2013 Annual Report
Upper Cache la Poudre River
Collaborative Water Quality Monitoring Program

Prepared for:

City of Fort Collins Utilities
City of Greeley
Tri-Districts

Prepared by:

Jill Oropeza, Watershed Specialist
Jared Heath, Watershed Technician
City of Fort Collins Utilities

August 22, 2014

EXECUTIVE SUMMARY

Upper Cache la Poudre Collaborative Water Quality Monitoring Program

Sample collection for the Upper Cache la Poudre (CLP) Collaborative Water Quality Monitoring Program consists of eleven sampling events between April and November at ten sites on the Mainstem CLP and nine sites on the North Fork Cache la Poudre River, including Seaman Reservoir. Water samples are analyzed for a total of up to 39 parameters.

The objective of this collaborative water quality monitoring program is to assist the City of Fort Collins, the City of Greeley and the Tri-Districts in meeting current and future drinking water treatment goals by reporting current water quality conditions and trends within the Upper CLP watershed and issues that potentially impact watershed health.

Scope of 2013 Annual Report

The 2013 annual report summarizes the hydrologic and water quality data collected as part of the Upper CLP Collaborative Water Quality Monitoring Program and provides a comparison with water quality information from the years 2010 – 2012. The report also summarizes significant events, issues of concern, and results from special studies.

Seven key sites were identified that are considered representative of conditions on the Mainstem and North Fork CLP. The discussion of results focuses primarily on these seven key sites as well as Seaman Reservoir, although data for all sites were analyzed. Significant events and trends are also included in the discussion of results. Summary graphs for all parameters, and locations of monitoring sites are presented in separate attachments (Attachment 7 and 2, respectively).

Significant Events, Issues of Concern & Special Studies

- **Geosmin.** Sampling for geosmin, a naturally occurring organic compound that imparts an earthy odor to water, began following an outbreak that occurred during the winter of 2009-2010 in raw Poudre River water at the Fort Collins Water Treatment Facility (FCWTF). The goal of sampling efforts was to identify the source of high geosmin concentrations and the factors that influence geosmin production on the Upper CLP.

  Monthly geosmin sampling efforts began in July of 2010 following a series of reconnaissance sampling events that identified the area of high geosmin. This initial sampling period continued through April 2011 and is referred to as Phase I monitoring. Phase II sampling began in May 2011, and incorporated changes in the sampling program, including a reconfiguration of monitoring sites and the addition of quantitative area-based periphyton sampling methods (versus qualitative samples for ranked relative abundance). In 2013, paired nutrient and phytoplankton samples were dropped from the sampling routine due to a general lack of correlation between nutrients and geosmin concentrations, as well as limited access to the river substrates due to weather and flow conditions. However, geosmin samples were consistently collected at six locations on the Upper CLP.in 2013.

The results of Phase I geosmin monitoring were documented in the manuscript, “Navigating uncharted waters: Assessing Geosmin Occurrence in a Colorado Rocky Mountain Source Water River” (Oropeza, Billica and Elmund, 2011) that was presented at the AWWA Water Quality Technology Conference in Phoenix, AZ, November 13-17, 2011.

With the exception of total phosphorus (Total P), a full review of Phase I & II results in 2011 did not identify any point sources of nutrient or fecal contamination or establish significant links between nutrients and geosmin occurrence. No up- to down-stream trends in geosmin concentrations have been observed, suggesting that geosmin production is regulated by site-specific conditions that affect the local cyanobacteria populations (Oropeza, 2012).

2013 geosmin results indicate that during the month of July, geosmin concentrations exceeded the taste and odor threshold of 4 ng/L at five sites upstream of the Fort Collins Poudre supply intake facility, with the highest concentration of 14.87 ng/L observed at the Poudre below Mishawaka monitoring site. Despite the relatively high concentrations at upstream locations, concentrations did not exceeded 4 ng/L at the Fort Collins intake facility on the Poudre River or in the raw Poudre water supply at the FCWTF in 2013. These results support previous findings of local production of geosmin (vs. downstream transport) (Oropeza, 2012). As a result, the geosmin monitoring program will be further refined and limited to two key locations on the Upper CLP - Poudre below Rustic (PBR) and above the Fort Collins Poudre intake facility (PNF) in 2014 and beyond.

- **Northern Water Collaborative Emerging Contaminant Study.** The Cities of Greeley and Fort Collins have participated in the Northern Water collaborative emerging contaminant study since 2009 to determine the presence of pharmaceuticals and personal care products, pesticides, hormones, and phenolic endocrine disrupting compounds in waters of the Colorado-Big Thompson system. Two sites in the Upper Poudre Watershed have been included in this study: Poudre above North Fork (PNF) and North Fork at gauge below Seaman Reservoir (NFG). Currently, samples are screened for 139 compounds at the University of Colorado Center for Environmental Mass Spectrometry. The Upper Poudre sites are sampled three times per year. The compounds detected in 2013 include recreational indicators such as caffeine, DEET (insect repellent), and Triclosan (antibacterial agent) as well as the herbicides 2,4-D and Atrazine. These compounds were detected using sophisticated low level detection technology and methodologies, which report at the nanograms per liter (ng/L) level (0.000000001 mg/L). These analyses are useful for identifying the presence of compounds in drinking water supplies in order to establish baseline for future monitoring, but at the levels detected, they are not considered to pose a risk to human health.

- **Hewlett and High Park Wildfires, 2012.** The Hewlett Fire (May 14-May 22, 2012) burned 7,685 acres, including sub-watersheds that drain both to the Mainstem Poudre and into Seaman Reservoir on the North Fork Poudre River. The High Park Fire (June 9-July 2, 2012) burned 87,415 acres and included numerous sub-drainages that are tributary to the Mainstem Poudre River and the South Fork of the Poudre River. Combined, the two fires created a contiguous burned area approximately 95,000 acres in size. While no homes were damaged in the Hewlett Fire, the High Park Fire destroyed 259 homes and cabins.

The immediate widespread loss of vegetation and burned soils resulted in an unstable watershed that were susceptible to erosion and flooding. In 2012 and 2013 following the fires, localized summertime thunderstorms resulted in large sediment and debris flows into the Mainstem CLP and Seaman Reservoir. The movement of large volumes or ash, sediment and large debris into the river channel produced rapid and dramatic changes in water quality and posed a threat to the safety of people and homes in the Poudre Canyon. For the duration of 2012 and 2013, rapid changes in river water quality (turbidity) were observed in response to even small rain events and changes in water surface elevation due to water releases from upstream reservoirs. Water quality changes in Seaman Reservoir were less visible due to the lack of flow through the reservoir, long residence time and distance between the debris flow inputs and the reservoir outlet. However, sediment deltas are present within the direct watershed to Seaman Reservoir, indicating that inputs of fire-impacted materials have occurred.

Water quality sampling efforts in 2013 have continued to focus on routine monitoring to understand impacts of fire on baseline (non-storm event) water quality. In addition, the storm event sampling which was initiated in 2012 and continued in 2013 serves as an indicator of the progress of watershed recovery and water supply reliability over time. Storm event sampling is planned to continue in 2014 and beyond.

Increases in baseline concentrations of several nutrients occurred at the fire-impacted site, Mainstem Poudre above the North Fork (PNF) following the fires, including nitrate, ortho-phosphate, and to a lesser degree, ammonia. These increased concentrations, although notable, did not exceed any drinking water standards or nutrient regulations. The small increases in nutrient concentrations are likely due to continued deposition and persistence of fire impacted ash and sediments in the river channel as well as an increase in nutrient runoff due to decreased plant uptake on the surrounding landscape.

Unlike the Poudre River, the impacts of the fires on Seaman Reservoir water quality are influenced by internal reservoir dynamics, and as such, they were not as directly measureable, but rather delayed in time. Water level, water temperature, and inputs of watershed materials, are important influences on reservoir water quality and vary year to year.

In 2013, storm events continued to produce rapid and dramatic changes in water quality. The reliability of the Poudre River as a source drinking water supply is in large part determined by the water quality response to and frequency of these storm events. Summer thunderstorms are typically very localized and intense, with the tendency to initiate debris flows. On three occasions, these events produced turbidity values that exceeded 1000 NTU at PNF. In general concentrations of all measured parameters were elevated over baseline values, often by several orders of magnitude (Section 3). All storm samples were analyzed for hardness, pH, turbidity, organic carbon (TOC or DOC), nutrients and select metals. These responses, as measured at PNF, were typically of short duration, with a return to baseline water quality within several hours after the end of the rain event.

Emergency hillslope stabilization measures were undertaken in the High Park Fire burn areas by the US Forest Service on federal Forest Service lands and on private lands through a partnership between the Natural Resource Conservation Service (NRCS), the Cities of Fort Collins and Greeley and Larimer County. This work was completed as part of the NRCS Emergency Watershed Protection (EWP) program, which reimburses 75% of the costs for work completed by the co-sponsoring agencies. As part of the EWP program, a combined 3,881 acres of burned land were treated by aerial applications of wood mulch or agricultural straw in 2012 and 2013 in effort to decrease hillslope erosion. An additional 250 acres of wood shred mulch is planned for 2014.

Emergency stabilization measures on the Hewlett Fire burn area were coordinated by the NRCS and the City of Greeley in 2012 and included aerial straw mulching, seeding and tree felling into stream channels. No additional work around Seaman Reservoir was done in 2013.

- **2013 Flood.** In September of 2013 an extreme precipitation event resulted in historic flooding throughout Northern Colorado's Front Range when rainfall amounts over a seven day period (September 9-16) exceeded annual precipitation totals. In areas of the Upper CLP watershed, rainfall totals were estimated between 8-10 inches and resulted in significant flooding downstream of the canyon mouth. Streamflow, measured at the Colorado Divison of Water Resources Canyon Mouth stream gauge (CLAFTFO), increased from less than 100 cfs to a peak of 3,760 cfs, which was more than twice that observed during peak spring snowmelt at this site. Streamflow measurements at this site represent total combined flows for the North Fork and Mainstem of the Poudre.

  This event had short term, yet significant impacts on water quality in the Poudre River which restricted the water providers' abilities to use the water supply for a period of time. Turbidity values in the River during this time exceeded 1,000 NTU, however, impacts on nutrient concentrations were limited and occasionally lower than baseline concentrations due to the dilution effect of the high volume flow in the River (Section 3.5.4).

Significant Results

Mainstem & North Fork CLP

- Peak 2013 stream flows on the Mainstem during snowmelt runoff (1,787 cfs on June 8th) were higher than 2012, but lower than 2010 and 2011. At the onset of spring runoff, the amount of water in the snowpack, or snow water equivalent (SWE) was 99% of historical average. Peak streamflow during snowmelt runoff on the North Fork occurred nearly a month earlier (May 5^{th}) than on the Mainstem, and was 231 cfs.

- In contrast to previous years, annual peak streamflow did not occur during snowmelt runoff. Rather, the September 2013 flood event produced the highest annual peak flows, which were 2,440 and 2,590 cfs on the Mainstem (PNF) and North Fork (NFG), respectively.

- In general, water from the north Fork basin was warmer with higher levels of dissolved constituents than the Mainstem, which was reflected by relatively elevated hardness, conductivity, alkalinity and concentrations of major ions. In both drainages, concentrations of dissolved constituents, temperature, and conductivity increased with decreasing elevations. Across all sites, minimum values occurred during periods of high flow.

- Peaks in turbidity were observed at all sites during spring snowmelt runoff, although a second, higher spike in turbidity was observed at the lower Mainstem sites near the Fort Collins Intake (PNF) and Greeley's Bellvue Diversion (PBD) in July. This routine sampling event coincidentally captured the effects of a storm event (July 13^{th}) that mobilized a significant amount of sediment and debris into the river within the High Park Fire burn area. Spikes in turbidity in response to summertime storms have occurred frequently since the 2012 wildfires.

- 2013 peak total organic carbon (TOC) concentrations occurred during spring runoff at Mainstem sites, whereas the September flood event produced the highest TOC concentrations on the North Fork. The highest TOC concentrations on the Maintstem were observed at the highest elevation sites below Joe Wright Reservoir (JWC) and the Poudre above the confluence with Joe Wright Creek (PJW). 2013 peak TOC concentrations were higher than the previous three years.

- Nutrient concentrations on the Mainstem have historically been low during non-runoff times of the year. The 2012 wildfires resulted in small, yet notable increases in baseline concentrations of nitrate and ortho-phosphate, and to a lesser extent, ammonia. Furthermore, at the onset of 2013 runoff, there were large deposits of burned ash and sediment that were stored along the river banks and within the river channel. Much of this stored material was scoured and transported downstream by the high spring flows; however the initial re-suspension of these sediments resulted in unusually high concentrations of many nutrients.

- In general, observed concentrations of nutrients were comparable at the North Fork and Mainstem sites. Halligan and Seaman Reservoir appear to be sources of nitrate, nitrite, ammonia, TKN, ortho-phosphate and Total P to the North Fork. The high concentrations of these nutrients were typically observed during mid- to late summer when dissolved nutrients are released from the bottom sediments under very low dissolved oxygen concentrations. The tributaries, Rabbit Creek (RCM) and Lone Pine Creek (PCM) were also sources of ortho-phosphate and Total P to the North Fork during spring snowmelt.

- The Mainstem and the North Fork CLP were in compliance with proposed nutrient standards for Total N and Total P, as measured at North Fork below Seaman Reservoir (NFG) and the Mainstem at Fort Collins Intake (PNF) and Greeley's Bellvue Diversion (PBD).

- The most commonly detected metals were aluminum, iron and manganese. The highest concentrations on the Mainstem were observed prior to spring runoff, and like other constituents, may have been influenced by the stored sediments in the river channel from the previous summers' debris flows.

- *Giardia* was more abundant than *Cryptosporidium* at both the Mainstem and North Fork sites. *Giardia* concentrations were similar to the previous three years. Cryptosporidium was detected only three times in the last four years, with zero detections in 2012 or 2013. No trends in levels of either pathogen were observed at any Mainstem or North Fork sites.

- 2013 *E.coli* and total coliform concentrations at the Mainstem and North Fork sites were similar to previous three years, with the exception of a spike in concentration observed during the July sampling event. Elevated concentrations of total coliforms occurred on the Mainstem at PNF, PBD and on the North Fork at NFG; the concurrent spike in *E.coli* concentrations occurred only at the Mainstem sites, PNF and PBD.

Seaman Reservoir

- Following 2013 Spring runoff, Seaman Reservoir was at 4,882 acre feet, which is 97% of its 5,000 acre-feet capacity. The reservoir exceeded capacity during a storm event on August 3rd, and again during the September flood event. During this time, water was released into the North Fork via the spillway and/or the bottom out. The reservoir remained 100% full for the remainder of the year.

- Seaman Reservoir followed its typical pattern of season thermal stratification and was fully stratified by July, 2013. On this sampling date, the top temperature of 23.2°C exceeded the aquatic life temperature standard of 22.5°C. Water temperatures at the top fell below the standard by August. No information about the timing of fall turnover is available, as the September 2013 flood event damaged the bridges that serve as access to Seaman Reservoir, and sampling was not conducted for the remainder of the year.

- As in previous years, dissolved oxygen (D.O.) levels fell below the aquatic life standard of 6 mg/L and reached near zero under fully stratified conditions. By August, the zone of oxygen depletion extended from 5 m below the surface to the bottom, at 16m. These low oxygen conditions have important implications for algae growth, internal nutrient loading and aquatic life suitability.

- Early season nitrate concentrations were elevated over previous years at both the top and bottom of the reservoir, although concentrations fell below detection limit by early summer. 2012 and 2013 concentrations of ortho-phosphate and Total P at the bottom of the reservoir significantly higher than observed in 2010 and 2011. The higher concentrations of phosphorus may originate from internal nutrient loading under prolonged periods of low dissolved oxygen and/or from sediment loading into the reservoir from drainages burned in the Hewlett Fire.

- Total organic carbon (TOC) concentrations in 2013 were within the range of values observed in previous years. 2013 values ranged from approximately 5 mg/L at the beginning of the monitoring season, to a seasonal peak concentration of 8.71 mg/L.

- Based on 2013 chlorophyll-a, Total P and secchi depth values, and consistent with previous years' findings, the trophic status of Seaman Reservoir can be characterized as mesotrophic to eutrophic.

- Blue-green algae (Cyanophytes) were the most abundant algae in both the top and bottom of the Reservoir at the start of the 2013 monitoring season. This differs from 2010-2011 when the Reseroivr top was dominated by golden algae (chyrsophyta) and green algae (chlorophyta). A predominance of blue-green algae poses some concern because certain species of these algae can produce toxins (cyanotoxins) that pose public health concerns. Others can produce taste and odor compounds, including geosmin and MIB, which affect the aesthetic quality of drinking water and are difficult to remove during water treatment.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS & ACRONYMS

%	percent
Ag	Silver
BMR	Barnes Meadow Reservoir Outflow (routine monitoring site)
Ca	Calcium
Cd	Cadmium
CDPHE	Colorado Department of Public Health and Environment
CDWR	Colorado Division of Water Resources
CEC	Contaminants of Emerging Concern
cells/mL	cells per milliliter
cfs	cubic feet per second
CHR	Chambers Lake Outflow (routine monitoring site)
Cl	Chloride
CLP	Cache la Poudre River
Cr	Chromium
Cu	Copper
CU	University of Colorado, Boulder
cysts/L	cysts per liter
D.O.	Dissolved Oxygen
DBP	Disinfection By-Product
DOC	Dissolved Organic Carbon
EDC	Endocrine Disrupting Chemical
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
EWP	Emergency Watershed Protection
FCWQL	Fort Collins Water Quality Lab
FCWTF	Fort Collins Water Treatment Facility
Fe	Iron
GPS	Global Positioning System
HSWMP	Halligan-Seaman Water Management Project
JWC	Joe Wright Creek above the Poudre River (routine monitoring site)
K	Potassium

LC/MS-MS	Liquid Chromatography with Tandem Mass Spectrometry
LC/TOF-MS	Liquid Chromatography – Time of Flight – Mass Spectrometry
LRT	Laramie River Tunnel
m	meter
M&E List	Colorado's Monitoring & Evaluation List
MCL	Maximum Contaminant Level
Mg	Magnesium
mg/L	milligrams per liter
Na	Sodium
NBH	North Fork of the Poudre River below Halligan Reservoir (routine monitoring site)
NDC	North Fork of the Poudre River above Dale Creek Confluence (routine monitoring site)
NEPA	National Environmental Policy Act
NFG	North Fork of the Poudre River below Seaman Reservoir (routine monitoring site)
NFL	North Fork of the Poudre River at Livermore (routine monitoring site)
ng/L	nanograms per liter
NH_4	Ammonia
Ni	Nickel
NISP	Northern Integrated Supply Project
NO_2	Nitrite
NO_3	Nitrate
NTU	Nephelometric Turbidity Units
^oC	degrees Celsius
Pb	Lead
PBD	Poudre River at the Bellvue Diversion (routine monitoring site)
PBR	Poudre River below Rustic (routine monitoring site)
PCM	Pine Creek Mouth (routine monitoring site)
PPCP	Pharmaceuticals and Personal Care Product
PJW	Poudre River above the confluence with Joe Wright Creek
PNF	Poudre River above the North Fork (routine monitoring site)
PO_4	Phosphate

ppt	parts per trillion
RCM	Rabbit Creek Mouth (routine monitoring site)
SCFP	Soldier Canyon Filter Plant
SCM	Stonewall Creek Mouth (routine monitoring site)
SFM	South Fork of the Poudre River above the Mainstem (routine monitoring site)
SO_4	Sulfate
T&O	Taste & Odor
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TOC	Total Organic Carbon
TP	Total Phosphorus
TSI	Trophic State Index
ug/L	micrograms per liter
uS/cm	microSeimens per centimeter
USGS	United States Geological Survey
WQCD	Water Quality Control Division
WTP	Water Treatment Plant
Zn	Zinc

1.0 INTRODUCTION

1.1 Background

The Upper Cache la Poudre (CLP) River is an important source of high-quality drinking water supplies for communities served by the City of Fort Collins Water Treatment Facility (FCWTF), the City of Greeley-Bellvue Water Treatment Plant (WTP), and the Tri-Districts Soldier Canyon Filter Plant (SCFP). In the shared interest of sustaining this pristine water supply, the City of Fort Collins, the City of Greeley and the Tri-Districts partnered in 2007 to design the Upper CLP Collaborative Water Quality Monitoring Program. The Program was subsequently implemented in spring 2008. The overarching goal of this monitoring partnership is to assist the participants in meeting current and future drinking water treatment goals by providing up-to-date information about water quality and trends within the Upper CLP watershed.

Raw Poudre River water quality parameters that have historically had the most impact on treatment at the three treatment plants include turbidity, total organic carbon (TOC), pH, alkalinity, temperature, pathogens (*Giardia* and *Cryptosporidium*), and taste and odor (T&O) compounds, such as geosmin. A more in-depth discussion of TOC, geosmin, and pathogens and the challenges they present for water treatment is included in the program design document, "Design of a Collaborative Water Quality Monitoring Program for the Upper Cache la Poudre River" (Billica, Loftis and Moore, 2008). This document also provides a complete description of the scope and objectives of the monitoring program as well as a detailed description of the watershed, sampling design and methods.

Two proposed water supply projects that influence Upper CLP waters are currently under consideration. The proposed Northern Integrated Supply Project (NISP) includes a new off-channel reservoir (Glade Reservoir) that will take water from the Upper CLP downstream of the North Fork CLP River (North Fork) confluence. The proposed Halligan-Seaman Water Management Project (HSWMP) includes the expansion of both Halligan Reservoir and Seaman Reservoir on the North Fork. NISP and HSWMP are currently undergoing review as part of the National Environmental Policy Act (NEPA) process. Water quality data collected for the Upper CLP Collaborative Water Quality Monitoring Program may be used to support the water quality studies conducted for these proposed projects and their respective Environmental Impact Statements (EIS).

Annual and five-year reports for the collaborative program are prepared by City of Fort Collins staff to keep participants informed of current issues and trends in water quality of the Upper CLP. The purpose of annual reports is to summarize hydrologic and water quality information for the current water year, provide a comparison with water quality from the preceding three years, describe notable events and issues, and summarize the results of special studies. The five-year report provides a more in-depth analysis of both spatial and temporal trends in watershed hydrology and water quality, including concentrations. The first five-year report was completed for the years 2008-2012 (Oropeza & Heath, 2013). Upper CLP reports are available through the City of Fort

Collins Utilities Source Water Monitoring website (http://www.fcgov.com/utilities/what-we-do/water/water-quality/source-water-monitoring).

1.2 Watershed Description and Sampling Locations

Sampling efforts are divided between the Mainstem (including the Little South Fork CLP River) and North Fork Poudre River watersheds. Collectively these drainages encompass approximately 645,500 acres of forest, other natural land types and agricultural land (see Attachment 1). An additional 4,700 acres, representing less than 1% of land surface, is developed for commercial, industrial, utility, urban or residential purposes.

The monitoring network consists of 19 sampling locations selected to characterize the headwaters, major tributaries and downstream locations of the CLP near the City of Fort Collins, Tri-Districts and City of Greeley raw water intake structures (Figure 1). The 19 sampling sites include one reservoir - Seaman Reservoir. A description and rationale for each site is provided in Attachment 2.

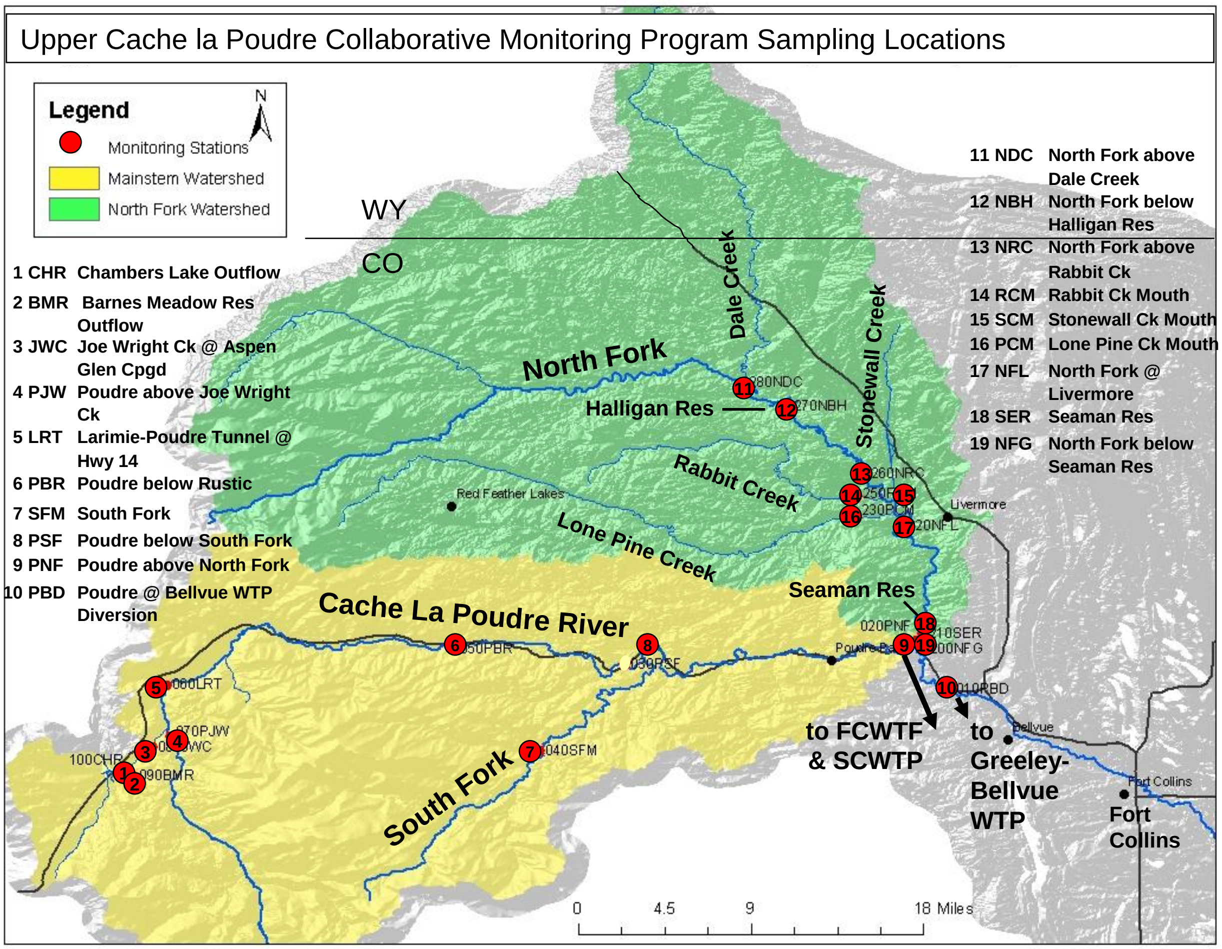


Figure 1.1 – Map of the Upper CLP collaborative water quality monitoring network.

1.3 Sampling Schedule and Parameters

The sampling frequency for the Upper CLP Collaborative Water Quality Monitoring Program was determined based on both statistical performance and cost considerations. Parameters included in the monitoring program were selected based on analysis of historical data and aim to provide the best information possible within current budgetary constraints. A list of parameters is included in Attachment 3. Complete discussions of parameter selection and sampling frequency are provided in Sections 5.3 and 5.4, respectively, of the original design document by Billica, Loftis and Moore (2008). The 2010 sampling schedule is provided as Attachment 4 of this report.

1.4 Sample Collection and Analysis

Dr. William Lewis was contracted by the City of Greeley in agreement with the City of Fort Collins and the Tri-Districts to perform sampling activities for the Upper CLP monitoring program at 17 of the 19 Mainstem and North Fork CLP sites. Staff members from the City of Fort Collins, City of Greeley, and Tri-Districts collect samples at the remaining two locations: North Fork of the Poudre River above confluence with Dale Creek (NDC) and North Fork of the Poudre River below Halligan Reservoir (NBH). Sampling methods, including those for the collection of field measurements for temperature, pH, conductivity, and dissolved oxygen (D.O.) are documented in Section 5.5 of Billica, Loftis and Moore (2008). All bulk water samples were analyzed by the City of Fort Collins Water Quality Lab (FCWQL), except for *Cryptosporidium* and *Giardia* filter samples, which were delivered to CH Diagnostic and Consulting, Inc., in Berthoud, CO for analysis. In addition, phytoplankton samples were collected from April through November at the top and bottom of Seaman Reservoir in 2011. Phytoplankton samples were identified and enumerated at the species level by Dick Dufford (private consultant) of Fort Collins, CO. The analytical methods and detection limits for the FCWQL parameters are included in Attachment 5.

1.5 Scope of 2013 Annual Report

The 2013 annual report summarizes the hydrologic and water quality data collected for the Upper CLP Collaborative Water Quality Monitoring Program and highlights the significant events, issues of concern, and the results of special studies. This report compares water quality information from 2013 with the previous three years 2010-2012.

2.0 SIGNIFICANT EVENTS, ISSUES OF CONCERN & SPECIAL STUDIES

2.1 Poudre River Geosmin

Geosmin is a naturally occurring organic compound that imparts an earthy odor to water and can be detected by the most sensitive individuals at concentrations as low as 4 nanograms per liter (ng/L) or 4 parts per trillion (ppt). Geosmin does not pose a public health risk, but it is of concern because its detectable presence can negatively affect customer confidence in the quality of drinking water. The Poudre River raw water supply is routinely monitored for geosmin concentrations on a monthly basis. As shown in Figure 2.1, the Poudre River raw water supply has experienced periodic episodes of elevated geosmin concentrations above the 4 ng/L odor threshold over time, with the most recent outbreak occurring in early 2010. Geosmin continues to be monitored in the raw Poudre water supply at the FCWTF on a routine basis.

In response to the elevated geosmin in raw water supply in 2010, intensive sampling on the Mainstem of the Poudre River was initiated to evaluate in-stream concentrations and delineate the approximate area of elevated geosmin concentrations along the river. Geosmin monitoring activities on the Poudre River focus on the following objectives:

- Identify the areas on the Poudre River with high geosmin concentrations that are sources of geosmin to the FCWTF;
- Identify spatial and seasonal geosmin and nutrients trends in areas of geosmin production;
- Evaluate potential sources of nutrients to the target areas, and;
- Characterize the periphyton community and identify known geosmin-producing species, when possible.

For further detail on the intensive monitoring plan and subsequent monitoring refer to the "2011 Annual Report Upper Cache la Poudre River Collaborative Water Quality Monitoring Program" (Oropeza, 2012) and the "Five Year Summary Report (2008-2012) Upper Cache la Poudre River Collaborative Water Quality Monitoring Program" (Oropeza and Heath, 2013). In this report, results presented for the time period of January 2013 through December 2013 are the last results for Phase II routine monitoring. River sampling locations associated with Phase II routine monitoring included *Poudre above Rustic*, *Poudre below Rustic (PBR), Stevens Gulch*, *Mishawaka*, and the *Greyrock* bridge. For each sampling event, geosmin samples were also collected from the raw Poudre River water at the FCWTF, which is representative of water at the intake facility on the river. Paired nutrient and periphyton date were not collected in 2013.

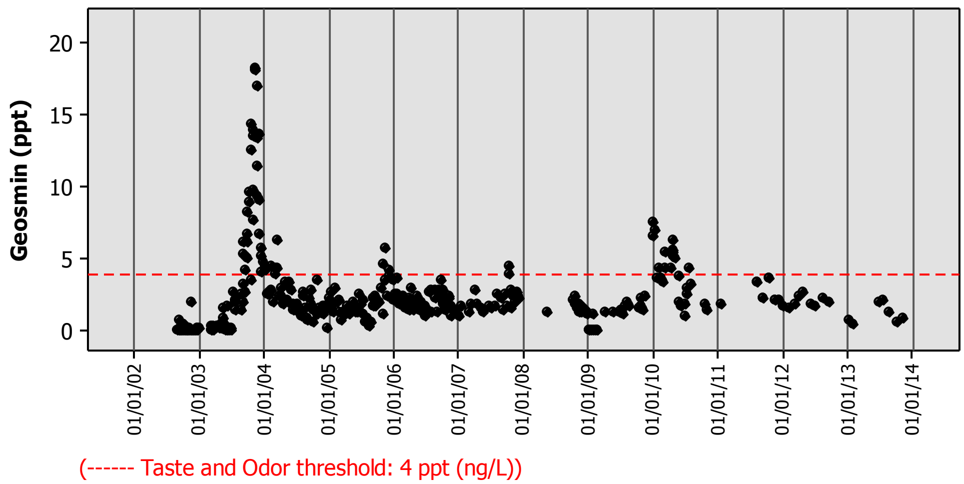


Figure 2.1 – Geosmin concentrations in raw Poudre River water wupply at the FCWTF from 2002-2013.

In 2013, geosmin concentrations on the Poudre River exceeded 4 ppt at all monitoring locations on July 24th, except for raw Poudre water collected at the FCWTF. In contrast to previous years, July was the only month that geosmin concentrations exceeded the 4 ppt T&O threshold, except for a slight exceedance of 4.37 ppt in June at the PBR monitoring location. In previous years the maximum geosmin concentrations were typically observed during the winter months; however, in 2013, the maximum geosmin concentration (14.87 ppt) was measured on July 24th at the Poudre River below Mishawaka. Concentrations decreased throughout the remaining monitoring season. Samples were not collected in September due to restricted access to the Poudre River Canyon following the flood event, but geosmin concentrations at most monitoring sites were at or below detection limit (<1.0 ppt) when sampling resumed in October and remained at these levels through December. Despite the elevated July concentrations on the River, concentrations at the FCWTF remained below the T&O threshold throughout the year (Figure 2.2).

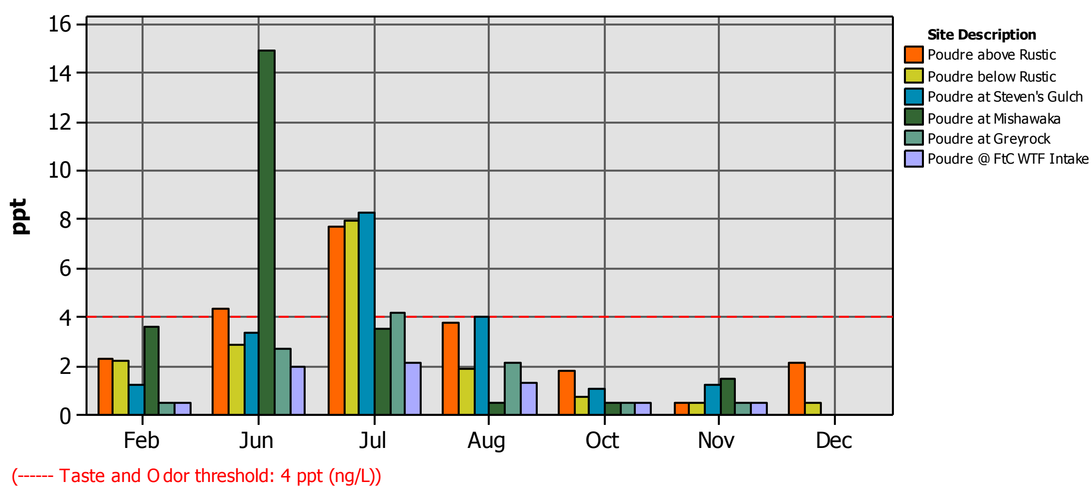


Figure 2.2 – Monthly geosmin concentrations at key locations on the Poudre River in 2013.

2.2 Colorado's 2010 Section 303(d) and Monitoring and Evaluation (M&E) Lists

Colorado's Section 303(d) List and Monitoring and Evaluation (M&E) List (Regulation #93) for the 2012 listing cycle were adopted on February 13, 2012 and became effective on March 30, 2012. When water quality standard exceedances are suspected, but uncertainty exists regarding one or more factors (such as the representative nature of the data used in the evaluation), a water body or segment is placed on the M&E List.

Segments of the North Fork of the CLP River that are on the state of Colorado's Section 303(d) List of impaired waters and Monitoring and Evaluation (M&E) List, as of March 30, 2012 are outlined on Table 1. Segments with 303(d) impairment require total maximum daily loads (TMDLs) and are prioritized with respect to TMDL development. The two North Fork segments on the 303(d) List have both been assigned a medium (M) priority. When water quality standard exceedances are suspected, but uncertainty exists regarding one or more factors (such as the representative nature of the data used in the evaluation), a water body or segment is placed on the M&E List. Three North Fork segments are currently on the M&E List. The North Fork sites listed below were scheduled for review in 2012 by the State of Colorado Water Quality Control Division (WQCD), but due to staffing shortage and the need to work on large water projects, the Water Quality Control Commission postponed the next 303(d) listing hearing until 2016.

Table 1 – Segments of Upper CLP waters that are listed on the state of Colorado's Section 303(d) List of impaired waters and Monitoring and Evaluations (M&E) Lists.

WBID	Segment Description	Portion	Colorado's Monitoring & Evaluation Parameter(s)	Clean Water Act Section 303(d) Impairment	303(d) Priority
COCSPCP06	Mainstem of the North Fork of the Cache la Poudre River, including all tribs from source to Halligan Reservoir	All	Cu		
COSPCP07	North Fork of the Cache la Poudre from Halligan Reservoir to the Cache la Poudre	All		Pb, Cd	M
COSPCP08	All tributaries to the North Fork of the Cache la Poudre from Halligan Reservoir to the Cache la Poudre	All	*E. coli*		
COSPCP09	Rabbit Creek and Lone Pine Creek	All	Cd, Pb		
COSPCP20	Lakes and reservoirs tributary to the North Fork of the Cache la Poudre from Halligan Reservoir to the Cache la Poudre River.	Seaman Reservoir		D.O.	M

2.3 Northern Water Collaborative Emerging Contaminant Study

Contaminants of emerging concern (CEC) and their presence in drinking water have recently received national attention. CEC are trace concentrations (at the ng/L or part per trillion (ppt) level, or less) of the following types of chemicals:

- Pharmaceuticals: prescription and non-prescription human drugs (including pain medications, antibiotics, β-blockers, anti-convulsants, etc) and veterinary medications

- Personal care products (PCP): fragrances, sunscreens, insect repellants, detergents, household chemicals

- Endocrine disrupting chemicals (EDC): chemicals that interfere with the functioning of natural hormones in humans and other animals; includes steroid hormones (estrogens, testosterone, and progesterone), alkylphenols, and phthalates

- Pesticides and herbicides

In 2008, Northern Water (NW) initiated a collaborative emerging contaminant study to determine the presence of these compounds in waters of the CBT system. In 2009, two monitoring sites on the Upper Cache la Poudre, the Poudre River above the North Fork and the North Fork below Seaman Reservoir (PNF and NFG, respectively) were included in the study with funding provided by the City of Fort Collins and the City of Greeley. Sampling conducted in 2013 for CEC in the UCLP occurred once in February, June, and August.

Samples were submitted to the Center for Environmental Mass Spectrometry Laboratory at the University of Colorado at Boulder (CU) for analysis of 40 pharmaceuticals and personal care products (PPCP) and 64 herbicides/pesticides by the presence/absences screening method using Liquid Chromatography – Time of Flight – Mass Spectrometry (LC/TOF-MS). Beginning with the June 2009 sampling event, samples were also submitted to Underwriters Laboratories, Inc. for analysis of estrogens and other hormones (9 compounds, UL Method L211), and phenolic EDC (8 compounds including bisphenol A, UL Method L200). Beginning in 2010, the CU laboratory also began conducting low-level analysis using liquid chromatography with tandem mass spectrometry (LC/MS-MS) for a subset of 22 different PPCP, in addition to the analysis of compounds measured by LC/TOF-MS. In 2013, three hormones included in the Environmental Protection Agency's (EPA) Third Unregulated Contaminant Monitoring Rule were added to the list; 4-Androstene-3,17-dione, Equilin, and Estriol. The total list of compounds analyzed by LC/MS-MS in 2013 included 27 herbicides/pesticides and PPCP and eight EDC, in addition to the 104 compounds measured using LC/TOF-MS.

The following bullets summarize findings from NW's Emerging Contaminants Program: 2013 Annual Report for emerging contaminants detected in UCLP surface waters during the 2013 monitoring seasons:

Emerging Contaminants Summary (2013):

- Pharmaceuticals and Personal Care Products (PPCP) were not detected at PNF or NFG.

- Endorcrine disrupting chemicals (EDC) were not detected at PNF or NFG.

- Herbicide and insecticide concentrations were generally low or below detection at PNF and NFG (<20 ng/L). The only herbicide detected in 2013 was 2,4-D (25 ppt) at NFG in February and August. Concentrations were very low and likely associated with weed control in agricultural applications as well as along fences and highways, and canals and reservoirs in the North Fork Poudre River watershed. A maximum contaminant level (MCL) of 0.07 milligrams per liter (mg/L) (70,000 ng/L or ppt) has been set for 2,4-D by the U.S.E.P.A. for finished drinking water.

- Recreational contaminants, DEET, caffeine, and triclosan, were all detected at low levels. DEET and triclosan were found only during the summer in June and July. Triclosan was detected at both PNF and NFG, while DEET was only detected at PNF. Caffeine was detected in February at NFG. Caffeine can indicate the presence of domestic wastewater (treatment plant effluents and septic systems) in a water supply system. In addition, the large amount of caffeine that is consumed and discarded (i.e., pouring out unused caffeinated beverages) in our watersheds can also contribute to continuous loading of caffeine to the aquatic environment.

2.4 2012 Wildfires

The Upper CLP watershed was impacted by two major wildfires in 2012 (Figure 2.3). The Hewlett Fire (May 14- 22) burned 7,685 acres in dense Ponderosa Pine forest stands on the north-facing slopes, as well as shrub and grasslands that occupied much of the south-facing aspects. The burned area includes sub-watersheds that drain both to the Mainstem Poudre and into Seaman Reservoir on the North Fork Poudre River.

The High Park Fire (June 9 - July 2) burned 87,415 acres of primarily forested landscape, characterized by Ponderosa and Lodgepole Pine at the lower elevations and mixed conifer species at the upper elevations. To a lesser degree, shrublands, grasslands and riparian areas were also impacted (Figure 1). The burned area includes numerous sub-drainages that are tributary to the Mainstem Poudre River and the South Fork of the Poudre River. The two fires were in close proximity to each other; the northeastern edge of the High Park Fire shares the southern boundary of the Hewlett Fire, creating a contiguous burned area approximately 95,000 acres in size (Figure 2). In total, the High Park Fire destroyed 259 homes and cabins. No homes were damaged in the Hewlett Fire.

Upper CLP monitoring sites that were impacted by the wildfires were limited to the middle to lower elevations of the watershed and included Poudre River below the South Fork (PSF), PNF, North Fork of the Poudre River below Seaman Reservoir (NFG), Poudre River at the Bellvue Diversion (PBD) and Seaman Reservoir, as shown in Figure 2.3.

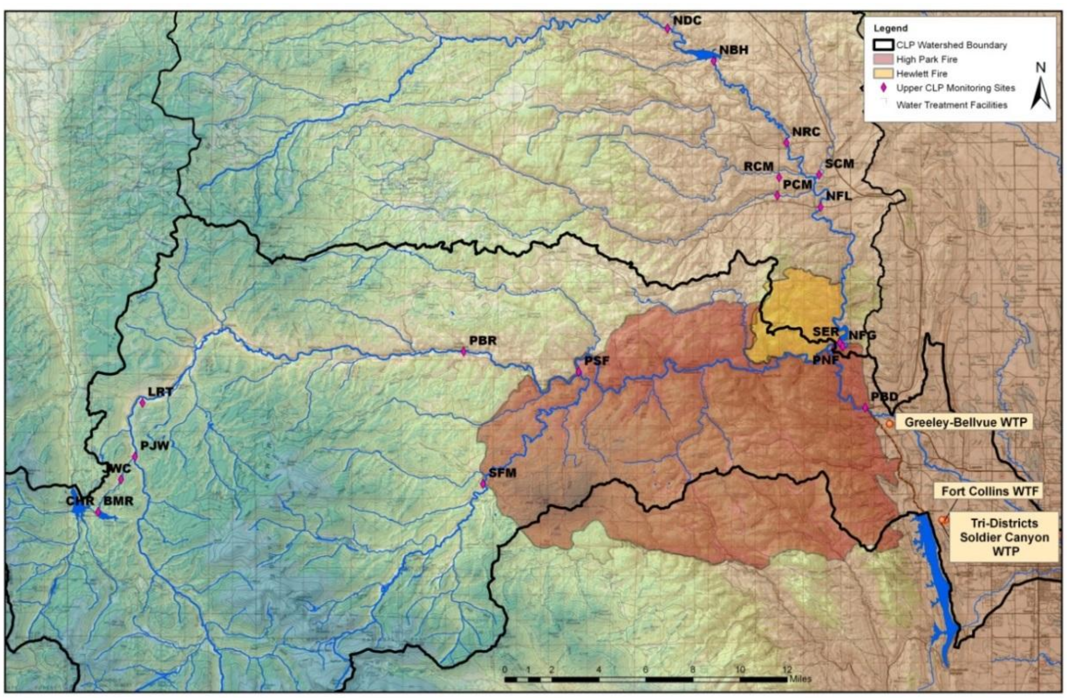


Figure 2.3 – Map of the Upper CLP monitoring locations and the area affected by the 2012 Hewlett and High Park Fires.

Approximately 41,113 acres (47%) of the High Park burn area 2,152 acres (28%) of the Hewlett Fire area burned at the moderate or high severity level (Oropeza and Heath, 2013). Within these areas, dramatic transformations of the live and dead organic materials occurred (Figure 2.3). The breakdown of organic matter through heating and combustion changes the form and availability of many constituents to the system. Furthermore, in response to the removal of the above and below ground vegetation, the hydrology on the surrounding burned hillslopes shifts from primarily subsurface flows to flashy and more erosive overland flows.

Figure 2.4 – Burned organic matter collected from the Upper Poudre River following a rain event and debris flow.

The physical and chemical changes that occurred during the 2012 fires set the stage for significant and frequent debris flows that occurred in response the afternoon convective thunderstorms in 2012 and 2013 (Oropeza and Heath, 2013). These debris flows transported large loads of sediment, ash and debris into the river, which produced immediate and dramatic changes in water quality. However, the water quality impacts of debris flows were typically short term, with water quality returning to near baseline conditions within a day or even hours after the event. As water levels receded following storm events, the sediment and debris were then stored on the banks and within the active river channel where they became an available source of turbidity, nutrients, and metals over the remainder of the sampling season (Figure 2.4 and 2.5). These sediments were largely scoured from the river channel during the increased streamflows the following Spring and were again deposited in the river during the summer months. This cycle is expected to continue for several years as the watershed recovers. The influence of these events and stored sediments is reflected by the baseline (non-storm event) concentrations of constituents collected through routine monitoring.

Figure 2.5 – Debris flow into the Mainstem of the Poudre River (a), and ash and sediment accumulation above the Munroe Tunnel (b).

In addition to routine water quality monitoring, Fort Collins Utilities staff collected water samples at the Fort Collins Poudre Intake Facility (PNF) during rain events during 2012 and 2013 to monitor the constituent and their concentrations that are produced by storm events (Figure 2.6). These storm samples serve as indicators of watershed recovery and water supply reliability over time.

The impacts of the fires and storm events on specific water quality parameters on the Mainstem of the Poudre are discussed in Sections 3.3 – 3.6.

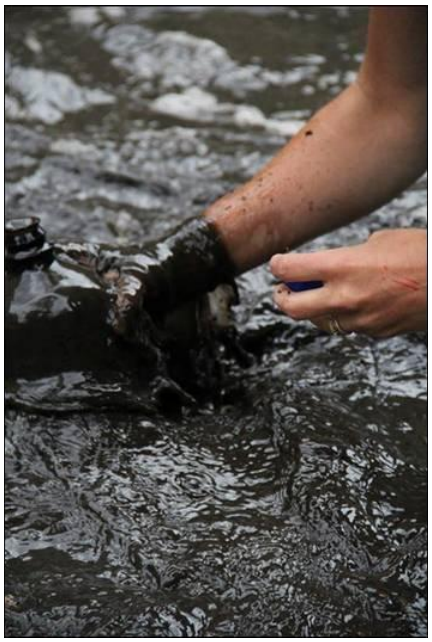


Figure 2.6 – Water quality sample collected following a storm event on July 12, 2013.

