Storm Events	Increase in TP Loading with Storm Events	Increase in TSS Loading with Storm Events
2016 (Annual Load)	8%	30%	45%
July 2016 (Monthly Load)	16%	159%	592%
August 2016 (Monthly Load)	85%	377%	167%

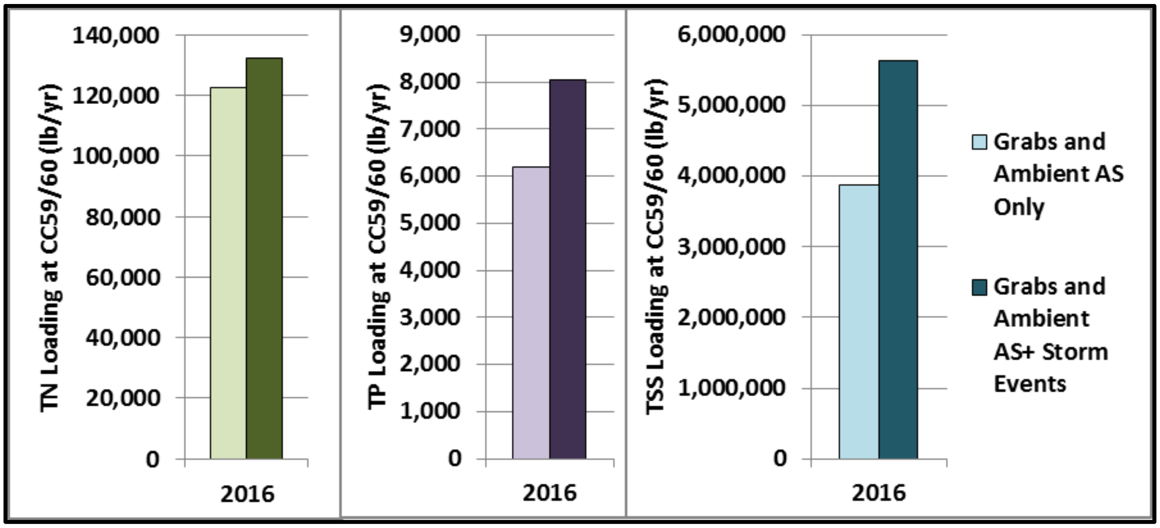


Figure 36. Total Nitrogen, Total Phosphorus, and Total Suspended Solids Loading in 2016, With and Without Storm Events

F. Upper Basin Summary

In summary, annual flows at CC26 and CC60 were slightly below the 5-year averages. However, at CC60 the flows were slightly above the longer-term average. The pattern and timing of peak flows was generally consistent with past years. However, in 2016 a period of cold weather in the upper extent of the Clear Creek watershed resulted in a period of decreased flows and a two-peaked pattern. The annual loads of TSS and TP, as measured at both CC26 and CC60 were below average. This appears to be primarily driven by decreases in concentrations in May and June. It appears that the timing of the sampling in 2016 may have bracketed the period of likely highest concentrations (associated with peak snowmelt flows). The loads and concentrations of TN were consistent in pattern and magnitude with past years. At the CC26 station, the pattern of lower TN concentrations in the post 2011-period, versus the pre-2011 period, appears to continue. This pattern is likely to be primarily the result of WWTF upgrades and process improvements with contributions from other and other watershed activities intended to improve WQ in the Clear Creek watershed.

V. Canal Zone Flows and Water Quality

The Upper Basin is the source for the water diverted into the inflow canals to feed Standley Lake. This section presents the timing and volume of flows for the inflow canals. In addition, this section provides a description of water-quality changes along the FHL and Croke canals from their points of diversion on Clear Creek to the reservoir.

A. Flows

Water enters Standley Lake via four conveyances (Figure 7): Church Ditch, Croke Canal, Farmers' High Line Canal (FHL), and Kinnear Ditch Pipeline (KDPL). Inflows for 2016 from each of these sources are shown in Figure 37. During the irrigation season (April to October), the FHL Canal was the dominant source of inflows. Later in the irrigation season, additional water was delivered by the Church Ditch and the KDPL. The Croke Canal has the most senior rights in the Clear Creek Basin during the non-irrigation season (November – March). As is typical, following the curtailment of flows from FHL in early November the Croke Canal provided the only inflow to Standley Lake until early April.

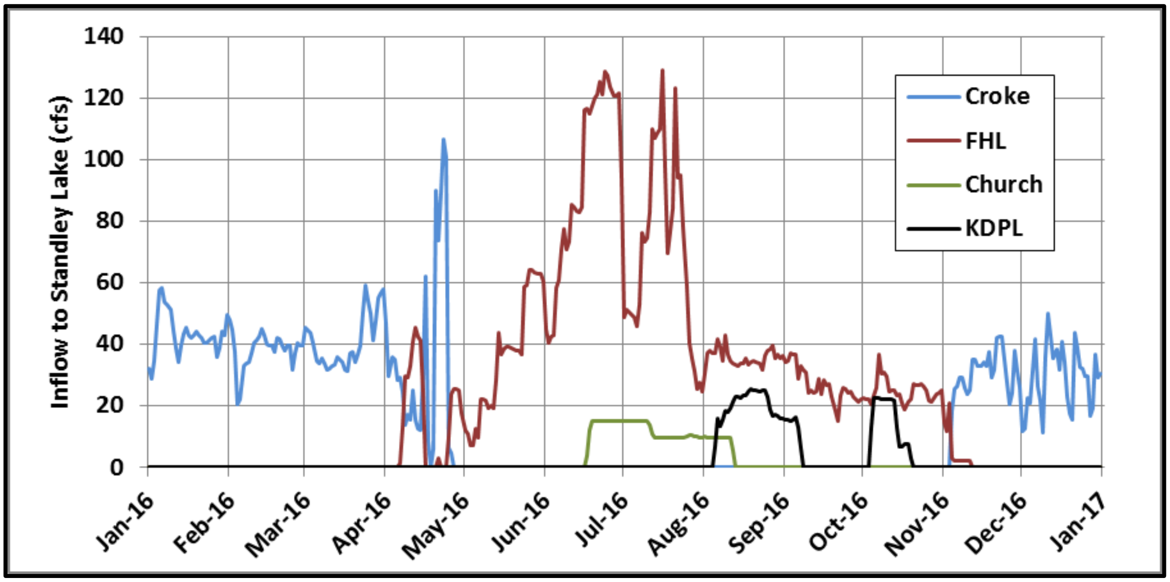


Figure 37. Inflow to Standley Lake, 2016

B. Water Quality

The Croke Canal and the FHL Canal are the dominant sources of water to Standley Lake. These canals follow parallel paths for approximately 15 miles between their headgates at Clear Creek and their turnouts to Standley Lake. Over this distance the canals pass through a diverse range of land uses. When a canal is in use, water-quality samples are collected at both the headgate and at the release point to Standley Lake. To better understand the effects of the Canal Zone on water quality, an analysis of concentration differences observed between the canal headgates and turnouts was performed. As with the Upper Basin and Standley Lake water quality discussions, this analysis focused on TSS, TP, and TN.

Average annual concentrations were calculated for TSS, TP, and TN. These averages were calculated for the canal headgate and at the turnout locations for the Croke and FHL. For the Croke Canal, there is substantial increase in TSS concentrations between the headgate and the turnout (Figure 38, right). The increase in TSS is associated with a corresponding increase in TP (Figure 39, right). However, there is little differences between locations for TN (Figure 40, right). In contrast, typically little difference is observed in the FHL between headgate and turnout for TSS, TP, or TN (Figures 38-40, left). The specific sources of TSS and associated TP along the Croke Canal are unknown at this time. However, the activities described to address land use issues by the Croke Canal (Section III.B.3) have the potential to limit or control sources of TSS and TP.

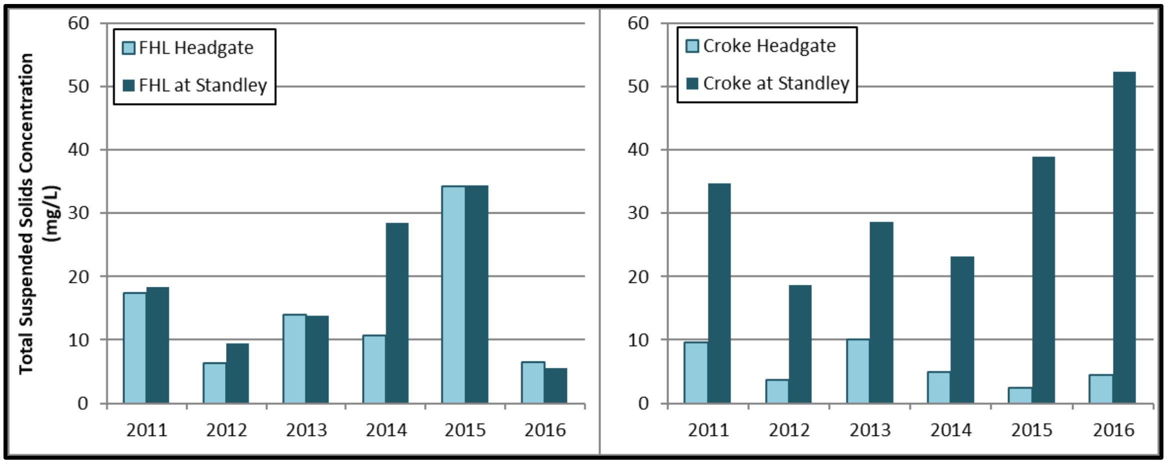


Figure 38. Total Suspended Solids in FHL (left) and Croke (right) Canals

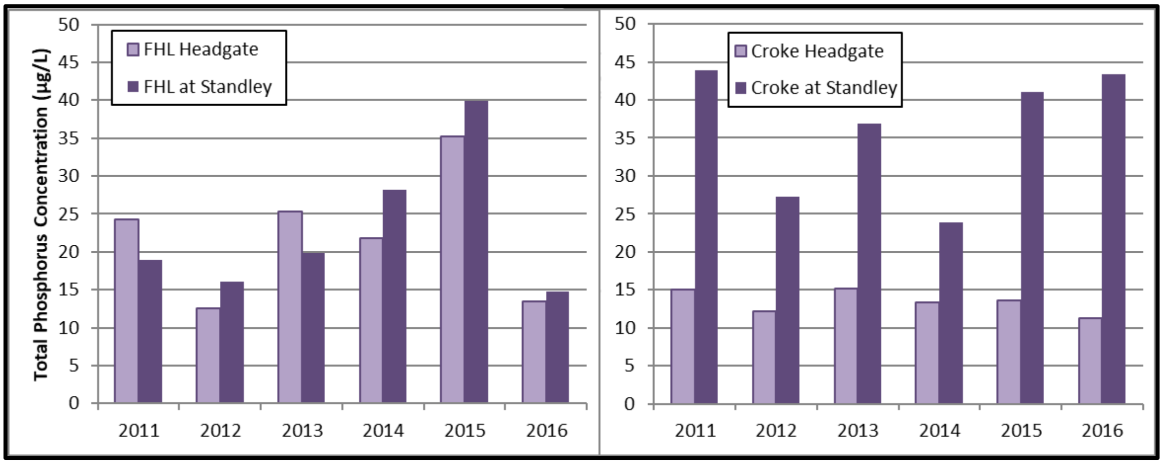


Figure 39. Total Phosphorus Concentrations in FHL (left) and Croke (right) Canals

