2010 Annual Report

Upper Cache la Poudre River

Collaborative Water Quality Monitoring Program

Prepared for:

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Tri-Districts

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City of Fort Collins

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 consisted of 11 sampling events between April and November, 2010 at ten sites on the Mainstem CLP and nine sites on the North Fork, including Seaman Reservoir. Water samples were 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.

Scope of 2010 Annual Report

The 2010 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 2007 – 2010. The report also summarizes significant events, issues of concern, and results from special studies.

Six 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 six key sites as well as Seaman Reservoir, although data for all sites were analyzed and significant events and trends are also included in the discussion. Summary graphs for all parameters and locations are presented in a separate attachment (Attachment 5).

Significant Events, Issues of Concern & Special Studies

- **Summer Attached Algae Bloom**. An attached algae bloom occurred during the summer of 2010 in the middle reaches of the Mainstem Poudre River. A similar bloom occurred in 2009. Dense mats of dried and live filamentous green algae (*Ulothrix* sp.) were observed in the area. Although septic systems associated with the resorts and trailer parks in the area may be potential sources of nutrients, sampling did not indicate the presence of elevated nutrient levels that may have triggered the algal bloom. In addition, no taste and odor (T&O) issues were experienced at the treatment plants during this time, indicating that potential off-taste and odor compounds were not strongly associated with this algae bloom, or were adequately volatilized, degraded, and/or diluted prior to reaching the raw water intakes.
- **Winter/Spring Geosmin Episode.** From January 2010 through the beginning of May 2010, geosmin concentrations near or above the odor threshold of 4 nanograms per liter (ng/L) or 4 parts per trillion (ppt) were detected in the raw Poudre River water supply at the Fort Collins Water Treatment Facility (FCWTF). A peak geosmin concentration of 7.5 ppt was measured in raw Poudre River water at the FCWTF on January 5, 2010. Reconnaissance sampling on the Mainstem CLP identified the primary area of geosmin production to extend from above Rustic downstream to the Eggers fishing area. In January and February, peak geosmin concentrations at

locations within this segment of the river ranged from 21 to 38 ppt, three to five times those observed in raw Poudre River water at the FCWTF. Sampling for geosmin, periphyton (attached algae), nutrients, *E.coli* and total coliforms was conducted monthly at four main sites to monitor in stream geosmin concentrations, assess the presence of geosmin-producing algae, and to identify potential sources of nutrients. To date, data show that geosmin producing species of attached cyanobacteria are present within this segment of the river, although they are minor contributors to the total periphyton population. Elevated nutrient concentrations have not been observed, making it difficult to assess the root cause of the geosmin episode. It is not currently known whether the 2010 winter geosmin episode is related to the previous summer (2009) attached algae bloom. A revised monitoring plan will guide geosmin-related sampling activities in 2011and beyond.

- **Colorado's 2010 Section 303(d) List and Monitoring & Evaluation List.** Two segments of the North Fork CLP were placed on the 2010 Section 303(d) List of impaired waters: North Fork from Halligan to mainstem CLP for cadmium and lead; and Seaman Reservoir for dissolved oxygen. Three segments of the North Fork CLP were placed on Colorado's 2010 Monitoring & Evaluation List: North Fork upstream of Halligan Reservoir for copper; North Fork tributaries downstream of Halligan (except Rabbit and Lone Pine Creeks) for *E.Coli*; and Rabbit Creek and Lone Pine Creek for cadmium and lead.
- **Dissolved Organic Matter (DOM) Studies.** Two DOM characterization studies have recently been conducted that included the Upper CLP – the 2008 UCLA Study and a tailored collaboration Water Research Foundation Study with CU Boulder. DOM from the Upper CLP is dominated by humic-like (terrestrially derived) components. Humic-like components exhibit strong positive correlations with disinfection byproduct (DBP) formation, although coagulation is effective at removing these components. Bulk total organic carbon (TOC) is strongly correlated to total trihalomethane formation potential (TTHMFP) and therefore serves as a good predictor of this DBP (i.e., higher Poudre River TOC concentrations will result in higher TTHM unless the TOC is adequately removed during treatment). The final report for the UCLA study has not yet been completed. The final report for the Water Research Foundation project should be completed in 2011. A significant portion of the results from both studies has been reported in detail in Beggs (2010)
- **Northern Water Collaborative Emerging Contaminant Study.** In 2008, Northern Water initiated a collaborative emerging contaminant study to determine the presence of 51 pharmaceuticals, 103 pesticides, nine hormones, and eight phenolic endocrine disrupting compounds in waters of the Colorado- Big Thompson system. In 2009, two sites on the Upper CLP (Poudre above North Fork (PNF), and North Fork at gage below Seaman Reservoir (NFG)) were added to the study. The Poudre above North Fork site has been sampled three times through 2010 (June 2009, June 2010, August 2010) while the North Fork site has been sampled twice (June 2009 and June 2010). No compounds have been detected in samples collected from the North Fork site. The only compound detected in the Poudre above North Fork site is progesterone, although concentrations were at or very close to the extremely low detection limit of 0.1 ng/L. In 2011, samples will be collected at both sites in February, June, and August.

- **Colorado Water Quality Control Division High Quality Water Supply Reservoir Study.** The Colorado Water Quality Control Division (WQCD) has proposed a chlorophyll-a standard to support a new Protected Water Supply Reservoirs sub-classification of the existing Water Supply use classification. The WQCD is basing their proposed chlorophyll-a standard on an understanding of relationships of DBPs with nutrients, phytoplankton, chlorophyll, and organic carbon. In 2010, the WQCD conducted the High Quality Water Supply Reservoir Study with CU Boulder to better understand these relationships in Colorado reservoirs. The City of Greeley participated in this study by supporting the intensive sampling of Seaman Reservoir to coincide with the routine Upper CLP monitoring program. Samples were collected near the dam from the reservoir surface and the reservoir bottom during two sampling events in May, two in June, and one sampling event in each of the months of July, August, September, and October. Although the sample collection and laboratory analysis for the WQCD High Quality Water Supply Study has been completed, the final report is not yet available from the WQCD.

- **Mountain Pine Beetle (MPB) Infestation.** Areas of Larimer County infested by MPB continued to increase in 2010. The 2010 USFS Forest Health Aerial Survey showed rapid eastward spread of the MPB from the Continental Divide into lower elevation Lodgepole and Ponderosa pine stands along the Northern Colorado Front Range. The Upper Cache la Poudre watershed is located within this area of high forest mortality.

- **Upper CLP Wildfire Watershed Assessment.** In 2010, the City of Fort Collins and the City of Greeley jointly funded the Cache la Poudre Wildfire Watershed Assessment Project conducted by J.W. Associates Inc. The susceptibility of water supply infrastructure in the Upper CLP watershed to impacts from severe wildfires was evaluated, with an emphasis on impacts from debris/sediment flow. The project included an opportunities and constraints analysis to help prioritize possible opportunities for active management to reduce potential impacts in zones of concern. The full report is available at: http://www.jw-associates.org/Projects/Poudre_Main/Poudre_Main.html. The next steps in the process include meeting with stakeholders to further evaluate the possible opportunities, and identifying grants or other funding sources to support site-specific design and implementation.

Significant Results

Mainstem and North Fork

- Peak 2010 stream flows on the Mainstem were nearly two times greater than observed over the previous three years. Peak 2010 North Fork stream flows, while lower than in 2008, were still considerably higher than in 2007 or 2009.
- In general, water from the North Fork basin was warmer with higher levels of dissolved constituents than the Mainstem, which was reflected by higher levels of hardness, conductivity, alkalinity, and major ions. In both drainages, these characteristics increased with decreasing elevation. Across all sites, minimum values occurred during periods of high flow due to the diluting effect of snowmelt runoff.
- Turbidity peaked at all sites during spring run-off. In contrast to previous years, 2010 turbidity values on the Mainstem were similar to the North Fork sites, due in large part to the unusually high spring runoff on the Mainstem.
- Peak total organic carbon (TOC) concentrations occurred during peak run-off across the watershed. The highest value was observed at the highest elevation site, Poudre above Joe Wright Creek (PJW), and was significantly higher than in previous years. Mainstem TOC decreased to low levels following runoff, while the North Fork exhibited persistently elevated TOC concentrations during periods of low flows, as also seen in previous years.
- As in previous years, Mainstem nutrient concentrations were generally low during non-runoff times of the year. The Poudre above Joe Wright (PJW) consistently experienced higher nitrate concentrations than lower-elevation sites on the Mainstem with values similar to North Fork sites. In 2010, peak nitrate concentrations at PJW were significantly higher than in previous years.
- 2010 peak concentrations of total kjeldahl nitrogen (TKN) and total phosphorus (TP) on the Mainstem Poudre above the North Fork (PNF) site were considerably higher than in previous years, most likely due to greater amounts of suspended sediments that accompanied the unusually high spring snowmelt runoff.
- The North Fork generally had higher concentrations of total phosphorus, ortho-phosphate, and TKN than Mainstem sites during non-runoff times of the year. The influence of Seaman Reservoir on downstream water quality was particularly evident during the summer months, as reflected by spikes in total phosphorus and ortho-phosphate concentrations on the North Fork at the gage below Seaman Reservoir (NFG).
- *Giardia* was more abundant than *Cryptosporidium* on both the Mainstem and the North Fork. *Giardia* concentrations were similar to the previous three years. *Cryptosporidium* was only detected once at very low concentrations on the Mainstem (PNF) in both 2009 and 2010, values which represented a decrease from 2007 and 2008.
- *E.coli* and total coliform concentrations on the Mainstem (PNF) and North Fork sites were generally higher than in previous years. The North Fork consistently experienced much higher concentrations of these indicators of pathogenic bacteria

than the Mainstem. There were no consistent relationships observed between *E.coli* or total coliform concentrations at NFL, NFG and in Seaman Reservoir.

Seaman Reservoir

- Seaman Reservoir became thermally stratified during the summer of 2010, but later in the season than in previous years. The hypolimnion experienced a period of near-zero dissolved oxygen (D.O.) concentrations, as seen in previous years.
- During the early stages of thermal stratification, in June and July, a D.O. minimum was observed in the metalimnion, but was absent by the August sampling date. A similar pattern of profile development was observed in 2009.
- Spikes in turbidity and nutrients (except nitrite) occurred in Seaman Reservoir during the late summer, and were similar to late season spikes observed in the previous three years.
- TOC concentrations in Seaman Reservoir show a gradual increasing trend from 2007 through 2010.
- Seaman Reservoir trophic status can be characterized as mesotrophic to eutrophic, based on 2010 chlorophyll-a values.
- Geosmin concentrations at the bottom of Seaman Reservoir were at or above the odor threshold, as in previous years and reached a peak concentration of 37 ppt in August. Geosmin data for the top of the reservoir was not available for the August sampling event.
- Blue-green algae were prevalent in Seaman Reservoir during the late summer. In August, over 78% of the blue-green algal density was comprised of known geosmin-producing genera.

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LIST OF ABBREVIATIONS & ACRONYMS

#/100 mL	number per 100 milliliters
%	percent
Ag	Silver
BMR	Barnes Meadow Outflow (routine monitoring site)
Ca	Calcium
Cd	Cadmium
CDPHE	Colorado Department of Public Health and Environment
CDWR	Colorado Division of Water Resources
CEC	Contaminant 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
DOM	Dissolved Organic Matter
EDC	Endocrine Disrupting Chemical
EEM	Excitation and Emission Matrix
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
FCU	Fort Collins Utilities
FCWQL	Fort Collins Water Quality Lab
FCWTF	Fort Collins Water Treatment Facility
Fe	Iron
GPS	Global Positioning System

HAA5	Haloacetic Acid
HAA5FP	Haloacetic Acid Formation Potential
HSWMP	Halligan-Seaman Water Management Project
ISDS	Individual Sewage Disposal System
JWC	Joe Wright Creek above the Poudre River (routine monitoring site)
K	Potassium
kDa	kiloDalton
L/mg-m	Liter per milligram meter
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
MPB	Mountain Pine Beetle
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
nm	nanometers
NO_2	Nitrite
NO_3	Nitrate

NTU	Nephelometric Turbidity Units
^{o}C	degrees Celsius
PARAFAC	Parallel Factor Analysis
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)
PCP	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
PRAM	Polarity Rapid Assessment Method
PWSR	Protected Water Supply Reservoir
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)
SHAA5FP	Specific Haloacetic Acid Formation Potential (HAA5FP/DOC)
SO_4	Sulfate
STTHMFP	Specific Total Trihalomethane Formation Potential (TTHMFP/DOC)
SUVA	Specific UV Absorbance (UV_{254}/DOC)
SWAP	Source Water Assessment and Protection program
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
TTHM	Total Trihalomethane

TTHMFP	Total Trihalomethane Formation Potential
UCLA	University of California, Los Angeles
ug/L	micrograms per liter
UL	Underwriters Laboratories
uS/cm	microSeimens per centimeter
USFS	United States Forest Service
USGS	United States Geological Survey
UV_{254}	Ultraviolet absorbance at 254 nm
WQCD	Water Quality Control Division
WQL	Water Quality Lab
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 Cache la Poudre River Collaborative Water Quality Monitoring Program. The Program was subsequently implemented in spring 2008. The over arching 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 impound 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 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.

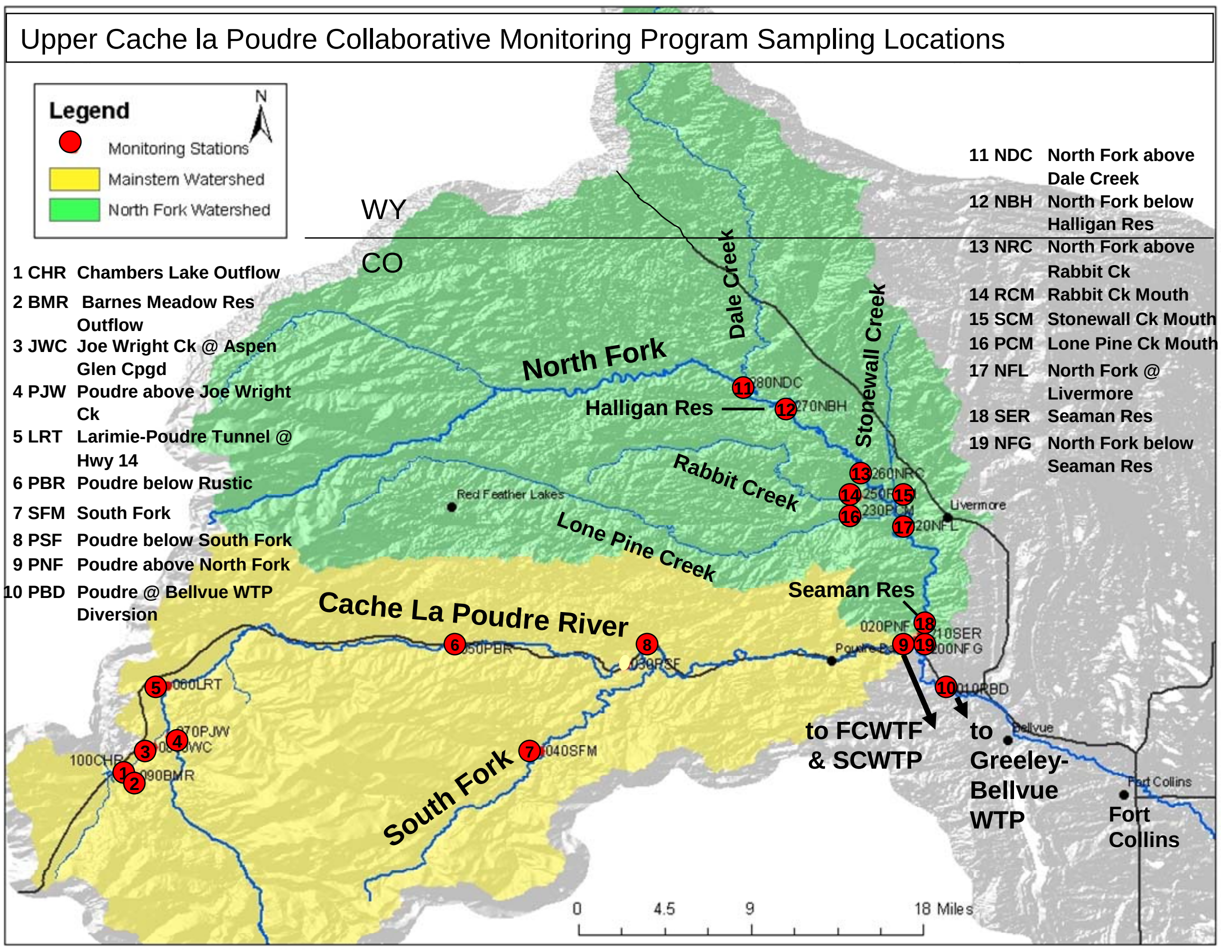
Annual and five-year reports for the collaborative program are prepared by City of Fort Collins staff to keep participants abreast of current issues and trends in water quality of the Upper CLP. The purpose of annual reports is to summarize hydrologic and water quality information for the current water 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 reports will provide a more in-depth analysis of both spatial and temporal trends in watershed hydrology and water quality, including concentrations and loads.

1.2 Watershed Description and Sampling Locations

Sampling efforts are divided between the Mainstem and North Fork Poudre River drainages. 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 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. 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 from the City of Fort Collins, City of Greeley, and Tri-Districts collect samples at the remaining two locations: North Fork Poudre above confluence with Dale Creek (NDC) and North Fork Poudre below Halligan Reservoir (NBH). Sampling methods, including those for the collection of field measurements for temperature, pH, conductivity, and dissolved oxygen 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 2010. 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 2010 Annual Report

The 2010 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 2010 with the previous three years 2007-2009. Data for 2007 were obtained from the historic City of Fort Collins and City of Greeley sampling program records.

2.0 SIGNIFICANT EVENTS, ISSUES OF CONCERN & SPECIAL STUDIES

2.1 Attached Algae Bloom in Poudre River

During the summer of 2010, an attached algae bloom occurred along the middle reaches of the Mainstem Poudre River, from areas near Big Bend Campground and the State fish hatchery to downstream around Indian Meadows, which corresponds to the Upper CLP monitoring site, Poudre below Rustic (PBR). The 2010 algae bloom was similar in location and severity to the 2009 algae bloom. From July through November, samples from this general area were collected from rock surfaces and identified by Dick Dufford. Dense mats of dried filamentous algae covered rocks along the river banks in areas where high flows had receded, and live green algae was observed in areas of flowing and standing water (Figures 2.a & 2.b). As in 2009, the dominant form of algae was identified as the green algae, *Ulothrix* (sp) (Figure 3). Although algal blooms typically occur in response to increased nutrient availability, there was no evidence of elevated nutrient concentrations at PBR or upstream locations from June through September (See Section 2.2, Figure 6 (a-h)).

No taste and odor (T&O) issues were experienced at the treatment plants during this time. This indicates that potential off-taste and odor compounds (including geosmin) were not strongly associated with this algae bloom, or were adequately volatilized, degraded, and/or diluted prior to reaching the raw water intakes.

The dense mats of aquatic weeds that were observed on the North Fork below Halligan Reservoir in 2009 and previous years were not present in 2010.

Figures 2.a. and 2.b. Attached algae on Mainstem of the Poudre.

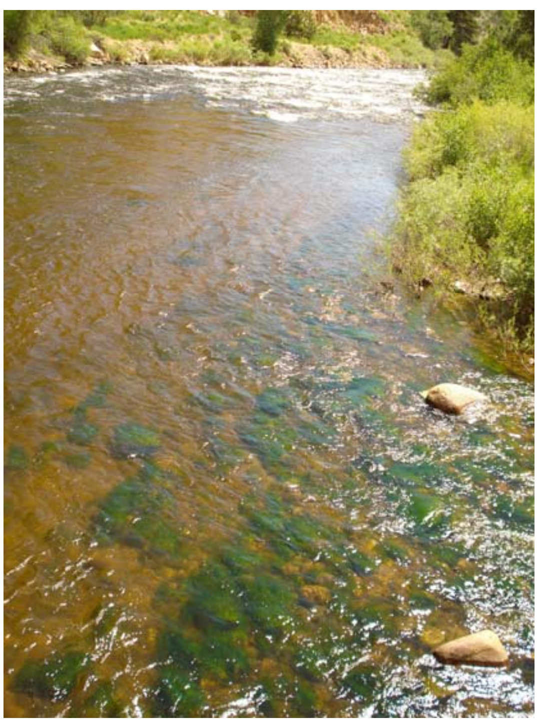


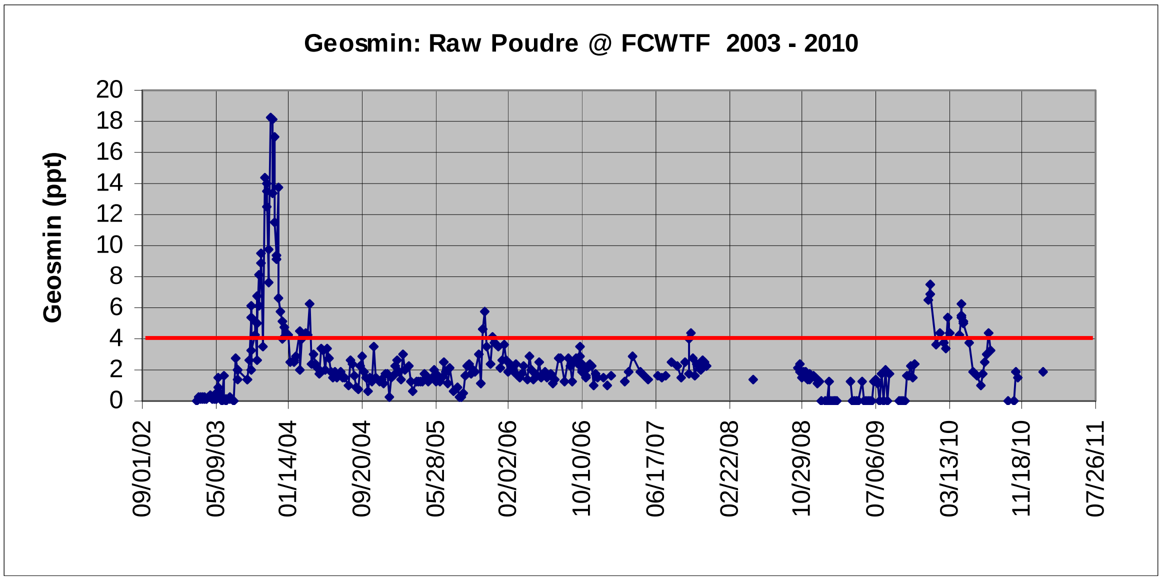
Figure 2.a. Live attached alage on rocks near Poudre Below Rustic (PBR) monitoring site in June 2010.

Figure 2.b. Dried algae on rocks near Eggers Fishing area in September 2009.

2.2 Poudre River Geosmin Episode

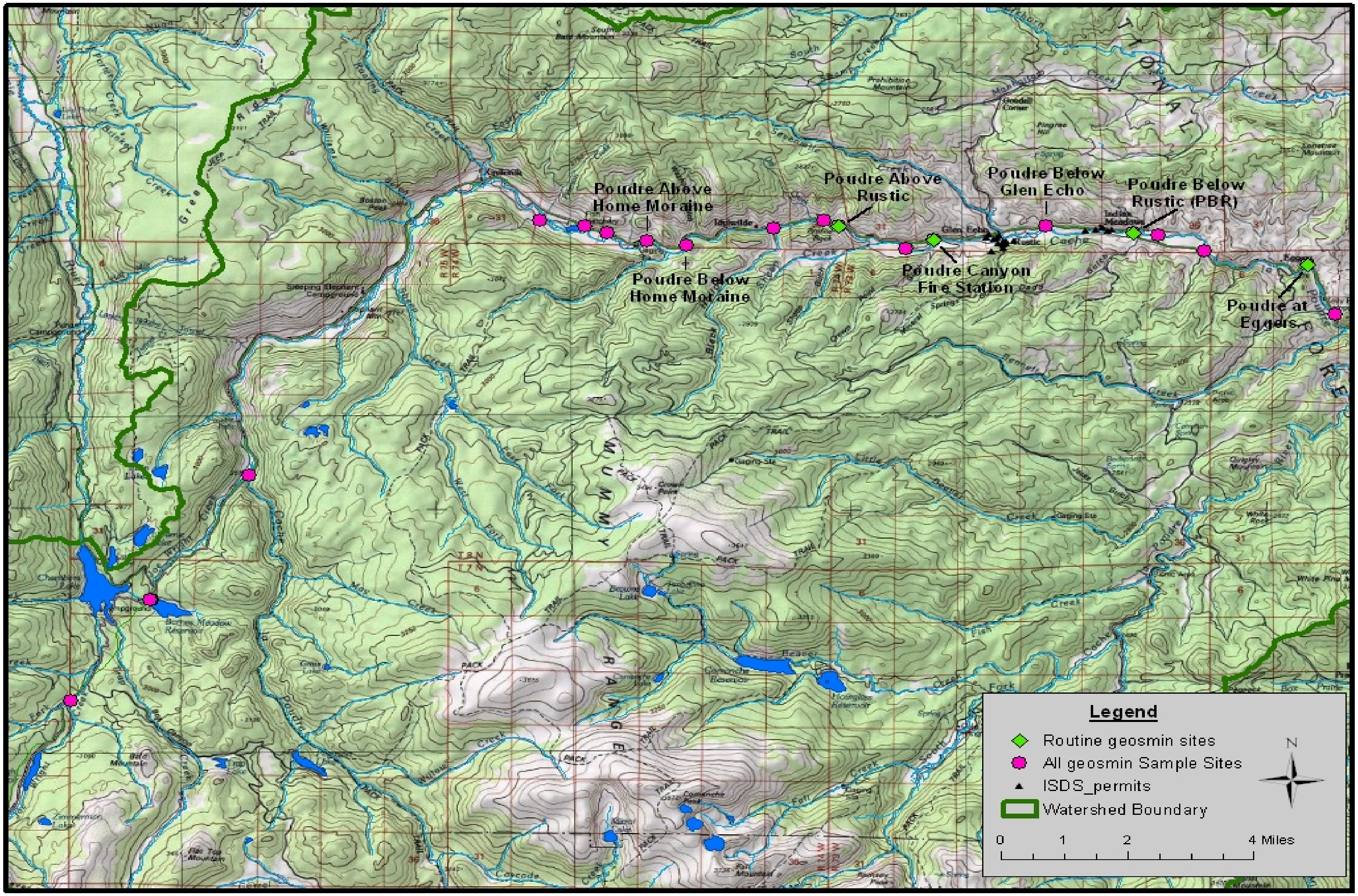
Geosmin is a naturally occurring organic compound that imparts an earthy odor to water and can be detected by the most sensitive individuals at concentrations as low as 4 nanograms per liter (ng/L) or 4 parts per trillion (ppt). Geosmin does not pose a public health risk, but its detectable presence can negatively affect customer confidence in the quality of drinking water. The Poudre River raw water supply is routinely monitored for geosmin concentrations from January through December. As shown in Figure 3, the Poudre River raw water supply has experienced periodic episodes of elevated geosmin concentrations above the 4 ppt odor threshold over time. In 2010, geosmin concentrations in raw Poudre River water at the FCWTF increased abruptly between November 2009 and January 2010 and peaked at 7.53 ppt on January 5, 2010. Geosmin concentrations remained near or above 4 ppt through the beginning of May, and then dropped below the 4 ppt threshold for the duration of 2010, with one exception (at 4.4 ppt) in July.

Figure 3. Geosmin concentrations in raw Poudre River water supply at the FCWTF from 2003-2010.



In response to the elevated geosmin in the raw Poudre River water in 2010, intensive sampling on the Mainstem of the Poudre River was initiated in January 2010 to evaluate in-stream concentrations and delineate the approximate area of elevated geosmin concentrations along the river. Geosmin sampling initially focused on the area upstream and downstream of Rustic based on the location of the summer algae bloom and the prevalence of seasonal and year-round housing, the State of Colorado Division of Wildlife Fish Hatchery, and camping facilities in the area. Reconnaissance sampling spanned from below Joe Wright Reservoir downstream to Eggers Fishing Area. The area of highest geosmin concentrations was found to extend from approximately one-quarter mile above Rustic, near the Poudre Canyon Chapel downstream to the Eggers Fishing area (Figure 4).

Figure 4. Map of 2010 Poudre River geosmin sampling sites.



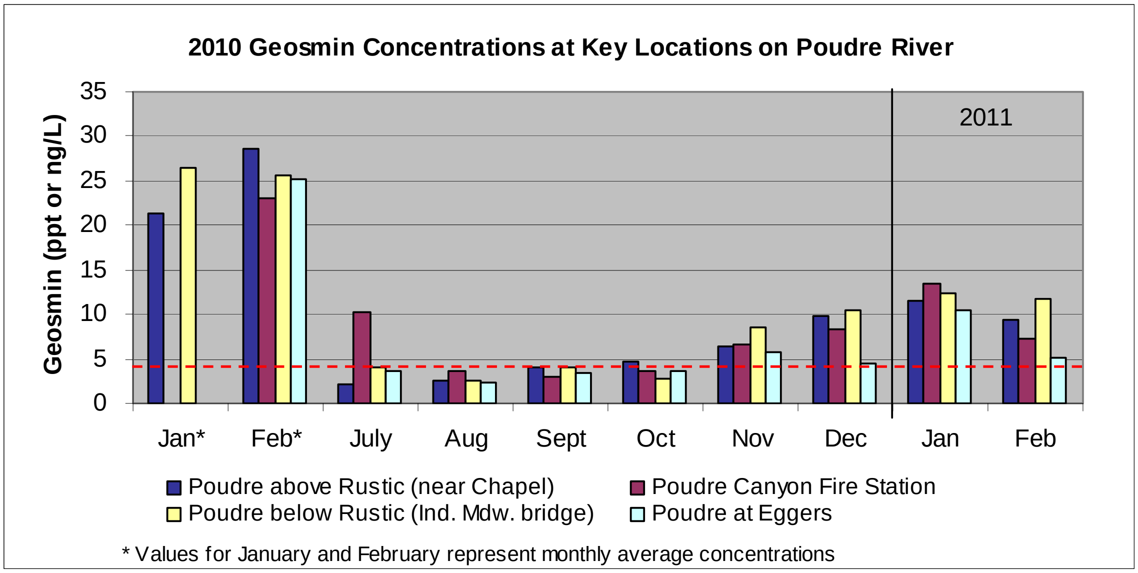
Four routine monitoring sites were selected within the delineated area and included Poudre above Rustic (near Chapel), Poudre at Poudre Canyon Fire Station (mile marker 90), Poudre below Rustic (PBR) and Poudre at Eggers fishing area. Initial concentrations within this segment of the river ranged from 20.61 ppt at Poudre Canyon Fire Station (2/3/10) to 38.14 ppt at the Poudre below Rustic (PBR) site at Indian Meadows (1/21/10). This area of high geosmin production corresponds to the stretch of river where the attached algae bloom occurred in the summers of 2009 and 2010, although it is not known at this time if the two issues are related.

Nutrients were added to the sampling program in February to determine whether elevated nutrients were available to stimulate geosmin-producing algae growth. Periphyton samples were collected monthly beginning in July at the four main locations within the identified area of concern. Note that periphyton sampling is not possible in the winter and early spring due to the ice cover. The algae samples were identified to the species level when possible and qualitatively ranked for abundance.

Total coliform and *E.coli* analyses were added to the sampling program in August to help determine whether leaking septic systems and septic vaults associated with single-family homes, campgrounds and rental cabin properties were possible sources of nutrients to the river. During the August sampling event, three additional sites that were upstream and downstream of permanent and seasonal residential developments were sampled. These sites included above and below Home Moraine residential area, and below the Glen Echo Resort. To better assess these potential sources of nutrients, all available individual sewage disposal system (ISDS) permits for the area of interest were obtained from the Larimer County Department of Health and Environment and mapped where possible. Twenty ISDS permit locations were identified for this area (Figure 4).

Results show that late summer and fall geosmin concentrations (2.17 to 10.22 ppt) decreased considerably from the high concentrations observed in January and February (20.61 to 38.14 ppt) (Figure 5). Between July and October, concentrations generally remained below 4 ppt at all four sites, but increased again during the winter months. From November 2010 to January 2011, peak monthly concentrations ranged from 8.49 to 13.45 ppt; however, concentrations at the FCWTF Poudre intake remained below 2 ppt during this time (Figure 3) likely due to the biodegradation, volatilization, and/or dilution processes occurring in the 25 miles between the Rustic area and the FCWTF Poudre intake. There were no consistent upstream to downstream trends in concentration observed.

Figure 5. 2010 geosmin concentrations at key locations on the Poudre River.



Nutrient data did not show any consistent upstream to downstream trends that would indicate significant nutrient sources along this segment of the river. All parameters were within the ranges seen at the routine Upper CLP monitoring sites, and were often not detected above reporting limits (Figure 6.a -6.f). Some of the differences in concentrations observed between sites may reflect localized sources of nutrients, but their effect is small, and when available, it is expected that the nutrients would be rapidly assimilated by stream biota. It is also possible that some of the differences observed between sites may be due to analytical detection error and may not reflect actual differences in conditions. Geosmin appeared to follow a similar seasonal trend as nitrate concentrations at Poudre above Rustic and Poudre Canyon Fire Station sites, and to a lesser degree at the lower two sites (Figure7.a - 7.d). There were no apparent relationships between geosmin and any other nutrient parameters.

E. coli and total coliform data (Figures 6.g and 6.h) showed elevated summer concentrations relative to fall and winter. In August, *E. coli* concentrations were much higher above and below Home Moraine (230.6 and 176.4 cells/100ml, respectively) than at the other routine geosmin sampling sites, but similar to those seen downstream at PNF (216.2 cells/100ml on 8/2/10). Total coliform concentrations among the geosmin sampling sites were similar and were also within the range of concentrations seen at the routine Upper CLP watershed monitoring sites. While the significantly higher concentrations of *E.coli* at the Home Moraine sites may indicate the presence of leaking septic system upstream, the nutrient data do not lend evidence for this possibility. Furthermore, elevated concentrations of *E.coli* and total coliforms are expected during the summer months due to the high levels of summer recreational activity on the river.

Figures 6 (a-h). Nutrient, *E.coli* and Total Coliform concentrations at key geosmin monitoring sites on the Mainstem CLP.

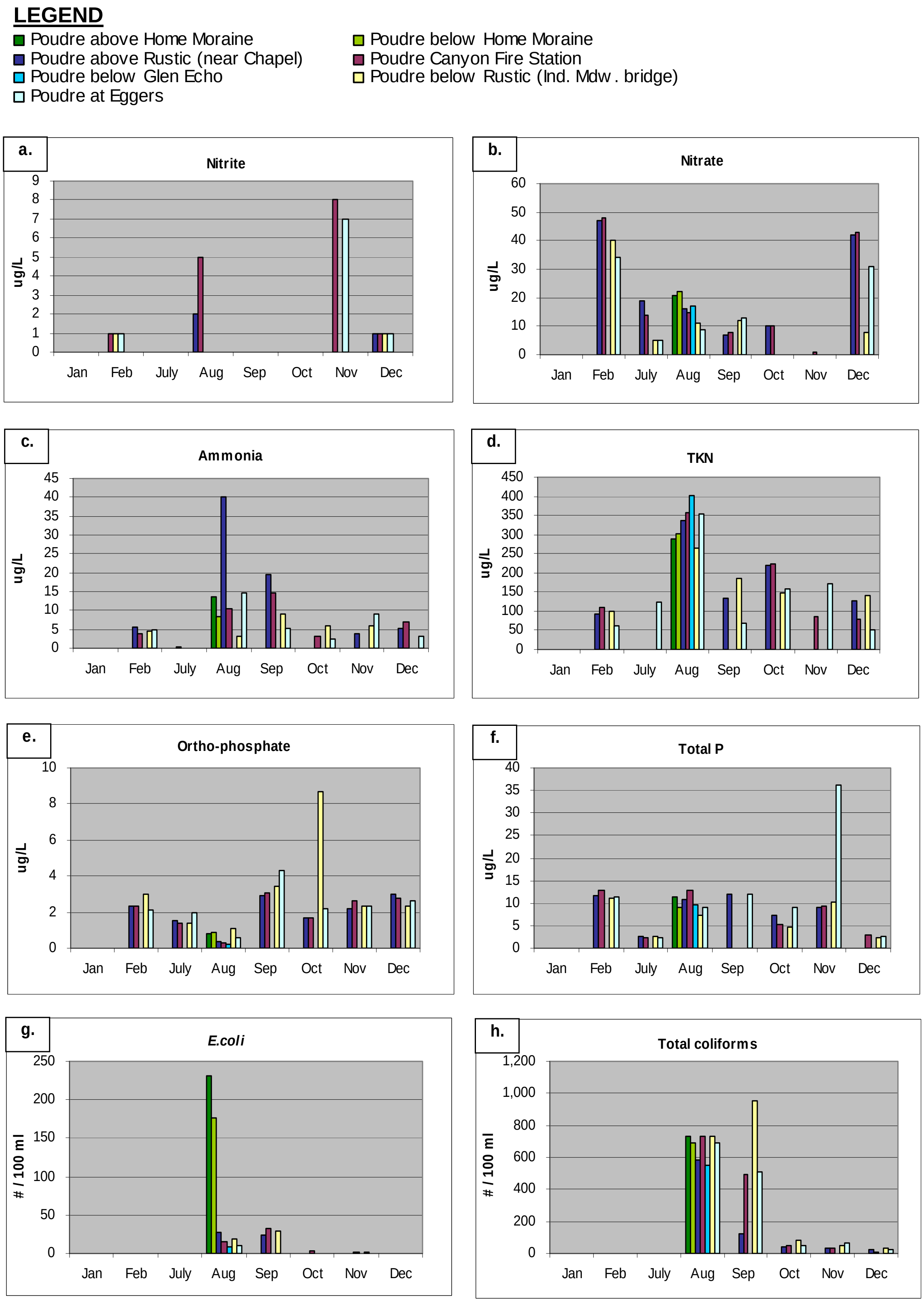
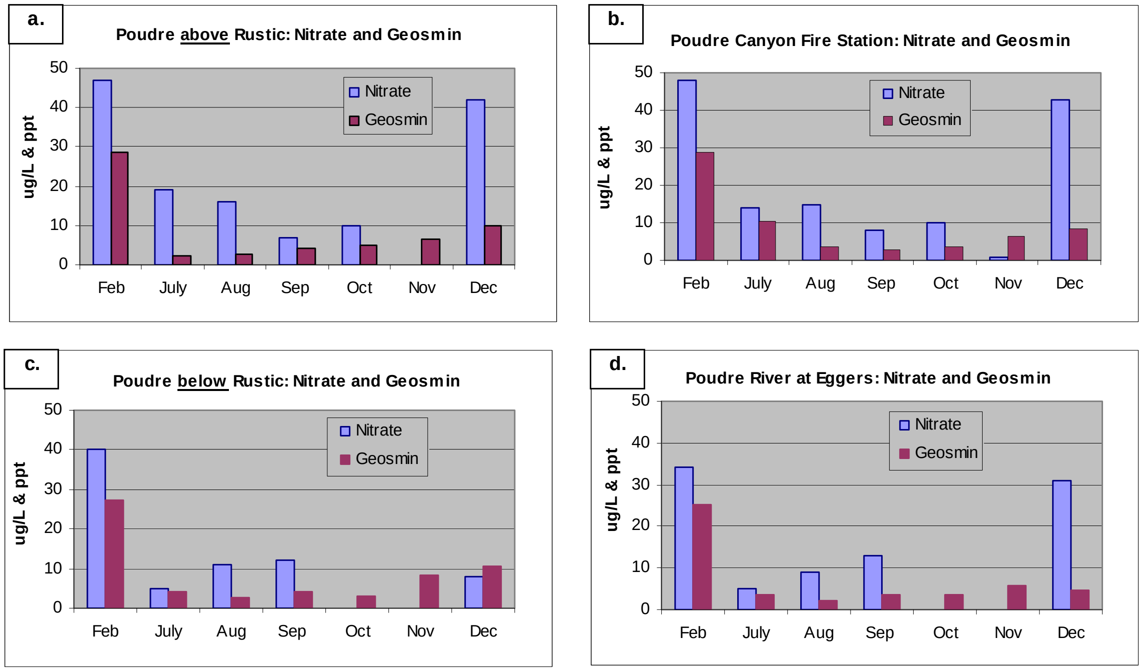


Figure 7(a-d). Nitrate and geosmin concentrations at key geosmin monitoring sites on the Mainstem CLP.