3.0 UPPER CACHE LA POUDRE RIVER RESULTS

For this annual report, seven key sites were identified that are considered representative of conditions on the Mainstem and North Fork CLP River. The selected sites are:

- Mainstem above North Fork
  - JWC – Joe Wright Creek above the Poudre River
  - PJW – Poudre above Joe Wright Creek
  - PBR – Poudre below Rustic
  - PNF – Poudre above North Fork
- North Fork above Mainstem
  - NFL – North Fork at Livermore (above Seaman Reservoir)
  - NFG – North Fork at Gage below Seaman Reservoir
- Mainstem below North Fork Confluence
  - PBD – Poudre at Bellvue Diversion

This is the first year that PBR was added to the discussion of results because it is the closest upstream site to the 2012 High Park Fire burn area and serves as a useful reference for “unimpacted” versus “impacted” sites downstream. Discussion of the results will focus primarily on these seven key sites; however, data from all sites were reviewed and analyzed and any notable events and trends are included in the discussion. A full list of monitoring sites, abbreviations and descriptions is available in Attachment 2. All data summary graphs are contained in Attachment 7; raw data are available upon request from the City of Fort Collins.

3.1 Watershed Hydrology

The hydrology of the Upper CLP plays an important role in regulating water quantity and quality. Precipitation events and snowmelt runoff largely control the quantity and timing of deliveries of material to the river, and the amount of water in the system at a given time affects the concentration of water quality constituents.

Discharge is measured as part of the routine Upper CLP monitoring activities at two key sites on the Mainstem: Poudre above Joe Wright Creek (PJW) and South Fork of the Poudre above the Mainstem (SFM). Discharge values presented for these sites represent instantaneous discharge measurements collected on the specified sampling dates.

Discharge measurements are also collected on four tributaries of the North Fork CLP: North Fork above Rabbit Creek (NRC), Rabbit Creek Mouth (RCM), Stonewall Creek Mouth (SCM), and Lone Pine Creek Mouth (PCM), but are not included for the purposes of this discussion. A full graphical summary of all Upper CLP hydrology and water quality measurements is presented in (Attachment 6); data are available upon request from the City of Fort Collins.

Continuous streamflow data were obtained from the U.S. Geological Survey (USGS) and Colorado Division of Water Resources (CDWR) online reporting sites for flow gauging stations at JWC, NFL, NFG and PBD. Stream discharge values at PNF were calculated using continuous flow data from the Canyon Mouth gage and NFG as well as head gate flow values at the Poudre Valley Canal diversion. Poudre Valley Canal diversion discharge measurements were obtained from the Poudre River Commissioner, Mark Simpson. Discharge values for these sites are presented as daily averages.

3.1.1 Cache la Poudre Basin Snowpack. To understand observed trends in discharge, one must also look at the spatial and temporal trends in snowpack, snow water equivalent, and temperature, as these are the key factors that control the quantity, timing, and magnitude of streamflow in the Upper CLP.

Snow water equivalent (SWE) is a common snowpack measurement, which represents the amount of water contained in the snowpack. The snow telemetry (SNOTEL) network includes approximately 600 automated monitoring sites located in remote mountain watersheds throughout the United States that measure SWE, accumulated precipitation, and air temperature. Some more advance SNOTEL sites measure other climate variables such as, snow depth, soil moisture and temperature, wind speed, solar radiation, humidity, and atmospheric pressure. Snow course monitoring sites require manual surveying of snow depth and SWE, generally on the first of every month throughout the duration of the winter season. There are approximately 1,600 permanent snow courses national wide. The SNOTEL and snow course network are managed and operated by the Natural Resource Conservation Service (NRCS).

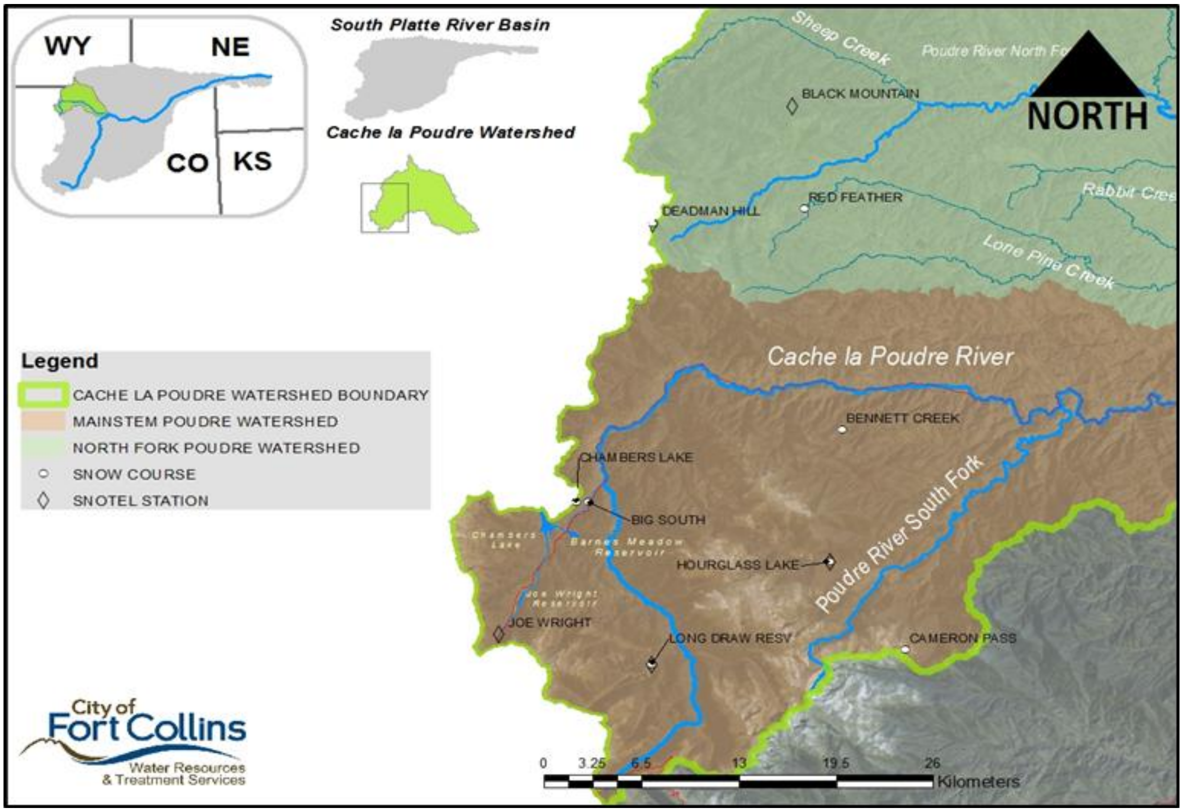


Figure 3.1 – Locations of SNOTEL and snow course monitoring sites in the UCLP.

Peak snow water equivalent data was collected and plotted from five NRCS SNOTEL and five snow course monitoring sites to evaluate differences across the basin as well as between years. Deadman Hill and Red Feather Lakes sites represent snow conditions in the North Fork drainage, while Cameron Pass, Joe Wright, Big South, Hourglass and Long Draw represent conditions in the major basins of the Mainstem (Figure 3.1). The data suggest that on an annual basis, Cameron Pass receives significantly more SWE than any of the other sites, while the Big South and Hourglass Reservoir sites consistently maintain relatively lower SWE (Figure 3.2). These differences in SWE are driven primarily by differences in elevation and the orographic nature of winter storms in the Rocky Mountains. In 2013, peak SWE was normal (99% of average) compared to the five year average (2008-2013) at all sites throughout the North Fork Poudre and Mainstem Poudre Watershed.

Joe Wright SNOTEL contains the longest record of continuous SWE measurements in the Cache la Poudre Watershed dating back to 1978. The long-term data record provides a valuable tool for evaluating the progression of the snowpack, in terms of quantity of water, compared to the historical average, maximum, and minimum SWE (Figure 3.3). In 2013, the beginning of the snow accumulation season was the driest on record, but heavy snow storms beginning in February and continuing through mid-May provided relief to a dry start to the season. A peak SWE of 23.6 inches was observed on May 10th of 2013, which was 99% of the historical average peak SWE of 24.7 inches. Peak SWE was observed in mid-May during 2013, which was later than expected when compared to

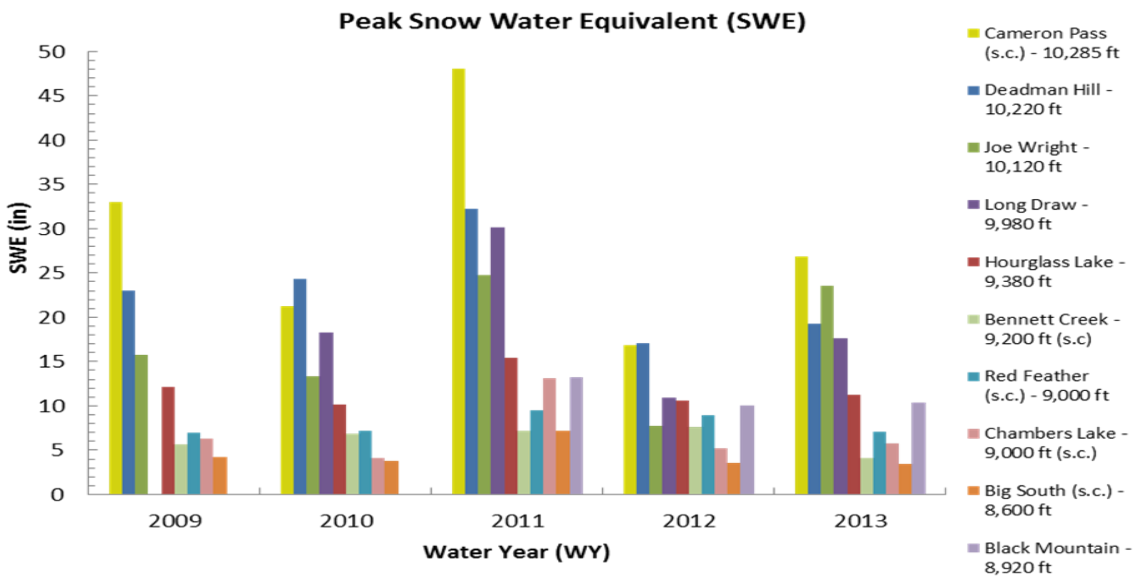


Figure 3.2 – Peak snow water equivalent measured at SNOTEL and snow courses (s.c.) throughout the UCLP from 2009-2013.

the historical average peak SWE date. Snowmelt followed immediately after peak SWE when average daily temperatures measured at Joe Wright SNOTEL remained above freezing through the remainder of the month of May and the snowmelt season. Average daily temperatures were greater than the historical average throughout most of the runoff season from May through July, which yielded a more rapid decline of SWE in 2013 influencing streamflow dynamics in 2013 (Figure 3.3).

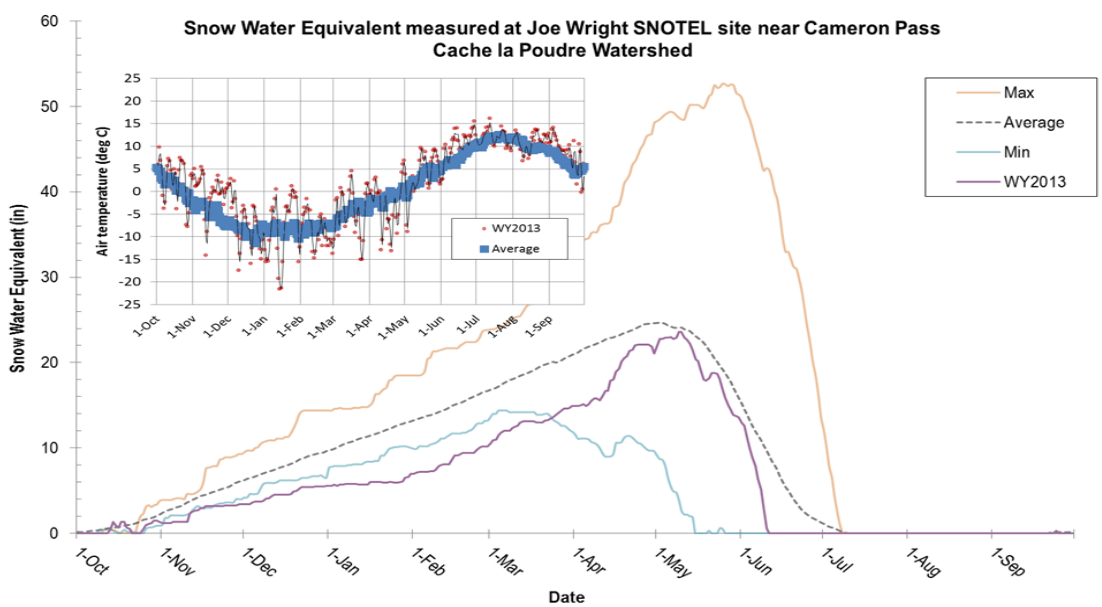


Figure 3.3 – Snow water equivalent measured at Joe Wright SNOTEL site near Cameron Pass and air temperature (inset) over the 2013 water year (October 2012-September 2013).

3.1.2 Cache la Poudre Watershed Streamflow. Both the Mainstem and North Fork sites exhibit snowmelt-dominated hydrographs. Water is stored in the snowpack as precipitation accumulates through the winter and is released later in the spring when temperatures allow the snowpack to melt. The Cache la Poudre at Canyon Mouth near Fort Collins (CLAFTCCO) streamflow monitoring station managed by the CDWR (http://www.dwr.state.co.us/) contains the longest record of continuous streamflow in the Upper CLP Watershed dating back to 1883. The streamflow monitoring station is located at the canyon mouth and includes streamflow contribution from both the Mainstem and North Fork watersheds. The long-term data record provides a valuable tool for evaluating the progression of streamflow compared to the historical average (Figure 3.4). In an average year, snowmelt runoff on the Mainstem begins in mid to late-April with streamflows peaking by mid-June. Following spring runoff, the hydrograph slowly recedes through the summer months returning to baseflow conditions in late fall (Figure 3.4). The North Fork of the Poudre follows a similar pattern. However, runoff and peak streamflows occur a week or two before the Mainstem because of differences in elevation. Multiple spikes in the hydrograph reflect natural and human influenced fluctuations of river levels that result from snowmelt runoff, rainfall events, and reservoir releases and water diversions in the Upper CLP watershed (Figure 3.4). More recently, streamflow on the Poudre River near the Canyon Mouth displays dramatic fluctuations in response to summertime thunderstorms and subsequent flash flooding of burned areas from the High Park and Hewlett Gulch wildfires of 2012 (Figure 3.4).

In 2013, the rising limb of the snowmelt hydrograph exhibited a similar trend to the

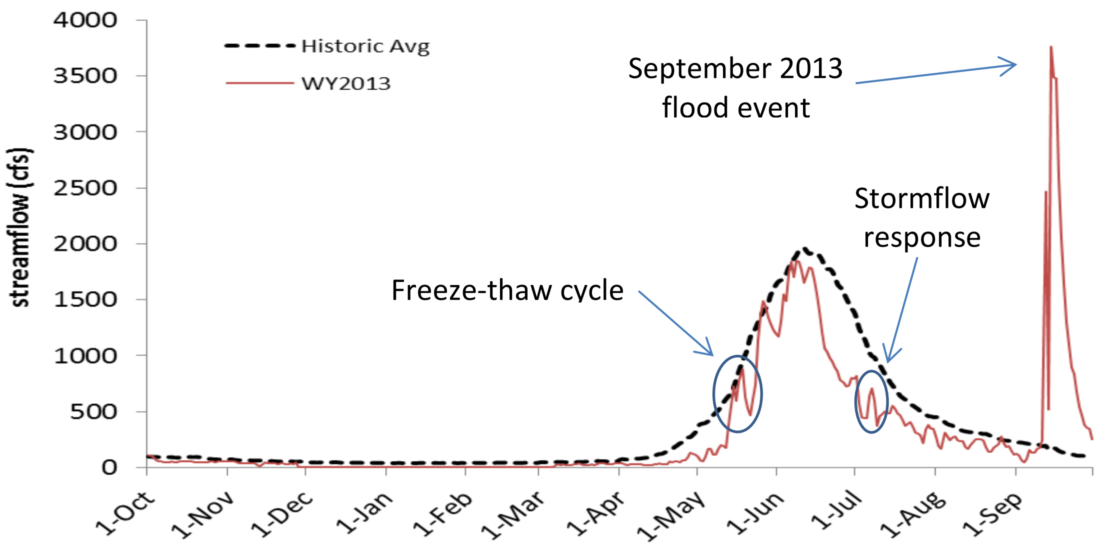


Figure 3.4 – Streamflow measured over the 2013 water year at the CLP at Canyon Mouth near Fort Collins (CLAFTCCO) streamflow monitoring station.

historic average. Snowmelt runoff began in late-April and peaked in mid-June. A snowmelt peak streamflow of 1,850 cfs was 94% of average and occurred earlier than the historical average date. Snowmelt driven peak streamflow on the Mainstem (PNF) was measured at 1,787 cubic feet per second (cfs) on June 8th and receded to baseflows of less than 100 cfs by early September.

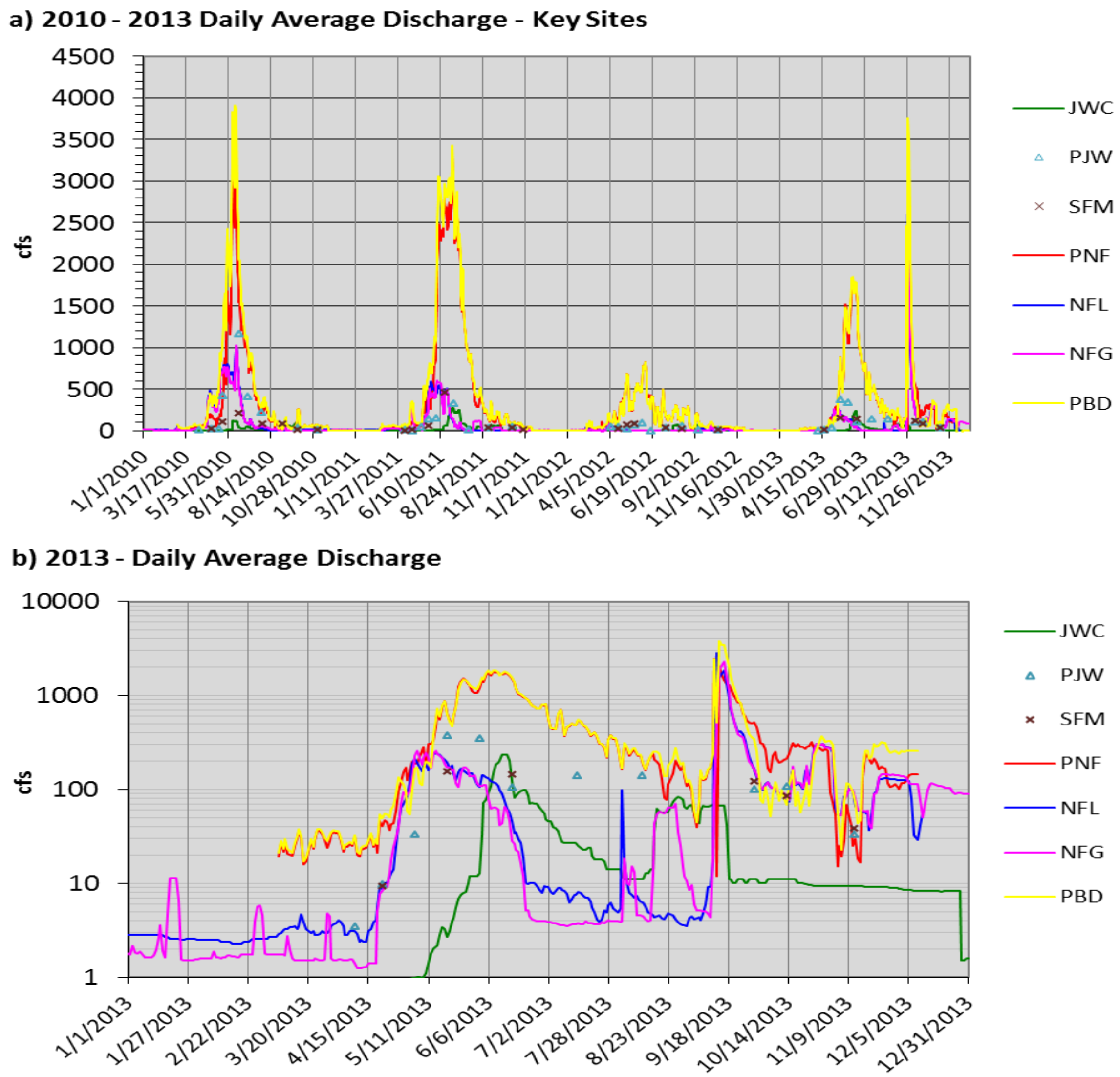


Figure 3.5 – Daily average streamflow measured at key Upper CLP monitoring sites from a) 2010-2013 and b) 2013.

Debris flows and flooding were common on the Mainstem and North Fork during the 2013 summer monsoon season following high intensity, short duration precipitation events localized over burn scar areas in Upper CLP watershed. The hydrograph response to rainfall driven flooding is a rapid increase shortly after or during the precipitation event, followed by a slower return back to pre-storm flows. Streamflow response to flooding is highly dependent on the magnitude, duration, and intensity of the precipitation event. An extreme precipitation event in September of 2013 resulted in historic flooding throughout Northern Colorado's Front Range when rainfall amounts over the seven day event (September 9-16) exceeded annual precipitation totals resulting in unprecedented flooding throughout the Upper CLP watershed. Streamflow increased from less than 100 cfs to a peak of 3,760 cfs (Figure 3.4). Peak streamflow during this event was more than two times the snowmelt peak streamflow early in the year.

3.1.2a Mainstem CLP

Headwater Sites. Snowmelt peak streamflow measured at JWC was 237 cfs on June 13th, 2013, and the snowmelt peak flow measured at SFM on the South Fork of the Poudre was 153 cfs on May 20, 2013 (Figure 3.5b). Measurements for the July and August sampling dates were not collected at SFM, but it is expected that the actual peak flow occurred on a later date and was likely higher than that measured on May 20th, 2013. Streamflows measured at JWC and SFM in 2013 were greater than 2012, but less than the higher water years of 2010 and 2011. A water release from Joe Wright Reservoir began on August 17th when flows out of the Reservoir were increased from 10 cfs to flows ranging between 70 and 80 cfs until September 17th. Flows at JWC were decreased to approximately 10 cfs and remained nearly constant through December. The greatest streamflow measured at the high elevation site PJW was 345 cfs on June 3rd, 2013, and steadily decreased following peak discharge.

Middle and Lower Mainstem. The lower reaches of the Mainstem CLP also experienced similarly average flows in 2013. Streamflow was greater than those observed in 2012, but lower than 2010 and 2011 (Figure 3.5a). The hydrographs for PNF and PBD show peak streamflows of similar magnitude and timing, occurring on June 8th. Snowmelt peak streamflows at PNF and PBD were 1787 cfs and 524 cfs, respectively (Figure 3.5b).

As expected, the timing and magnitudes of snowmelt peak streamflow at PBD were similar to PNF (Figures 3.5a and 3.5b). Typically, the hydrograph for PBD tracks closely with PNF, as the Mainstem contributes the majority of flow at PBD, with relatively small contributions provided by North Fork flows from Seaman Reservoir (NFG). Exceptions occur in years of greater than normal North Fork runoff or in the event of substantial releases from Seaman Reservoir or flooding, as was observed in September of 2013. The September flood event caused peak streamflows of 2,240 cfs at PNF on September 12th, 2013. PBD peaked two days later on September 14th, 2013 at 3,760 cfs as a result of increased contributions from the North Fork Poudre River. Storm flows receded following peak, but flows remained higher than normal for the remainder of the year due to groundwater recharge from highly saturated soils and water releases from the North Fork.

Mainstem Tributaries. There are a number of tributaries and diversions that contribute to the overall streamflow and water quality of the Mainstem CLP above the North Fork. Table 2 details the actual and percent contributions of Barnes Meadow Reservoir Outflow (BMR), Chambers Lake Outflow (CHR) and the Laramie River Tunnel (LRT) to Mainstem flows, as measured above the Munroe Tunnel and North Fork confluence (PNF + Munroe Tunnel). Figure 3.6 is a graphical representation of proportional flows by month. Note that contributions from SFM and PJW could not be estimated due to a lack of continuous flow measurements. The sum of contributions from these and other river segments and tributaries was calculated by subtraction, and categorized as "Other Mainstem Contributions". The majority of water on the Mainstem above the North Fork can be accounted for from PJW and SFM. In 2013, water diversions from CHR and LRT began in May. Contributions from LRT were terminated in July, but water contributions from CHR continued through October. Water releases from BMR occurred in March, April, and November of 2013.

Table 2 – Tributary contributions by month to the Mainstem Cahce la Poudre River above the Munroe Tunnel in 2013.

	Barnes Meadow Outflow (BMR)		Chambers Lake Outflow (CHR)		Laramie Tunnel (LRT)		Other Mainstream Contributions		Poudre above Munroe Tunnel & North Fork	
	AF/day	%	AF/day	%	AF/day	%	AF/day	%	AF/day	%
Jan										
Feb										
Mar	300	23%	861	65%			169	13%	1,330	------
Apr	9	0%	536	22%			1,887	78%	2,432	------
May			2014	5%	3662	9%	35,589	86%	41,265	------
Jun			11881	15%	10044	12%	59,990	73%	81,915	------
Jul			5630	15%	4731	12%	20,141	73%	30,502	------
Aug			4947	22%	415	2%	9,632	76%	14,993	------
Sep			1279	3%			41,841	97%	43,120	------
Oct			976	5%			18,072	95%	19,047	------
Nov			0				4,899	100%	4,899	------
Dec			0				2341	100%	2,341	

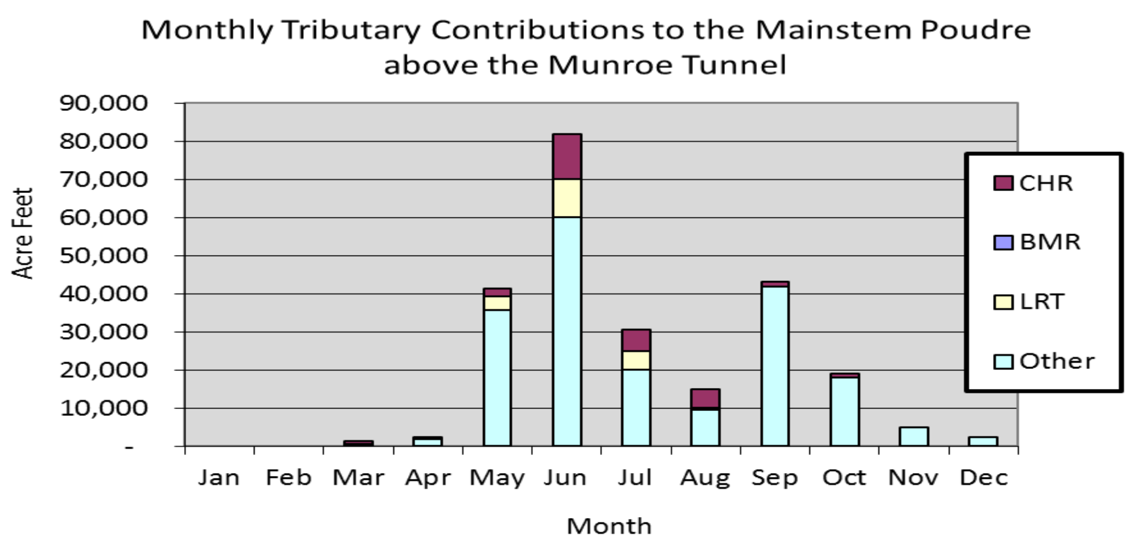


Figure 3.6 – Box plot of tributary contributions by month to the Mainstem CLP above the Munroe Tunnel in 2013. *Note that continuous flow measurements were not available for calculating "other" flow contributions in January and February.*

3.1.2b North Fork CLP

Streamflow measured at NFL represent cumulative flows of the North Fork CLP above Seaman Reservoir and provide information about the timing and relative magnitude of snowmelt runoff in the upper North Fork drainage. Streamflow measurements at NFG include contributions from both the North Fork and Seaman Reservoir and represent the total North Fork contributions to Mainstem flows (measured at PBD). Although streamflow at NFG is influenced by reservoir operations, the hydrographs for NFL and

NFG are typically very similar (Figure 3.7a and 3.7b) because during the period of highest flow (snowmelt runoff) the majority of flow going into Seaman Reservoir is usually flowing over the spillway and not being stored in the reservoir. The September rainfall event resulted in a peak stormflow response of 2,290 cfs at NFG.

In 2013, snowmelt peak streamflows at NFL and NFG were greater than 2012, but substantially less than in 2010 and 2011 (Figure 3.7a). Hydrographs for both sites tracked closely, with similar flows recorded at both sites. Snowmelt peak streamflows occurred on May 13th, 2013 at NFL and on May 14th, 2013 at NFG with discharge values of 244 cfs and 259 cfs, respectively (Figure 3.7b).

During the months of May through June from 2010 to 2013, the North Fork has comprised, on average, 21% of Mainstem streamflow at PBD (Figure 3.8). In 2013, the North Fork contributed 16% of streamflow to the Mainstem.

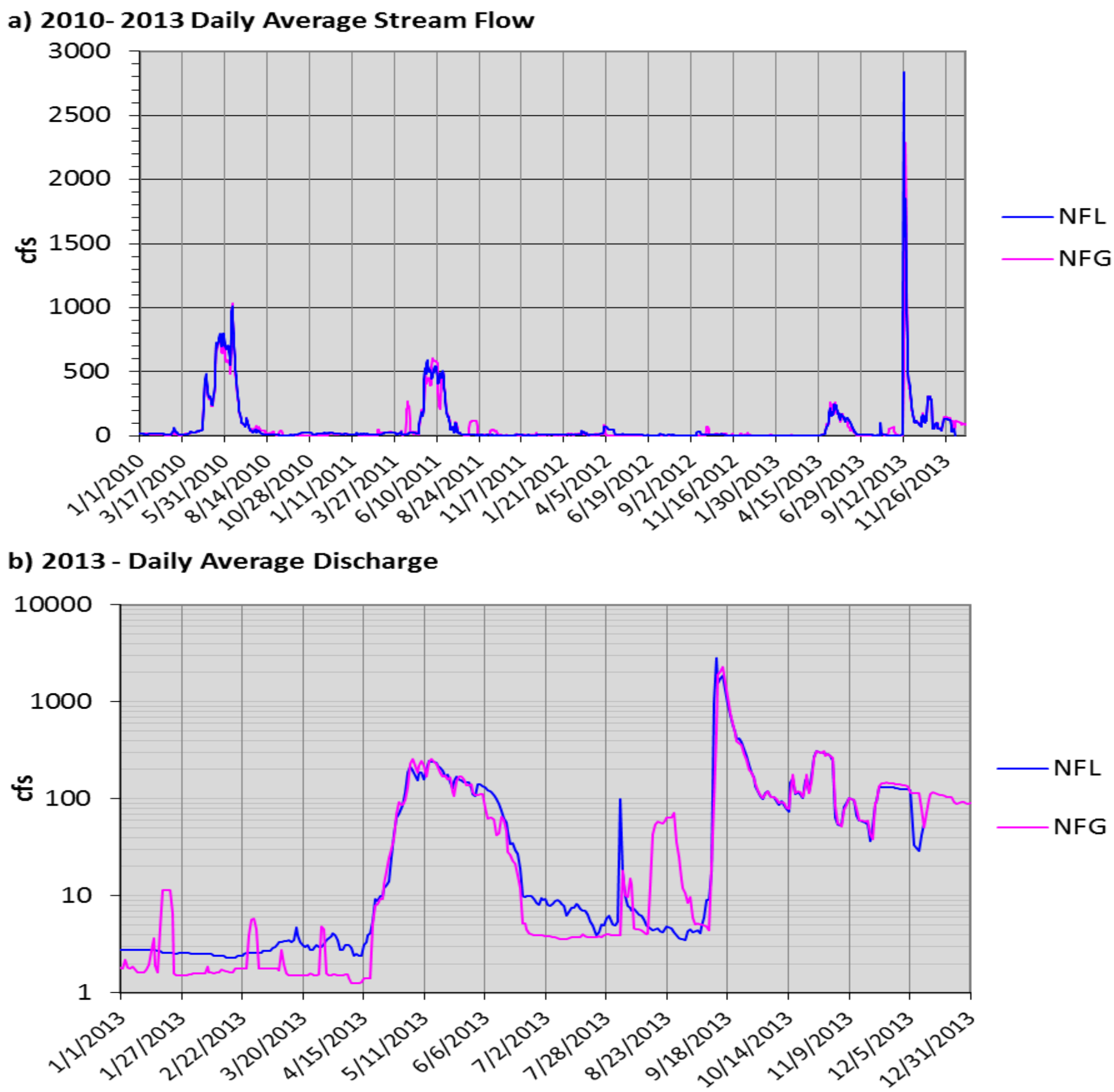


Figure 3.7 - Daily average streamflow measured at NFL and NFG monitoring sites from a) 2010-2013 and b) during the 2013 monitoring season.

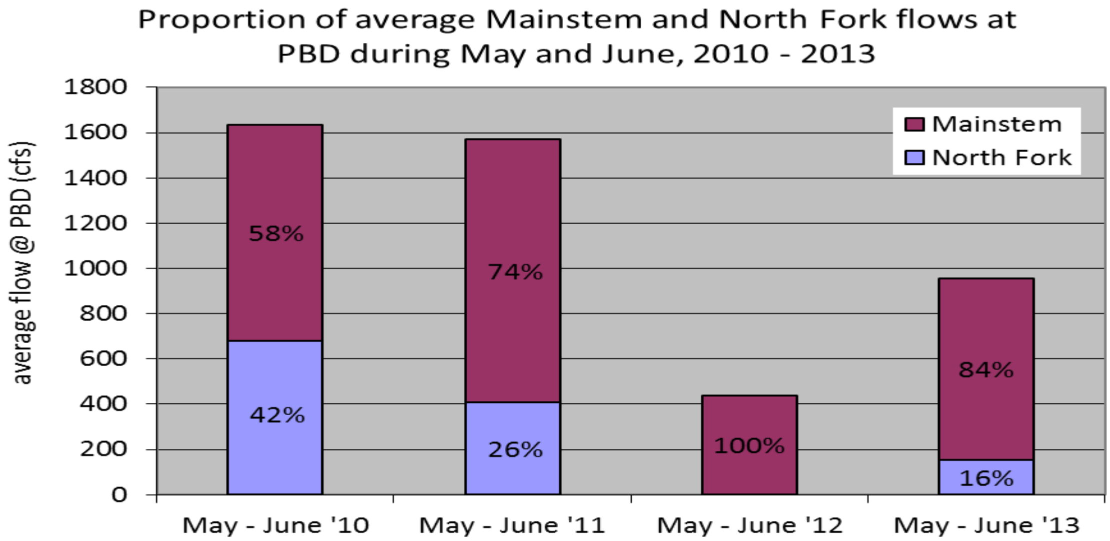


Figure 3.8 – Proportion of average Mainstem and North Fork flows at PBD during May and June from 2010-2013.

3.2 Water Temperature

Water temperature increases with decreasing elevation throughout the watershed (Figure 3.9). The timing of peak water temperatures on the North Fork and the Mainstem are similar, and typically occur in mid-summer. The highest stream temperatures generally occur at the North Fork site, NFL, with the exception of 2012. Peak temperatures observed at the Mainstem sites, PNF and PBD, were approximately five degrees warmer in 2012 than in the other three years, reaching maximum temperatures of 22.7 and 23.3^{o}C, respectively, on July 16th. In 2013, peak temperatures on the Mainstem and North Fork occurred on 7/13/13. Seaman Reservoir had a cooling effect on North Fork streamflow in 2012 and 2013, which can be seen by the differences in temperature at NFL and below Seaman Reservoir at NFG. This differs from the previous two years when Seaman Reservoir did not appear to have any discernible influence on North Fork water temperature.

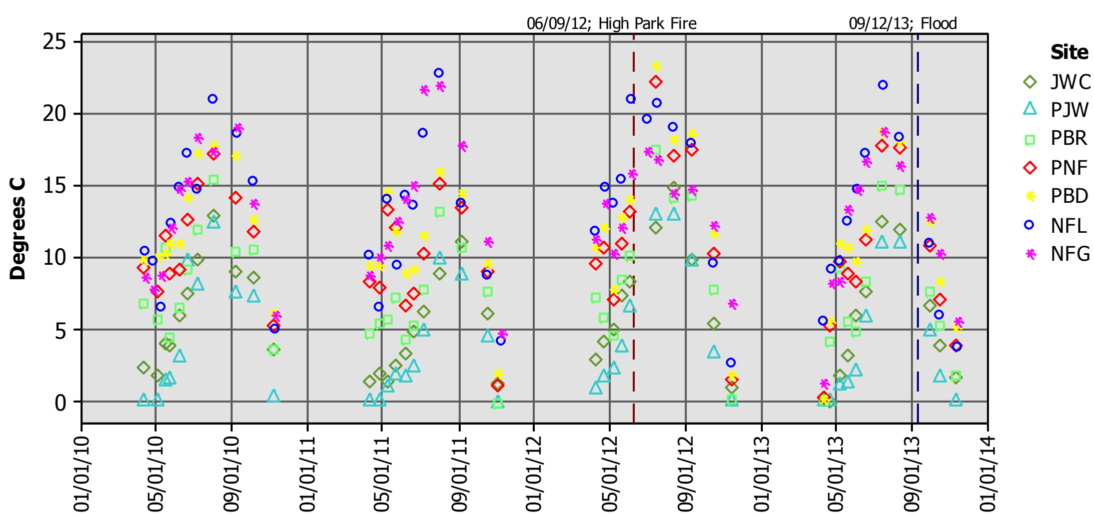


Figure 3.9 – Water temperature at key Upper CLP monitoring sites from 2010 through 2013.

3.3 General Parameters: Conductivity, Hardness, Alkalinity, pH, and Turbidity

3.3.1 Conductivity, Hardness and Alkalinity. Conductivity is an index of dissolved ionic solids in the water and hardness is an index of the total calcium (Ca) and magnesium in the water. Alkalinity is a measure of the effective acid buffering capacity of the water, and is derived, in large part, from the dissociation of mineral carbonates (CO_3^-), bicarbonates (HCO_3^-) and hydroxides (OH^-). Conductivity, hardness and alkalinity are influenced by the local geology as well as the dissolved constituents derived from other watershed activities. Across the watershed, these three parameters track closely, with minimum values occurring during peak run-off when the concentrations of all dissolved constituents are diluted by large volume flows, and high values occurring at times of low flow (Figure 3.10a-3.10c).

In general, conductivity, hardness and alkalinity increased with decreasing elevation. Accordingly, North Fork sites showed consistently higher values and greater variability for these parameters than Mainstem sites, which reflect the combined influences of differing geology and elevation. The below average discharge during the 2012 spring runoff resulted in a relatively small dilution effect compared to previous years, which is reflected by the higher than usual spring time values. The wildfires of 2012 do not appear to have had a noticeable impact on background (excluding storm events) specific conductance or concentrations of alkalinity and hardness, as all post-fire values were within the ranges seen in previous years. There was a notable decrease in late summer values of all three parameters in 2013 that was not observed in previous years. These lower values may have resulted from the higher streamflows that occured on both the North Fork and the Mainstem following the flood event in September 2013.

Post-fire storm samples were analyzed for hardness at PNF. Results from these samples varied, but in general debris flows and flooding from burn scars in the Poudre River watershed translated to elevated hardness concentrations. Concentrations increased from a baseline of approximately 20 mg/L to levels two to nearly five times greater (Figure 3.11). The September flood event resulted in lower hardness values due to the effect of dilution.

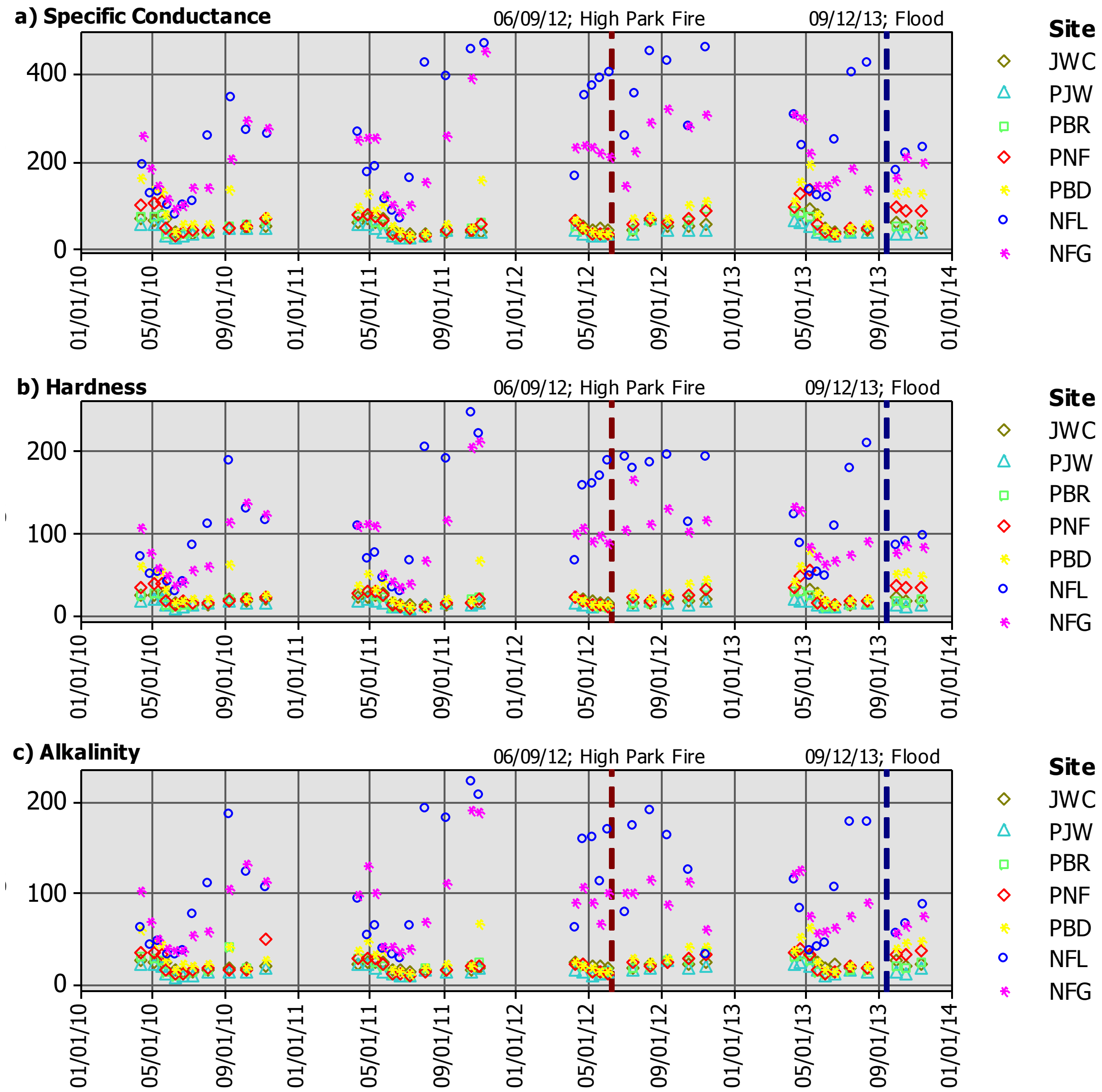


Figure 3.10 – General water quality parameters a) specific conductance, b) hardness, and c) alkalinity measured at key Upper CLP monitoring sites.

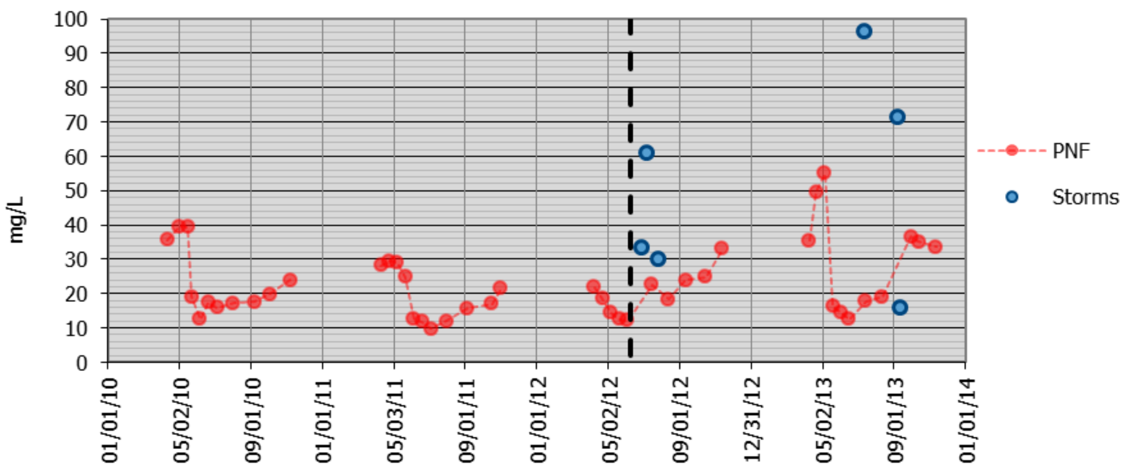


Figure 3.11 – Comparison of baseline hardness concentrations and post-fire storm water hardness concentrations measured at PNF.

3.3.2 pH. In 2013, the pH of the Upper CLP waters followed similar patterns influenced by seasonality and elevation as was observed in alkalinity, conductivity and hardness concentrations (Figure 3.12). In general, the North Fork exhibited higher pH levels than the Mainstem. North Fork pH values ranged from 7.50 - 9.00 in 2013, with the highest observed values of 9.0 and 8.93 occurring on the June 4th and June 18th sampling events, respectively. These high values occurred at NFL on the receding limb of the hydrograph and are the highest on record from 2010-2013 for all sites. In 2013, pH values on the Mainstem were more variable than in the previous three years and ranged from 6.30 – 8.48. Although the direct causes of increased variability is unknown, the presence of fire sediments from the 2012 wildfires and the scouring effect of the 2013 flood are likely contributors. A minimum pH value of 6.30 was measured at the highest elevation site, PJW, during spring runoff (May 20th), while a maximum value of 8.48 was observed at the mid-elevation site, PBR, during low flows (Aug. 12th). All sites experienced a particularly sharp decrease in pH (0.82-1.26 units) during spring runoff. pH typically increases quickly at all sites following spring snowmelt runoff; however, summer and fall pH trends vary between Mainstem and North Fork sites as well as between years.

Post-fire storm samples indicate that the pH at PNF was not significantly affected by debris flows during storm events (Figure 3.16), as all storm samples had pH values that were within the range of variability seen in previous years.

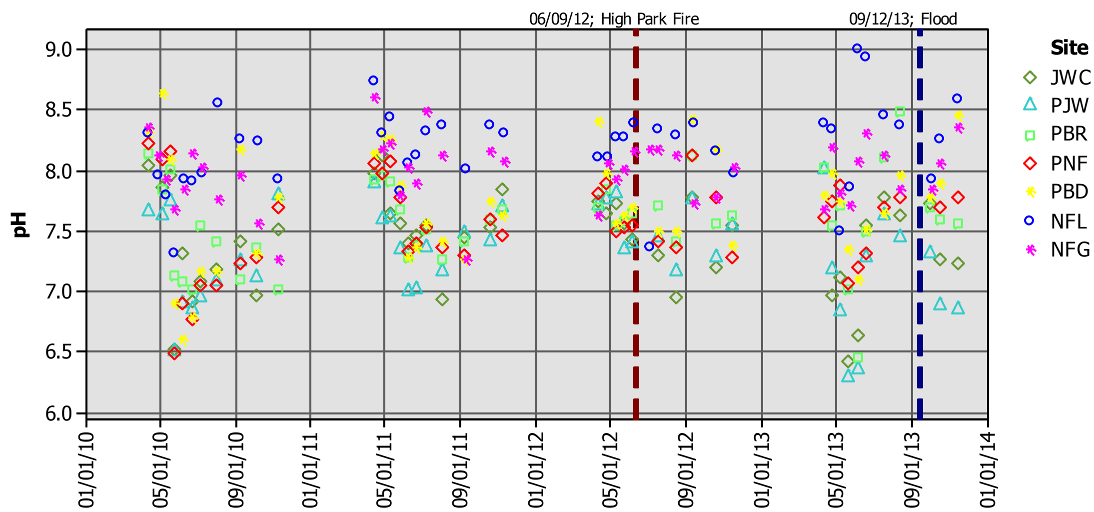


Figure 3.12 – pH levels measured at key Upper CLP monitoring locations from 2010 through 2013.