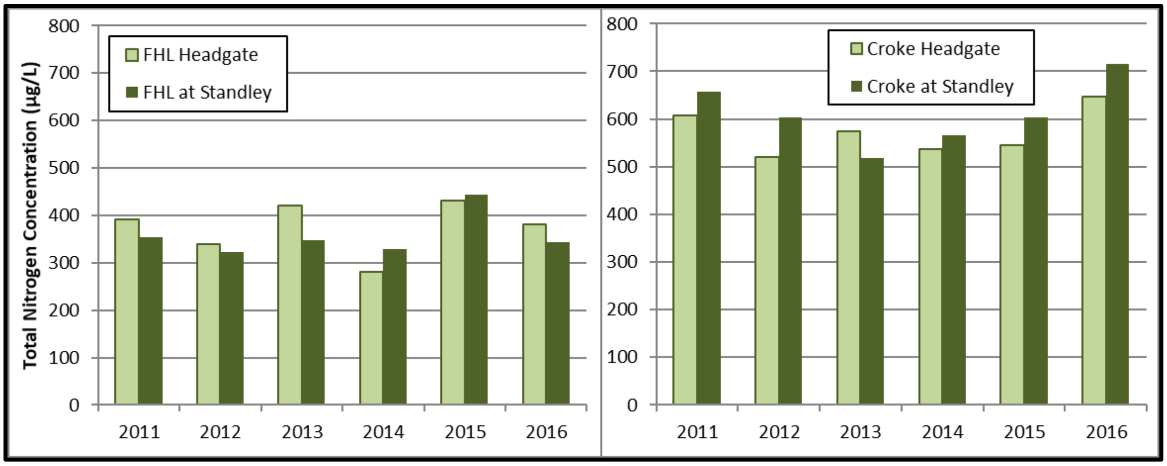


Figure 40. Total Nitrogen Concentrations in FHL (left) and Croke (right) Canals

VI. Standley Lake Flows, Contents, and Loadings

This section provides a discussion of the quantity and quality of the inflows to and outflows from Standley Lake. In addition, the loadings of TSS, TN and TP are described along with the lake contents.

A. Flows and Contents

The daily flow rates, and associated season patterns, for each of the four conveyances to Standley Lake were presented previously (Figure 37). Annual inflow volume from each source is shown in Figure 41 for the period of 2011 through 2016. The largest sources of water to Standley Lake are the FHL and Croke Canals. They provide, respectively, 54% and 37% of total inflows. Church Ditch and KDPL inflows are smaller sources, combining to provide the remaining 9% of total inflows.

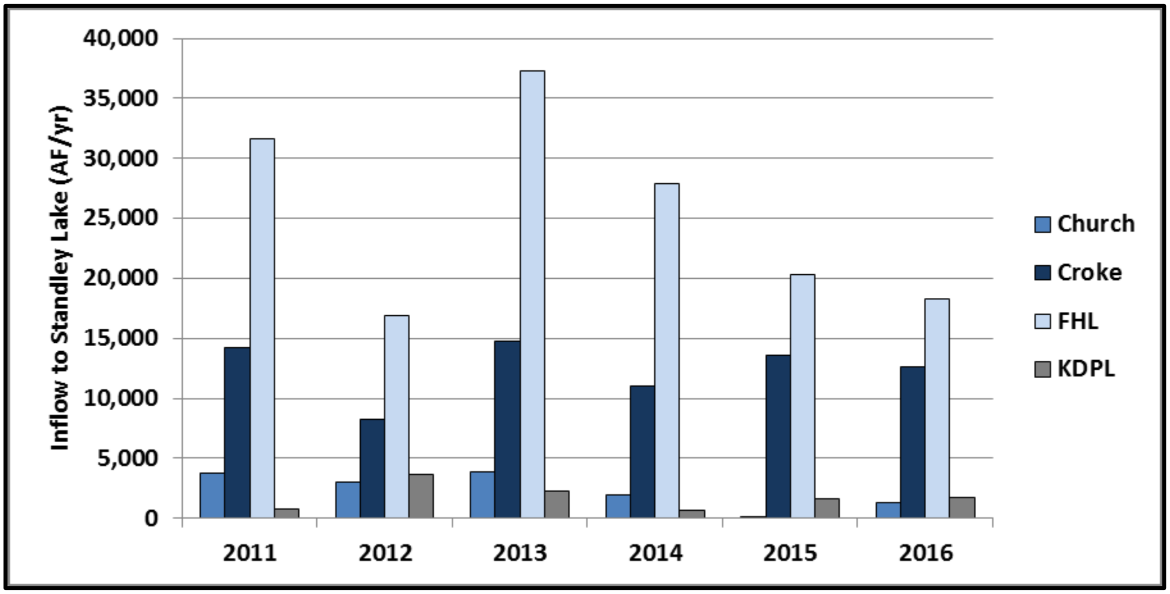


Figure 41. Annual Inflow to Standley Lake by Source, 2011-2016

Inflow and outflow rates from the lake in 2016 are presented in Figure 42. Inflows outpace outflows during the March through May period. During the later summer and early fall (August through September) outflows outpace inflows. Overall, the most rapid outflows occurred during the summer and fall. Total measured annual inflow (the sum of all four sources) and outflow for 2011-2016 are presented in Figure 43. In 2016, total inflows were 22% lower than the 2011-2015 average. Outflows were only 3% higher than the average of the previous five years.

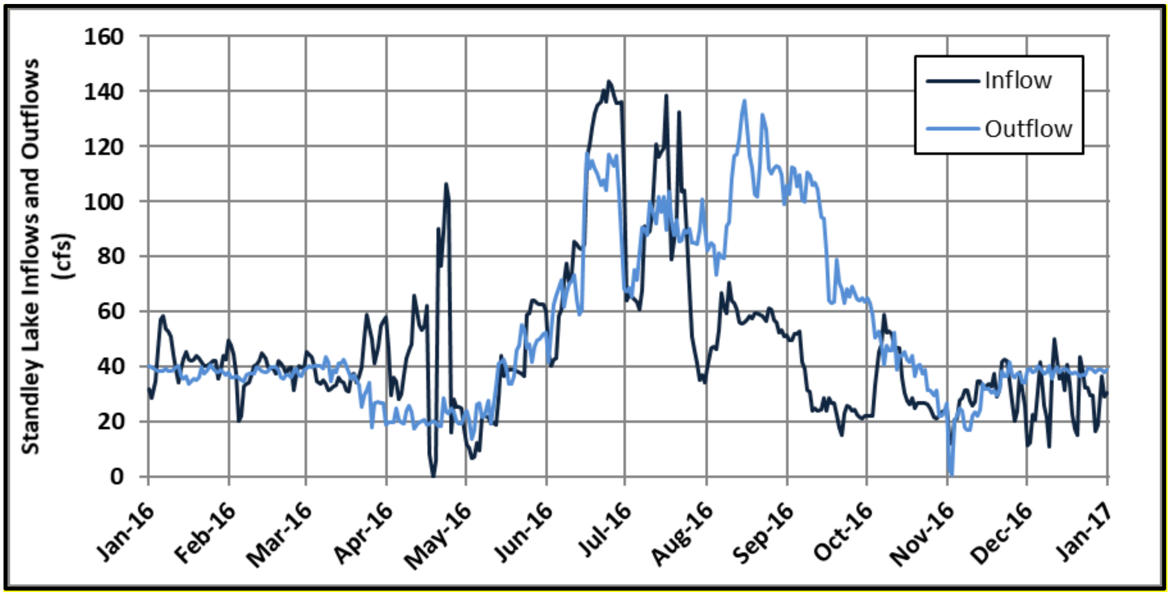


Figure 42. Inflows to and Outflows from Standley Lake, 2016

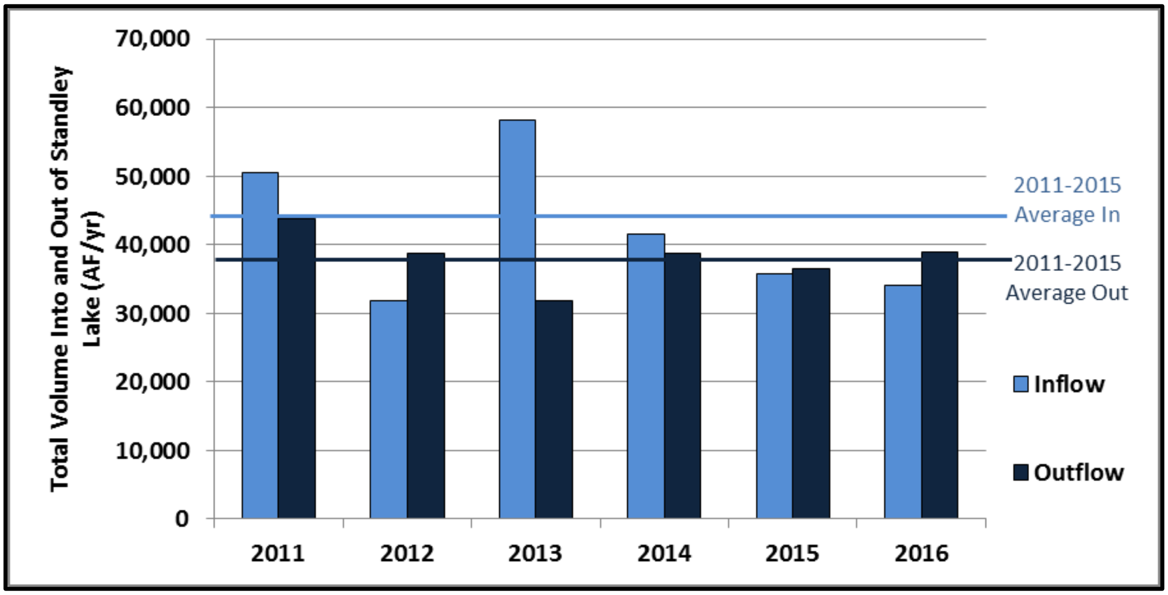


Figure 43. Total Measured Annual Standley Lake Inflow and Outflow, 2011-2016

Daily contents for Standley Lake for each of the past six years are presented in Figure 44. Contents were calculated from gage-height measurements using the elevation-area-volume relationship for the lake. At the beginning of 2016, lake contents were nearly as high as the two previous years. In the spring, the lake filled to near capacity where it remained for May, June and much of July. Following this, lake contents decreased to levels not seen since 2012. Nonetheless, in 2016, the annual average lake content was nearly identical (2% greater) to the average of the previous five years.