Periphyton data collected in 2010 identify the species of periphyton present at different times of the year and an indication of their relative abundance by rank for a particular sampling event (Attachment 6). They do not, however, provide information about the population densities throughout the year. In general, the periphyton community for this segment of the Poudre River was dominated by green algae *Ulothrix sp.* and diatoms, including *Didymosphenia geminate*, while the known geosmin-producing cyanophytes were relatively rare. The known geosmin-producing species that were identified in 2010 were *Oscillatoria tenuis*, *Pseudanabaena catenata*, *Pseudanabaena limnetica and Pseudanabaena sp. (*Juttner and Watson, 2007). Typically, there were only one or two geosmin-producing species present on a given sampling date. The most frequently occurring geosmin-producing cyanbacteria was *Psuedanabaena sp*., which occurred in the majority of 2010 samples.

The Upper CLP geosmin monitoring plan is currently being revised to guide geosmin-related sampling activities in 2011and beyond. The ultimate goal of a comprehensive monitoring program would be to provide an in-depth understanding of geosmin occurrence, sources, transport and fate in the Upper CLP such that: 1) future geosmin episodes in raw Poudre River water at the water treatment plants could be predicted and/or be preceded by an improved early warning system, and 2) if possible, appropriate watershed management activities could be identified and implemented for its control. Monitoring activities could potentially include the analysis of sediment, water and biofilm samples for geosmin-producing species of actinomycetes and cyanobacteria; analysis of watershed soils and leaf litter to assess terrestrially produced geosmin and its potential to enter the river; and evaluation of factors that affect biodegradation and volatilization of geosmin from the river. However, these types of activities are very difficult to conduct and are likely most suitable for a university research project. At a more basic level, there is still an incomplete understanding of the range of geosmin occurrence along the length of the Mainstem Upper CLP down to the treatment plant intakes. Monitoring to date has focused in the Rustic area (Figure 4) and in raw Poudre River water at the FCWTF. The occurrence of geosmin within the 25 miles between the Rustic area and the water treatment plant intakes is currently unknown. It may be that geosmin sources closer to the treatment plant intakes are responsible for geosmin issues at the treatment plants. Monitoring in 2011 will include geosmin sampling at sites on the Mainstem between Rustic and the treatment plant intakes, and geosmin sampling of the North Fork at the gage below Seaman Reservoir. Monitoring in 2011 will also include a quantitative assessment of the periphyton community, identification of potential geosmin producing species of cyanobacteria, and continued sampling for nutrients and bacteria. Fish hatchery effluent and individual sewage disposal systems will be further evaluated as potential nutrient sources for geosmin-producing organisms.

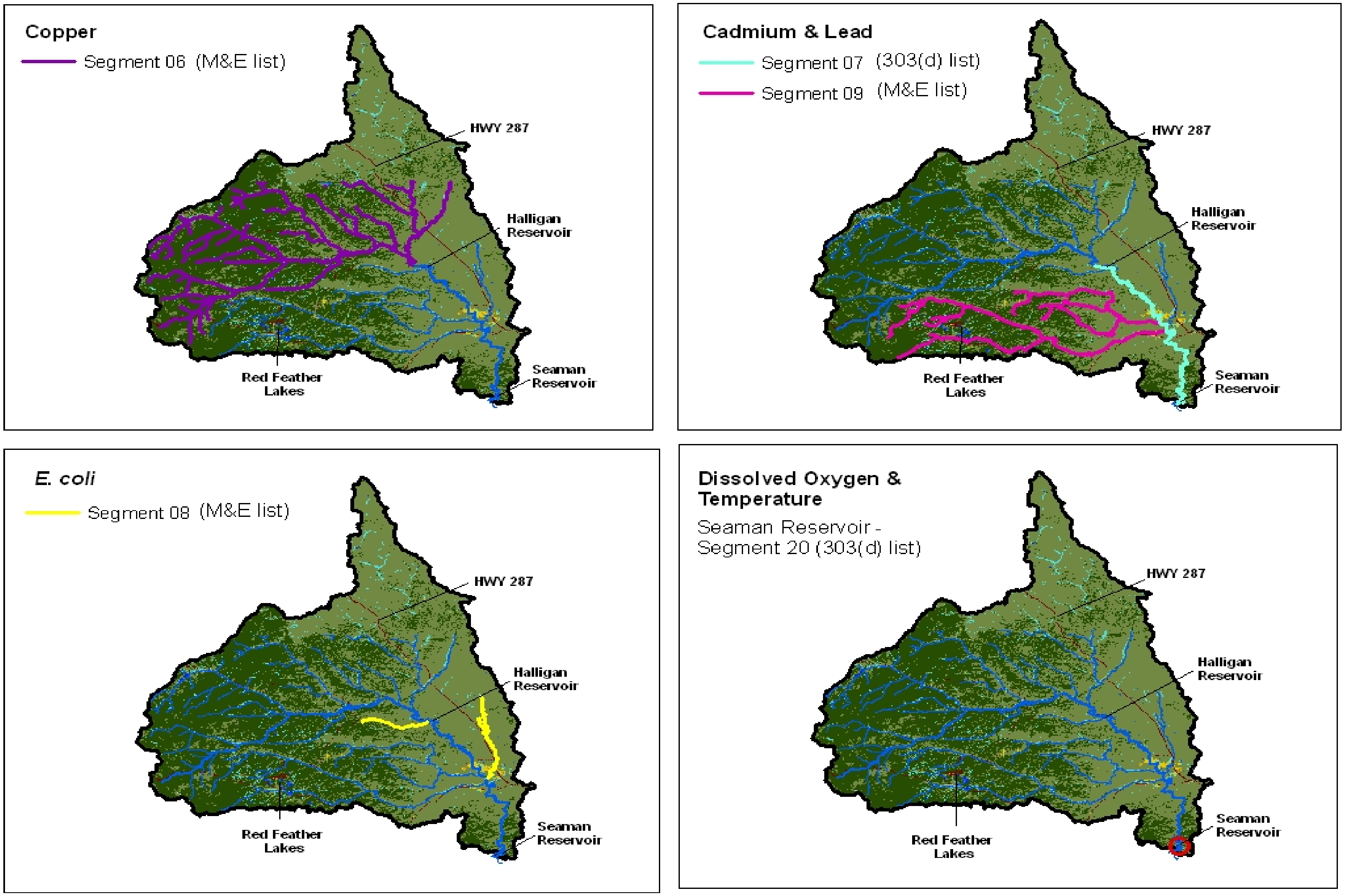
2.3 Colorado's 2010 Section 303(d) and Monitoring and Evaluation (M&E) Lists

Colorado's 2010 Section 303(d) List of impaired waters and 2010 Monitoring and Evaluation (M&E) List were adopted on March 9, 2010 and became effective on April 30, 2010. Segments of the North Fork of the Cache la Poudre River are included on both lists as outlined on Table 1 and shown on Figure 8. Segments with a 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 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 on the M&E List.

Table 1. Summary of Upper CLP segments on Colorado's 2010 Section 303(d) List of Impaired Waters and 2010 Monitoring and Evaluation (M&E) List

Segment	Segment Description	Portion	Monitoring & Evaluation Parameters	Section 303(d) Impairment	303(d) Priority
COSPCP06	Mainstem of the North Fork, including all tributaries from the source to inlet of Halligan Res.	all	Copper		
COSPCP07	Mainstem of the North Fork from Halligan Reservoir to confluence with CLP River.	all		Cadmium, Lead	Medium
COSPCP08	All tributaries to the North Fork from Halligan Res to confluence with CLP River, except for listings in Segment 9.	all	*E.Coli*		
COSPCP09	Rabbit Creek & Lone Pine Creek from the source to the confluence with the North Fork	all	Cadmium, Lead		
COSPCP20	All lakes and reservoirs tributary to the North Fork, from Halligan Resevoir to confluence with CLP River.	Seaman Reservoir		dissolved oxygen	Medium

Figure 8. Upper CLP segments on Colorado's 2010 Section 303(d) List of Impaired Waters and 2010 Monitoring and Evaluation (M&E) List .



2.4 Dissolved Organic Matter (DOM) Studies

Dissolved organic matter (DOM) (commonly measured as Total Organic Carbon (TOC)) is one of the most important water quality parameters for the source waters of the FCWTF, SCFP, and the Greeley Bellvue WTP. DOM is important because it can affect the optimization and efficiency of water treatment unit operations including coagulation and settling, and serves as the precursor for the formation of disinfection by-products (DBPs). DOM is a complex mixture of many different naturally occurring organic compounds, and measurements of bulk TOC do not tell us anything about the nature, source, composition, structure, or reactivity of the DOM. Additional (and sometimes more sophisticated) laboratory analysis is required to obtain information about the characteristics of DOM.

2.4.1 Overview of DOM Studies

A DOM characterization study was conducted in 2008 by Dr. Mel Suffet (Professor of Environmental Health Sciences at UCLA) and was jointly funded by the City of Fort Collins, City of Greeley, Tri-Districts, and the Northern Colorado Water Conservancy District. The study area included two sites within the Upper CLP watershed (PNF – Poudre above North Fork, and NFG – North Fork at gage below Seaman Reservoir) as well as Horsetooth Reservoir and associated components of the CBT Project. Laboratory analyses and parameters investigated for this study included:

- **Total Organic Carbon (TOC):** TOC for this study was determined at the FCWTF Process Control Laboratory using a Sievers 5310C Laboratory TOC Analyzer.

- **Ultraviolet absorbance at 254 nm (UV_{254}):** measures the amount of light absorbed at a wavelength of 254 nm; indicates presence of humic substances and aromatic (ringed organic molecules) groupings.

- **Specific UV Absorbance (SUVA):** SUVA (L/mg m) = (UV_{254}/DOC) x 100 ; SUVA> 4 indicates high humic character, hydrophobic organics, aromatic, high molecular weight; SUVA < 2 indicates mostly non-humic, aliphatic characteristics (long-chain organic molecules), hydrophilic, low molecular weight; 2< SUVA <4 indicates a mix of DOM.

- **Fluorescence Spectroscopy:** measures the presence of humic-like and protein-like compounds and other DOM characteristics, and can be used to distinguish the origin of DOM (between terrestrial and algal sources). Fluorescence measurements for the 2008 UCLA Study were conducted at the University of Colorado at Boulder (CU). Three-dimensional fluorescence excitation and emission matrices (EEMs) were collected at CU and used to calculate several fluorescence parameters (Overall Fluorescence Intensity, Peak C Intensity, Peak C Location, Fluorescence Index, Redox Index).

- **Ultrafiltration:** molecular size (or weight) characterization. Ultrafiltration uses membranes with different pore sizes to quantify the fractions of DOM according to their molecular weight (<1 kDa, 1-5 kDa, 5-10 kDa and >10 kDa, where kDa is kiloDalton, and fractions > 5kDa are considered to be high molecular weight). Ultrafiltration in conjunction with DOC and UV_{254} analysis allows for the tracking of individual size fractions in the watershed and treatment plant. Higher molecular weight DOM is generally easier to remove by coagulation.

- **Polarity Rapid Assessment Method (PRAM):** polarity characterization. The polarity of DOM (charge and functional group content) influences its reactivity with coagulants and chlorine. PRAM was used in this study to characterize the polarity and charge of DOM by quantifying the amount of material adsorbed onto different solid-phase extraction sorbents (polar, non-polar and anionic sorbents).

- **Total Trihalomethane Formation Potential (TTHMFP):** TTHMFP is a measure of the presence of DBP precursors and reactivity of DOM to chlorine. Samples were analyzed for TTHMFP by the City of Fort Collins Water Quality Lab (Standard Methods 5710 and 4500-Cl.C.3m) and allowed for correlations to be tested and established between specific DOM characteristics and the presence of DBP precursors.

- **Specific TTHMFP (STTHMFP):** calculated by dividing TTHMFP concentration by the TOC concentration; STTHMFP provides information on the amount of TTHM formed per mg of TOC present in the sample.

A second study that built on the 2008 UCLA Study was funded in 2009 by the City of Fort Collins and the Water Research Foundation as a Tailored Collaboration Project with Dr. Scott Summers and other researchers at the University of Colorado at Boulder (CU): Water Research Foundation Project 04282 "Watershed Analysis of Dissolved Organic Matter and the Control of Disinfection By-Products." This project included the same study area as the 2008 UCLA Study, but focused on the use of fluorescence parameters and three-dimensional fluorescence EEMs to develop relationships between DOM characteristics in the watershed and DBP formation at the FCWTF. Laboratory analysis was also conducted for TOC, UV_{254}, TTHMFP (formed after 24 hours under uniform formation conditions), haloacetic acid formation potential (HAA5FP; formed after 24 hours under uniform formation conditions), and chlorine residual. Several parameters were calculated from the EEM data including overall fluorescence intensity, Peak A Intensity, Peak C Intensity, Fluorescence Index, and Humification Index. Parallel factor analysis (PARAFAC) modeling was used to statistically decompose the EEMs into individual or groups of fluorescent components to provide more information about the origin and character of DOM. This study only included the PNF (Poudre above North Fork) site within the Upper CLP watershed.

2.4.2 Summary of Upper CLP Results

2008 UCLA Study Results. Fluorescence analysis results for the 2008 UCLA Study, along with the TOC, UV_{254}, SUVA, TTHMFP, and STTHMFP data, are presented in detail in Chapter 3 of Beggs (2010). The findings from the ultrafiltration and PRAM analysis conducted at UCLA are still pending. The TOC, UV_{254}, SUVA, TTHMFP, STTHMFP, and fluorescence data indicate the following with respect to the Upper CLP watershed (PNF and NFG sampling sites):

- **Time Series Plots:** The 2008 UCLA Study data set shows the typical increase in TOC during the spring runoff period (Figure 9-A). The peak in TOC during the runoff period was associated with increases in UV254, SUVA, and TTHMFP (Figures 9-B,C, and D, respectively).

- **Specific TTHMFP and DOM reactivity with chlorine:** Specific TTHMFP data (Figure 9-E) suggest that the main stem DOM is more reactive with chlorine than the North Fork DOM during both spring runoff and non-runoff seasons (i.e., more TTHM formed per mg TOC for the main stem). The data also indicate that, for both the main stem Poudre and the North Fork sites, the DOM is more reactive with chlorine during the spring runoff than other times of the year (there are more TTHM precursors available during the spring runoff).

- **Relationships with TTHMFP:** Bulk TOC and UV254 are both strongly correlated to TTHMFP (Figure 9-F and G) and therefore serve as good predictors of TTHMFP. The relationship between SUVA and TTHMFP is not very strong (Figure 9-H), with high SUVAs exhibiting a large range of TTHMFPs; SUVA is not a good predictor of TTHMFP. Note that the correlations for NFG appear strong, but the NFG data set only consists of four sampling dates.

- **Fluorescence Parameters during Runoff:** Fluorescence parameters obtained during the spring runoff season indicate that both the main stem Poudre and the North Fork are dominated by aromatic, terrestrially derived DOM.

- **Fluorescence Parameters during non-Runoff Seasons:** Fluorescence parameters obtained during the non-runoff seasons indicate that the North Fork DOM is more microbial, less aromatic, and more oxidized than the non-runoff main stem DOM. Differences in watershed characteristics as well as reservoir processes (including photobleaching and algal activity) may contribute to the differences in character between the main stem Poudre and the North Fork DOM during non-runoff seasons.

Water Research Foundation/CU Study Results. Results of the fluorescence analysis conducted for the Water Research Foundation/CU Study are presented in Chapters 4 and 5 of Beggs (2010). A formal Water Research Foundation report that presents the results and findings for all project tasks is expected in 2012.

The data from the Water Research Foundation/CU Study are consistent with the findings of the 2008 UCLA Study. The data show that DOM from the Upper CLP site is dominated by humic-like (terrestrial) components. The humic-like components make up the chlorine reactive fraction of the DOM as measured by chlorine demand and DBP formation. While humic-like components exhibited strong positive correlations with

TTHM and HAA5 formation, coagulation is effective at removing the material associated with DBP formation (primarily humic-like components).

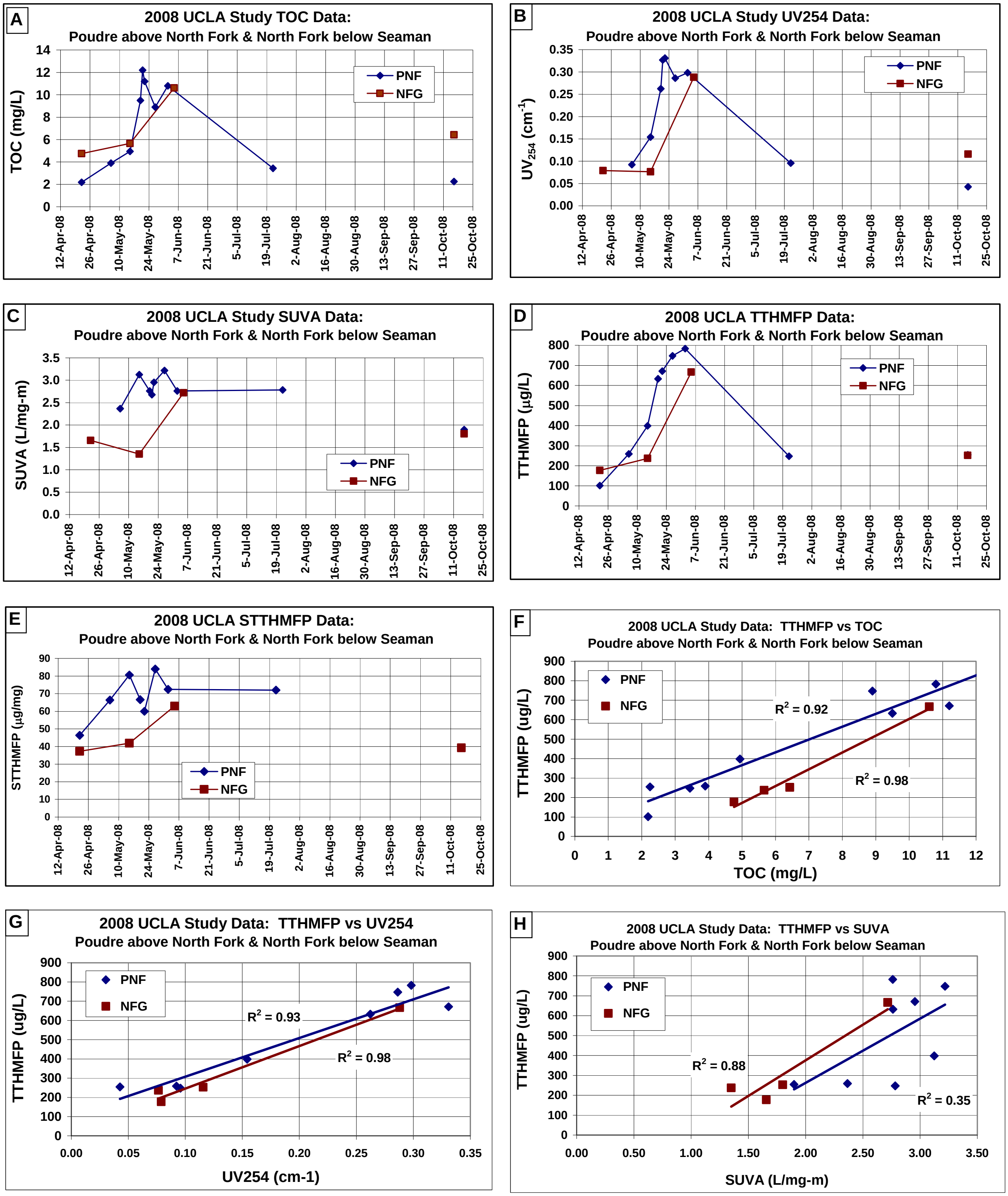


Figure 9(A-H). 2008 UCLA DOM Study Data: Plots of TOC, UV254, SUVA, TTHMFP and STTHMFP data collected for the main stem Poudre above the North Fork (PNF) and the North Fork at the gage below Seaman Reservoir (NFG)

2.5 Northern Water Collaborative Emerging Contaminant Study

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

- Personal care products (PCPs): fragrances, sunscreens, insect repellants, detergents, household chemicals
- Pharmaceuticals: prescription and non-prescription human drugs (including pain medications, antibiotics, β-blockers, anti-convulsants, etc) and veterinary medications
- Endocrine disrupting chemicals (EDCs): 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 initiated a collaborative emerging contaminant study to determine the presence of these compounds in waters of the Colorado- Big Thompson system. In 2009, two sites on the Upper Cache la Poudre (Poudre above North Fork (PNF), and North Fork at gage below Seaman Reservoir (NFG)) were added to the study with funding provided by the City of Fort Collins and the City of Greeley. The Poudre above North Fork site has been sampled three times through 2010 (June 2009, June 2010, August 2010) while the North Fork below Seaman Reservoir site has been sampled twice (June 2009 and June 2010).

Laboratory Analysis. Samples are submitted to the Center for Environmental Mass Spectrometry Laboratory at the University of Colorado at Boulder (CU Lab) for analysis of 51 pharmaceuticals and 103 pesticides by Liquid Chromatography – Time of Flight – Mass Spectrometry (LC/TOF-MS). Beginning with the June 2009 sampling event, samples are also submitted to Underwriters Laboratories (UL), Inc. for analysis of estrogens and other hormones (9 compounds, UL Method L211), and phenolic endocrine disrupting chemicals (8 compounds including bisphenol A, UL Method L200). Beginning in 2010, the CU Lab also began conducting low-level analysis by liquid chromatography with tandem mass spectrometry (LC/MS-MS) for a subset of 22 different pharmaceuticals and personal care products, in addition to the analysis of 51 pharmaceuticals and 103 pesticides by LC/TOF-MS.

Results through 2010. No compounds have been detected above their respective reporting limits by the CU Lab in the June 2009, June 2010, and August 2010 samples collected at the Poudre above North Fork site. The UL Lab reported very low levels of progesterone in the June 2009 sample (0.1 ng/L) and the June 2010 sample (0.4 ng/L) from the Poudre above North Fork site. However, 0.1 ng/L is the method reporting limit for progesterone and caution must be exercised in terms of assigning any level of importance to results at or near this extremely low value. No compounds were detected by either laboratory in the June 2009 and June 2010 samples collected from the North Fork below Seaman Reservoir site.

2011 Sampling. In 2011, samples will be collected at both Upper CLP sites in February, June, and August. These sampling dates will span the range of conditions experienced by the Upper CLP, from low flow winter conditions, to high flow spring runoff, to the period of peak summer recreational use.

2.6 Colorado Water Quality Control Division High Quality Water Supply Reservoir Study and Evaluation of Seaman Reservoir Data

The Colorado Water Quality Control Division (WQCD) has proposed a chlorophyll-a standard to support a new Protected Water Supply Reservoirs sub-classification of the existing Water Supply use classification. The intent of this chlorophyll-a standard is to help maintain or reduce the disinfection byproduct (DBP) formation potential of lakes and reservoirs that supply raw water directly to water treatment plants. Controlling nutrients and algal growth may also result in other benefits for drinking water utilities, including reduced coagulant dosages and/or reduced usage of activated carbon for taste and odor control. The draft interim numeric chlorophyll-a value is 5 ug/L (summer average chlorophyll-a in the mixed layers) with a one in five year exceedance frequency. The WQCD anticipates that the chlorophyll-a standard for Protected Water Supply Reservoirs would not automatically apply to all direct-use water supply reservoirs, but would be applied to individual reservoirs through the basin regulation rulemaking hearing process. The draft interim chlorophyll-a standard will be considered by the Water Quality Control Commission at the nutrient standards rulemaking hearing scheduled for March 2012.

The WQCD is basing their proposed chlorophyll-a standard on an understanding of relationships of DBPs with nutrients, phytoplankton, chlorophyll, and organic carbon. In 2010, the WQCD conducted the High Quality Water Supply Study with the University of Colorado, Boulder (CU) to better understand these relationships in Colorado reservoirs. The study included synoptic sampling of 28 lakes/reservoirs and intensive sampling of 10 lakes/reservoirs. The intensive sampling was conducted by several utilities in Colorado, with the laboratory analysis conducted by CU. Laboratory analysis included dissolved organic carbon (DOC), total organic carbon (TOC), ammonia, nitrite, nitrate, total nitrogen, total phosphorus, chlorophyll-a, UV_{254}, haloacetic acid formation potential (HAA5FP; formed after 24 hours under uniform formation conditions), and total trihalomethane formation potential (TTHMFP; formed after 24 hours under uniform formation conditions). The City of Greeley participated in this study by supporting the intensive sampling of Seaman Reservoir to coincide with the routine Upper CLP monitoring program. Samples were collected near the dam from the reservoir surface and the reservoir bottom during two sampling events in May, two in June, and one sampling event in each of the months of July, August, September, and October.

Although the sample collection and laboratory analysis for the WQCD High Quality Water Supply Study has been completed, the final report is not yet available from the WQCD. The final report will investigate correlations developed by combining the data collected from all reservoirs included in the study to support chlorophyll-a criteria development for the whole state.

Seaman Reservoir Data. The Seaman Reservoir data collected for the WQCD High Quality Water Supply Study were obtained by Fort Collins Utilities (FCU) from the WQCD for review, and Seaman Reservoir-specific correlations were investigated by FCU. Findings from the evaluation of the 2010 Seaman Reservoir data by FCU are summarized below and on the graphs shown on Figure 10:

- **Relationship of DOC to Chlorophyll-a** (Figure 10-A1 and A2)**:** The 2010 Seaman Reservoir data show that the DOC peaks with the spring runoff and then slowly declines throughout the summer and into the fall, the typical pattern observed in historic Upper CLP data. The chlorophyll-a increased from spring through the summer, and peaked in August. No correlation is observed in the chlorophyll-a versus DOC plot for Seaman Reservoir (Figure 10-A2) since Seaman Reservoir DOC appears to be dominated by terrestrial sources of dissolved organic matter that are mobilized during the spring runoff.

- **Chlorophyll-a, DOC, and Disinfection Byproduct Formation Potential** (Figure 10-B1, B2, C1, C2, D1, D2, E1, and E2)**:** For Seaman Reservoir, disinfection byproduct formation potential peaks with DOC during the spring runoff, and not with the chlorophyll-a peak in August. This applies to both TTHMFP and HAA5FP. TTHMFP is strongly correlated to DOC concentrations (Figure 10-D2). HAA5FP shows a slightly weaker correlation with DOC (Figure 10-E2). The 2010 chlorophyll-a data (Figure 10-B2 and C2) do not show a meaningful relationship with TTHMFP or HAA5FP data (the data generally show DBP formation potential decreasing with increasing chlorophyll-a).

- **Ratio of Dissolved to Total Organic Carbon, DOC/TOC** (Figure 10-F1 and F2)**:** Approximately 92% of the TOC is in the dissolved form (range of 89% to 97% for the surface samples, and range of 90% to 96% for the bottom samples).

- **Specific Ultraviolet Absorbance at 254 nm, SUVA** (Figure 10-G1 and G2)**:** SUVA (= UV_{254}/DOC) is an indicator of the presence of aromatic compounds. Higher SUVA values indicate higher aromatic content which can impact the reaction of DOC with coagulants and chlorine. The 2010 Seaman Reservoir SUVA data indicate that as the DOC concentration decreased from spring to fall, the character also changed and became less aromatic (lower SUVA in the fall). Figure 10-G2 indicates that SUVA is not a particularly good predictor of TTHMFP; DOC by itself is a much better predictor of TTHMFP (Figure 10-D2).

- **Specific TTHMFP and Specific HAA5FP** (Figure 10-H)**:** Specific TTHMFP (STTHMFP = TTHMFP/DOC) and Specific HAA5FP (SHAA5FP = HAA5FP/DOC) are TTHMFP and HAA5FP concentrations normalized with respect to DOC concentrations. The plots of STTHMFP (Figure 10-H) show that it increases at the beginning of the runoff period, peaks from the beginning of June to the beginning of July, and then decreases again. These changes in STTHMFP indicate changes in the character of the DOC that impact its reactivity with chlorine. The DOC is most reactive during the spring runoff period, with more TTHM formed per mg of DOC. The SHAA5FP data plotted on Figure 10-H indicates that the DOC during the runoff is significantly more reactive in terms of HAA5FP than during the other times of year (more ug of HAA5 formed per mg of DOC during the runoff period).

- **DOC versus UV_{254}** (Figure 10-I)**:** UV_{254} is an indicator of humic substances and aromaticity. Figure 10-I shows the strong correlation between DOC and UV_{254} for the Seaman Reservoir data.

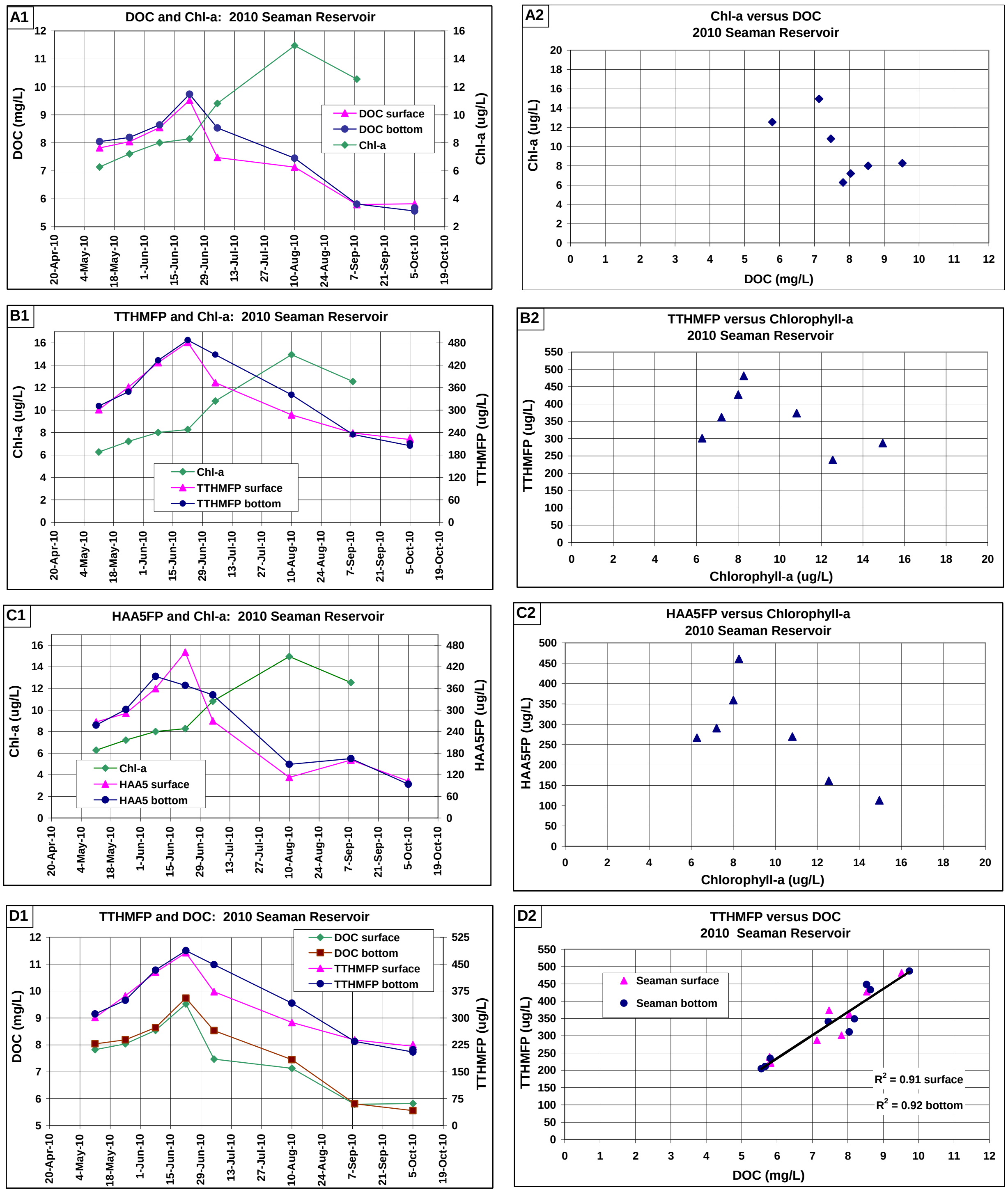


Figure 10 (A-I). Plots of 2010 Seaman Reservoir Chlorophyll-a, TOC, DOC, UV254, SUVA, TTHMFP, HAA5FP, STTHMFP, and SHAA5FP data collected for the Colorado WQCD High Quality Water Supply Reservoir Study (laboratory analysis by CU Boulder).

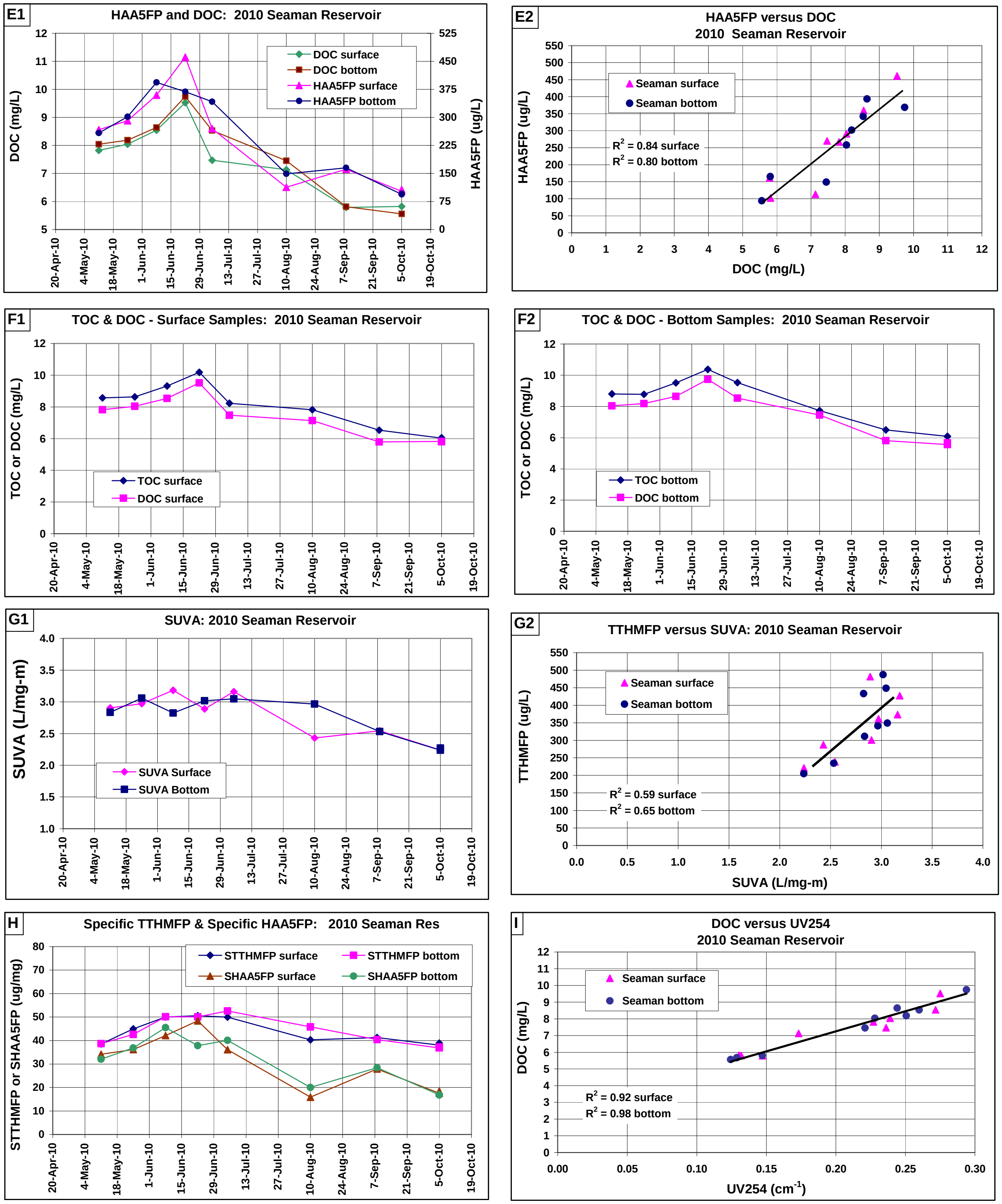


Figure 10 (A-I) (CONTINUED). Plots of 2010 Seaman Reservoir Chlorophyll-a, TOC, DOC, UV254, SUVA, TTHMFP, HAA5FP, STTHMFP, and SHAA5FP data collected for the Colorado Water Quality Control Division High Quality Water Supply Reservoir Study (laboratory analysis by CU Boulder).

2.7 Special North Fork Sampling for the Halligan-Seaman Water Management Project

The proposed Halligan-Seaman Water Management Project (HSWMP) includes the expansion of both Halligan Reservoir and Seaman Reservoir on the North Fork. The U.S. Army Corps of Engineers, Omaha District, and its third party consultants are currently preparing a Draft Environmental Impact Statement (EIS) to analyze the effects of the HSWMP. As part of the studies being conducted for the EIS, the third party consultants requested special sampling of the North Fork and its tributaries in 2010. This special sampling generally coincided with the routine Upper CLP sampling but included some additional parameters. Of particular interest are the metals data collected as part of the special sampling since North Fork metals are not part of the routine Upper CLP monitoring program.

Dissolved and total recoverable concentrations of aluminum, cadmium, chromium, copper, iron, lead, manganese, selenium, silver, and zinc were measured at seven locations (Halligan Reservoir, North Fork above Rabbit Creek, Rabbit Creek Mouth, Stonewall Creek Mouth, Lone Pine Creek Mouth, North Fork at Livermore, and North Fork at gage below Seaman Reservoir) during four sampling events (once/month in May, June, July, and August). Analysis was conducted by the City of Fort Collins Water Quality Laboratory (FCWQL). Cadmium, chromium, copper, lead, selenium, and silver were all below their respective reporting limits at all sites and for all sampling events.

2.8 Mountain Pine Beetle in Upper CLP Watershed

The mountain pine beetle (MPB), *Dendroctunus ponderosae*, is native to forests of western North America. Periodically, populations increase to result in regional outbreaks of beetle-related tree deaths. The current outbreak, which began in the late 1990's, has grown to ten times the size of the largest previously known outbreak and continues to expand through forests dominated by Lodgepole and Ponderosa pines (*Pinus contorta* and *Pinus ponderosa*). The result has been expansive swaths of dead and dying trees across the Rocky Mountain West.

Information from the US Forest Service (USFS) and Colorado State Forest Service 2010 Forest Health Aerial Survey provided by the USFS (http://www.fs.fed.us/r2/news/press-kits/2010/index.shtml) reports that the total number of infested acres in Colorado and southern Wyoming increased by 400,000 acres in 2010, bringing the total number of affected acres to 4 million since 1996. The 2010 USFS Forest Health Aerial Survey shows rapid eastward spread of the MPB into lower elevation Lodgepole and Ponderosa pine stands along the Northern Colorado Front Range. The Upper Cache la Poudre and the adjacent contributing watersheds (Laramie River and Michigan River) are located within this area of high forest mortality (Figure 11).

During the phase of forest dieback in which affected trees retain their needles, there is a short-term elevated risk of high severity wildfire. Research continues on forest management options to improve post-outbreak forest health (McDonald and Stednick, 2003; Uunila et. al, 2006; LeMaster et al., 2007), as well as options for protecting communities and critical water supplies against the effects of wildfire (LeMaster et al., 2007; FRWWPP, 2009). However, potentially widespread changes in the vegetative cover that occur either as a result of extensive forest die-back or from severe wildfire, have the potential to affect water quality in the Upper CLP watershed, including potential changes in stream flow and temperatures, sediment loads, as well as in-stream nutrient and TOC levels.

Figure 11. 2010 images of mountain pine beetle (MPB) mortality in the Mainstem CLP watershed, near Rustic, CO.