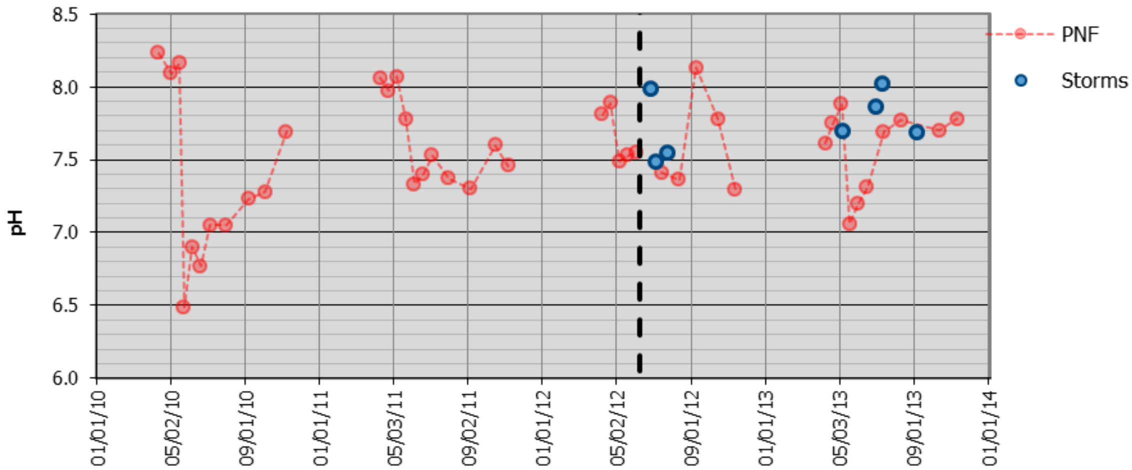


Figure 3.13 - Comparison of baseline pH levels and post-fire storm water pH levels measured at PNF.

3.3.3 Turbidity. In general, turbidity at all Mainstem and North Fork sites peaks during spring runoff. Higher streamflow increases the amount of sediment and organic material, transported from the surrounding landscapes, to be suspended throughout the water column, which translates to increased turbidity levels. Turbidity values typically follow the hydrograph, increasing to a seasonal maximum at the onset of spring runoff, followed by a decline during the lower flow months of the year. Turbidity values in 2013 showed more variability than in 2010-2012.

The maximum values observed during 2013 spring runoff were 22.6 Nephelometric Turbidity Units (NTU) on the Mainstem at PNF and 14.5 NTU on the North Fork at NFL, which are similar to previous years. Overall, values ranged from 0.94 - 22.6 NTU, excluding the July 15th sampling event (97.6 NTU), which captured the influence of a rain storm on July 13th (Figure 3.14). As seen in previous years, occasional spikes in turbidity were observed in 2013 at NFG. These spikes in turbidity occur as a result of water being released from the outlet at the Reservoir bottom, but have typically not been of sufficient magnitude to impact downstream turbidity at Greeley's water supply intake (PBD).

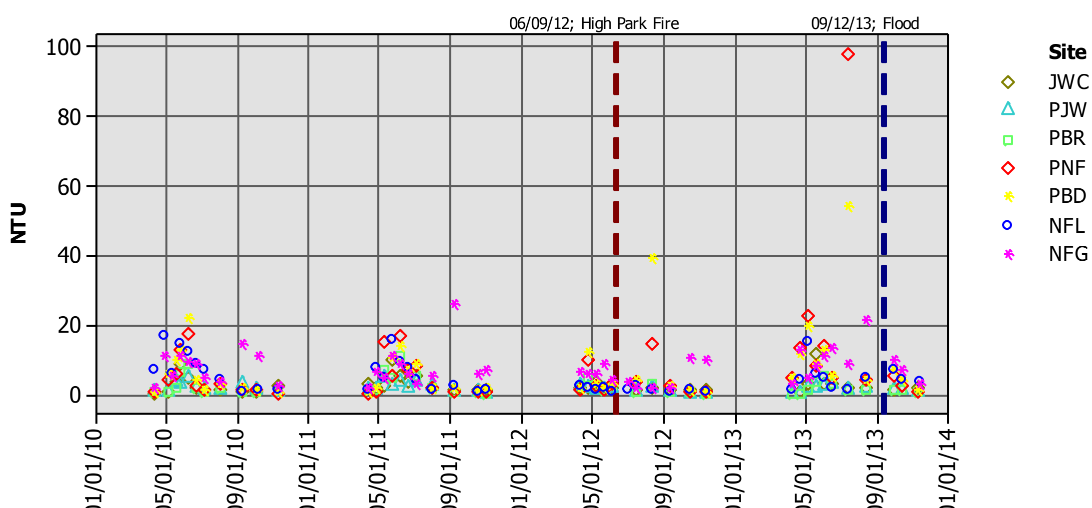


Figure 3.14 – Turbidity levels measured at key Upper CLP monitoring locations from 2010 through 2013.

Spikes in turbidity can be observed over the period of record, however much of the variability in turbidity is not evident in the routine monitoring data record because the routine sample frequency often does not capture the effect of individual events.

Figure 3.15 illustrates the effect of post-fire storm events on turbidity in the river. Note that values are presented on a logarithmic scale due to the magnitude of observed changes. These spikes in turbidity occur when large amounts of ash and sediment from the riverbanks and burned hillslopes in the watershed are mobilized and suspended in water (Oropeza and Heath, 2013).

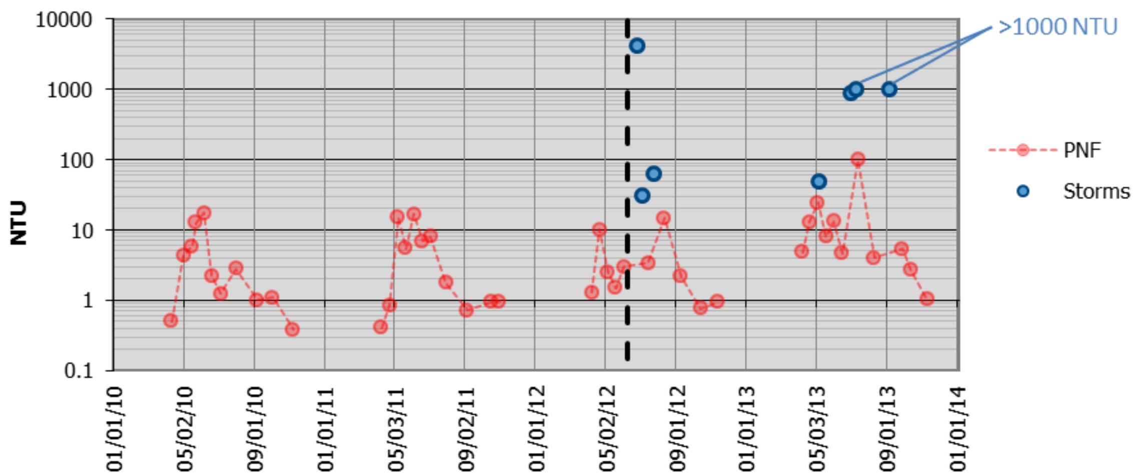


Figure 3.15 – Comparison of baseline turbidity levels and post-fire storm water turbidity levels measured at PNF.

3.4 Total Organic Carbon (TOC)

Seasonal patterns of TOC concentrations in the upper CLP watershed are generally consistent from year-to-year, with annual maximum TOC values occurring at the onset of spring snowmelt, as seen in years 2010 through 2013 (Figure 3.16). The timing and magnitude of peak TOC concentrations is determined by factors that influence spring runoff, including snowpack and weather conditions of the North Fork and Mainstem basins. In general, the timing of peak TOC concentrations in the basins occurs within 1-2 weeks of each other. In 2013, observed peak TOC concentrations occurred May 7th on the North Fork (NLF) and May 20th on the Mainstem (JWC). Peak concentrations for both basins were higher than all previous years, but especially compared to 2012 when peak concentrations were < 10 mg/L at all sites. It is notable that the comparatively high peak TOC concentrations of 2013 occurred primarily in the unburned portions of the watersheds (JWC, PJW, PBR, NFL), whereas concentrations in the burned areas (PNF, PBD, NFG) were within the range of values seen in previous years. The spatial differences in 2013 peak TOC concentrations suggest that the drought-impacted vegetation and soils were a larger influence on TOC during spring snowmelt than the presence of burned materials in the lower watershed.

Following spring runoff, TOC concentrations decrease on the Mainstem, whereas concentrations on the North Fork remain relatively high throughout the year (Figure 3.16). In contrast to previous years, the heavy rains and flooding that occurred in September 2013 produced a prominent increase in summer TOC concentrations at all Mainstem and North Fork sites.

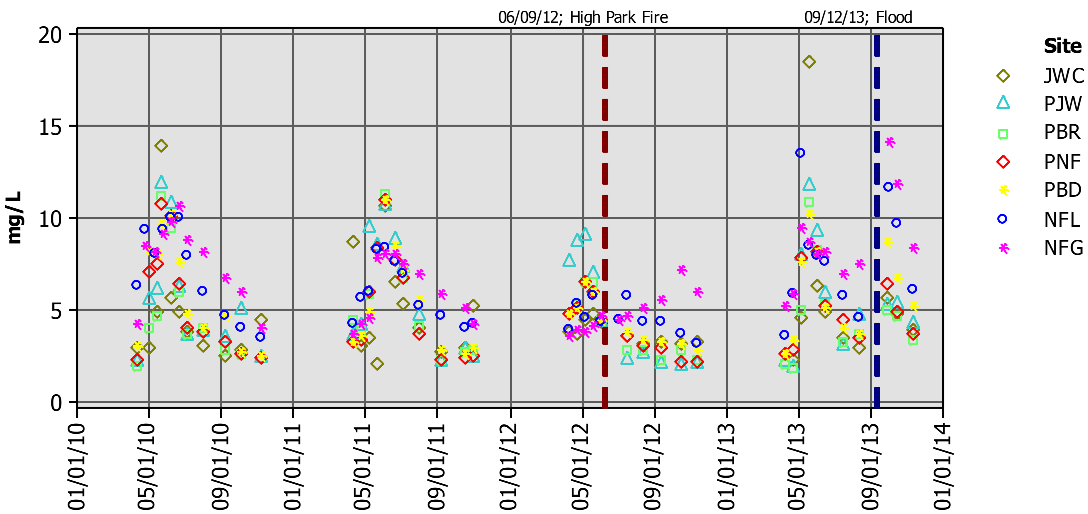


Figure 3.16 – Total organic carbon (TOC) levels measured at key Upper CLP monitoring locations from 2010 through 2013.

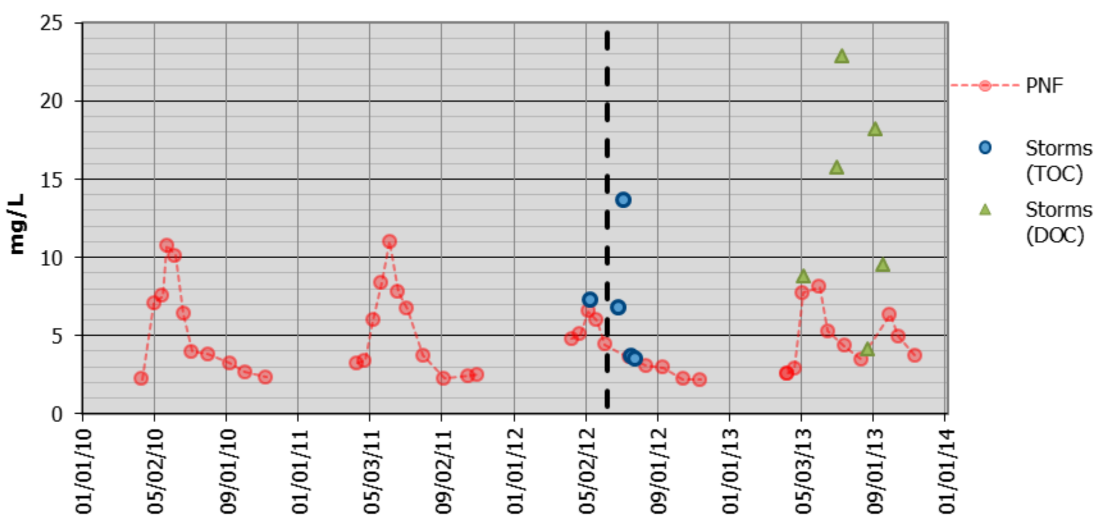


Figure 3.17 – Comparison of baseline turbidity levels and post-fire storm water turbidity levels measured at PNF.

Mainstem. In 2013, the peak TOC concentration sampled on the lower Mainstem at PNF was 8.1 mg/L on June 3rd, 2013, which was higher than 2012, but lower than 2010 and 2011. The highest TOC concentrations on the Mainstem in 2013 were observed at JWC at 18.5 mg/L, which was the highest concentration observed over the 2010-2013 period of record for all sites. Historically, the highest TOC concentrations have been observed at the highest elevation monitoring sites and reservoir release points (i.e. BMR, CHR, PJW, JWC, LRT), with lower peak concentrations in the lower basin (Figure 3.16)

Post-fire storm events resulted in elevated concentrations of organic carbon (Figure 3.17). In 2013, storm samples were analyzed by the CU Environmental Engineering Laboratory for Dissolved Organic Carbon (DOC), rather than TOC, as was done in 2012. DOC samples were filtered through a 0.7 micron glass fiber filter (GF/F) prior to analysis (Mandi Hohner, personal communication). Despite the difference in analytical methods, the two procedures compared well because more than 90% of organic carbon in the Poudre River is comprised of the dissolved fraction. In 2013, DOC concentrations in storm samples ranged from 4.10-22.85 mg/L, with five out of six samples having concentrations greater than 8 mg/L. Baseline values ranged from 2.26 – 8.82 mg/L. The highest observed storm sample concentration was 22.85 mg/L on July 12, 2013, which was nearly six times the baseline concentration for this time of year (Figure 3.17). Furthermore, DOC concentrations in the storm samples were frequently higher in 2013 than observed in 2012.

North Fork. SCM, RCM, and Lone Pine Creek (PCM) are ephemeral streams in the North Fork watershed meaning streamflow only persists for a short period of time, which is typically following snowmelt and precipitation events. Two of these monitoring locations, RCM and PCM, consistently display the highest peak TOC concentrations (5.9 – 14.6 mg/L) of all the North Fork sites, although overall streamflow is low. The 2013 spring peak TOC concentrations on the lower North Fork at NFL and NFG were 13.5 mg/L and 9.5 mg/L, respectively. Similar to the Mainstem, the majority of the North Fork sites experienced considerably higher peak TOC concentrations than in the previous three years, which is likely due to the similarly dry climatic conditions in 2012 and the subsequent spring snowmelt flush.

Differences in seasonal average TOC concentrations observed between Mainstem and North Fork sites were particularly pronounced in 2013 (Figure 3.18). North Fork TOC levels usually remain relatively high throughout the late summer season, after concentrations on the Mainstem have decreased following spring runoff. This longer period of elevated TOC is reflected by the higher late summer and fall average TOC values at NFL and NFG. Spring average TOC values were higher in 2013 than 2012, but similar to 2011 and reflected the influence of spring runoff; however, 2013 fall averages were significantly higher as a result of the heavy rainfall and flooding in September 2013.

The persistence of elevated TOC levels on the North Fork during periods of low streamflow can, in part, be attributed to the relatively low streamflow, especially during the summer. It may also indicate the presence of an additional source or sources of TOC other than that mobilized during spring snowmelt. Possible sources of additional TOC in the North Fork include water released from Halligan and Seaman Reservoirs, and runoff from agricultural land within the North Fork basin. While TOC concentrations on the North Fork are generally higher than those observed on the Mainstem, the TOC loads carried by the Mainstem are greater due to substantially higher stream flows and contributing watershed area.

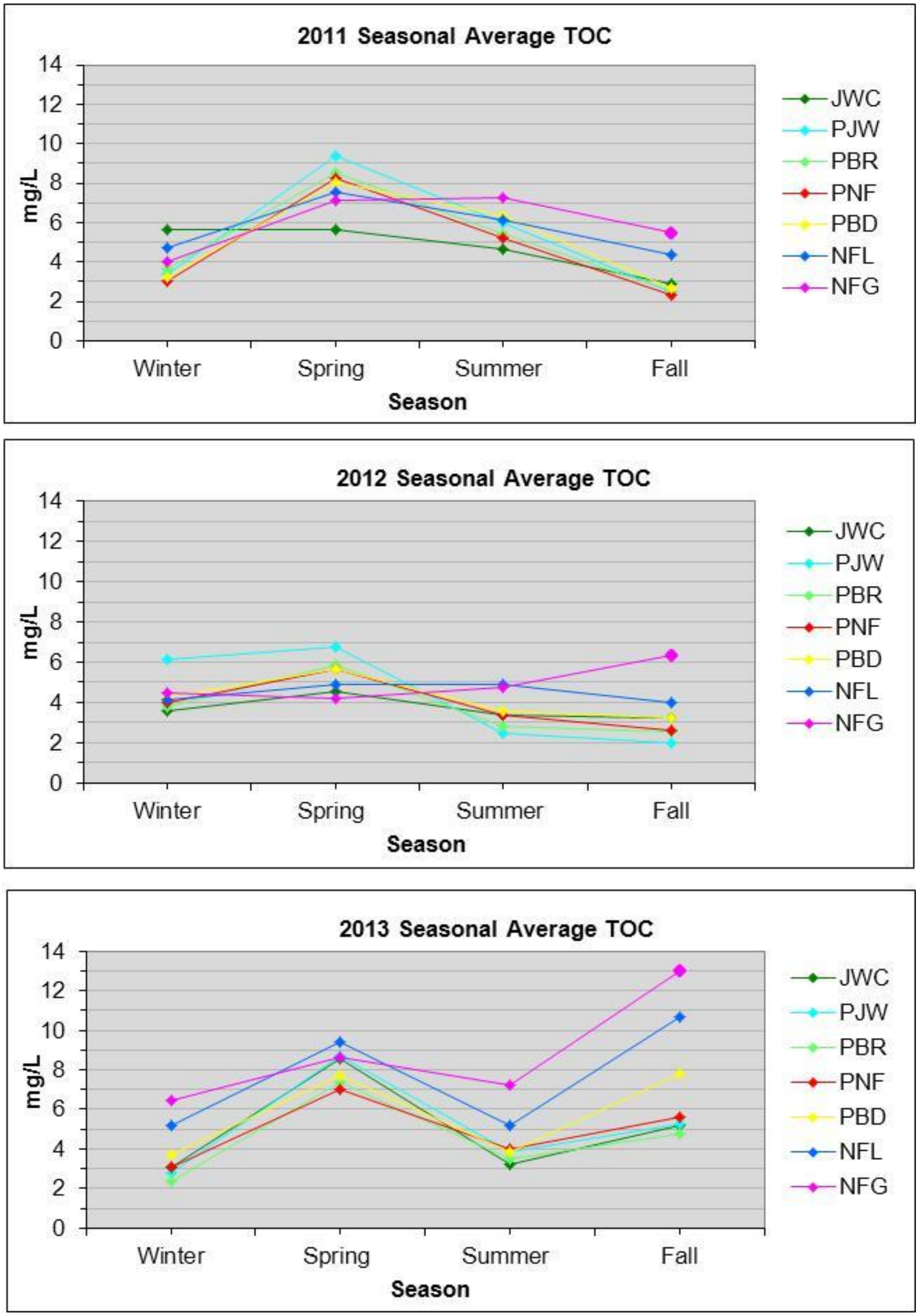


Figure 3.18 – 2011- 2013 Seasonal average TOC concentrations at key Upper CLP monitoring sites. Seasons: Winter (Nov-Dec, Jan-Apr); Spring (May-Jun); Summer (Jul-Aug); Fall (Sep-Oct)

3.5 Nutrients

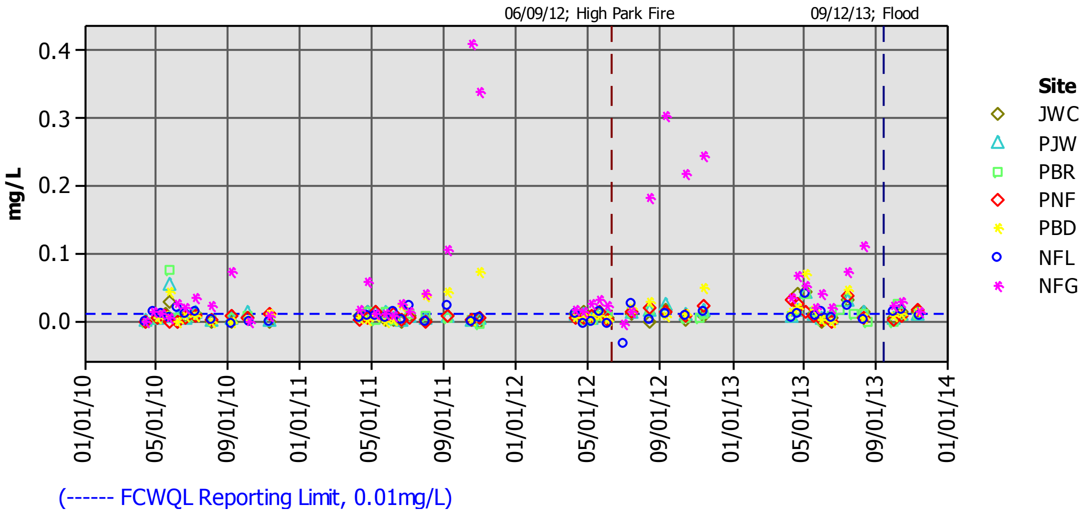
All Upper CLP samples were analyzed for a suite of nutrients, which includes ammonia (NH_3), nitrite (NO_2), nitrate (NO_3), total phosphorus (Total P) and ortho-phosphate (PO_4). For the purpose of this report, the discussion of results only pertains to values above the reporting limits currently used by the FCWQL for 2008 data and beyond. Current reporting limits are 5 micrograms per liter (ug/L) for ortho-phosphate, 10 ug/L for ammonia and Total P, and 40 ug/L for nitrate and nitrite.

Ammonia, nitrate, nitrite, and ortho-phosphate are dissolved forms of nitrogen and phosphorus that are readily available for plant uptake. Both Total Kjeldahl Nitrogen (TKN) and Total P serve as aggregate measures of potential nitrogen and phosphorus availability to the system. TKN is a measure of ammonia plus organic nitrogen. Total nitrogen (TN) is the sum of TKN, nitrate and nitrite. Likewise, Total P is a measure of dissolved phosphorus as well as phosphorus bound to sediments and organic matter. In aquatic systems, sources of nutrients include animal waste, leaking septic systems, fertilizer run-off and sediment loading.

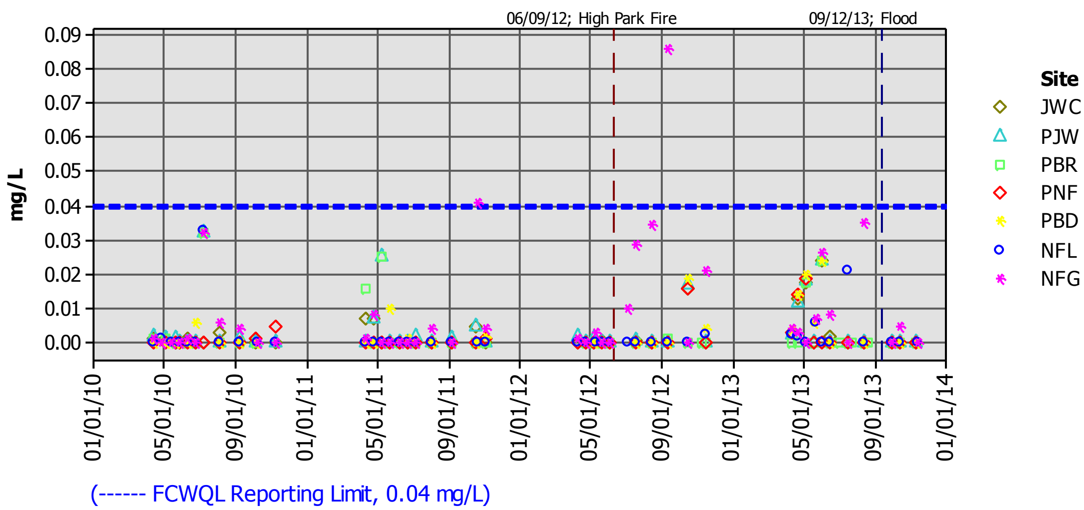
3.5.1 North Fork. In general, nutrient concentrations were comparable between the North Fork and Mainstem sites. The exceptions are the two sites situated below Halligan and Seaman Reservoirs on the North Fork. These reservoirs appear to be sources of nutrients to the North Fork, as reflected by relatively high nitrate (NO_3), nitrite (NO_2), ammonia (NH_3), TKN, TN, ortho-P (PO_4) and Total P concentrations observed at NFG below Seaman Reservoir and NBH below Halligan Reservoir (Figures 3.19a – 3.19f and Attachment 7).

The relatively high nitrogen and phosphorus concentrations that are frequently observed in late summer result from internal nutrient loading which occurs under low D.O. conditions at the bottom of the reservoirs. In the late summer and fall of 2011 and 2012, unusually high concentrations of ammonia, nitrite and ortho-phosphate were observed at NFG (Figure 3.19a-b,f). It should be noted that although observed concentrations of nitrite were higher at NFG than any other site, there were only two instances in which concentrations were above the FCWQL reporting limit. The reservoir processes and conditions that contributed to these high nutrient concentrations in Seaman Reservoir are discussed in further detail in Section 4.2. Across all river sites, there were no observed exceedances of the EPA drinking water quality standards for nitrate (10 mg/L) or nitrite (1 mg/L) for the years 2010 – 2013.

a. Ammonia (NH_3)



b. Nitrite (NO_2)



c. Nitrate (NO_3)

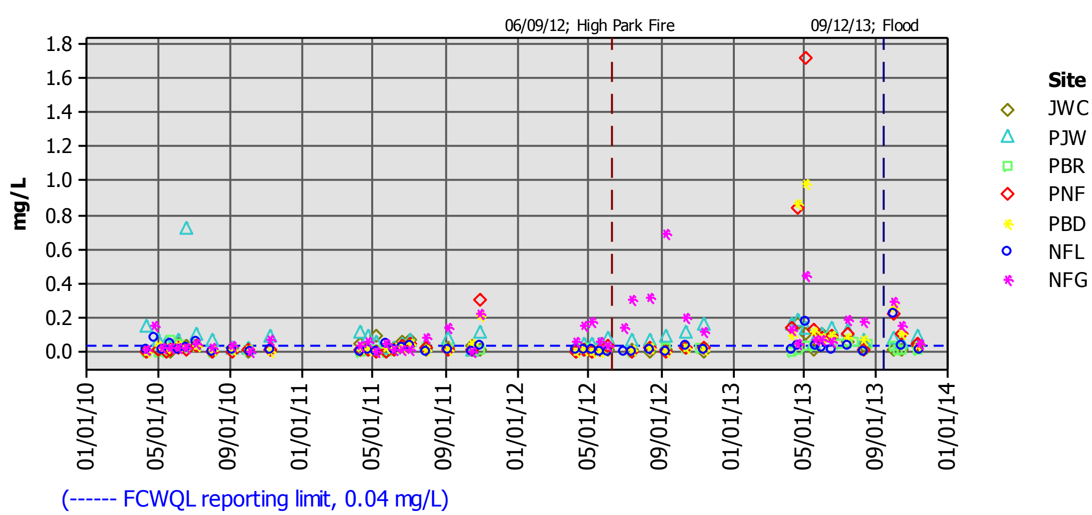
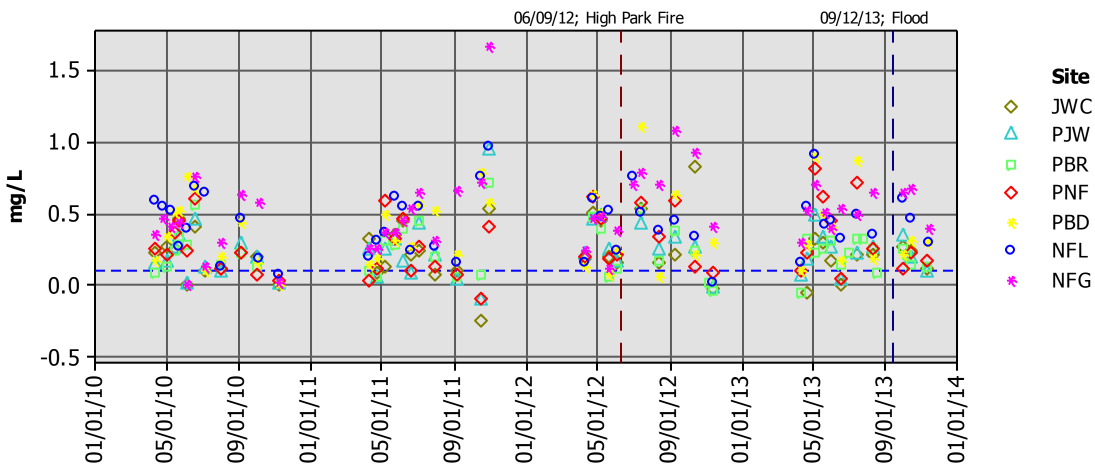


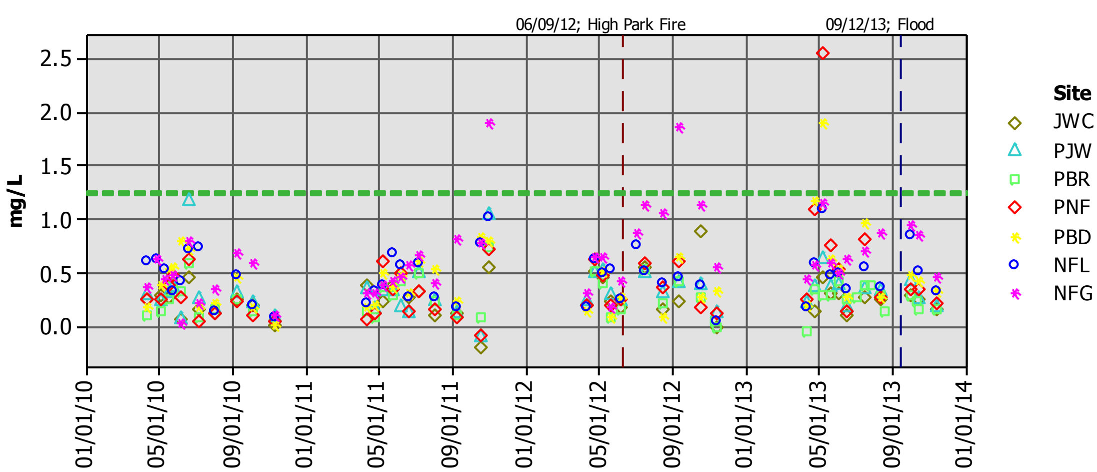
Figure 3.19 – Nutrient concentrations for a) ammonia, b) nitrite, and nitrate at key Upper CLP monitoring sites.

d. Total Kjeldahl Nitrogen (TKN)



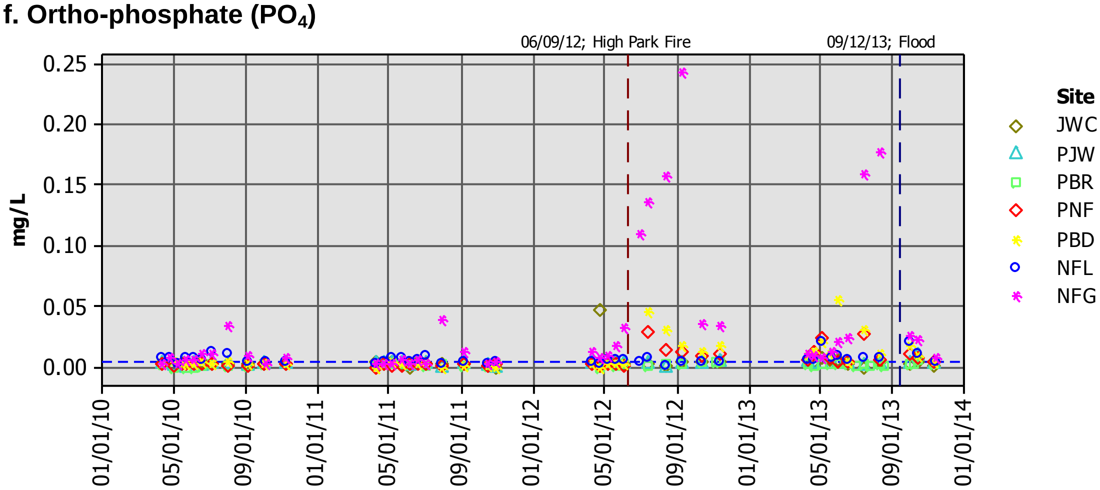
(------- FCWQL Reporting Limit, 0.100 mg/L)

e. Total Nitrogen (NO_2+NO_3+TKN)



(------ CDPHE proposed cold water stream standard for TN , 1.25 mg/L)

f. Ortho-phosphate (PO_4)



(------FCWQL Reporting Limit, 0.005 mg/L)

Figure 3.19 (continued) – Nutrient concentrations for d) TKN, e) TN, and f) ortho-phosphate at key Upper CLP monitoring sites.

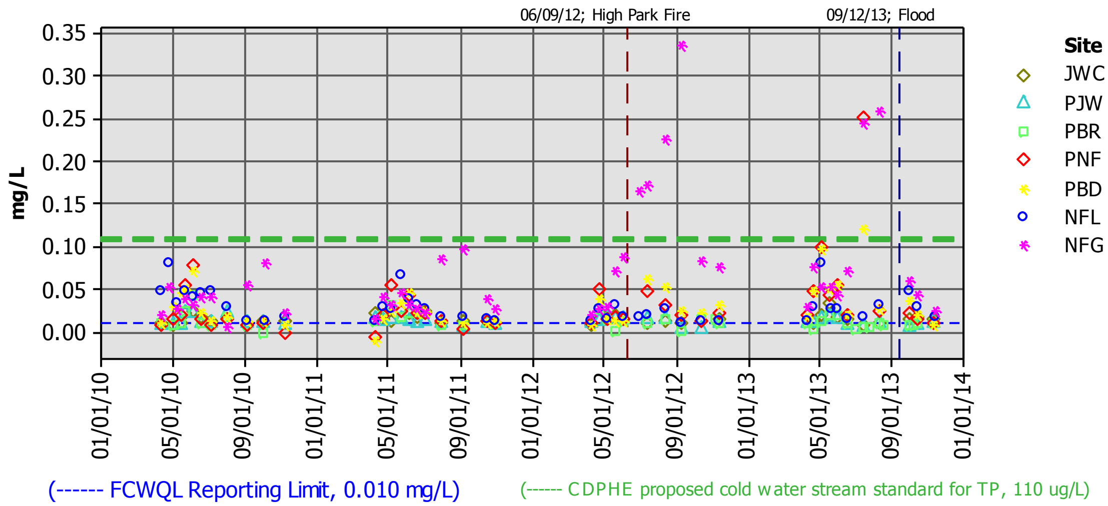


Figure 3.19 (continued) – Nutrient concentrations for g) Total P at key Upper CLP monitoring sites.

g. Total Phosphorus (Total P)

Elevated concentrations of nitrate, Total P and TKN were observed at NFL and other upstream North Fork tributary sites during spring runoff. These higher concentrations likely occurred in response to flushing and suspension of sediment and dissolved nutrients during snowmelt. The North Fork tributaries, RCM and Lone Pine Creek (PCM), had higher median Total P concentrations than the lower North Fork site, NFL, for the years 2010 – 2013 (Figure 3.20a). Total P concentrations at RCM and PCM ranged from 0.014 -0.164 mg/L, while concentrations at NFL ranged from 0.011- 0.081 mg/L. PCM, SCM, and particularly RCM had higher median concentrations of ortho-phosphate compared to NFL over the same years (Figure 3.20b). Ortho-P concentrations on the upper tributaries ranged from 0.003-0.034 mg/L, and concentrations downstream at NFL ranged from 0.001 – 0.021 mg/L. The relatively high concentrations of nutrients in these small tributaries are due, in large part, to the low stream flows, especially during the summer months, and represent small contributions to overall streamflow and nutrient loads to NFL.

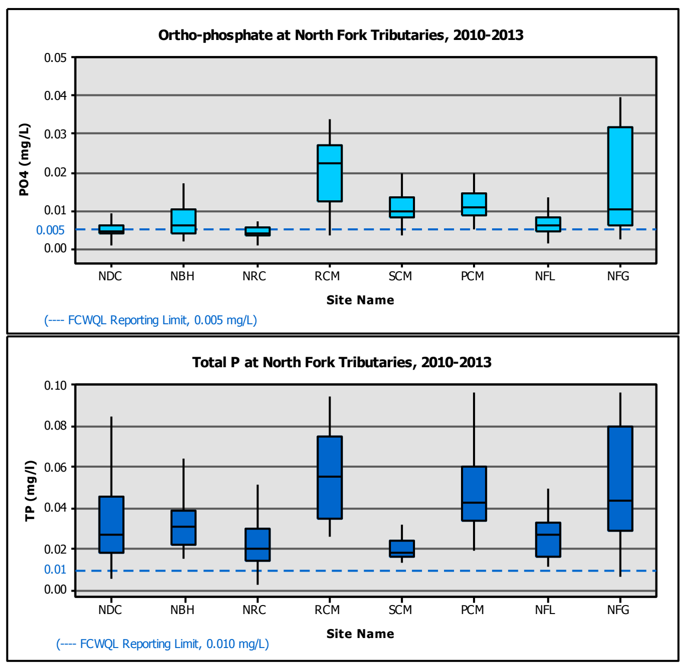


Figure 3.20 – Boxplots of Total P and ortho-phosphate concentrations on the North Fork and tributaries to the North Fork from 2010-2013.

The effects of reservoir releases on downstream nutrient concentrations can be seen below Seaman Reservoir at NFG.

3.5.2 Mainstem. Nitrite was not detected above reporting limits at any site on the Mainstem from 2010-2013. Ortho-phosphate was similarly low in 2010 and 2011 with the few reportable concentrations being observed in samples collected from the Laramie Tunnel (LRT), BMR, and at PJW monitoring sites.

The 2013 peak nitrate concentration at PNF of 1.72 mg/L was noticeably higher than previous years and occurred on May 6th, 2013 at the onset of spring runoff. In contrast, the peak ammonia concentration at PNF was 0.03 mg/L and occurred prior to spring runoff on April 4th, 2013, nearly a month earlier than the spring nitrate pulse was observed. The maximum ammonia concentration was similar to previous years (2010-2012).

Similar to the North Fork, the high concentrations of TKN and Total P on the Mainstem typically occur during spring runoff, followed by sharp declines during the summer months. Total P tends to follow similar trends as streamflow. In 2013, the peak Total P concentration at PNF of 0.10 mg/L occurred during spring runoff and was greater than the previous three years. The 2013 maximum TKN concentration at PNF was 0.81 mg/L, as compared with previous years' peak concentrations (0.59 - 0.61mg/L). TN tracks closely with TKN, as TKN comprises the largest fraction of TN, with nitrate and nitrite representing lesser fractions.

3.5.3 Impacts of 2012 Wildfires and Drought on Baseline Water Quality. During the summer of 2012, hot and dry conditions in the Upper Poudre basin resulted in not only contributed to the Hewlett and High Park wildfires, but also resulted in lower than usual base flows in the river. These factors likely influenced the higher concentrations of constituents observed at many locations.

The deposits of fire sediments in the river channel and the frequent pulses of materials from rain events serve as sources of nutrients to the river, and have both immediate and delayed response. Sediments stored along the banks and in the active river channel can serve as a continuous source of nutrients to the system. The influence of stored sediments is reflected as elevated baseline (non-storm event) concentrations of some nutrients, particularly nitrate and ortho-phosphate, and to a lesser degree, ammonia, at fire impacted sites (Figures 3.19a & 3.21a). Changes in baseline nutrient concentrations were not observed at sites located outside of the High Park Fire burn scar area.

Prior to the 2012 wildfires, ortho-phosphate (PO_4) concentrations at PNF had not exceeded the reporting limit of 0.005 mg/L, whereas concentrations immediately following the fires and through 2013 were consistently above, and occasionally more than five times the reporting limit (Figure 3.19f and 3.21d). Concentrations downstream at PBD were slightly higher than PNF due to the additional accumulation of sediment in this reach of the river and inputs from the North Fork of the Poudre.

In contrast to ortho-phosphate, post-fire nitrate (NO_3) concentrations at PNF and PBD were not elevated in 2012 and were generally near or below the reporting limit of 0.04 mg/L. In 2013, however, nitrate showed a notable increase, with concentrations three to five times higher than observed in 2010- 2012. The highest nitrate concentration at PNF occurred on May 6th, 2013 at 1.72 mg/L (Figure 3.19c). This trend of elevated background concentrations of nitrate is expected to persist into coming years as it has in other fire-impacted water bodies (Robinson and Minshall,1996), including those impacted by the Hayman Fire, in the South Platte River basin of Colorado (Rhoades et al., 2011).

The effect of the stored riverbank sediments and ash on water quality was very pronounced at the onset of the 2013 spring snowmelt runoff. The deposits of sediment and ash were re-suspended as streamflow increased, causing dramatic and rapid changes in water quality, particularly at the lower elevations sites, PNF and PBD. The 2013 spring runoff produced evidently higher concentrations of all nitrogen and phosphorus fractions than were observed in the previous three years during the same period (Figures 3.19a-g).

Nutrient concentrations were also higher during spring snowmelt runoff than previous years at several higher elevation monitoring sites that were not impacted by the 2012 wildfires, including BMR, JWC, PJW, LRT, and PBR. The higher than usual nutrient concentrations at these sites can likely be attributed to a combination of factors related to the flushing of materials affected by drought conditions in the basin during the preceding summer or to upstream reservoir releases.

3.5.4 Impacts of Post-Fire Storm Events on Nutrients. In contrast to chronic nutrient inputs from sediments, storm events can result in large and sudden spikes in concentrations that diminish over a relatively short period of time after the event has passed (Oropeza and Heath, 2013). The influence of these events is captured by storm sampling. Storm samples collected in 2012 and 2013 showed elevated concentrations of ammonia (NH_3), Total Kjeldahl Nitrogen (TKN), ortho-phosphate (PO_4), and Total P (Figures 3.21a-e). The concentrations of nitrate (NO_3) in storm samples were significantly elevated above baseline concentrations at PNF compared to previous years, especially in 2013 (Figure 3.21b). These results suggest that not only are baseline concentrations of nitrate in 2013 elevated compared to previous years, but nitrate that was mobilized from hillslopes during rain events was also greater in 2013 than immediately after the fire in 2012.

Note that in order to more accurately identify post-fire changes in water quality, the nutrient data were presented in logarithmic scale (mg/L) due to the degree of seasonal and annual variability.

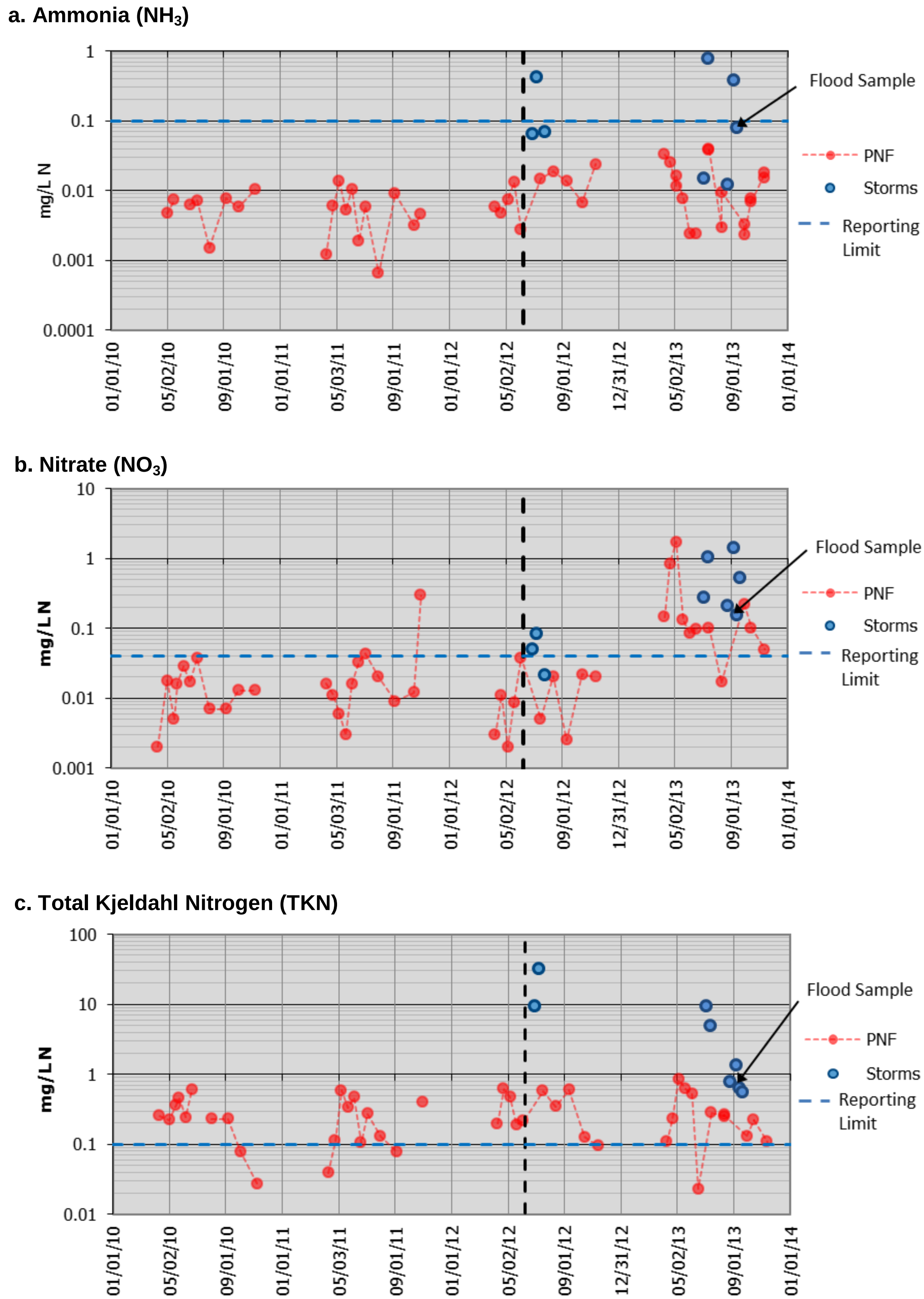
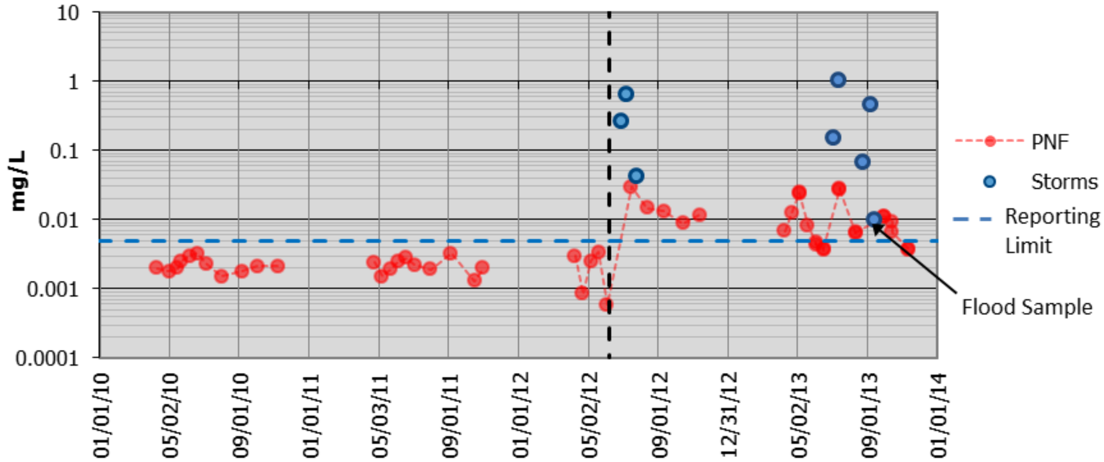


Figure 3.21 - Comparison of baseline a) ammonia, b) nitrate, and c) TKN concentrations and post-fire storm water concentrations measured at PNF.

d. Ortho-phosphate (PO_4)



e. Total Phosphorus (Total P)

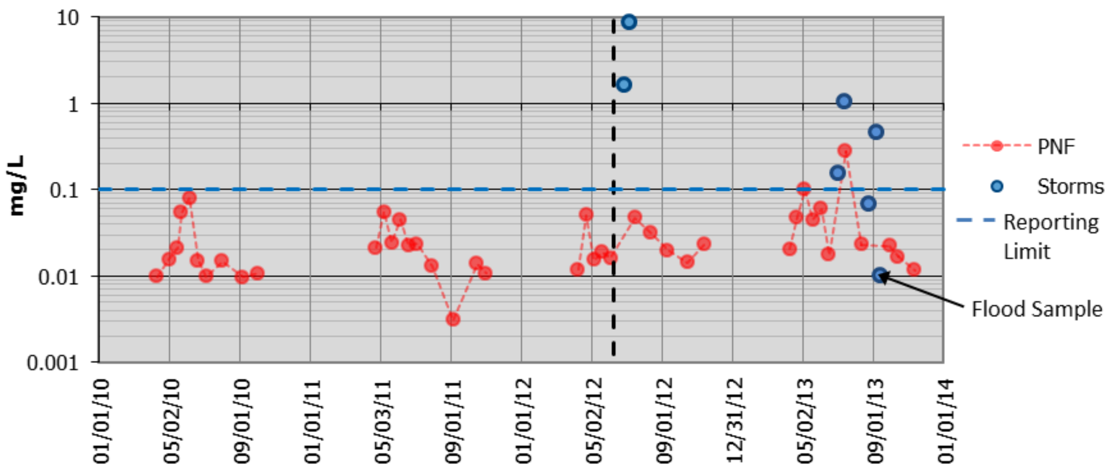


Figure 3.21 (continued) - Comparison of baseline d) ortho-phosphate and e) total phosphorus concentrations and post-fire storm water concentrations measured at PNF.