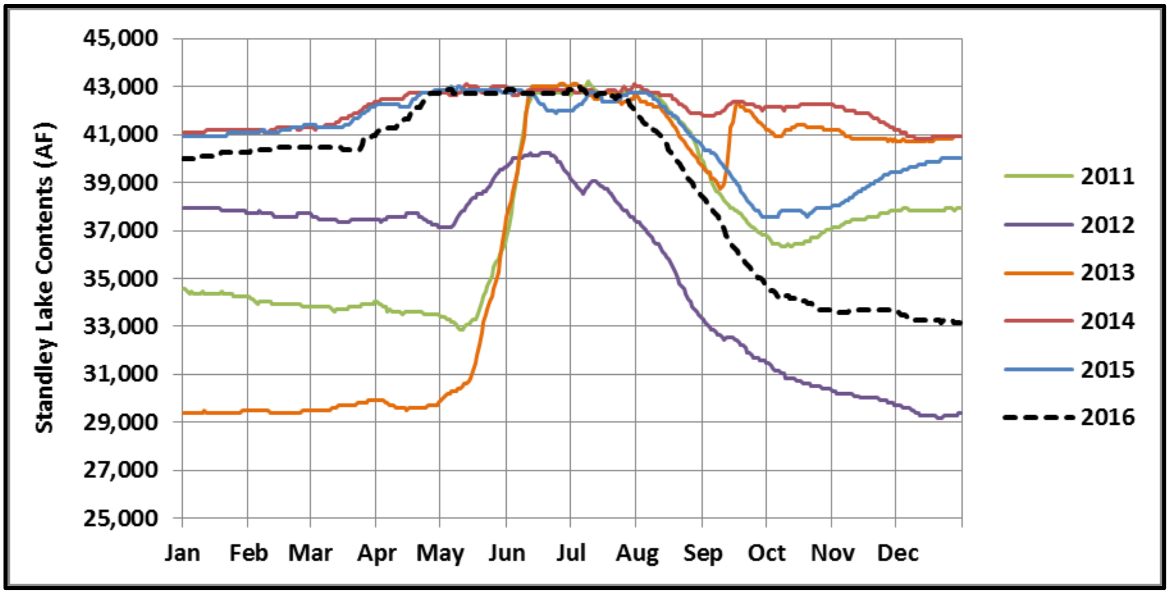


Figure 44. Standley Lake Contents, 2011-2016

B. Loading Into and Out of Standley Lake and Inflow Water Quality

Estimates of nutrient loading into and out of the lake are described in this sub-section. The concentration data are from samples collected as part of the Upper Clear Creek/Standley Lake Watershed Water Quality Monitoring Program. The sampling data used for inflows includes ambient grab samples and 24-hour ambient composites. Loads are calculated using daily flows and concentration data. To compute the loads, a mid-point function was used to fill daily concentrations between the available sample data. Event samples collected on the canals have included storm event samples and first flush samples. These types of samples provide an indication of the effects of different events on loading to the reservoir.

1. Total Phosphorus

Total phosphorus loading into Standley Lake is presented by source for the 2011-2016 period in Figure 45. The canals which contributed the greatest volumes of water to Standley Lake, the Croke and FHL Canals (Figure 41), delivered the largest TP loads (Figure 45). However, in 2016 the Croke canal contributed more TP relative to the FHL even as it provided a lower volume of water. This pattern is in contrast to past years. The observed change in pattern appears to be primarily driven by a decrease in loading from and concentrations in the FHL (Figure 39). Loading from the Croke in 2016 is generally consistent with the magnitude of past years.

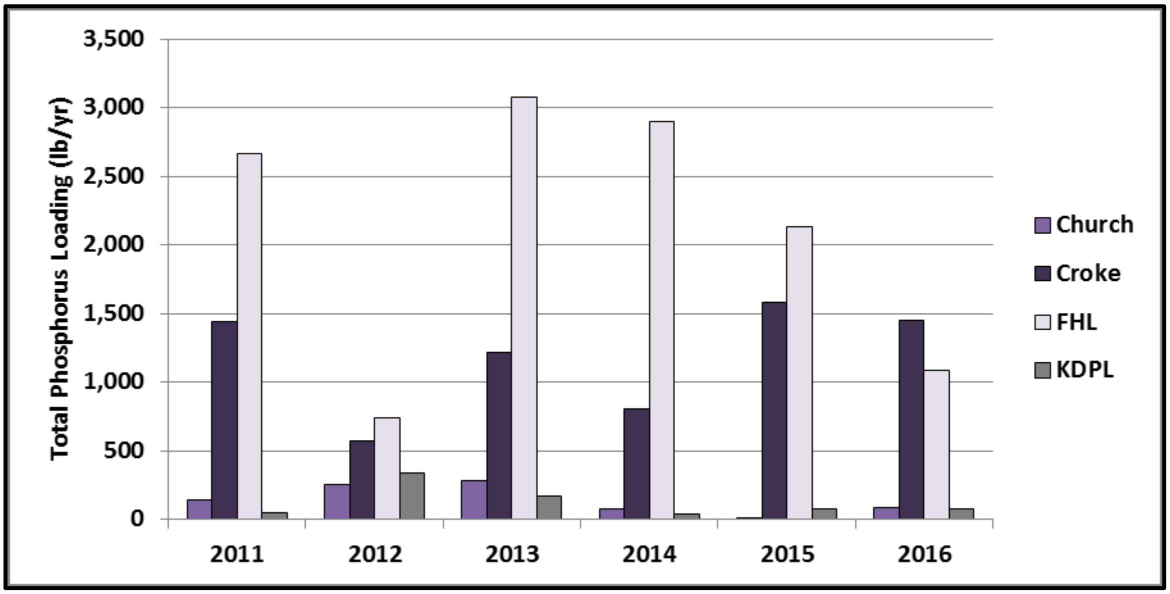


Figure 45. Total Phosphorus Loading into Standley Lake by Source, 2011-2016

Estimated annual TP loadings into and out of Standley Lake for 2011-2016 are shown in Figure 46. Non-storm event loading of total phosphorus in 2016 was below (-27%) the average of the past five years. This decrease is primarily driven by the decrease in loading from the FHL. As with previous years, loadings of total phosphorus into the lake were greater than outflow, indicating some level of phosphorus retention.

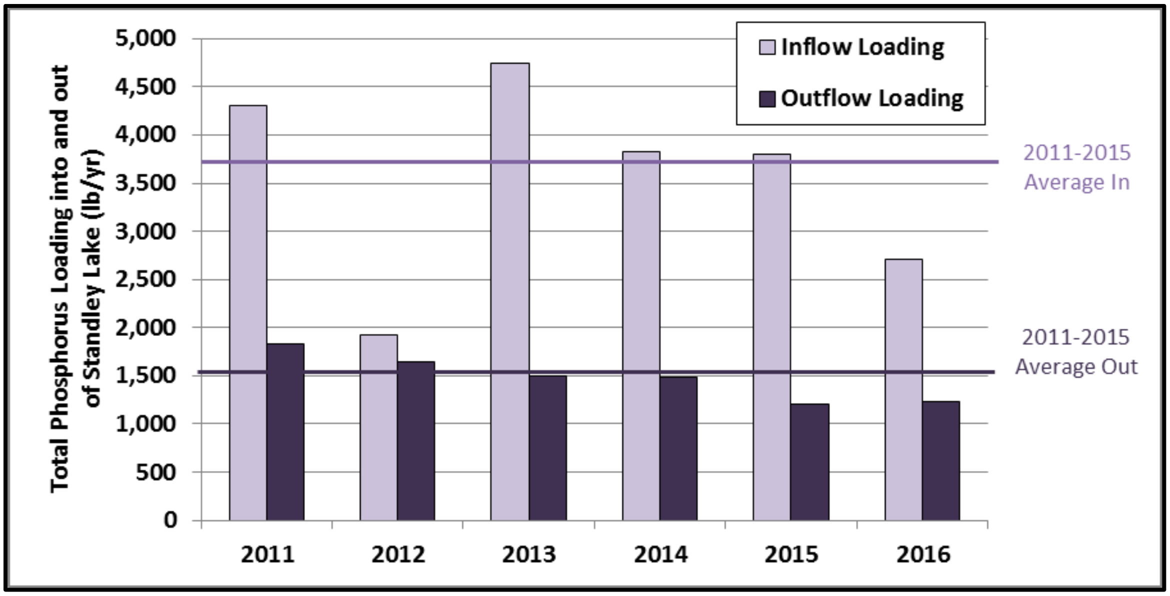


Figure 46. Total Phosphorus Loading into and Out of Standley Lake, 2011-2016

The volume-weighted TP concentrations into Standley Lake are presented in Figure 47 by source. The Croke had the highest volume-weighted concentration and KDPL the lowest. The combined average of the canals (29 µg/L) in 2016 was 7% lower than the 2011-2015 average.

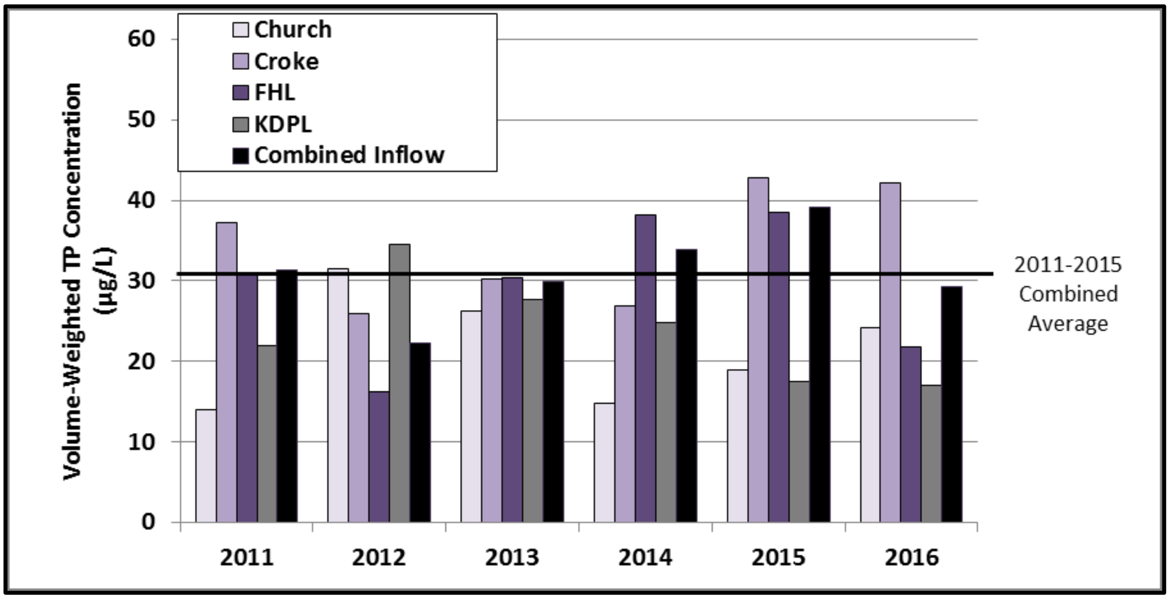


Figure 47. Volume-Weighted Total Phosphorus Concentrations into Standley Lake by Source, 2011-2016

2. Total Nitrogen

Total nitrogen loading into Standley Lake, grouped by source and based on data from ambient grab and ambient composite samples, is displayed in Figure 48. Combined TN loading into and out of the lake is presented in Figure 49. As with TP, loads were the highest in the Croke Canal and for the FHL loads in 2016 were lower than all but one year from the 2011-2015 period. The mass of TN entering Standley Lake in 2016 was 27% lower than the average of the previous five years. Outflow of total nitrogen in 2016 was 19% lower than the 2011-2015 average. As with previous years, loading into the lake was higher than outflow from the lake, indicating some level of nitrogen retention.