2.9 Upper CLP Wildfire/Watershed Assessment

In 2010, the City of Fort Collins and the City of Greeley jointly funded the Cache la Poudre Wildfire Watershed Assessment Project as conducted by J.W. Associates Inc. The project included four meetings attended by key watershed stakeholders including the City of Fort Collins, City of Greeley, Tri-Districts, U.S. Forest Service, Colorado State Forest Service, Larimer County, and Northern Water. The susceptibility of water supplies to impacts from severe wildfires was evaluated based on four main watershed characteristics: wildfire hazard, flooding/debris flow hazard, soil erosivity and the location of critical water supply infrastructure. In addition, the project identified opportunities to protect water supplies from debris flows and sediment loads resulting from high-severity wildfires. All sixth-level watersheds of the Mainstem and North Fork sub-basins of the CLP watershed were considered. Results identified a limited number of opportunities for protection in areas along roadsides and around reservoirs where hazard-fuel reduction work is planned by the State and US Forest Service, as well as areas where existing forest treatments could potentially be expanded or linked together. The full report, including a full summary of identified opportunities, is available at:

http://www.jw-associates.org/Projects/Poudre_Main/Poudre_Main.html.

The next steps in the process include meeting with stakeholders to further evaluate the possible opportunities and identifying grants or other funding sources to support site-specific design and implementation. This effort should also include researching debris flow mitigation technologies and related permit requirements as well as creating specific treatment and emergency response plans for Joe Wright Reservoir and the City of Fort Collins and City of Greeley water supply intake facilities on the Poudre River. This work is expected to begin in late 2011.

2.10 Assessment of Existing/Abandoned Mine Sites as Potential Sources of Contamination

In 2004, the Colorado Department of Public Health and Environment (CDPHE) conducted an assessment of potential hazards to source water supplies as part of the Source Water Assessment and Protection (SWAP) program. Assessments for the City of Fort Collins and the City of Greeley identified a number of existing and abandoned mine sites within the Mainstem watershed (65 sites) and North Fork Cache la Poudre watershed (16 sites) that were determined to pose a moderate to high risk of contaminating water supplies. Routine monitoring data have not indicated any detectable influence from mine sites within the watershed to date. However, activities are planned to verify the existence of these sites in order to gain a better understanding of the actual risks they may pose to water quality.

The geographical coordinates of the Upper CLP mine sites were obtained from CDPHE and will be used to develop a prioritized list of sites for field verification. Field verification work is expected to begin in the summer of 2011 and may take several years to complete. The locations of all identified mine sites in the Mainstem and North Fork CLP watersheds are shown on Figure 12.

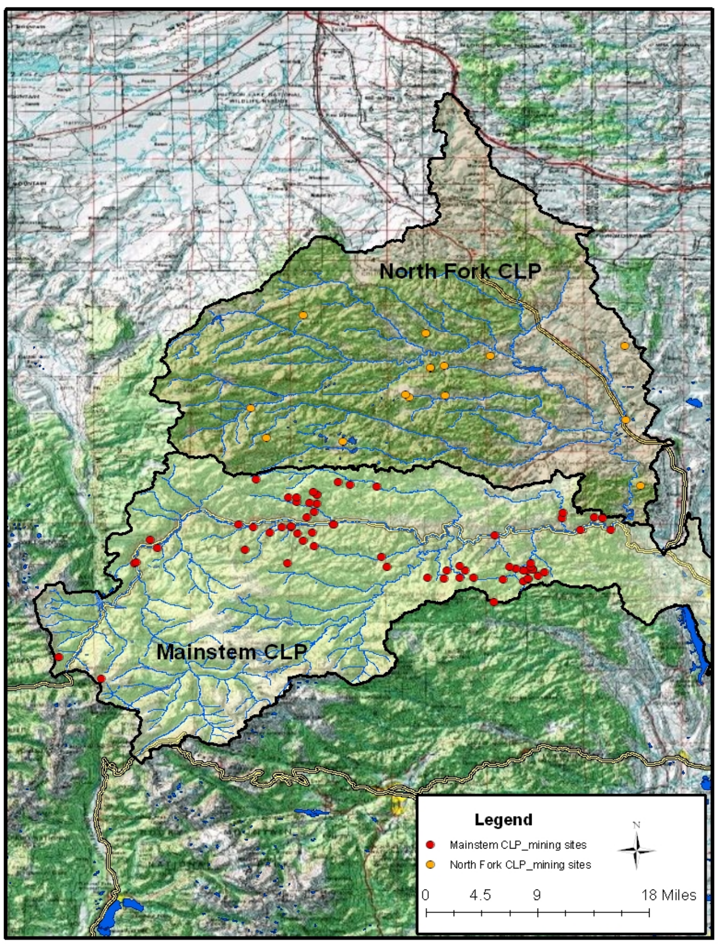


Figure 12. Locations of existing or abandoned mining claims in the North Fork and Mainstem Cache la Poudre River watersheds as identified in the 2004 CDPHE Source Water Assessments for the City of Fort Collins and City of Greeley.

Field verification of mine sites will entail locating the latitude/longitude coordinates of the sites using geographic positioning system (GPS) and topographic maps and photo-documenting the site conditions. Sites will be surveyed for evidence of past or current mining activity (mine excavations and tailings) and possible migration of materials or drainage from the site into streams or tributaries of the Cache la Poudre River.

3.0 UPPER CACHE LA POUDRE RIVER RESULTS

For this annual report, six 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 Mainstem
  - PJW – Poudre above Joe Wright Creek
  - 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

Discussion of the results will focus primarily on these 6 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 Hydrology

Discharge was 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 Poudre (SFM). Discharge values presented for these sites represent instantaneous discharge measurements collected on the specified sampling dates.

Continuous stream flow data were obtained from U.S. Geological Survey (USGS) and Colorado Division of Water Resources (CDWR) online reporting sites for flow gauging stations at Joe Wright Creek (JWC), North Fork at Livermore (NFL), North Fork below Seaman Reservoir (NFG) and the Canyon Mouth (representing Poudre at Bellvue Diversion (PBD)). Stream discharge values at Poudre above North Fork (PNF) were calculated using continuous flow data from the Canyon Mouth and NFG as well as head gate flow values at the Poudre Valley Canal diversion, which were obtained from the current Poudre River Commissioner, George Varra. Discharge values for these sites are presented as daily averages.

Both the Mainstem and North Fork sites show snowmelt-dominated hydrographs (Figure 13). As in previous years, the 2010 spring runoff began in mid-May. The hydrographs for 2007-2010 at the lower Mainstem sites PNF and PBD are characterized by two peaks in stream flow during the spring run-off season. This double peak reflects natural fluctuation of the river levels that result from rainfall events and/or snowmelt in the lower elevations as well as the freeze-thaw cycles that are characteristic of early spring conditions in the Upper CLP watershed (Figure 13).

Figure 13. 2007 – 2010 Daily average stream flow at key Upper CLP monitoring sites.

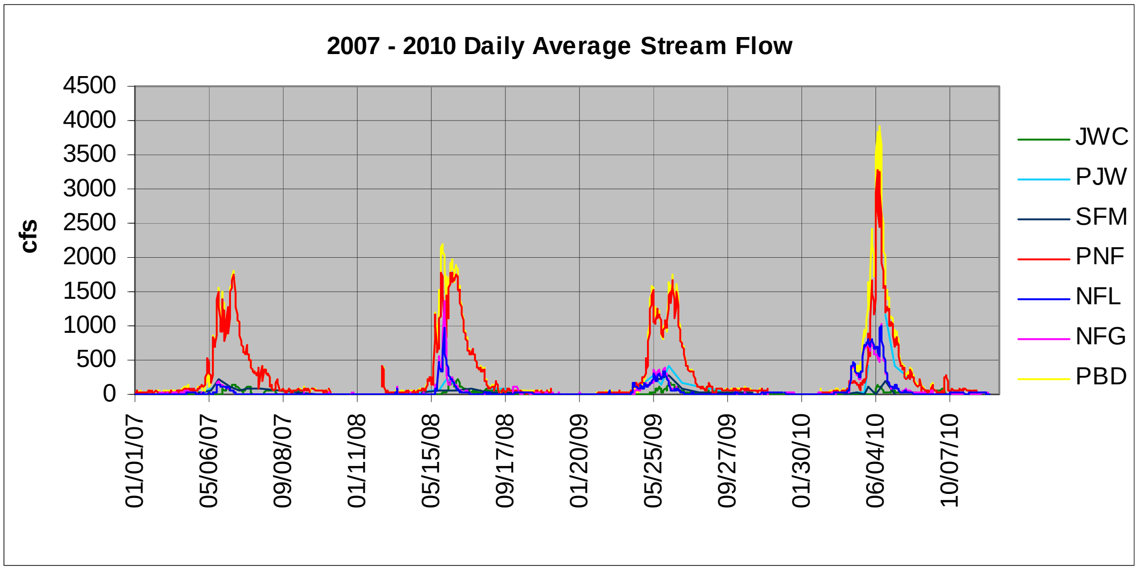
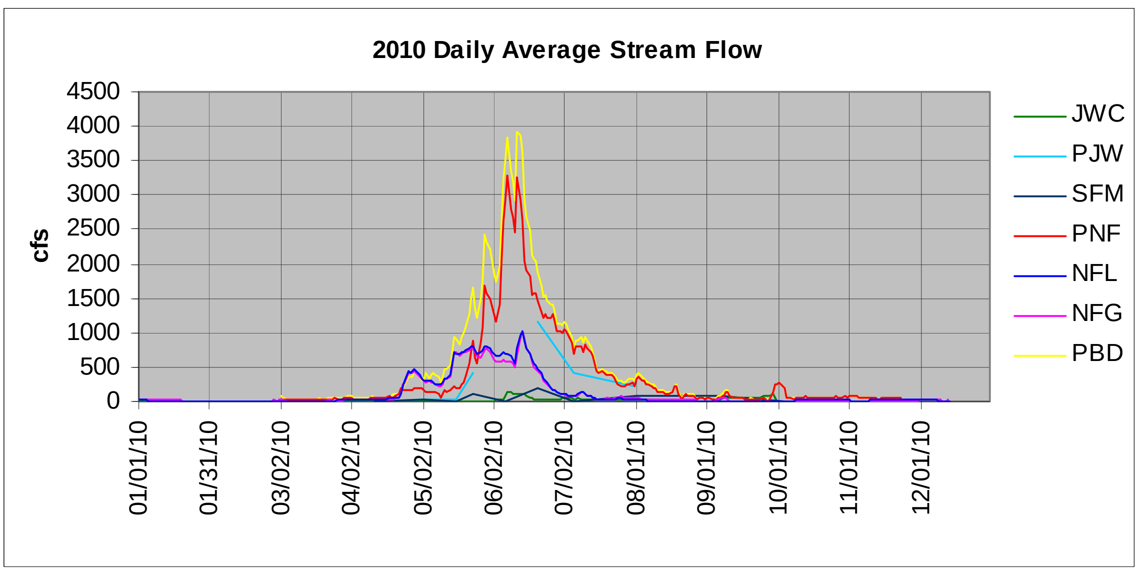


Figure 14. **2010 Daily average stream flow at key Upper CLP monitoring sites.**



3.1.1 Mainstem CLP. Headwater sites on the South Fork above the Mainstem CLP (SFM) and JWC experienced peak stream flows of 207 cfs and 126 cfs, respectively, which were consistent with years 2007 - 2009. In contrast, the 2010 peak stream flow at PJW (1,207 cfs) was significantly higher than the previous three years. This high stream flow is not, however, unprecedented; in 2006 (not shown here), the peak observed stream flow was of similar magnitude (1,026 cfs). Note that discharge measurements were not collected on 6/7/10 at PJW.

The lower reaches of the Mainstem CLP also experienced unusually high flows during the 2010 spring runoff, as evidenced by stream flow values for PNF and PBD. The hydrographs for these sites show two peaks of similar magnitude, occurring just days apart. The highest stream flow values observed at PNF and PBD were 3,272 cfs (6/8/10) and 3,910 cfs (6/12/10), respectively.

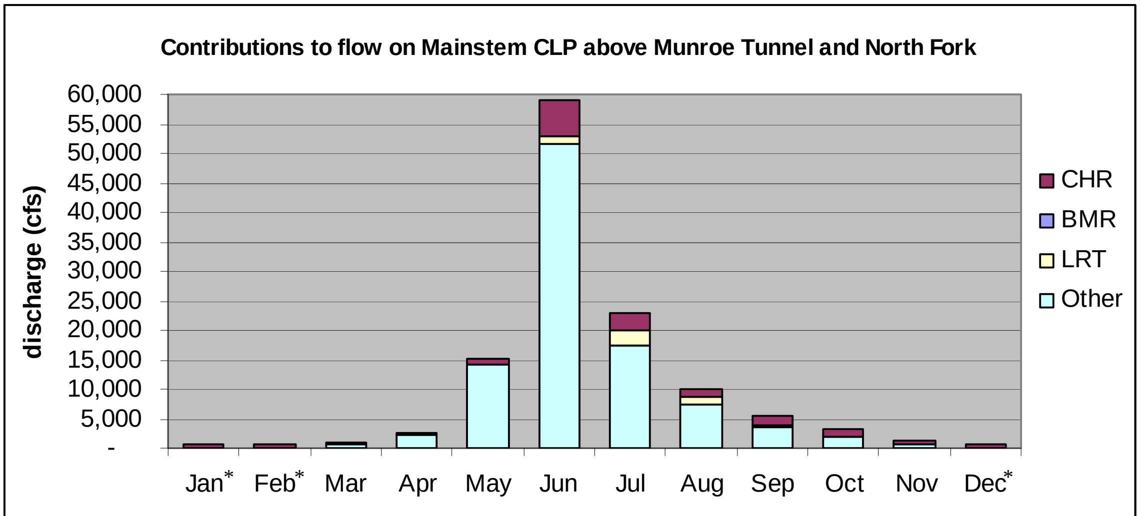
As expected, the timing and magnitudes of peak runoff at PBD were similar to PNF. Typically, the hydrograph for PBD tracks closely with PNF, as the Mainstem contributes the majority of flow at PBD, with relatively small contributions provided by North Fork flows out of Seaman Reservoir (NFG). Exceptions occur in years of greater than normal North Fork runoff or in the event of substantial releases from Seaman Reservoir, as was observed in 2008. Events contributing to the higher 2008 North Fork flows at NFG and PBD are detailed in the 2008 Upper CLP annual report (Oropeza and Billica, 2009).

There are a number of tributaries and diversions that contribute to the overall stream flow 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 15 is a graphical representation of proportional flows by month. Note that contributions from the South Fork of the Poudre (SFM) and Poudre above Joe Wright Creek (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”.

Table 2. Contributing flows by month to the Mainstem Cache la Poudre River above the Munroe Canal for 2010.

	Barnes Meadow Outflow (BMR)		**Chambers Lake Outflow (CHR)**		**Laramie Tunnel (LRT)**		**Other Mainstream Contributions**		**Poudre above Munroe Tunnel & North Fork**	
Month	cfs	%	cfs	%	cfs	%	cfs	%	cfs	%
Jan	100		620							
Feb	81		423							
Mar	115	12%	330	35%		0%	484	52%	930	----
Apr		0%	294	11%		0%	2,303	89%	2,597	----
May		0%	1,060	7%		0%	14,200	93%	15,260	----
Jun		0%	6,251	11%	1,116	2%	51,666	88%	59,033	----
Jul		0%	2,802	12%	2,702	12%	17,308	76%	22,813	----
Aug		0%	1,343	13%	1,137	11%	7,544	75%	10,024	----
Sep		0%	1,549	28%	287	5%	3,618	66%	5,453	----
Oct		0%	1,015	33%		0%	2,088	67%	3,104	----
Nov		0%	608	47%		0%	695	53%	1,303	----
Dec			620							

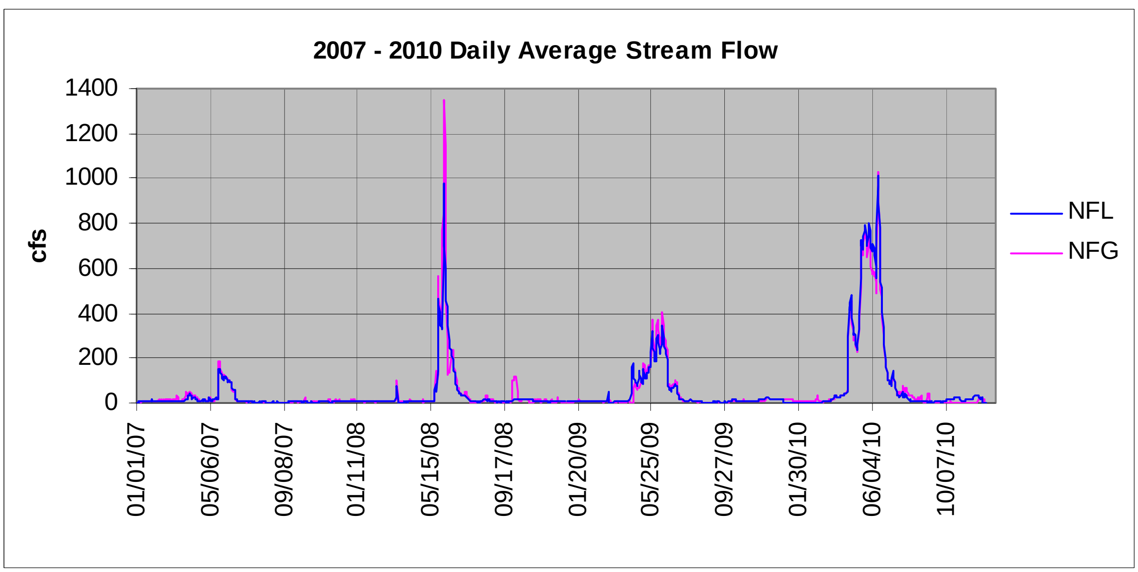
Figure 15. 2010 Contributing flows by month to the Mainstem Cache la Poudre River above the Munroe Canal.



* Continuous flow measurements were not available for calculating "other" flow contributions in Jan., Feb., or Dec.

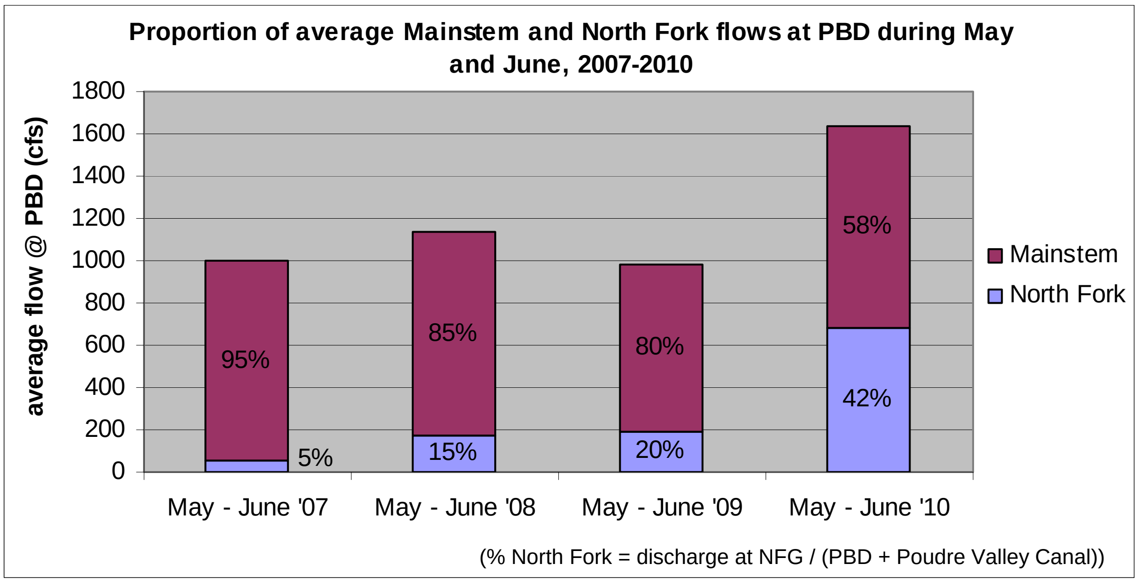
3.1.2 North Fork CLP. Stream flows measured at NFL represent cumulative flows of the North Fork CLP above Seaman Reservoir and provide information about the timing and relative magnitude of spring run-off in the upper North Fork drainage. Stream flow measurements at NFG include contributions from both the North Fork and Seaman Reservoir and represent the total North Fork contributions to Mainstem flows (measured at PBD). Although stream flow at NFG is influenced by reservoir operations, the hydrographs for NFL and NFG are typically very similar (Figure 16) because during the period of highest flow (spring runoff) the majority of flow going into Seaman Reservoir is flowing over the spillway and not being stored.

Figure 16. 2007 - 2010 Daily average stream flow at NFL and NFG



In 2010, stream flows at NFL and NFG were considerably higher than in both 2007 and 2009, yet slightly lower than 2008 flows. Hydrographs for both sites tracked closely, with only slightly higher flows recorded at NFL. Peak stream flows occurred on 6/14/10 at NFL and NFG, and were 1,010 cfs and 1,030 cfs, respectively. From May through June, the North Fork has comprised, on average, 5% to 42% of Mainstem stream flow at PBD (Figure 17). The large percent contribution of North Fork flows in 2010 is likely due to the fact that Seaman Reservoir was at capacity prior to the onset of runoff and the majority of spring runoff flowed directly over the spillway of the reservoir.

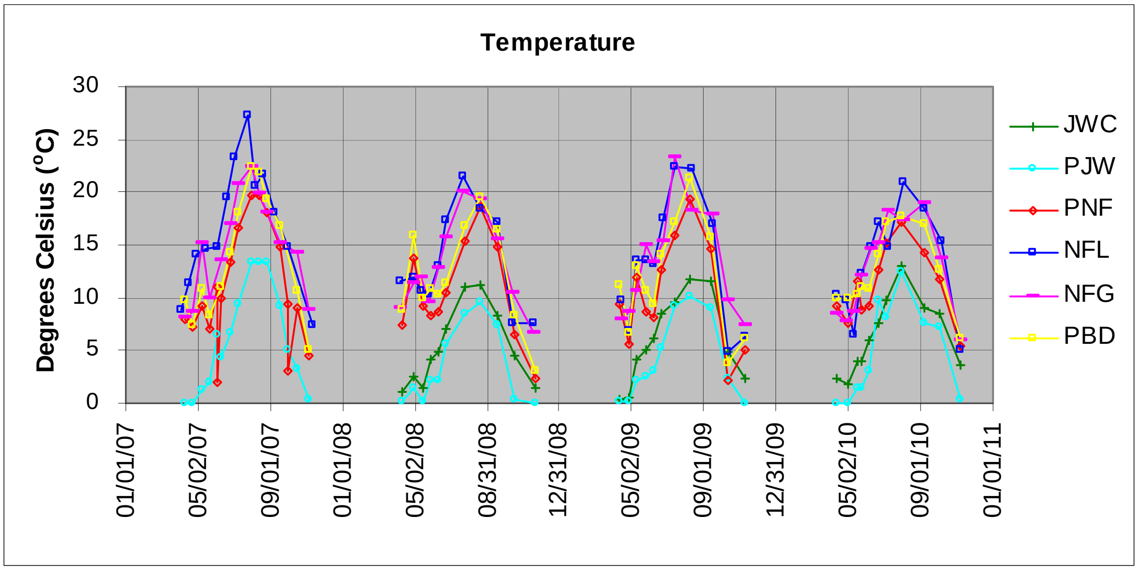
Figure 17. Proportion of average Mainstem and North Fork CLP flows at PBD during May and June from 2007 to 2010.



3.2 Water Temperature

Water temperature increases with decreasing elevation throughout the watershed (Figure 18). Peak temperatures occur mid-summer, with North Fork sites typically peaking a few days earlier than the Mainstem sites due to the influence of the warmer temperatures within this lower elevation drainage. In 2010, peak temperatures on the North Fork and Mainstem occurred on 8/3/10. The similarity between temperatures at NFG and NFL indicate that Seaman Reservoir did not have any discernible influence on North Fork water temperature.

Figure 18. Water temperature at key Upper CLP monitoring sites.



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

3.1.1 Conductivity, Hardness and Alkalinity. Conductivity is an index of dissolved ionic solids in the water and hardness is an index of the total calcium 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 19.a -18.c).

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. With the exception of 2008 spikes in hardness and alkalinity at NFG, observed values at each site remained consistent between years.

3.3.2 pH. In 2010, the pH of the Upper CLP waters followed similar patterns related to season and elevation as alkalinity, conductivity and hardness (Figure 19.d.). In general, the North Fork exhibited higher pH than the Mainstem. Exceptions occurred in 2009 and 2010 when pH values at PNF and PBD were the same or higher than North Fork sites prior to the onset of spring runoff. In 2010, pH values ranged from 6.5 – 8.6 on the Mainstem and from 6.8 – 8.6 on the North Fork. All values were within the ranges observed in previous years, with all sites experiencing a sharp decrease in pH (0.7-2.2

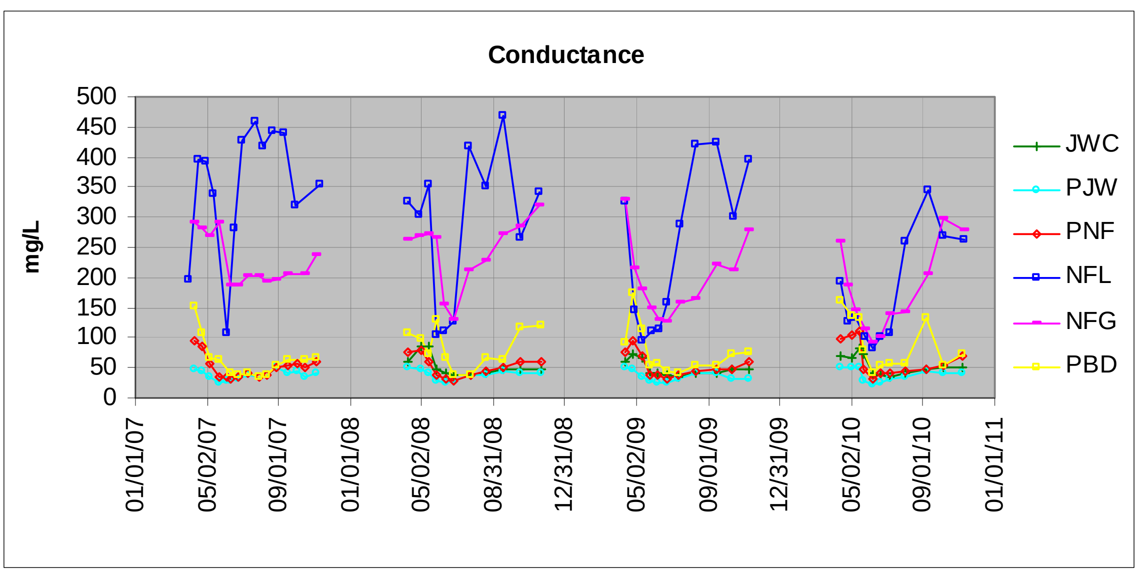
units) during spring runoff. Following runoff, pH typically increases quickly at all sites; however, summer and fall pH trends vary between Mainstem and North Fork sites as well as between years.

3.3.3 Turbidity. In general, turbidity at all Mainstem and North Fork sites peaks during spring run-off, when higher volume and velocity flows increase the amount of sediment and organic material transported from the surrounding landscapes. Consistent with higher 2010 peak stream flows, peak turbidity values were likewise elevated over the previous year on the Mainstem and the North Fork (Figure 19.e). Peak values at the Mainstem sites PNF and PBD were 17.4 NTU and 21.7 NTU (6/7/10), respectively, with PBD reflecting the combined influence of the Mainstem and the North Fork.

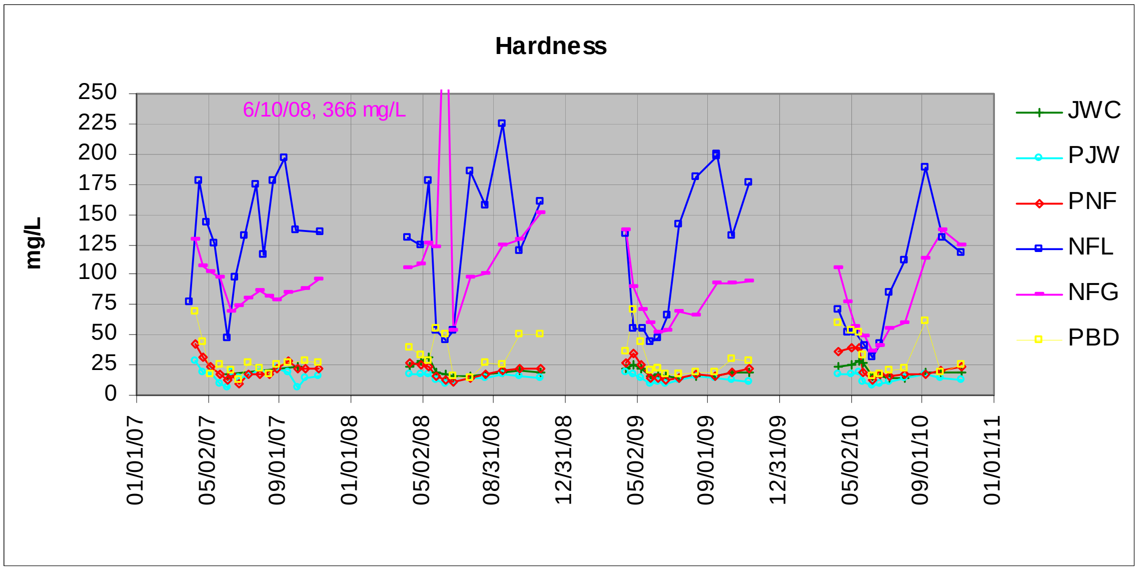
During spring run-off, North Fork turbidity values at NFL and NFG were 17 NTU and 11.2 NTU, respectively. While these North Fork sites also experienced higher turbidity than in 2009, values were lower than in 2008 when a storm event on the North Fork coincided with large release of water from Seaman Reservoir (Oropeza and Billica, 2009). A second spike in turbidity occurred at NFG (14.7 NTU) on 9/7/10. This late summer spike coincided with a slight increase in stream flow at NFG, but similar increases were not observed at nearby monitoring sites. This suggests that the turbidity spike was caused by a small release of water and sediment from the bottom of Seaman Reservoir, but was not sufficient quantity or duration to impact turbidity at downstream sites (PBD). During periods of low flow, turbidity was generally below 3.0 NTU at all Mainstem and North Fork sites.

Figure 19 (a –e). General water quality parameters at key Upper CLP monitoring sites: Conductance, Hardness, Alkalinity, pH and Turbidity

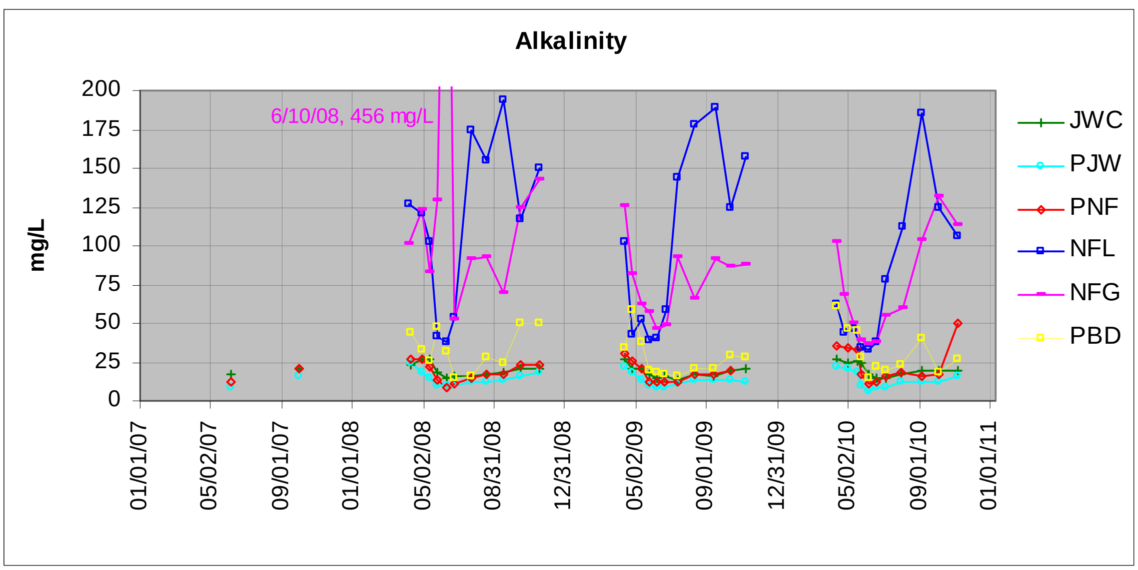
19a. Conductance



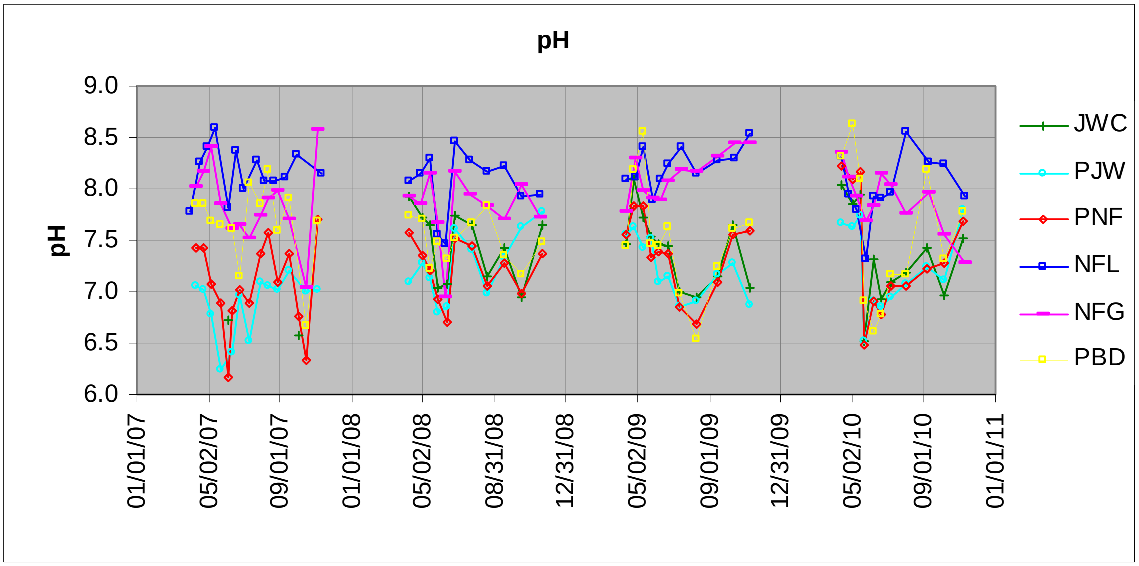
19.b. Hardness



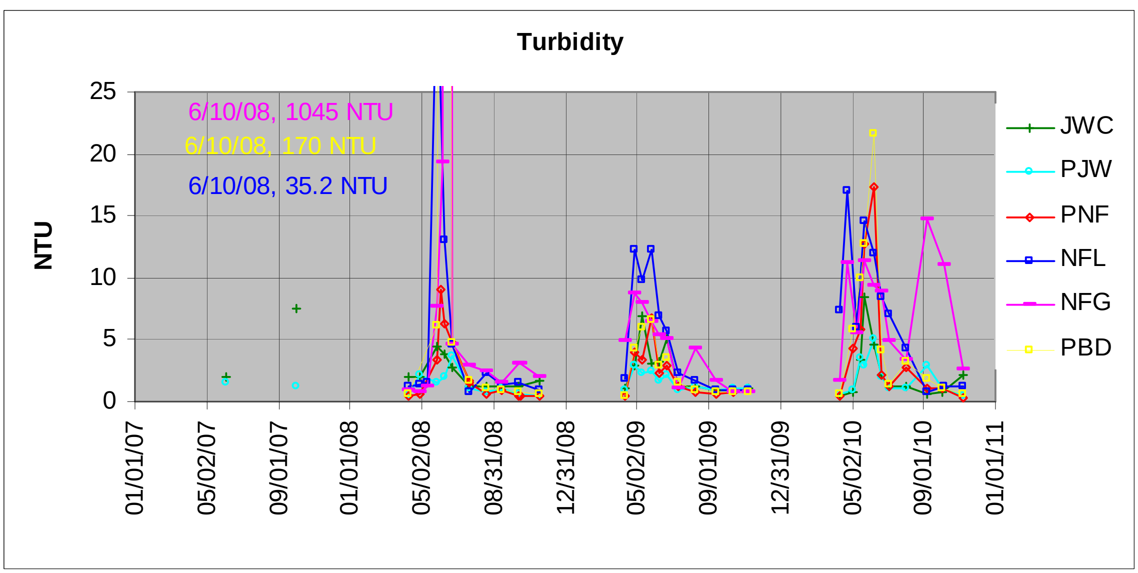
19.c. Alkalinity



19.d. pH



19.e. Turbidity

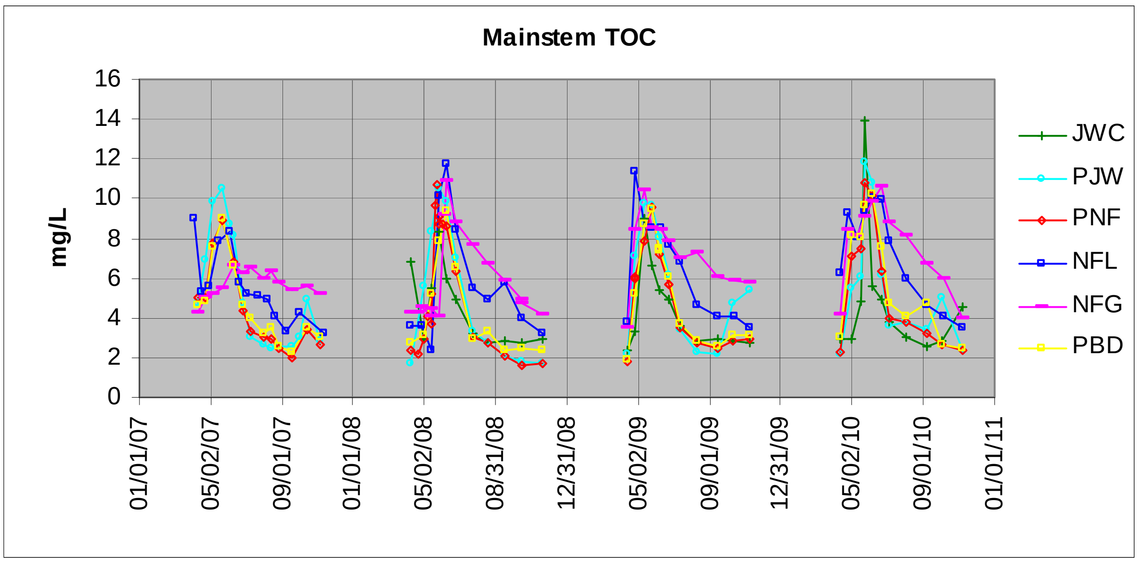


3.4 Total Organic Carbon (TOC)

Seasonal patterns of TOC concentrations in the upper CLP watershed are generally consistent year-to-year, with annual maximum TOC values occurring during the onset of spring snowmelt. This trend was evident in years 2007 through 2010. Mainstem TOC concentrations at PNF typically peak approximately two weeks to a month earlier than North Fork concentrations at NFL and NFG.

In 2010 both the North Fork and the Mainstem experienced an initial small peak in TOC, followed by larger main peaks at the height of spring runoff, with the Mainstem peaking two weeks before the North Fork (Figure 20).

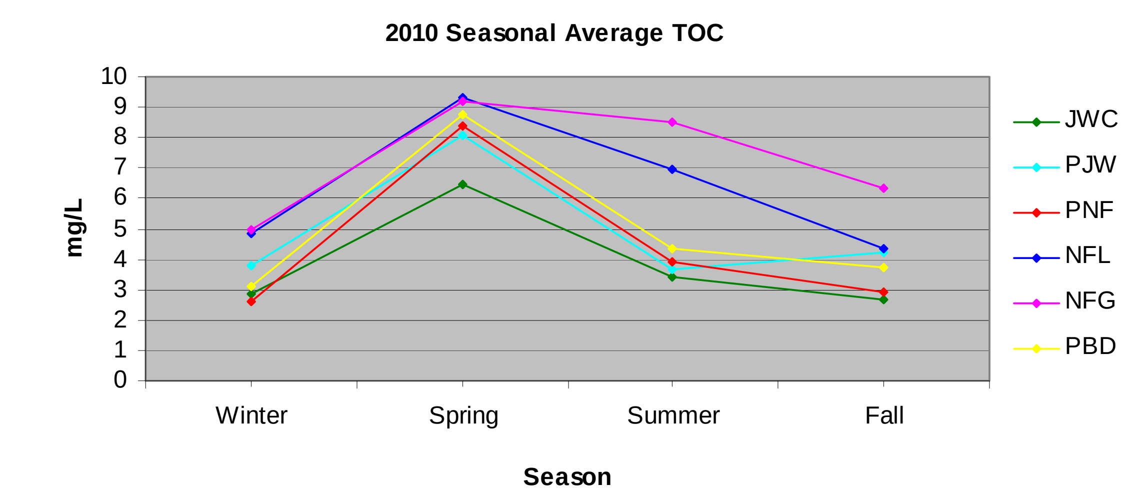
Figure 20. TOC concentrations at key Upper CLP monitoring sites.