3.5.5 Effects of the September 2013 Flood Event. As described in Section 3.1 the large precipitation event that occurred in September 2013 resulted in extreme streamflows on the Mainstem and North Fork CLP Rivers. This event produced several debris flows, primarily in drainages that had been affected by the 2012 wildfires. The high flows also resulted in substantial erosion and deposition of new material. The cumulative effect of the 2013 flood on nutrients was a spike in nitrate, ortho-phosphate and TKN, however, the high volume flows provided sufficient dilution so that concentrations were not extreme (Figures 3.21a-e).

3.5.6 Proposed Nutrient Standards. In June 2012, the Colorado Water Quality Control Commission adopted numerical Regulation #31, which provides for scientifically-based numerical nutrient values designed to protect the designated uses of waters in the state of Colorado, including the protection of aquatic life, recreation and municipal water supplies. The initial phase of implementation from 2012 – 2017 applies interim numerical values for phosphorus, nitrogen and chlorophyll-*a* for headwaters upstream of dischargers, Direct Use Water Supply Lakes and Reservoirs (chlorophyll-*a*) and where voluntary efforts to control nonpoint sources of nutrients under the Nutrient Control Regulation #85 are not effective.

All rivers and reservoirs within the Upper CLP Watershed are designated "cold" waters. For cold water streams, the interim nutrient values are based on annual median values with a 1-in-5 year exceedance frequency. Proposed interim values are 1,250 ug/L for TN and 110 ug/L Total P.

To evaluate the current status of the Mainstem and North Fork CLP Rivers in respect to these proposed standards, annual median value for TN (2008-2013) and the annual median values (2008 – 2013) for Total P were calculated for three river locations: PNF on the Mainstem above the Fort Collins water supply intake facility, PBD above the Greeley-Bellvue water supply diversion, and NFG on the North Fork below Seaman Reservoir (Tables 3 & 4). Results indicate that the annual median TN and Total P values at all three sites were well below the proposed interim values (Table 3 - 4). There was only one instance from 2010-2013 when TN concentrations on the Mainstem exceeded the 1,250 ug/L standard. This occurred on May 6th, 2013 during spring runoff when concentrations at PNF and PBD were 1,902 ug/L (1.90 mg/L) and 2,550 ug/L (2.55 mg/L) respectively.

Table 3 – Comparison of annual median TN concentrations (ug/L) at Mainstem CLP and North Fork CLP sites to 2012 CDPHE/WQCD proposed interim TN value of 1,250 ug/L.

	2008	**2009**	**2010**	**2011**	**2012**	**2013**
Poudre above North Fork (PNF)	259.1	226.8	248.5	150.4	309.6	340.4
Poudre at Bellvue Diversion (PBD)	247.7	329.0	214.9	477.4	295.1	476.6
North Fork Poudre at Gage below Seaman Reservoir (NFG)	460.0	376.2	447.7	454.8	649.3	615.0

*All reported concentrations are expressed in ug/L.

Table 4 – Comparison of annual median Total P concentrations (ug/L) at Mainstem CLP and North Fork CLP sites to 2012 CDPHE/WQCD proposed interim Total P value of 110 ug/L.

	2008	**2009**	**2010**	**2011**	**2012**	**2013**
Poudre above North Fork (PNF)	8.6	12.7	14.7	21.2	19.3	24.4
Poudre at Bellvue Diversion (PBD)	11.7	15.6	17.0	16.2	23.3	37.3
North Fork Poudre at Gage below Seaman Reservoir (NFG)	23.3	30.2	38.8	32.2	83.5	52.3

3.6 Metals

In From 2010 through 2012, metals were sampled twice annually on the Mainstem at PNF and on the North Fork at NFG for dissolved metals. In 2013, routine sample frequency was increased to three times per year and new analytes were added to the monitoring plan to better evaluate the effects of the 2012 wildfires. Additional sites, above and below the burn scar were also added, (Attachment 4) and all samples were analyzed for total and dissolved metals. In 2013, the spring sample was collected on May 21^{st}, a summer sample on July 15^{th}, and a fall sample on Oct.14^{th}. Silver (Ag), mercury (Hg), nickel (Ni), selenium (Se) and zinc (Zn) were not detected at concentrations above their respective reporting limits. All other metals were detected in either the dissolved or total fraction on at least one date and location, and are summarized in Table 5.

The most commonly detected metals were aluminum (Al), iron (Fe) and manganese (Mn), which are shown in Figure 3.22.

The highest concentrations on the Mainstem (PBR, SFM, PSF, PNF, PBD) were observed prior to spring runoff during the May sampling event. Like other constituents, the high metals concentrations may have been influenced by the stored sediments in the river channel from the previous summer’sdebris flows along with the relatively low streamflow prior to spring snowmelt runoff. This expectation is supported by results of a 2012-2013 sediment leaching study that indicated that the fire-impacted sediments were capable of releasing high concentrations of metals into the water column (Steninger, 2013).

The lowest concentrations were observed in July, likely as a result of sediment scour during runoff and dilution effect of the increased streamflows.

The North Fork sites, NFL and NFG, exhibited high concentrations of aluminum and iron during the spring and fall sampling events.

Figure 3.22 – Metal concentrations for a) dissolved iron, b) dissolved manganese, and c) dissolved aluminum at key Upper CLP monitoring sites.

While these elevated concentrations may be partially attributed to relatively low flow conditions in the river, reservoir dynamics also have a large influence on water quality at NFG. Manganese concentrations at NFG during the July sampling event were extremely high and suggest that D.O. was low enough in Seaman Reservoir at this time to facilitate the release of manganese from the bottom sediments.

Iron, manganese and aluminum exceeded their respective secondary drinking water MCL, on at least one sample date. Secondary drinking water MCLs are guidelines for constituents that may cause aesthetic effects such as discoloration, but do not pose a threat to public health. The concentrations reported for the Upper CLP are not expected to have adverse effects on finished water quality because the exceedances were minor and water treatment processes remove much of these dissolved metals in raw water supplies.

Storm events produced variable concentrations of dissolved aluminum, manganese and iron, with some storms producing higher than usual concentrations, and some producing relatively low concentrations. Iron and aluminum concentrations in storm samples were within the range of values observed during routine sampling, whereas the onset of the September flood event (Sept. 6th) produced the highest observed concentration of manganese (183 ug/L). The second highest value of 74 ug/L was observed on May 21, 2012, immediately after the Hewlett Fire.

Table 5 – 2013 dissolved and total metals concentrations on the Mainstem and North Fork of the Poudre River.

Metal	Site	20-May		15-Jul		14-Oct	
		Soluble	Total	Soluble	Total	Soluble	Total
Aluminum (Al)	PBR*	< 10	----	----	71.70	< 10	68.65
	SFM	457.87	----	----	----	----	----
	PSF	----	----	35.50	436.03	58.79	107.07
	PNF	367.53	----	77.30	8,333	55.07	224.76
	PBD	339.13	----	44.56	4,296	64.62	237.08
	NFL**	264.09	----	< 10	22.48	131.31	170.12
	NFG	286.57	----	22.36	442.84	135.05	380.60
Arsenic (As)	PBR*	< 2	----	< 2	< 2	< 2	< 2
	SFM	< 2	----	----	----	----	
	PSF	----	----	< 2	< 2	< 2	< 2
	PNF	< 2	----	< 2	< 2	< 2	< 2
	PBD	< 2	----	< 2	< 2	< 2	< 2
	NFL**	< 2	----	< 2	< 2	< 2	< 2
	NFG	< 2	----	2.07	2.40	< 2	< 2
Cadmium (Cd)	PBR*	< 0.1	----	< 0.1	< 0.1	< 0.1	< 0.1
	SFM	< 0.1	----	----	----	----	----
	PSF	----	----	< 0.1	< 0.1	< 0.1	< 0.1
	PNF	< 0.1	----	< 0.1	0.22	< 0.1	< 0.1
	PBD	< 0.1	----	< 0.1	0.14	< 0.1	< 0.1
	NFL**	< 0.1	----	< 0.1	< 0.1	< 0.1	< 0.1
	NFG	< 0.1	----	< 0.1	< 0.1	< 0.1	< 0.1
Chromium (Cr)	PBR*	< 0.5	----	< 0.5	< 0.5	< 0.5	< 0.5
	SFM	< 0.5	----	----	----	----	----
	PSF	----	----	< 0.5	0.67	< 0.5	0.52
	PNF	< 0.5	----	< 0.5	11.14	< 0.5	0.71
	PBD	< 0.5	----	< 0.5	5.89	< 0.5	0.64
	NFL**	< 0.5	----	< 0.5	< 0.5	< 0.5	< 0.5
	NFG	< 0.5	----	< 0.5	0.54	< 0.5	0.58
Copper (Cu)	PBR*	< 3	----	< 3	< 3	< 3	< 3
	SFM	< 3	----	< 3	----	< 3	----
	PSF	< 3	----	< 3	< 3	< 3	< 3
	PNF	< 3	----	< 3	8.89	< 3	4.27
	PBD	< 3	----	< 3	5.31	< 3	< 3
	NFL**	< 3	----	< 3	< 3	< 3	< 3
	NFG	< 3	----	< 3	< 3	< 3	< 3
Iron (Fe)	PBR*	233.76	----	40.96	120.73	87.64	136.39
	SFM	301.20	----	----	----	----	----
	PSF	----	----	47.10	515.01	105.80	184.72
	PNF	213.54	----	267.17	6,042	80.04	9,064
	PBD	265.11	----	52.50	4,637	157.77	389.84
	NFL**	250.08	----	32.99	132.55	321.67	502.02
	NFG	234.10	----	80.84	752.12	304.56	603.46
Lead (Pb)	PBR*	< 2	----	< 2	< 2	< 2	< 2
	SFM	----	----	----	----	----	----
	PSF	----	----	< 2	----	< 2	< 2
	PNF	< 2	----	< 2	14.36	< 2	< 2
	PBD	< 2	----	< 2	7.58	< 2	< 2
	NFL**	< 2	----	< 2	< 2	< 2	< 2
	NFG	< 2	----	< 2	< 2	< 2	< 2
Managense (Mn)	PBR*	1.07	----	< 1	6.28	1.43	3.88
	SFM	7.26	----	----	----	----	----
	PSF	----	----	3.77	21.86	3.31	5.16
	PNF	9.04	----	7.42	388	5.08	11.66
	PBD	14.04	----	9.44	186	20.49	29.96
	NFL**	8.23	----	11.30	21.06	20.71	22.95
	NFG	11.36	----	173.60	268.87	39.49	63.50

* Mainstem Unburned site

** North Fork Unburned site

3.7 Pathogens: *Cryptosporidium and Giardia*

Cryptosporidium and *Giardia* testing on the North Fork sites above and below Halligan Reservoir (at NDC and NBH, respectively) began in 2006. In 2008, the NDC sampling site was moved upstream of the confluence with Dale Creek to accommodate potential future expansion of Halligan Reservoir. This site represents the water quality of the North Fork flows, above Dale Creek, as source waters to Halligan Reservoir. Samples on the Mainstem Poudre are collected from the raw Poudre water supply at the FCWTF, but are considered comparable values at PNF since there are no additional inflows to the water supply between the intake structure at PNF and the FCWTF.

Giardia is more abundant than *Cryptosporidium* on both Mainstem and North Fork (Figure 3.23 and 3.24). From 2010 - 2013, *Giardia* was present at levels ranging from 0-36 cysts per liter (cysts/L), whereas *Cryptosporidium* was frequently not detected; values did not exceed 0.5 cysts/L. 2013 concentrations were similar to previous years at all sites.

From 2010 – 2013, the North Fork at NDC consistently had the highest seasonal maximum *Giardia* concentrations which ranged from 24-36 cysts/L. October 1, 2013 produced the exception, when the peak 2013 concentration of 34 cysts/L occurred below Halligan Reservoir at NBH. In comparison, the annual maximum Mainstem (PNF) concentrations were somewhat lower, ranging from 13-20 cysts/L. The outflow from Seaman Reservoir (NFG) consistently had the lowest *Giardia* concentrations. *Cryptosporidium* concentrations were relatively very low at all sites, with concentrations ranging from 0 - 0.5 cysts/L from 2010 – 2013.

Giardia and *cryptosporidium* were only infrequently detected below Seaman Reservoir at NFG, and when detections did occur, concentrations were less than 0.5 cysts/L of giardia and less than 0.21 cysts/L of *cryptosporidium*.

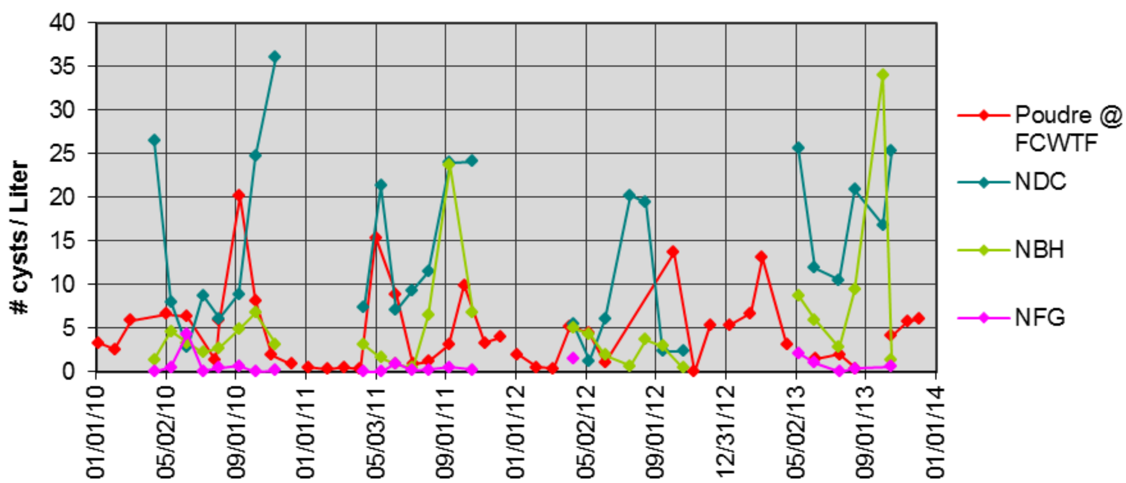


Figure 3.23 – Concentrations of *Giardia* on Mainstem and North Fork CLP.

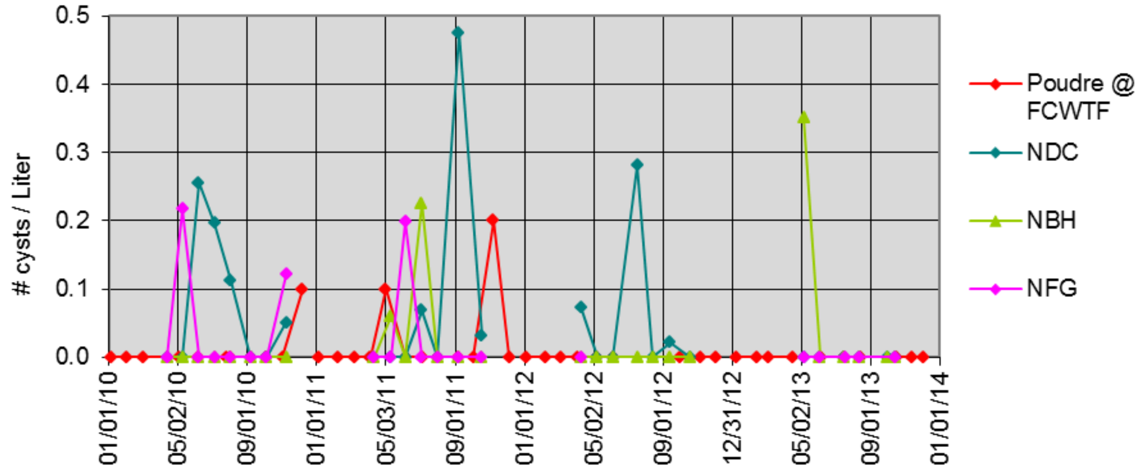


Figure 3.24 – Concentrations of *Cryptospordium* on Mainstem and North Fork CLP.

3.8 Total Coliforms and *E. coli*

Samples from five sites – NFL, NFG, PBR, PNF and PBD - were analyzed for total coliforms and *E.coli*. NFL was added as a sample site in 2009 to gain a better understanding of the sources of total coliforms and *E. coli* within the North Fork watershed. An error in the 2011 sampling plan resulted in no samples being collected at one of the North Fork sites. In 2013, it was decided to no longer collect *E.coli* samples at this site. As a result, a comparison of total coliform concentrations above and below Seaman Reservoir could not be made for 2011 or 2013.

2013 produced the highest peak values for both *E. coli* and total coliforms observed over the period of record at both Mainstem and the North Fork sites (Figures 3.25 and 3.26). The peak values occurred on July 15, following a storm event which influenced the relatively high observed concentrations. On this occasion, *E.coli* concentrations were 472.5 cfu/100mL at PNF and 816 cfu/100mL at PBD. Total coliform concentrations reached 24,195 cfu/100mL and 19,863 cfu at PNF and PBD, respectively. In general, PBD exhibited similar concentrations of total coliforms and *E. coli* concentrations as PNF.

In previous years the North Fork showed higher concentrations of both total coliforms and *E.coli* than the Mainstem sites; however, in 2013, concentrations at PNF and PBD were similar to or exceeded the North Fork values. On the July 15 sample date, which followed a significant storm event, NFG experienced a spike in total coliforms which exceeded the Mainstem sites (34,411 cfu/100 mL). A coincident spike in *E.coli* was not observed.

The data show that over the last three years, concentrations of *E.coli* at both north Fork and Mainstem sites have occasionally exceeded the Colorado Department of Public Health and Environment (CDPHE) recreational standard of 126 colonies/100mL. In contrast to previous years, the Mainstem sites PNF and PBD were the only sites that exceeded the standard in 2013.

Note that the *E.coli* and total coliform data were presented in logarithmic scale (mg/L) due to the degree of seasonal and annual variability.

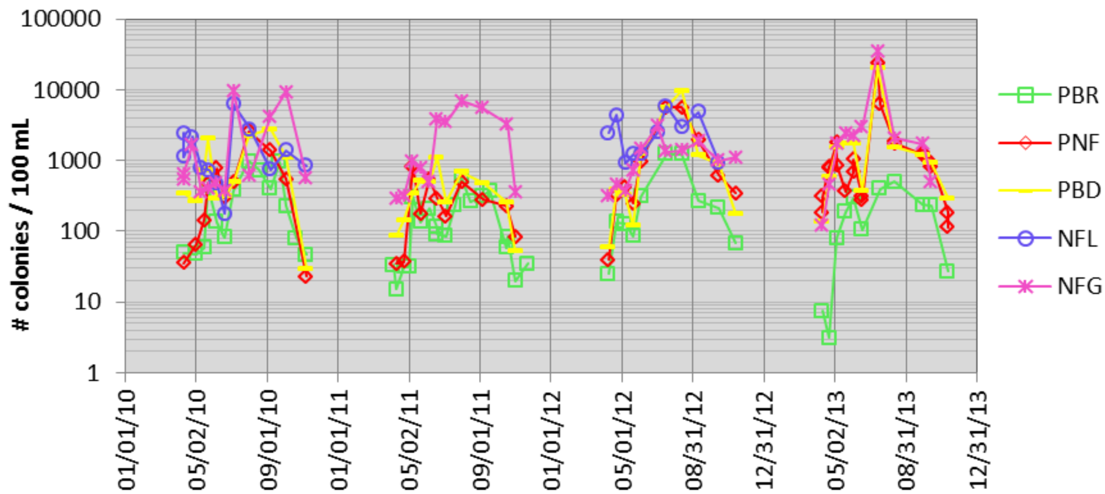
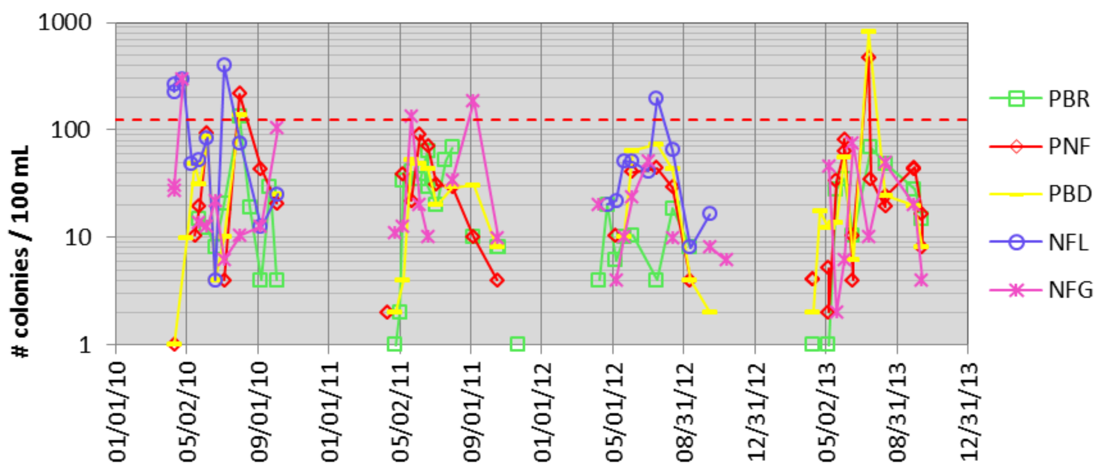


Figure 3.25 – Concentrations of total coliforms at key Upper CLP monitoring sites.



(------ Recreational Water Quality Standard: 126 colonies/100ml)

Figure 3.26 – Concentrations of *E. coli* at key Upper CLP monitoring sites.

4.0 SEAMAN RESERVOIR RESULTS

4.1 Reservoir Operations

Water storage operations for Seaman Reservoir in 2013 are shown in Figure 4.1. The maximum water storage capacity for Seaman Reservoir is 5,000 acre-feet. At the beginning of 2013 the Reservoir was at an annual minimum storage of 3,500 acre-feet of water. Storage levels fluctuated around this level through January, but in early February, prior to snowmelt runoff, storage level steadily increased. Snowmelt runoff on the North Fork began in mid-April when inflow to Seaman Reservoir increased and remained greater than outflow releases resulting in an increase in storage to approximately 4,000 acre-feet by the beginning of May. Outflow from the reservoir was greater than inflow following peak streamflow on the North Fork above Seaman Reservoir, which resulted in a quick reservoir draw down to 3,558 acre-feet on May 18th, 2013. Outflow releases were dropped to levels below the remaining snowmelt runoff levels following this date, and Reservoir storage increased through the months of June and July to 4,882 acre-feet on August 1st. A high intensity precipitation event on August 3rd caused moderate flooding on the North Fork resulting in Reservoir storage levels reaching maximum capacity of 5,008 acre-feet. Outflow from the Reservoir was increased following the

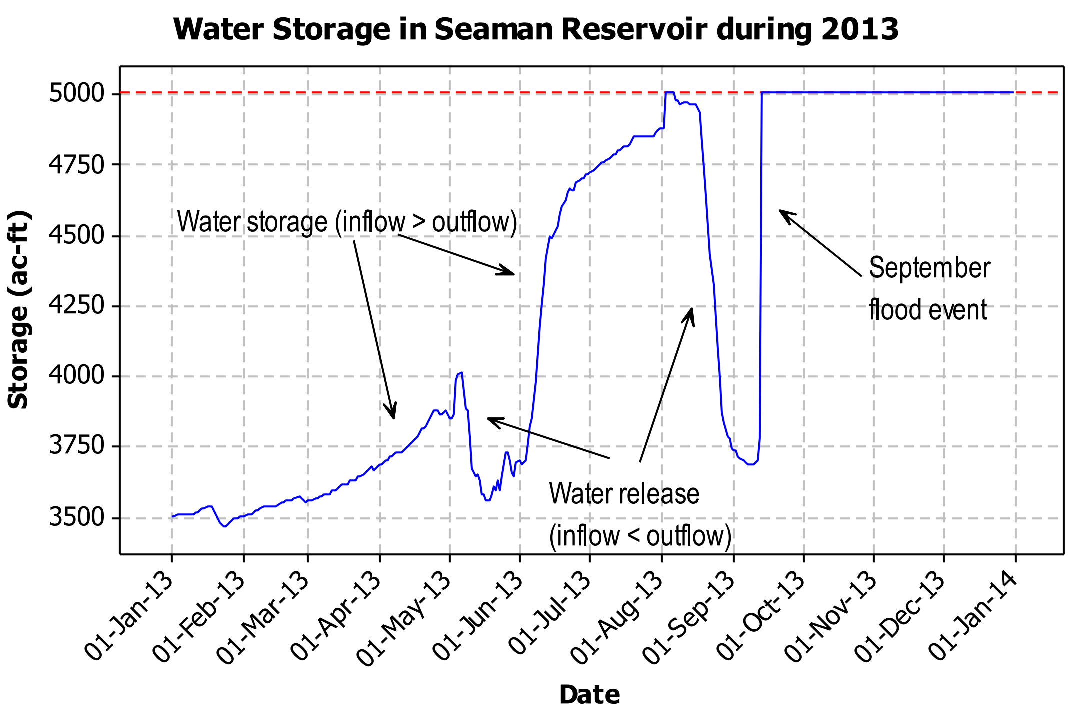


Figure 4.1 – Water levels in Seaman Reservoir in 2013.

flood event resulting in reservoir draw-down through the remainder of August. By early September the storage level was 3,688 acre-feet, but storage rapidly increased during the September 2013 flood event. Maximum inflow to Seaman Reservoir during the flood event was measured at 4,000 cfs on August 13th, which resulted in an increase in storage of 1,233 acre-feet bringing the Reservoir to full capacity. During this period, reservoir outflow was increased to a maximum capacity of 400 cfs and the remaining inflow was released over the spillway. Inflow to Seaman Reservoir remained elevated for the remainder of the year, which maintained storage at maximum capacity through December.

4.2 Depth Profiles

The 2013 Seaman Reservoir depth profiles for temperature, D.O., pH and specific conductance are shown in Figure 4.2. Reservoir operations were typical for Seaman Reservoir in 2013, except for the flood event that occurred in August and September, which re-filled the Reservoir to capacity. Access to Seaman Reservoir was closed following the September flood event and sampling was not conducted for the remainder of the year. It is likely that the cold flood waters help initiate fall turnover, but no data are available to support this assumption.

When the reservoir is fully stratified, three physically distinct layers can be identified (Figure 4.2.1) and are discussed in detail the following sections. The uppermost layer, or *epilimnion*, is characterized by relatively warm, well oxygenated water where the majority of photosynthetic algae production occurs. The middle layer or the *metalimnion* is the transition zone between the upper and lower water column where temperature decreases rapidly. The bottom layer is termed the *hypolimnion*, and is where the most dense, cold waters reside. Because the hypolimnion is physically isolated from the mixing action of the wind and light penetration is minimal, oxygen concentrations become depleted throughout the season, as microbes consume the available oxygen.

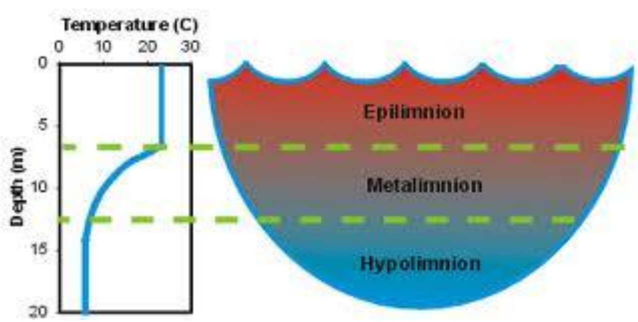


Figure 4.2 – Temperature profile and the corresponding layers of a thermally stratified lake.

Image Source: Upstate Freshwater Institute.

The following discussion outlines data obtained from April through August of 2013.

4.2.1 Temperature (Figure 4.3a). Seaman Reservoir temperature profiles show similar seasonal patterns of most deep temperate lakes and reservoirs. The coldest temperatures occur during the winter months. The reservoir begins to warm in the late spring and early summer with the warmest temperatures typically occurring from late July through August. Reservoir turnover occurs in September or October.

Water temperature in Seaman Reservoir on April 24th was uniform from the Reservoir surface to the bottom. Temperatures began to slowly increase throughout the water column with surface water temperatures warming more rapidly than water temperatures deeper in the water column. A weak temperature gradient was evident on the May 7th followed by progressive development and deepening of the thermocline throughout the remainder of the sampling season. The largest temperature gradient was observed on July 16th with a maximum surface water temperature of 23.2°C and a minimum bottom water temperature of 15.0°C. The temperature profiles indicate water temperatures near the surface exceeded the aquatic life temperature standard of 22.5°C on the July 16th sampling event. Surface water temperatures decreased to levels below the aquatic life temperature standard in August; however, thermal stratification was still evident. The cooler flood waters entering Seaman Reservoir from the North Fork likely cooled surface waters and helped promote fall turnover.

4.2.2 Dissolved Oxygen (Figure 4.3b). Seaman Reservoir displays seasonal characteristics in D.O. In 2013, the highest D.O. concentrations were observed in the spring near the water surface, while the lowest oxygen concentrations were observed in the fall near the bottom of the reservoir. Dissolved oxygen concentrations steadily decreased throughout the 2013 monitoring season with early development of a positive heterograde, where concentrations are higher in the upper water column and decrease moving down the water column. The positive heterograde evolved in the spring strengthening through the summer and fall when D.O. concentrations near the Reservoir bottom were completed depleted to concentrations near 0 mg/L, a condition known as anoxia. Prolonged periods of anoxia can mobilize nutrients (nitrogen and phosphorus) and metals (manganese and iron) from Reservoir bottom sediments potentially causing algal blooms, or eutrophic conditions that further deplete oxygen supply. Seaman Reservoir was officially added to the 303(d) list of impaired waters in 2010 due to occurrences of D.O. below 6 mg/L in the metalimnion combined with exceedances of the temperature standard in the epilimnion (adequate refuge for fish is not available in these types of situations). In 2013, the D.O. standard was first exceeded on June 4th when D.O. concentrations were below 6 mg/L near the reservoir bottom. Conditions progressively deteriorated throughout the water column as the summer progressed. Dissolved oxygen concentrations in both the meta- and hypolimnion were well below the water quality standard on July and August sampling dates. The duration of low D.O. concentrations in Seaman Reservoir is not known due to lack of late season sampling data; however, it is expected that highly concentrated flood water may have aided in reservoir turnover and the re-oxygenation of Seaman Reservoir.

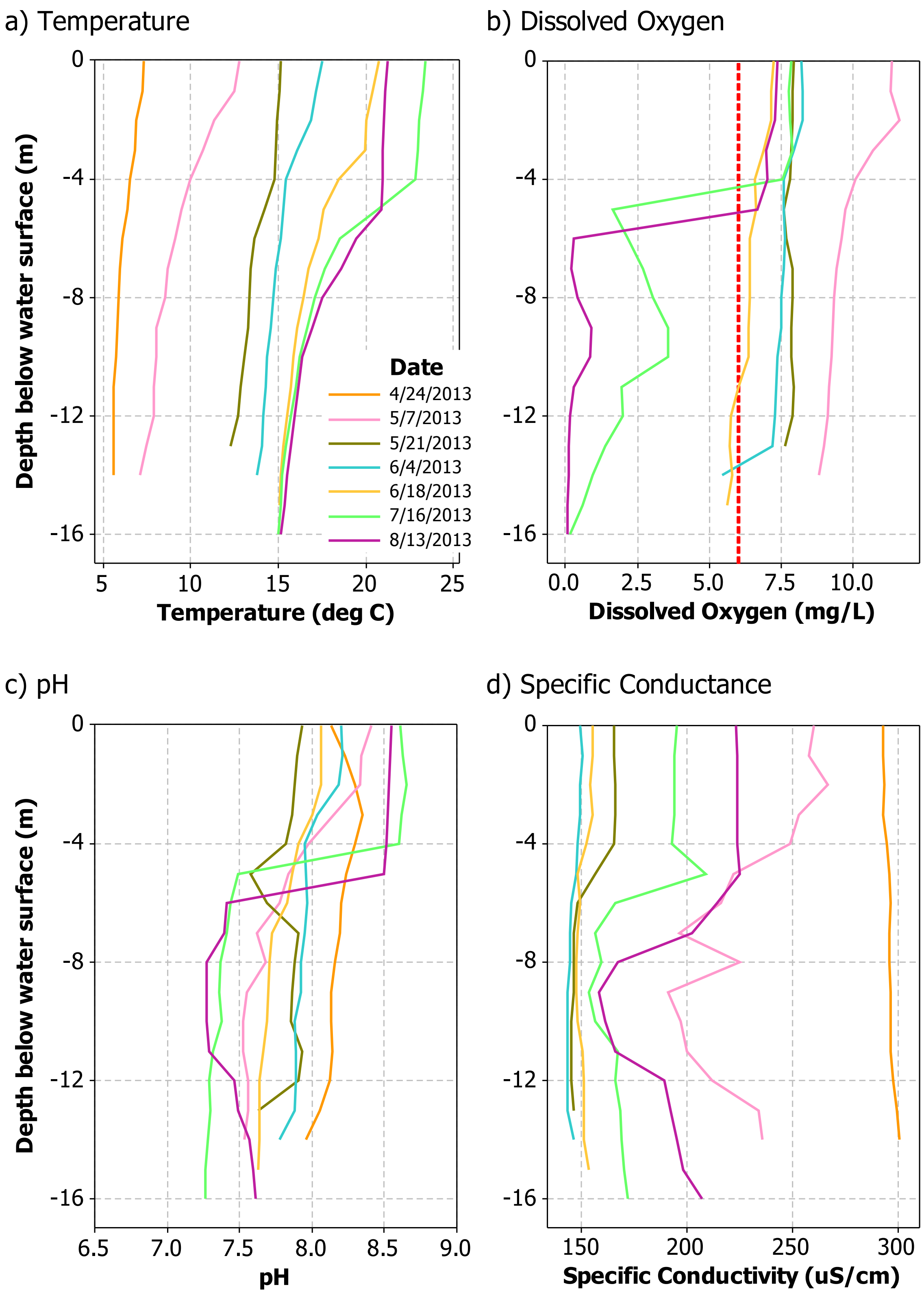


Figure 4.3 – Seaman Reservoir depth profiles for a) water temperature, b) dissolved oxygen, c) pH, and d) specific conductance.

4.2.3 pH (Figure 4.3c). pH values in Seaman Reservoir displayed seasonal trends comparable to temperature and D.O. Changes in pH are closely related to changes in temperature and D.O. with deceasing water temperature and D.O. correlating with decreasing pH. As expected, pH in the epilimnion of Seaman Reservoir increased throughout the summer as temperature increased in the surface waters. In contrast, pH decreased in the metalimnion and hypolimnion as D.O. was depleted throughout the summer monitoring season. The 2013 pH values ranged from 7.3 to 8.7, which fall within the pH water quality standard of 6.5 to 9.0.

4.2.4 Specific Conductance (Figure 4.3d). Specific conductivity values were greater in 2013 compared to previous years ranging from approximately 150 microSeimens per centimeter (uS/cm) to 300 uS/cm. Expected seasonal characteristics were observed with specific conductivity values decreasing during spring runoff as a result of low conductivity snowmelt water entering Seaman Reservoir from May through mid-June. Specific conductance increased in the epilimnion and hypolimnion in July and August, but remained lower in the metalimnion exhibiting a negative heterograde profile.

4.3 General Parameters: Hardness and Alkalinity

Hardness and alkalinity concentrations in Seaman Reservoir follow similar trends through the monitoring season (Figure 4.4a and 4.4b). The highest concentrations are generally observed in the spring and fall, while seasonal minima occur during and following spring snowmelt runoff. In 2013, both hardness and alkalinity ranged from near 150 mg/L to approximately 50 mg/L. Almost identical seasonal trends were observed between hardness and alkalinity concentrations near the Reservoir surface and bottom. Maximum concentrations were sampled in late April. Concentrations decreased to a minimum by the July sampling event and then increased throughout the rest of the summer. In previous years, seasonal trends followed a similar pattern, but maximum concentrations were observed following fall turnover in November. Samples were not obtained following the August sampling event due to inaccessibility to the Reservoir as a result of the 2013 flood event. It is assumed that alkalinity and hardness concentrations decreased as a result of dilute flood waters filling the Reservoir.

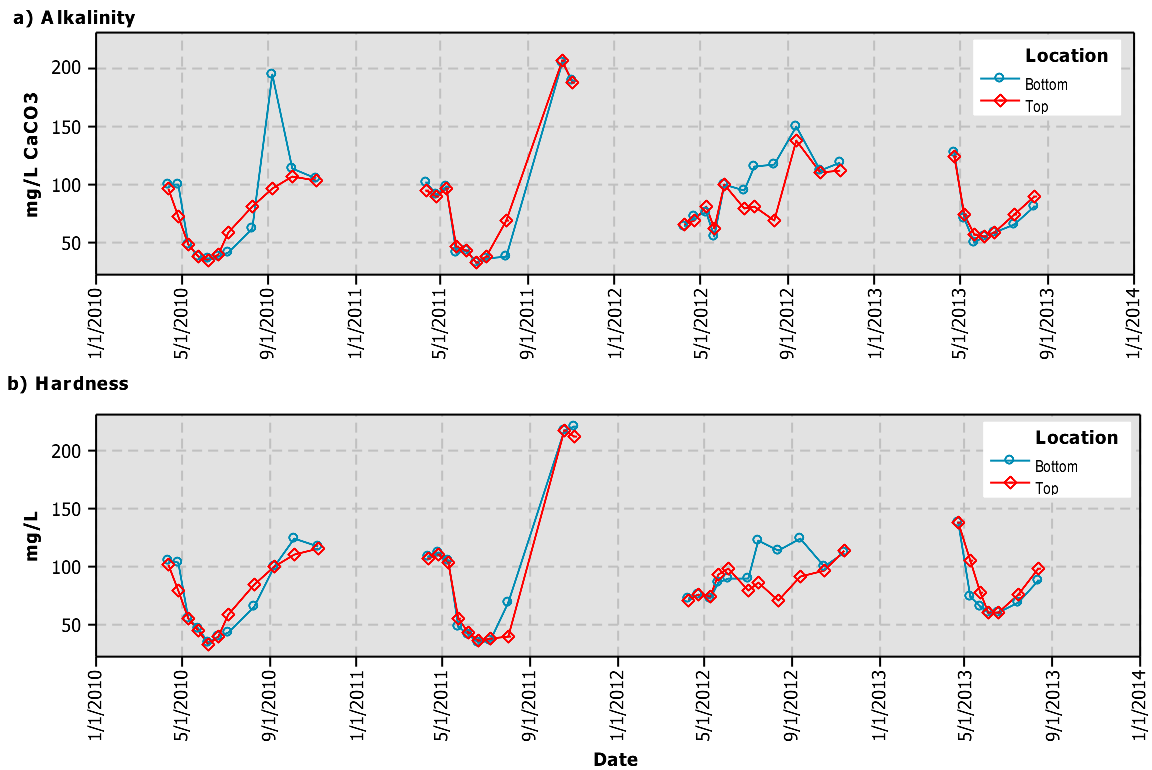


Figure 4.4 – General water quality parameters a) alkalinity and b) hardness measured in Seaman Reservoir from 2010-2013.

4.4 Turbidity, Chlorophyll-a and Secchi Depth

Turbidity values in 2013 were comparable to 2010 and 2011 (Figure 4.5a). In general, turbidity near the bottom of the Reservoir was greater than values near the water surface. Turbidity in both the top and bottom increased during spring snowmelt runoff. Turbidity near the water surface peaked at 3.94 NTU on May 7th, and then steadily decreased throughout the remaining monitoring season. Turbidity near the Reservoir bottom exhibited a similar peak on May 7th of 12.2 NTU, and then decreased to values comparable to the Reservoir surface before abruptly increasing to a annual maximum of 17 NTU on August 12th. The late season peak is likely a result of the August 3rd flood event that occurred in the North Fork watershed.

Chlorophyll-a concentrations were lower in 2013 compared to the previous three years (Figure 4.5b). 2012 produced the highest concentration observed over the period of record at 183 ug/L. Peak 2013 chlorophyll-a concentrations in both the top and bottom of the Reservoir were observed on April 22nd with concentrations of 8.26 ug/L and 1.87 ug/L, respectively. Concentration near the Reservoir bottom decreased to below reporting limit by June and remained below reporting limit for the rest of the monitoring season. Chlorophyll-a concentrations near the Reservoir surface displayed a similar seasonal trend, but spiked to 3.34 ug/L in July before falling to below reporting limit for the rest of the monitoring season.

Epilimnetic (top) chlorophyll-a values greater than 7.3 ug/L may indicate eutrophic conditions, based on Carlson's Trophic State Index (TSI) for a TSI from (Carlson, 1977):

$$TSI\ (Chl\text{-}a) = 30.6 + 9.81 \times \ln(Chl\text{-}a \text{ in ug/L})$$

Chlorophyll-a concentrations exceed 7.3 ug/L in all years from 2010 through 2013, with most exceedances occurring in samples collected near the Reservoir surface.

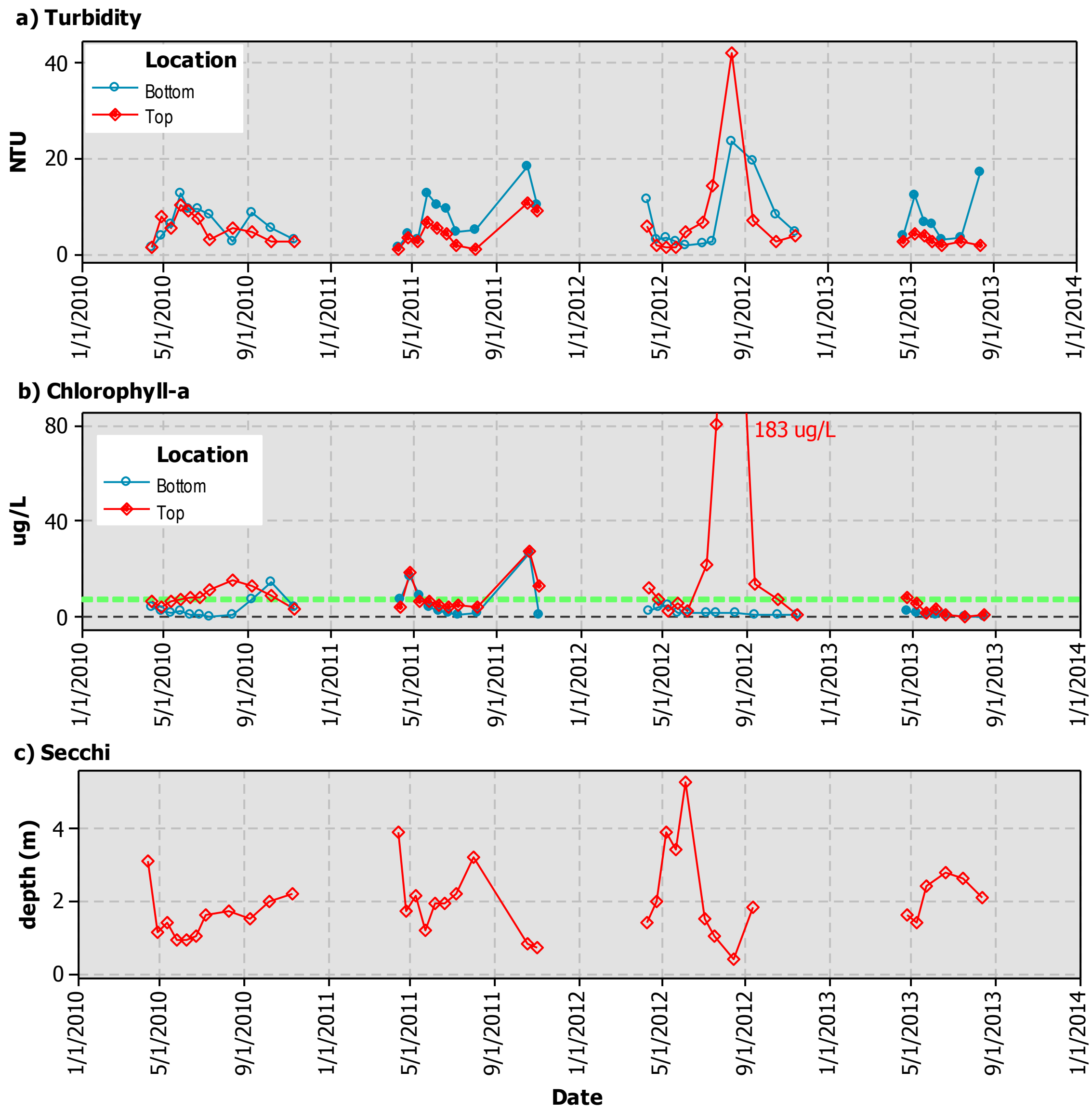


Figure 4.5 – Turbidity (a), chlorophyll-a (b), and Secchi depth (c) measurements in Seaman Reservoir from 2010-2013.

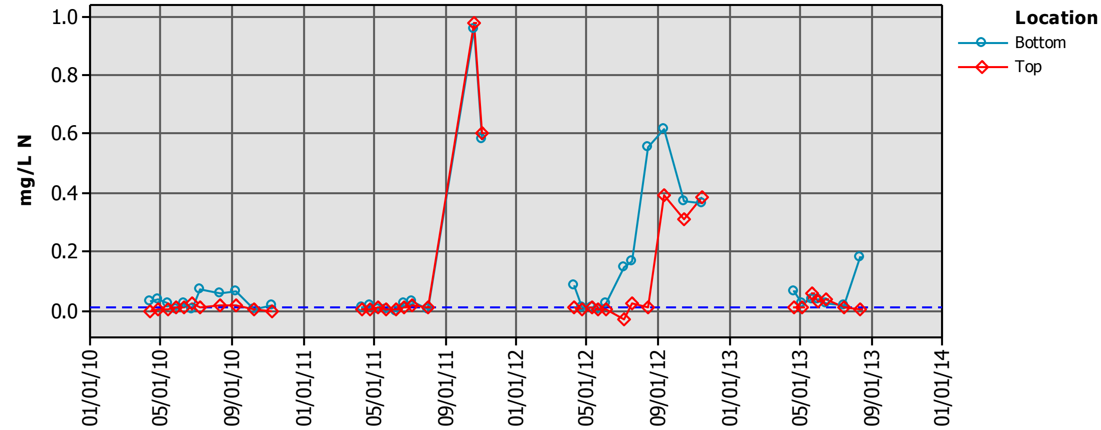
Secchi depth measurements indicated that Seaman Reservoir experienced relatively consistent water clarity in 2013 (Figure 4.5c). Secchi depth was at a minimum (lowest light penetration) of 1.6 meters and 1.4 meters during the first two monitoring events in April and May, respectively, and steadily increased to a maximum of 2.8 meters (greatest light penetration) in July. In all years, the lowest secchi depths corresponded to times of highest chlorophyll-a concentrations suggesting that algal growth was the primary influence on increased turbidity and decreased water clarity. The one anomaly was the last monitoring event of August 2013 when turbidity spiked with no apparent increase in chlorophyll-a concentration. This observation further supports the assumption that flood waters associated with the August 3rd precipitation event entering Seaman Reservoir from the North Fork Poudre contributed to the late season spike in turbidity rather than algal growth. In addition, the increased turbidity was observed near the Reservoir bottom consequently where colder, denser flood water was likely to settle, and where algal growth is limited. In 2013, the secchi depth ranged from 1.4 meters to 2.8 meters.