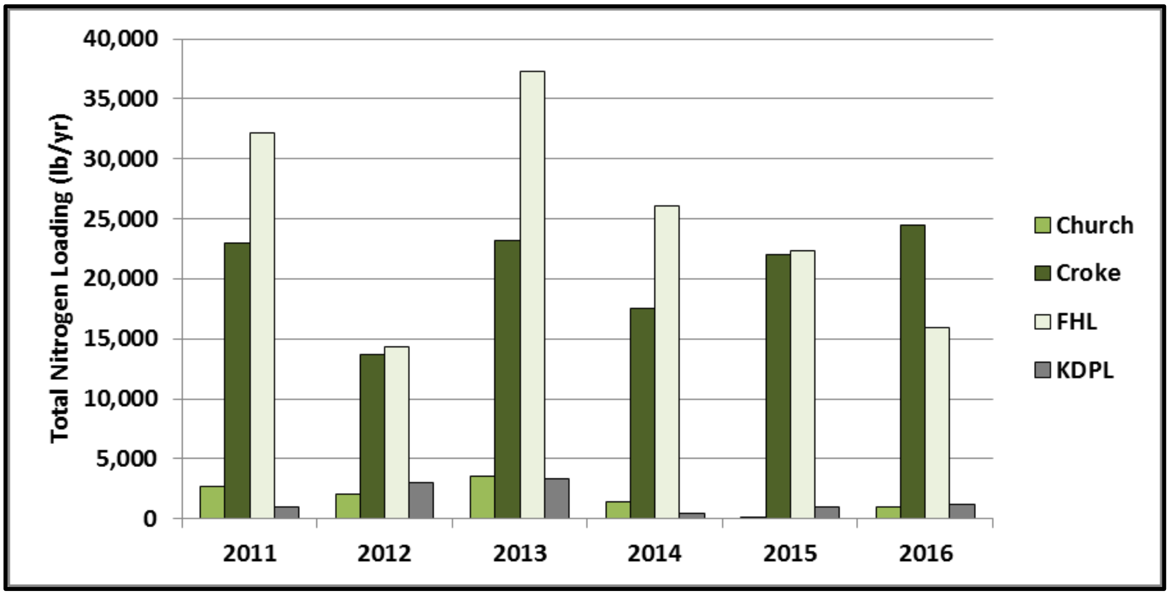


Figure 48. Total Nitrogen Loading into Standley Lake by Source, 2011-2016

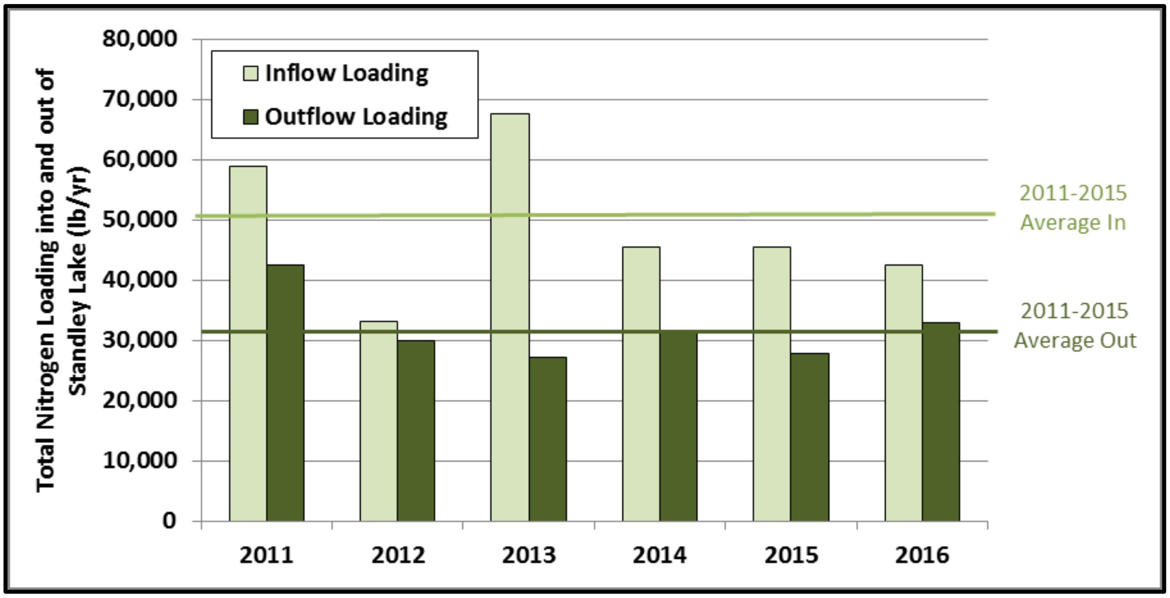


Figure 49. Total Nitrogen Loading into and Out of Standley Lake, 2011-2016

Volume-weighted total nitrogen concentrations into the lake are presented in Figure 50. The combined average from all sources in 2016 (460 µg/L) was slightly higher than the 2011-2015 average of (422 µg/L). The increased volume weighted concentrations in the Croke are a reflection of the higher estimated loads and associated higher observed concentrations observed in this source in 2016.

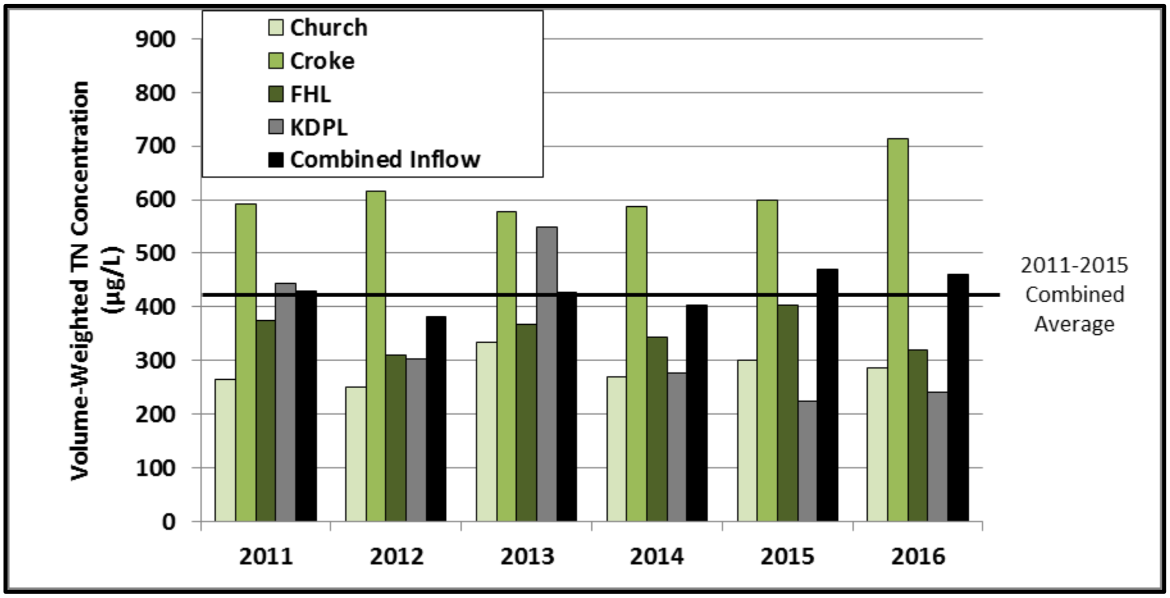


Figure 50. Volume-Weighted Total Nitrogen Concentrations into Standley Lake by Source, 2011-2016

3. Effect of Storm Events on Nutrient Loading

In 2016, no storm event data were collected on the canals feeding Standley Lake. However, first flush samples were collected. The effects of first flush are included in the load estimates in the previous section.

C. Standley Lake Loading Summary

Standley Lake began 2016 with relatively high levels with the lake filling to near capacity in May. This level was maintained until near the end of the summer, when drawdown began. Overall, the average contents in 2016 were very close to the five-year average of 2011- 2016. The loading of nutrients, TN and TP, to the Lake in 2016 were below average. This decrease in loading was primarily driven by concentration decreases seen in FHL and supplemented by a decrease in overall inflow volumes. As is typical, the outflow of nutrients from the lake was lower than the inflow indicating the retention of nutrients in the lake.

VII. Standley Lake Water Quality

In this section, the in-reservoir water-quality responses to the hydrology and nutrient loads are discussed. The data considered here were measured at sampling location SL-10 (Figure 2). This sampling location was selected as it has an extensive sampling history, is directly relevant to water treatment plant operations, and is the location of the automatic lake profiler station. The water-quality measurements discussed include: dissolved oxygen (DO), TP, TN, chlorophyll *a*, and clarity.

A. Dissolved Oxygen

Dissolved oxygen is an important water-quality constituent because of its effect on aquatic life and drinking water treatment. Dissolved oxygen at the sediment-water interface (i.e. the bottom of the lake) is of particular relevance. Low DO at this location can result in the loading of nutrients and certain metals from the sediment to the water column. These releases can lead to increases in water treatment costs and the potential for taste and odor events in drinking water.

Each year, Standley Lake experiences hypoxia (DO concentrations ≤ 2.0 mg/L) in the hypolimnion. This is common for stratified reservoirs in Colorado. In 2016, DO concentrations started dropping at the bottom in mid-May and hypoxic conditions were well developed by the beginning of August. These hypoxic conditions were maintained until turnover in early October. A contour plot of dissolved oxygen concentrations in Standley Lake for March through early December 2016 is provided in Figure 51.

Dissolved oxygen concentrations measured at the top and bottom of Standley Lake through 2016 are provided in Figure 52. At the surface, the cyclical patterns in DO concentrations are driven by the decrease in oxygen solubility with increasing temperatures. The onset of stratification is observed to occur in mid-May, as indicated by the divergence of lake-bottom DO concentrations from surface concentrations. This divergence increases in magnitude as dissolved oxygen is depleted in the hypolimnion, and is maintained by continued stratification. Consistent with the contour plot (Figure 51), the divergence between surface and bottom DO concentrations is rapidly extinguished with turnover in early October.

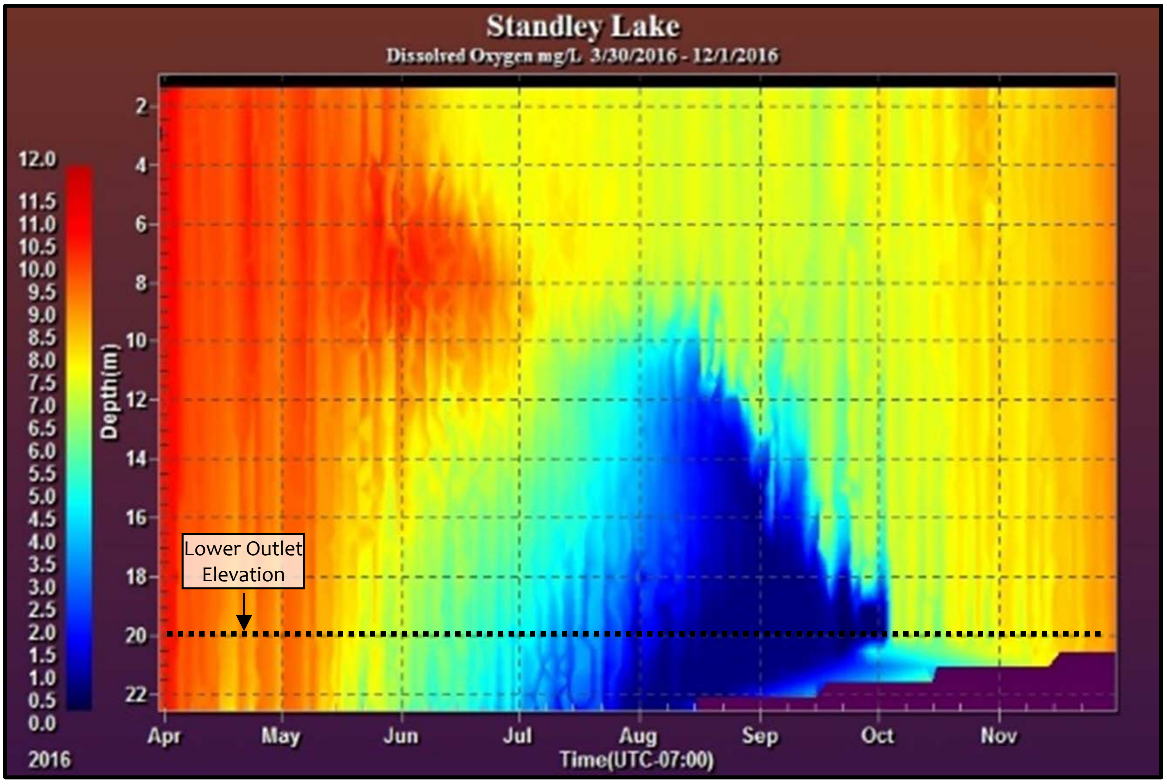


Figure 51. Contour Plot of Dissolved Oxygen in Standley Lake, March-December 2016