The 2010 peak TOC concentrations on the Mainstem were greater than previous years as well as those observed on the North Fork. The highest Mainstem TOC concentrations were observed at the high-elevation sites, JWC (14 mg/L) and PJW (12 mg/L), an occurrence that is likely related to the high proportion of runoff occurring as snowmelt near the Mainstem headwaters. Water released from Barnes Meadow Reservoir (BMR) during spring runoff serves as an exception to this pattern. Flows from BMR have historically resulted in exceptionally high concentrations of TOC entering into Mainstem flows due to boggy conditions within this sub drainage (Billica, Loftis and Moore, 2008). From 2007 – 2010, peak TOC concentrations at BMR were between 10.5 -13.8 mg/l and often exceeded TOC concentrations at PJW. Releases from BMR were, however, infrequent and of short duration, thereby minimizing their impact on source water supplies at PNF and PBD. Large spikes in TOC were also observed in 2008 through 2010 in the incoming waters diverted through the Laramie River Tunnel (LRT). Peak TOC concentration at LRT for this period was approximately 15 mg/L, and was significantly higher than the peak value recorded for 2007, which was slightly less than 9 mg/L. Like BMR, the impact of elevated TOC concentrations at LRT on lower Mainstem sites is minimal due to the relatively small volume of flow from this source.

Peak TOC concentrations on the lower North Fork (NFL and NFG) and the North Fork tributaries in 2010 were similar to the previous two years, but in most cases, considerably higher than in 2007. As seen previously, seasonal differences in TOC concentrations were also observed between Mainstem and North Fork sites. The North Fork TOC levels remained relatively high throughout the late summer season, after levels at Mainstem sites had decreased dramatically. This longer period of elevated TOC is reflected by the higher late-summer and fall average TOC values at NFL and NFG (Figure 21). While TOC concentrations on the North Fork are consistently higher than those observed on the Mainstem, the TOC load carried by the Mainstem is greater due to substantially higher flow volume.

Figure 21. 2010 Seasonal average TOC concentrations at key Upper CLP monitoring sites.



* Winter (Nov-Dec'09, Jan-Apr'10); Spring (May-Jun); Summer (Jul-Aug); Fall (Sep-Oct)

The persistence of elevated TOC levels on the North Fork, and to a lesser degree, the Mainstem site PJW, during periods of low flow can, in part, be attributed to the relatively low volume flows, 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 this additional TOC in the North Fork include water released from Halligan and Seaman Reservoirs, and runoff from agricultural land within the North Fork basin. Water released from Long Draw Reservoir on the Mainstem is a potential contributor to the small increase in Fall average TOC values over Summer average concentrations at PJW. A similar seasonal increase was also observed at PJW in 2009.

3.5 Nutrients

A complete comparison of 2010 data with years 2007 - 2009 was not possible for nutrients due to differences in reporting limits between the former monitoring programs. Those parameters include ammonia (NH_4), nitrite (NO_2), nitrate (NO_3), phosphorus (TP) 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 ug/L for ortho-phosphate, 10 ug/L for ammonia and total phosphorus, and 40 ug/L for nitrate and nitrite, and are considerably higher than those used by Dr. Lewis in 2007. Routine analysis of Total Kjeldahl Nitrogen (TKN) began in 2008.

Ammonia, nitrate, nitrite, and ortho-phosphate are dissolved forms of nitrogen and phosphorus that are readily available for plant uptake. Both 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 N 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, higher concentrations of nutrients were observed on the North Fork than at Mainstem sites, as reflected by values at NFL and NFG (Figures 22.a - 22.f). Although frequent spikes of ammonia, nitrate, ortho-phosphate and total phosphorus from 2007 – 2010 were observed at both sites, nutrient spikes at NFG were larger and more frequent because of the influence of Seaman Reservoir, especially in non-runoff times of the year. There were no exceedances of the EPA drinking water quality standard for nitrate (10,000 ug/L) or nitrite (1,000 ug/L) from 2007 - 2010.

Elevated concentrations of nitrate, Total P and TKN were observed at NFL and other upstream North Fork tributary sites during spring run-off. These higher concentrations likely occurred in response to flushing of sediment and dissolved nutrients during snowmelt. From 2007 – 2010, Total P concentrations on the North Fork tributaries, Stonewall Creek (SCM) and Lone Pine Creek (PCM), were 2 to 6 times higher than those observed on the lower North Fork site, NFL, throughout most of the monitoring year. Concentrations at SCM and PCM generally ranged from 87- 670 ug/L, while concentrations at NFL ranged from 0-160 ug/L. Another North Fork tributary, Rabbit Creek (RCM), exhibited relatively high concentrations of ortho-phosphate. The high concentrations of nutrients in these small tributaries are due, in large part, to the relatively low flows, especially during the summer months, and represent small contributions to overall stream flow and nutrient loads at NFL.

The effects of reservoir releases on downstream nutrient concentrations can be seen at below Seaman Reservoir at NFG and below Halligan Reservoir at NBH. At NFG, late-summer peaks in Total P and ortho-phosphate and elevated ammonia concentrations were observed, and are indicative of low dissolved oxygen concentrations in Seaman Reservoir (See section 4.2). Similarly, spikes in ammonia were observed on the North Fork below Halligan Reservoir (NBH) in all years. The observed spikes in nutrient concentrations at NBH and NFG were not sufficient in size or duration to increase downstream nutrient concentrations.

3.5.2 Mainstem. Nitrite and ortho-phosphate were generally not detected above reporting limits on the lower Mainstem (PNF). On the upper Mainstem, BMR and LRT regularly experienced reportable concentrations of ortho-phosphate, while JWC, SFM and PJW each had once instance of reportable concentrations, all which occurred in 2008.

Ammonia concentrations on the Mainstem were similar to the previous three years, which have generally remained below 50 ug/L. Releases from Barnes Meadow Reservoir (BMR) serve as the major exceptions, with concentrations ranging from 75 - 289 ug/L from 2007 through 2010. The upper Mainstem site, PJW, experiences a pulse of ammonia with the onset of spring runoff, which potentially results from an initial spring flush of inorganic soil N. In 2010, this seasonal peak was especially pronounced at PJW, PSF and PBR. Elevated ammonia concentrations were also occasionally observed during low flows conditions from October – December. At the lower Mainstem site, PNF, ammonia concentrations have not exceeded 20 ug/L in the last four years.

In 2010, nitrate concentrations on the Mainstem generally followed similar seasonal pattern as was seen during the previous three years; a decrease in concentrations during spring runoff followed by an increase through the summer as stream flows subside. In general, PJW had the highest peak nitrate concentrations among the Mainstem sites, although higher concentrations are occasionally seen in inflowing waters from BMR, JWC and LRT. In the previous three years, peak concentrations at PJW ranged from 116-157 ug/L; however, in 2010, an exceptionally high spike in nitrate (712 ug/L) was observed on 6/21/10, just following peak stream runoff. An even higher concentration of 849 ug/L was observed on the South Fork of the Poudre (SFM) during late summer, on 9/7/10. These high values were verified as correct by the Fort Collins Water Quality Lab. While the causes for the spikes in nitrate are not clear, in both cases, the high concentrations were not sustained and did not affect nitrate concentrations at downstream locations.

It is notable that the two main dissolved forms of nitrogen, nitrate and ammonia experience different trends related to spring runoff. In high elevation, snowmelt dominated watersheds like the Upper CLP, some of the numerous factors that affect in-stream N availability include the amount of snowpack, the forms and concentrations of N stored in the snowpack from atmospheric deposition (Campbell et. al, 1995), the degree to which soil microbes are able to produce mineralized forms of N under the snowpack (Brooks et. al, 1996), as well as the degree to which snowmelt infiltrates the soil during runoff (Williams et. al, 2009). Because there is considerable temporal and spatial variability in the environmental factors that influence these processes across the watershed, it is therefore, not surprising that the timing and concentrations of these forms of nitrogen also differ in time and space.

Similar to the North Fork, the highest concentrations of TKN and Total P on the Mainstem typically occur during spring runoff, followed by sharp declines during the summer months. Total P follows similar trends as stream flow. In 2010, the peak Total P concentration at PNF occurred during spring runoff and was higher than in the previous three years, with a concentration of 80 ug/L. The 2010 peak TKN concentration at PNF was 604 ug/L. Total N tracks closely with TKN, as TKN comprises the largest fraction of Total N, with nitrate and nitrite representing lesser fractions.

In 2010, the Colorado Department of Health and Environment, Water Quality Control Division (CDPHE/WQCD) released a set of proposed nutrient criteria for warm and cold water lakes/reservoirs and streams in an effort to prevent future water quality degradation as mandated by the U.S. Environmental Protection Agency. A rulemaking hearing is scheduled for March, 2012 and in the interim, the current proposed standards will be the subject of much discussion in a series of nutrient workgroup meetings conducted by the WQCD. All rivers and reservoirs within the Upper Cache la Poudre River Watershed are designated "cold" waters. For cold water streams, the proposed standards are based on 5 year median values and are 400 ug/L for Total N and 110 ug/L Total P.

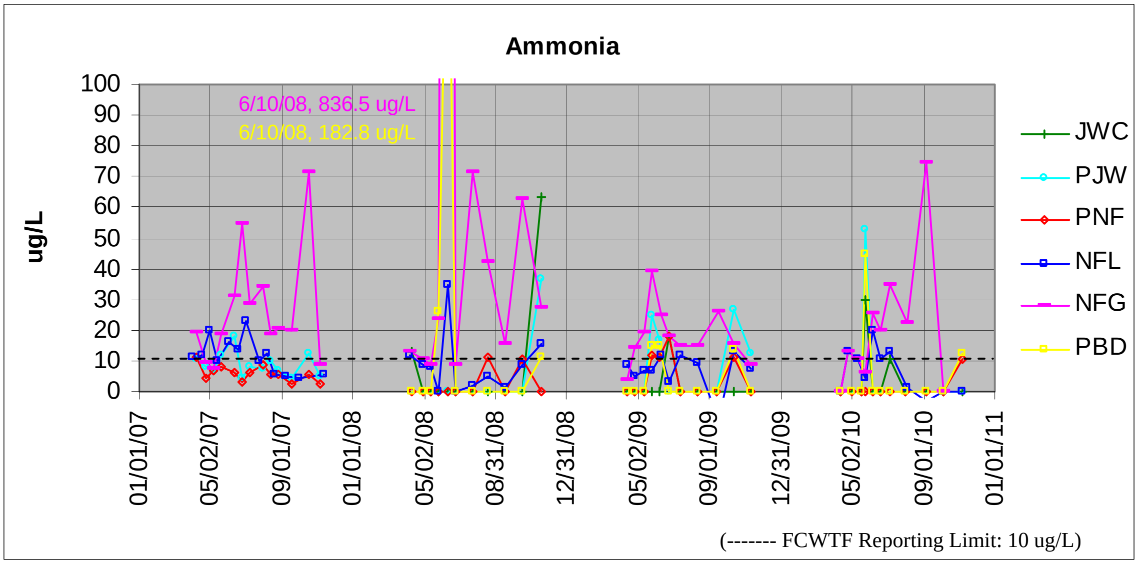
To evaluate the current status of the Mainstem and North Fork Cache la Poudre Rivers in respect to these proposed standards, a three-year median value for Total N and a five-year median value for Total P was calculated for three river locations: PNF on the Mainstem above the Fort Collins water supply intake facility, PBD above the Greeley-Bellvue water supply diversion, and NFG on the North Fork below Seaman Reservoir (Table 3). Results indicate that the 3-year median Total N value at NFG currently exceeds the proposed standard, while other sites were well below the proposed standards. The Total N value for NFG (416.7 ug/L) is similar to median concentrations of Total N in Seaman Reservoir. A similar comparison of proposed nutrient standards for Seaman Reservoir is presented in Section 4.5.

Table 3. Comparison of Mainstem CLP and North Fork CLP sites 3-year median Total N and 5-year median Total P values to 2010 CDPHE/WQCD proposed nutrient criteria.

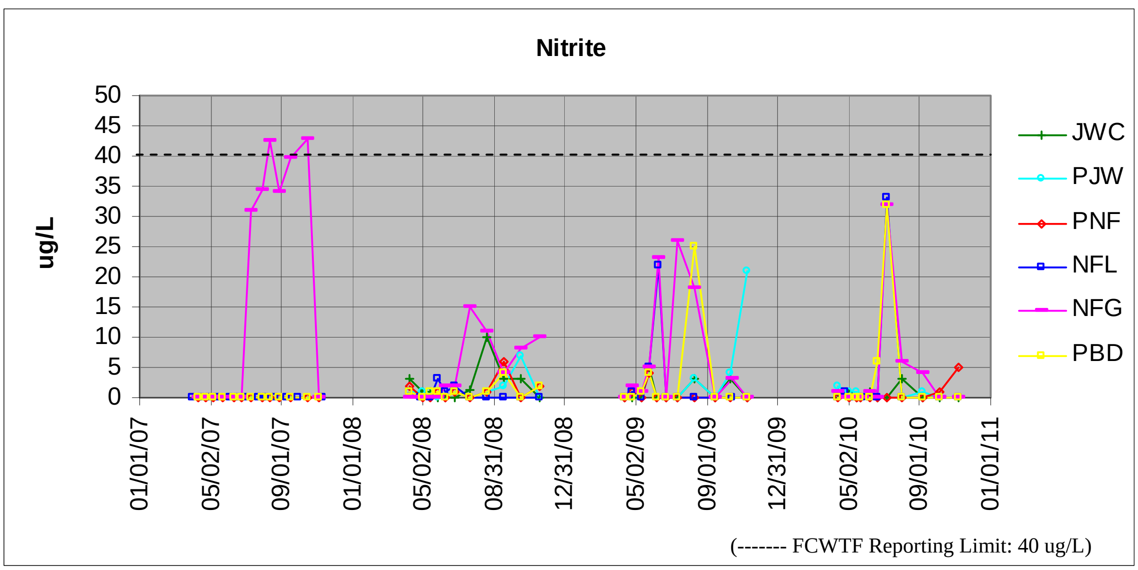
Proposed Standard	PNF	NFG	PBD
TN: 400 ug/L (5-yr median, not to exceed)	240.6 ug/L	**416.7 ug/L**	274.1 ug/L
TP: 110 ug/L (5-yr median, not to exceed)	9.9 ug/L	32.8 ug/L	11.2 ug/L

Figure 22 (a-g). Nutrient concentrations at key Upper CLP monitoring sites.

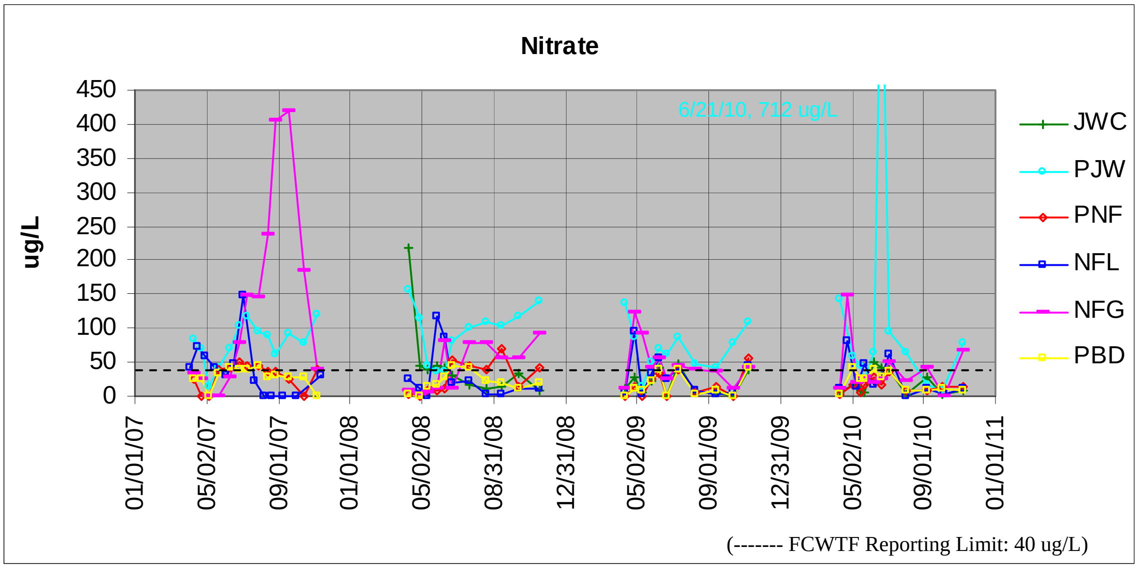
22.a. Ammonia (NH_3)



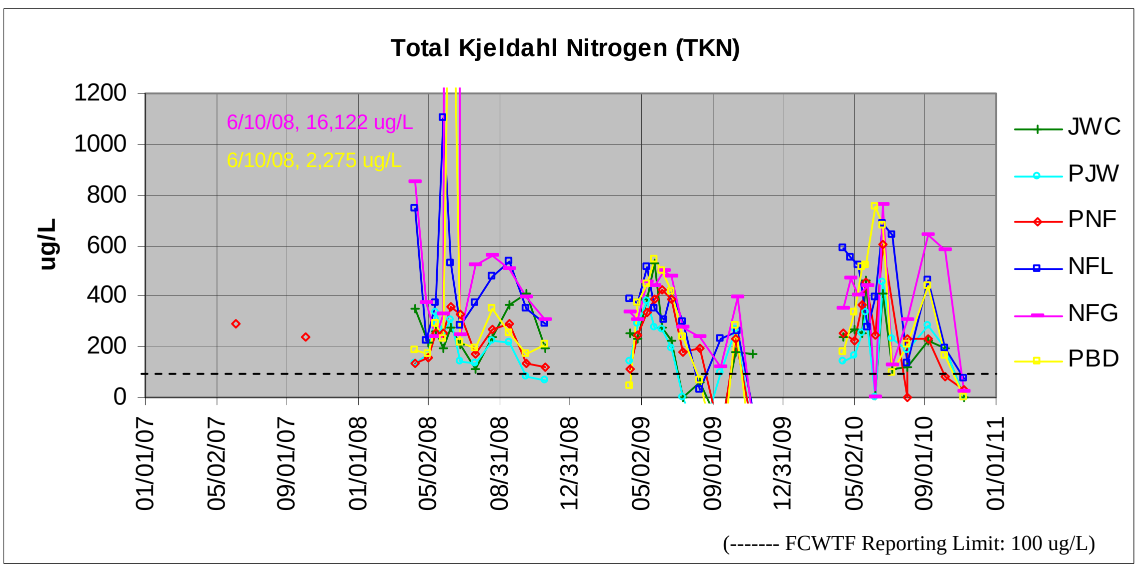
22.b. Nitrite (NO_2)



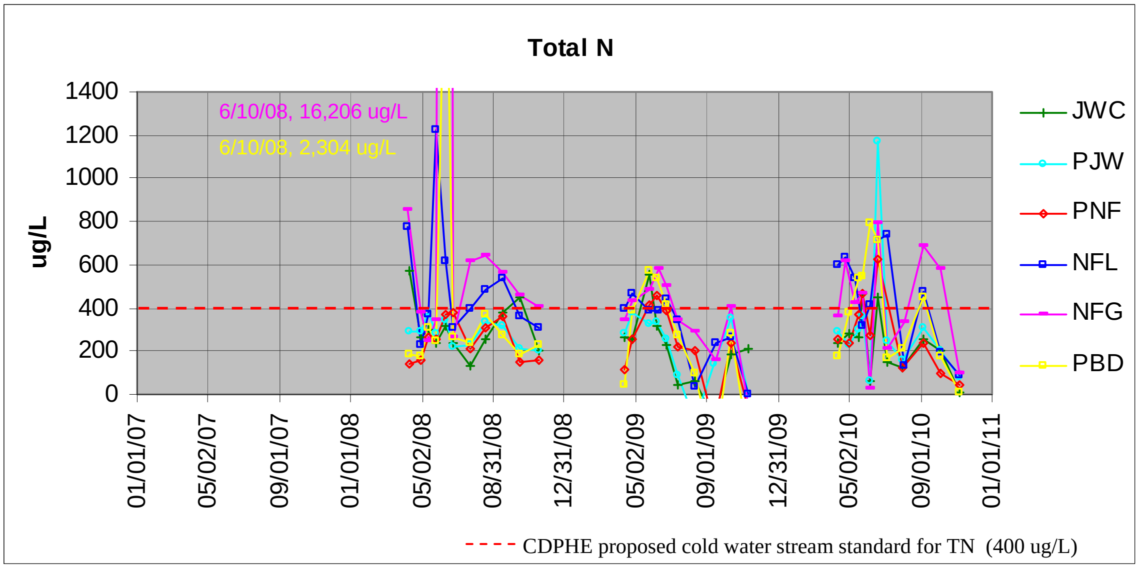
22.c. Nitrate (NO_3)



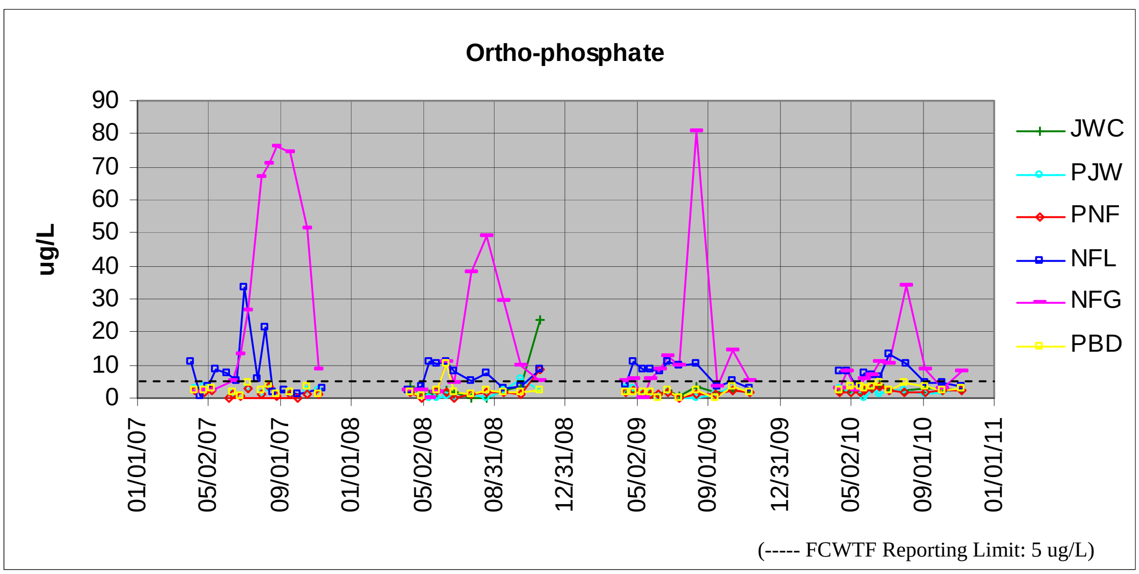
22.d. Total Kjeldahl Nitrogen (TKN)



22.e. Total Nitrogen (TKN + NO_3+NO_2)

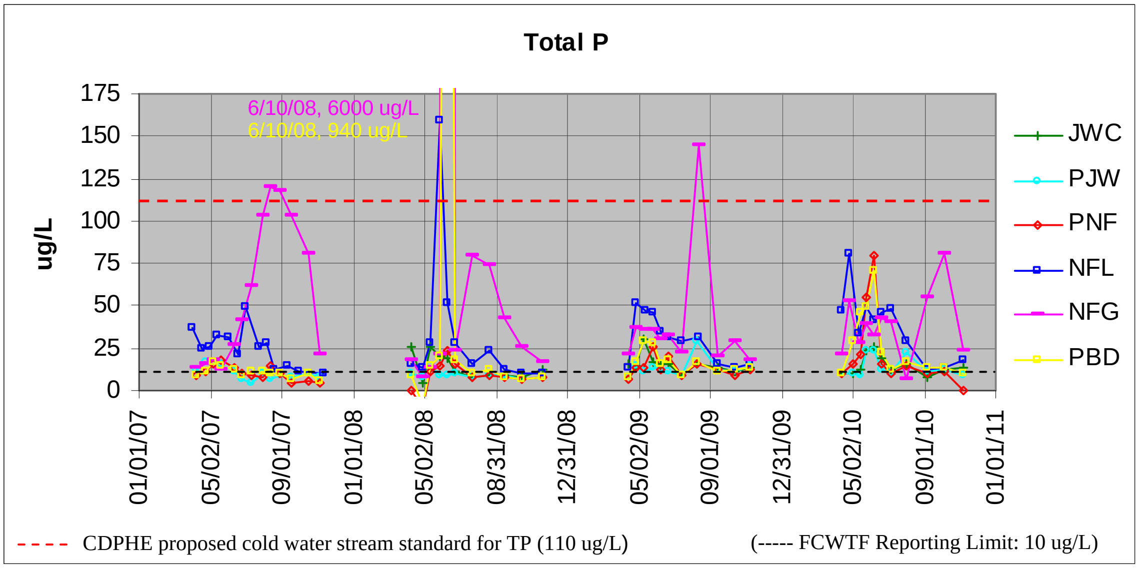


22.f. Ortho-phosphate (PO_4)



* 2007 values reported as Soluble Reactive Phosphorus (SRP)

22.g. Total Phosphorus (TP)



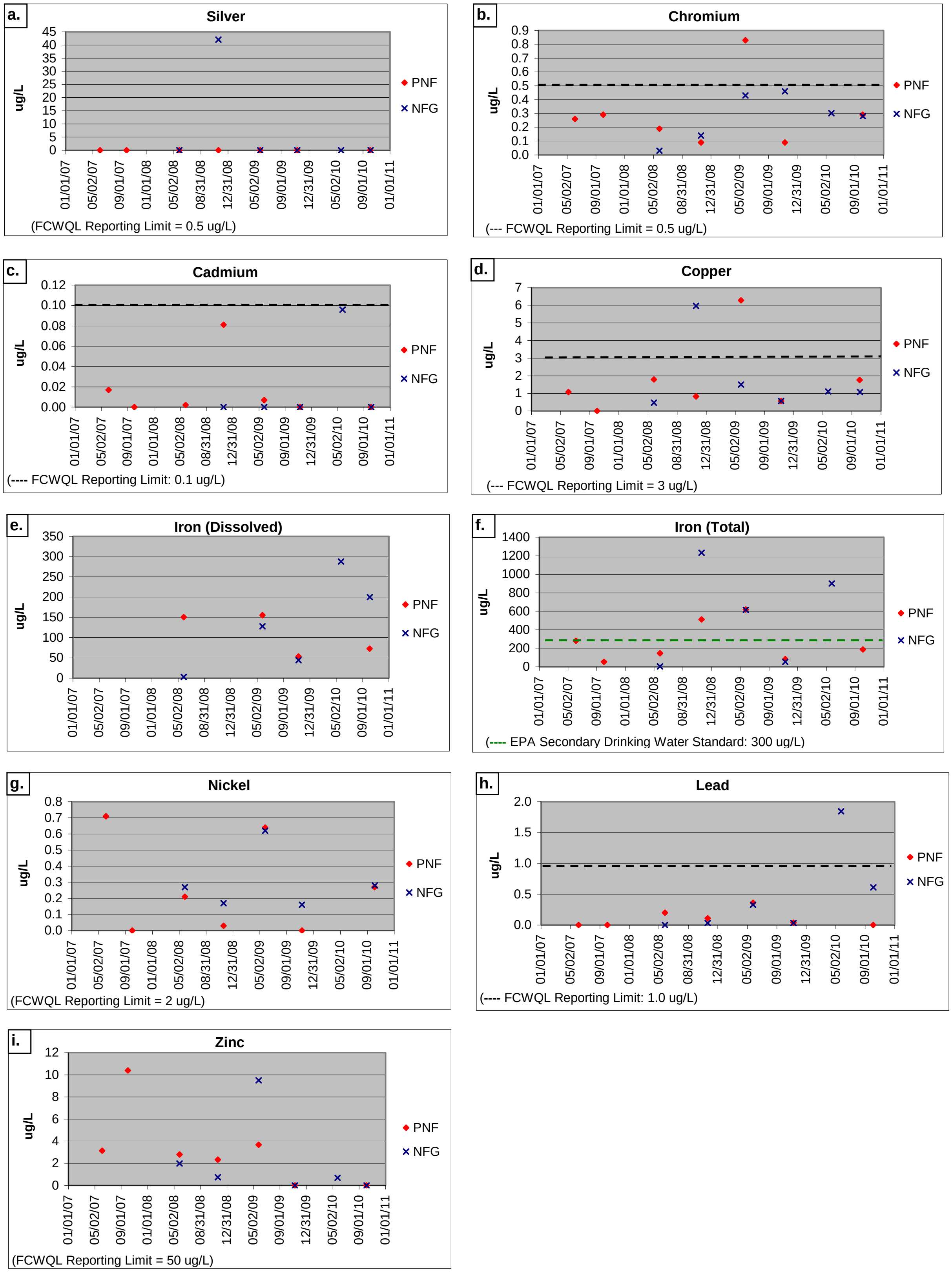
3.6 Metals

Metals are sampled twice annually on the Mainstem at PNF and on the North Fork at NFG. A spring sample was collected on 5/25/10 and a fall sample was collected on 10/05/10. The PNF metals sample collected on 5/25/10 was inadvertently discarded, and so metals data for this date are not available. In addition, the October NFG total iron sample was not analyzed because the sample was not properly preserved. All metals are analyzed for dissolved fractions except iron (Fe), which is analyzed for both total and dissolved fractions. In 2010, dissolved concentrations of silver (Ag), cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), and zinc (Zn) were not detected at concentrations above their respective reporting limits (Figure 23.a – 23.i).

One reportable concentration of lead (Pb) was observed at NFG during the spring sampling event (1.8 ug/L), but was significantly lower than the EPA drinking water standard of 15 ug/L.

Dissolved and total iron are the constituents most frequently observed at concentrations above reporting limits. The fall concentration of dissolved iron was 73 ug/L on the Mainstem at PNF and was similar to the previous year. Spring values were not available for 2010, but in 2009, the spring sample concentration at PNF was higher than fall concentration and similar seasonal differences are observed on the North Fork at NFG. The North Fork at NFG had slightly higher spring and fall dissolved iron concentrations than observed in previous years (288 and 200 ug/L, respectively). As expected and seen in previous years, total iron concentrations were significantly higher than the dissolved fraction at both NFG and PNF. From 2008 to 2010, concentrations have ranged widely, from 4 - 1,277 ug/L. Both sites have experienced total iron concentrations above the EPA secondary drinking water maximum contaminant level (MCL) for total iron (300 ug/L) during the past three years. The 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. Because water treatment processes remove much of the iron in raw water supplies, the iron concentrations reported for the Upper CLP are not expected to have adverse effects on finished water quality.

Figure 23 (a-i). Metals concentrations at PNF and NFG.



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 representative of 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 24 and 25). From 2007 - 2010, *Giardia* was present at levels ranging from 0-36 cysts/L, whereas *Cryptosporidium* was frequently not detected; values did not exceed 0.8 cysts/L.

Beginning in 2008, pathogens were consistently more abundant on the North Fork (NDC) than on the Mainstem (PNF). *Cryptosporidium* concentrations at PNF in 2009 and 2010 show a decreased below 2007 and 2008 values and are generally not detected. The outflows from Halligan and Seaman Reservoirs (NBH and NFG, respectively) consistently had the lowest *Giardia* concentrations. *Cryptosporidium* concentrations were generally similar above and below Halligan Reservoir (at NDC and NBH, respectively), with the exception of 2010 when *Cryptosporidium* was not detected at NBH. *Cryptosporidium* and *Giardia* both show an increase from 2007 through 2008 at NDC, although no change was observed from 2008 to 2010. Because of the change in sampling site location, it is not possible to know whether the observed increase from 2006 -2008 is due to changes that occurred within the watershed, or is a response to site-specific conditions. A general seasonal trend of increasing *Giardia* concentrations did, however, occur throughout the summer and fall months at NDC. The 2010 peak *Giardia* concentration of 36 cysts/L was observed on 11/9/10.

Testing for pathogens below Seaman Reservoir at NFG began in 2008. *Giardia* was generally not detected. In contrast, *Cryptosporidium* is occasionally detected at low numbers in the past three years, with the highest value occurring on 4/14/09 (0.78 cysts/L).

Figure 24. Concentrations of *Giardia* on Mainstem and North Fork CLP.

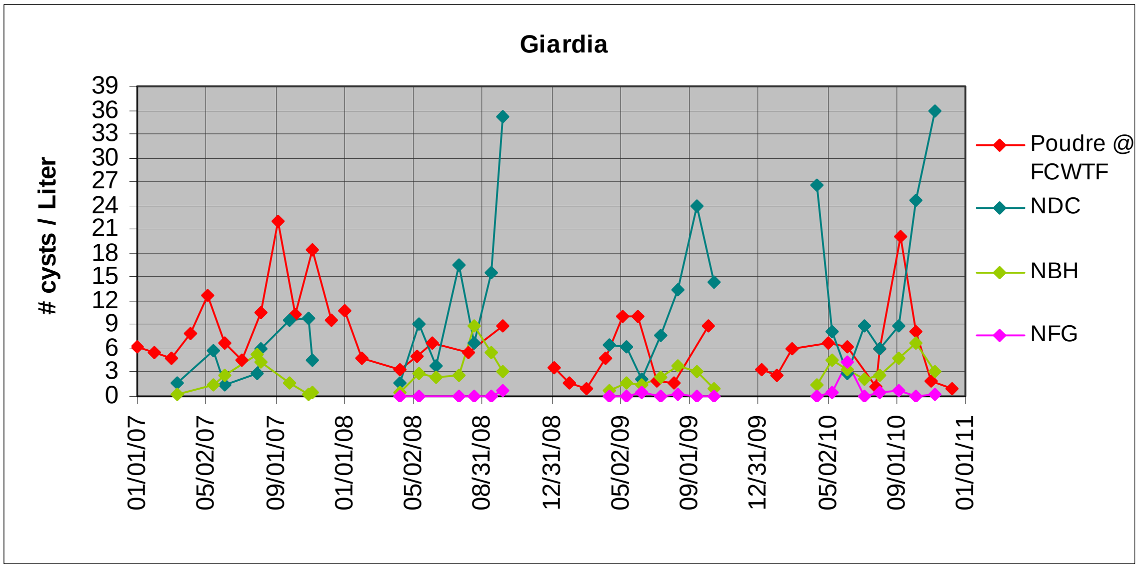
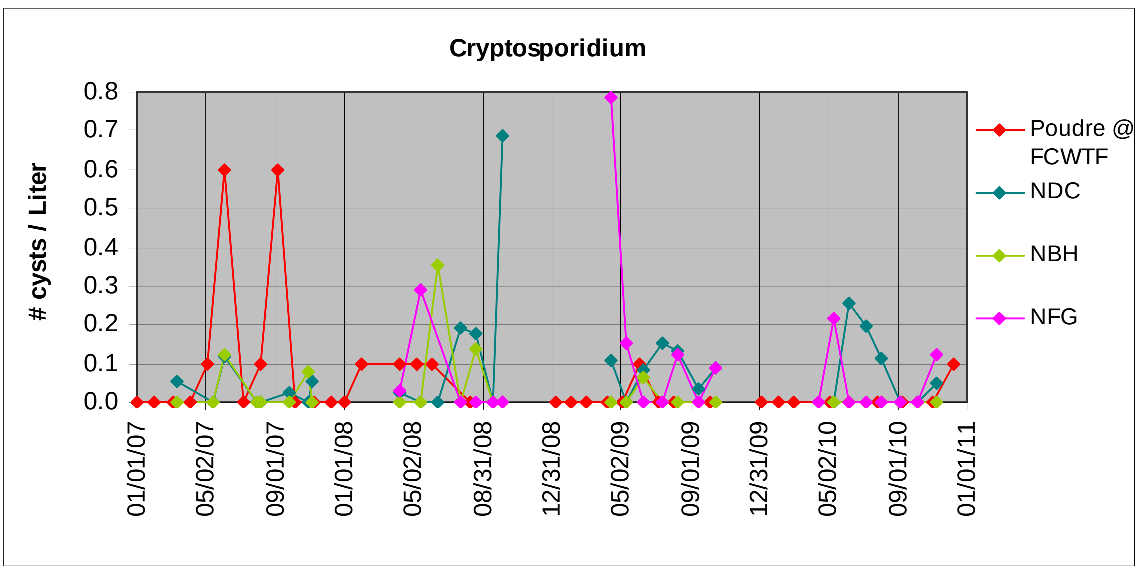


Figure 25. Concentrations of *Cryptosporidiu*m on Mainstem and North Fork CLP.



3.8 Total Coliforms and *E. coli*

Total coliforms and *E. coli* samples were collected from 2005 - 2007 as part of the City of Greeley's water quality monitoring program as well as by the City of Fort Collins. A comparison of all available data suggests that differences in the concentrations reported by the two programs are larger than what would be expected by inter-annual variation and are not supported by similar trends in nutrients, other water quality parameters or reported events within the watershed. Therefore, the data are not considered comparable and only results from the FCWQL are presented in this report.

PNF was the only site for which a complete data set from the FCWQL was available for 2007 – 2010. In 2010, peak values for both *E. coli* and total coliforms were higher than observed in the previous three years at PNF (Figures 26 and 27). In general, PBD had similar concentrations of total coliforms and *E. coli* concentrations as PNF. The major exceptions occurred on 6/10/08, when spikes in *E.coli* occurred in response to the unusually high spring run-off on the North Fork, and on 8/2/10 when *E.coli* concentrations at PBD more closely represented an average of the low concentration at NFG and the higher concentration at PNF.

Consistent with 2008 and 2009 results, the North Fork showed higher concentrations of both total coliforms and *E.coli* than the Mainstem in 2010. At the North Fork sites NFL and NFG, the mid- and late-summer peak concentrations of Total Coliforms were lower than in 2009, but higher than in 2008. In contrast, 2010 peak *E.coli* concentrations at NFL (395 colonies/100ml) and NFG (295 colonies/100ml) were two times higher than in 2009. 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. Results showed that peak total coliform concentrations above and below the reservoir coincided (at NFL and NFG, respectively), but the concentrations of total coliforms at NFL were considerably less than at NFG.

Unlike total coliforms, the timing of peak *E. coli* concentrations at NFL and NFG did not coincide. At both NFL and NFG, *E. coli* peaked at the onset of spring run-off, followed by a sharp decrease. Both sites also experienced late season spikes in *E.coli*, although the timing was different. In contrast to the previous year, *E. coli* did not remain elevated over the summer at NFL. These results suggest that while the North Fork drainage is an important source of *E.coli* and total coliforms to Seaman Reservoir, there is no clear relationship between concentrations above (at NFL) and below the reservoir (at NFG). The lack of direct relationship is likely due to a complex set of interacting factors, some of which may include the timing and magnitude of stream flow at NFL, reservoir holding time and release rates. The relationships between total coliforms and *E.coli* concentrations on the North Fork and in Seaman Reservoir are explored in more detail in Section 4.7.

The data show that over the last two years, concentrations of *E.coli* at NFL and NFG have exceeded the CDPHE recreational standard of 126 colonies/100mL; however, in 2010, the Mainstem sites, PNF and PBD also experienced concentrations above the standard for the first time over the four year period of record.