4.5 Nutrients

The processes of thermal stratification and dynamics of D.O. concentrations in the water column can influence the distribution and seasonality of nutrients within Seaman Reservoir. In aquatic ecosystems, nutrients are typically limited in availability, regulating the growth and survival of aquatic organisms and plants. In excess, nitrogen and phosphorus lead to nutrient pollution and eutrophication resulting in undesirable changes to water quality, and serious environmental and human health issues, including cyanotoxin production by blue green algae. Seasonal trends are not consistent from year to year in Seaman Reservoir, which is likely a result of annual variability of Reservoir operations and the influence on thermal stratification and dissolve oxygen dynamics.

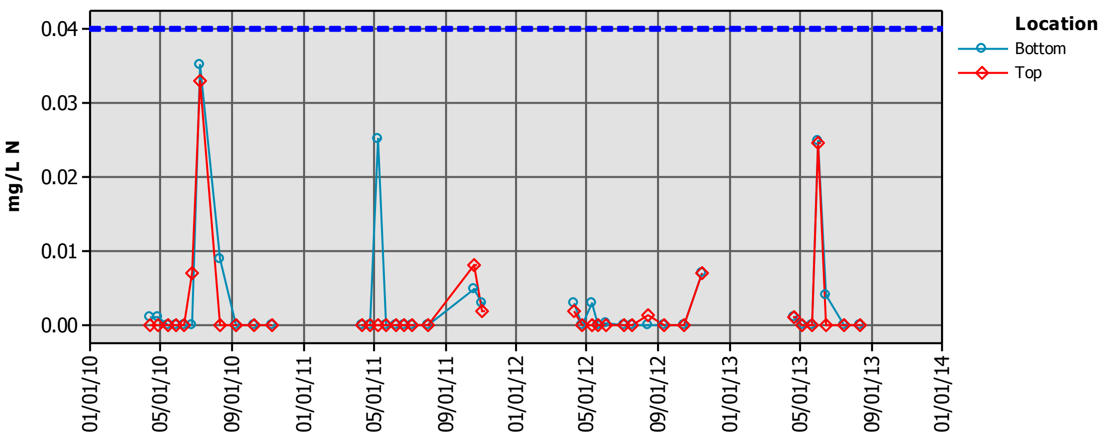
4.5.1 Nitrogen (Figure 4.6a-e). In general, ammonia concentrations tend to be higher near the bottom of Seaman Reservoir compared to concentrations near the surface. This trend was observed at the beginning of the monitoring season in April and May, but by June, top and bottom ammonia concentrations were comparable. Ammonia concentrations near the Reservoir surface exhibited an expected yet small seasonal increase in the spring due to the influence of snowmelt. An early peak of 0.06 mg/L in ammonia concentrations near the surface was observed on May 22nd and concentrations steadily decreased throughout the remainder of the monitoring season to near the detection limit. Ammonia concentrations near the Reservoir bottom in 2013 were similar to previous years. The August 12 sampling event identifies the onset of high ammonia concentrations in the hypolimnion; however, information about the duration and peak concentrations of this ammonia spike are not available because access to Seaman Reservoir was restricted for the remainder of the year following the September flood event. These late season spikes in ammonia occur when anoxic conditions are present at the bottom of the reservoir and typically decrease following fall turnover.

a. Ammonia (NH_3)



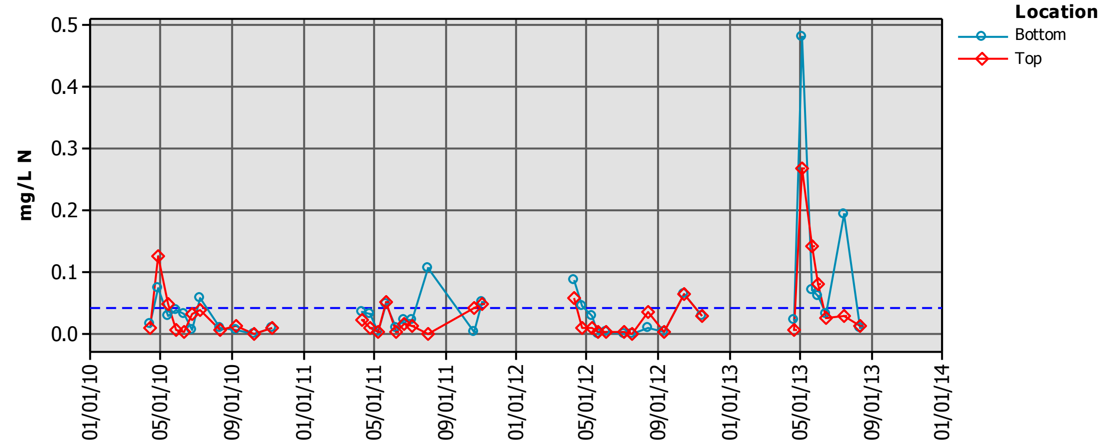
(------ FCWQL Reporting Limit, 0.01mg/L)

b. Nitrite (NO_2)



(------ FCWQL Reporting Limit, 0.04 mg/L)

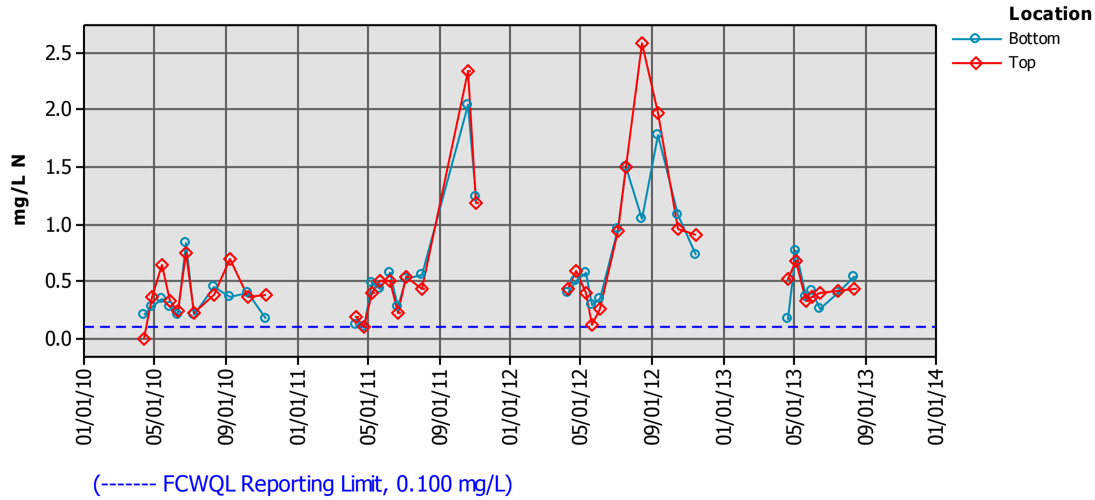
c. Nitrate (NO_3)



(------ FCWQL reporting limit, 0.04 mg/L)

Figure 4.6 – Nutrient concentrations for a) ammonia, b) nitrite, and c) nitrate measured in Seaman Reservoir from 2010-2013.

d. Total Kjeldahl Nitrogen (TKN)



e. Total Nitrogen (NO_2+NO_3+TKN)

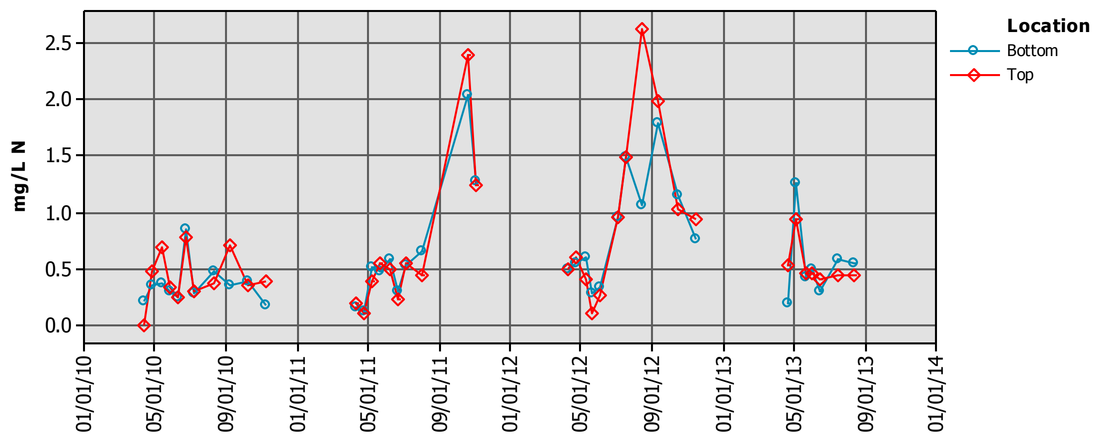
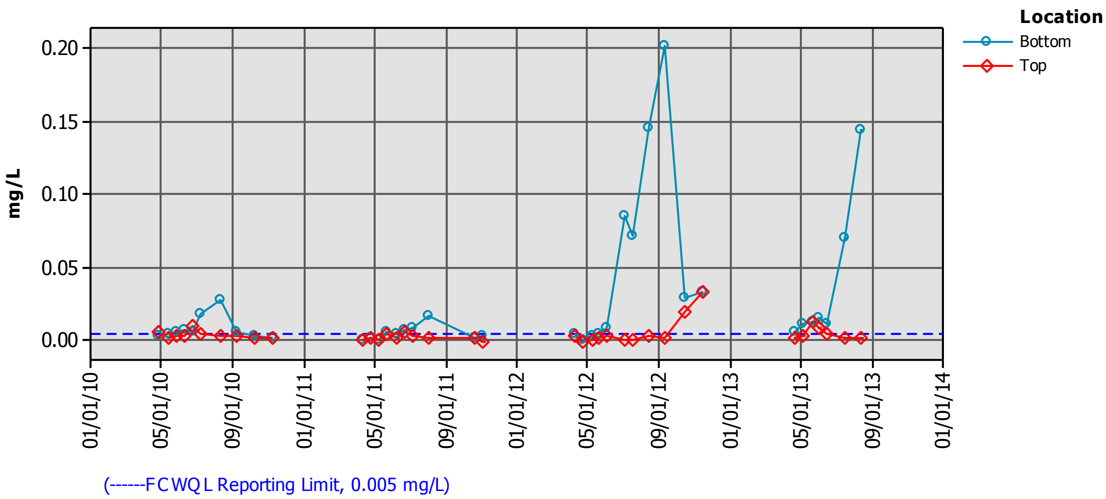


Figure 4.6 (continued) – Nutrient concentrations for d) TKN and e) TN measured in Seaman Reservoir from 2010-2013.

Nitrate concentrations in Seaman Reservoir appeared to be elevated in 2013 compared to previous years. In previous years, concentrations in both top and bottom samples fluctuated around the reporting limit with an occasional spike in concentrations of no more than 0.15 mg/L. In contrast 2013 nitrate concentrations near the surface and bottom spiked above detection limit to seasonal maximums of 0.27 mg/L and 0.48 mg/L on May 7th. Nitrate levels near the water surface decreased gradually, and were below reporting limit by June 17th. The seasonal decrease in nitrate likely occurred in response to consumption by algae at the surface of the Reservoir. Nitrate levels near the Reservoir bottom followed a similar decreasing trend, but spiked to 0.19 mg/L on July 15th. The nitrate spke in July was most likely influenced by anoxic conditions in the hypolimnion, and the release of ammonium from bottom sediments and subsequent nitrification to nitrate. Nitrite concentrations remained below the reporting limit throughout the entire 2013 monitoring season.

4.5.2 Phosphorus (Figure 4.7a-e). Ortho-phosphate and Total P concentrations in 2013 appeared to follow a similar seasonal pattern to that observed in 2012 (Figure 4.7). Concentrations were similar and generally low in the epiliminon and hypolimnion in the spring and early summer. Total P and PO_4 concentrations in the hypolimnion increased throughout the summer and into the fall, while epilimnetic concentrations remained at or below reporting limit. The seasonal increase in hypolimnetic Total P was likely caused by the settling of inorganic particles and organic matter from the epilimnion and metalimnion to the hypolimnion, while the increase in hypolimnetic PO_4 was a result of depleted DO levels promoting the release of PO_4 from bottom sediments. PO_4 concentrations in the epilimnion were generally low because PO_4 was regulated through uptake by algae as it became readily available throughout the monitoring season.

a. Ortho-phosphate (PO_4)



b. Total Phosphorus (Total P)

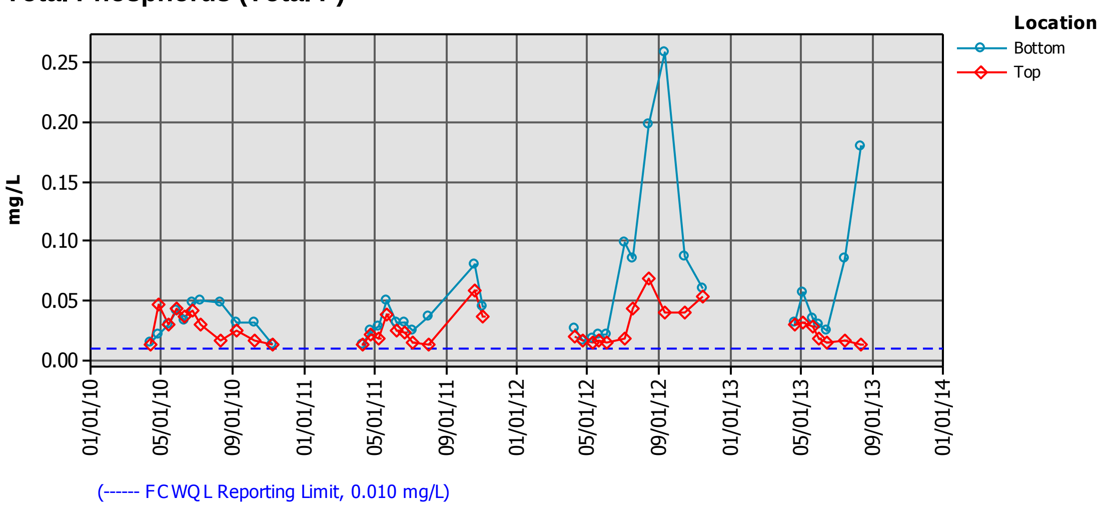


Figure 4.7 – Nutrient concentrations for a) ortho-phosphate and b) total phosphorus in Seaman Reservoir from 2010-2013.

4.5.1 Trophic Status. Water bodies are classified into three trophic states primarily related to concentrations of nutrients, plant production rates and abundance. Eutrophic lakes are high in nutrient concentrations, and high in plant production rates abundance (chlorophyll-a >7.3 µg/L), while oligotrophic lakes are low in nutrient concentrations, and low in plant production rates and abundance (chlorophyll-a <2.6 µg/L). Mesotrophic lakes are in the middle of these two trophic states and typically have concentrations of chlorophyll-a that range between 2.6 µg/L and 7.3 µg/L. The Trophic State Index (TSI) can be calculated based on chlorophyll-a data according to the equation (Carlson, 1977) (Figure 4.8):

$$\text{TSI (CHL)} = 30.6 + 9.81 \ln[\text{Chlor-a in } \mu g/L]$$

Similarly, the TSI can be calculated using Secchi depth readings and Total P concentrations. Depths of two meters to four meters (TSI values between 50 and 40) fall into the mesotrophic range, while Secchi disk readings of 0.5 meters to two meters (TSI values between 70 and 50) fall in the eutrophic range. The TSI is calculated based on Secchi depth (SD) according to the following equation (Carlson, 1977) (Figure 4.8):

$$\text{TSI (SD)} = 60 - 14.41 \ln(\text{SD in meters})$$

Total phosphorus concentrations of 12-24 µg/L (TSI values between 50 and 40) fall into the mesotrophic range, while Total P concentrations of 24-96 µg/L (TSI values between 70 and 50) fall in the eutrophic range. The TSI is calculated based on TP according to the following equation (Carlson, 1977) (Figure 4.7):

$$\text{TSI (Total P)} = 4.15 + 14.42 \ln(\text{TP})$$

The trophic state of Seaman Reservoir in 2013 varied throughout the year. The annual average TSI values for Total P, chlorophyll-a and Secchi depth indicated slightly different in trophic states (Figures 4.8). Chlorophyll-a TSI values were in the mesotrophic range at the start of the season, but steadily decreased to oligotrophic conditions. Total P TSI values suggested eutrophic conditions at the start of the season, and fluctuated between the mesotrophic and eutrophic conditions throughout the remainder of the season suggesting phosphorus is not a limiting factor for algae growth. Secchi depth TSI values also ranged between mesotrophic and eutrophic and were higher than chlorophyll-a TSI values. This result suggests that dissolved inorganic and/or organic matter contributed to reduced transparency and turbidity levels in Seaman Reservoir in 2013 rather than algal growth.

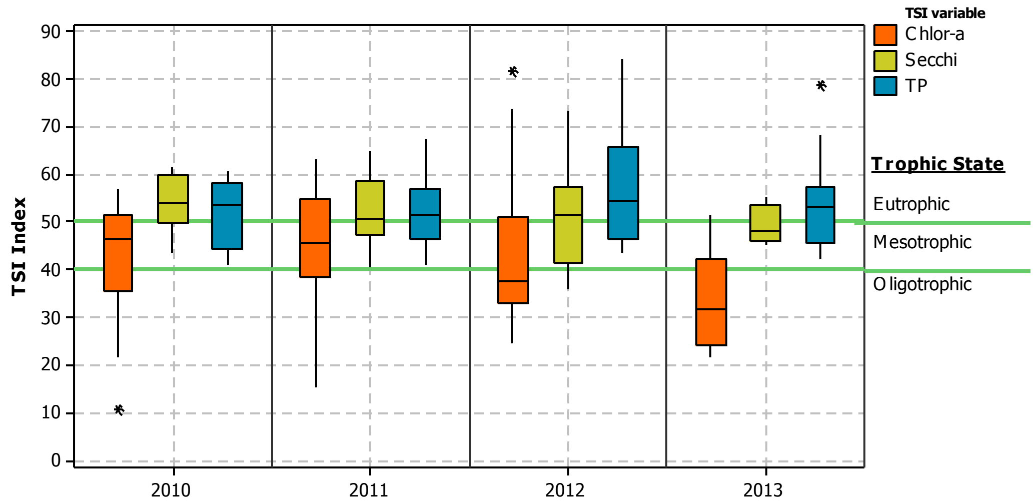


Figure 4.8 – Trophic state index for Seaman Reservoir based on chlorophyll-a, Secchi depth, and total phosphorus values from 2010-2013.

4.6 Total Organic Carbon (TOC)

Seaman Reservoir TOC concentrations in 2013 fell within the range of values observed from 2010-2012 (Figure 4.9). Concentrations were similar between the top and bottom of the Reservoir, and followed similar seasonal trends. TOC concentrations in the top and bottom were approximately 6.0 mg/L at the beginning of the monitoring season, and steadily increased to seasonal peak concentrations of 8.71 mg/L and 8.49 mg/L on May 21st, respectively. TOC concentrations decreased throughout the remainder of the season before slightly spiking on August 12th, which was likely a result of the the August 3rd flood event. It is expected that the 2013 flood event resulted in an even greater spike in TOC concentrations; however, data during or following the flood are not available to support this assumption.

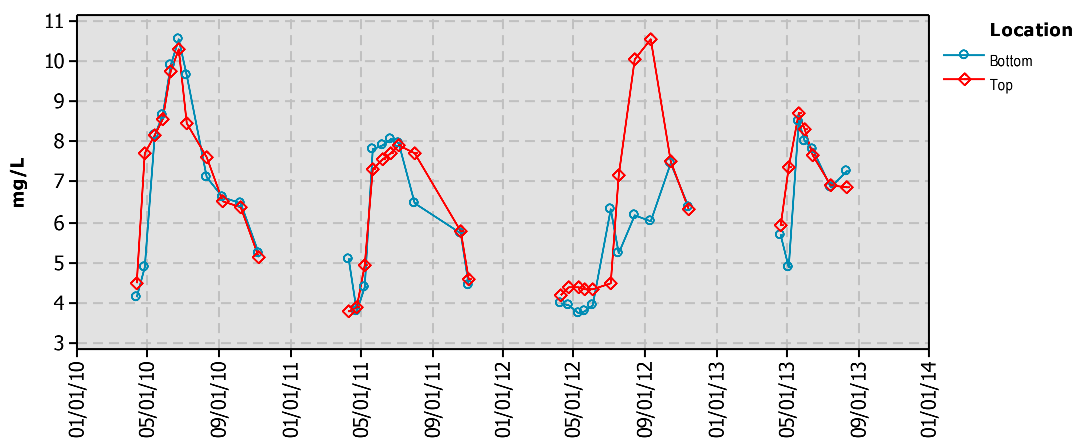


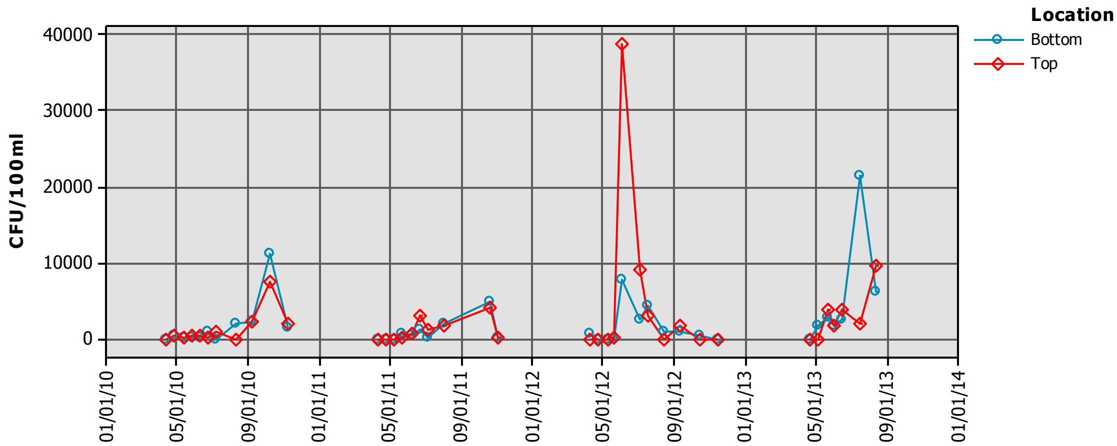
Figure 4.9 – Total organic carbon (TOC) concentrations in Seaman Reservoir from 2010-2013.

4.7 Total Coliforms and *E. coli* (Figure 4.10 a-b)

Total coliform concentrations were variable throughout the 2013 monitoring season, but generally increased in both the top and bottom of the Reservoir. Total coliforms were not detected in top and bottom samples at the beginning of the season, but increased to peaked concentrations of 9,678 and 21,416 cfu/100 ml, respectively. The maximum colony count in the bottom of the Reservoir was observed on July 15th, 2013, which occurred as spring streamflow was decreasing at NFL, and when the Reservoir storage was approaching capacity. The timing of this peak suggests total coliform inputs to Seaman Reservoir were mostly derived from the natural environment, including sediment and water transported during snowmelt, which then settled near the bottom of the Reservoir. Non-detection of *E. coli* colonies on the same date as peak total coliforms provides additional evidence supporting natural inputs rather than anthropogenic, such as sewage and/or agriculture. The peak in total coliforms was the highest observed over the four year monitoring period (2010-2013).

In most years, *E. coli* is detected in the top and bottom of the Reservoir, primarily during spring snowmelt runoff. The primary source of *E. coli* during this time of year is surrounding agricultural land, a non-point source of pollution in the North Fork watershed. E. coli colonies were not detected in Seaman Reservoir water samples at the beginning of the monitoring season in 2013. Concentrations increased in response to seasonal snowmelt in both the top and bottom samples reaching maximum snowmelt driven concentrations of 4.1 and 66.9 cfu/100 ml, respectively, much lower than the CDPHE recreational standard of 126 cfu/100 ml. *E. coli* concentrations returned to non-detectable levels following spring snowmelt, which was identical to the previous years. An unexpected late season spike of 299 cfu/100 ml was observed on the August 12, 2013 sampling event. The late season spike was likely associated with the high intensity precipitation event on August 3rd, which caused moderate flooding in the North Fork watershed. Subsequent samples were not collected from Seaman Reservoir due to the September flooding, but it is expected that both total coliform and *E. coli* concentrations displayed a greater response than previously observed due to the magnitude and timing of the flood event.

a) Total coliforms



b) *E. coli*

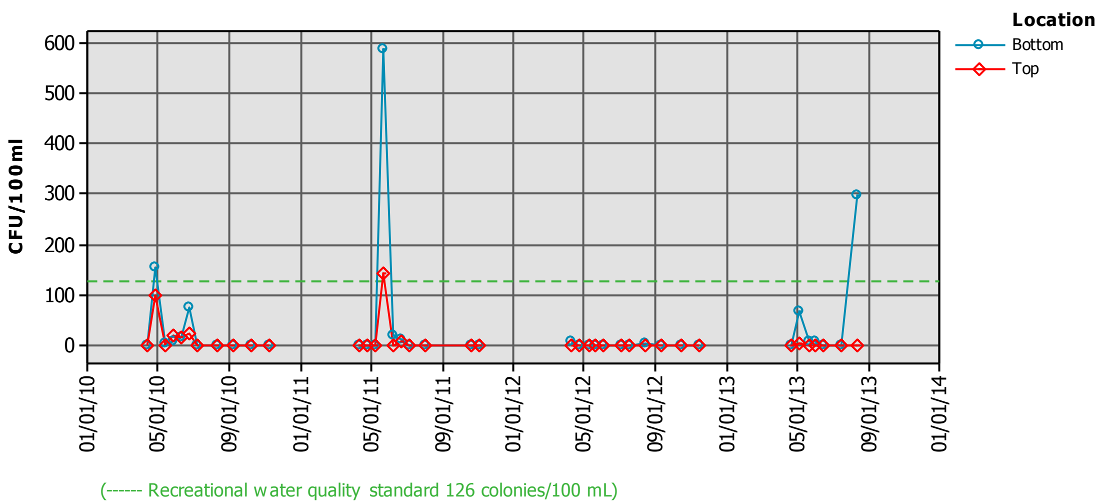


Figure 4.10 – Total coliforms (a) and *Escherichia coli* (*E.coli*) (b) colony counts in Seaman Reservoir.

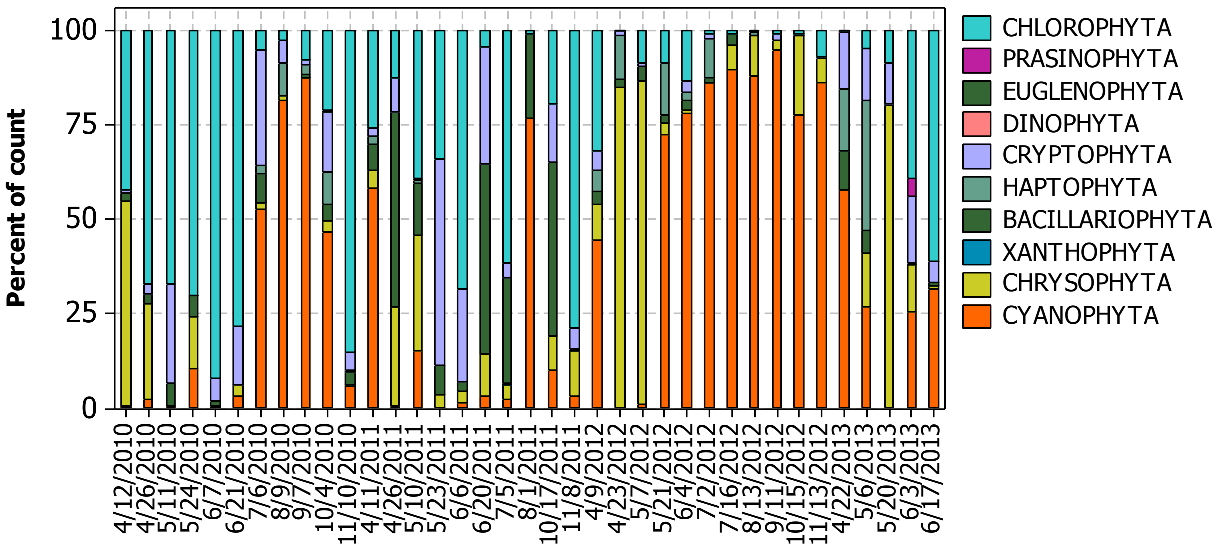
4.8 Phytoplankton (Figure 4.11a-b)

Phytoplankton data were provided by Dick Dufford (private consultant). A summary of the 2013 phytoplankton data is provided in Attachment 6. Make note that 2013 data were only available from April through June.

Blue-green algae (Cyanophytes) are of concern because certain species of Cyanophytes produce compounds known as cynanotoxins that pose public health concerns. Other species produce T&O compounds, including geosmin and MIB, which affect the aesthetic quality of drinking water and are difficult to remove during water treatment.

Blue-green algae were the most abundant algae in both the top and bottom of the Reservoir at the start of the 2013 monitoring season. A similar observation was seen at the beginning of the 2012 monitoring season, but in previous years (2010 and 2011) the Reservoir top was primarily dominated by golden algae (chyrsophyta) and green algae (chlorophyta). The Reservoir bottom was composed of a mix of blue-green, golden, and green, euglenophyta. Cell counts of all groups in top and bottom samples were below 10,000 cells per milliliter (cells/mL) at the beginning of the monitoring season through June, which was similar to seasonal trends in previous years.

a) Phytoplankton in the top of Seaman Reservoir



b) Phytoplankton in the bottom of Seaman Reservoir

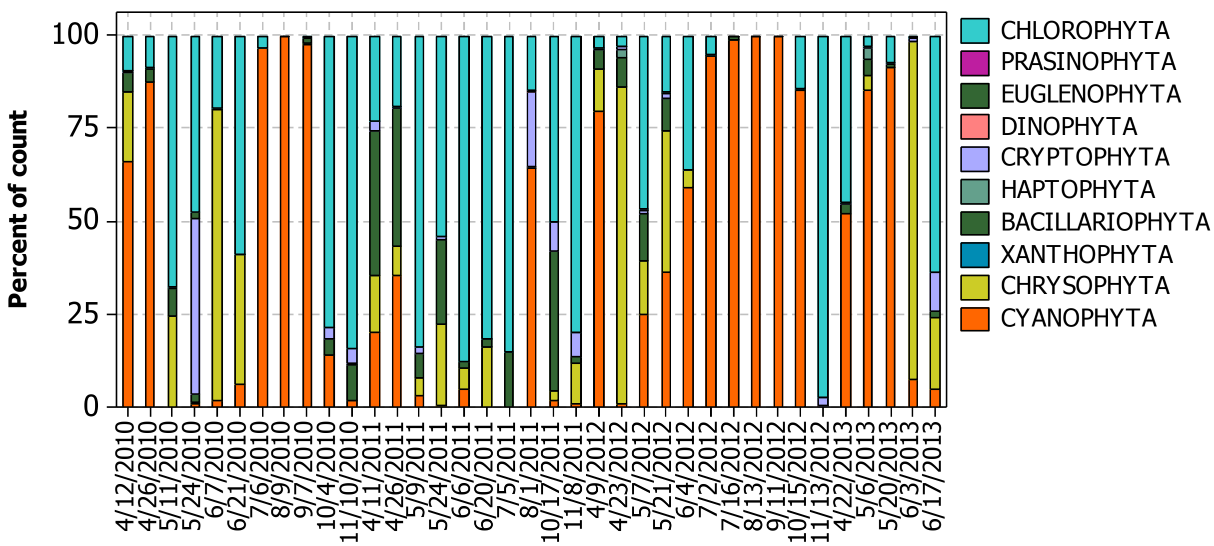


Figure 4.11 – Relative abundance of phytoplankton in the a) top and b) bottom of Seaman Reservoir.

5.0 SUMMARY

5.1 Program Performance

Review of the 2013 Upper CLP Collaborative Water Quality Monitoring Program data indicates that the program adequately captures the seasonal trends in water quality and provides a spatial context for examining notable events. Additional sampling for metals and nutrients in 2013 provided important information about the influence of the 2012 Hewlett and High Park Wildfires.

The 2013 5-year annual report (Oropeza and Health, 2013) highlighted the need for improved streamflow measurements to better calculate annual constituent loads from the major tributaries. In 2013, the feasibility of installing a continuous streamflow gauge on the South Fork above the confluence of the Mainstem was evaluated. Site evaluations were conducted in 2013 and the permitting process through the U.S. Forest Service began in early 2014. Continuous streamflow measurement at this site began in the sprinf of 2014.

An additional area identified for improvement was the collection and reporting of periphyton data. Periphyton sampling was initiated in response to the green algae bloom that occurred on the middle reaches of the Mainstem. There were challenges with maintaining a consistent sampling frequency and obtaining representative samples due to very limited access to the bottom substrates due to water depth and ice cover. This challenge could not be overcome with available resources. In addition, there were difficulties in obtaining the phytoplankton data in time to coordinate with annual reporting cycle. For these reasons, the decision was made to cease periphyton sampling on the Mainstem Poudre in 2013.

5.2 Hydrology

The Mainstem and North Fork both exhibit snowmelt driven hydrographs, with spring snowpack conditions (depth and snow water equivalent) being the primary influences on peak discharge. In 2013 Mainstem snowpack snow water equivalent (SWE) was 100% of the historical basin average and spring peak flows were likewise consistent with average conditions. The September flood of 2013 produced unprecedented late season streamflow. During this event, peak discharge at the canyon mouth was measured at 3,760 cfs and resulted in significant flooding downstream of the canyon mouth. This large precipitation event had notable impacts on water quality and transported a significant amount of sediment to locations downstream of the Poudre Canyon.

5.3 General Water Quality

The Mainstem and the North Fork, as expected, exhibited different water quality characteristics, resulting from differences in geology, land use, and elevation. In general, no significant concerns were identified for the Mainstem or North Fork CLP that would immediately impact drinking water quality or treatment operations.

During spring runoff, the typical challenges for water treatment were observed on the Mainstem and the North Fork, including the delivery of waters with high TOC, high turbidity and low alkalinity. The primary differences in water quality between the two drainages include higher alkalinity and nutrient concentrations, as well as persistently elevated TOC concentrations on the North Fork.

The effect of spring runoff on Mainstem water quality was heightened by the accumulation of large amounts of sediment and ash stored in the river channel. As streamflows on the Mainstem increased at the onset of snowmelt, these fire-impacted materials were re-suspended, bringing relatively high concentrations of nutrients, turbidity and metals into solution. This effect on water quality was particularly notable at the lowermost sites near the Fort Collins and Greeley Intake facilities (PNF and PBD, respectively). However, impacts were short lived, and water quality returned to expected condition as the materials were scoured from the channel during peak flows.

Seaman Reservoir water quality was improved in 2013 over the previous two years. As usual, anoxic conditions (a period of near-zero dissolved oxygen concentration) developed near the bottom of the Reservoir during August, but the duration was unknown because the September flood event damaged bridges used for accessing the Reservoir and sampling for the remainder of the year was not possible. Elevated ammonia and ortho-phosphate concentrations during August suggest that oxygen depletion at the bottom of the reservoir persisted long enough to facilitate the release of nutrients from the bottom sediments. Moderate flooding in the North Fork watershed in early August was likely an additional source of elevated nutrients and bacteria in Seaman Reservoir. Although late season phytoplankton data are not available, total organic carbon and chlorophyll-a concentrations suggest that algae production was lower than in 2012.

Unlike the Poudre River, the impacts of the fires on Seaman Reservoir water quality are influenced by internal reservoir dynamics. As such, they were not as directly measureable, but rather are expected to be delayed in time. Water levels, water temperature, and inputs of watershed materials, are important influences on reservoir water quality and vary year to year. Water quality data do suggest that the impacts of the post-fire sediment deposition may have been most evident in 2012, and do not appear to have persisted into 2013. It should be noted that the impaired water quality observed in 2012 (Oropeza and Heath, 2013) cannot be directly attributed to fire impacts, but was likely due to a combination of influences including reservoir operations, weather, and fire inputs.

5.4 Wildfire Impacts on Water Quality

The 2012 wildfires left an indelible mark on the landscape that will continue to affect the hydrology and water quality of the Upper CLP watershed within and downstream of the burn scars. Storm events, which occur frequently during July and August, deliver large amounts of eroded hillslope sediments and cause major changes in water quality, specifically, turbidity, metals, conductivity and nutrients. In 2013, storm events continued to produce rapid and dramatic changes in water quality, with several events resulting in turbidity levels that exceeded 1,000 NTU. During these times, all water providers ceased treating Poudre water until water quality recovered to acceptable levels. In addition to the impacts of storm events, the fires have resulted in elevated background concentrations of some nutrients, including nitrate and ortho-phosphate.

It is expected that the river will remain in an annual cycle of sediment and debris deposition the summertime, stored sediment in the active stream channel during the low flows of Fall and Winter, followed by riverbank scour during Spring snowmelt runoff.

How long watershed recovery takes depends upon how quickly the hillslope vegetation, soil stability and nutrient cycling processes reestablish. In the meantime, water operations for the Cities of Fort Collins and Greeley and the Tri-Districts will continue to focus on being responsive to changing conditions and are prepared to monitor water quality impacts for many years into the future.

5.5 Flood Impacts on Water Quality

In flood of September 2013 resulted in an increase in several parameters associated with land use activities, including nutrients, turbidity, total coliforms and *E. coli*. It also provided the beneficial effect of scouring sediments that had been deposited in the river during July and August.

5.6 2014 Water Quality Monitoring

Planned water quality monitoring and other related Upper CLP activities for 2014 are summarized below:

- **Routine Monitoring Program**. Samples will continue to be analyzed for all parameters in 2014. The increased frequency and number of locations for post-fire metals sampling has indicated that dissolved concentrations are do not pose threats to the water supply quality. Metals sampling will return to the former frequency and locations; samples will be collected at PNF and NFG in May and October in 2014.

- **Emerging Contaminant Monitoring**. The Northern Water collaborative study on emerging contaminants will continue in 2014, with sampled to be collected as at PNF and NFG in February, June and August.

- **Attached Algae.** Periphyton density and composition sampling was eliminated from the sampling program in 2013 due to challenges with sampling design and timeliness of data acquisition. In the event an algae bloom reoccurs, periodic sampling will be conducted to verify the community composition.

- **Geosmin**. Geosmin monitoring will continue on the Mainstem CLP in 2014 at two key sites – below Rustic (PBR) and above the Fort Collins Intake Facility (PNF). Geosmin sampling will be conducted on a monthly basis in coordination with routine water quality monitoring, so that samples will be paired with all available water quality information.

- **Post-Fire Storm Event Sampling.** Storm event samples will be collected whenever possible. These samples will be analyzed for TOC, dissolved metals, nutrients, turbidity, conductivity and pH and will continue to serve as indicators of post-fire watershed recovery and water supply recovery.

- **Little South Fork Streamflow Monitoring.** An additional monitoring site on the Little South Fork of the Poudre River just upstream of the confluence with the Mainstem was included in the 2014 routine monitoring program to evaluate the influence of the fire related effects in Little South Fork basin on the Mainstem water quality. An In-Situ Level TROLL® 700 Data Logger and TROLL® Link 201 Telemetry System were installed to measure continuous streamflow. The 2014 monitoring plan will focus on developing a stage-discharge relationship. In addition, water quality samples will be collected on a routine basis.

6.0 REFERENCES

Billica, Loftis and Moore, 2008. Design of a Collaborative Water Quality Monitoring Pogram for the Upper Cache la Poudre River. July 14, 2008.

Brooks, Paul D., Mark W. Williams and Steven K. Schmidt, 1996. Microbial activity under alpine snowpacks, Niwot Ridge, Colorado. *Biogeochemistry*, Vol. 32 (2). pp. 93-113.

Campbell, D. H., Clow, D. W., Ingersoll, G. P., Mast, M.A., Spahr, N. E., Turk, J. T. 1995. Processes controlling the chemistry of two snowmelt-dominated streams in the Rocky Mountains. *Water Resources Research* 31(11): 2811-2821.

Carlson, R.E. 1977. A trophic state index for lakes. *Limnology and Oceanography*. 22:361-369.

Collins, Jim A. and L.A. Sprague, 2005. The Cache la Poudre River, Colorado, as a Drinking-Water Source, U.S. Geological Survey Fact Sheet 2005-3037, 4 p.

Front Range Wildfire Watershed Protection Planning (FRWWPP) - Data Refinement Work Group, 2009. Protecting Critical Watersheds in Colorado from Wildfire: A technical approach to watershed assessment and prioritization.

Graham, James M., James A. Kranzfelder and Martin T. Auer, 1985. **Light and Temperature as Factors Regulating Seasonal Growth and Distribution of Ulothrix Zonata (Ulvophyceae).** *Journal of Phycology* 21(2), p. 228–234.

Juttner, F. and S. Watson, 2007. MiniReview: Biochemical and Ecological Control of Geosmin and 2-Methylisoborneol in Source Waters, *Applied and Environmental Microbiology*, Vol. 73, No. 14, July 2007, p. 4395-4406.

J.W. Associates, 2010. Cache la Poudre Wildfire/Watershed Assessment: A prioritization of watershed-based risks to water supplies. Final Report, November 2010.

Le Master, Dennis C., Guofan Shao, and Jacob Donnay, 2007. Protecting Front Range Forest Watersheds from High-Severity Wildfires. An assessment by the Pinchot Institute for Conservation, funded by the Front Range Fuels Treatment Partnership.

MacDonald, Lee H. and John D. Stednick, 2003. Forests and Water: A State-of-the-Art Review for Colorado. C*olorado Water Resources Research Institute Completion Report No. 196*. Colorado State University, Fort Collins, CO.

Oropeza, J. and J. Billica, 2009. City of Fort Collins Utilities 2008 Annual Report for the Upper Cache la Poudre River Collaborative Water Quality Monitoring Program, *Internal Water Production Report*, February 23, 2009, 36 pages plus appendices.

Oropeza, J., Billica, J. and K.Elmund. 2011. Navigating Uncharted Waters: Assessing Geosmin Occurrence in a Colorado Rocky Mountain Source Water River. *In:*

Proceedings of the 2011© American Water Works Association AWWA WQTC Conference (Nov. 13-17, 2011, Phoenix, AZ).

Rhoades, C., D. Entwistle, and D. Butler. 2011. The influence of wildfire extent and severity on streamwater chemistry, sediment and temperature following the Hayman Fire, Colorado. *Journal of Wildland Fire Vol. 20, p. 430-442.*

Robinson CT, Minshall GW (1996) Physical and chemical responses of streams in Yellowstone National Park following the 1988 wildfires. In '*The ecological implications of fire in greater Yellowstone*'. (Ed. JM Greenlee) pp. 217–221. International Association of Wildland Fire:Fairfield, WA

Sundareshwar, P.V., S. Upadhayay, M. Abessa, S. Honomichl, B. Berdanier, S.A. Spaulding, C.Sandvik, and A. Trennopohl, 2011. *Didymosphenia geminata*: Algal blooms in oligotrophic streams and rivers. *Geophysical Research Letters*, Vol 38, L10405, p.1-5.

Taylor W.D., R.F. Losee, M. Torobin, G. Izaguirre, D. Sass, D. Khiari, and K. Atasi, 2006. Early Warning and Management of Surface Water Taste-and-Odor Events, AWWA Research Foundation, Denver, CO.

Uunila, L., B. Guy, and R. Pike. 2006. Hydrologic effects of mountain pine beetle in the interior pine forests of British Columbia: Key questions and current knowledge. Extended Abstract. *BC Journal of Ecosystems and Management.* 7(2):37–39.
URL: *http://www.forrex.org/publications/jem/ISS35/vol7_no2_art4.pdf*

Wetzel, R.G., 2001. *Limnology: Lake and River Ecosystems*, Third Edition. Academic Press, San Diego, California.

Williams, M.W., Seibold, C. and K. Chowanski, 2009. Storage and release of solutes from a subalpine seasonal snowpack: soil and stream water response, Niwot Ridge, Colorado. *Biogeochemistry* 95:77-94.

ATTACHMENT 1

Land use comparison of the North Fork and Mainstem CLP (areas calculated using USGS Seamless GIS data sets)

Land Use Comparison	North Fork (acres)	Main Stem (acres)	North Fork Area (%)	Main Stem Area (%)
Developed land (commercial, industrial, residential, urban, and utilities)	2,817	1,945	0.8	0.7
Agricultural use and grassland (Cropland, pasture, other agriculture, scrub and grasses)	183,719	54,765	52.3	18.3
Forest (forest and brush)	154,654	213,879	44.1	71.5
Natural lands (exposed rock, bare ground, wetlands, tundra, lakes)	9,926	28,473	2.8	9.5
Total	**351,116**	**299,062**	**100**	**100**

ATTACHMENT 2

Upper CLP collaborative water quality monitoring program sampling sites

	MAIN STEM	Description	Rationale	GPS Coordinates
1	100CHR	Chambers Lake Outflow	Outflow from Chambers Lake	N 40° 36.039 W 105° 50.203
2	090BMR	Barnes Meadow Reservoir outflow	High TOC and nutrients compared to CHR	N 40° 36.039 W 105° 50.203
3	080JWC	Joe Wright Creek at Aspen Glen Campground	Joe Wright Creek above confluence with main stem	N 40° 37.233 W 105° 49.098
4	070PJW	Poudre at Hwy14 crossing (Big South Trailhead)	Above confluence Joe Wright Creek	N 40° 38.074 W 105° 48.421
5	060LRT	Laramie River at Tunnel at Hwy 14 crossing	Laramie River diversion water	N 40° 40.056 W 105° 48.067
6	050PBR	Poudre below Rustic	Midpoint between Laramie River Tunnel and South Fork; impacts to river from Rustic	N 40° 41.967 W 105° 32.476
7	040SFM	South Fork at bridge on Pingree Park Rd	Only access point on South Fork; South Fork water quality differs from main stem	N 40° 37.095 W 105° 31.535
8	030PSF	Poudre below confluence with South Fork - Mile Marker 101	Below confluence with South Fork	N 40° 41.224 W 105° 26.895
9	020PNF	Poudre above North Fork 1/2 mile upstream from Old FC WTP#1	Represents water diverted at Munroe Tunnel and at Old FC WTP #1	N 40° 42.087 W 105° 14.484
10	010PBD	Poudre at Bellvue Diversion	Greeley WTP Intake	N 40° 39.882 W 105° 12.995
	NORTH FORK			
11	280NDC	North Fork above Halligan Reservoir; above confluence with Dale Creek	Inflow to Halligan Reservoir	N 40° 53.852' W 105° 22.556'
12	270NBH	North Fork at USGS gage below Halligan Reservoir	Outflow from Halligan Reservoir	N 40° 52.654' W 105° 20.314'
13	260NRC	North Fork above Rabbit Creek	Main stem North Fork above Rabbit Creek; downstream of Phantom Canyon	N 40° 49.640 W 105° 16.776
14	250RCM	Rabbit Creek Mouth	Tributary to North Fork; drainage area includes agricultural/grazing lands; significant flows late spring to early summer only	N 40° 48.615 W 105° 17.146
15	240SCM	Stonewall Creek Mouth	Tributary to North Fork; drains area east of Hwy 287; significant flows late spring to early summer only	N 40° 48.458 W 105° 15.195
16	230PCM	Lone Pine Creek Mouth	Tributary to North Fork; drainage area includes Red Feather Lakes; significant flows late spring to early summer only	N 40° 47.696 W 105° 17.231
17	220NFL	North Fork at Livermore	At USGS gage	N 40° 47.269 W 105° 15.130
18	210SER	Seaman Reservoir	Reservoir profiles; impacts to water quality from nutrient loadings	N 40° 42.274 W 105° 14.210
19	200NFG	North Fork below Seaman Reservoir	At gage below Seaman Res; sample before flow enters Poudre main stem	N 40° 42.143 W 105° 14.064

ATTACHMENT 3

Upper CLP collaborative water quality monitoring program parameter list

	Rationale	Notes
Field Parameters		
Conductance	Indicator of total dissolved solids.	Profile at Seaman Reservoir
Dissolved Oxygen	Profile indicates stratification, importance for aquatic life and chemical processes.	Profile at Seaman Reservoir
Secchi Disk	Measure of transparency.	Seaman Reservoir only
Temperature	Reflects seasonality; affects biological and chemical processes; water quality standard.	Profile at Seaman Reservoir
pH	Measure of acidity.	
General & Miscellaneous Parameters		
Alkalinity	Indicator of carbonate species concentrations; Acid neutralizing capacity of water; treatment implications.	
Chlorophyll-a	Reflects algal biomass.	Seaman Reservoir only
Discharge	Necessary for flow dependant analysis and load estimation.	Measured during sampling at NRC, RCM, SCM, PCM, PJW, SFM
Hardness	Treatment implications. Hard water causes scaling and soft water is considered corrosive.	
Total Dissolved Solids (TDS)	Indicator of overall water quality; includes both ionic and non-ionic species.	
Total Organic Carbon (TOC)	Important parameter for water treatment; precursor of disinfection byproducts.	
Turbidity	Indicator of suspended material; important for water treatment.	
Nutrients		
Nitrogen, Ammonia	Primary source of nitrogen to algae, indicator of pollution by sewage, septic tanks, agriculture; water quality standard.	
Nitrate	Primary source of nitrogen to algae; indicator of pollution by sewage, septic tanks, agriculture; water quality standard.	
Nitrite	Toxic inorganic nitrogen species; rarely encountered at significant concentrations; water quality standard.	
Total Kjeldahl Nitrogen	Sum of organic nitrogen and ammonia.	
Ortho-Phosphorus (Soluble Reactive Phosphorus)	Form of phosphorous (dissolved PO_4^{-3}) most available to algae; indicator of pollution by sewage, septic tanks, agriculture.	