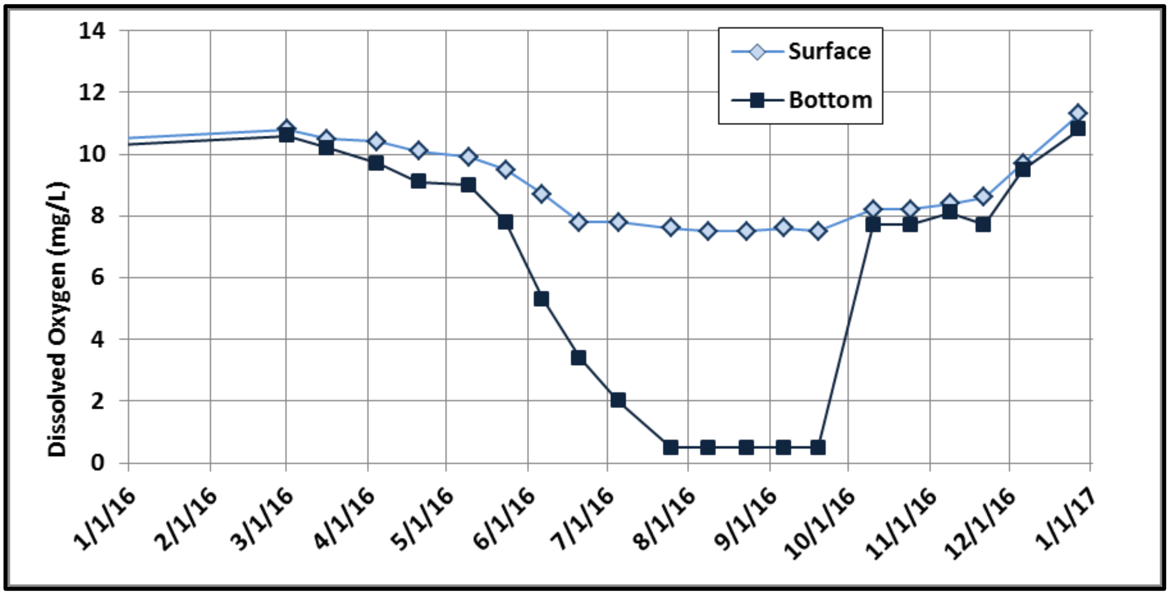


Figure 52. Dissolved Oxygen Concentrations in Standley Lake, 2016

The 2016 seasonal dissolved oxygen patterns generally match those observed in previous years in Standley Lake, as shown in Figure 53. In comparison to recent years however, the development of hypoxic conditions occurred later and turnover was earlier.

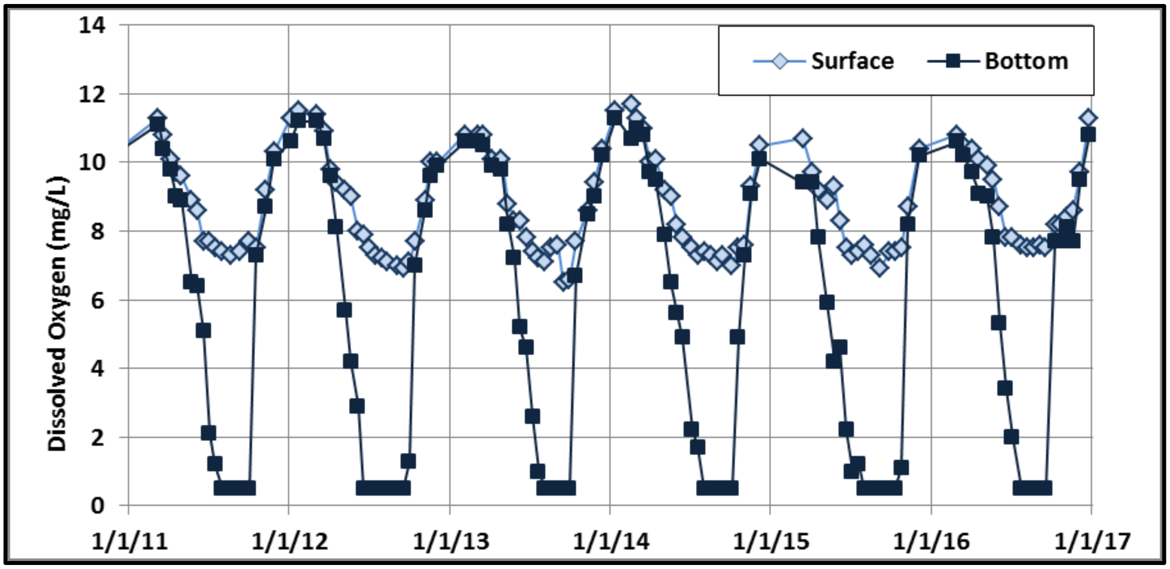


Figure 53. Dissolved Oxygen Concentrations in Standley Lake, 2011-2016

Hypoxia occurs each year in the hypolimnion of Standley Lake, but the start date, end date, and duration vary from year to year. In 2016, the hypoxic period started July 10th and lasted until turnover on October 4th. The period of hypoxia was lower than the 2011-2015 average of 103 days (Figure 54). After a longer than usual period of hypoxia in 2015, the number of days of hypoxia in 2016 was similar to the longer-term average (2005-2015, 93 days) and lower than the five-year (2011-2015) average of 103 days.

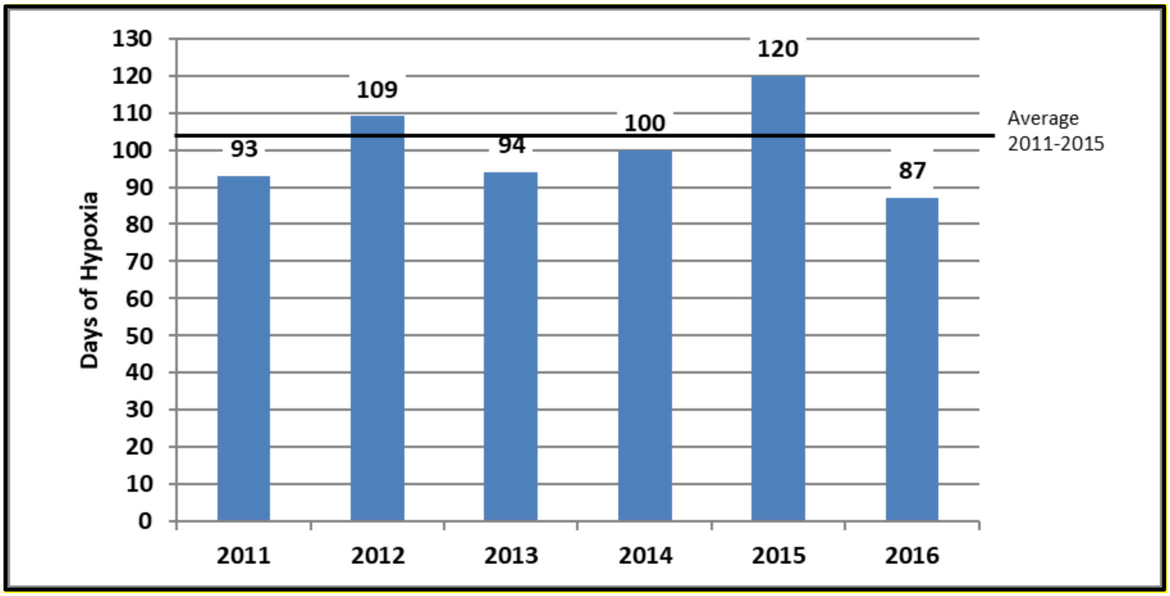


Figure 54. Days of Hypoxia (DO < 2.0 mg/L), 2011-2016

B. Total Phosphorus

Total phosphorus concentrations observed in Standley Lake in 2016 are displayed in Figure 55. Measurements are made at the bottom of the photic zone, defined as twice the Secchi depth, and at the bottom of Standley Lake. Concentrations in the photic zone and the hypolimnion were comparable and relatively consistent for much of the year. Concentrations at the bottom of Standley Lake increases slightly in the July to September period relative to the photic zone.

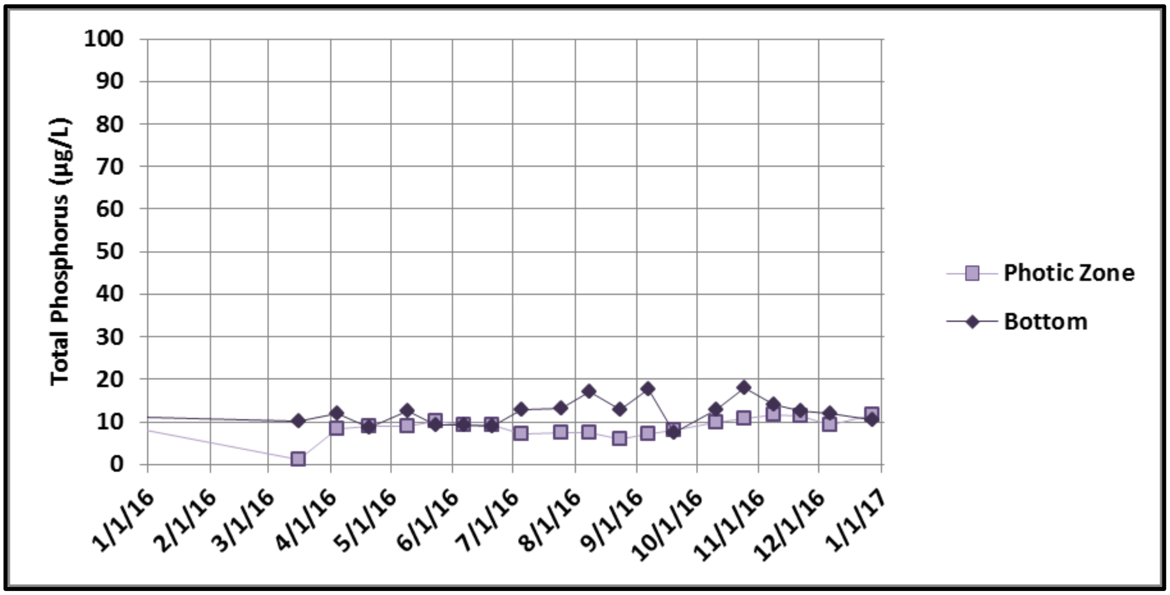


Figure 55. Total Phosphorus Concentrations in Standley Lake, 2016

The observed pattern in 2016 is sharply different from previous years, as shown in Figure 56. The averages in 2016 (12.0 µg/L hypolimnion and 8.7 µg/L photic zone) were 48% lower in the hypolimnion and 17% lower in the photic zone when compared to the 2011-2015 period. In 2016, higher nitrate concentrations at the bottom of the reservoir later in the summer likely affected redox conditions (Figure 57). This served to inhibit phosphorus releases in 2016, even though oxygen concentrations were very low.