Figure 26. Concentrations of total coliforms at key Upper CLP monitoring sites

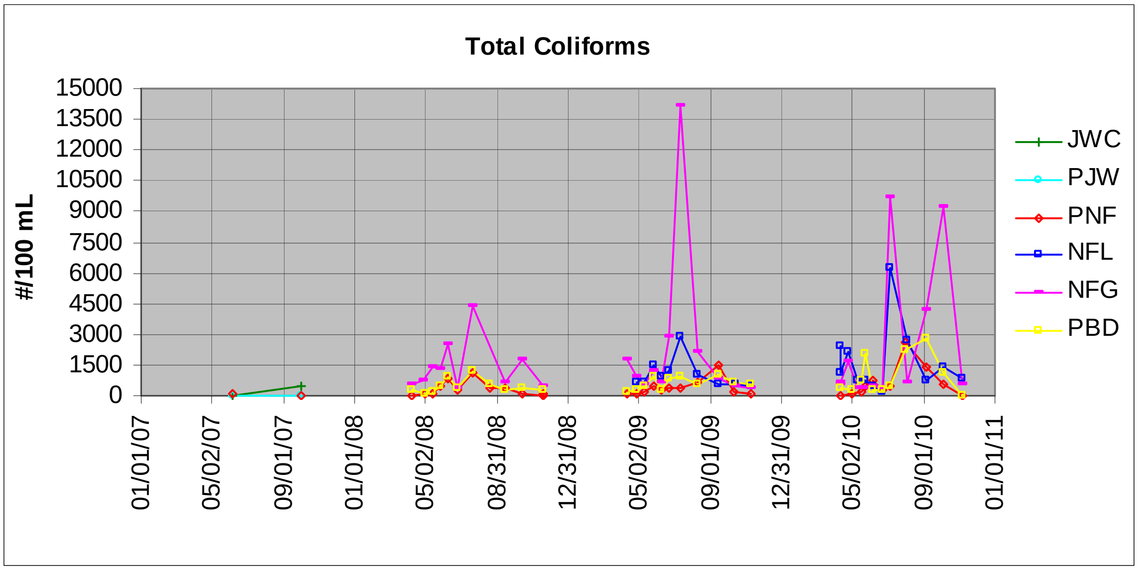
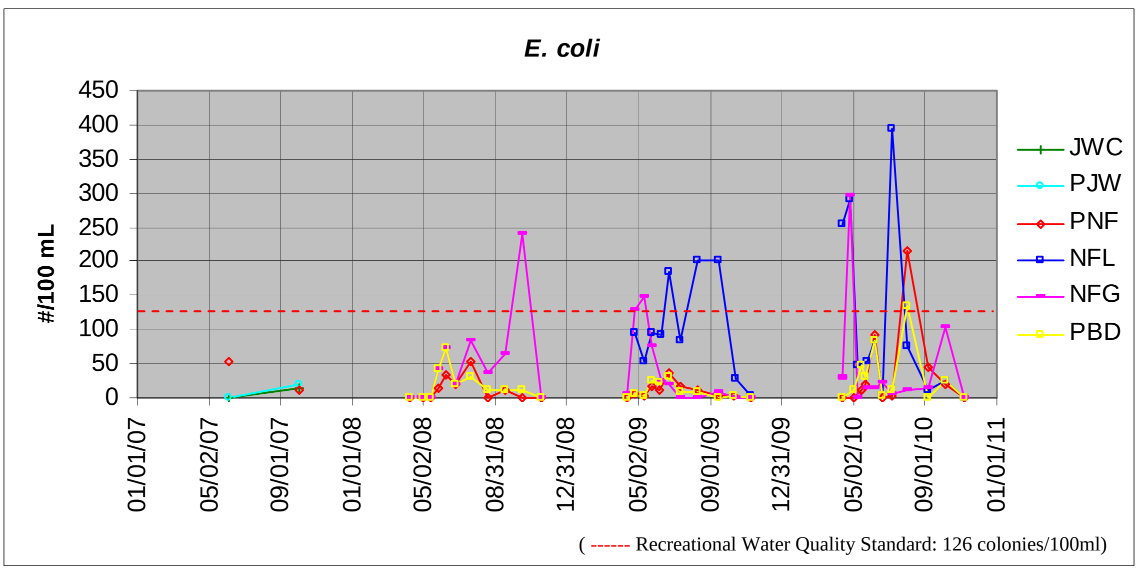


Figure 27. Concentrations of *E. coli* at key Upper CLP monitoring sites.

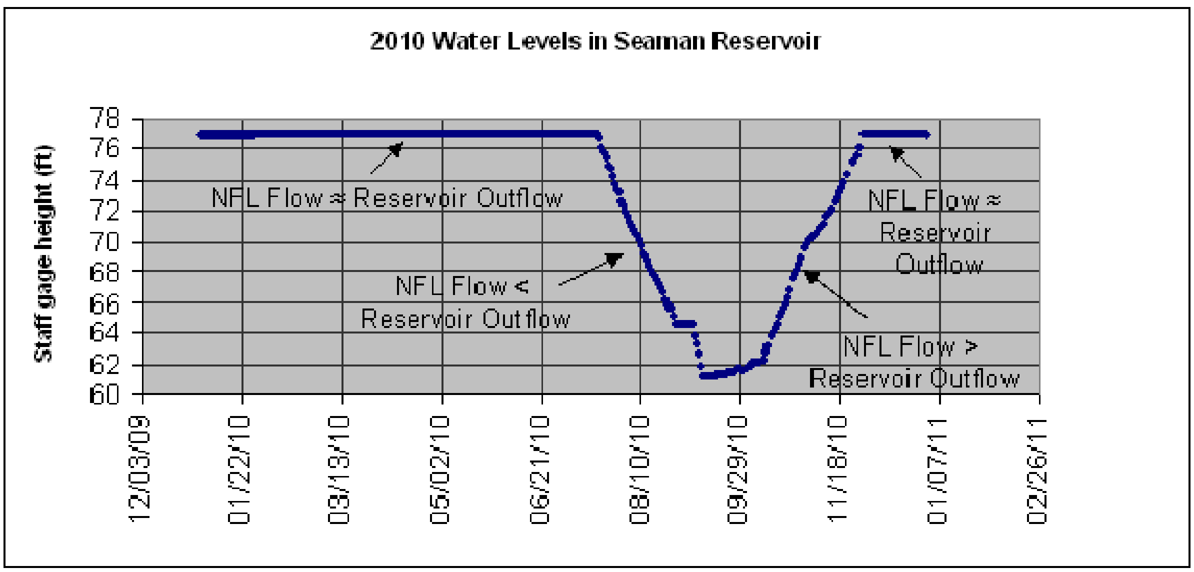


4.0 SEAMAN RESERVOIR RESULTS

4.1 Reservoir Operations

From January through mid-July of 2010, Seaman Reservoir was at full capacity with water levels at 77ft, or 23.3 m. (Figure 28). During this period, reservoir outflows were released over the spillway and closely approximated the incoming flow from the upper North Fork watershed (NFL). Beginning in mid-July the water level in the reservoir steadily decreased, reaching a minimum stage height of 61ft in mid-September. During the period of time when the reservoir was below capacity, all releases to NFG occurred via the bottom outlet of the reservoir. Following the summer draw-down, the reservoir water level steadily increased and returned to full capacity by the beginning of December, at which point, all excess flows were again released via the spillway. Information related to the operations of Seaman Reservoir was provided by Randy Gustafson, with the City of Greeley.

Figure 28. 2010 water levels in Seaman Reservoir.



4.2 Temperature, Dissolved Oxygen, pH, and Conductivity Profiles

The 2010 Seaman Reservoir profiles for temperature, dissolved oxygen, pH and specific conductance are shown in Figure 29.a-d. In 2010, the onset of thermal stratification in Seaman Reservoir began in April, with a thermocline becoming established by late May (Figure 29.a). The thermocline was disrupted during the period of peak stream runoff - an event that is reflected by the smoothing of June temperature profiles. Following spring runoff, the reservoir became stratified once again. By July, a weak thermocline was evident; however, it persisted only until September. Although there was not a strong separation of upper and bottom waters beginning in September, there was a distinct and visible gradient of temperatures from the top to the bottom of the reservoir. Water temperatures were approximately three to four degrees warmer at depth in August and September than they were in 2009. The temperature profiles indicate that water temperatures at the surface did not exceed the aquatic life temperature standard of 22.5° C in 2010.

Reservoir turnover, which occurs as surface water cools and begins to mix with the bottom water, is characterized by increasingly uniform temperature and dissolved oxygen (D.O.) values from top to the bottom of the reservoir. Reservoir mixing began in October, as evidenced by an increase in D.O. concentrations at middle depths and was complete by the November sampling date (11/9/10). While the halted progression of thermal stratification during peak runoff season was unusual, the timing of reservoir mixing and turnover were similar to previous years. It should be noted that in 2008, reservoir dynamics differed from other years due to the reservoir operations related to the draw-down and subsequent refilling as detailed in the 2008 annual report (Oropeza and Billica, 2009).

Typically, dissolved oxygen profiles develop a *positive heterograde*, where concentrations are highest in the upper waters of a reservoir and decrease with depth. However, profile development differed from this expected pattern during mid-summer months of 2009 and 2010. During mid-summer months, the reservoir profile presented as a *negative heterograde*, meaning that D.O. minima were observed in the metalimnion and were underlain by higher D.O. concentrations. In July 2010, a D.O. minimum of 5.2 mg/L was observed in the metalimnion (4 m), while concentrations at intermediate depths (5-12m) were higher; up to 6.2 mg/L at 12m (Figure 28.b). There are several possible reasons for this type of development, including the situation where respiration is greater than photosynthesis in the metalimnion. If photosynthesis is light limited by suspended organic matter or sediments, and/or if there is an abundance of zooplankton grazing (increased respiration) near the thermocline, respiration can be greater than photosynthesis and can result in low oxygen in the metalimnion. In 2009, the negative heterograde persisted until fall turnover; however, in 2010, it was only present during July.

Regardless of duration, these periods of low oxygen can limit suitable habitat for aquatic life. In 2010, Seaman Reservoir was officially added to the 303(d) list of impaired waters due to occurrences of D.O. below 6 mg/L in the metalimnion combined with exceedances of the temperature standard in the epilimnion (adequate D.O. refuge for fish is not available in these types of situations).

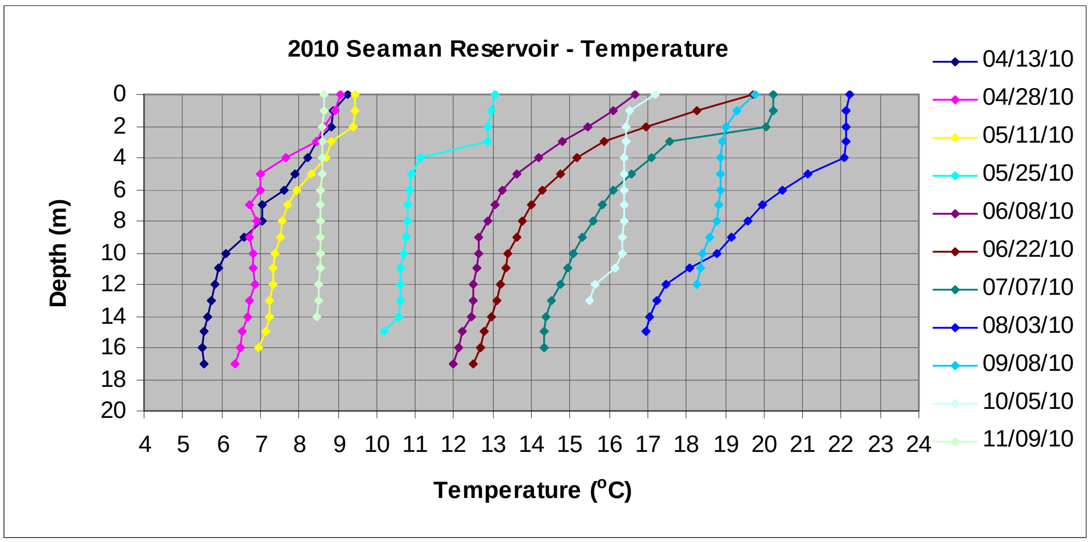
As observed in previous years, the concentration of D.O. in the lower waters decreased progressively from the onset of thermal stratification until fall turnover (Fig 29.b). Bottom D.O. concentrations decreased to 5 mg/L in July and reached anoxic conditions (0 mg/L) during the months of August and September. The duration of low bottom D.O. concentrations in 2010 was similar to 2007 and 2009; complete D.O. depletion did not occur in 2008 (Figure 30). Prolonged periods of low D.O. concentrations at the bottom of the reservoir are of concern because they can mobilize trace metals (e.g. manganese) and phosphorus from the bottom sediments.

In general, pH decreases with decreasing temperature and D.O. concentrations. As expected, Seaman Reservoir profiles show that pH minima occur at the bottom and during the summer months, when the reservoir is thermally stratified and D.O. is also at a minimum. In 2010, pH values ranged from 7.3 to 8.9 at the surface and 7.0 to 7.8 at the bottom (Figure 29.c). These values fall within the pH water quality standard of 6.5 to 9.0.

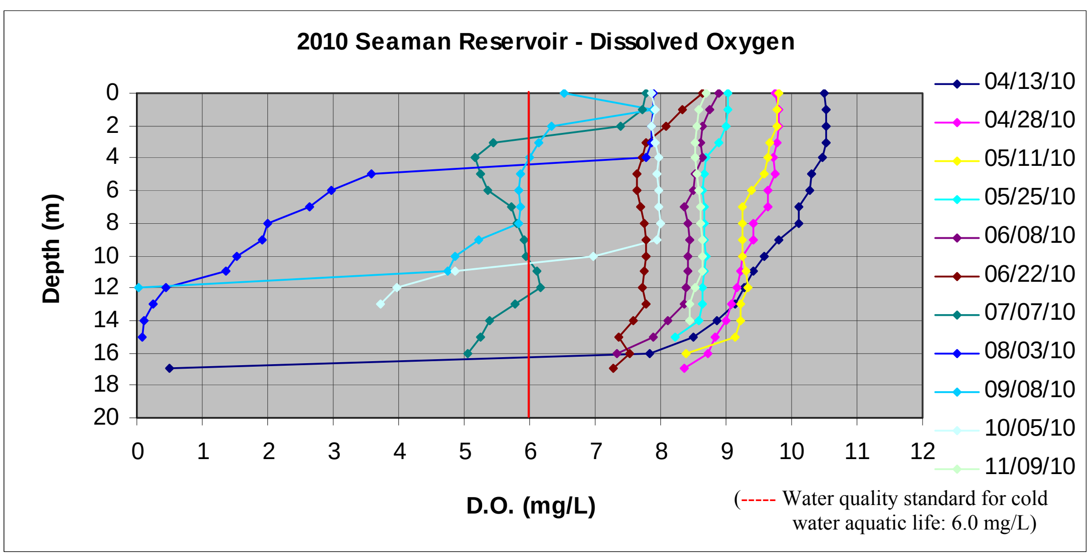
Specific conductance decreased with the spring runoff, with minimum values observed at the beginning of June (Figure 29.d). Specific conductance then increased again throughout the summer and into the fall. The only times that the top and bottom values varied substantially were late April and during the months of July and August.

Figure 29 (a-d). 2010 Seaman Reservoir Profiles

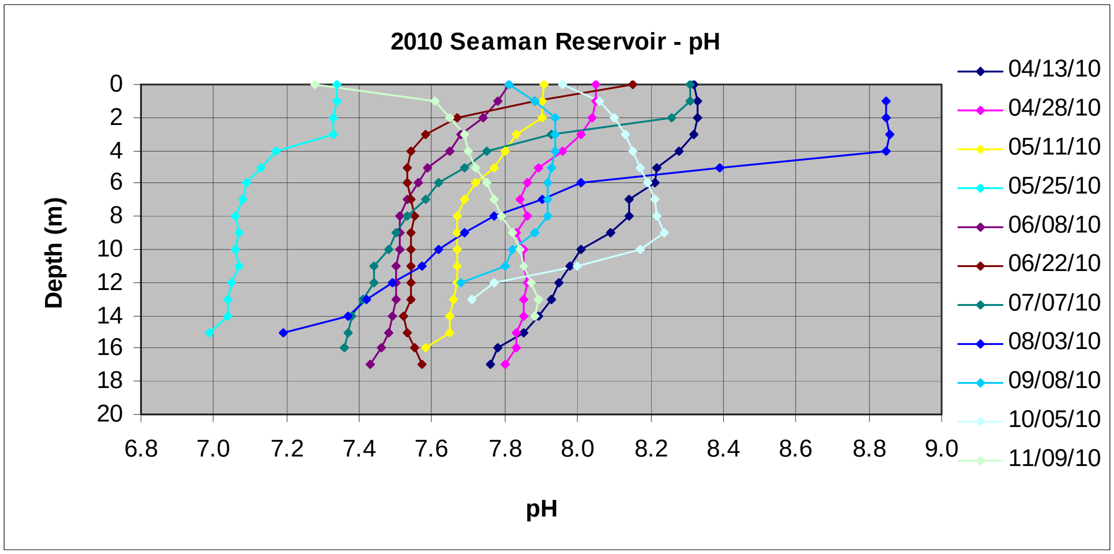
29.a Temperature



29.b. Dissolved Oxygen



29.c. pH



29.d. Specific Conductance

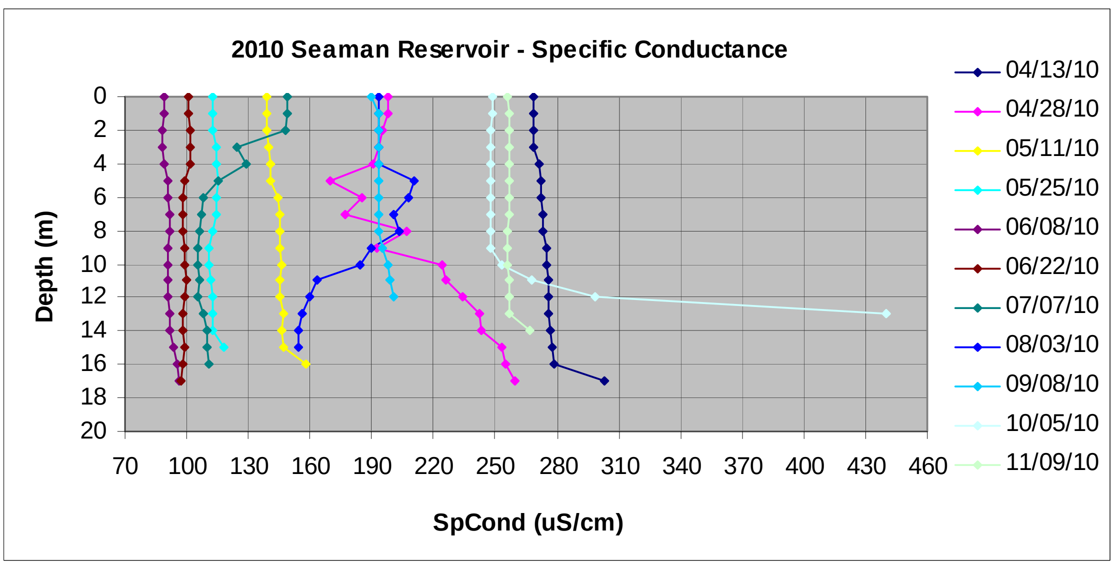
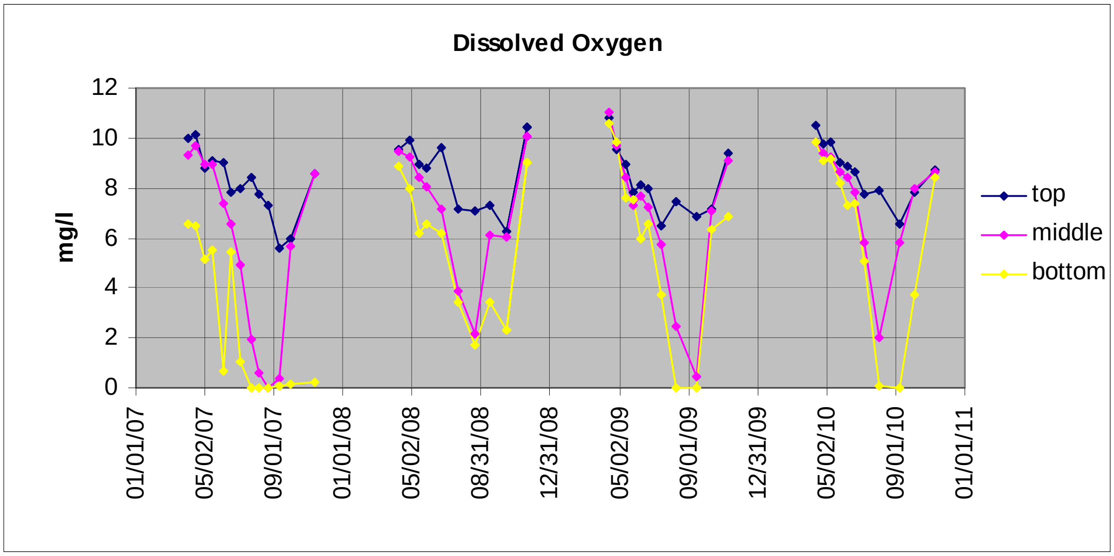


Figure 30. Dissolved oxygen concentrations at the top, middle and bottom of Seaman Reservoir.



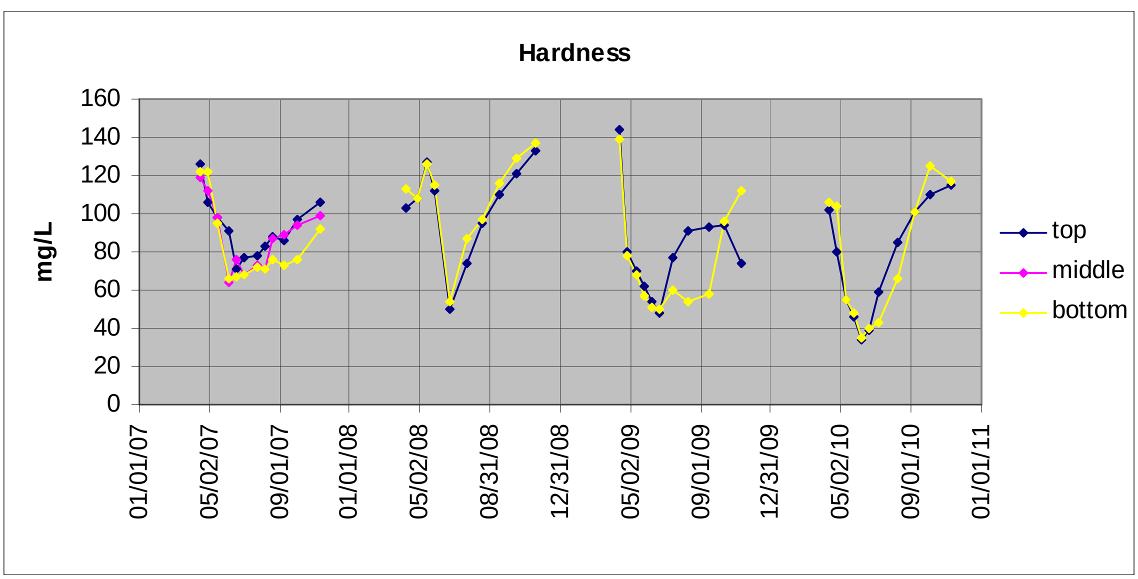
4.3 General Parameters: Hardness and Alkalinity

Hardness and alkalinity both track closely on the reservoir top and bottom (Figure 31.a and 31.b) and experience minimum values during spring runoff. In 2010, the seasonal trend in hardness was similar to 2007-2009 during which a significant spring decrease in hardness was observed, followed by a steady return to early spring values.

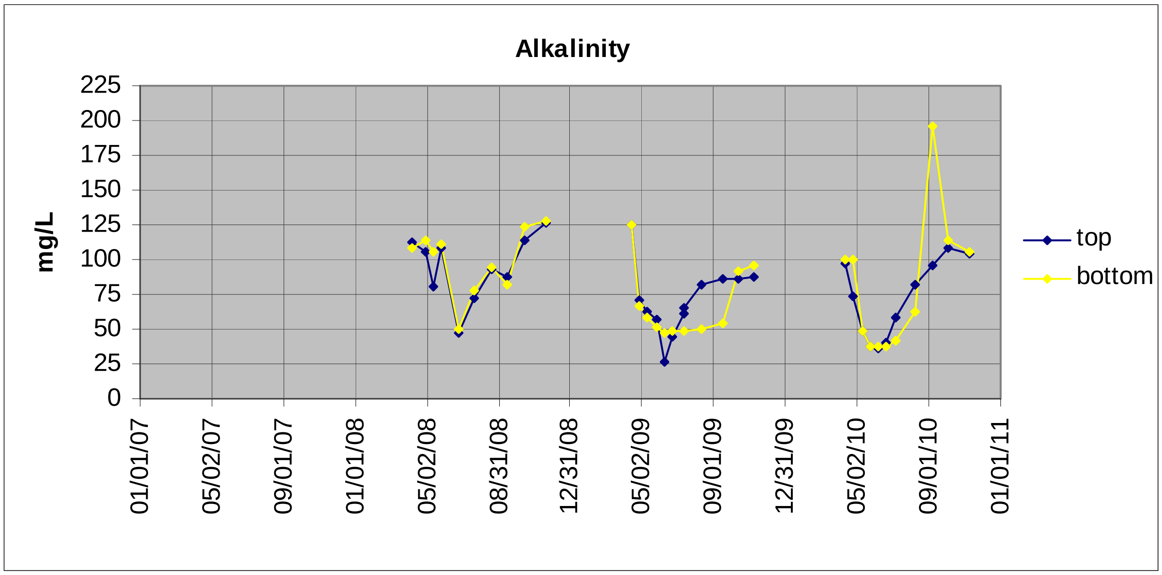
Alkalinity followed a similar seasonal pattern as hardness from 2008 - 2010. One exception was a strong spike in alkalinity at the bottom of the reservoir (196 mg/L) that occurred on 9/7/10, but it had no effect on surface alkalinity and was not observed on subsequent sampling dates. Alkalinity data were not available for 2007.

Figure 31 (a-b). General water quality parameters at Seaman Reservoir: Hardness and Alkalinity.

31.a. Hardness



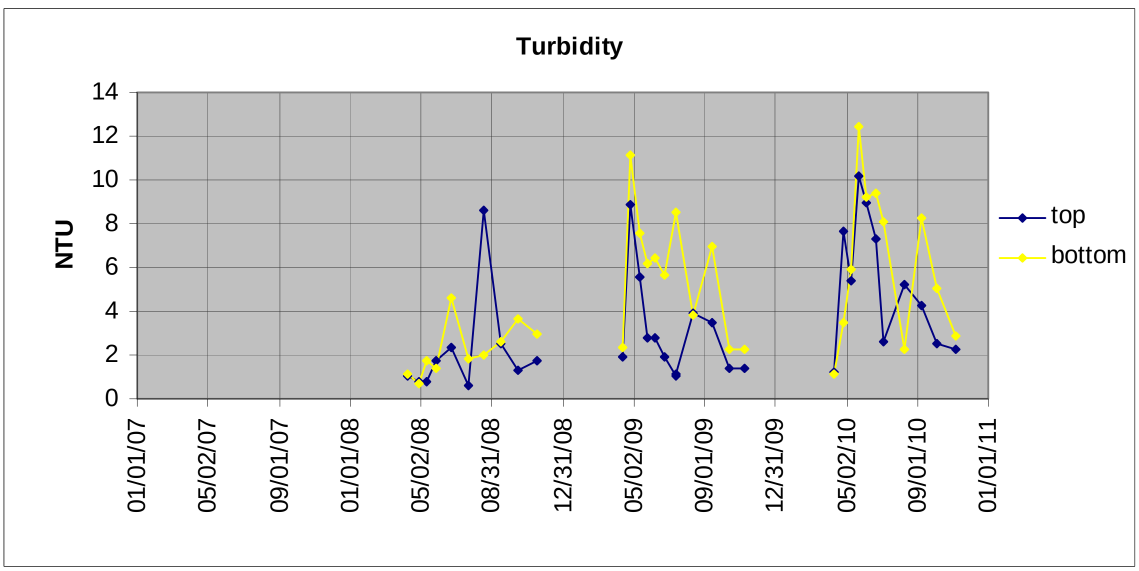
31.b. Alkalinity



4.4 Turbidity, Chlorophyll-a and Secchi Depth

Turbidity values at the top and bottom of Seaman Reservoir were similar throughout the year and slightly higher than values observed in 2008 and 2009 (Figure 32). In 2010, turbidity values on the top ranged from 1.2 to a peak value of 10.2 NTU, which coincided with the second pulse in upstream flow at NFL on 5/25/10 and the flush of sediments transported by the snowmelt run-off (Figure 16). The bottom values ranged from 1.1 - 12.4 NTU.

Figure 32. Turbidity in Seaman Reservoir.



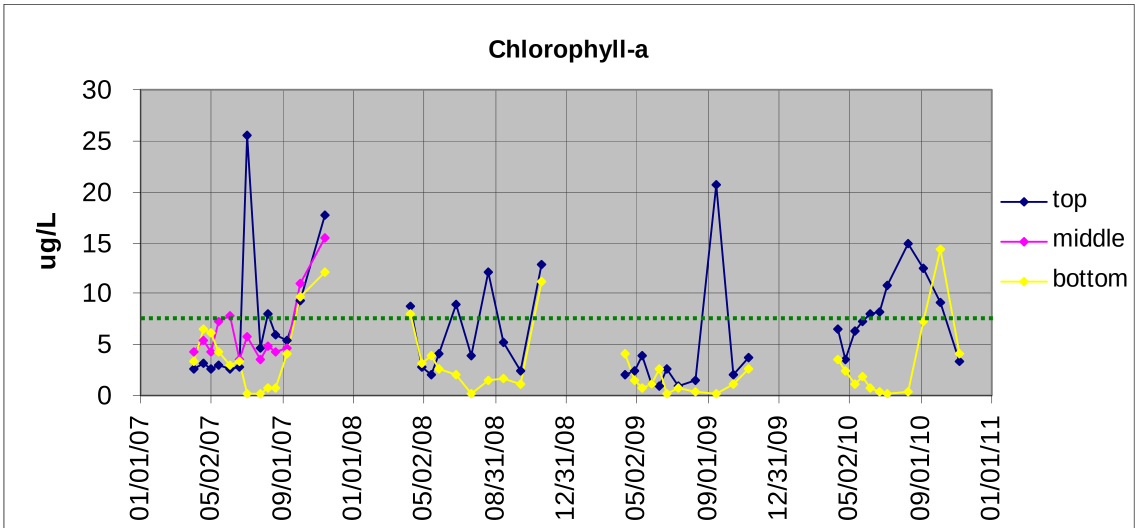
Chlorophyll-a concentrations in Seaman Reservoir were within the range observed for the previous three years (Figure 33). Chlorophyll-a was consistently higher on the top than on the bottom from 2007 to 2010, with the exception of a 2010 late season spike in bottom concentrations. From 2007 to 2010, late summer peaks in chlorophyll-a concentrations ranged from 12-25 ug/L and coincided with an expected peak in algae growth in the reservoir.

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 ≥ 50 as calculated from (Carlson, 1977):

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

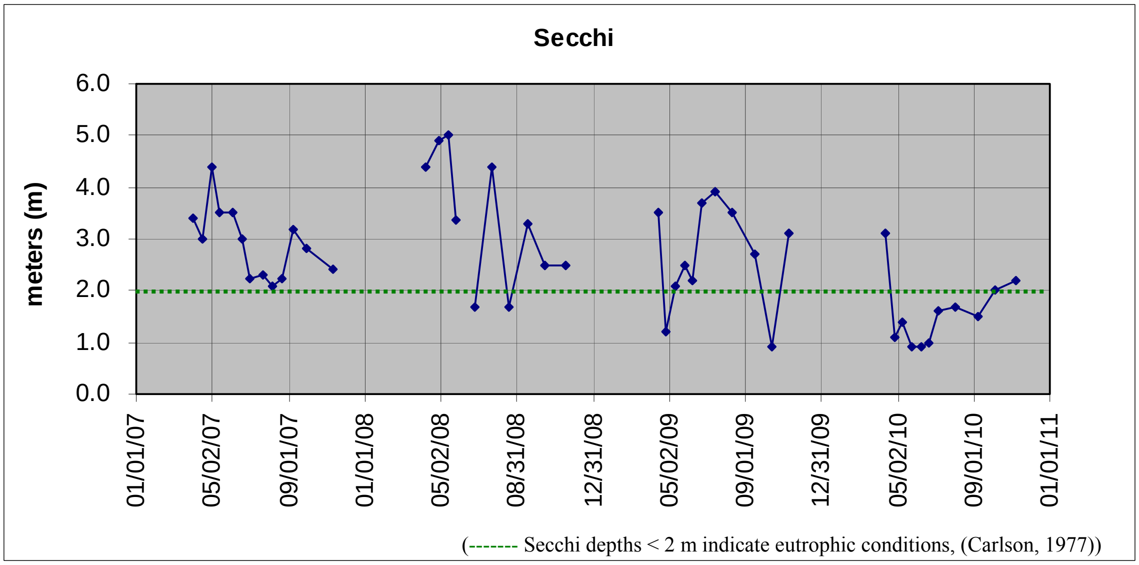
From 2007 through 2010, chlorophyll-a concentrations in Seaman Reservoir frequently exceeded 7.3 ug/L, with most exceedances occurring in the upper portion of the reservoir.

Figure 33. Chlorophyll-a concentrations in Seaman Reservoir.



Secchi depth results indicate that Seaman Reservoir experienced a general decrease in water clarity from 2007 through 2010 (Figure 34). Secchi depth minima (periods of lowest light penetration) can typically coincide with periods of high turbidity and chlorophyll-a levels, suggesting that algal growth may contribute to turbidity and decreased clarity in the reservoir, especially during the summer months (Figure 35). However, secchi depths can also decrease due to an increase in inorganic turbidity alone and may not be related to algal growth. The relationships for Seaman Reservoir are not always consistent and evident. In 2010, the secchi depth ranged from 0.9 to 3.1 m with the minimum depths occurring in late spring and early summer, coinciding with the spring runoff and peak turbidities. Seasonal trends in secchi depth are not consistent year to year.

Figure 34. Secchi depth in Seaman Reservoir.

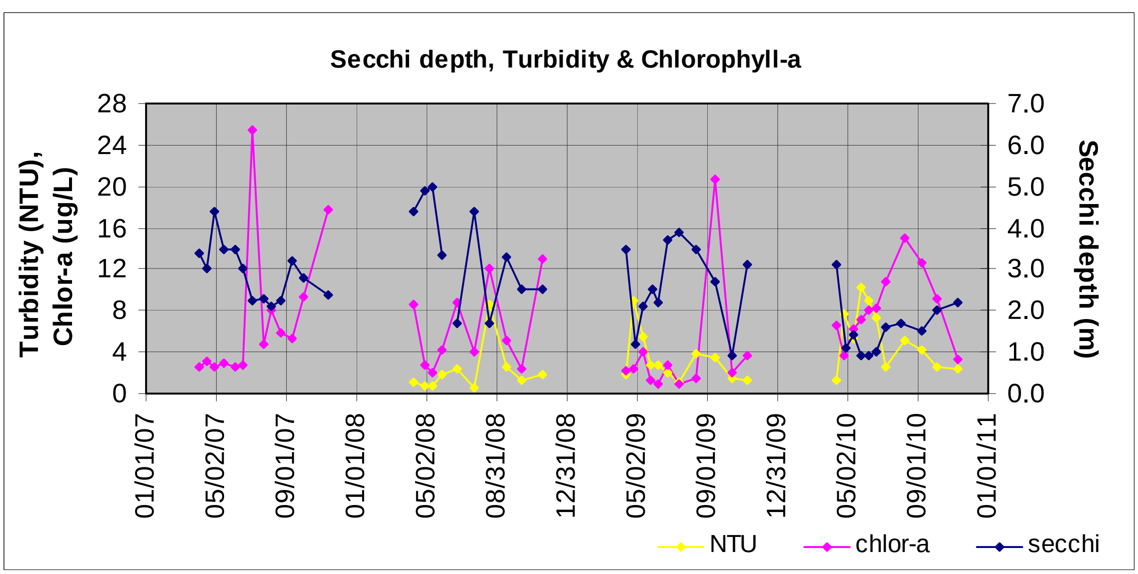


Note that secchi depth values less than 2.0 m may indicate eutrophic conditions based on Carlson's TSI for a TSI ≥ 50 as calculated from (Carlson, 1977):

TSI (secchi depth) = 60 – 14.41 x ln (secchi depth in meters).

The number of secchi depth measurements below 2.0 m has consistently increased since 2007 suggesting a trend toward more eutrophic conditions. However, secchi depths may also decrease due to high inorganic turbidity or dissolved organic matter, without any increase in algal activity. In 2007, there were no values below 2.0 m compared with 2010, in which all but two measurements were below 2.0 m. There has been a general decrease over time in both annual peak values (periods of highest clarity) and annual minimum values (periods of lowest clarity).

Figure 35. Comparison of secchi depth, turbidity and chlorophyll-a concentrations in Seaman Reservoir.



4.5 Nutrients

The processes of thermal stratification and related changes in dissolved oxygen concentrations in the water column have the ability to affect the distribution of nutrients within Seaman Reservoir. As seen in previous years, concentrations of nitrate, nitrite, ammonia, ortho-phosphate and total phosphorus at the bottom of the reservoir peaked during the period of lowest observed pH and D.O. values in the hypolimnion (Figures 36.a – 36.g). For 2010, this period extended from 8/3/10 to 10/5/10. The late season peaks in nitrate, ortho-phosphate and total phosphorus (TP) concentrations at the reservoir bottom were significantly lower than the previous year. Late summer ammonia concentrations at the reservoir bottom have decreased over the last four years. Nitrite values have not exceeded the reporting limit during the last four years.

During other times of the year, concentrations of dissolved nutrients are generally low at the top and bottom of the reservoir. In the last two years, nitrate has proved to be the exception; unusually high spring nitrate concentrations were observed in the top and bottom of Seaman Reservoir. In 2009 and 2010, peak nitrate concentrations occurred in late April at 258 ug/L and 127 ug/L, respectively, and were roughly four to six times higher than observed in the previous two years. The high spring peaks at the top and bottom of Seaman Reservoir coincide with early stages of spring runoff on the North Fork and show a strong decrease in nitrate as runoff progresses. Top and bottom values were also generally higher and more variable throughout the entire year. For both years, seasonal trends in nitrate concentrations at the surface of Seaman Reservoir and the upstream site NFL track closely (Figure 37), although reservoir concentrations were much higher than at NFL. It is expected that the higher in-reservoir nitrate concentrations are due to a net accumulation of nitrate over time. The close correspondence between nitrate dynamics upstream, within and downstream of the reservoir illustrates that while the reservoir is at full capacity (inflow equals outflow), inflowing water from the North Fork CLP exerts strong control over in-reservoir chemistry. At other times, the relationships between inflow, outflow and in-reservoir chemistry are not as clear.

TKN concentrations are of similar magnitude at the top and bottom of the reservoir and while they generally track the seasonal patterns in ammonia and nitrate, the overall concentrations are considerably higher and more variable (0 – 843 ug/L in 2010) (Figure 36.d). The similarities between the time series for Total Nitrogen (TN) and TKN reflect the fact that TKN is the major fraction of Total Nitrogen, with nitrate and nitrite representing lesser fractions. Both Total P and ortho-phosphate concentrations were similar to 2008 values and lower than observed in 2009.