Total Phosphorus	Includes dissolved and adsorbed, organic and inorganic forms of phosphorus, indicator of pollution by sewage, septic tanks, agriculture.	
Major Ions		
Calcium	Major ion.	Monitor for two years at half frequency (6x/yr)
Chloride	Major ion.	Monitor for two years at half frequency (6x/yr)
Magnesium	Major ion.	Monitor for two years at half frequency (6x/yr)
Potassium	Major ion, minor importance as a nutrient.	Monitor for two years at half frequency (6x/yr)
Sodium	Major ion.	Monitor for two years at half frequency (6x/yr)
Sulfate	Major ion.	Monitor for two years at half frequency (6x/yr)
Microbiological Constituents		
E. Coli	Indicator of human or animal waste contamination; water quality standard.	Only from Rustic downstream, NFL, NFG, SER
Total Coliform	Indicator of human or animal waste contamination.	Only from Rustic downstream, NFL, NFG, SER
Cryptosporidium	Pathogen, indicator of human or animal waste contamination.	Above and below Halligan Reservoir, and below Seaman Reservoir
Giardia	Pathogen, Indicator of human or animal waste contamination.	Above and below Halligan Reservoir, and below Seaman Res
Algal Species Composition	Shows presence of nuisance species and trophic state.	Seaman Reservoir surface sample only
Metals		
Cadmium, dissolved	Indicator of pollution from mining activity at elevated levels; water quality standard.	Only PNF & NFG (2x/yr)
Chromium, dissolved	Water quality standard.	Only PNF & NFG (2x/yr)
Copper, dissolved	Water quality standard.	Only PNF & NFG (2x/yr)
Iron, Total	Affects aesthetic quality of treated water.	Only PNF & NFG (2x/yr)
Iron, dissolved	Affects aesthetic quality of treated water.	Only PNF & NFG (2x/yr)
Lead, dissolved	Indicator of pollution from mining activity at elevated levels; water quality standard.	Only PNF & NFG (2x/yr)
Nickel, dissolved	Indicator of pollution from mining activity at elevated levels; water quality standard.	Only PNF & NFG (2x/yr)
Silver, dissolved	Indicator of pollution from mining activity at elevated levels.	Only PNF & NFG (2x/yr)
Zinc, dissolved	Indicator of pollution from mining activity at elevated levels.	Only PNF & NFG (2x/yr)
Mercury, Low Level	Accumulates in fish tissue even when present in very low concentrations.	Sample every 3 to 5 yrs.

ATTACHMENT 4

Upper CLP Collaborative Water Quality Monitoring Program 2013 Sampling Plan

	Sampling Date										
	4/8 – 4/9*	**4/22 - 4/23**	**5/6 - 5/7**	**5/20 - 5/21**	**6/3 - 6/4**	**6/17 - 6/18**	**7/15 - 7/16**	**8/12 - 8/13**	**9/16 - 9/17**	**10/14 - 10/15**	**11/12 - 11/13**
Station											
North Fork											
NDC[3]	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G,I
NBH[3]	F,G	F,G,I,**B**	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G,I
NRC	F,G,D	F,G,I,D	F,G,D,	F,G,I,D	F,G,D	F,G,I,D	F,G,D	F,G,I,D	F,G,D	F,G,I,D	F,G,I,D
RCM	G,D	F,G,I,D	F,G,D	F,G,I,D,**B**	F,G,D	F,G,I,D					
SCM	G,D	F,G,I,D	F,G,D	F,G,I,D	F,G,D,	F,G,I,D					
PCM	G,D	F,G,I,D	F,G,D	F,G,I,D	F,G,D	F,G,I,D,**B**					
NFL	F,G	F,G,I	F,G	F,G,I,M	F,G	F,G,I	F,G,M,	F,G,I	F,G	F,G,I,M	F,G,I,
NFG	F,G,E	F,G,I,E	F,G,E	F,G,I,M,E	F,G,E	F,G,I,E	F,G,E	F,G,I,E,**B**	F,G,E	F,G,I,M,E	F,G,I,E
Main Stem											
CHR	F,G,**B**	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G,I
BMR[2]	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G,I
JWC	F,G	F,G,I	F,G,**B**	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G,I
PJW	F,G,D	F,G,I,D	F,G,D	F,G,I,D	F,G,D	F,G,I,D	F,G,D	F,G,I,D	F,G,D	F,G,I,D,**B**	F,G,I,D
LRT	F,G	F,G,I	F,G	F,G,I	F,G,**B**	F,G,I	F,G	F,G,I	F,G	F,G,I	F,G,I
PBR	F,G,E	F,G,I,E	F,G,E	F,G,I,E,M	F,G,E	F,G,I,E,	F,G,E,M	F,G,I,E	F,G,E	F,G,I,E,M	F,G,I,E
SFM		F,G,I,D		F,G,I,D		F,G,I,D		F,G,I,D		F,G,I,D	F,G,I,D
PSF	F,G,E	F,G,I,E	F,G,E	F,G,I,E,M	F,G,E	F,G,I,E	F,G,E,M,**B**	F,G,I,E	F,G,E,	F,G,I,E,M	F,G,I,E
PNF	F,G,E,**2**	F,G,I,E,**2**	F,G,E,**2**	F,G,I,E,M,**2**	F,G,E,**2**	F,G,I,E,**2**	F,G,E,M,**2**	F,G,I,E,**2**	F,G,E,**2**	F,G,I,E,M,**2**	F,G,I,E,**2**
PBD	F,G,E	F,G,I,E	F,G,E	F,G,I,E,M	F,G,E	F,G,I,E	F,G,E,M	F,G,I,E	F,G,E	F,G,I,E,M	F,G,I,E,**B**
Reservoir											
SER[1]	F,G,A,C,E	F,G,I,A,C,E,	F,G,A,C,E	F,G,I,A,C,E,M,	F,G,A,C,E	F,G,I,A,C,E	F,G,A,C,E,M	F,G,I,A,C,E	F,G,A,C,E,**B**	F,G,I,A,C,E,M	F,G,I,A,C,E

[1] Grab samples taken at two depths (Top & Bottom); meter readings taken at 1-m intervals.
[2] Call commissioner to find out if water is flowing. If not flowing, skip sample.
[3] Sampled by City of Fort Collins personnel; all other stations to be sampled by Dr. Bill Lewis' Team.

2 = Duplicate; A = Algae (Lugol's); **B= Blank**; C = Chlorophyll (500 mL sample); D = Flow; F = Field data (Temp, pH, conductance streams + Secchi, DO for lake); G = 1 liter sample for general, nutrients, TOC; E = *E. coli*, coliform (500 mL sterile bottle); I = Major ions; M = Metals). M = new sampling to evaluate fire impacts

2013 Changes: 10% Field Quality Control ~1 blank +1 duplicate per sampling event
* Sampled on 4/10 at NFG, NFL, PBD, PBR, PJW, PNF, PSF, Field Blank, Duplicate only, due to adverse weather conditions

ATTACHMENT 5

Analytical methods, reporting limits, sample preservation, and sample holding times

	Parameter	Method	Reporting Limit	Preser-vation	Holding Time
Micro-biological	Total Coliform, *E.coli* - QT	SM 9223 B	0	cool, 4C	6 hrs
	Giardia & Cryptosporidium (CH Diagnostics)	EPA 1623	0	cool, 4C	4 days
	Algae I.D. (Phyto Finders)	SM 10200E.3, SM 10200F.2c1		Lugol's Solution, cool, 4C	12 mo
General & Misc.	Alkalinity, as $CaCO_3$	SM 2320 B	2 mg/L	cool, 4C	14 days
	Chlorophyll a	SM10200H modified	0.6 ug/L	cool, 4C	48 hrs
	Hardness, as $CaCO_3$	SM 2340 C	2 mg/L	none	28 days
	Specific Conductance	SM 2510 B		cool, 4C	28 days
	Total Dissolved Solids	SM 2540 C	10 mg/L	cool, 4C	7 days
	Turbidity (NTU)	SM2130B,EPA180.1	0.01 units	cool, 4C	48 hrs
Nutrients	Ammonia - N	Lachat 10-107-06-2C	0.01 mg/L	H_2SO_4	28 days
	Nitrate	EPA 300 (IC)	0.04 mg/L	cool, 4C (eda)	48 hrs
	Nitrite	EPA 300 (IC)	0.04 mg/L	cool, 4C (eda)	48 hrs
	Total Kjeldahl Nitrogen	EPA 351.2	0.1 mg/L	H_2SO_4 pH<2	28 days
	Phosphorus, Total	SM 4500-P B5,F	0.01 mg/L	H_2SO_4 pH<2	28 days
	Phosphorus, Ortho	SM 4500-P B1,F	0.005 mg/L	filter, cool 4C	48 hrs
Major Ions	Calcium	EPA 200.8	0.05 mg/L	HNO_3 pH <2	6 mos
	Chloride	EPA 300 (IC)	1.0 mg/L	none (eda)	28 days
	Magnesium, flame	EPA 200.8	0.2 mg/L	HNO_3 pH <2	6 mos
	Potassium	EPA 200.8	0.2 mg/L	HNO_3 pH <2	6 mos
	Sodium, flame	EPA 200.8	0.4 mg/L	HNO_3 pH <2	6 mos
	Sulfate	EPA 300 (IC)	5.0 mg/L	cool, 4C (eda)	28 days
Metals	Cadmium	EPA 200.8	0.1 ug/L	HNO_3 pH <2	6 mos
	Chromium	EPA 200.8	0.5 ug/L	HNO_3 pH <2	6 mos
	Copper	EPA 200.8	3 ug/L	HNO_3 pH <2	6 mos
	Iron, (total & dissolved)	EPA 200.8	10 ug/L	HNO_3 pH <2	6 mos
	Lead	EPA 200.8	1 ug/L	HNO_3 pH <2	6 mos
	Nickel	EPA 200.8	2 ug/L	HNO_3 pH <2	6 mos
	Silver	EPA 200.8	0.5 ug/L	HNO_3 pH <2	6 mos
	Zinc	EPA 200.8	50 ug/L	HNO_3 pH <2	6 mos
TOC	TOC	SM 5310 C	0.5 mg/L	H_3PO_4 pH <2	28 days
Analysis conducted by City of Fort Collins Water Quality Lab (FCWQL), unless otherwise noted.					
Reporting Limit = lowest reportable number based on the lowest calibration standard routinely used.					

ATTACHMENT 6

2013 Seaman Reservoir Phytoplankton Data

Phytoplankton Densities (cells/ml)	SAMPLING DATE				
Seaman Reservoir - Top Potential geosmin producing cyanophyta (highlighted)	04/22/13	05/06/13	05/20/13	06/03/13	06/17/13
CYANOPHYTA (blue-green algae)					
Anabaena inaequalis					
Anabaena sp.					
Aphanizomenon flos-aquae				2486.4	
Aphanocapsa conferta					
Aphanocapsa delicatissima		2500.0			
Aphanocapsa holsatica	1020.0	1750.0			500.0
Aphanocapsa sp.	230.0				
Aphanothece clathrata					
Aphanothece smithii	3250.0				1250.0
Coelosphaerium aerugineum					
Cuspidothrix issatschenkoi					
Cyanobium sp.					
Dactylococcopsis acicularis					
Dactylococcopsis sp.					
Dolichospermum (Anabaena) flos-aquae		42.4			
Dolichospermum (Anabaena crassa) crassum					
Dolichospermum (Anabaena) lemmermannii	1.6	18.4		716.8	26.4
Dolichospermum (Anabaena planctonica) planctonicum					
Geitlerinema sp.					
Gloeotrichia echinulata					
Jaaginema sp.					
Limnothrix sp.					
Lyngbya birgei					
Merismopedia sp.					
Merismopedia tenuissima					
Microcystis flos-aquae					
Microcystis wesenbergii					
Myxobaktron hirudiforme					
Oscillatoria tenuis					
Planktolyngbya limnetica					
Planktothrix agardhii					
Pseudanabaena limnetica					
Pseudanabaena mucicola					
Pseudanabaena sp.					
Rhabdogloea smithii					
Romeria leopoliensis					
Snowella litoralis					
Synechococcus capitatus					
Synechococcus nidulans		10.0			
Synechocystis sp.					
Woronichinia naegeliana					72.0
TOTAL CYANOPHYTA	**4,502**	**4,321**	**0**	**3,203**	**1,848**

Phytoplankton Densities (cells/ml)	SAMPLING DATE				
Seaman Reservoir - Top	04/22/13	05/06/13	05/20/13	06/03/13	06/17/13
CHRYSOPHYTA (golden-brown algae)					
Chromulina parvula		1250.0	1000.0	1500.0	
Chrysococcus sp.					
Dinobryon bavaricum					
Dinobryon cylindricum var. *alpinum*	1.6				
Dinobryon cylindricum					
Dinobryon cylindricum var. *palustre*					
Dinobryon divergens					
Dinobryon sociale var. *americanum*					
statospore of *Dinobryon*					
Mallomonas akrokomos				60.0	50.0
Mallomonas caudata					
Mallomonas sp.					
cyst of *Mallomonas* sp.					
Ochromonas minuscula		1000.0			
Synura petersenii					
Uroglenopsis americana					
TOTAL CHRYSOPHYTA	**1.6**	**2250**	**1000**	**1560**	**50**
XANTHOPHYTA					
Gloeobotrys limneticus					
BACILLARIOPHYTA (diatoms)					
Amphora sp.					
Asterionella formosa	760.8	956.4	0.8	69.2	
Aulacoseira ambigua					
Aulacoseira granulata var. *angustissima*					
Aulacoseira italica	4.0	2.4			
Aulacoseira italica var. *tenuissima*	4.0	2.4			
Aulacoseira subarctica					
Cyclostephanos sp.					
Cymatopleura solea	0.2				
Diatoma anceps					
Diatoma moniliformis					
Diatoma tenuis					
Discostella glomerata					
Discostella pseudostelligera	40.0				
Discostella stelligera					
Fragilaria crotonensis		1.6		8.0	42.4
Fragilaria sp.					
Gomphonema sphaerophorum					
Gyrosigma acuminatum					
Melosira varians	0.8		1.6	0.8	
Navicula capitatoradiata					
Navicula lanceolata					

Phytoplankton Densities (cells/ml)	SAMPLING DATE				
Seaman Reservoir - Top	04/22/13	05/06/13	05/20/13	06/03/13	06/17/13
BACILLARIOPHYTA (diatoms) continued					
Navicula rhynchocephala					
Navicula tripunctata					
Nitzschia archibaldii					
Nitzschia draveillensis					
Nitzschia fonticola					
Nitzschia gracilis					
Nitzschia linearis					
Nitzschia nana					
Nitzschia sigma					
Nitzschia sp.					
Nitzschia supralitorea					
Punticulata bodanica					1.2
Stephanocyclus meneghiniana					
Stephanodiscus medius					
Stephanodiscus niagarae	0.4		0.4	1.6	
Stephanodiscus parvus					
Synedra acus					
Synedra cyclopum					
Synedra delicatissima var. *angustissima*		1.2			
Synedra radians					
Synedra rumpens var. *familiaris*	9.6	7.2			
Synedra rumpens					
Synedra tenera	0.4	1.2			
Synedra ulna var. *danica*					
Synedra ulna var. *subaequalis*					
Synedra ulna	0.4				
Tabellaria fenestrata					
Urosolenia eriensis					
TOTAL BACILLARIOPHYTA	**820.6**	**972.4**	**2.8**	**79.6**	**43.6**
HAPTOPHYTA					
Chrysochromulina parva	1280.0	5500.0			

Phytoplankton Densities (cells/ml)	SAMPLING DATE				
Seaman Reservoir - Top	04/22/13	05/06/13	05/20/13	06/03/13	06/17/13
CRYPTOPHYTA					
Chroomonas coerulea			2.8		3.2
Chroomonas nordstedtii					
Cryptomonas borealis	132.8	17.6	26.8	21.2	6.8
Cryptomonas curvata	17.2	160.8	3.2	4.0	2.8
Cryptomonas erosa					
Cryptomonas marsonii	2.0		2.0		0.4
Goniomonas truncata					
Hemiselmis sp.				1250.0	
Komma caudata		400.0			210.0
Plagioselmis nannoplanctica	1020.0	1680.0	100.0	920.0	120.0
cyst of *Cryptomonas*					
TOTAL CRYPTOPHYTA	**1172**	**2258.4**	**134.8**	**2195.2**	**343.2**
DINOPHYTA					
Ceratium hirundinella				0.2	2.4
Gymnodinium aeruginosum					
Gymnodinium fuscum					
Peridinium lomnickii					
Peridinium willei	0.2				
Tovellia (Woloszynskia) coronata	30.0				
TOTAL DINOPHYTA	**30.2**	**0**	**0**	**0.2**	**2.4**
EUGLENOPHYTA					
Euglena sp.	0.2				
Euglena viridis					
Lepocinclis acus					
Lepocinclis oxyuris					
Trachelomonas dybowskii					
Trachelomonas hispida					
Trachelomonas volvocina					
TOTAL EUGLENOPHYTA	**0.2**	**0**	**0**	**0**	**0**
PRASINOPHYTA					
Monomastrix sp.				600.0	
Pyramimonas sp.					
Scourfieldia sp.					
Tetraselmis cordiformis					
TOTAL PRASINOPHYTA	**0**	**0**	**0**	**600**	**0**

Phytoplankton Densities (cells/ml)	SAMPLING DATE				
Seaman Reservoir - Top	04/22/13	05/06/13	05/20/13	06/03/13	06/17/13
CHLOROPHYTA					
Acutodesmus acuminatus					
Acutodesmus dimorphus					
Ankistrodesmus falcatus					
Ankyra judayi				1480.0	50.0
Botryococcus braunii					
Chlamydomonas dinobryonis					
Chlamydomonas globosa				40.0	
Chlamydomonas snowiae					
Chlamydomonas sp. 1					
Chlamydomonas sp. 2					
Chlamydomonas tetragama					
Chlorella minutissima		750.0		250.0	3375.0
Chlorella sp.					
Chloromonas sp.					
Choricystis minor				3125.0	
Closterium aciculare					
Closterium acutum var. *variabile*					
Closterium dianae					
Closterium moniliferum					
Coelastrum indicum					
Coelastrum pseudomicroporum				19.2	
Coelastrum pulchrum					
Coenochloris fottii	2.4		108.0	14.4	158.0
Cosmarium bioculatum					
Cosmarium candianum					
Cosmarium depressum var. *achondrum*					
Desmodesmus armatus					
Desmodesmus bicaudatus					
Desmodesmus communis		0.8			
Desmodesmus intermedius var. *balatonicus*					
Dictyosphaerium pulchellum var. *minutum*					
Elakatothrix viridis					
Eudorina elegans					
Gonatozygon kinahanii					
Heimansia pusilla					
Keratococcus sp.					
Micractinium pusillum					
Monoraphidium contortum					
Monoraphidium minutum					
Monoraphidium sp.					
Mougeotia sp.					
Nephrocytium limneticum					
Oocystis apiculata					1.6
Oocystis borgei					

Phytoplankton Densities (cells/ml)	SAMPLING DATE				
Seaman Reservoir - Top	04/22/13	05/06/13	05/20/13	06/03/13	06/17/13
CHLOROPHYTA (continued)					
Oocystis parva					
Oocystis pusilla					
Pandorina charkowiensis					
Pandorina smithii					
Pediastrum boryanum		2.4			
Pediastrum duplex					
Pediastrum tetras					
Pseudodictyosphaerium elegans					
Pseudodictyosphaerium sp.					4.8
Pseudodidymocystis planctonica					
Quadrigula sp.					
Raphidocelis contorta					
Raphidocelis sp.					
Scenedesmus arcuatus					
Scenedesmus ellipticus					
Schroederia setigera					
Staurastrum planctonicum					0.2
Tetraedron minimum					
Tetraspora lemmermannii					
Volvox sp.					
TOTAL PRASINOPHYTA	**2.4**	**753.2**	**108**	**4928.6**	**3589.6**
TOTAL ALGAL DENSITY (cells/mL)	**7,809**	**16,055**	**1,246**	**12,567**	**5,877**

Phytoplankton Densities (cells/ml)	SAMPLING DATE				
Seaman Reservoir - Bottom Potential geosmin producing cyanophyta	04/22/13	05/06/13	05/20/13	06/03/13	06/17/13
CYANOPHYTA (blue-green algae)					
Anabaena inaequalis	11.2				
Anabaena sp.					
Aphanizomenon flos-aquae					
Aphanocapsa conferta					
Aphanocapsa delicatissima					
Aphanocapsa holsatica	6500.0		1500.0		
Aphanocapsa sp.					
Aphanothece clathrata					
Aphanothece smithii		7500.0		200.0	
Coelosphaerium aerugineum					
Cuspidothrix issatschenkoi					
Cyanobium sp.					
Dactylococcopsis acicularis					
Dactylococcopsis sp.					
Dolichospermum (Anabaena) flos-aquae					
Dolichospermum (Anabaena crassa) crassum					
Dolichospermum (Anabaena) lemmermannii					1.2
Dolichospermum (Anabaena planctonica) planctonicum					
Geitlerinema sp.					
Gloeotrichia echinulata					
Jaaginema sp.					
Limnothrix sp.					
Lyngbya birgei					
Merismopedia sp.					
Merismopedia tenuissima					
Microcystis flos-aquae					
Microcystis wesenbergii					
Myxobaktron hirudiforme					
Oscillatoria tenuis					
Planktolyngbya limnetica					
Planktothrix agardhii					
Pseudanabaena limnetica					5.4
Pseudanabaena mucicola					
Pseudanabaena sp.					
Rhabdogloea smithii					3.2
Romeria leopoliensis					
Snowella litoralis					
Synechococcus capitatus					
Synechococcus nidulans	130.0		125.0		
Synechocystis sp.					
Woronichinia naegeliana					40.0
TOTAL CYANOPHYTA	**6,641**	**7,500**	**1,625**	**200**	**50**

Phytoplankton Densities (cells/ml)	SAMPLING DATE				
Seaman Reservoir - Bottom	04/22/13	05/06/13	05/20/13	06/03/13	06/17/13
CHRYSOPHYTA (golden-brown algae)					
Chromulina parvula		375.0		2500.0	206.0
Chrysococcus sp.					
Dinobryon bavaricum					
Dinobryon cylindricum var. *alpinum*					
Dinobryon cylindricum					
Dinobryon cylindricum var. *palustre*					
Dinobryon divergens			0.2		
Dinobryon sociale var. *americanum*					
statospore of *Dinobryon*					
Mallomonas akrokomos					0.4
Mallomonas caudata					
Mallomonas sp.					
cyst of *Mallomonas* sp.					
Ochromonas minuscula					
Synura petersenii					
Uroglenopsis americana					
TOTAL CHRYSOPHYTA	**0**	**375**	**0.2**	**2500**	**206.4**
XANTHOPHYTA					
Gloeobotrys limneticus					
BACILLARIOPHYTA (diatoms)					
Amphora sp.			0.2		
Asterionella formosa	168.0	340.4	8.0		5.6
Aulacoseira ambigua					
Aulacoseira granulata var. *angustissima*					
Aulacoseira italica	13.2	2.4			
Aulacoseira italica var. *tenuissima*					
Aulacoseira subarctica					
Cyclostephanos sp.					
Cymatopleura solea	0.2	0.2			
Diatoma anceps					
Diatoma moniliformis					
Diatoma tenuis		0.4			
Discostella glomerata					
Discostella pseudostelligera					
Discostella stelligera					
Fragilaria crotonensis		1.2	3.6		16.0
Fragilaria sp.					
Gomphonema sphaerophorum					
Gyrosigma acuminatum					
Melosira varians		0.6			0.6
Navicula capitatoradiata					
Navicula lanceolata					

Phytoplankton Densities (cells/ml)	SAMPLING DATE				
Seaman Reservoir - Bottom	04/22/13	05/06/13	05/20/13	06/03/13	06/17/13
BACILLARIOPHYTA (diatoms) continued					
Navicula rhynchocephala					
Navicula tripunctata					
Nitzschia archibaldii					
Nitzschia draveillensis		0.8	0.2		
Nitzschia fonticola					
Nitzschia gracilis					
Nitzschia linearis					
Nitzschia nana		0.4			
Nitzschia sigma					
Nitzschia sp.					
Nitzschia supralitorea					
Punticulata bodanica					1.0
Stephanocyclus meneghiniana					
Stephanodiscus medius	0.8				
Stephanodiscus niagarae	2.4	0.2	0.4		0.1
Stephanodiscus parvus	200.0				
Synedra acus					
Synedra cyclopum					
Synedra delicatissima var. *angustissima*		4.4			
Synedra radians					
Synedra rumpens var. *familiaris*	2.4	1.6			
Synedra rumpens					
Synedra tenera		1.2			
Synedra ulna var. *danica*		0.4			
Synedra ulna var. *subaequalis*		6.0	0.4		
Synedra ulna	3.2	1.6			
Tabellaria fenestrata					
Urosolenia eriensis					
TOTAL BACILLARIOPHYTA	**390.2**	**361.8**	**12.8**	**0**	**23.3**
HAPTOPHYTA					
Chrysochromulina parva		280.0			

Phytoplankton Densities (cells/ml)	SAMPLING DATE				
Seaman Reservoir - Bottom	04/22/13	05/06/13	05/20/13	06/03/13	06/17/13
CRYPTOPHYTA					
Chroomonas coerulea			0.2		
Chroomonas nordstedtii					
Cryptomonas borealis					1.2
Cryptomonas curvata		0.4			
Cryptomonas erosa					
Cryptomonas marsonii					
Goniomonas truncata					
Hemiselmis sp.					
Komma caudata					63.0
Plagioselmis nannoplanctica	10.0	30.0	10.0	20.0	45.0
cyst of *Cryptomonas*					
TOTAL CRYPTOPHYTA	**10**	**30.4**	**10.2**	**20**	**109.2**
DINOPHYTA					
Ceratium hirundinella					0.5
Gymnodinium aeruginosum					
Gymnodinium fuscum					
Peridinium lomnickii					
Peridinium willei					
Tovellia (Woloszynskia) coronata		0.2			
TOTAL DINOPHYTA	**0**	**0.2**	**0**	**0**	**0.5**
EUGLENOPHYTA					
Euglena sp.					
Euglena viridis					
Lepocinclis acus					
Lepocinclis oxyuris					
Trachelomonas dybowskii					
Trachelomonas hispida					
Trachelomonas volvocina					
TOTAL EUGLENOPHYTA	**0**	**0**	**0**	**0**	**0**
PRASINOPHYTA					
Monomastrix sp.					
Pyramimonas sp.					
Scourfieldia sp.					
Tetraselmis cordiformis					
TOTAL PRASINOPHYTA	**0**	**0**	**0**	**0**	**0**

Phytoplankton Densities (cells/ml)	SAMPLING DATE				
Seaman Reservoir - Bottom	04/22/13	05/06/13	05/20/13	06/03/13	06/17/13
CHLOROPHYTA					
Acutodesmus acuminatus			0.8		
Acutodesmus dimorphus					
Ankistrodesmus falcatus	0.4				
Ankyra judayi				20.0	4.5
Botryococcus braunii					
Chlamydomonas dinobryonis					
Chlamydomonas globosa					
Chlamydomonas snowiae					
Chlamydomonas sp. 1					
Chlamydomonas sp. 2					
Chlamydomonas tetragama					
Chlorella minutissima	5750.0	250.0	125.0		566.5
Chlorella sp.					
Chloromonas sp.					
Choricystis minor					
Closterium aciculare					
Closterium acutum var. *variabile*					
Closterium dianae					
Closterium moniliferum			0.2		
Coelastrum indicum					
Coelastrum pseudomicroporum					
Coelastrum pulchrum					
Coenochloris fottii					112.4
Cosmarium bioculatum					
Cosmarium candianum					
Cosmarium depressum var. *achondrum*					
Desmodesmus armatus					
Desmodesmus bicaudatus					
Desmodesmus communis					
Desmodesmus intermedius var. *balatonicus*					
Dictyosphaerium pulchellum var. *minutum*					
Elakatothrix viridis					
Eudorina elegans					
Gonatozygon kinahanii					
Heimansia pusilla					
Keratococcus sp.					
Micractinium pusillum					
Monoraphidium contortum					
Monoraphidium minutum					
Monoraphidium sp.					
Mougeotia sp.					
Nephrocytium limneticum					
Oocystis apiculata					
Oocystis borgei					

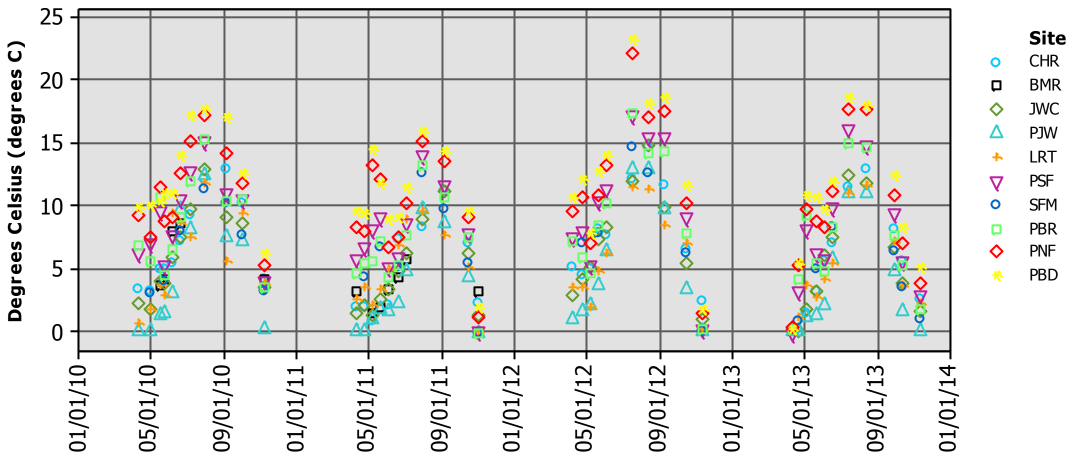
Phytoplankton Densities (cells/ml)	SAMPLING DATE				
Seaman Reservoir - Bottom	04/22/13	05/06/13	05/20/13	06/03/13	06/17/13
CHLOROPHYTA (continued)					
Oocystis parva					
Oocystis pusilla					
Pandorina charkowiensis					
Pandorina smithii					
Pediastrum boryanum					
Pediastrum duplex					
Pediastrum tetras					
Pseudodictyosphaerium elegans					
Pseudodictyosphaerium sp.					
Pseudodidymocystis planctonica					
Quadrigula sp.					
Raphidocelis contorta					
Raphidocelis sp.					
Scenedesmus arcuatus					
Scenedesmus ellipticus					
Schroederia setigera					
Staurastrum planctonicum					0.4
Tetraedron minimum					
Tetraspora lemmermannii					
Volvox sp.					
TOTAL PRASINOPHYTA	**5750.4**	**250**	**126**	**20**	**683.8**
TOTAL ALGAL DENSITY (cells/mL)	**12,792**	**8,797**	**1,774**	**2,740**	**1,073**

ATTACHMENT 7

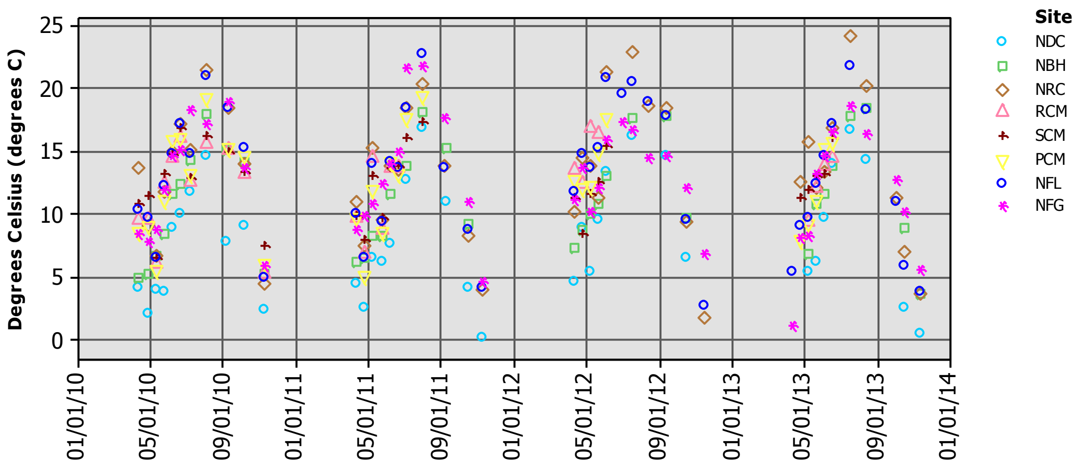
2013 Upper CLP Collaborative Water Quality Monitoring Program Graphical Summary

Mainstem and North Fork CLP: General Parameters

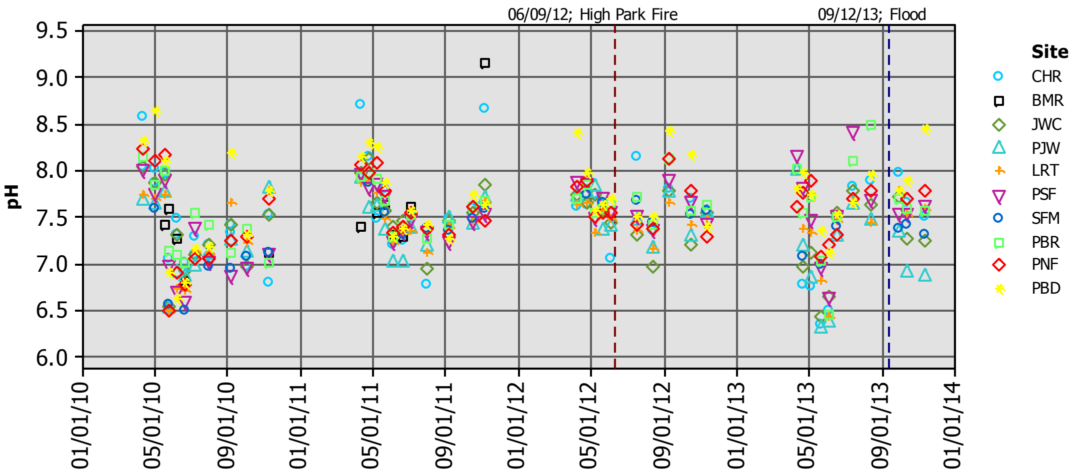
a) Temperature on the Mainstem CLP



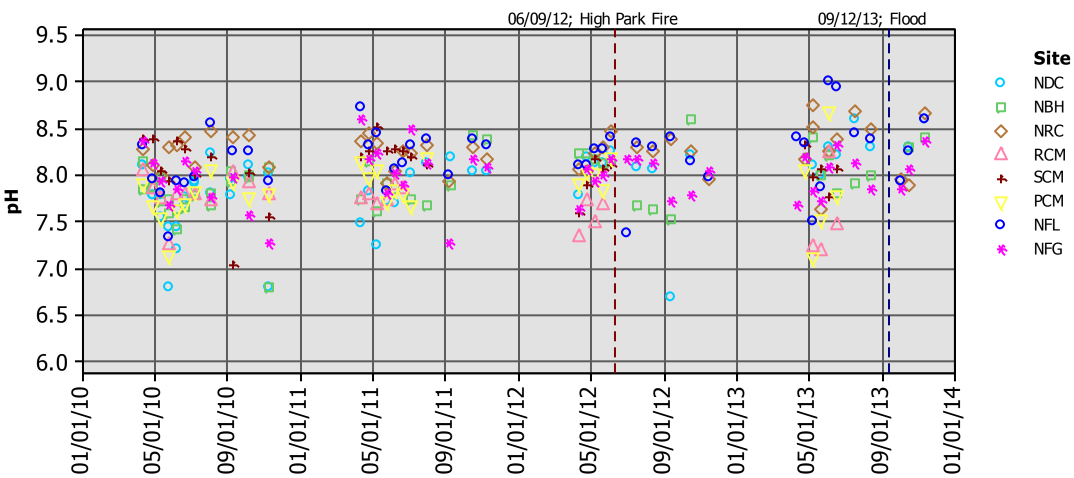
b) Temperature on the North Fork CLP



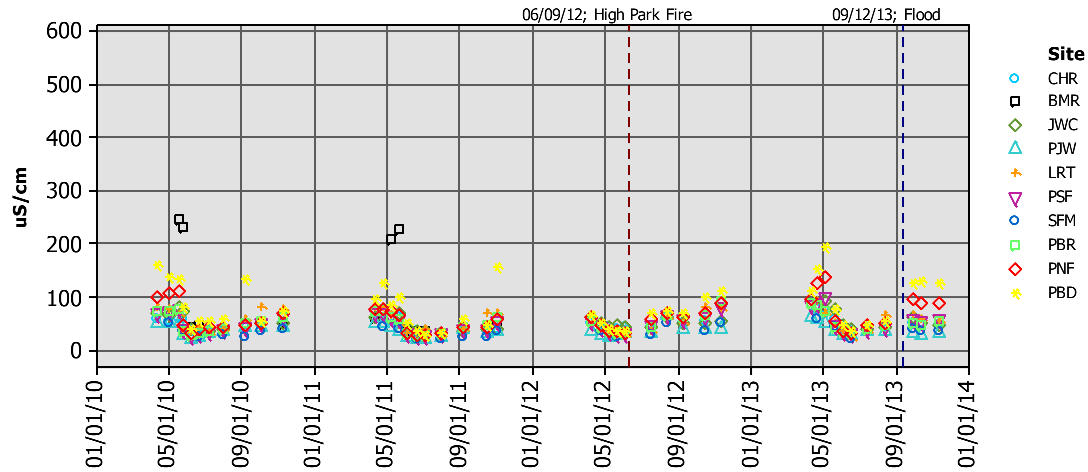
a) pH on the Mainstem CLP



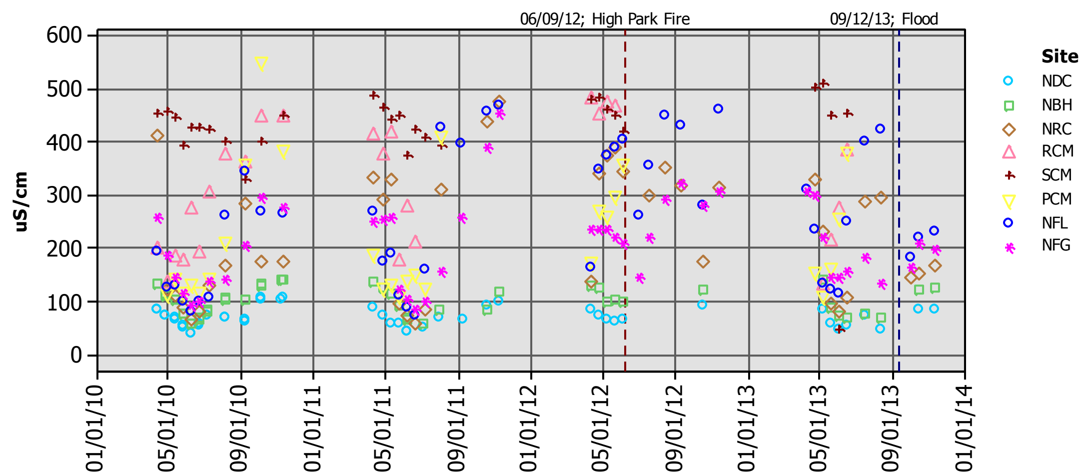
b) pH on the North Fork CLP



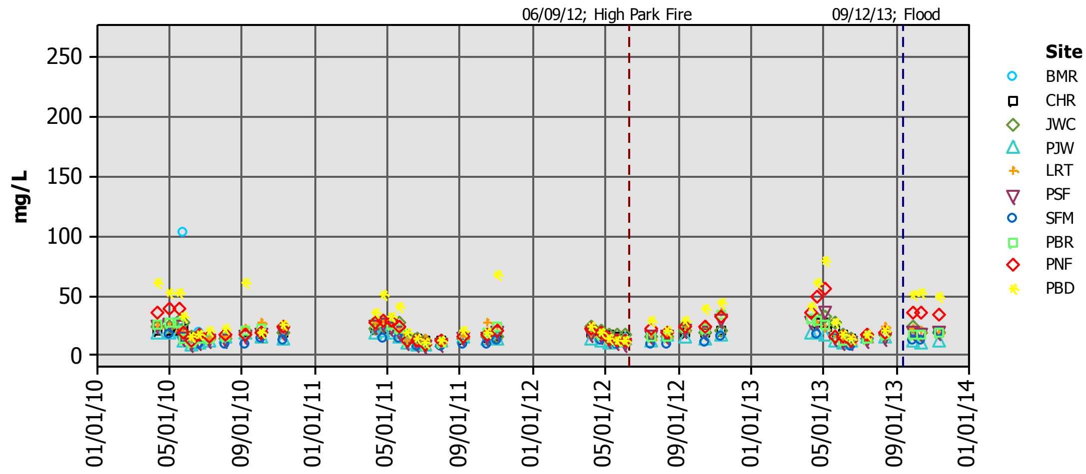
a) Specific Conductance on the Mainstem CLP



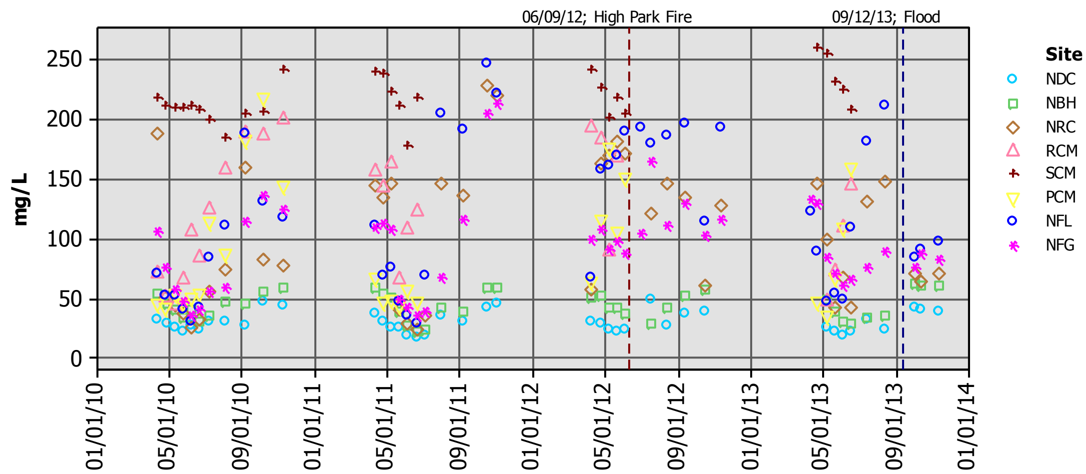
b) Specific Conductance on the North Fork CLP