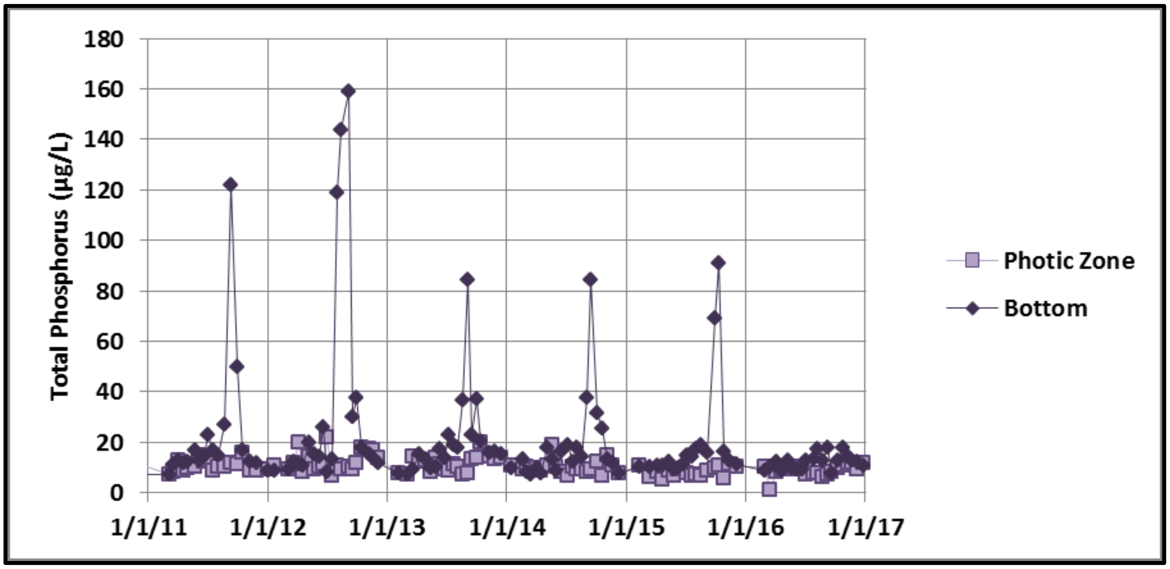


Figure 56. Total Phosphorus Concentrations in Standley Lake, 2011-

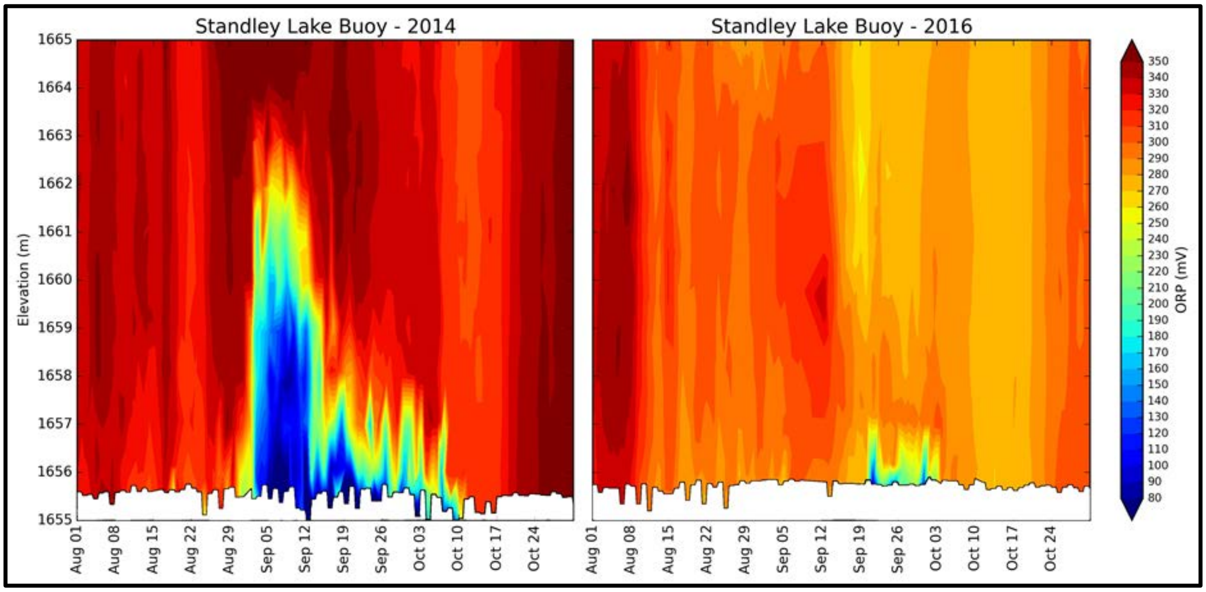


Figure 57. Comparison of ORP in the Bottom 10 Meters of Standley Lake; Typical Year (2014) and 2016

C. Total Nitrogen

Concentrations of TN observed in Standley Lake in 2016 in the photic zone and hypolimnion are shown in Figure 58. The pattern in the hypolimnion is similar to that seen in other years and is a reflection of external loading during runoff and internal loading in late summer. The maximum 2016 concentration observed in the hypolimnion (650 µg/L), was observed on July 25, 2016. As in past years, concentrations in the photic zone had smaller fluctuations relative to the hypolimnion.

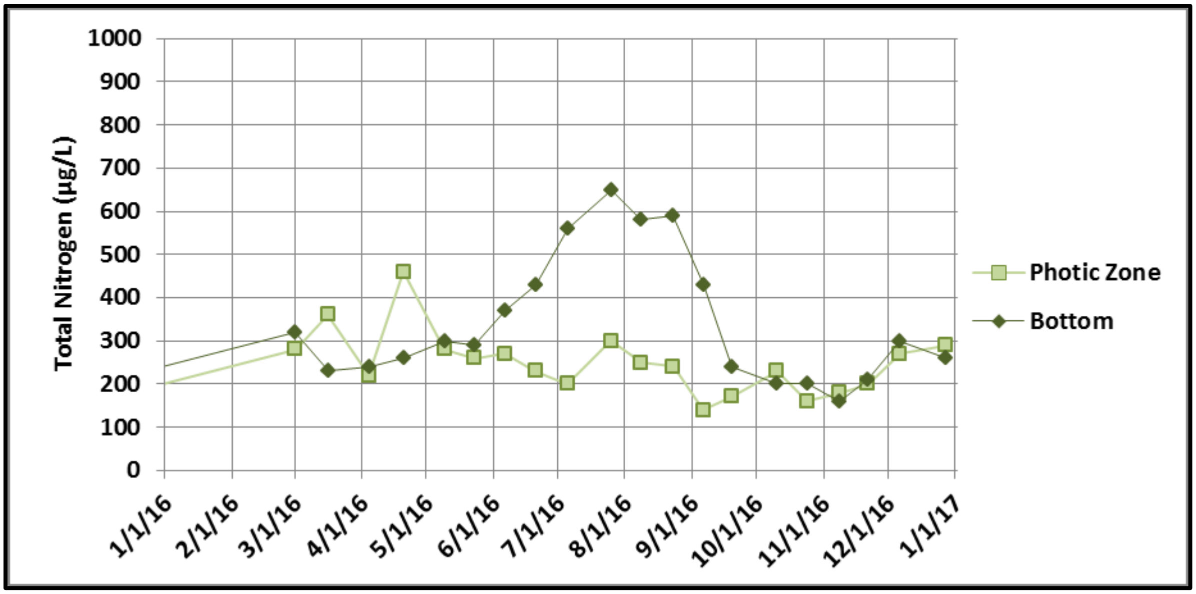


Figure 58. Total Nitrogen Concentrations in Standley Lake, 2016

Concentrations of TN in the lake for 2011-2016 are shown in Figure 59. Overall, TN concentration ranges observed in 2016 at the bottom and in the photic zone were comparable to previous years. The 2016 average TN concentrations (341 µg/L hypolimnion, 250 µg/L photic zone) were 13% lower in the hypolimnion and 7% lower in the photic zone when compared with the 2011-2015 annual average concentrations.

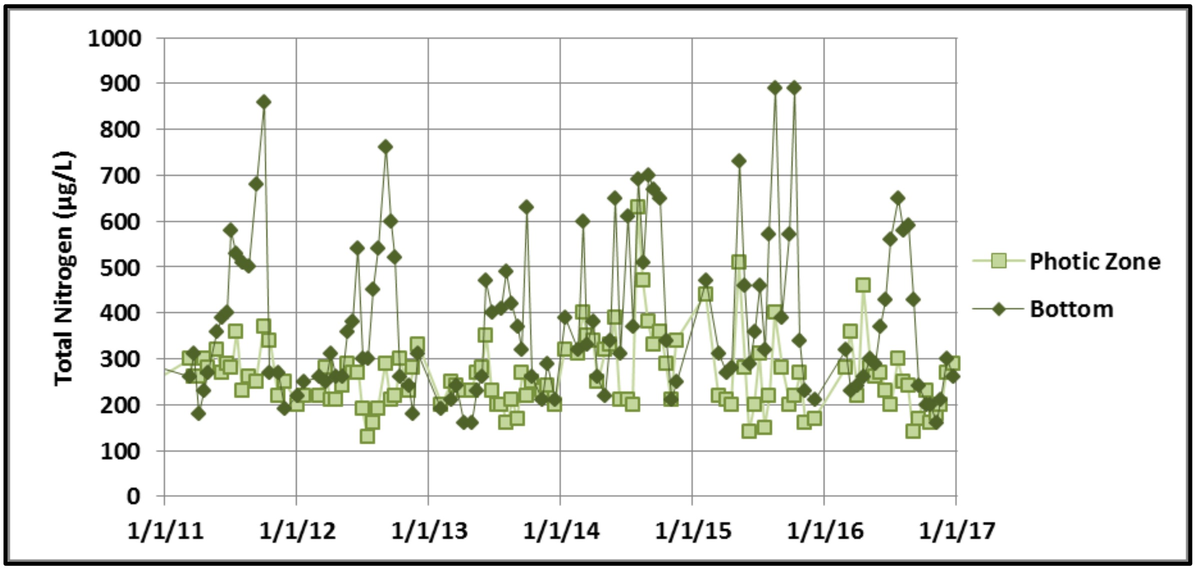


Figure 59. Total Nitrogen Concentrations in Standley Lake, 2011-2016

D. Chlorophyll *a*

Chlorophyll *a* concentrations observed in Standley Lake in 2016 are presented in Figure 60. March through November is the relevant period for standards assessment, these observations are outlined in green. The maximum concentration measured in 2016 was 6.6 µg/L and occurred on October 24, 2016. In 2016, there was a secondary peak (5.8 µg/L) on May 9, 2016.