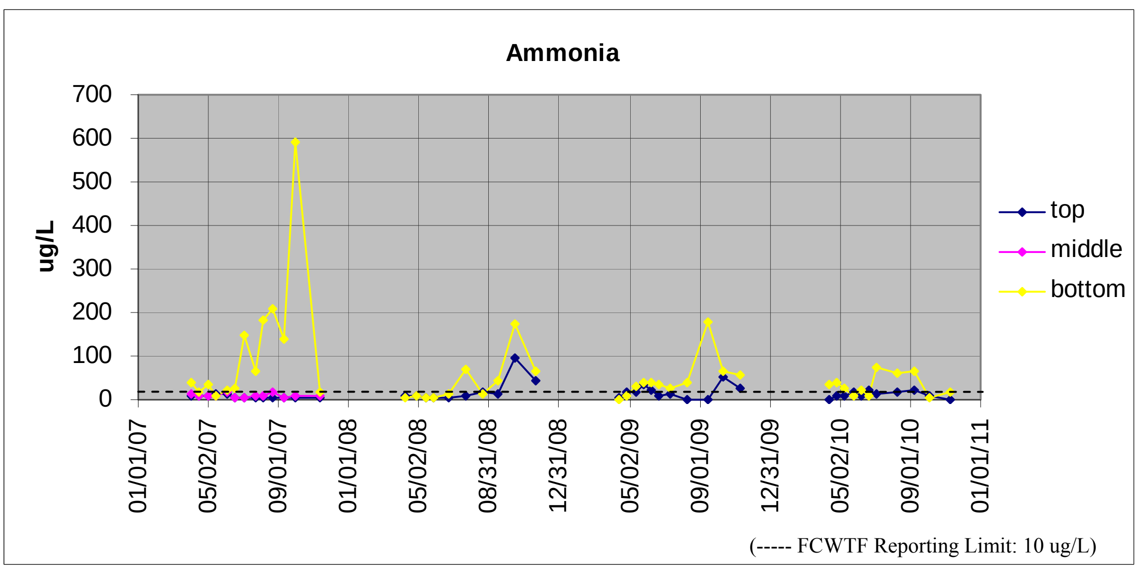
The CDPHE/WQCD has proposed nutrient standards for cold water lakes and reservoirs for total nitrogen (TN), total phosphorus (TP), and chlorophyll-a and were compared to values in Seaman Reservoir (Table 4). A reservoir or lake that directly supplies water to a water treatment facility may fall under the “Protected Water Supply Lake and Reservoirs (PWSR)” designation and be subject to the lower proposed standard for chlorophyll-a of 5 ug/L. Seaman Reservoir is not considered a PWSR site, and therefore, falls under the higher proposed standard of 8 ug/L chlorophyll-a. While the rulemaking hearing to consider the adoption of these proposed nutrient and chlorophyll-a standards is not scheduled to occur until March 2012, this comparison shows that if adopted, Seaman Reservoir will likely not meet the proposed standards for TN or TP.

Table 4. Comparison of Seaman Reservoir summer average (June – Sept) Total N, Total P and chlorophyll-a values to 2010 CDPHE/WQCD proposed nutrient criteria

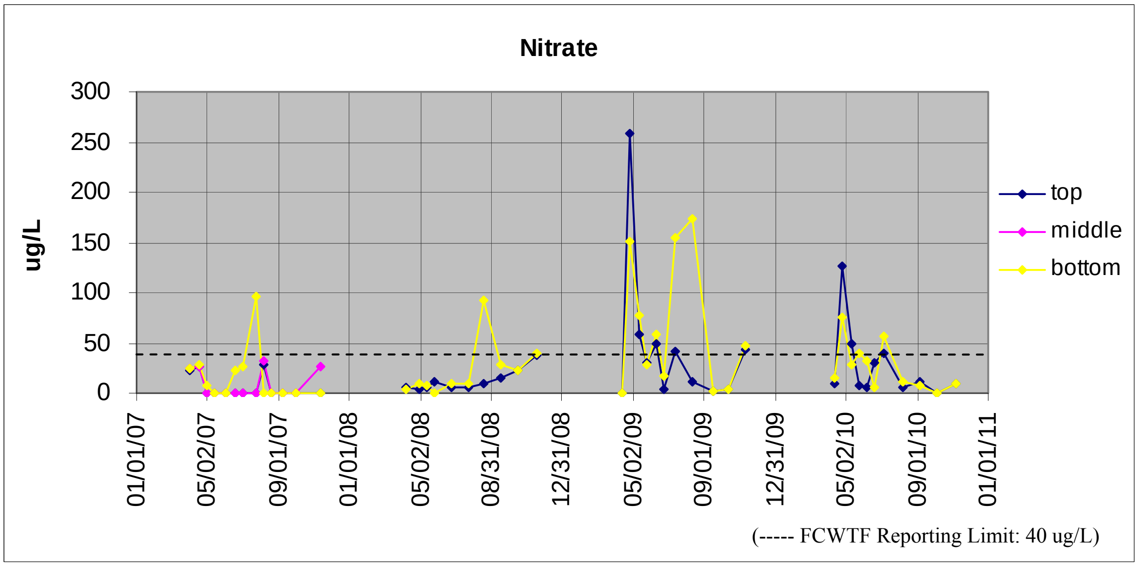
Interim Proposed Standard	Seaman Reservoir Top (1 meter) Summer (June-Sept) Average	
TN: 410 ug/L (summer avg in mixed layer, 1 in 5 yr exceedance frequency)	2006: -- **2008: 514 ug/L** **2010: 487 ug/L**	2007: -- 2009: 370 ug/L
TP: 20 ug/L (summer avg in mixed layer, 1 in 5 yr exceedance frequency)	2006: 11.4 ug/L **2008: 25.5 ug/L** **2010: 30.3 ug/L**	2007: 12.8 ug/L 2009: 18.6 ug/L
Chlor-a: 8 ug/L (summer avg in mixed layer, 1 in 5 yr exceedance frequency)	2006: 2.8 ug/L 2008: 7.6 ug/L **2010: 10.9 ug/L**	2007: 7.8 ug/L 2009: 5.3 ug/L

Figure 36 (a-g). Nutrient concentrations in Seaman Reservoir.

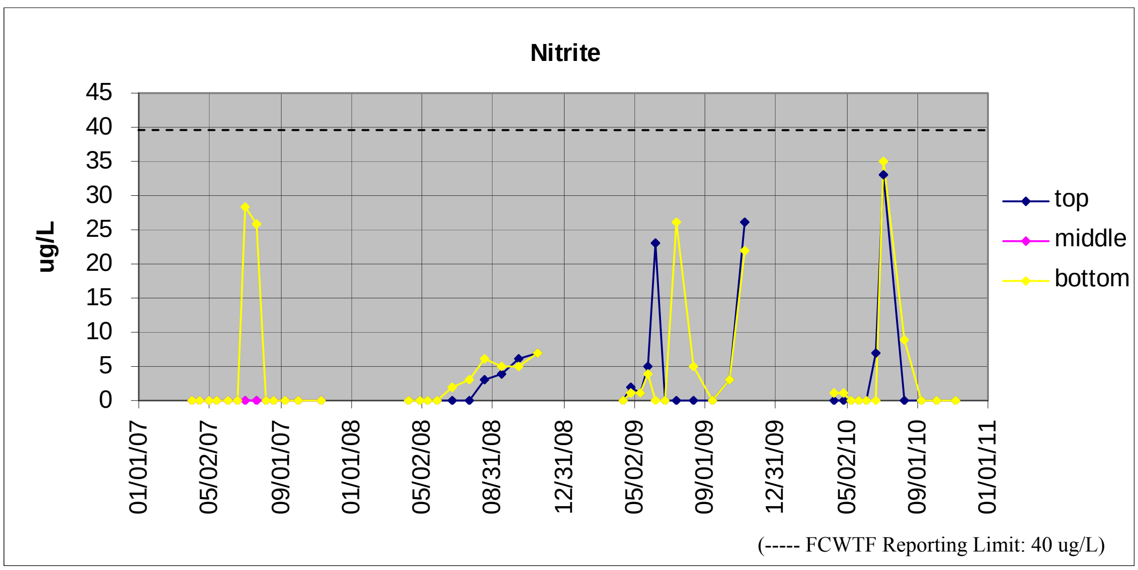
36.a. Ammonia (NH_3)



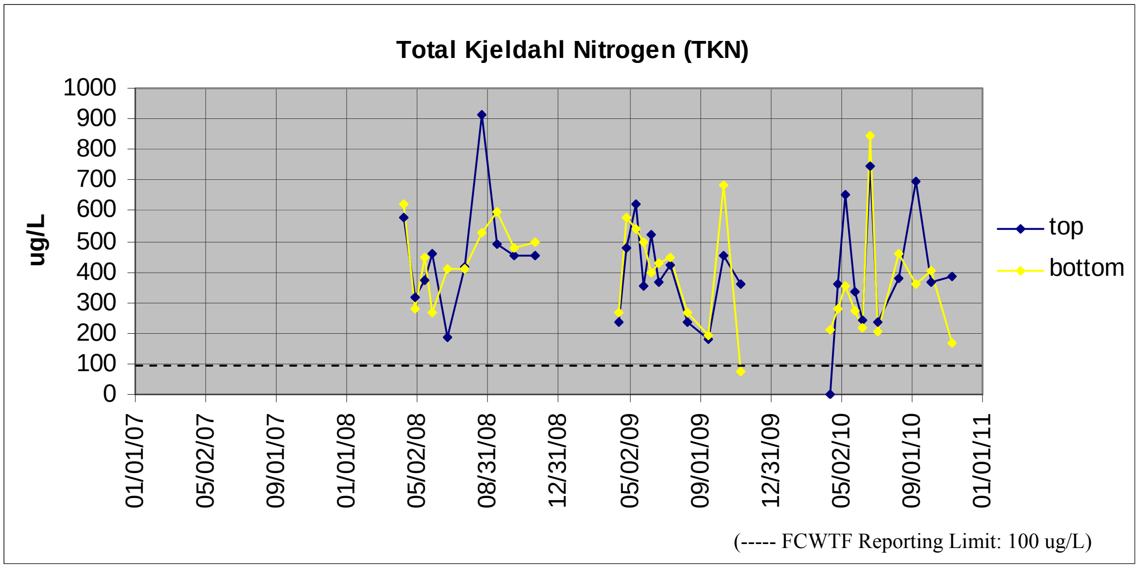
36.b. Nitrate (NO_3)



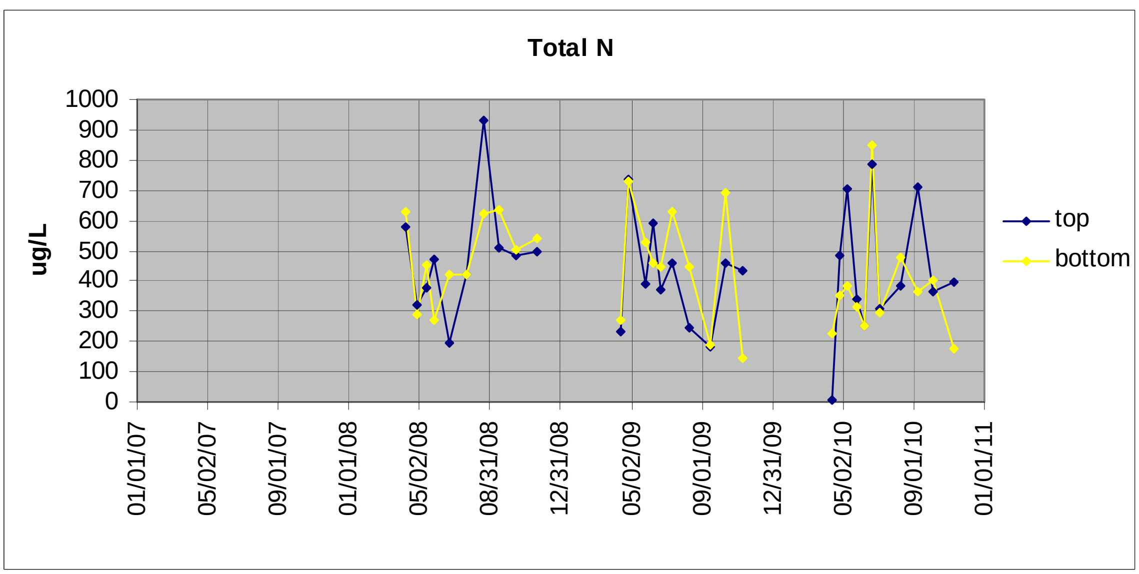
36.c. Nitrite (NO_2)



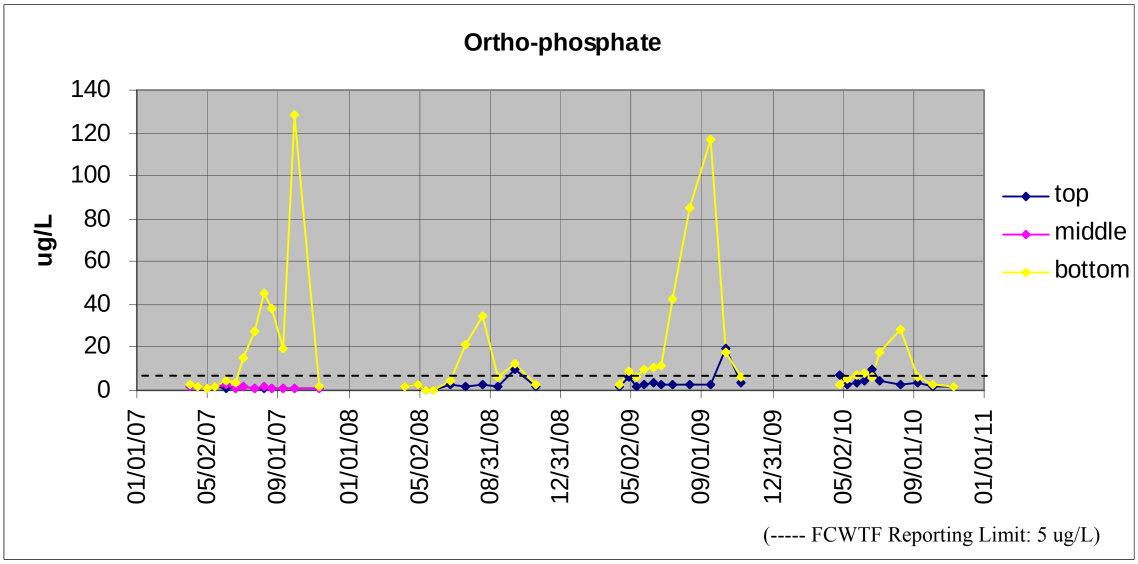
36.d. Total Kjeldahl Nitrogen (TKN)



36.e Total Nitrogen (TKN+NO_3+NO_2)

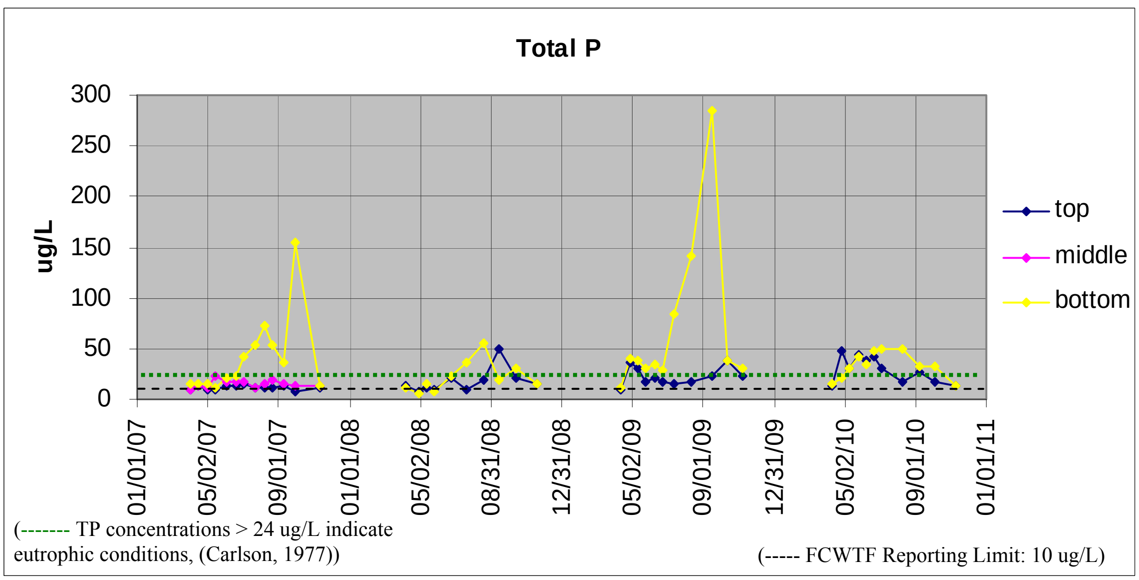


36.f Ortho-phosphate (PO_4)



* Values in 2006 – 2007 reported as Soluble Reactive Phosphorus (SRP)

36.g. Total Phosphorus (TP)

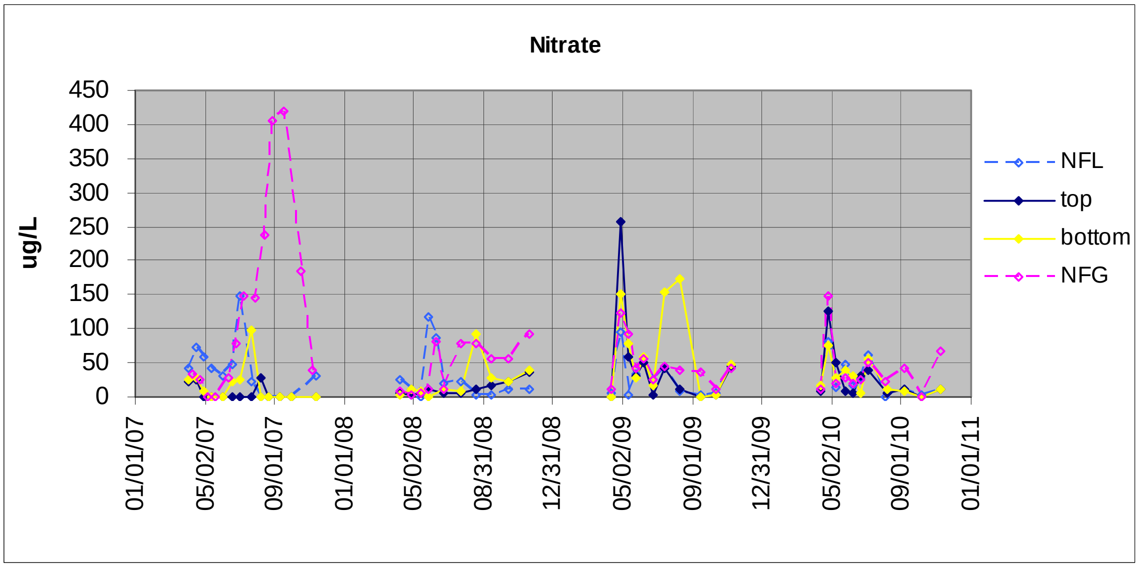


According to Carlson's TSI, epilimnetic (top) total P concentrations above 24 ug/L may indicate eutrophic conditions, corresponding to a TSI ≥ 50 as calculated from (Carlson, 1977):

$$\text{TSI (total P)} = 4.15 + 14.42 \times \ln(\text{total P in mg/L}).$$

In 2007, surface total P concentrations in Seaman Reservoir were consistently below 24 ug/L. Concentrations increased slightly in 2008 to 2009 and resulted in four events in which total P concentrations were within the eutrophic range. In 2010, total P concentrations exceeded the 24 ug/L threshold on seven out of eleven sampling events, indicating a progression toward eutrophic conditions.

Figure 37. Comparison of nitrate concentrations in Seaman Reservoir, upstream at NFL and downstream at NFG.



4.5.1 Seaman Reservoir Trophic Status

For comparison, TSI values for Total P, chlorophyll-a and secchi depth were plotted together in Figure 38. Possible interpretations of the relationships between chlorophyll-a, secchi depth and total phosphorus TSI values are provided by Wetzel (2001, pg. 284):

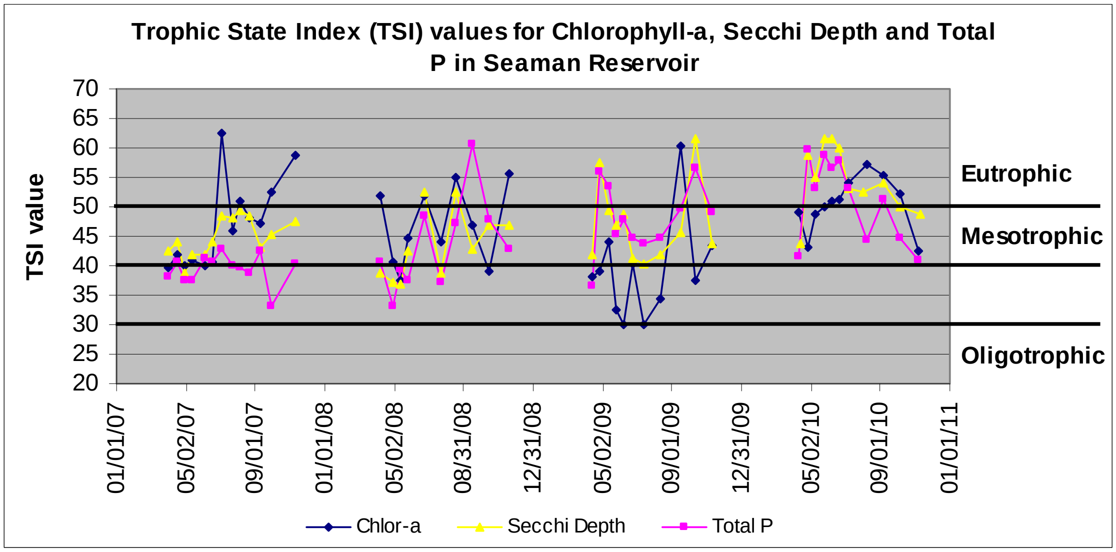
TSI Relationship	Interpretation
Total P TSI < Chl-a TSI	phosphorus is the limiting nutrient
Chl-a TSI < Secchi Depth TSI	dissolved organic matter and/or inorganic turbidity contribute significantly to reduced transparency (reduced transparency not due to algae)

The data suggest that over the past four years, there has been a general increase in TSI values for Total P and secchi depth, while TSI values for chlorophyll-a have been more variable between years.

In 2007, algal growth appears to be phosphorus limited, as indicated by the fact that the total phosphorus TSI is generally lower than the chlorophyll-a TSI. 2008 marks a possible change in the reservoir trophic status, as demonstrated by an increased similarity between the three indices (note, however, that there was a change in laboratory in 2008, from Dr. Bill Lewis' lab prior to 2008 to the City of Fort Collins WQL beginning in 2008). While algal growth in Seaman Reservoir appears to have been phosphorus limited throughout much of 2008 (TN:TP $\geq$ 33:1), TSI values for total P exceeded chlorophyll-a TSI values during late summer, suggesting a period of possible N-limitation (TN:TP <

33:1). In 2009, algal growth appears to have been non-phosphorus limited (i.e. N or light limited) over much of the growing season, as shown by chlorophyll-a TSI values that were generally much lower than TSI values for total P.

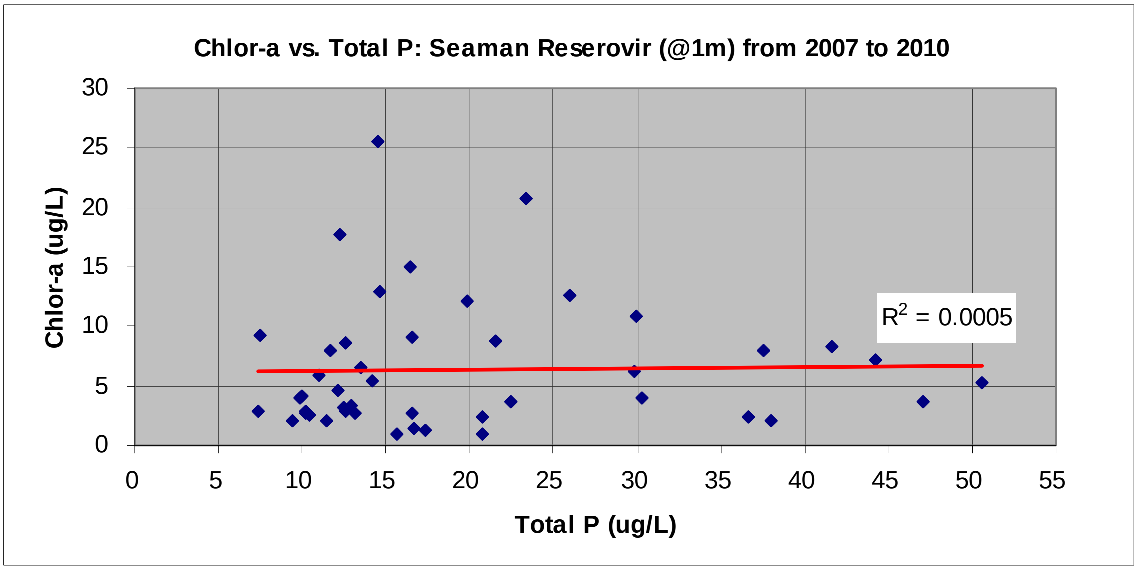
Figure 38. Carlson's Trophic State Index (TSI) values for chlorophyll-a, secchi depth and total P in Seaman Reservoir.



In 2010, Seaman Reservoir followed a similar trend as in 2009, with algal growth appearing to be non-phosphorus limited until the 7/6/10. During this period, the TSI values for secchi depth and TP were much higher than TSI for chlorophyll-a, suggesting that the lack of transparency is likely not due to algal growth, but rather to the presence of high dissolved organic matter (DOM) and/or suspended sediment. This reasoning is supported by high TOC and turbidity values as well as the unusually high spring runoff during this period. Following spring runoff, the reservoir became increasingly thermally stratified until fall turnover. Beginning in July, the TSI for chlorophyll-a moved into the eutrophic range, while the TSI for TP decreased into the mesotrophic range. This distinct shift potentially signals a period of rapid algae growth, fueled by warming surface temperatures and increasing light penetration. The phytoplankton data collected from Seaman Reservoir indicate that during this time, algae density increased dramatically and the dominant class of algae shifted from green algae to nitrifying blue-green algae (See Section 4.8, Figures 45– 48. At the peak of summer algae growth, blue-green algae comprised nearly 90% of the total algae population.

Chlorophyll-a versus total P is plotted on Figure 39 using 1 meter data from Seaman Reservoir. As expected for reasons discussed above, there was no direct relationship observed between chlorophyll-a and total P concentrations, despite the fact that algal growth appears to be limited primarily by phosphorus availability in 2007 and 2008.

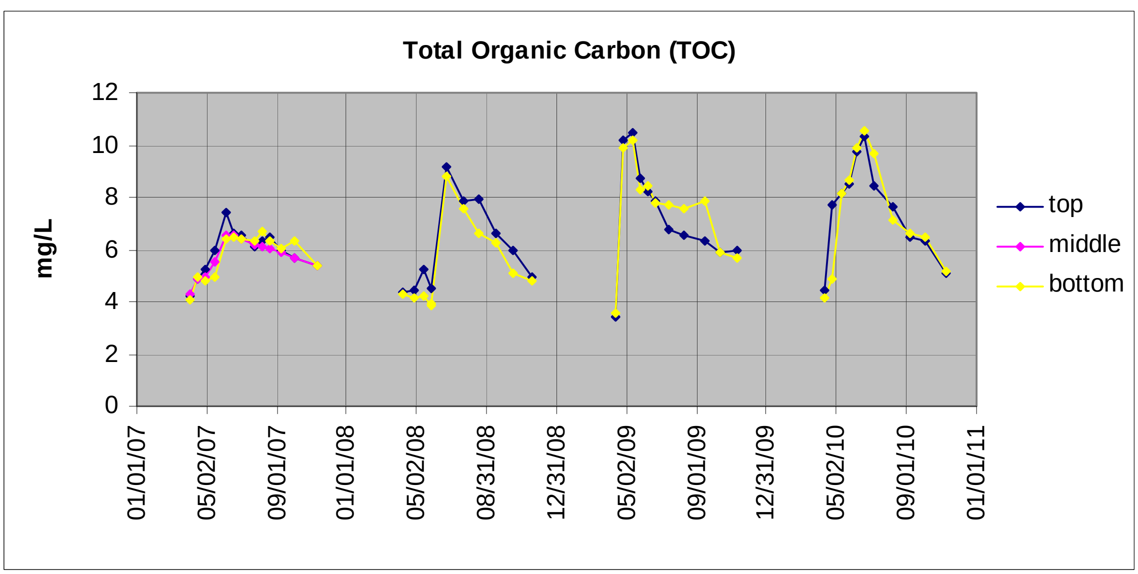
Figure 39. Plot of chlorophyll-a versus total P using data collected at 1m in Seaman Reservoir from 2007 to 2010.



4.6 Total Organic Carbon (TOC)

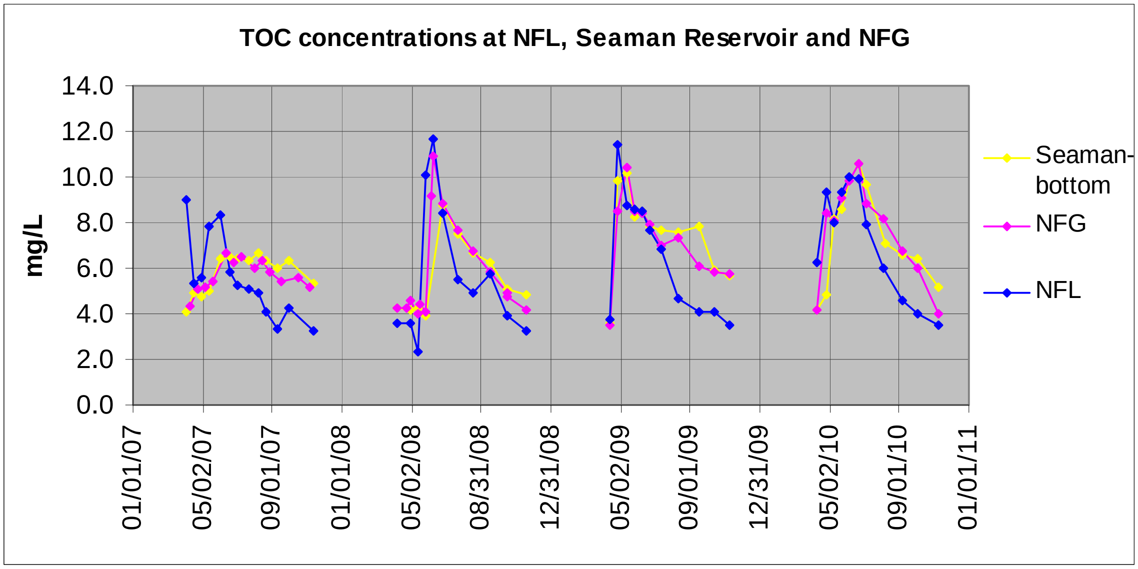
2010 TOC concentrations in Seaman Reservoir were comparable to 2009 values with similar concentrations at the top and bottom of the reservoir (Figure 40). The peak measured TOC value was 10.6 mg/l on 6/21/10, which coincided with peak runoff on the North Fork. A subsequent decline in TOC was observed throughout the summer and fall due to dilution by lower TOC inflows, as seen in previous years. Seaman Reservoir TOC values showed a gradual increasing trend in Seaman from 2007 – 2010. A trend analysis conducted for a 5.6 year period from 2005 to 2010, indicates a statistically significant increase of approximately 1.5 mg/L since 2005 (p=0.03).

Figure 40. TOC concentrations in Seaman Reservoir.



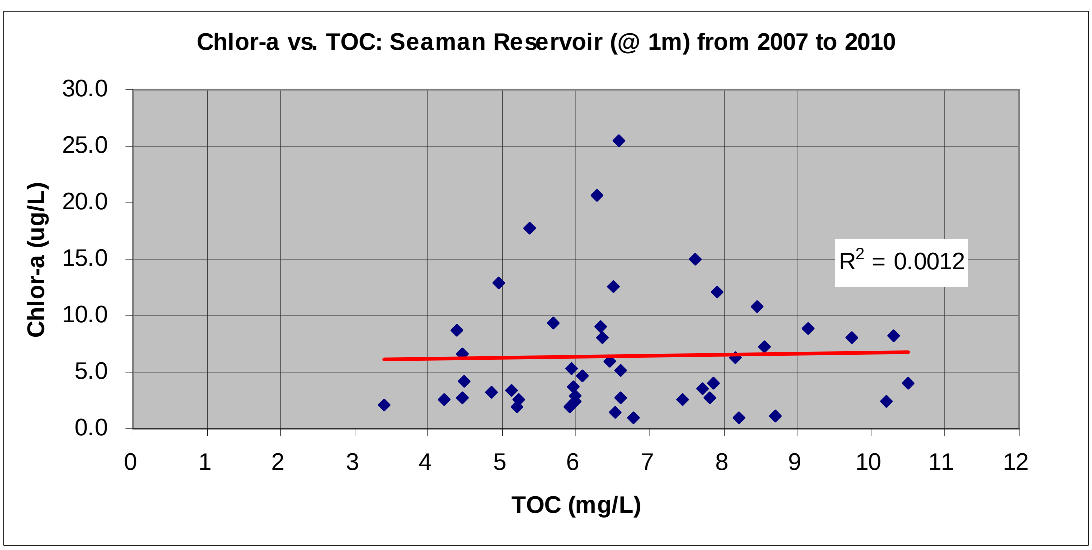
The TOC concentrations on the North Fork below Seaman Reservoir (NFG) were generally similar to the TOC concentrations at the bottom of Seaman Reservoir (Figure 41). After the spring runoff period, TOC at both of these locations is higher than the TOC in waters entering Seaman Reservoir (NFL).

Figure 41. Comparison of TOC concentrations at NFL, Seaman Reservoir, and NFG.



In-reservoir production of TOC from algal growth provides a possible explanation for the higher TOC concentrations within and below Seaman Reservoir at NFG. However, the lack of relationship between TOC and chlorophyll-a concentrations at 1M, suggests that TOC concentrations in Seaman Reservoir can not be explained by algal growth alone (Figure 42). Higher in-reservoir TOC concentrations may also be attributed to the fact that the reservoir stores high-TOC spring runoff water which is blended with lower TOC inflows and released over the course of the year.

Figure 42. Plot of chlorophyll-a versus TOC using data collected at 1m in Seaman Reservoir from 2007 to 2010.



4.7 Total Coliforms and *E. coli*

As seen in previous years, there was a late season peak in total coliform concentrations in Seaman Reservoir, which occurred on 10/05/10. Peak concentrations at the top and bottom of the reservoir were 7,701 and 11,199 colonies/100ml, respectively (Figure 43). A coincident peak also occurred downstream of Seaman Reservoir at NFG, likely due to water being released from the bottom outlet of the reservoir. In comparison, the concentrations upstream at NFL were relatively low at this time. The data also indicate that on 7/05/10, a large spike in total coloforms occurred both upstream and downstream of the reservoir on 7/05/10 (6,212 and 9,677 colonies/100ml, respectively), at a time when concentrations at the top and bottom of the reservoir were relatively much lower (99 and 1,119 colonies/100 ml, respectively).

The highest concentrations of *E. coli* in Seaman Reservoir occurred during the initial pulse of spring runoff on 4/25/10 (Figure 44).Coincident spikes occurred at the upstream and downstream North Fork locations. This pulse is to be expected during a time in which sediments and animal waste in the upper watershed are flushed from the landscape along with the melting snowpack. Concentrations at NFL, the top of the reservoir and at NFG were higher than previous years, while bottom peak concentrations were the same as in 2009. Peak concentrations at the top and bottom of the reservoir were 101 and 155 colonies/100ml, respectively. This peak in bottom concentrations represents the one instance in 2010 in which concentrations exceeded the recreational water quality standard of 126 colonies/100ml; one exceedance was also observed in 2009 on 5/24/09 (154 colonies/100ml). With the exception of a second small spike in bottom concentrations during peak runoff (75 colonies/100ml), *E.coli* concentrations remained below 25 colonies/100ml in the reservoir for the remainder of the year.

Instances of isolated high concentrations of *E.coli* and total coliforms at NFG occurred in 2010 as well as in previous years, suggesting that there may be an additional or alternate source of these bacteria at NFG. Because the data record is limited, it is recommended that monitoring for these indicators of fecal contamination at NFL continue in order to gain a better understanding of their sources and fate in Seaman Reservoir.

Figure 43. Total Coliforms at NFL, in Seaman Reservoir and at NFG

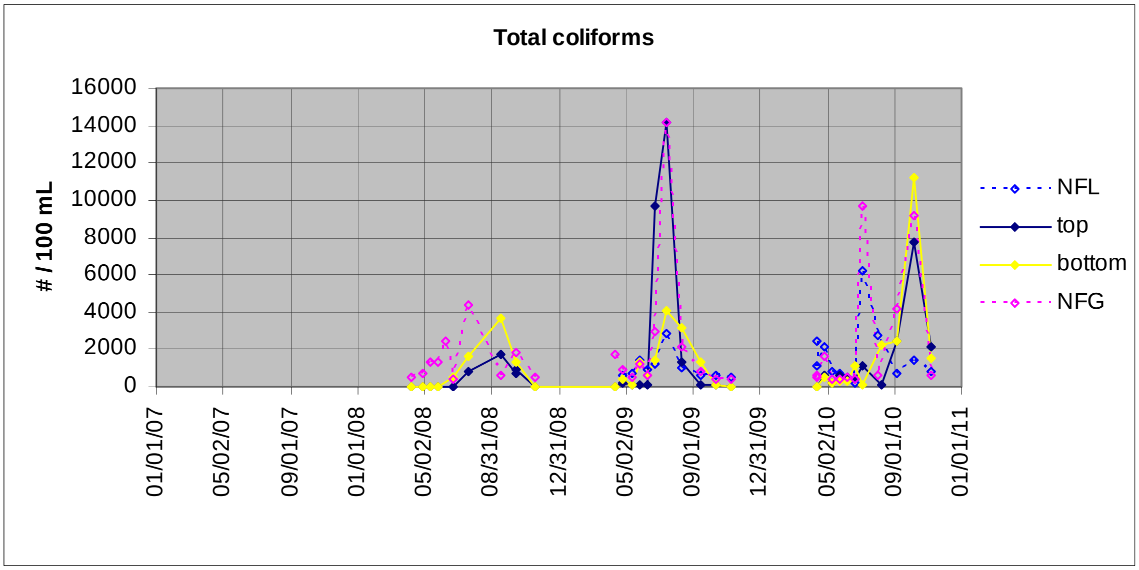
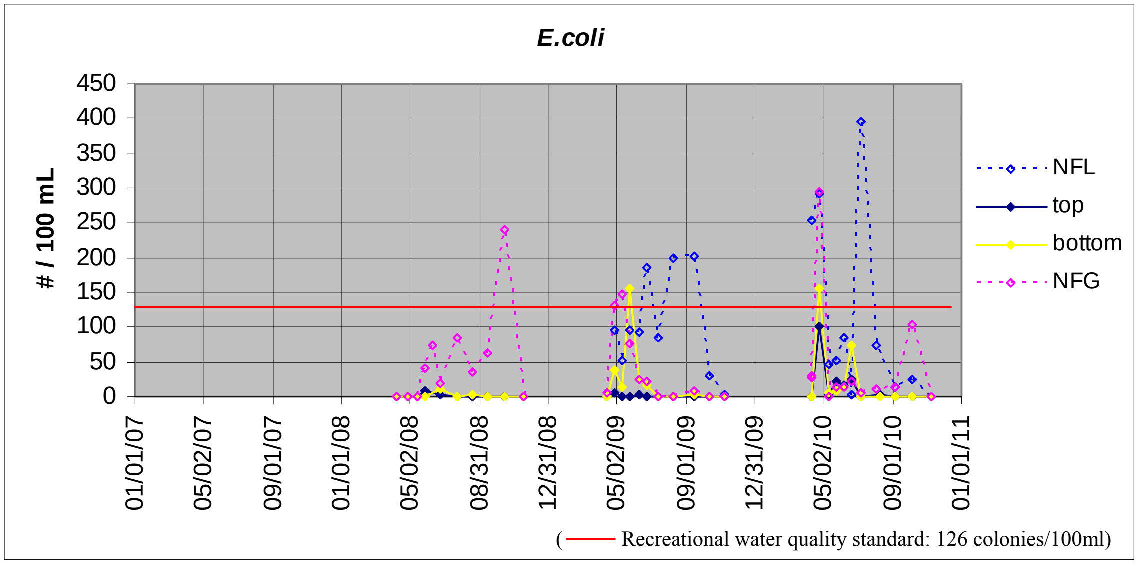


Figure 44. Concentrations of *Escherichia coli (*E. coli*)* at NFL, in Seaman Reservoir and at NFG.



4.8 Phytoplankton and Geosmin

Phytoplankton. All 2010 phytoplankton data were provided by Dick Dufford (private consultant). A full summary of the 2010 phytoplankton data is provided in Attachment 6. In 2010, the total phytoplankton population was highest from July through September, at both the top and bottom of Seaman Reservoir, with lower population densities (measured as cells/mL) observed during spring (April – June) and fall (October-November), (Figures 45 and 46). During the spring, the phytoplankton community at the top of the reservoir was dominated by green algae (Chlorophytes) and to a lesser degree by golden-brown algae (Chrysophyta) (Figures 47 and 48). Green algae abundance peaked in mid-June at the reservoir top, with a density of 13,260 cells/ml observed on 6/21/10. In contrast, blue-green algae (Cyanophytes) were dominant at the bottom of the reservoir during early spring (April), although total phytoplankton densities were relatively low through June (total density < 5,300 cells/ml). Following the period of relative blue-green algae abundance at the bottom, populations fell to zero in May, and green and golden-brown algae remained dominant until July.