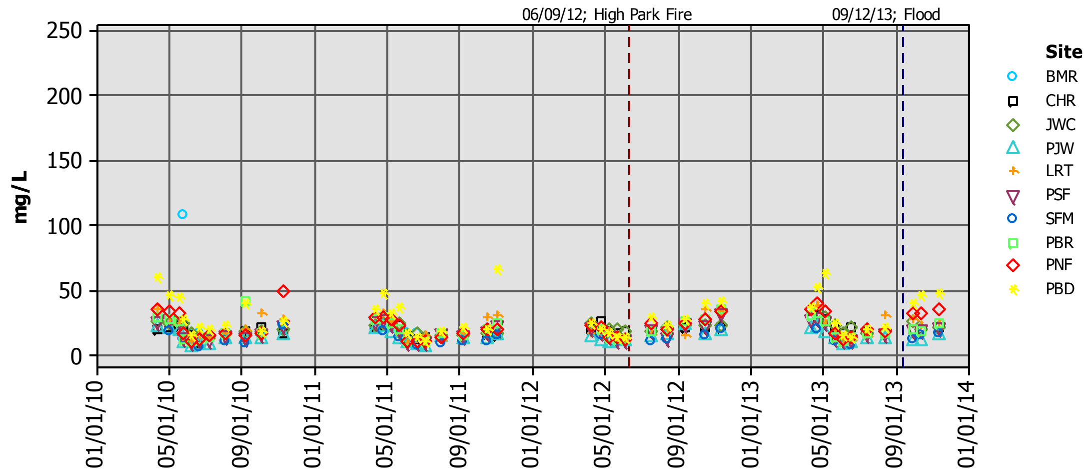
a) Hardness on the Mainstem CLP



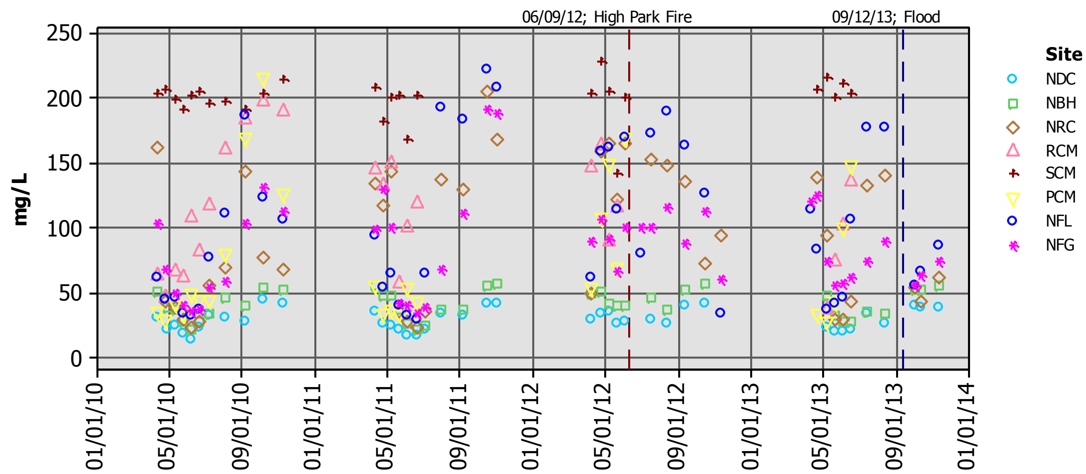
b) Hardness on the North Fork CLP



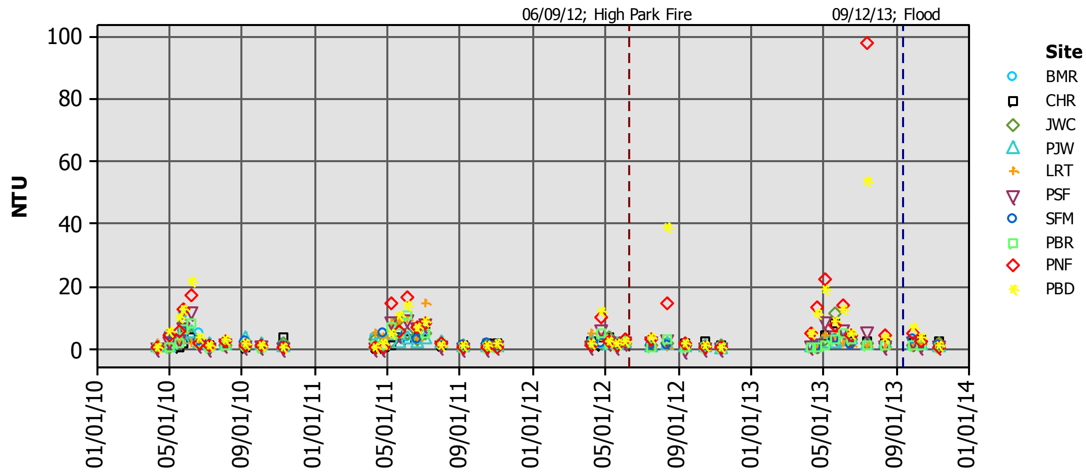
a) Alkalinity on the Mainstem CLP



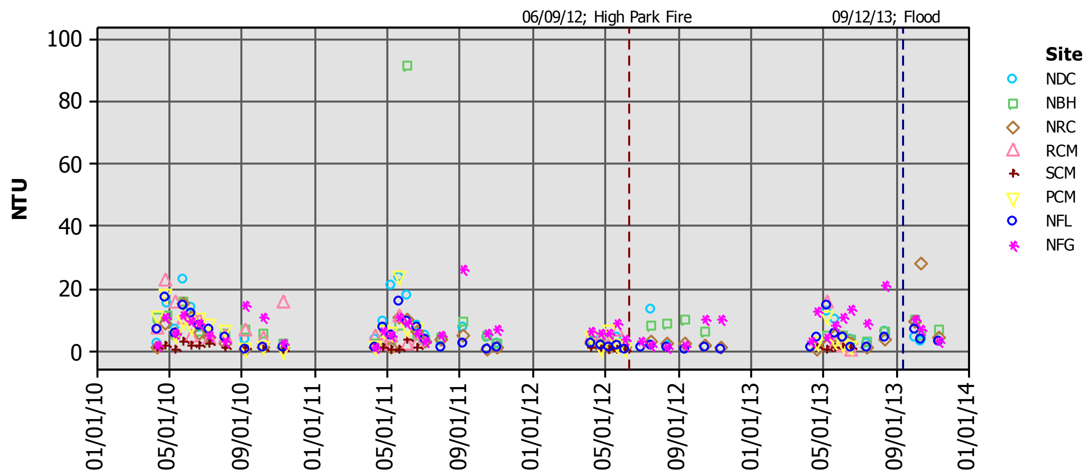
b) Alkalinity on the North Fork CLP



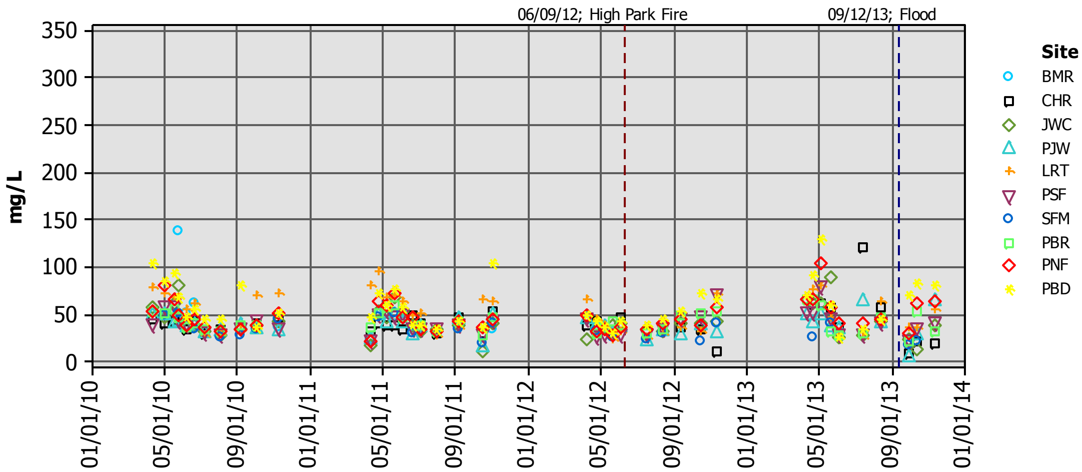
a) Turbidity on the Mainstem CLP



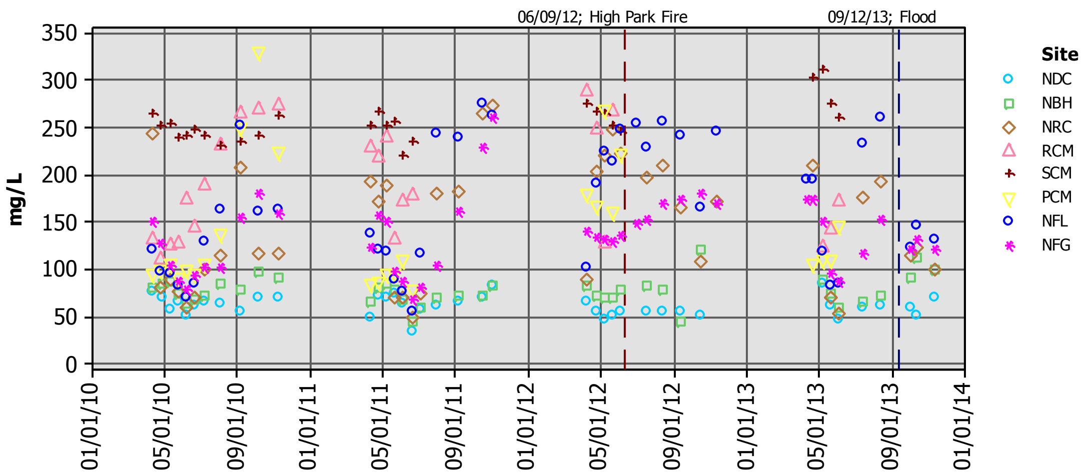
b) Turbidity on the North Fork CLP



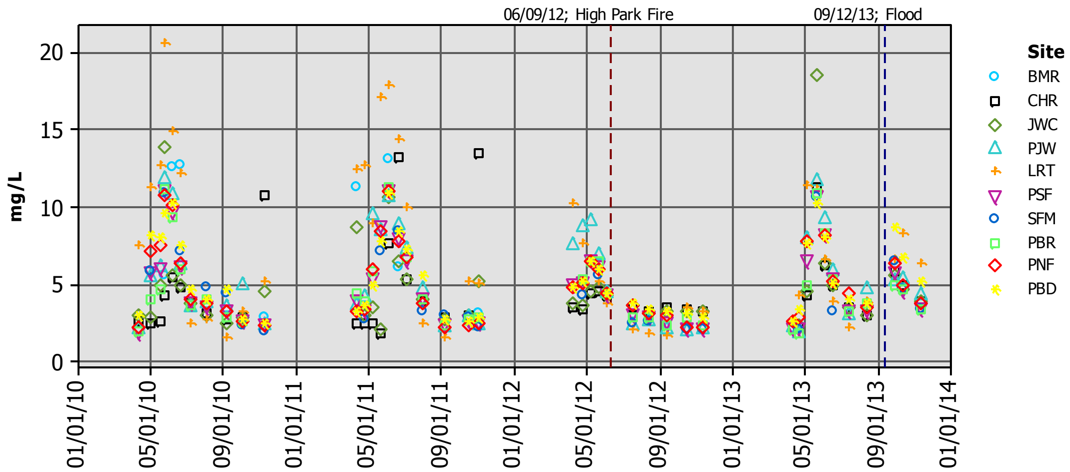
a) Total Dissolved Solids (TDS) on the Mainstem CLP



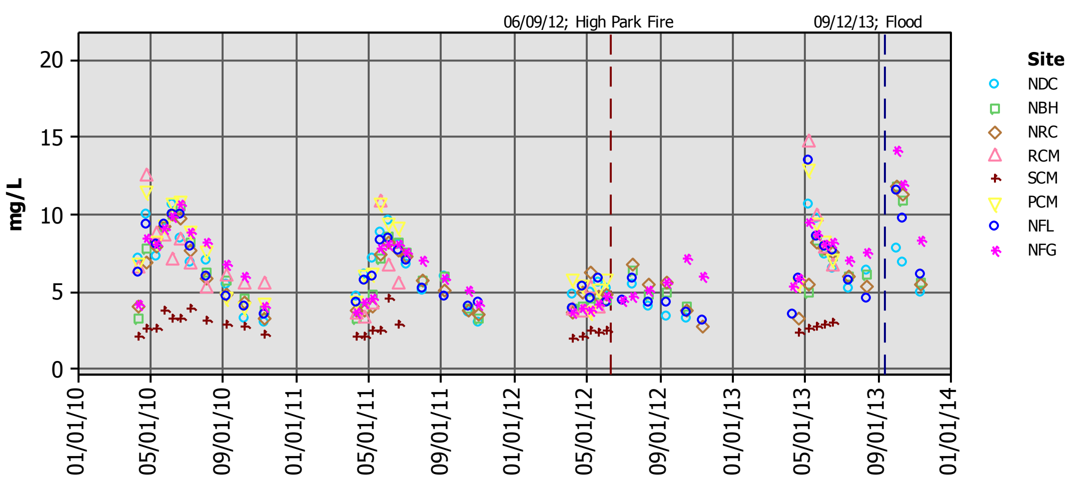
b) Total Dissolved Solids (TDS) on the North Fork CLP



a) Total Organic Carbon (TOC) on the Mainstem CLP

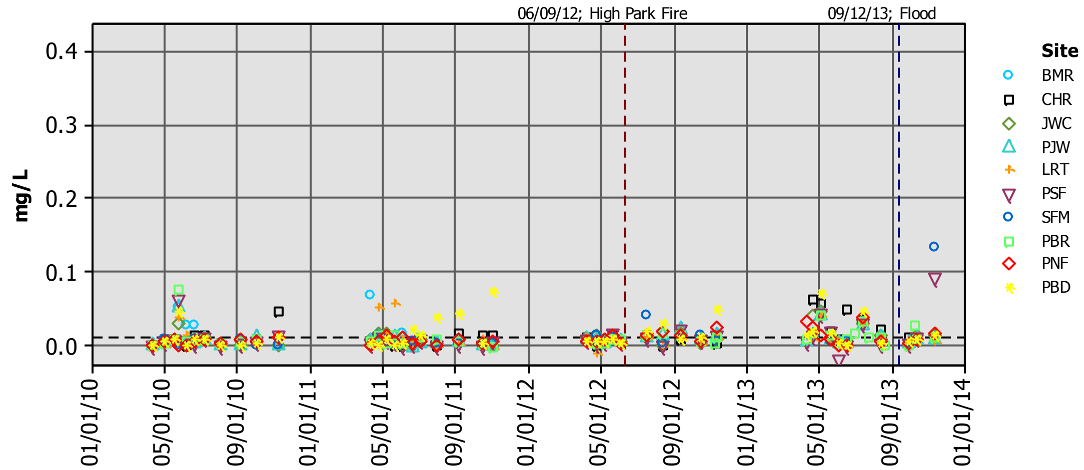


b) Total Organic Carbon (TOC) on the North Fork CLP



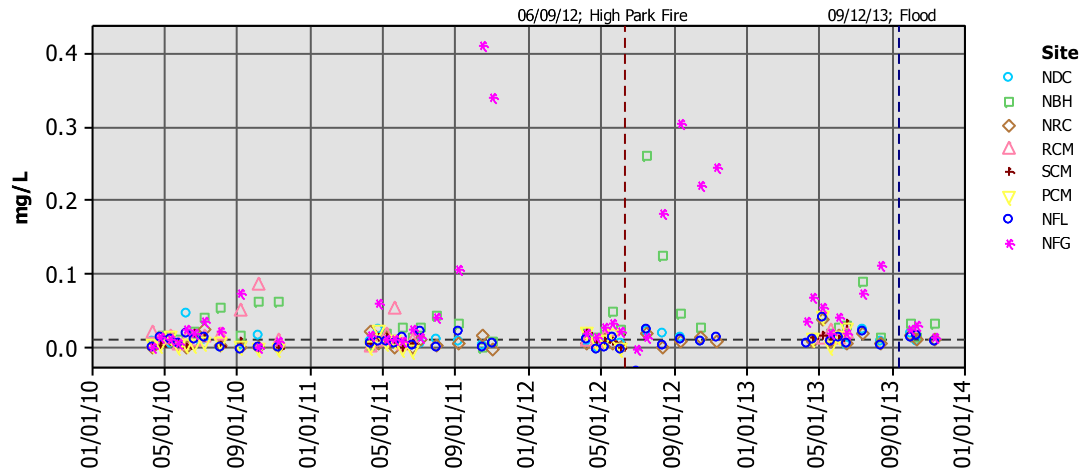
Mainstem and North Fork CLP: Nutrients

a) Ammonia (NH3) on the Mainstem CLP

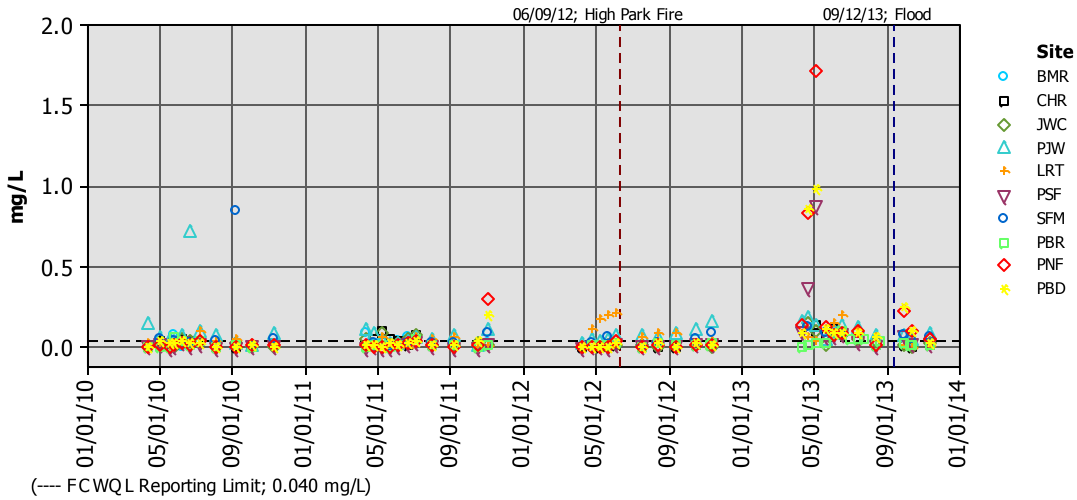


(---- FCWQL Reporting Limit; 0.010 mg/L)

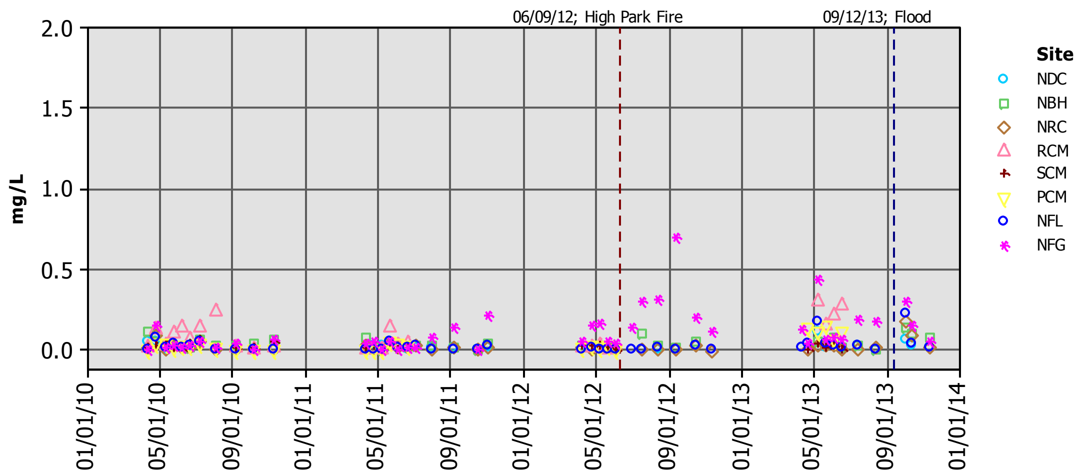
b) Ammonia (NH3) on the North Fork CLP



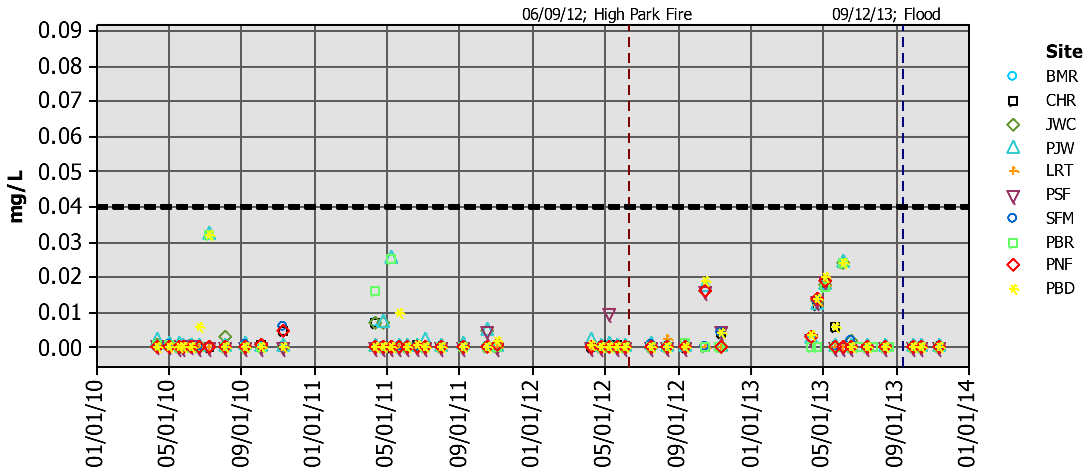
a) Nitrate (NO3) on the Mainstem CLP



b) Nitrate (NO3) on the North Fork CLP

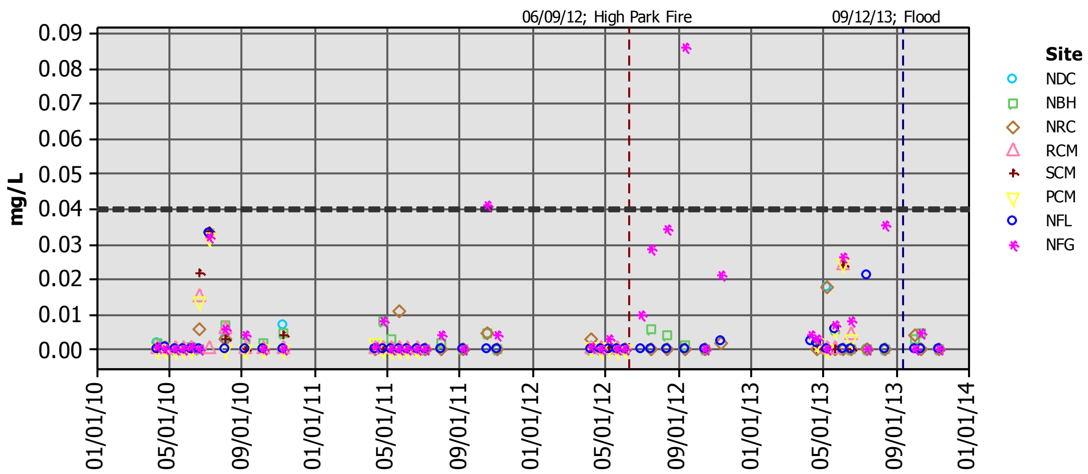


a) Nitrite (NO2) on the Mainstem CLP

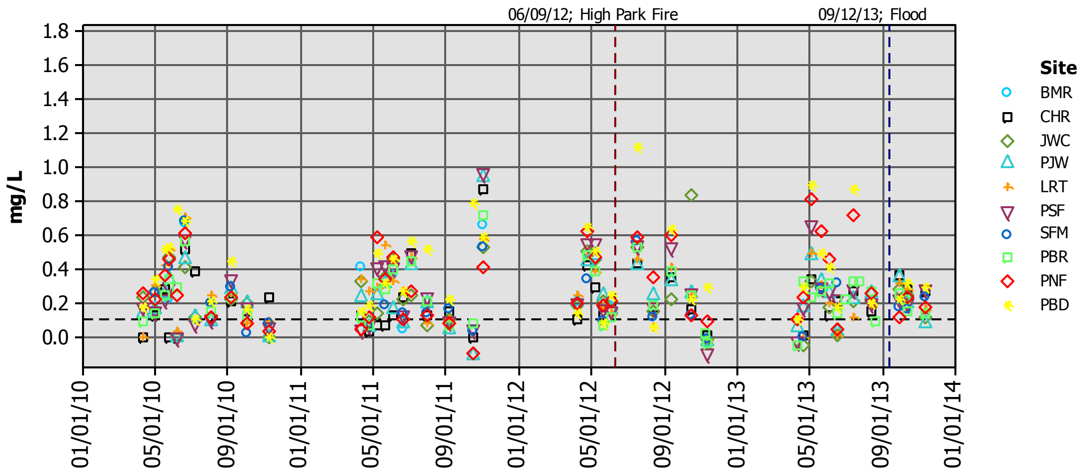


(---- FCWQL Reporting Limit; 0.04 mg/L)

b) Nitrite (NO2) on the North Fork CLP

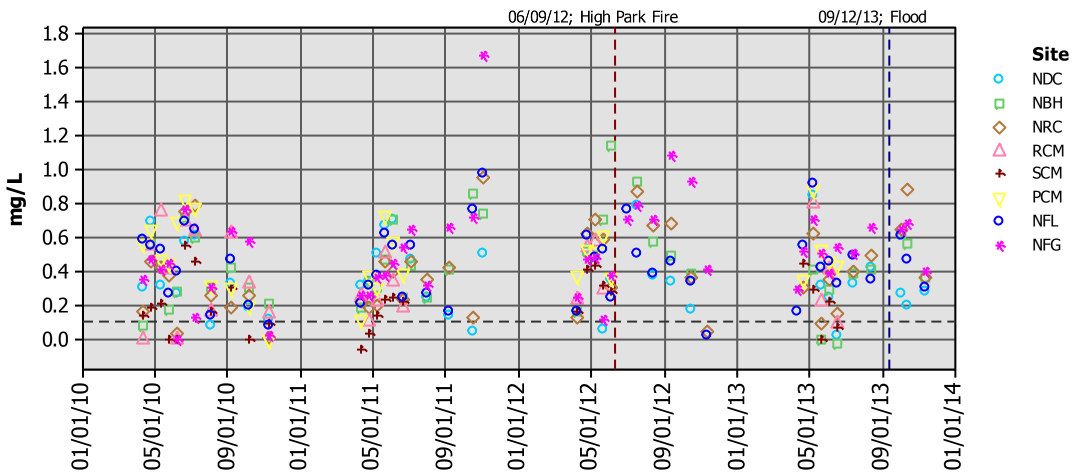


a) Total Kjeldahl Nitrogen (TKN) on the Mainstem CLP

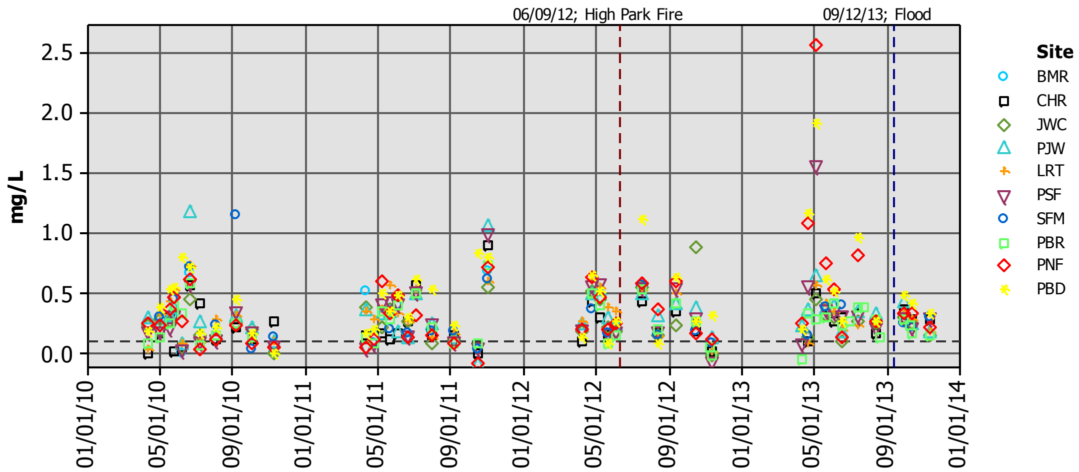


(---- FCWQL Reporting Limit; 0.100 mg/L)

b) Total Kjeldahl Nitrogen (TKN) on the North Fork CLP

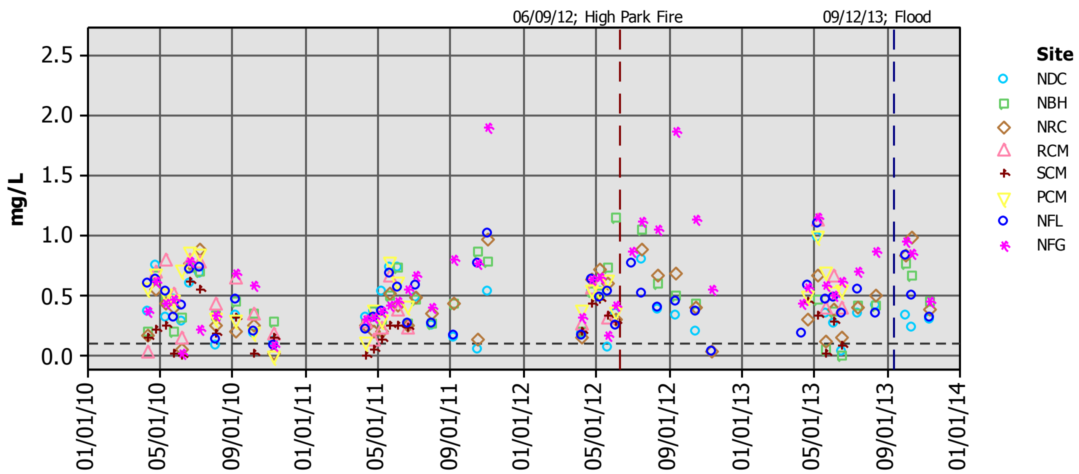


a) Total Nitrogen (TN) on the Mainstem CLP

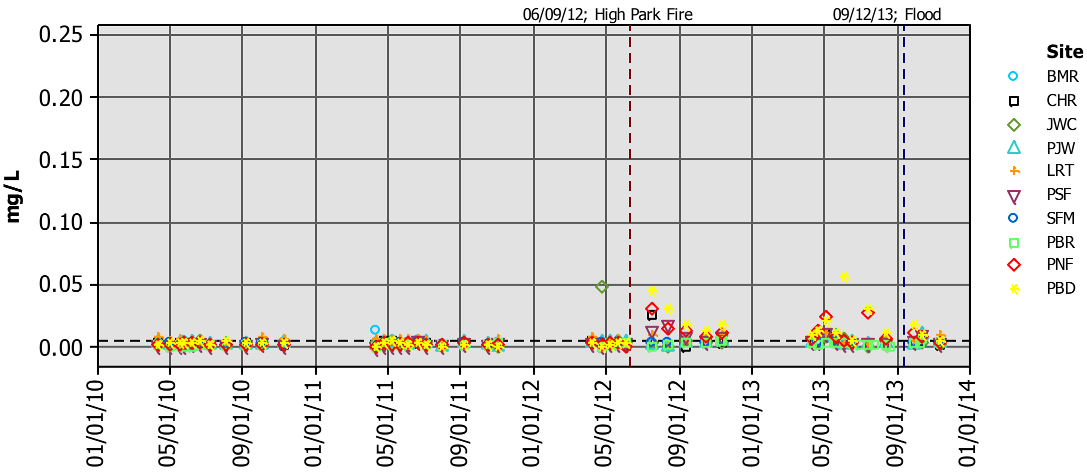


(---- FCWQL Reporting Limit; 0.10 mg/L)

b) Total Nitrogen (TN) on the North Fork CLP

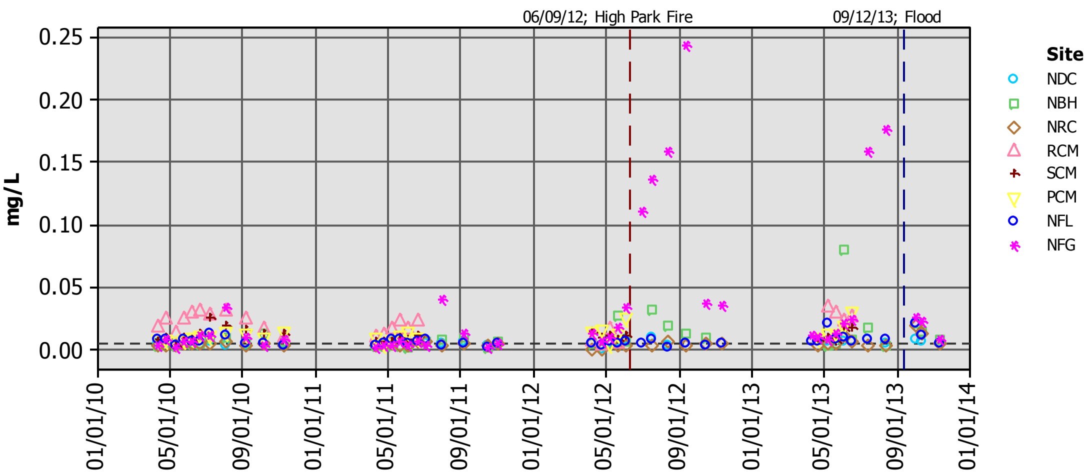


a) Ortho-phosphate (PO4) on the Mainstem CLP

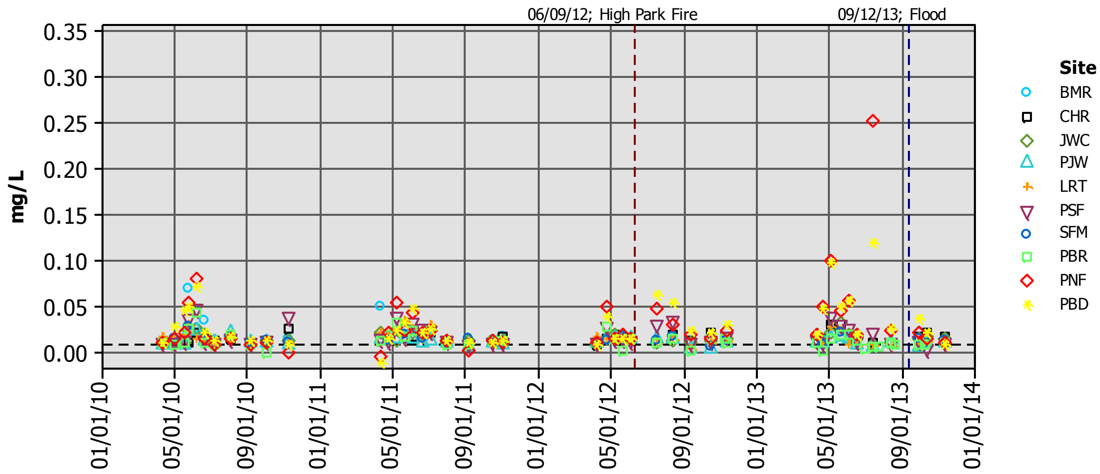


(---- FCWQL Reporting Limit; 0.005 mg/L)

b) Ortho-phosphate (PO4) on the North Fork CLP

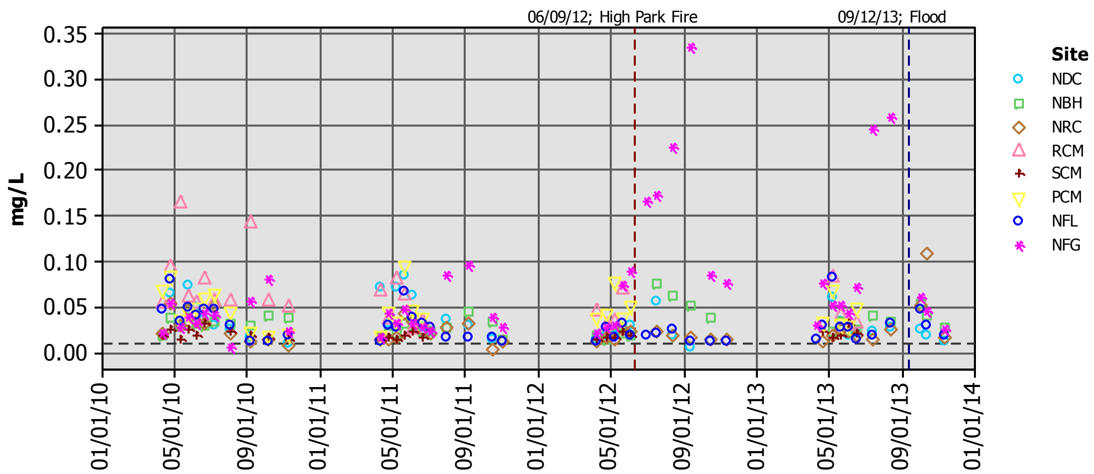


a) Total Phosphorus (TP) on the Mainstem CLP



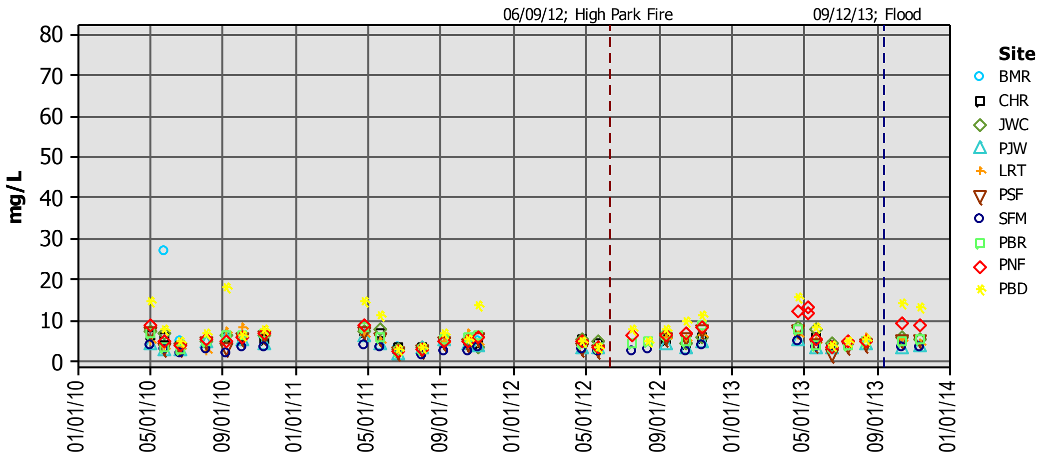
(---- FCWQL Reporting Limit; 0.010 mg/L)