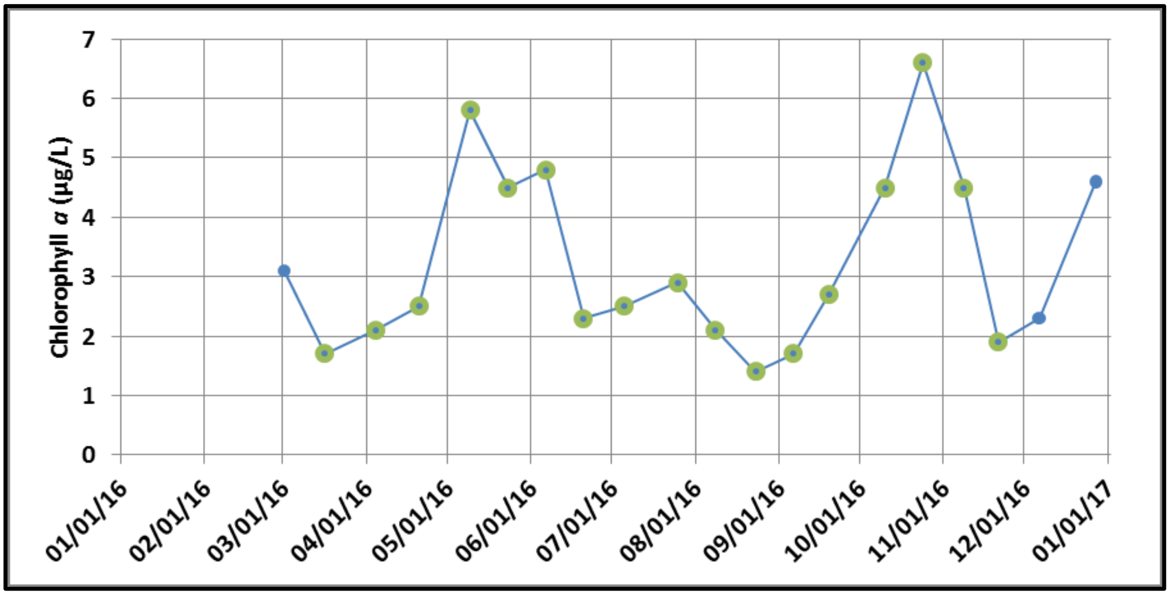


Figure 60. Chlorophyll *a* Concentrations in Standley Lake, 2016 (March-November observations highlighted in green)

Chlorophyll *a* concentrations observed from 2011 through 2016 are shown in Figure 61. Consistent with the previous figure, the green-outlined markers indicate March-November. The temporal patterns and the concentrations observed in 2016 were generally consistent with those seen during the 2011-2016 period. A seasonal pattern with chlorophyll *a* concentrations peaking after fall turnover is typical for Standley Lake. This fall peak in chlorophyll *a* is the result of turnover and an increase in concentrations of nutrients at the surface. The spring peak is slightly smaller relative to the fall peak, a pattern consistent with past years. Increasing temperatures in the spring, combined with a well-mixed water column and adequate nutrients provide conditions amenable to phytoplankton growth.

A contour plot of chlorophyll *a* concentrations in Standley Lake for March-December 2016 is shown in Figure 62. The spring time bloom is apparent in May and early June concentrated in the mid-depths of the reservoir. During this period, an analysis of in-reservoir water temperature found that depths of approximately 6 to 8 m are approximately isothermal with the temperature of water entering the reservoir from the FHL canal. This depth is consistent with the upper portion of the zone of high chlorophyll *a* observed in the spring. This suggests that interflow in spring acts to deliver nutrients to these mid-depths, helping to fuel the chlorophyll *a* concentrations. In contrast, the fall bloom is distributed evenly through the entire reservoir as a result of the fall turnover. Concentrations of chlorophyll *a* remained low for the June through September period.

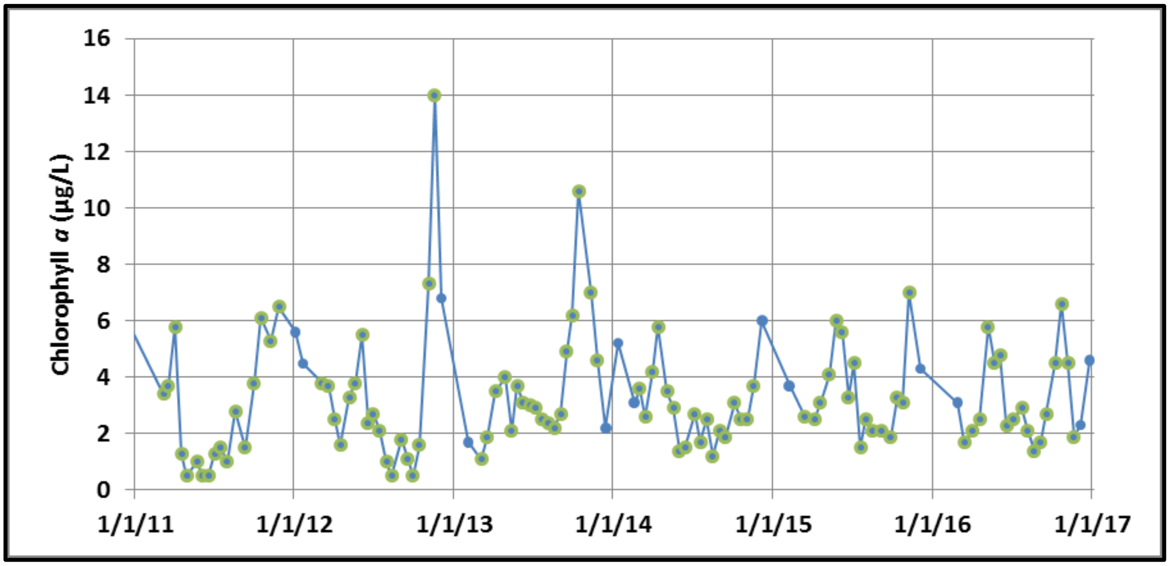


Figure 61. Chlorophyll *a* Concentrations in Standley Lake, 2011-2016 (with March-November observations highlighted in green)

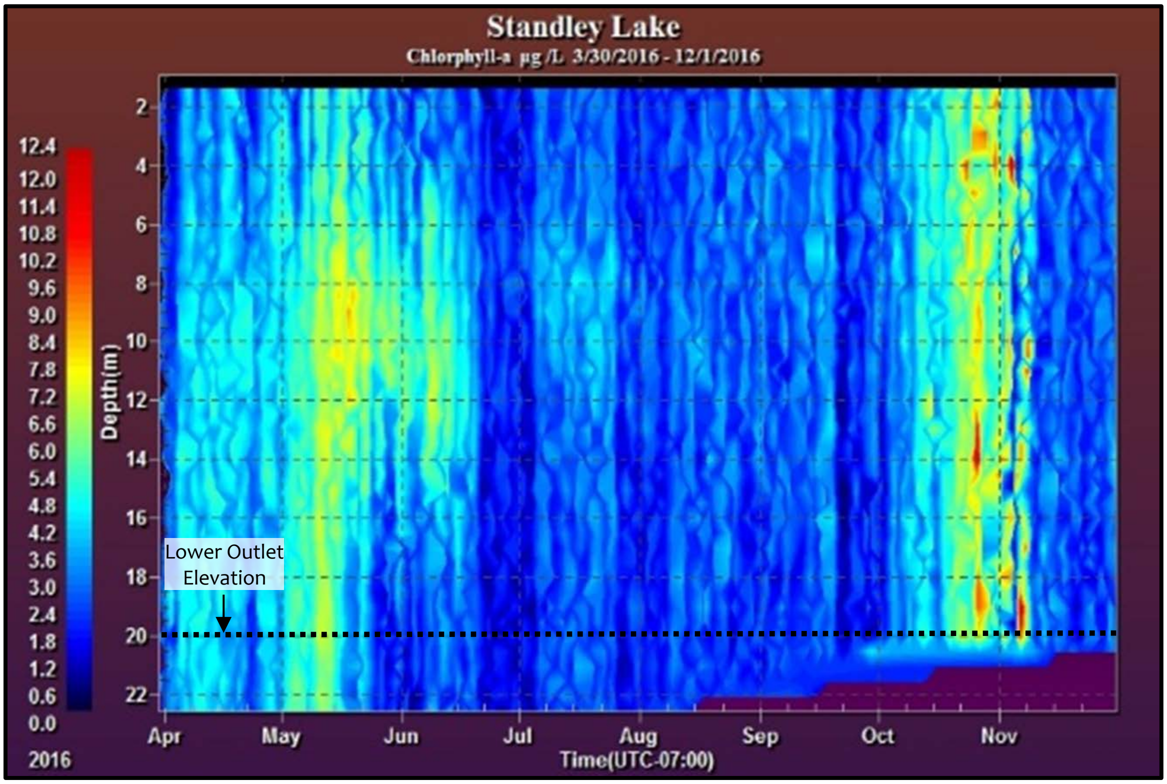


Figure 62. Contour Plot of Chlorophyll *a* Concentrations in Standley Lake, March-December 2016

A chlorophyll *a* standard of 4.0 µg/L was established in 2009 for Standley Lake. This standard is evaluated on an annual basis using the average of observed data for the nine-month period from March through November. To account for the natural variability in chlorophyll *a* concentrations, the standard is assessed using a concentration of 4.4 µg/L. In 2016, the average concentration was 3.2 µg/L (Figure 63). This average is calculated as the average of all measurements from the photic zone for the period of March through November.

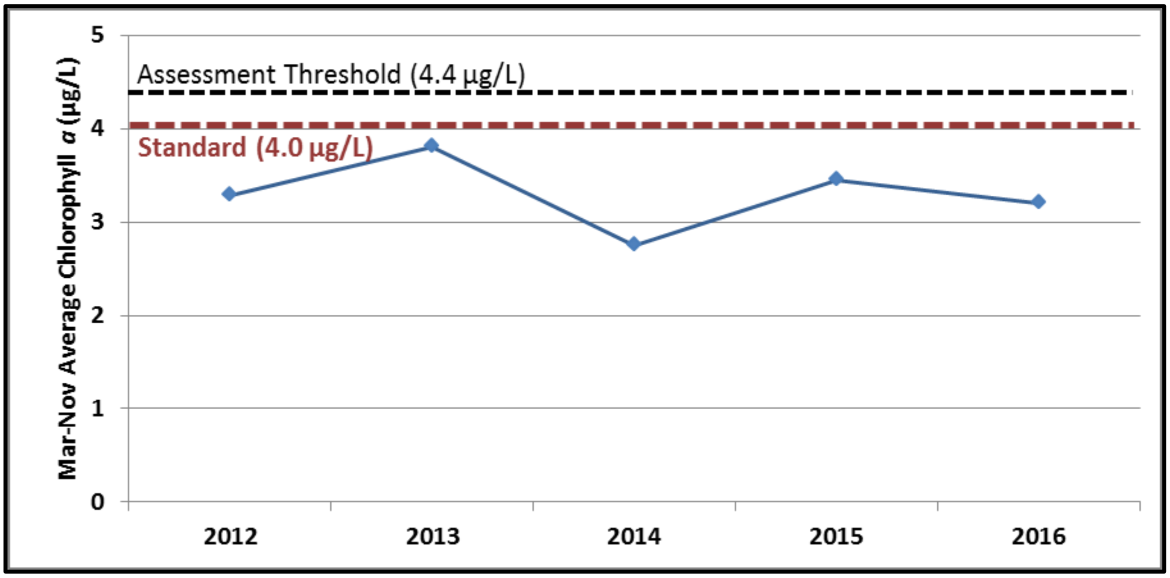


Figure 63. March - November Average Chlorophyll *a* Concentrations, 2012-2016

The chlorophyll *a* standard for Standley Lake was met once again in 2016. The 2016 average complies with both the 4.0 µg/L standard and 4.4 µg/L assessment threshold. The standard is met when four out of the five most recent years have a March-though-November average concentration below 4.4 µg/L. Every year in the five-year period from 2012 to 2016 has had a March-November average concentration below 4.0 µg/L. Of the last ten years, only one year (2007, at 4.8 µg/L) had a March-November average concentration above 4.0 µg/L.

E. Secchi Depth

Clarity in Standley Lake is measured using a Secchi disk. When taking this measurement, a black-and-white disk is lowered vertically into the lake until the disk is no longer visible. The resulting depth, termed the Secchi depth, provides a measure of the scattering and absorption of light in the upper portion of the water column. This includes the effects of algae, non-algal organic particulate matter, inorganic suspended solids, dissolved organic matter, and the water molecules themselves. Secchi-depth measurements for Standley Lake in 2016 are shown in Figure 64. The measure of clarity with the greatest depth (5.8 m) occurred on July 25, 2016. Through the year clarity is variable, reflecting a combination of effects such as inflowing suspended solids, algal growth, particle settling, and stratification.