Beginning in July, the phytoplankton communities at the top and bottom of the reservoir experienced a rapid shift in size and composition; the population density of blue-green algae populations increased rapidly to replace green algae as the most abundant class of algae. At the top of the reservoir, population density of blue-green algae peaked at 33,312 cells/ml on 9/7/10 and represented 88% of the total phytoplankton community. The bottom blue-green algae population peaked one month prior to peak concentrations at the top of the reservoir, with a population density of 76,655 cells/ml observed on 8/9/10 and represented nearly 100% of the total algae present. During October and November, the blue-green algae population decreased rapidly at both the top and bottom of the reservoir and was replaced by green-algae as the most relatively abundant group of algae. Total phytoplankton abundance was significantly lower during this period. August concentrations are not available for 2009; however September 2010 concentrations were considerably higher than observed in the previous year.

Figure 45. Phytoplankton densities at the top of Seaman Reservoir in 2010.

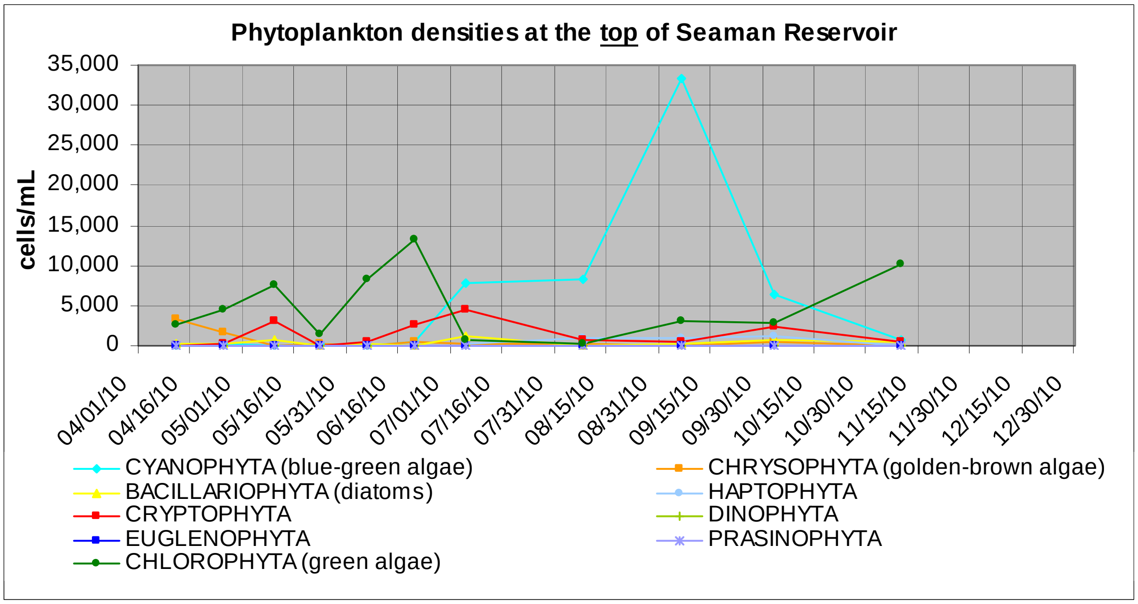


Figure 46. Phytoplankton densities at the bottom of Seaman Reservoir in 2010

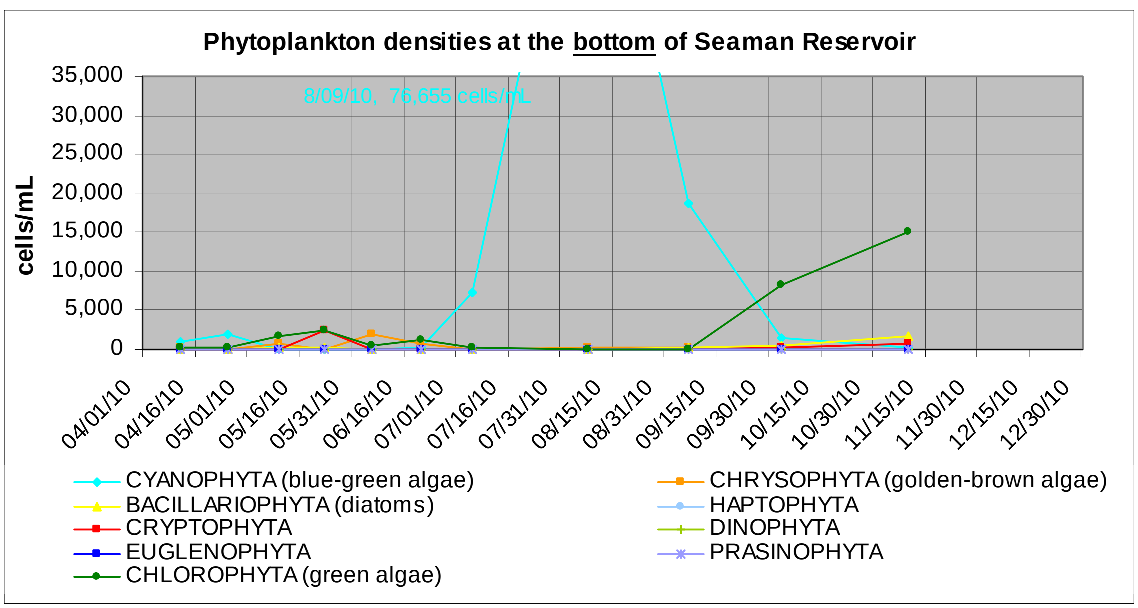


Figure 47. Relative abundance of phytoplankton in top of Seaman Reservoir in 2010.

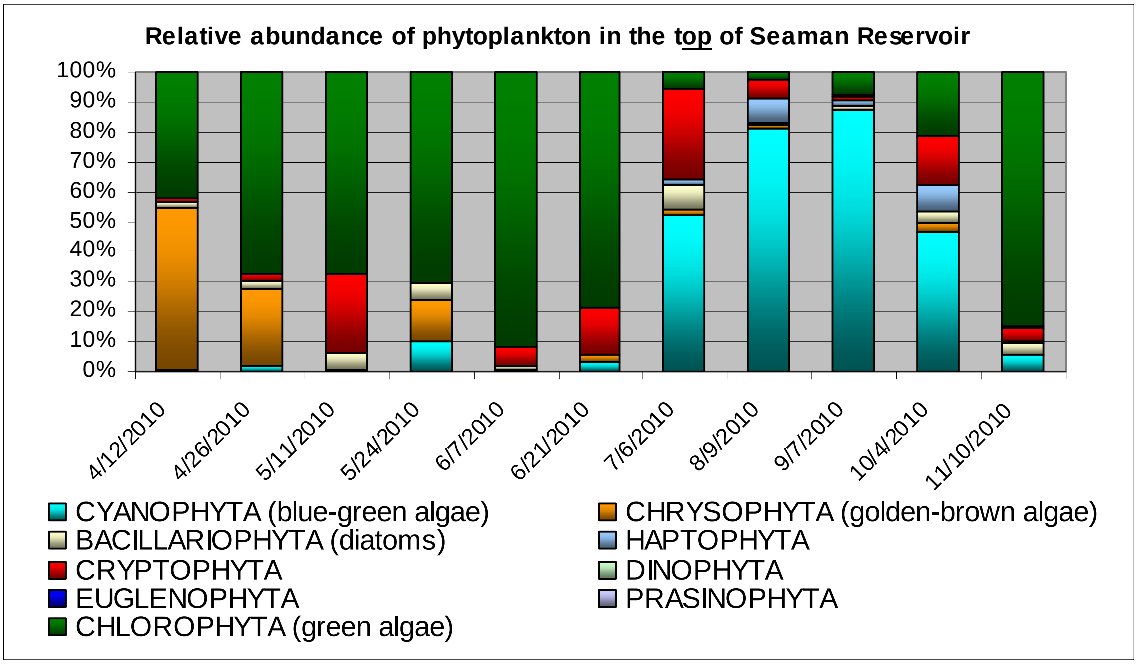
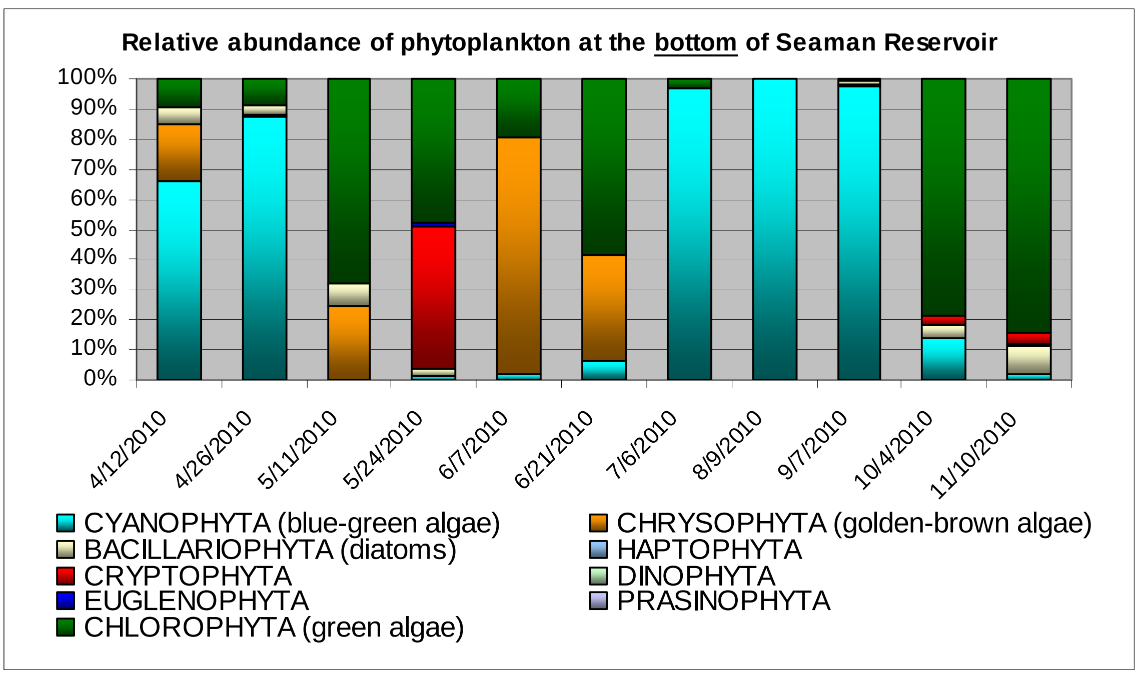
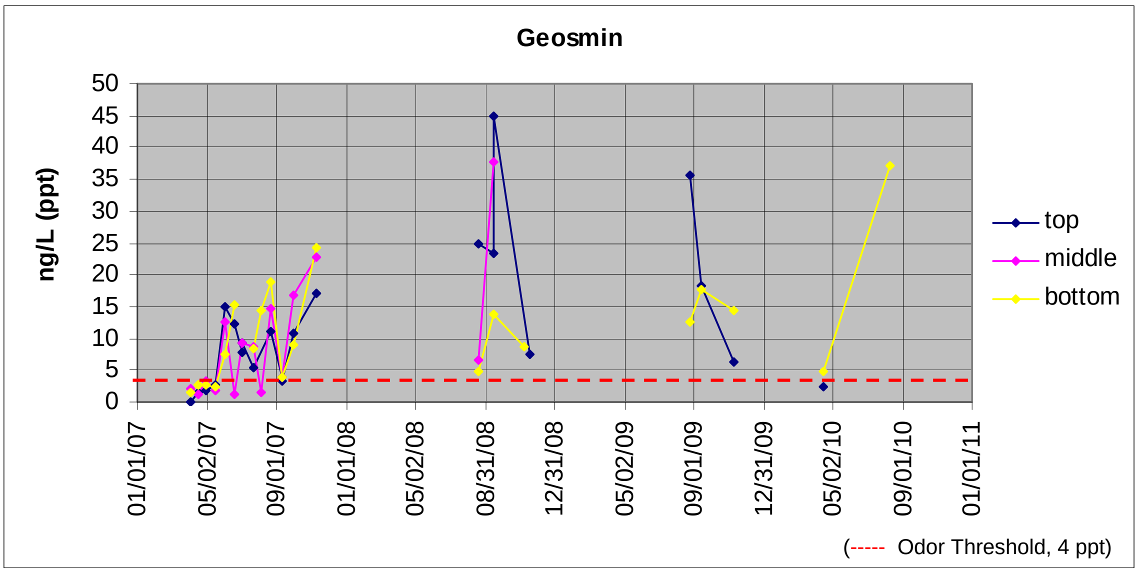


Figure 48. Relative abundance of phytoplankton at the bottom of Seaman Reservoir in 2010.



Geosmin. In 2010, geosmin samples were collected at the top and bottom of the reservoir profile on two occasions: one sample in April and one sample in August. The "top" sample for the August sampling event was not collected, and therefore, there are only three data points for 2010. Geosmin concentrations in Seaman Reservoir were at or below the odor threshold of 4 ppt on 4/15/10 (Figure 49). By the 8/9/10 sampling event, the bottom concentration had increased to 37 ppt, which was the highest bottom concentration observed in four years. From 2007 to 2009, peak concentrations at the top of the reservoir ranged from 17.2 to 44.9 ppt, and were significantly lower than the previous high concentration of 129 ppt that occurred in 2006.

Figure 49. Geosmin concentrations in Seaman Reservoir.



In September, 88% of the total phytoplankton community in Seaman Reservoir (top) was comprised of cyanophytes, or blue-green algae (Figure 47). This contrasts greatly with conditions in October and November, during which cyanophytes represented only 46% and 6% percent of the total phytoplankton density, respectively. Of the blue-green algae identified in Seaman Reservoir, six of the genera are known to include geosmin producers and include *Anabaena, Aphanizomenon, Synechoccoccus, Lyngbya, Planktothrix, and Pseudanabaena.*

During August, when the bottom algae population density was at its peak, over 78% of the blue-green algal density was comprised of known geosmin producing genera. Note, however, that not all species within a genus produce geosmin. The geosmin producing species identified in the 2010 samples include *Aphanizomenon flos-aquae*, *Planktothix agardhii* and *Pseudanabaena limnetica* (Juttner and Watson, 2007). On 8/9/10, the geosmin concentration at the bottom of the reservoir was 37.2 ng/L. At this time, the identified geosmin-producing species, *Psuedanabaena limnetica* comprised nearly 100% of the known geosmin-producing genera of blue-green algae, lending strong evidence that species is likely the key contributor to high geosmin concentrations. This situation contrasts sharply to 2009, when the known geosmin producing species only comprised one percent of the known geosmin-producing genera of blue-green algae at a time of high geosmin concentrations. The 2009 case illustrates the fact that there is often little to no correlation between geosmin concentrations and density of geosmin producing algae, as the source of geosmin is often a minor or inconspicuous component of the phytoplankton community (Taylor et al, 2006). Furthermore, some species do not release geosmin until cellular decomposition, thereby creating a time lag between algal abundance and geosmin levels. To verify any particular species as a geosmin producer, a laboratory culture test would be required.

5.0 SUMMARY

Review of the 2010 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.

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 Mainstem and the North Fork both presented the usual challenges to water treatment, 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.

Thermal stratification of Seaman Reservoir was interrupted in 2010 by high spring runoff, but once the reservoir became thermally stratified in July, it exhibited anoxic conditions in the bottom waters during the summer months, as seen in previous years. The observed D.O. minima in the reservoir metalimnion can negatively affect aquatic life by restricting available habitat, and while this does not pose water treatment concerns, these occurrences contribute to it being listed on the Colorado 303(d) List for impaired waters. Fall turnover began in October and was complete by early November. A continuation of increasing TOC trends in Seaman Reservoir has the potential to create future challenges for the City of Greeley in meeting regulatory requirements related to disinfection by-product formation.

Water quality monitoring and other related Upper CLP activities for 2011 are summarized below:

- **Routine Monitoring Program**. Samples will continue to be analyzed for all parameters in 2011.

- **Emerging Contaminant Monitoring**. Additional samples will be collected as part of the Northern Water collaborative study on emerging contaminants at PNF and NFG in February, June and August.

- **Geosmin**. Geosmin monitoring will continue on the Mainstem CLP with an emphasis on the reach between Rustic and the treatment plant intakes. In addition, geosmin sampling will be conducted on the North Fork at the gage below Seaman Reservoir. The geosmin monitoring plan, including objectives and planned sampling activities for 2011 and beyond, will be outlined in a separate Technical Memorandum.

- **Wildfire/Watershed Assessment:** Several opportunities were identified in the 2010 Cache la Poudre Wildfire/Watershed Assessment (JW Associates, 2010) for protecting critical water supplies and infrastructure from the potential impacts of wildfire. The next steps in the process include meeting with stakeholders to further evaluate and refine the possible opportunities and identifying grants or other funding sources to support site-specific design and implementation. This effort should also include researching debris flow mitigation technologies, identifying relevant NEPA and permitting requirements, and creating specific treatment and emergency response plans for Joe Wright Reservoir and the City of Fort Collins and City of Greeley water supply intake facilities on the Poudre River. This work is expected to begin in 2011.

- **Abandoned/Existing Mine Sites.** Field verification of existing/abandoned mine sites within the Upper CLP watershed will begin in summer 2011 to gain a better understanding of the actual risks they may pose to water quality.

The 2010 reporting changes and corrections are summarized below:

- In 2010 all data values were reported and reporting limits are noted. In previous years, values below the reporting limit (RL) were reported as <RL. This change in reporting is reflected in the appearance of some of the graphs, but does not represent an actual change in the data values.
- Figure 17 (p.39): Total Flows at PBD (cfs) were incorrectly reported in 2009 as PBD + Poudre Valley Canal; values were corrected in 2010 to reflect stream flows as only those reported by the flow gage at the Mouth of Poudre Canyon (CLAFTCO).
- 2007 TKN values for site PSF and SFM were incorrectly reported in Figure 14.a of the 2009 Graphical Summary, Attachment 6. The corrected values are shown in Attachment 6 of this report.

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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 2010 Sampling Plan

	2010 Sampling Dates										
	Apr 12-13	Apr 26-27	May 10-11	May 24-25	Jun7-8	Jun 21-22	Jul 6-7	Aug 2-3	Sep 7-8	Oct 4-5	Nov 8-9
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	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	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					
NFL	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
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	F,G,E	F,G,I,M,E	F,G,I,E
Main Stem											
CHR	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
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	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	F,G,I,D
LRT	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
PBR	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,E	F,G,I,E	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	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,I,E
PNF	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	F,G,I,E	F,G,E	F,G,I,E,M	F,G,I,E
PBD	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,E	F,G,I,E	F,G,I,E
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	F,G,A,C,E	F,G,I,A,C,E	F,G,A,C,E	F,G,I,A,C,E	F,G,A,C,E	F,G,I,A,C,E	F,G,I,A,C,E

[1] Grab samples taken at two depths (Top & Bottom); meter samples 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.

A = Algae (Lugol's); C = Chlorophyll (500 mL sample); D = Flow; F = Field data (Temp, pH, conductance streams + Secchi, DO for lake); G = 1 liter sampleor general, nutrients, TOC; E = *E. coli*, coliform (500 mL sterile bottle); I = Major ions; M = Metals; P = *Giardia/Cryptosporidium* (collected by City of Fort Collins personnel).

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	SM 3111 B	0.05 mg/L	HNO_3 pH <2	6 mos
	Chloride	EPA 300 (IC)	1.0 mg/L	none (eda)	28 days
	Magnesium, flame	SM 3111 B	0.2 mg/L	HNO_3 pH <2	6 mos
	Potassium	SM 3111 B	0.2 mg/L	HNO_3 pH <2	6 mos
	Sodium, flame	SM 3111 B	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	SM 3113 B	0.1 ug/L	HNO_3 pH <2	6 mos
	Chromium	SM 3113 B	0.5 ug/L	HNO_3 pH <2	6 mos
	Copper, GFAA	SM 3113 B	3 ug/L	HNO_3 pH <2	6 mos
	Iron, GFAA (total & dissolved)	SM 3113 B	10 ug/L	HNO_3 pH <2	6 mos
	Lead	SM 3113 B	1 ug/L	HNO_3 pH <2	6 mos
	Nickel	SM 3113 B	2 ug/L	HNO_3 pH <2	6 mos
	Silver	SM 3113 B	0.5 ug/L	HNO_3 pH <2	6 mos
	Zinc, flame	SM 3111 B	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

2010 Mainstem CLP Periphyton Data

& Seaman Reservoir Phytoplankton Data

2010 Mainstem CLP Periphyton Data

Rankings: 8 Dominant; 7 abundant; 6 Common-abundant; 5 Common; 4 Occasional-common; 3 Occasional; 2 Rare-occasional; 1 Rare

Potential geosmin producing cyanophyta (highlighted)

Site	Poudre below Rustic (PBR @ bridge)	Poudre below Rustic (PBR @ outhouse)	Poudre above Rustic	Barn Meadows Outflow (BMR)	Poudre Canyon Fire Station	Archer Cabins	Willow Curve
Date	21-Jan-10	21-Jan-10	21-Jan-10	08-Feb-10	08-Feb-10	08-Feb-10	08-Feb-10
	Ranking	Ranking	Ranking	Ranking	Ranking	Ranking	Ranking
CYANOPHYTA (blue-green algae)							
Aphanocapsa muscicola		1					
Aphanothece nidulans		1		2			
Chamaesiphon confervicolus							
Chamaesiphon incrustans							
Chamaesiphon sp.	1	1	1	1	1	2	3
Clastidium sp.							
Geitlerinema cf. *lemmermannii*							
Heteroleibleinia kuetzingii							
Homoeothrix janthina	4		1				
Homoeothrix sp.				1			1
Leptolyngbya foveolarum	2						
Limnothrix sp.							
Merismopedia sp.							
Oscillatoria tenuis							
Phormidium aerugineo-caeruleum		2					
Phormidium autumnale				3			
Pseudanabaena catenata		1					
Pseudanabaena limnetica							
Pseudanabaena sp.						1	1
Spirulina sp.							
Synechococcus nidulans							
Synechococcus sp.							
Synechocystis sp.	3	2	1	4			
RHODOPHYTA (red algae)							
Audouinella hermanii		1					
Lemanea borealis							
CHRYSOPHYTA (golden-brown algae)							
Hydrurus foetidus			3				1

Rankings: 8 Dominant; 7 abundant; 6 Common-abundant; 5 Common; 4 Occasional-common; 3 Occasional; 2 Rare-occasional; 1 Rare

Potential geosmin producing cyanophyta

Site	Poudre below Rustic (PBR @ bridge)	Poudre below Rustic (PBR @ outhouse)	Poudre above Rustic	Barn Meadows Outflow (BMR)	Poudre Canyon Fire Station	Archer Cabins	Willow Curve
Date	21-Jan-10	21-Jan-10	21-Jan-10	08-Feb-10	08-Feb-10	08-Feb-10	08-Feb-10
	Ranking	Ranking	Ranking	Ranking	Ranking	Ranking	Ranking
BACILLARIOPHYTA (diatoms)							
Didymosphenia geminata	6	8	8		8	8	8
other diatoms:	5	7	7	7	7	7	6
CHLOROPHYTA (green algae)							
Chaetophora sp.	6	3					
Chlorella minutissima							
Closterium moniliferum					1		
Cosmarium botrytis var. *paxillisporum*							
Hyalotheca dissiliens							
Microspora sp.	2	2					
Monoraphidium mirabile							
Mougeotia sp.							
Oedogonium rivulare						3	
Oedogonium sp.							
Scenedesmus ellipticus							
Scenedesmus obliquus							
Spirogyra sp. 1							
Spirogyra sp. 2				3			
Spondylosium planum							
Staurastrum lapponicum							
Staurastrum punctulatum var. *pygmaeum*							1
Staurastrum sp.					1		
Staurodesmus brevispina							
Stigeoclonium lubricum	3			8			
Tetraspora sp.							
Ulothrix aequalis							
Ulothrix tenerrima				6			7
Ulothrix tenuissima	7						
Ulothrix zonata	8			5		2	7

Rankings: 8 Dominant; 7 abundant; 6 Common-abundant; 5 Common; 4 Occasional-common; 3 Occasional; 2 Rare-occasional; 1 Rare

(yellow) Potential geosmin-producing cyanophyta

Site	Poudre below Rustic (PBR @ bridge)	Poudre below Glen Echo	Poudre above Rustic	Poudre above Home Moraine	Poudre below Home Moraine	Poudre @ Eggers	Poudre Canyon Fire Station
Date	19-Aug-10	19-Aug-10	19-Aug-10	19-Aug-10	19-Aug-10	19-Aug-10	19-Aug-10
	Ranking	Ranking	Ranking	Ranking	Ranking	Ranking	Ranking
CYANOPHYTA (blue-green algae)							
Aphanocapsa muscicola		1			1	1	3
Aphanothece nidulans	1	1			1	2	1
Chamaesiphon confervicolus							
Chamaesiphon incrustans							
Chamaesiphon sp.		3	3	1		3	1
Clastidium sp.			2		1	2	
Geitlerinema cf. *lemmermannii*					1		
Heteroleibleinia kuetzingii			3				
Homoeothrix janthina	1	2	4	1	1	3	2
Homoeothrix sp.							
Leptolyngbya foveolarum							
Limnothrix sp.							
Merismopedia sp.							
Oscillatoria tenuis	1						
Phormidium aerugineo-caeruleum							3
Phormidium autumnale							
Pseudanabaena catenata							
Pseudanabaena limnetica							
Pseudanabaena sp.	1		1		1	1	
Spirulina sp.	1					1	
Synechococcus nidulans					1		
Synechococcus sp.							
Synechocystis sp.	1					1	
RHODOPHYTA (red algae)							
Audouinella hermanii							
Lemanea borealis							
CHRYSOPHYTA (golden-brown algae)							
Hydrurus foetidus					8		

Rankings: 8 Dominant; 7 abundant; 6 Common-abundant; 5 Common; 4 Occasional-common; 3 Occasional; 2 Rare-occasional; 1 Rare							
[yellow box] Potential geosmin-producing cyanophyta							
Site	Poudre below Rustic (PBR @ bridge)	Poudre below Glen Echo	Poudre above Rustic	Poudre above Home Moraine	Poudre below Home Moraine	Poudre @ Eggers	Poudre Canyon Fire Station
Date	19-Aug-10	19-Aug-10	19-Aug-10	19-Aug-10	19-Aug-10	19-Aug-10	19-Aug-10
	Ranking	Ranking	Ranking	Ranking	Ranking	Ranking	Ranking
BACILLARIOPHYTA (diatoms)							
Didymosphenia geminata	7	6	5	6	8	7	6
other diatoms:	6	7	7	6	6	6	7
CHLOROPHYTA (green algae)							
Chaetophora sp.							
Chlorella minutissima	1						1
Closterium moniliferum				1			
Cosmarium botrytis var. *paxillisporum*			1				
Hyalotheca dissiliens				1			1
Microspora sp.							
Monoraphidium mirabile							
Mougeotia sp.							
Oedogonium rivulare				8			
Oedogonium sp.							
Scenedesmus ellipticus							
Scenedesmus obliquus							
Spirogyra sp. 1							
Spirogyra sp. 2					7		
Spondylosium planum				1			
Staurastrum lapponicum							
Staurastrum punctulatum var. *pygmaeum*							
Staurastrum sp.							
Staurodesmus brevispina					1		
Stigeoclonium lubricum							
Tetraspora sp.				1			
Ulothrix aequalis							
Ulothrix tenerrima							
Ulothrix tenuissima							
Ulothrix zonata	8	8	8	5	7	8	8

Rankings: 8 Dominant; 7 abundant; 6 Common-abundant; 5 Common; 4 Occasional-common; 3 Occasional; 2 Rare-occasional; 1 Rare

(yellow) Potential geosmin producing cyanophyta

Site	Poudre above Rustic	Poudre below Rustic (PBR @ bridge)	Poudre @ Eggers	Poudre Canyon Fire Station	Poudre above Rustic	Poudre below Rustic (PBR @ bridge)	Poudre @ Eggers	Poudre Canyon Fire Station
Date	22-Sep-10	22-Sep-10	22-Sep-10	22-Sep-10	21-Oct-10	21-Oct-10	21-Oct-10	21-Oct-10
	Ranking	Ranking	Ranking	Ranking	Ranking	Ranking	Ranking	Ranking
CYANOPHYTA (blue-green algae)								
Aphanocapsa muscicola								1
Aphanothece nidulans		1	3	1	1			1
Chamaesiphon confervicolus				1				
Chamaesiphon incrustans								2
Chamaesiphon sp.	1		1		2	1	1	
Clastidium sp.				1				
Geitlerinema cf. *lemmermannii*								
Heteroleibleinia kuetzingii								3
Homoeothrix janthina	3		3		3			1
Homoeothrix sp.				2				
Leptolyngbya foveolarum								
Limnothrix sp.	1		4	1				
Merismopedia sp.								
Oscillatoria tenuis			1					
Phormidium aerugineo-caeruleum	2	2		4		2	2	
Phormidium autumnale								
Pseudanabaena catenata								
Pseudanabaena limnetica				2				
Pseudanabaena sp.	1		2	1	2	1	1	1
Spirulina sp.								
Synechococcus nidulans								
Synechococcus sp.								
Synechocystis sp.								
RHODOPHYTA (red algae)								
Audouinella hermanii								1
Lemanea borealis								8
CHRYSOPHYTA (golden-brown algae)								
Hydrurus foetidus								

Rankings: 8 Dominant; 7 abundant; 6 Common-abundant; 5 Common; 4 Occasional-common; 3 Occasional; 2 Rare-occasional; 1 Rare

Potential geosmin producing cyanophyta

Site	Poudre above Rustic	Poudre below Rustic (PBR @ bridge)	Poudre @ Eggers	Poudre Canyon Fire Station	Poudre above Rustic	Poudre below Rustic (PBR @ bridge)	Poudre @ Eggers	Poudre Canyon Fire Station
Date	22-Sep-10	22-Sep-10	22-Sep-10	22-Sep-10	21-Oct-10	21-Oct-10	21-Oct-10	21-Oct-10
	Ranking	Ranking	Ranking	Ranking	Ranking	Ranking	Ranking	Ranking
BACILLARIOPHYTA (diatoms)								
Didymosphenia geminata	8	8	6	6	7	7	5	7
other diatoms:	7	7	7	7	6	6	7	6
CHLOROPHYTA (green algae)								
Chaetophora sp.								
Chlorella minutissima								
Closterium moniliferum		1	1	1				
Cosmarium botrytis var. *paxillisporum*	1							
Hyalotheca dissiliens	1							
Microspora sp.								
Monoraphidium mirabile				1				
Mougeotia sp.	3	3						
Oedogonium rivulare		5				8		
Oedogonium sp.								
Scenedesmus ellipticus				1				
Scenedesmus obliquus				1				
Spirogyra sp. 1								
Spirogyra sp. 2		2			3		8	
Spondylosium planum		1						
Staurastrum lapponicum	1	1	1	1				
Staurastrum punctulatum var. *pygmaeum*								
Staurastrum sp.								
Staurodesmus brevispina						1		
Stigeoclonium lubricum								
Tetraspora sp.				1				
Ulothrix aequalis					4			
Ulothrix tenerrima	1		5	3				
Ulothrix tenuissima			4					
Ulothrix zonata	5	4	8	8	8	7		8

Rankings: 8 Dominant; 7 abundant; 6 Common-abundant; 5 Common; 4 Occasional-common; 3 Occasional; 2 Rare-occasional; 1 Rare Potential geosmin producing cyanophyta				
Site	Poudre above Rustic	Poudre below Rustic (PBR @ bridge)	Poudre @ Eggers	Poudre Canyon Fire Station
Date	08-Nov-10	08-Nov-10	08-Nov-10	08-Nov-10
	Ranking	Ranking	Ranking	Ranking
CYANOPHYTA (blue-green algae)				
Aphanocapsa muscicola				
Aphanothece nidulans			1	
Chamaesiphon confervicolus				
Chamaesiphon incrustans				
Chamaesiphon sp.	2	3	1	
Clastidium sp.			3	
Geitlerinema cf. *lemmermannii*				
Heteroleibleinia kuetzingii				
Homoeothrix janthina			1	
Homoeothrix sp.				
Leptolyngbya foveolarum				
Limnothrix sp.				
Merismopedia sp.	2			2
Oscillatoria tenuis				
Phormidium aerugineo-caeruleum	2	3	1	
Phormidium autumnale				
Pseudanabaena catenata				
Pseudanabaena limnetica				
Pseudanabaena sp.	1	2		2
Spirulina sp.				
Synechococcus nidulans				
Synechococcus sp.				4
Synechocystis sp.				
RHODOPHYTA (red algae)				
Audouinella hermanii				
Lemanea borealis				
CHRYSOPHYTA (golden-brown algae)				
Hydrurus foetidus				

Rankings: 8 Dominant; 7 abundant; 6 Common-abundant; 5 Common; 4 Occasional-common; 3 Occasional; 2 Rare-occasional; 1 Rare

Potential geosmin producing cyanophyta

Site	Poudre above Rustic	Poudre below Rustic (PBR @ bridge)	Poudre @ Eggers	Poudre Canyon Fire Station
Date	08-Nov-10	08-Nov-10	08-Nov-10	08-Nov-10
	Ranking	Ranking	Ranking	Ranking
BACILLARIOPHYTA (diatoms)				
Didymosphenia geminata	8	8	8	8
other diatoms:	6	7	6	5
CHLOROPHYTA (green algae)				
Chaetophora sp.				
Chlorella minutissima				
Closterium moniliferum				
Cosmarium botrytis var. *paxillisporum*				
Hyalotheca dissiliens				
Microspora sp.				
Monoraphidium mirabile				
Mougeotia sp.	3			
Oedogonium rivulare	4		6	3
Oedogonium sp.				2
Scenedesmus ellipticus				
Scenedesmus obliquus			1	
Spirogyra sp. 1	2			2
Spirogyra sp. 2	4	6	4	7
Spondylosium planum				
Staurastrum lapponicum				
Staurastrum punctulatum var. *pygmaeum*				
Staurastrum sp.				
Staurodesmus brevispina				
Stigeoclonium lubricum				
Tetraspora sp.				
Ulothrix aequalis				
Ulothrix tenerrima				
Ulothrix tenuissima				
Ulothrix zonata	7	5	8	6

2010 Seaman Reservoir Phytoplankton Data

Phytoplankton Densities (cells/ml)	SAMPLING DATE						
Seaman Reservoir - Top	12-Apr-10	26-Apr-10	11-May-10	24-May-10	7-Jun-10	21-Jun-10	6-Jul-10
Potential geosmin producing cyanophyta (highlighted)							
CYANOPHYTA (blue-green algae)							
Anabaena flos-aquae							
Anabaena crassa							
Anabaena planctonica							
Aphanizomenon flos-aquae							
Aphanocapsa conferta				35.2			
Aphanocapsa delicatissima							
Aphanothece clathrata							
Aphanothece smithii						375	5,750
Coelosphaerium aerugineum							
Cuspidothrix issatschenkoi			3.6				
Cyanobium (Synechococcus) sp.			40	125		125	
Dactylococcopsis sp.			20				
Geitlerinema sp.		5			5.2		
Jaaginema sp.					3.2		
Lyngbya birgei		5					
Merismopedia sp.							
Merismopedia tenuissima							2,000
Microcystis wesenbergii							
Myxobaktron hirudiforme							
Oscillatoria tenuis				3.6			
Planktolyngbya limnetica							
Planktothrix agardhii							
Pseudanabaena limnetica				35.2	6.4		
Romeria leopoliensis							
Snowella litoralis							
Synechococcus nidulans	30						125
Synechocystis sp.		125					
Woronichinia naegeliana							
TOTAL CYANOPHYTA	**30**	**135**	**63.6**	**199**	**14.8**	**500**	**7,875**

Phytoplankton Densities (cells/ml)	SAMPLING DATE						
Seaman Reservoir - Top	12-Apr-10	26-Apr-10	11-May-10	24-May-10	7-Jun-10	21-Jun-10	6-Jul-10
CHRYSOPHYTA (golden-brown algae)							
Chromulina parvula	125			250		500	250
Chrysococcus sp.				20			0.4
Dinobryon cylindricum var. *alpinum*	20			0.4	5.6		
Dinobryon cylindricum					0.4		
Dinobryon divergens	3,180	1,710	2.4		0.2		
Dinobryon sociale var. *americanum*							
Mallomonas akrokomos			0.2	0.4	2		2.4
Mallomonas caudata							
Mallomonas sp.	40		0.4		6.4		
cyst of Mallomonas sp.							
Ochromonas minuscula							
Synura petersenii							
TOTAL CHRYSOPHYTA	**3,365**	**1,710**	**3**	**270.8**	**14.6**	**500**	**252.8**
BACILLARIOPHYTA (diatoms)							
Asterionella formosa	18.4	15.2	80.8	43.2	124.8	0.2	111.2
Aulacoseira ambigua	3.2	33.6		24	5.2		12
Aulacoseira granulata var. *angustissima*	51.6	84.4	48.8				44
Aulacoseira italica				2.4	4.4		
Aulacoseira italica var. *tenuissima*			12.4	28.8			
Aulacoseira subarctica							
Cymatopleura solea			0.2	0.2			
Diatoma anceps	2						
Diatoma moniliformis			1.2	10			
Diatoma tenuis							
Discostella glomerata							
Discostella pseudostelligera							
Discostella stelligera	1.6	0.8	80		0.8		140
Fragilaria crotonensis	16.8				0.8		13.6
Gomphonema sphaerophorum							

Phytoplankton Densities (cells/ml)	SAMPLING DATE						
Seaman Reservoir - Top	12-Apr-10	26-Apr-10	11-May-10	24-May-10	7-Jun-10	21-Jun-10	6-Jul-10
BACILLARIOPHYTA (diatoms) - CONTINUED							
Gyrosigma acuminatum				0.4			
Melosira varians			0.8			0.4	
Navicula capitatoradiata				0.2			
Navicula lanceolata				0.2			
Navicula tripunctata				0.2			
Nitzschia draveillensis		30	4				2
Nitzschia fonticola							
Nitzschia gracilis		0.4	0.4				
Nitzschia sigma							
Nitzschia sp.							
Nitzschia supralitorea		2					
Punticulata bodanica	29.2	3.2	0.8				
Stephanodiscus medius		1.6	0.2				
Stephanodiscus niagarae	5.6	2.4		0.2	0.2		1.6
Stephanodiscus parvus			400				900
Synedra cyclopum	0.4		0.2	1.2			
Synedra delicatissima var. *angustissima*							
Synedra tenera		2	6.4	0.4	0.2		2.4
Synedra ulna var. *subaequalis*			0.8		0.2		
Synedra ulna		0.4		1.6	0.2		
Urosolenia eriensis							
TOTAL BACILLARIOPHYTA	**128.8**	**176**	**637**	**113**	**136.8**	**0.6**	**1,227**
HAPTOPHYTA							
Chrysochromulina parva							280

Phytoplankton Densities (cells/ml)	SAMPLING DATE						
Seaman Reservoir - Top	12-Apr-10	26-Apr-10	11-May-10	24-May-10	7-Jun-10	21-Jun-10	6-Jul-10
CRYPTOPHYTA							
Chroomonas coerulea							
Chroomonas nordstedtii		0.4			10		
Cryptomonas borealis	0.4	0.8	25.6		167.2		16.8
Cryptomonas curvata	1.2	4.4	12.4		8	206.6	6.8
Cryptomonas erosa							
Cryptomonas marsonii	0.8	0.4			1.2		
Komma caudata	10		400		160	1,040	3,600
Plagioselmis nannoplanctica	40	180	2,560		200	1,420	960
cyst of Cryptomonas							
TOTAL CRYPTOPHYTA	**52.4**	**186**	**2,998**	**0.0**	**546.4**	**2,667**	**4,584**
DINOPHYTA							
Ceratium hirundinella							
Gymnodinium fuscum		0.2					
Peridinium lomnickii							
Peridinium willei	0.2	0.2					
TOTAL DINOPHYTA	**0.2**	**0.4**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
EUGLENOPHYTA							
Lepocinclis (Euglena) acus							
Lepocinclis (Euglena) oxyuris							
Trachelomonas dybowskii							
Trachelomonas volvocina		0.4					
TOTAL EUGLENOPHYTA	**0.0**	**0.4**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
PRASINOPHYTA							
Scourfieldia sp.							4.0
Tetraselmis cordiformis							
TOTAL PRASINOPHYTA	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**4.0**