b) Total Phosphorus (TP) on the North Fork CLP

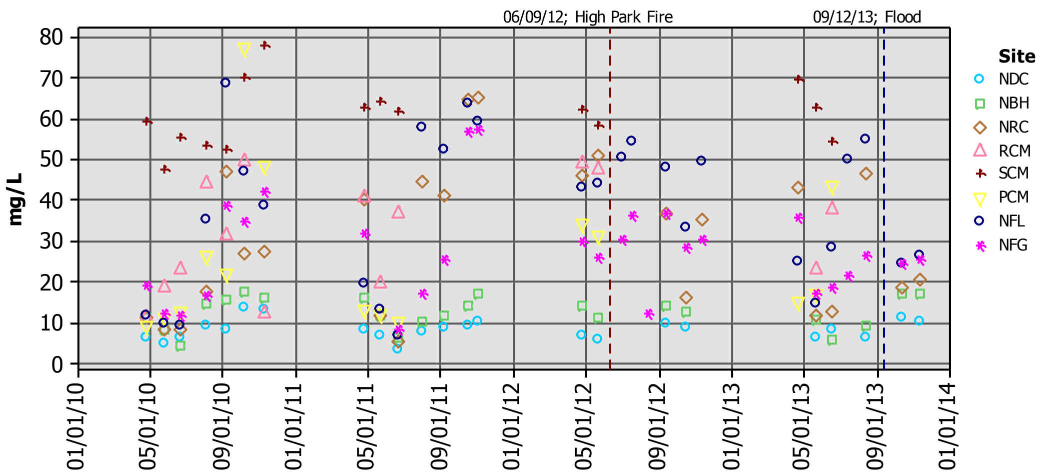


Mainstem and North Fork CLP:
Major Ions

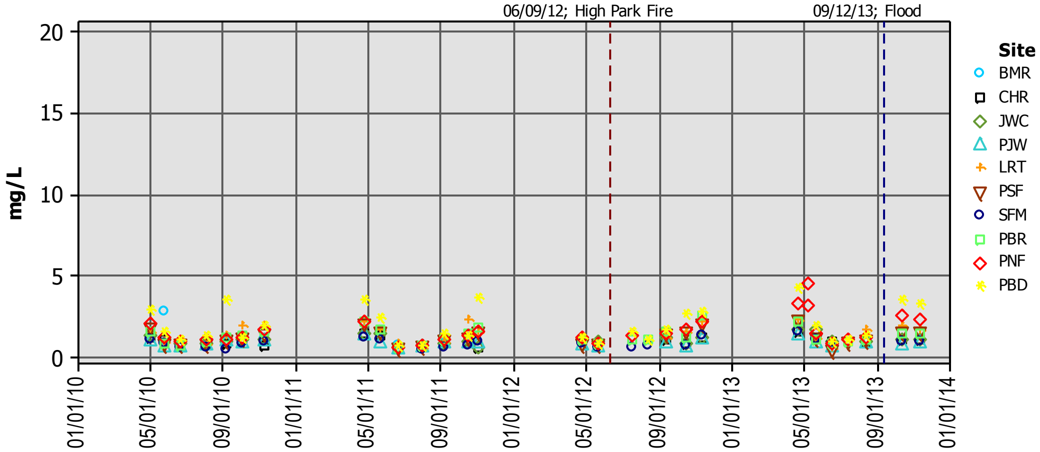
a) Calcium (Ca) on the Mainstem CLP



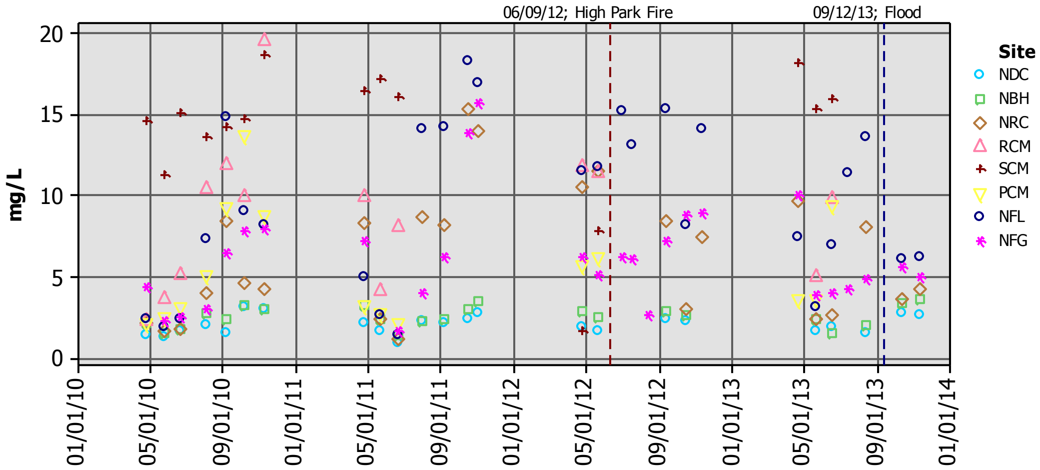
b) Calcium (Ca) on the North Fork CLP



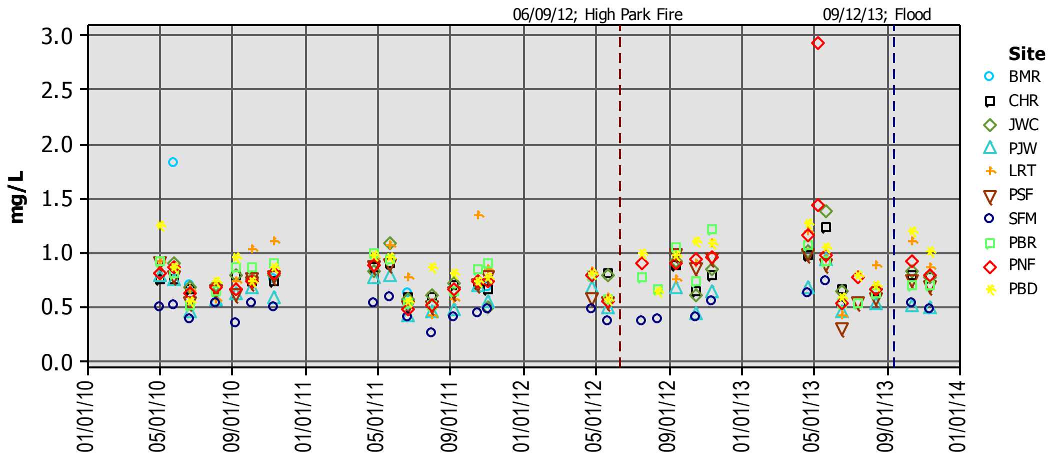
a) Magnesium (Mg) on the Mainstem CLP



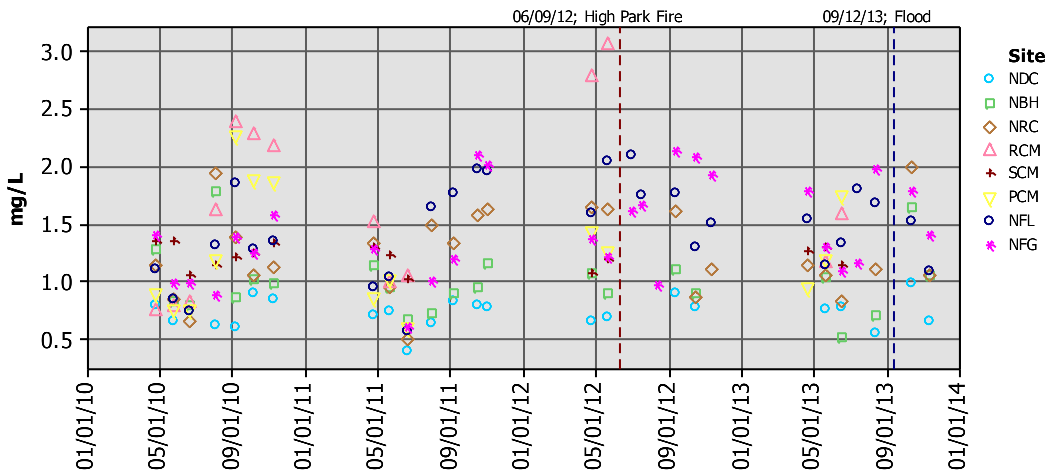
b) Magnesium (Mg) on the North Fork CLP



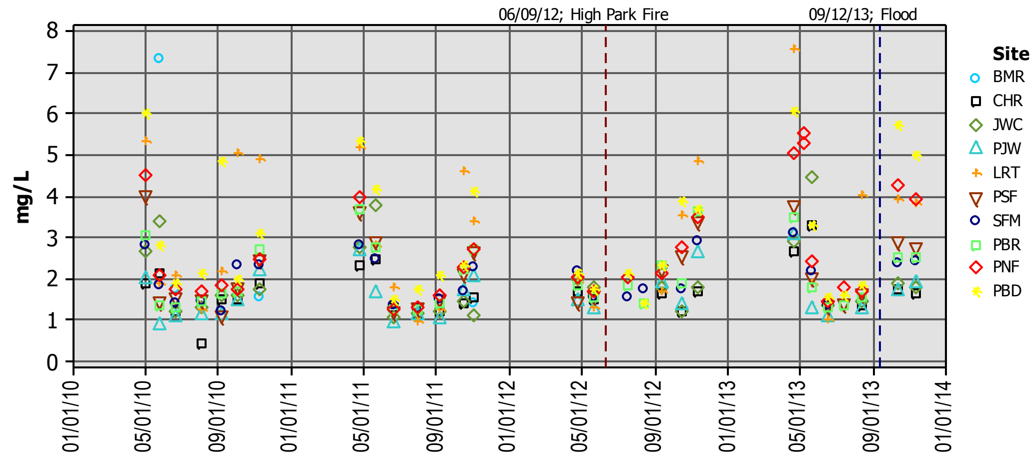
a) Potassium (K) on the Mainstem CLP



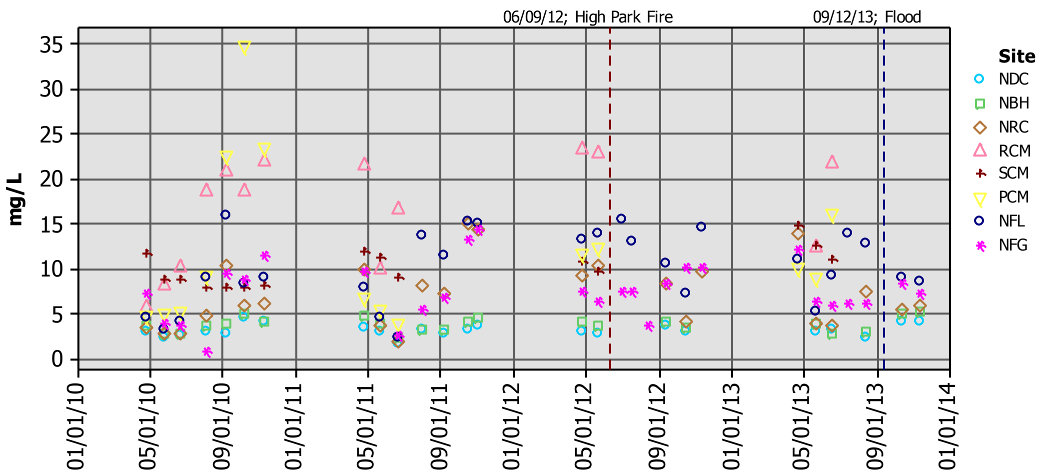
b) Potassium (K) on the North Fork CLP



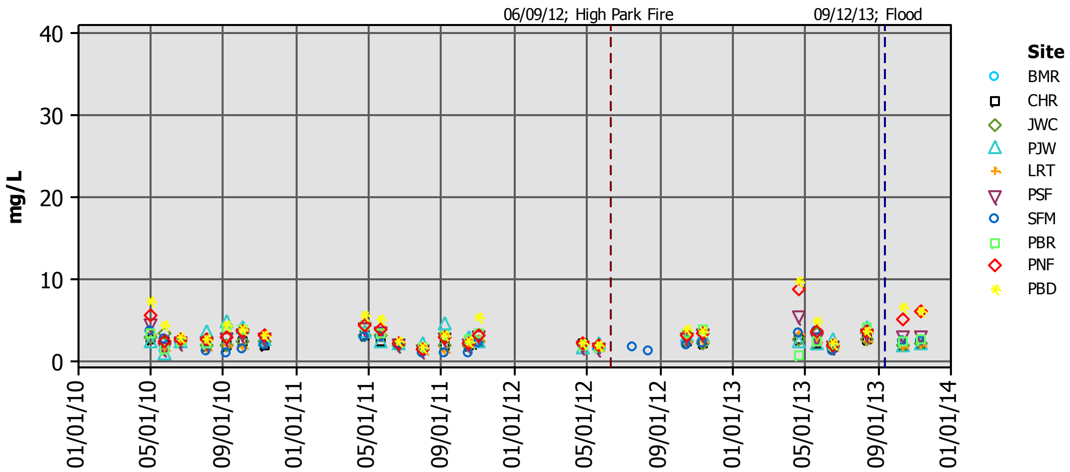
a) Sodium (Na) on the Mainstem CLP



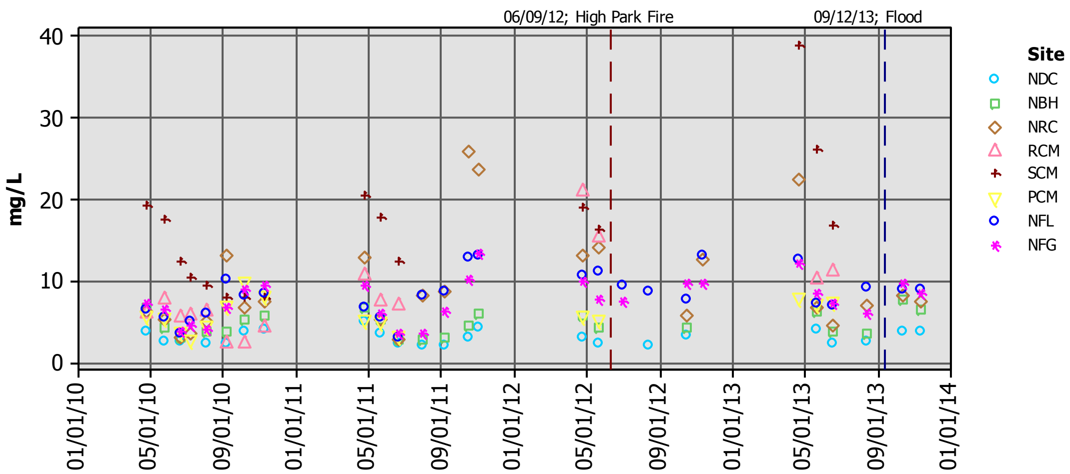
b) Sodium (Na) on the North Fork CLP



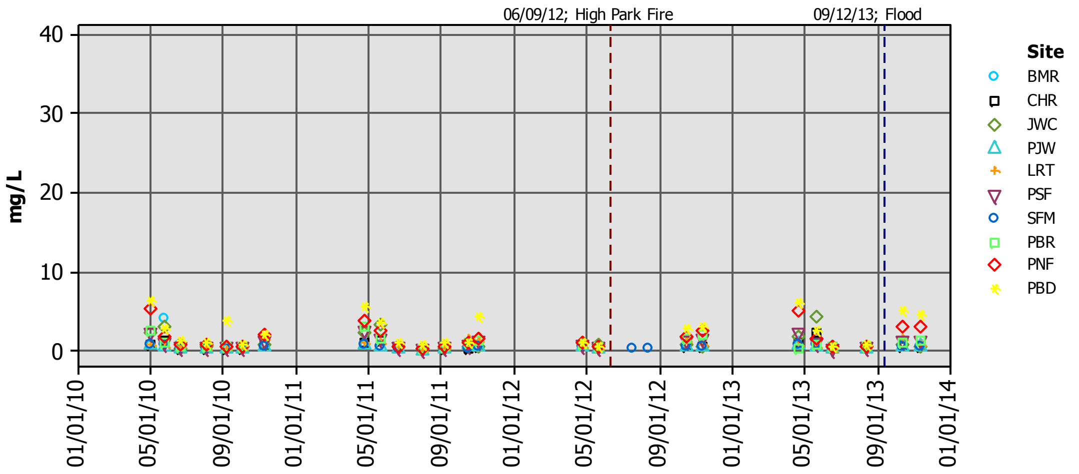
a) Sulfate (SO4) on the Mainstem CLP



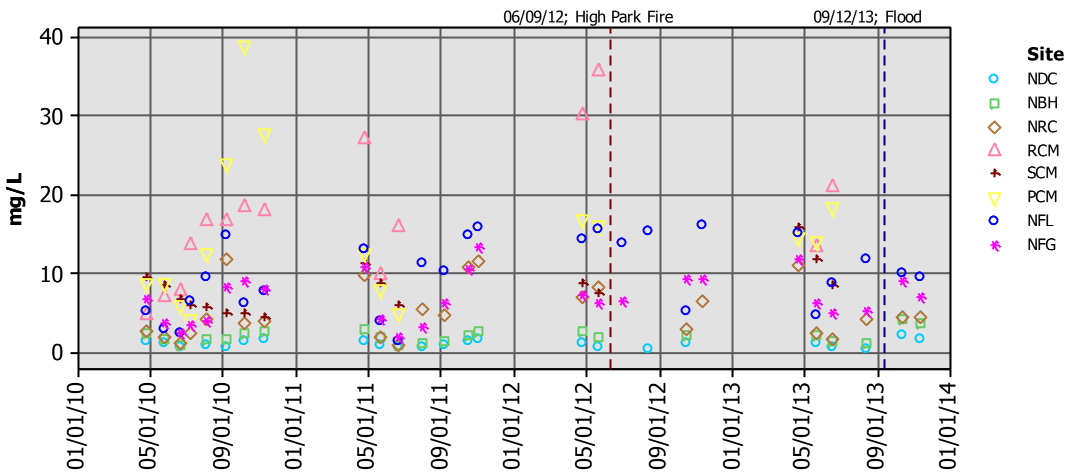
b) Sulfate (SO4) on the North Fork CLP



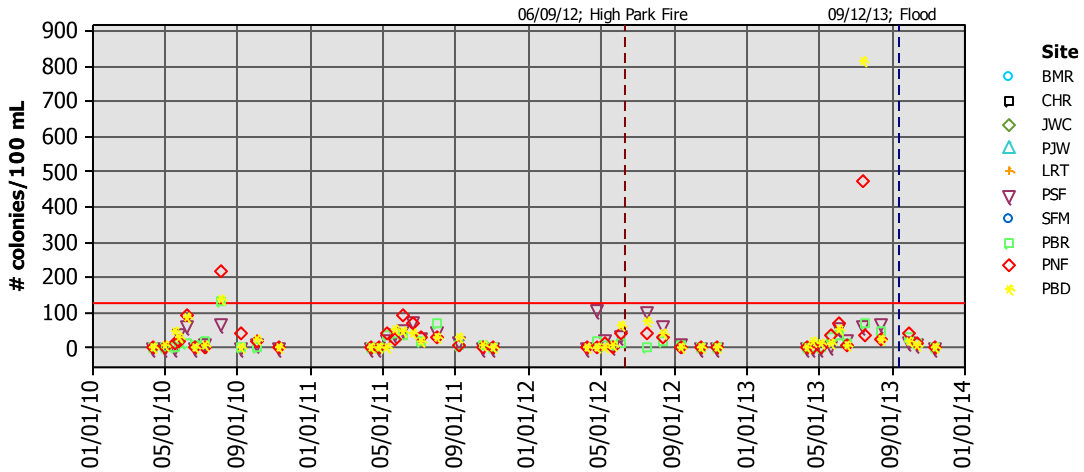
a) Chloride (Cl) on the Mainstem CLP



b) Chloride (Cl) on the North Fork CLP

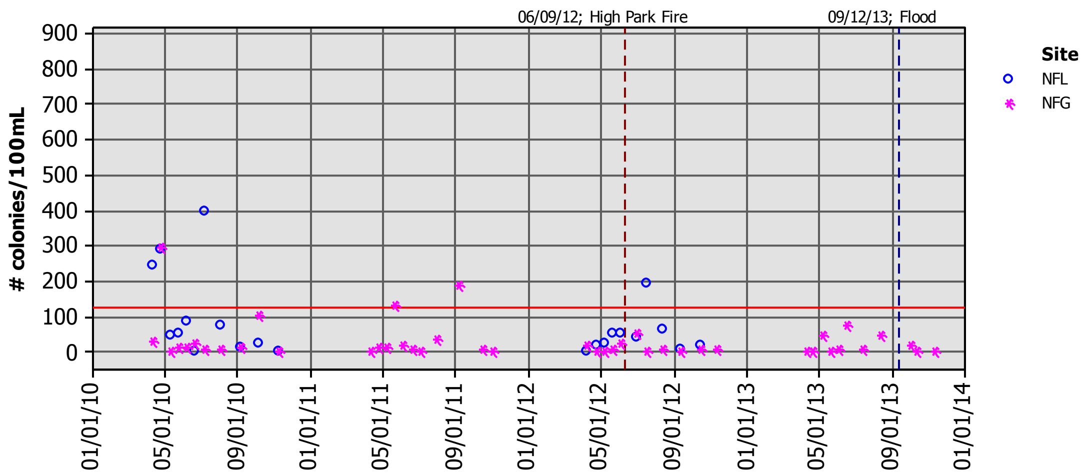


a) E.coli on the Mainstem CLP

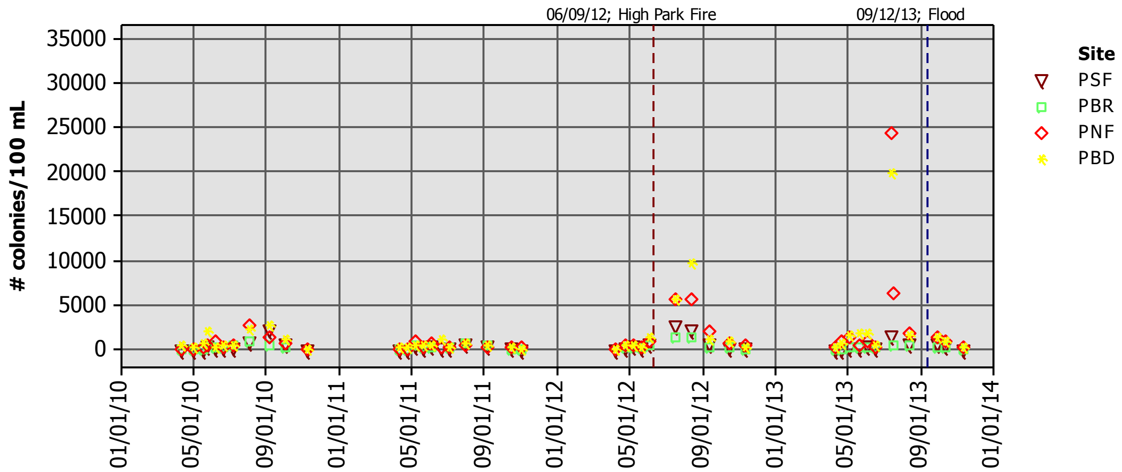


(Recreational water quality standard: 126 colonies/100 mL)

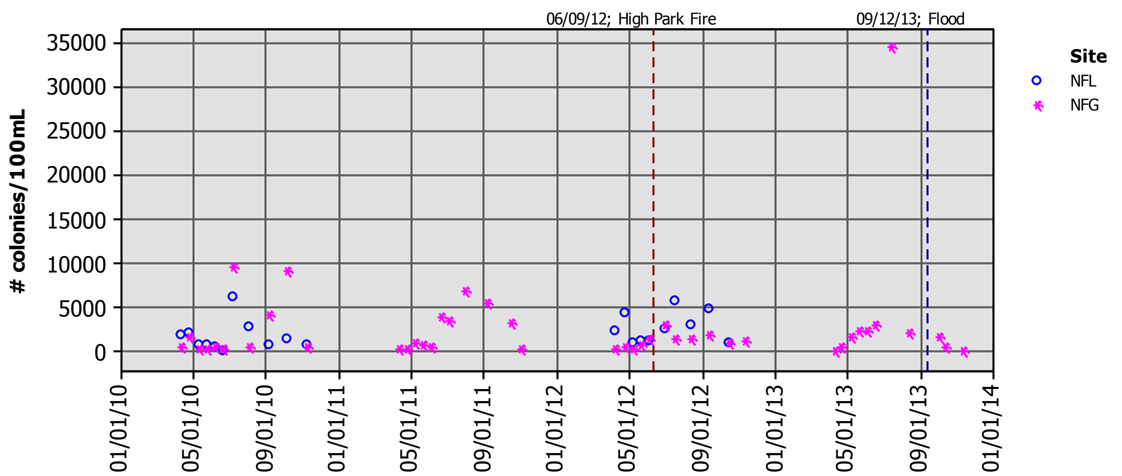
b) E. Coli on the North Fork CLP



a) Total coliforms on the Mainstem CLP

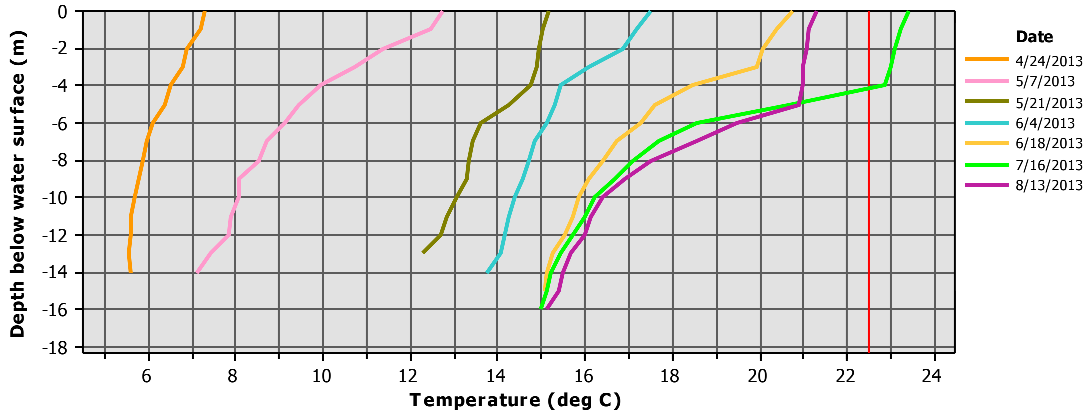


b) Total coliforms on the North Fork CLP



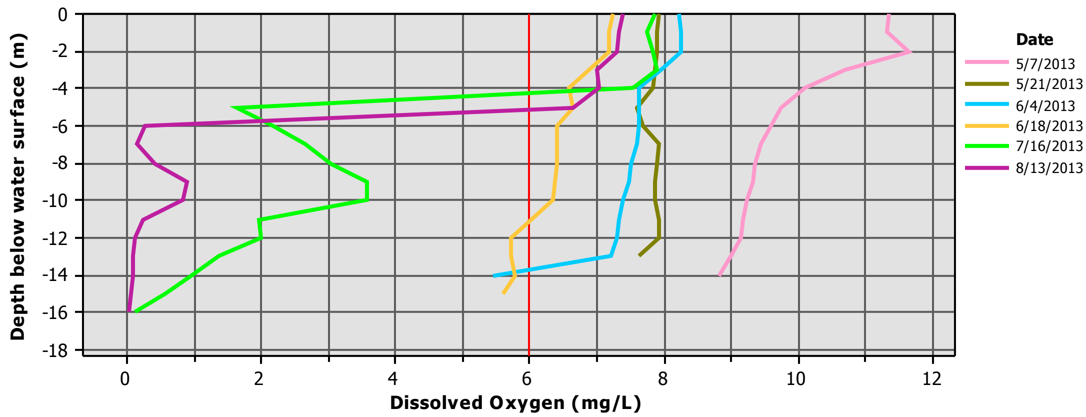
Seaman Reservoir:
Depth Profiles
(Temperature, D.O., pH & Conductance)

Temperature profiles measured in Seaman Reservoir (2013)



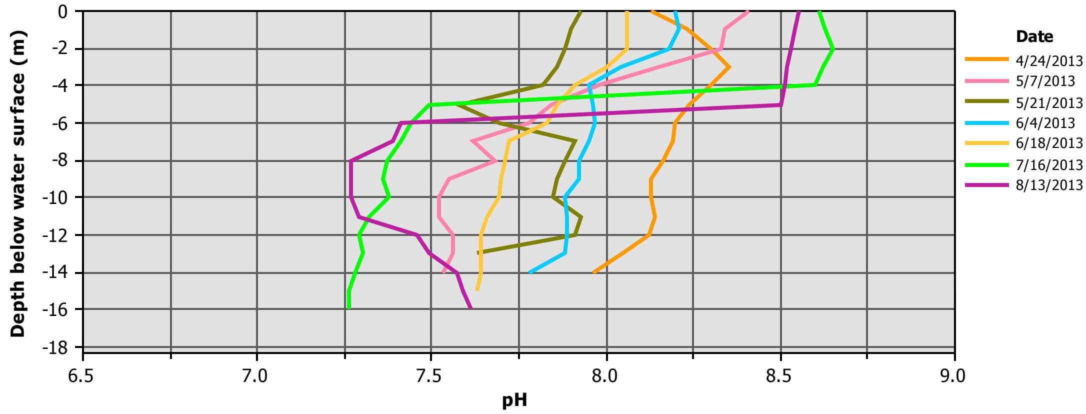
(Water quality standard for cold water aquatic life: 22.5 degress C)

Dissolved Oxygen profiles measured in Seaman Reservoir (2013)

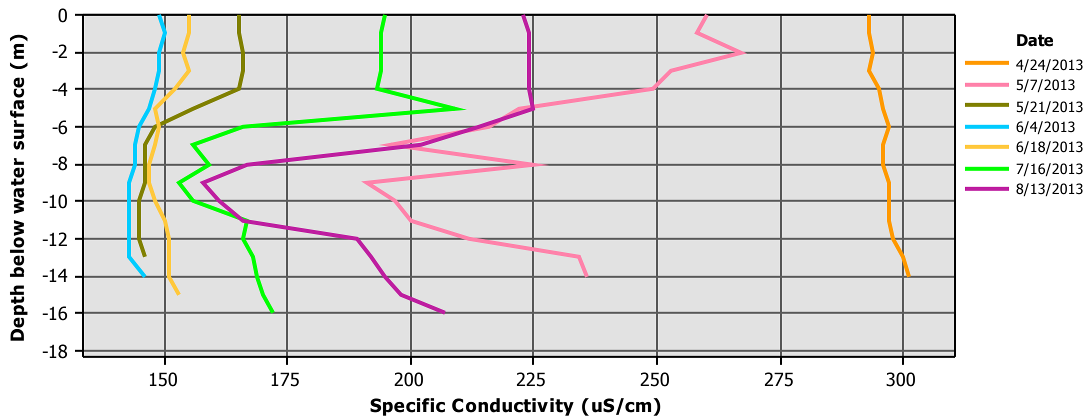


(Water quality standard for cold water aquatic life: 6.0 mg/L D.O.)

pH profiles measured in Seaman Reservoir (2013)

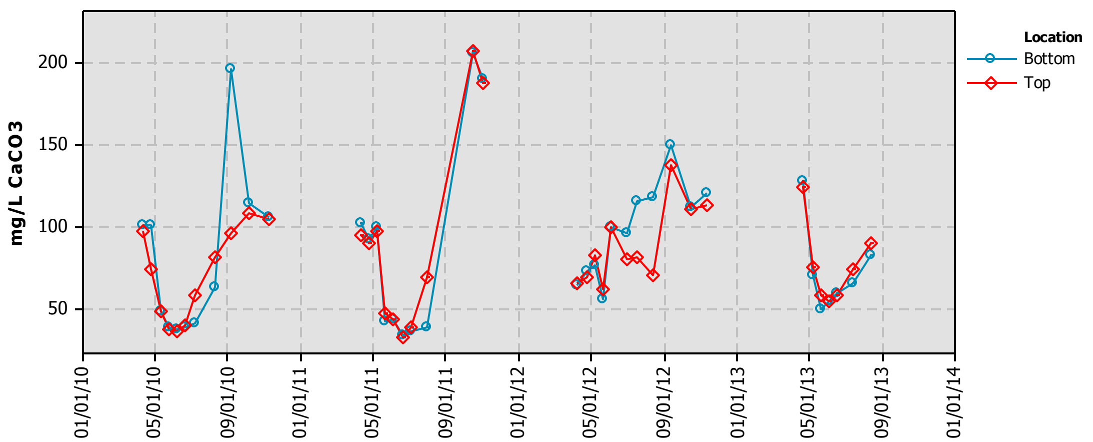


Specific Conductivity profiles measured in Seaman Reservoir (2013)

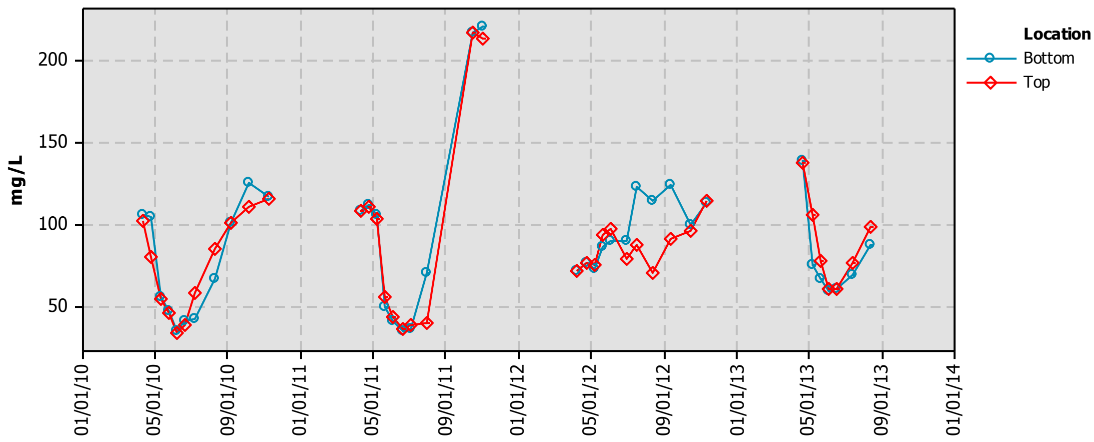


Seaman Reservoir:
General Parameters

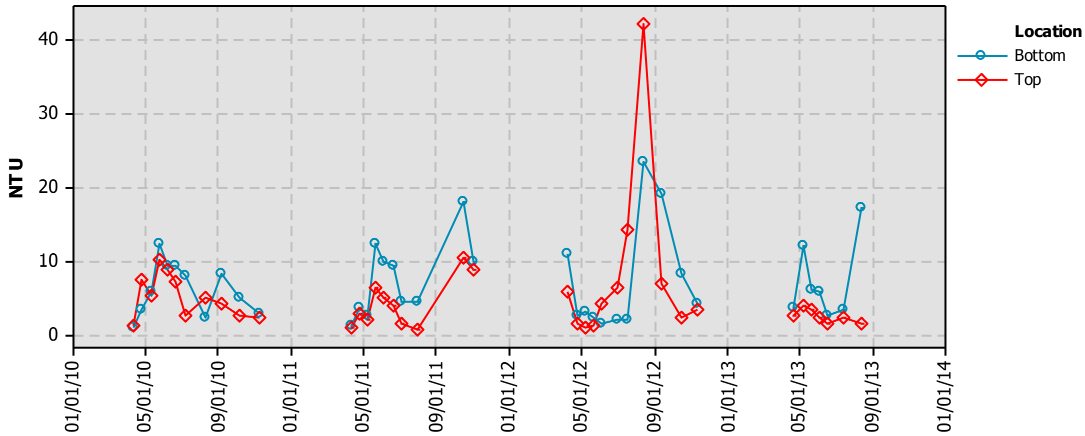
Alkalinity in Seaman Reservoir (SER)



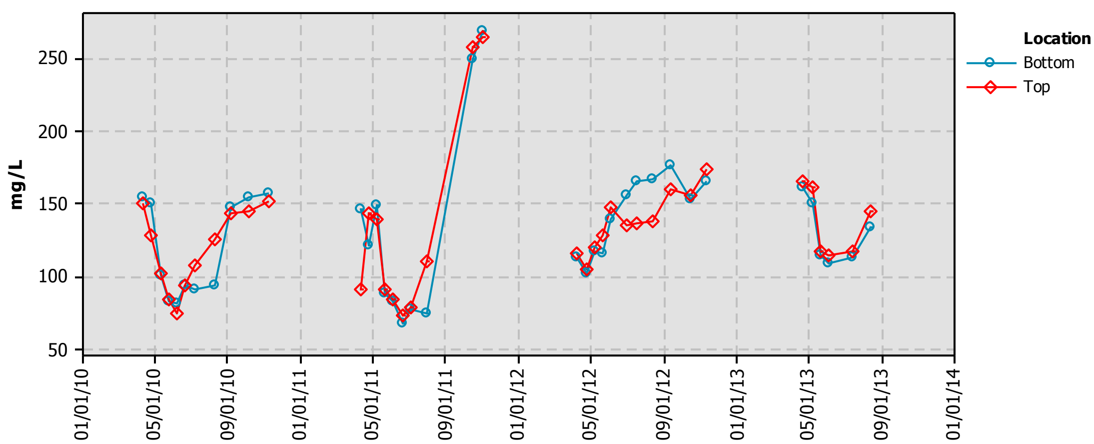
Hardness in Seaman Reservoir



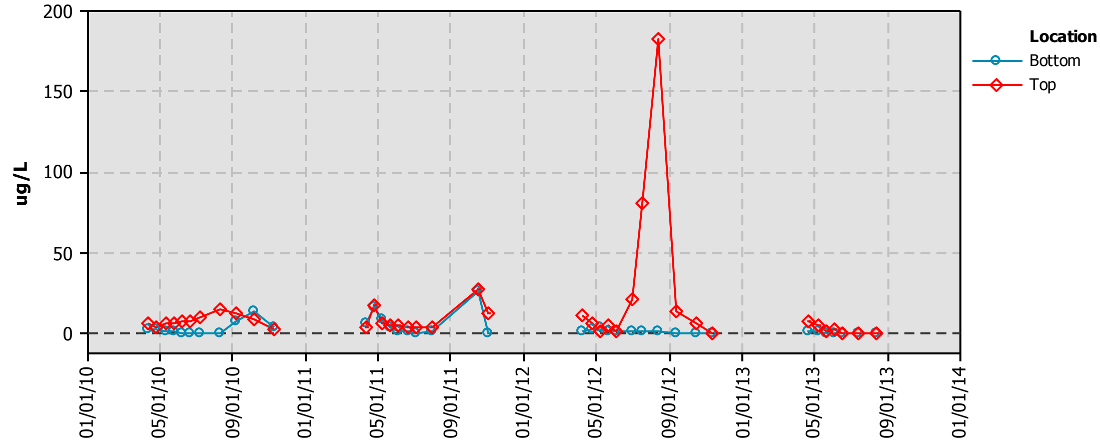
Turbidity in Seaman Reservoir (SER)



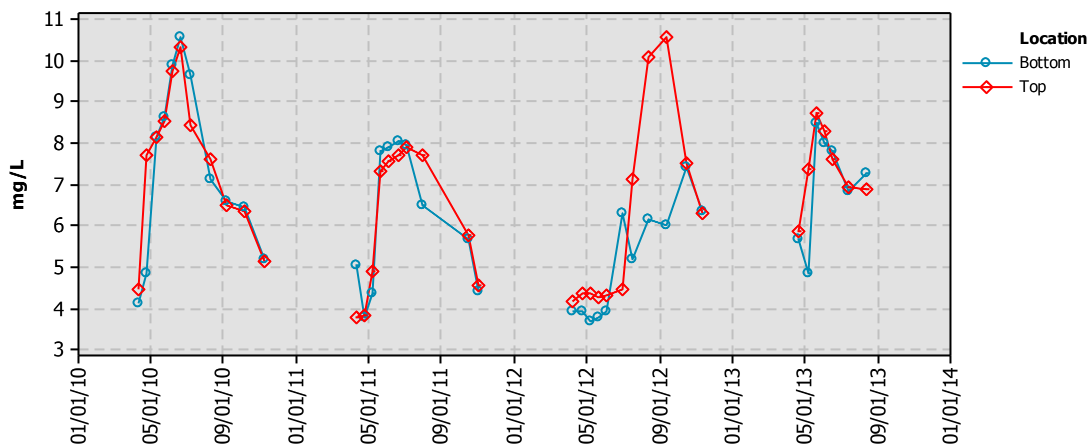
Total Dissolved Solids (TDS) in Seaman Reservoir (SER)



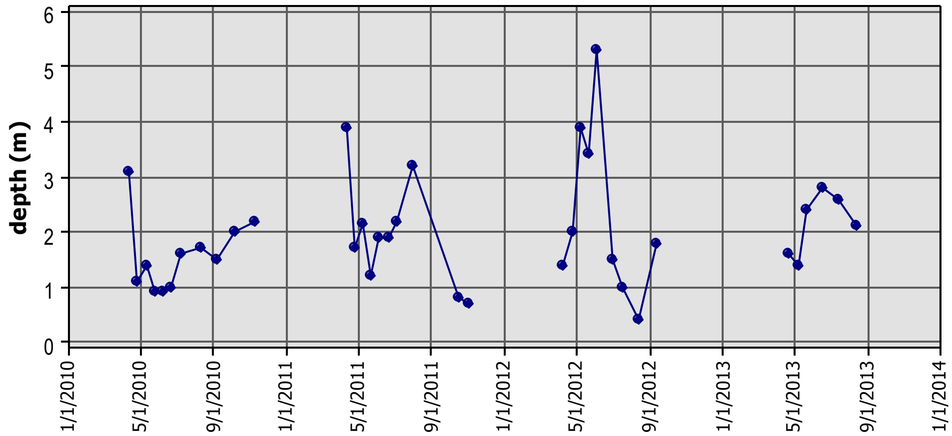
Chlorophyll-a in Seaman Reservoir (SER)



Total organic carbon (TOC) in Seaman Reservoir

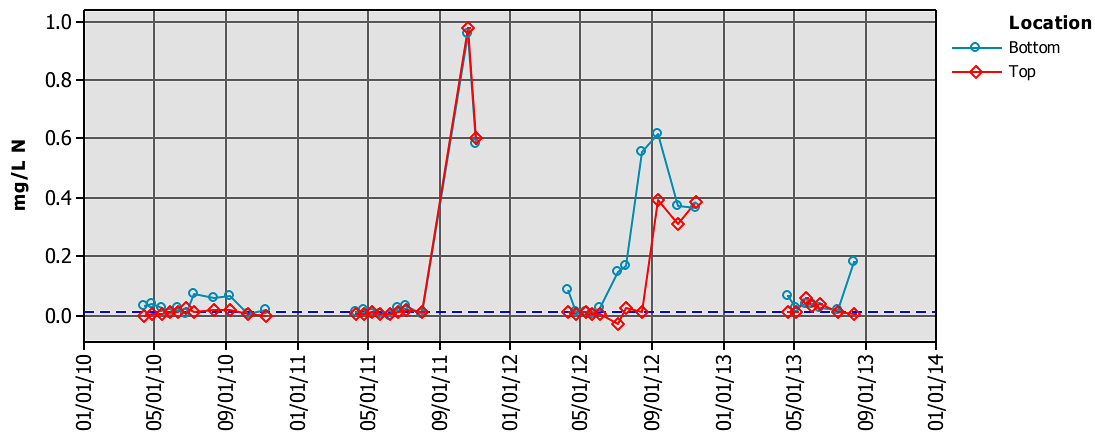


Secchi depth in Seaman Reservoir



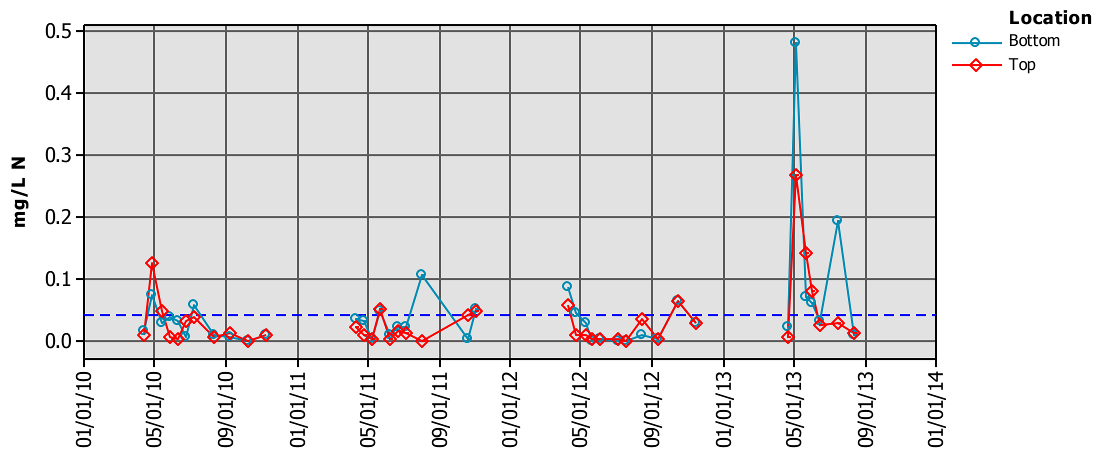
Seaman Reservoir:
Nutrients

Ammonia (NH3-N) concentrations in Seaman Reservoir



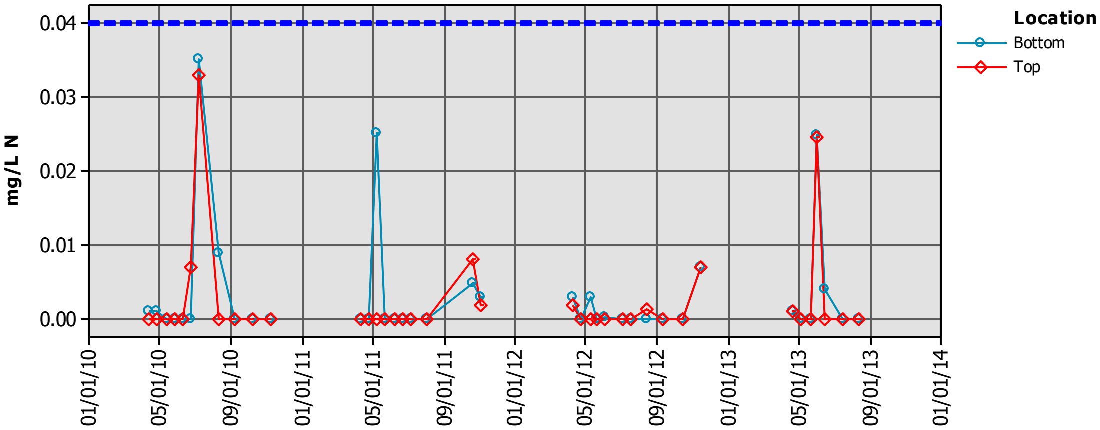
(------ FCWQL Reporting Limit, 0.01mg/L)

Nitrate (NO3-N) concentrations in Seaman Reservoir



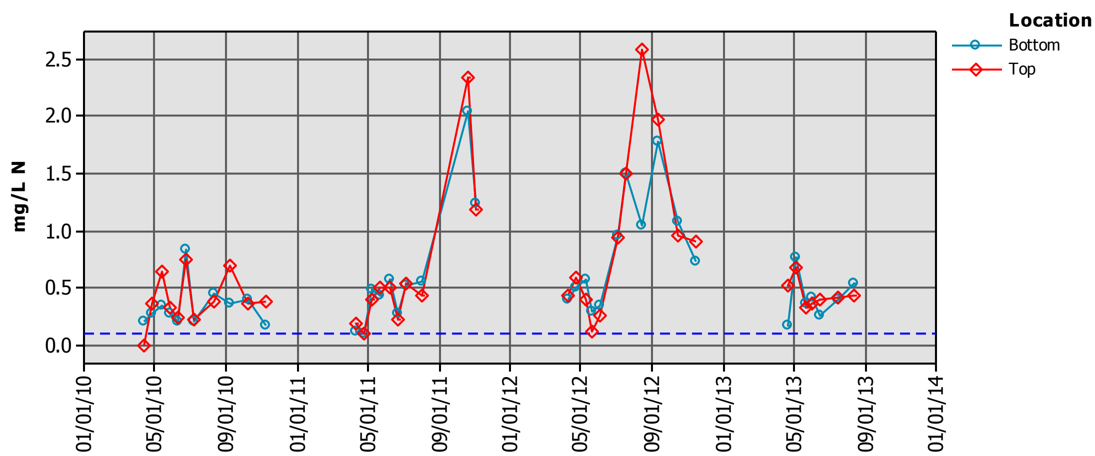
(------ FCWQL reporting limit, 0.04 mg/L)

Nitrite (NO2-N) concentrations in Seaman Reservoir



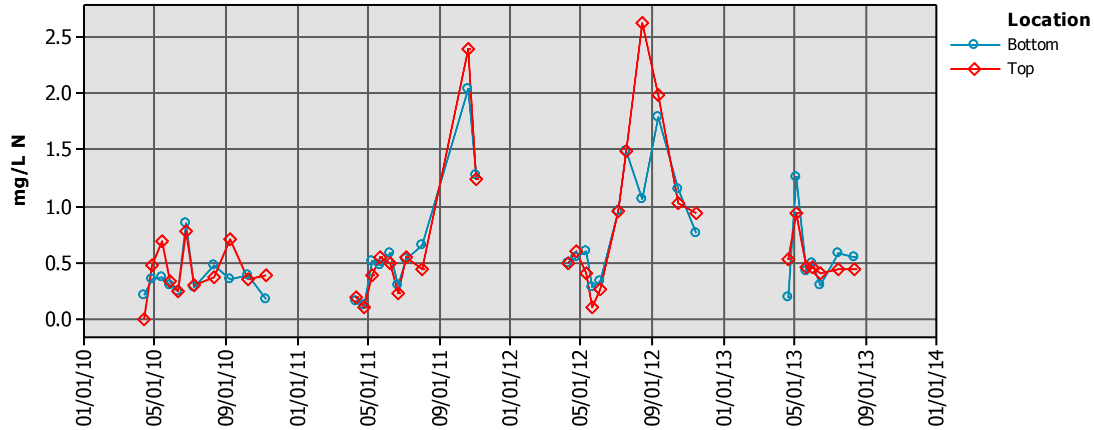
(------ FCWQL Reporting Limit, 0.04 mg/L)

Total Kjeldahl Nitrogen (TKN) concentrations in Seaman Reservoir

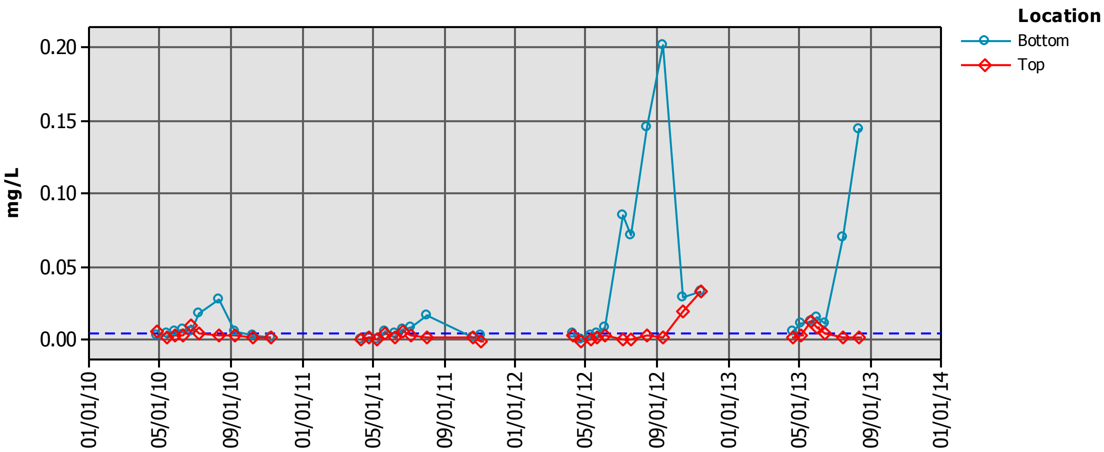


(------- FCWQL Reporting Limit, 0.100 mg/L)

Total Nitrogen (TKN + NO3 + NO2) concentrations in Seaman Reservoir



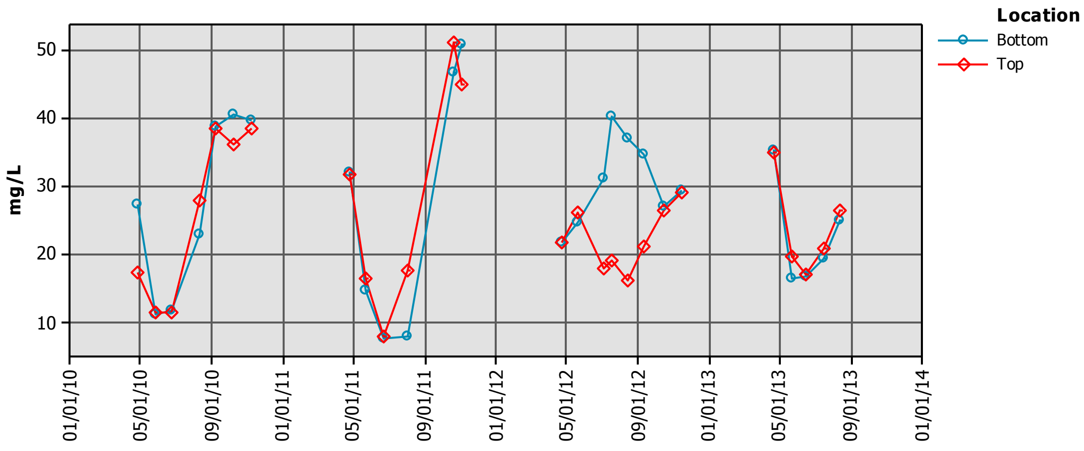
Orth-phosphate (PO4) concentrations in Seaman Reservoir



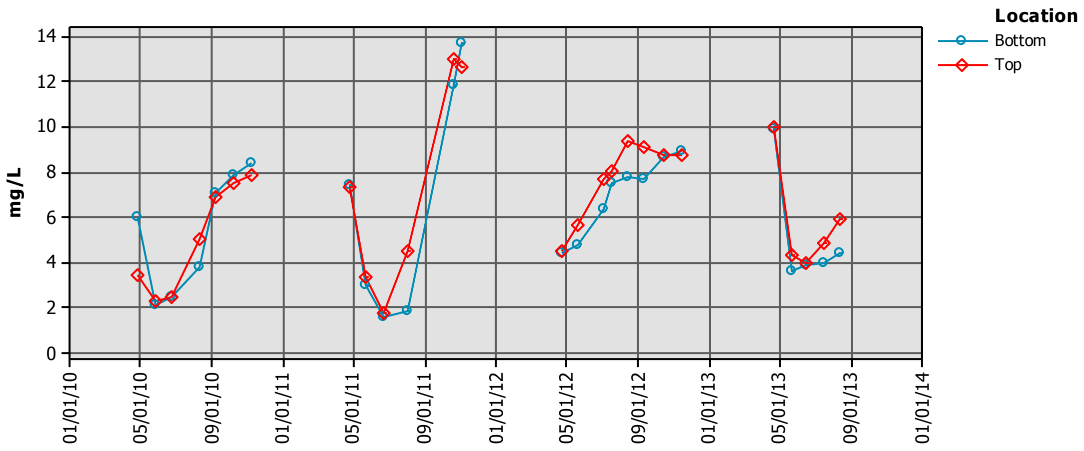
(------FCWQL Reporting Limit, 0.005 mg/L)

Seaman Reservoir:
Major Ions

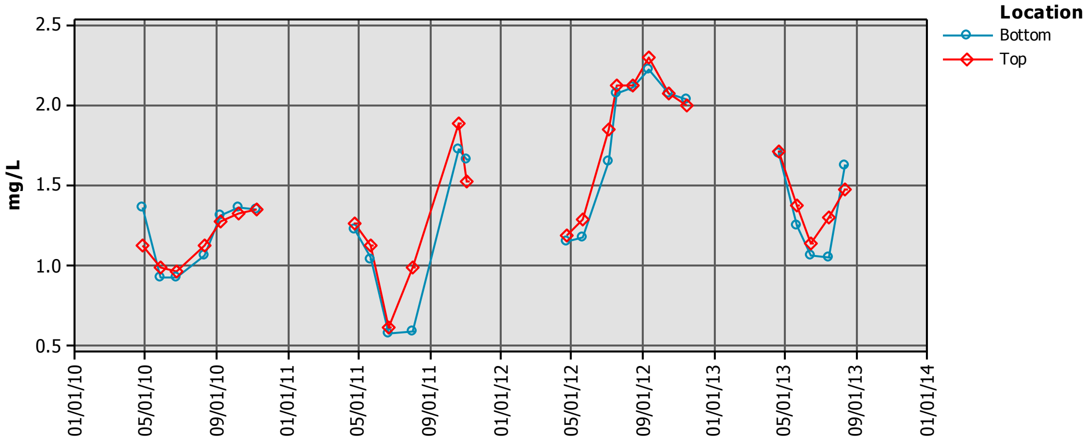
Calcium (Ca) concentrations in Seaman Reservoir



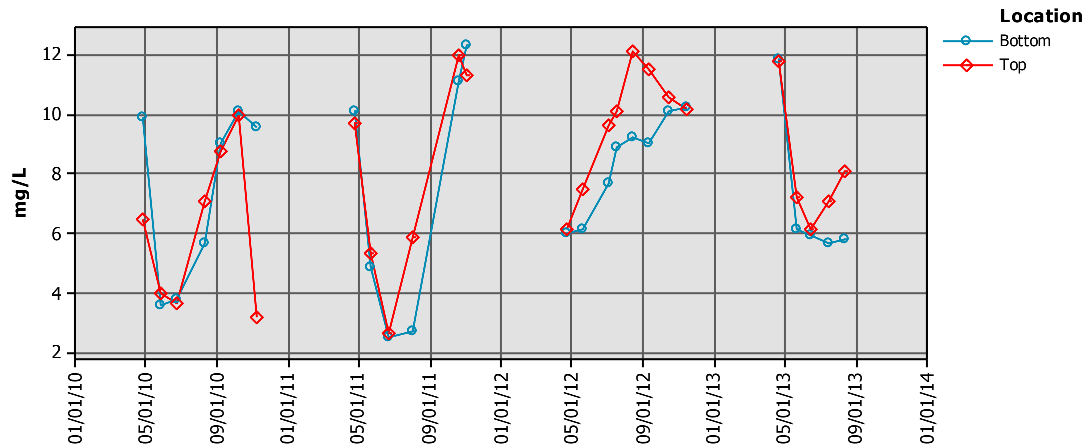
Magnesium (Mg) concentrations in Seaman Reservoir



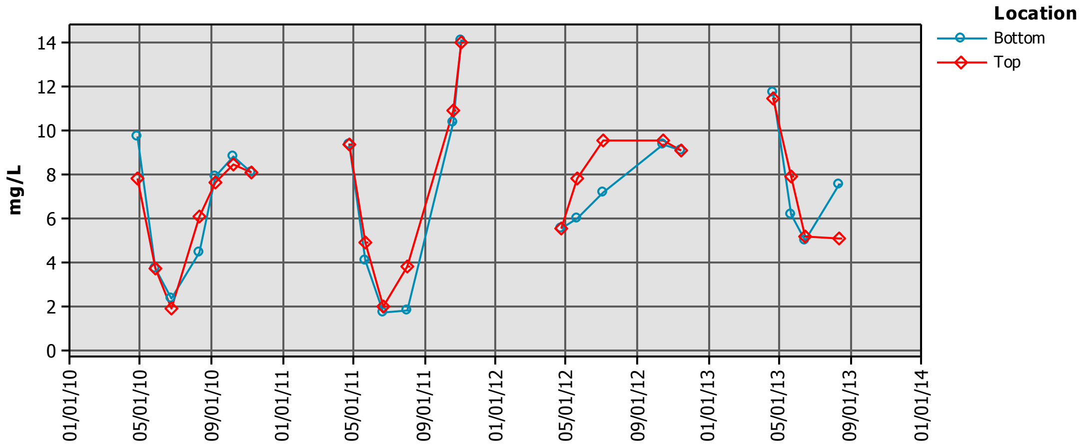
Potassium (K) concentrations in Seaman Reservoir



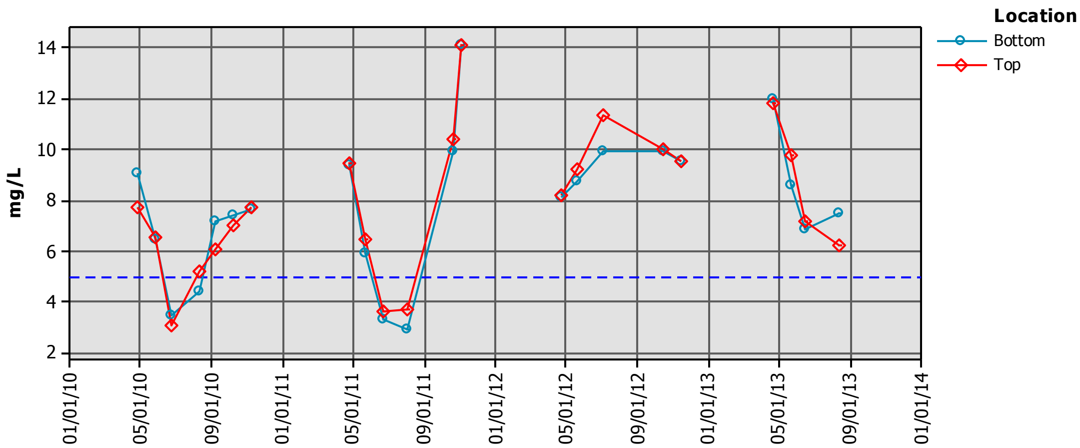
Sodium (Na) concentrations in Seaman Reservoir



Chloride (Cl) concentrations in Seaman Reservoir



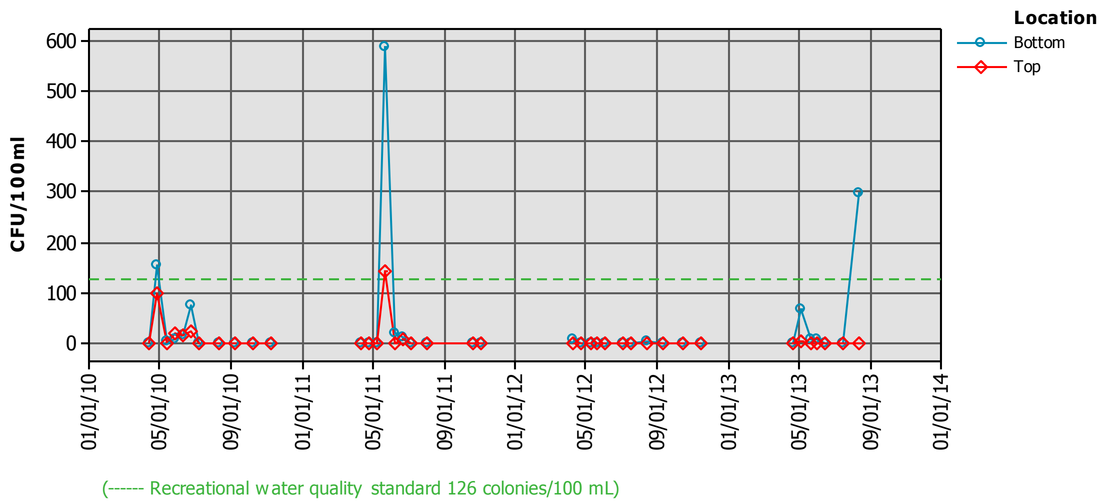
Sulfate (SO4) concentrations in Seaman Reservoir



(------ FCWQL Reporting Limit, 5 mg/L)

Seaman Reservoir: Microbiological Constituents

E. coli concentrations in Seaman Reservoir



Total coliform concentrations in Seaman Reservoir