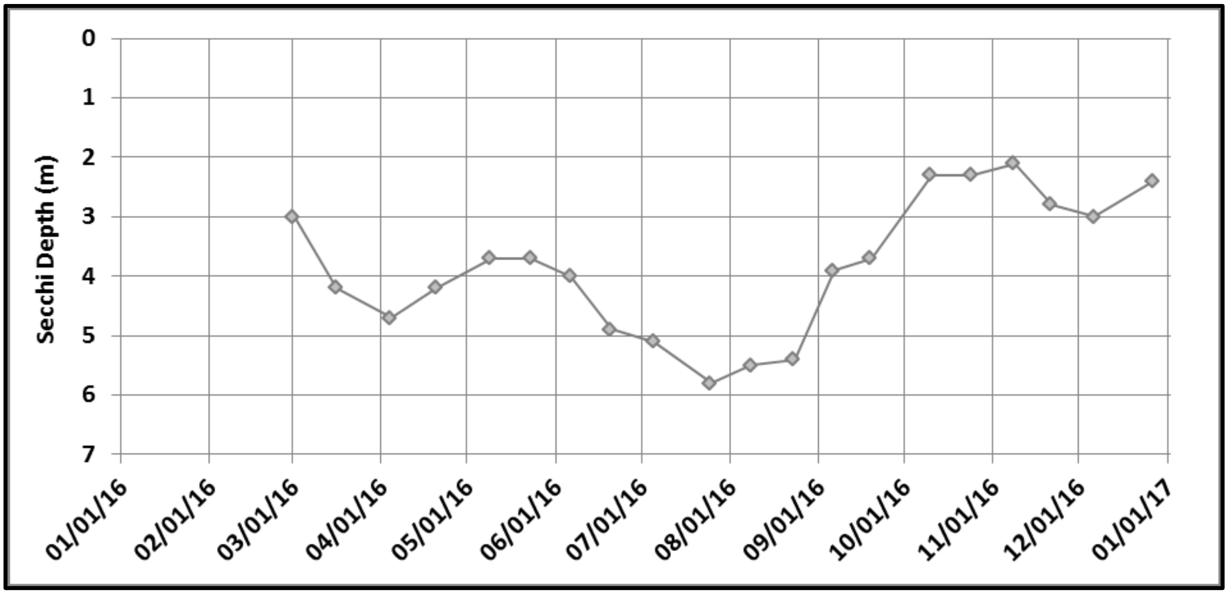


Figure 64. Clarity as Measured by Secchi Depth in Standley Lake, 2016

Individual Secchi-depth measurements for the past six years are shown in Figure 65. Average annual Secchi depths for the same period can be found in Figure 66. The annual average (3.8 m) and range of Secchi depths observed in 2016 were consistent with the range of those observed in recent years.

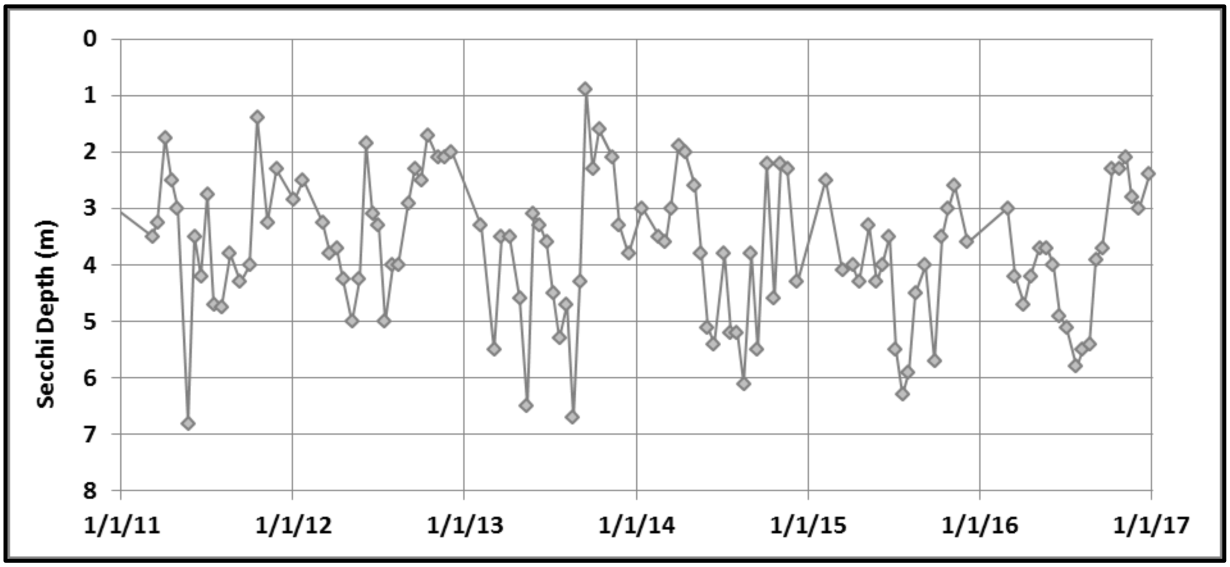


Figure 65. Clarity as Measured by Secchi Depth in Standley Lake, 2011-2016

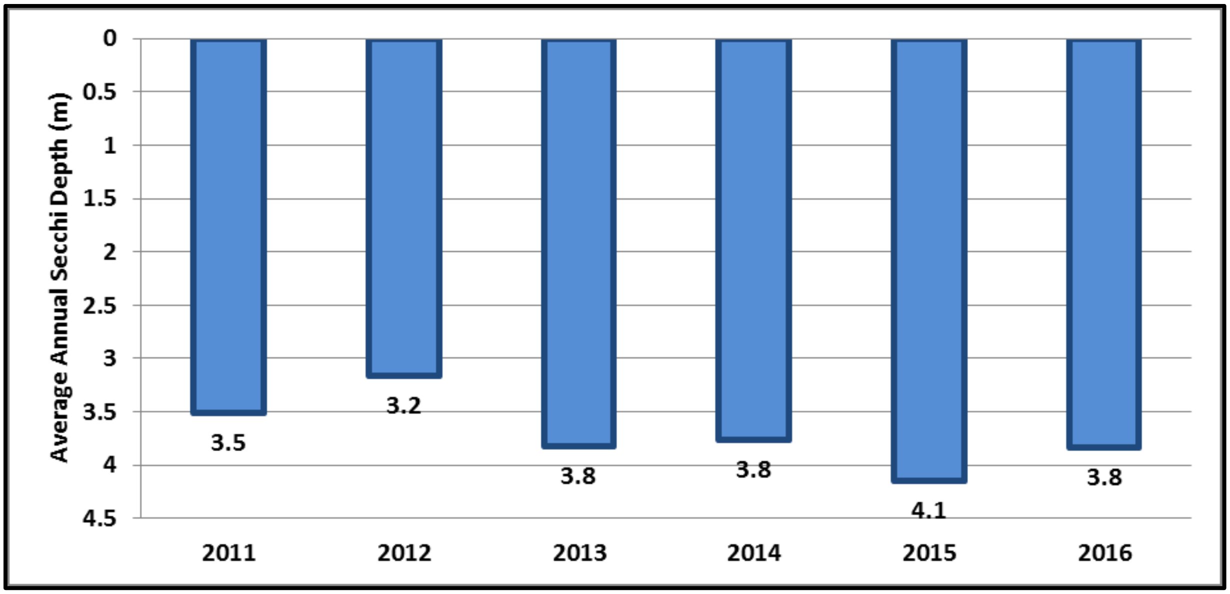


Figure 66. Average Annual Secchi Depth in Standley Lake, 2011-2016

F. Standley Lake Water Quality Summary

Water quality in Standley Lake, as indicated by the water-quality constituents discussed in this section, was good in 2016. As is typical, Standley demonstrated a period of summer stratification and associated hypolimnetic hypoxia. In contrast to past years, this period of hypoxia was not associated with an increase in TP concentrations in the hypolimnion. The patterns and magnitudes of TN concentrations were consistent with past years. Clarity, as measured by Secchi disk, and chlorophyll *a* are broad measures of water quality that provide a reflection of the overall water quality conditions in the lake. In 2016, chlorophyll *a* concentrations and Secchi depths were consistent with past years. Further, in 2016 chlorophyll *a* concentrations were in compliance with relevant standards.

VIII. Conclusions

Members of the UCCWA, the Standley Lake Cities, and other parties to the 1993 Agreement continued efforts in 2016 to monitor, preserve, and improve water quality in Clear Creek and Standley Lake. Across the watershed, a diverse set of activities occurred; these included: monitoring and improvement of WWTF operations, control of sediment and nonpoint sources of pollution, and remedial activities. These direct actions were supplemented by numerous public outreach and educational activities, extensive water-quality monitoring, and planning efforts to support management.

In Clear Creek, the observed annual flows at CC26 and CC60 were slightly below the average of the previous five years. At the downstream station (CC60), annual flows were slightly above the thirty-year (1975-2015) average. The pattern and timing of peak flows was generally consistent with past years. However, in 2016 a period of cold weather in the upper extent of the Clear Creek watershed resulted in a period of decreased flows and a hydrograph with two distinct peaks. The annual loads of TSS and TP, as measured at both CC26 and CC60 were below average. This appears to be primarily driven by decreases in the concentrations observed in May and June. It appears likely that the timing of the sampling in 2016 may have bracketed the typical period of highest concentrations (associated with peak snowmelt flows). The loads and concentrations of TN were consistent in pattern and magnitude with past years. At the upstream station (CC26), the pattern of decreased TN concentrations in the post-2011 period has continued. This pattern is likely to be primarily the result of WWTF upgrades and process improvements with contributions from other watershed activities. This observation is a testament to the effectiveness of the efforts undertaken to preserve and improve water quality in Clear Creek.

Standley Lake began 2016 with relatively high levels, and the lake filled to near capacity in May. This level was maintained until near the end of the summer, when drawdown began. Overall, the average contents in 2016 were very close to the average of the previous five years. In 2016 the loading of nutrients, TN and TP, to the lake was below average. This decrease in loading was primarily driven by concentration decreases seen in the FHL canal. As is typical, the outflow of nutrients from the lake was lower than the inflow, indicating the net retention of nutrients.

As is typical, Standley demonstrated a period of summer stratification and associated hypolimnetic hypoxia. In contrast to past years, this period of hypoxia was not associated with an increase in TP concentrations in the hypolimnion. Higher nitrate concentrations at the bottom of the reservoir later in the summer likely affected redox conditions, serving to inhibit phosphorus releases in spite of very low oxygen concentrations. The patterns and magnitudes of TN concentrations were consistent with past years. The maintenance of lower nutrient concentrations is manifested in the broader measures of water quality such as clarity and chlorophyll *a.* In 2016, chlorophyll *a* concentrations and Secchi depths were consistent with past years. Further, the chlorophyll *a* concentrations were in compliance with the standard. These observations demonstrate that good water quality is being maintained in Standley lake. This, in turn, provides strong evidence of the effectiveness of the efforts to manage, enhance, and protect water quality throughout the Clear Creek and Standley Lake watersheds.

IX. References

CDOT 2015. http://dtdapps.coloradodot.info/otis/trafficdata.

Colorado Department of Public Health and Environment (CDPHE) 2012. Nutrients Management Control Regulation. 5 CCR 1002-85 (Regulation 85). Water Quality Control Commission. Adopted June 11, 2012; Effective September 30, 2012.

Enviroscience 2013. 2013 Milfoil Weevil Survey at Standley Lake, Westminster, Colorado. Enviroscience, Stowe, Ohio.

Hydros Consulting 2016. Clear Creek/ Standley Lake Watershed Agreement. 2015 Annual Report. September 9, 2016