Phytoplankton Densities (cells/ml)	SAMPLING DATE						
Seaman Reservoir - Top	12-Apr-10	26-Apr-10	11-May-10	24-May-10	7-Jun-10	21-Jun-10	6-Jul-10
CHLOROPHYTA (green algae)							
Ankistrodesmus falcatus			1.2				
Ankyra judayi		5.0	10				60
Botryococcus braunii							
Chlamydomonas globosa							
Chlamydomonas snowiae					520		
Chlamydomonas sp. 1							
Chlamydomonas sp. 2							
Chlamydomonas tetragama							300
Chlorella minutissima	125	500	7,500	1,375	125	12,500	250
Choricystis minor	2,500	4,000			7,625	375	
Closterium aciculare							
Closterium acutum var. *variabile*	0.8						
Closterium dianae			0.2				
Closterium moniliferum							
Coelastrum pulchrum							6.4
Coenochloris fottii							
Cosmarium bioculatum							
Dictyosphaerium pulchellum var. *minutum*							
Elakatothrix viridis	2		2				
Eudorina elegans					3.2		68.8
Gonatozygon kinahanii							
Heimansia pusilla							
Keratococcus sp.				0.2			
Micractinium pusillum			40				
Monoraphidium contortum		5.0					
Monoraphidium sp.		0.4	1.6				
Nephrocytium limneticum							
Oocystis apiculata							
Oocystis borgei							
Oocystis pusilla							

Phytoplankton Densities (cells/ml)	SAMPLING DATE						
Seaman Reservoir - Top	12-Apr-10	26-Apr-10	11-May-10	24-May-10	7-Jun-10	21-Jun-10	6-Jul-10
CHLOROPHYTA (green algae) - CONTINUED							
Pandorina charkowiensis							88
Pandorina smithii							
Pediastrum boryanum		3.2				10	25.6
Pediastrum duplex							
Pseudodictyosphaerium elegans							
Pseudodictyosphaerium sp.							
Quadrigula sp.							
Raphidocelis contorta						250	
Raphidocelis sp.						125	
Scenedesmus arcuatus							
Scenedesmus armatus							
Scenedesmus bicaudatus							
Scenedesmus communis							1.6
Schroederia setigera							4.0
Staurastrum planctonicum							
Tetraedron minimum							
TOTAL CHLOROPHYTA	**2,628**	**4,514**	**7,555**	**1,375**	**8,273**	**13,260**	**804.4**
TOTAL ALGAL DENSITY (cells/mL)	**6,204**	**6,721**	**11,257**	**1,958**	**8,986**	**16,927**	**14,747**

Phytoplankton Densities (cells/ml)	SAMPLING DATE				
Seaman Reservoir - Top	9-Aug-10	7-Sep-10	4-Oct-10	10-Nov-10	
Potential geosmin producing cyanophyta					
CYANOPHYTA (blue-green algae)					
Anabaena flos-aquae		340.0	289.6		
Anabaena crassa	5260.0	233.6	202.8		
Anabaena planctonica	36.0	130.4	63.2		
Aphanizomenon flos-aquae		364.0	715.2		
Aphanocapsa conferta				375	
Aphanocapsa delicatissima	750	5,000			
Aphanothece clathrata			375		
Aphanothece smithii	2,140	26,250	4,000		
Coelosphaerium aerugineum			96.8		
Cuspidothrix issatschenkoi					
Cyanobium (Synechococcus) sp.					
Dactylococcopsis sp.				10	
Geitlerinema sp.					
Jaaginema sp.					
Lyngbya birgei		848	131.2		
Merismopedia sp.		10.4			
Merismopedia tenuissima					
Microcystis wesenbergii		17.6	27.2		
Myxobaktron hirudiforme					
Oscillatoria tenuis					
Planktolyngbya limnetica					
Planktothrix agardhii					
Pseudanabaena limnetica					
Romeria leopoliensis					
Snowella litoralis					
Synechococcus nidulans					
Synechocystis sp.					
Woronichinia naegeliana		125	552.8	294.4	
TOTAL CYANOPHYTA	**8,186**	**33,319**	**6,454**	**679.4**	

Phytoplankton Densities (cells/ml)	SAMPLING DATE				
Seaman Reservoir - Top	9-Aug-10	7-Sep-10	4-Oct-10	10-Nov-10	
CHRYSOPHYTA (golden-brown algae)					
Chromulina parvula	125		375		
Chrysococcus sp.					
Dinobryon cylindricum var. *alpinum*					
Dinobryon cylindricum					
Dinobryon divergens					
Dinobryon sociale var. *americanum*		14.4			
Mallomonas akrokomos					
Mallomonas caudata			48.8	14.4	
Mallomonas sp.					
cyst of Mallomonas sp.					
Ochromonas minuscula					
Synura petersenii					
TOTAL CHRYSOPHYTA	**125**	**14.4**	**423.8**	**14.4**	
BACILLARIOPHYTA (diatoms)					
Asterionella formosa		3.6	8.8	100.8	
Aulacoseira ambigua	1.6	15.2	12.4	20	
Aulacoseira granulata var. *angustissima*		178.8	100	20	
Aulacoseira italica					
Aulacoseira italica var. *tenuissima*			294	140	
Aulacoseira subarctica			26.4	120	
Cymatopleura solea					
Diatoma anceps					
Diatoma moniliformis					
Diatoma tenuis					
Discostella glomerata			0.4		
Discostella pseudostelligera		2.8			
Discostella stelligera		20	12		
Fragilaria crotonensis	20	44.8	6.4	7.2	
Gomphonema sphaerophorum					

Phytoplankton Densities (cells/ml)	SAMPLING DATE				
Seaman Reservoir - Top	9-Aug-10	7-Sep-10	4-Oct-10	10-Nov-10	
BACILLARIOPHYTA (diatoms) - CONTINUED					
Gyrosigma acuminatum					
Melosira varians					
Navicula capitatoradiata					
Navicula lanceolata					
Navicula tripunctata					
Nitzschia draveillensis					
Nitzschia fonticola					
Nitzschia gracilis		0.8			
Nitzschia sigma					
Nitzschia sp.				0.8	
Nitzschia supralitorea					
Punticulata bodanica	2.4			1.2	
Stephanodiscus medius			0.8		
Stephanodiscus niagarae	0.8	40	94.8	8.8	
Stephanodiscus parvus		40	10	40	
Synedra cyclopum					
Synedra delicatissima var. *angustissima*		0.4	5.6		
Synedra tenera					
Synedra ulna var. *subaequalis*					
Synedra ulna					
Urosolenia eriensis			20		
TOTAL BACILLARIOPHYTA	**24.8**	**346.4**	**591.6**	**458.8**	
HAPTOPHYTA					
Chrysochromulina parva	860	840	1,200	20	

Phytoplankton Densities (cells/ml)	SAMPLING DATE				
Seaman Reservoir - Top	9-Aug-10	7-Sep-10	4-Oct-10	10-Nov-10	
CRYPTOPHYTA					
Chroomonas coerulea			1.0		
Chroomonas nordstedtii					
Cryptomonas borealis	0.4	28.8	9.2	4	
Cryptomonas curvata	17.2	24.8	1.6	0.4	
Cryptomonas erosa		16			
Cryptomonas marsonii	0.8				
Komma caudata	360	120	240	40	
Plagioselmis nannoplanctica	220	340	2,000	540	
cyst of Cryptomonas					
TOTAL CRYPTOPHYTA	**598.4**	**529.6**	**2,252**	**584.4**	
DINOPHYTA					
Ceratium hirundinella	0.4		0.2	0.2	
Gymnodinium fuscum	0.8				
Peridinium lomnickii					
Peridinium willei					
TOTAL DINOPHYTA	**1.2**	**0.0**	**0.2**	**0.2**	
EUGLENOPHYTA					
Lepocinclis (Euglena) acus					
Lepocinclis (Euglena) oxyuris					
Trachelomonas dybowskii					
Trachelomonas volvocina			5.2	1.6	
TOTAL EUGLENOPHYTA	**0.0**	**0.0**	**5.2**	**1.6**	
PRASINOPHYTA					
Scourfieldia sp.					
Tetraselmis cordiformis		2.4	40.0	0.4	
TOTAL PRASINOPHYTA	**0.0**	**2.4**	**40.0**	**0.4**	

Phytoplankton Densities (cells/ml)	**SAMPLING DATE**				
Seaman Reservoir - Top	9-Aug-10	7-Sep-10	4-Oct-10	10-Nov-10	
CHLOROPHYTA (green algae)					
Ankistrodesmus falcatus				3.2	
Ankyra judayi	10	140		10	
Botryococcus braunii				16.8	
Chlamydomonas globosa					
Chlamydomonas snowiae					
Chlamydomonas sp. 1					
Chlamydomonas sp. 2				100	
Chlamydomonas tetragama			20		
Chlorella minutissima	250	2,500	1,500	10,000	
Choricystis minor		250	1,250		
Closterium aciculare			0.8		
Closterium acutum var. *variabile*					
Closterium dianae					
Closterium moniliferum					
Coelastrum pulchrum			7.2		
Coenochloris fottii		92.0	4.8		
Cosmarium bioculatum			120		
Dictyosphaerium pulchellum var. *minutum*					
Elakatothrix viridis		4.2			
Eudorina elegans					
Gonatozygon kinahanii					
Heimansia pusilla					
Keratococcus sp.					
Micractinium pusillum					
Monoraphidium contortum					
Monoraphidium sp.					
Nephrocytium limneticum			2.4		
Oocystis apiculata		0.8			
Oocystis borgei					
Oocystis pusilla	10.0				

Phytoplankton Densities (cells/ml)	SAMPLING DATE				
Seaman Reservoir - Top	9-Aug-10	7-Sep-10	4-Oct-10	10-Nov-10	
CHLOROPHYTA (green algae) - CONTINUED					
Pandorina charkowiensis					
Pandorina smithii	3.2				
Pediastrum boryanum					
Pediastrum duplex			1.6		
Pseudodictyosphaerium elegans			14.4		
Pseudodictyosphaerium sp.					
Quadrigula sp.		1.6			
Raphidocelis contorta					
Raphidocelis sp.					
Scenedesmus arcuatus					
Scenedesmus armatus					
Scenedesmus bicaudatus					
Scenedesmus communis		0.8	1.6		
Schroederia setigera					
Staurastrum planctonicum			4.8		
Tetraedron minimum					
TOTAL CHLOROPHYTA	**273.2**	**2,989**	**2,928**	**10,130**	
TOTAL ALGAL DENSITY (cells/mL)	**9,209**	**37,201**	**12,694**	**11,869**	

Phytoplankton Densities (cells/ml)	SAMPLING DATE						
Seaman Reservoir - Bottom	12-Apr-10	26-Apr-10	11-May-10	24-May-10	7-Jun-10	21-Jun-10	6-Jul-10
Potential geosmin producing cyanophyta							
CYANOPHYTA (blue-green algae)							
Anabaena flos-aquae							
Anabaena crassa							
Anabaena planctonica		4.0					
Aphanizomenon flos-aquae							
Aphanocapsa conferta							
Aphanocapsa delicatissima							
Aphanothece clathrata							
Aphanothece smithii	750	1,875				125	7,250
Coelosphaerium aerugineum							
Cuspidothrix issatschenkoi							
Cyanobium (Synechococcus) sp.	125			30			
Dactylococcopsis sp.		30		20			
Geitlerinema sp.					13.2		
Jaaginema sp.							
Lyngbya birgei							
Merismopedia sp.							
Merismopedia tenuissima							
Microcystis wesenbergii							
Myxobaktron hirudiforme							
Oscillatoria tenuis							
Planktolyngbya limnetica					5.2		
Planktothrix agardhii							
Pseudanabaena limnetica						2.4	
Romeria leopoliensis					30		
Snowella litoralis							
Synechococcus nidulans	1.2						
Synechocystis sp.							
Woronichinia naegeliana							
TOTAL CYANOPHYTA	**876.2**	**1,909**	**-**	**50**	**48.4**	**127.4**	**7,250**

Phytoplankton Densities (cells/ml)	SAMPLING DATE						
Seaman Reservoir - Bottom	12-Apr-10	26-Apr-10	11-May-10	24-May-10	7-Jun-10	21-Jun-10	6-Jul-10
CHRYSOPHYTA (golden-brown algae)							
Chromulina parvula	250		625		2,000	750	
Chrysococcus sp.							
Dinobryon cylindricum var. alpinum				6.4			
Dinobryon cylindricum							
Dinobryon divergens	2.8	6.4	8				
Dinobryon sociale var. americanum							
Mallomonas akrokomos							
Mallomonas caudata							
Mallomonas sp.							
cyst of Mallomonas sp.	1.6			5.6			
Ochromonas minuscula							
Synura petersenii							
TOTAL CHRYSOPHYTA	**254.4**	**6.4**	**633.0**	**12.0**	**2,000**	**750.0**	**-**
BACILLARIOPHYTA (diatoms)							
Asterionella formosa			19.6	110.4	0.8		
Aulacoseira ambigua	37.6	44.8	39.2		1		
Aulacoseira granulata var. angustissima		12.4	60.8				
Aulacoseira italica			16.8				
Aulacoseira italica var. tenuissima			50.8	7.2			
Aulacoseira subarctica							
Cymatopleura solea			0.2				
Diatoma anceps							
Diatoma moniliformis			1.6				
Diatoma tenuis				0.8			
Discostella glomerata			0.8				
Discostella pseudostelligera							
Discostella stelligera							
Fragilaria crotonensis			0.8				

Phytoplankton Densities (cells/ml)	SAMPLING DATE						
Seaman Reservoir - Bottom	12-Apr-10	26-Apr-10	11-May-10	24-May-10	7-Jun-10	21-Jun-10	6-Jul-10
BACILLARIOPHYTA (diatoms) - CONTINUED							
Gomphonema sphaerophorum			0.2				
Gyrosigma acuminatum							
Melosira varians			0.8	4	1.6		
Navicula capitatoradiata							
Navicula lanceolata							
Navicula tripunctata							
Nitzschia draveillensis			0.2				
Nitzschia fonticola							
Nitzschia gracilis			0.2				
Nitzschia sigma			0.2				
Nitzschia sp.							
Nitzschia supralitorea							
Punticulata bodanica	30.4	9.6					
Stephanodiscus medius			0.2				
Stephanodiscus niagarae	0.8	2	0.2				
Stephanodiscus parvus							
Synedra cyclopum	1.2						
Synedra delicatissima var. angustissima							
Synedra tenera				1.2			
Synedra ulna var. subaequalis			0.2				
Synedra ulna					0.2		
Urosolenia eriensis							
TOTAL BACILLARIOPHYTA	**70.0**	**68.8**	**192.8**	**123.6**	**3.6**	**-**	**-**
HAPTOPHYTA							
Chrysochromulina parva			10				

Phytoplankton Densities (cells/ml)	SAMPLING DATE						
Seaman Reservoir - Bottom	12-Apr-10	26-Apr-10	11-May-10	24-May-10	7-Jun-10	21-Jun-10	6-Jul-10
CRYPTOPHYTA							
Chroomonas coerulea							
Chroomonas nordstedtii							
Cryptomonas borealis	1.2			1.6			
Cryptomonas curvata	0.8			92.4			
Cryptomonas erosa							
Cryptomonas marsonii							
Komma caudata							
Plagioselmis nannoplanctica				2,400			
cyst of Cryptomonas							
TOTAL CRYPTOPHYTA	**2.0**	**-**	**-**	**2,494**	**-**	**-**	**-**
DINOPHYTA							
Ceratium hirundinella							
Gymnodinium fuscum							
Peridinium lomnickii							
Peridinium willei	0.2						
TOTAL DINOPHYTA	**0.2**	**-**	**-**	**-**	**-**	**-**	**-**
EUGLENOPHYTA							
Lepocinclis (Euglena) acus							
Lepocinclis (Euglena) oxyuris							0.2
Trachelomonas dybowskii							
Trachelomonas volvocina		10		80			
TOTAL EUGLENOPHYTA	**-**	**10.0**	**-**	**80.0**	**-**	**-**	**0.2**
PRASINOPHYTA							
Scourfieldia sp.							
Tetraselmis cordiformis							
TOTAL PRASINOPHYTA	**-**	**-**	**-**	**-**	**-**	**-**	**-**

Phytoplankton Densities (cells/ml)	SAMPLING DATE						
Seaman Reservoir - Bottom	12-Apr-10	26-Apr-10	11-May-10	24-May-10	7-Jun-10	21-Jun-10	6-Jul-10
CHLOROPHYTA (green algae)							
Ankistrodesmus falcatus							
Ankyra judayi				10			
Botryococcus braunii							
Chlamydomonas globosa							
Chlamydomonas snowiae							
Chlamydomonas sp. 1							
Chlamydomonas sp. 2							
Chlamydomonas tetragama							
Chlorella minutissima		187.5	750	2,500	500	1,250	250
Choricystis minor	125		1,000				
Closterium aciculare							
Closterium acutum var. variabile							
Closterium dianae							
Closterium moniliferum				0.2			
Coelastrum pulchrum							
Coenochloris fottii							
Cosmarium bioculatum							
Dictyosphaerium pulchellum var. minutum							
Elakatothrix viridis				0.4			
Eudorina elegans							
Gonatozygon kinahanii			0.2				
Heimansia pusilla							
Keratococcus sp.							
Micractinium pusillum							
Monoraphidium contortum			0.8				
Monoraphidium sp.							
Nephrocytium limneticum							
Oocystis apiculata							
Oocystis borgei							

Phytoplankton Densities (cells/ml)	SAMPLING DATE						
Seaman Reservoir - Bottom	12-Apr-10	26-Apr-10	11-May-10	24-May-10	7-Jun-10	21-Jun-10	6-Jul-10
CHLOROPHYTA (green algae) - CONTINUED							
Oocystis pusilla							
Pandorina charkowiensis							
Pandorina smithii							
Pediastrum boryanum							0.2
Pediastrum duplex							
Pseudodictyosphaerium elegans							
Pseudodictyosphaerium sp.							
Quadrigula sp.							
Raphidocelis contorta							
Raphidocelis sp.							
Scenedesmus arcuatus							
Scenedesmus armatus		0.8					
Scenedesmus bicaudatus			0.8				
Scenedesmus communis							
Schroederia setigera							
Staurastrum planctonicum							
Tetraedron minimum			1.6				
TOTAL CHLOROPHYTA	**125**	**188.3**	**1,753**	**2,511**	**500**	**1,250**	**250.2**
TOTAL ALGAL DENSITY (cells/mL)	**1,328**	**2,183**	**2,589**	**5,270**	**2,552**	**2,127**	**7,500**

Phytoplankton Densities (cells/ml)	SAMPLING DATE				
Seaman Reservoir - Bottom	9-Aug-10	7-Sep-10	4-Oct-10	10-Nov-10	
Potential geosmin producing cyanophyta					
CYANOPHYTA (blue-green algae)					
Anabaena flos-aquae		260.8	187.5	12.8	
Anabaena crassa	2.4	135.2	74.4	32	
Anabaena planctonica		43.2	33.6		
Aphanizomenon flos-aquae			244	180.8	
Aphanocapsa conferta					
Aphanocapsa delicatissima		4,000			
Aphanothece clathrata					
Aphanothece smithii	15,000	13,750	750		
Coelosphaerium aerugineum					
Cuspidothrix issatschenkoi					
Cyanobium (Synechococcus) sp.		250	125		
Dactylococcopsis sp.	20		20	40	
Geitlerinema sp.					
Jaaginema sp.					
Lyngbya birgei		80	4.8		
Merismopedia sp.		22			
Merismopedia tenuissima	2,000				
Microcystis wesenbergii			18.4		
Myxobaktron hirudiforme					
Oscillatoria tenuis					
Planktolyngbya limnetica				6.4	
Planktothrix agardhii		16			
Pseudanabaena limnetica	59,500	3.2			
Romeria leopoliensis					
Snowella litoralis					
Synechococcus nidulans					
Synechocystis sp.					
Woronichinia naegeliana		40		52.8	
TOTAL CYANOPHYTA	**76,522**	**18,600**	**1,458**	**324.8**	

Phytoplankton Densities (cells/ml)	SAMPLING DATE				
Seaman Reservoir - Bottom	9-Aug-10	7-Sep-10	4-Oct-10	10-Nov-10	
CHRYSOPHYTA (golden-brown algae)					
Chromulina parvula	125	125			
Chrysococcus sp.					
Dinobryon cylindricum var. alpinum					
Dinobryon cylindricum					
Dinobryon divergens					
Dinobryon sociale var. americanum					
Mallomonas akrokomos					
Mallomonas caudata			17.2	14.5	
Mallomonas sp.					
cyst of Mallomonas sp.					
Ochromonas minuscula					
Synura petersenii					
TOTAL CHRYSOPHYTA	**125.0**	**125.0**	**17.2**	**14.5**	
BACILLARIOPHYTA (diatoms)					
Asterionella formosa			13.2	93.2	
Aulacoseira ambigua		4.8	25	8.2	
Aulacoseira granulata var. angustissima	3.6	93.2	18	68	
Aulacoseira italica					
Aulacoseira italica var. tenuissima		27.2	165	1,530	
Aulacoseira subarctica			1.2	4.2	
Cymatopleura solea					
Diatoma anceps					
Diatoma moniliformis					
Diatoma tenuis					
Discostella glomerata					
Discostella pseudostelligera					
Discostella stelligera					
Fragilaria crotonensis		0.8	35.2		

Phytoplankton Densities (cells/ml)	SAMPLING DATE				
Seaman Reservoir - Bottom	9-Aug-10	7-Sep-10	4-Oct-10	10-Nov-10	
BACILLARIOPHYTA (diatoms) - CONTINUED					
Gomphonema sphaerophorum					
Gyrosigma acuminatum	0.1		0.2		
Melosira varians		0.8			
Navicula capitatoradiata					
Navicula lanceolata					
Navicula tripunctata					
Nitzschia draveillensis					
Nitzschia fonticola					
Nitzschia gracilis					
Nitzschia sigma		0.6			
Nitzschia sp.					
Nitzschia supralitorea					
Punticulata bodanica		21.6			
Stephanodiscus medius		2			
Stephanodiscus niagarae		52	190	8	
Stephanodiscus parvus		10		20	
Synedra cyclopum					
Synedra delicatissima var. angustissima			4.0		
Synedra tenera					
Synedra ulna var. subaequalis					
Synedra ulna					
Urosolenia eriensis					
TOTAL BACILLARIOPHYTA	**3.7**	**213.0**	**451.8**	**1,731.6**	
HAPTOPHYTA					
Chrysochromulina parva		40		40	

Phytoplankton Densities (cells/ml)	SAMPLING DATE				
Seaman Reservoir - Bottom	9-Aug-10	7-Sep-10	4-Oct-10	10-Nov-10	
CRYPTOPHYTA					
Chroomonas coerulea					
Chroomonas nordstedtii					
Cryptomonas borealis				1.6	
Cryptomonas curvata			0.2		
Cryptomonas erosa					
Cryptomonas marsonii					
Komma caudata					
Plagioselmis nannoplanctica			320	700	
cyst of Cryptomonas	2.8				
TOTAL CRYPTOPHYTA	**2.8**	**-**	**320.2**	**701.6**	
DINOPHYTA					
Ceratium hirundinella				0.4	
Gymnodinium fuscum		0.2			
Peridinium lomnickii					
Peridinium willei					
TOTAL DINOPHYTA	**-**	**0.2**	**-**	**0.4**	
EUGLENOPHYTA					
Lepocinclis (Euglena) acus					
Lepocinclis (Euglena) oxyuris					
Trachelomonas dybowskii					
Trachelomonas volvocina			1.6	2.4	
TOTAL EUGLENOPHYTA	**-**	**-**	**1.6**	**2.4**	
PRASINOPHYTA					
Scourfieldia sp.					
Tetraselmis cordiformis					
TOTAL PRASINOPHYTA	**-**	**-**	**-**	**-**	

Phytoplankton Densities (cells/ml)	SAMPLING DATE				
Seaman Reservoir - Bottom	9-Aug-10	7-Sep-10	4-Oct-10	10-Nov-10	
CHLOROPHYTA (green algae)					
Ankistrodesmus falcatus					
Ankyra judayi		40	40		
Botryococcus braunii					
Chlamydomonas globosa			20		
Chlamydomonas snowiae					
Chlamydomonas sp. 1			60		
Chlamydomonas sp. 2				520.0	
Chlamydomonas tetragama			40		
Chlorella minutissima			7,875	14,375	
Choricystis minor					
Closterium aciculare					
Closterium acutum var. variabile					
Closterium dianae					
Closterium moniliferum					
Coelastrum pulchrum					
Coenochloris fottii		23.2			
Cosmarium bioculatum			20		
Dictyosphaerium pulchellum var. minutum					
Elakatothrix viridis					
Eudorina elegans					
Gonatozygon kinahanii					
Heimansia pusilla					
Keratococcus sp.					
Micractinium pusillum					
Monoraphidium contortum					
Monoraphidium sp.					
Nephrocytium limneticum					
Oocystis apiculata		2.8			
Oocystis borgei					

Phytoplankton Densities (cells/ml)	SAMPLING DATE				
Seaman Reservoir - Bottom	9-Aug-10	7-Sep-10	4-Oct-10	10-Nov-10	
CHLOROPHYTA (green algae) - CONTINUED					
Oocystis pusilla					
Pandorina charkowiensis					
Pandorina smithii					
Pediastrum boryanum	0.8				
Pediastrum duplex		7.2			
Pseudodictyosphaerium elegans			9.6		
Pseudodictyosphaerium sp.			160	160	
Quadrigula sp.					
Raphidocelis contorta					
Raphidocelis sp.					
Scenedesmus arcuatus		4.8			
Scenedesmus armatus					
Scenedesmus bicaudatus					
Scenedesmus communis					
Schroederia setigera					
Staurastrum planctonicum		0.2	2.8		
Tetraedron minimum					
TOTAL CHLOROPHYTA	**0.8**	**78.2**	**8,227**	**15,055**	
TOTAL ALGAL DENSITY (cells/mL)	**76,655**	**19,057**	**10,476**	**17,870**	

ATTACHMENT 7

2010 Upper CLP Collaborative Water Quality Monitoring Program

Graphical Summary

LIST OF FIGURES

Mainstem and North Fork CLP: Daily Average Stream Flow

Figure 1 (a & b). Daily average stream flow on the Mainstem and North Fork CLP

Figure 1.a. 2010 Daily average stream flow on the Mainstem and North Fork CLP

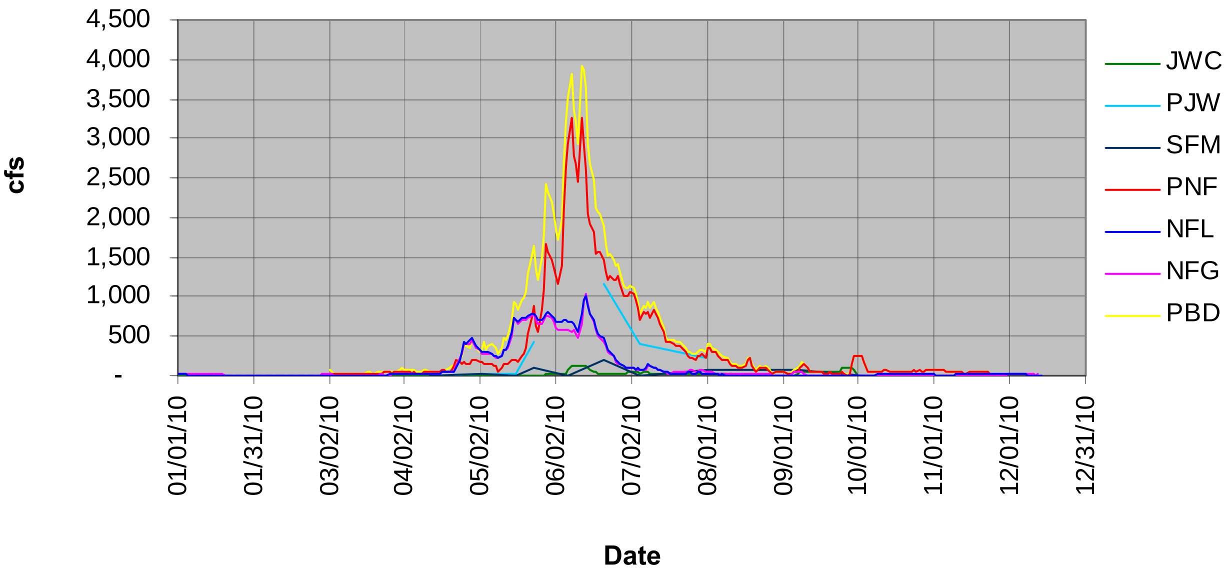


Figure 1.b. 2007 - 2010 Daily average stream flow on the Mainstem and North Fork CLP

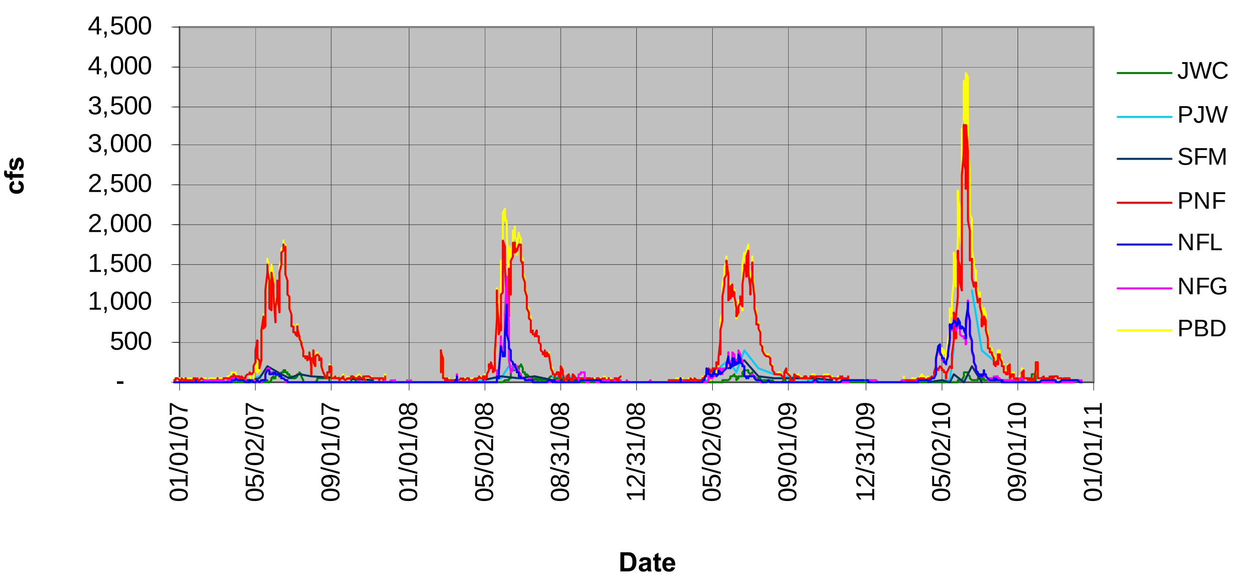


Figure 2 (a & b). Daily average stream flow on the North Fork tributaries

Figure 2.a. 2010 Daily average stream flow on the North Fork tributaries

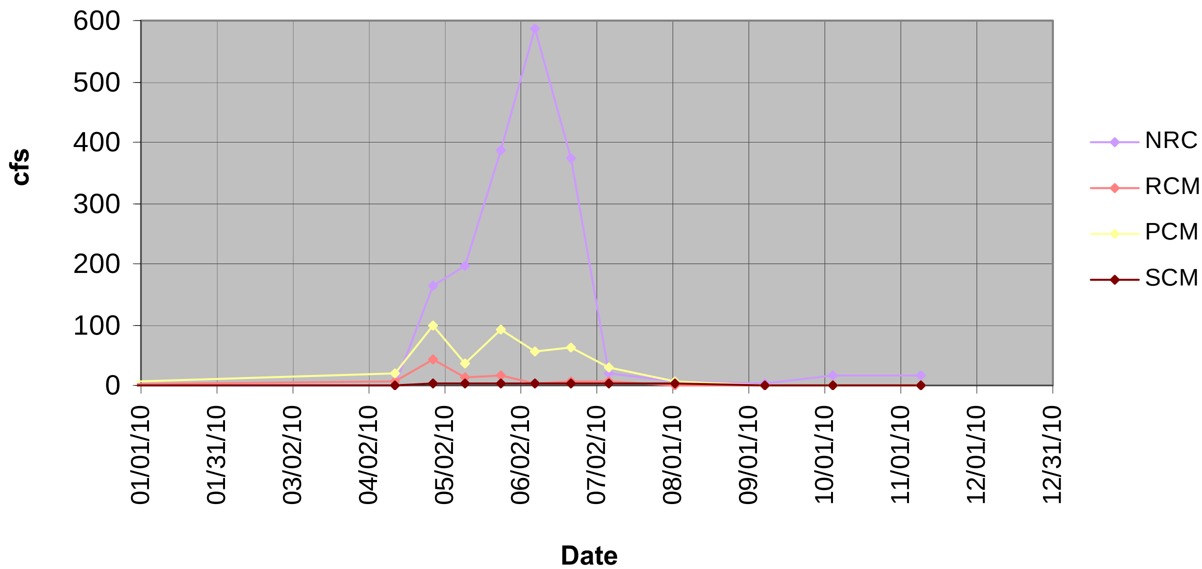
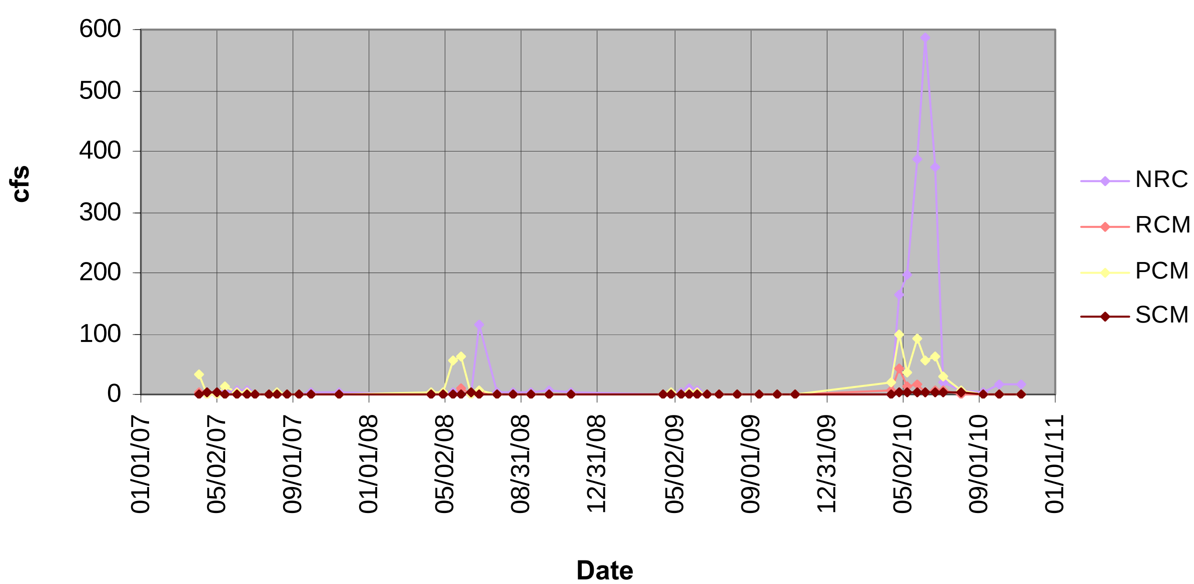


Figure 2.b. 2007 - 2010 Daily average stream flow on the North Fork tributaries



Mainstem and North Fork CLP:
General Parameters

Figure 3 (a & b). Water temperature

Figure 3.a. Water temperature on the Mainstem CLP

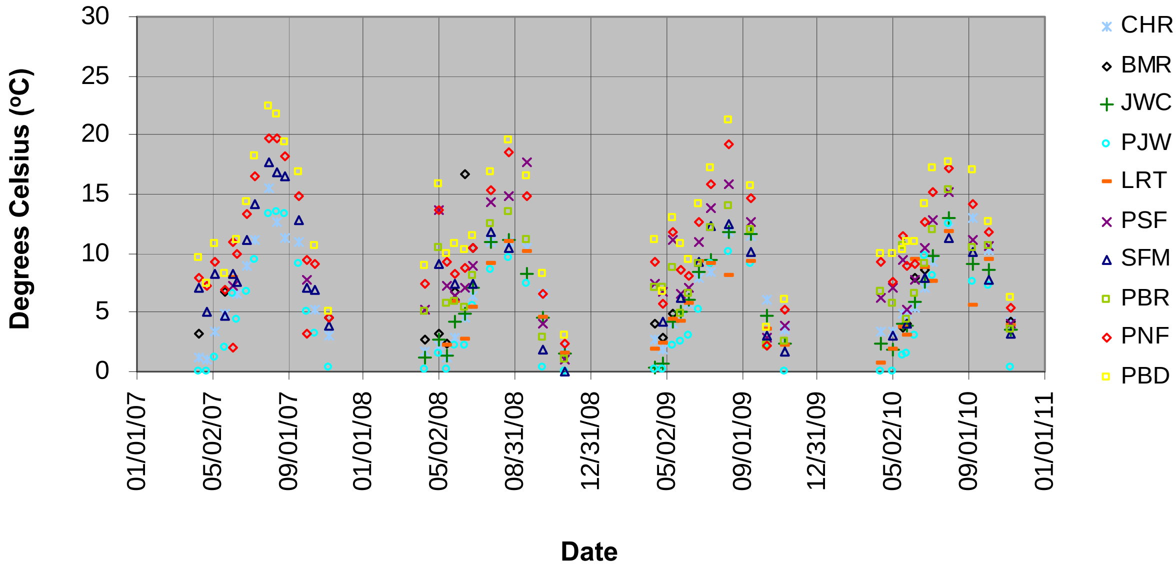


Figure 3.b. Water temperature on the North Fork CLP

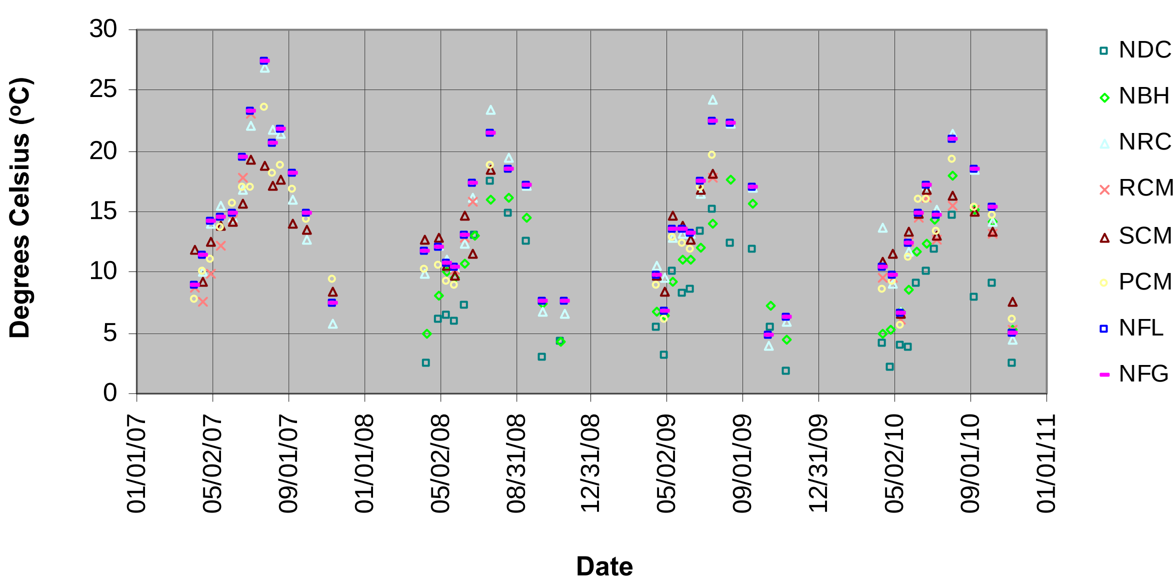


Figure 4 (a & b). pH

Figure 4.a. pH on the Mainstem CLP

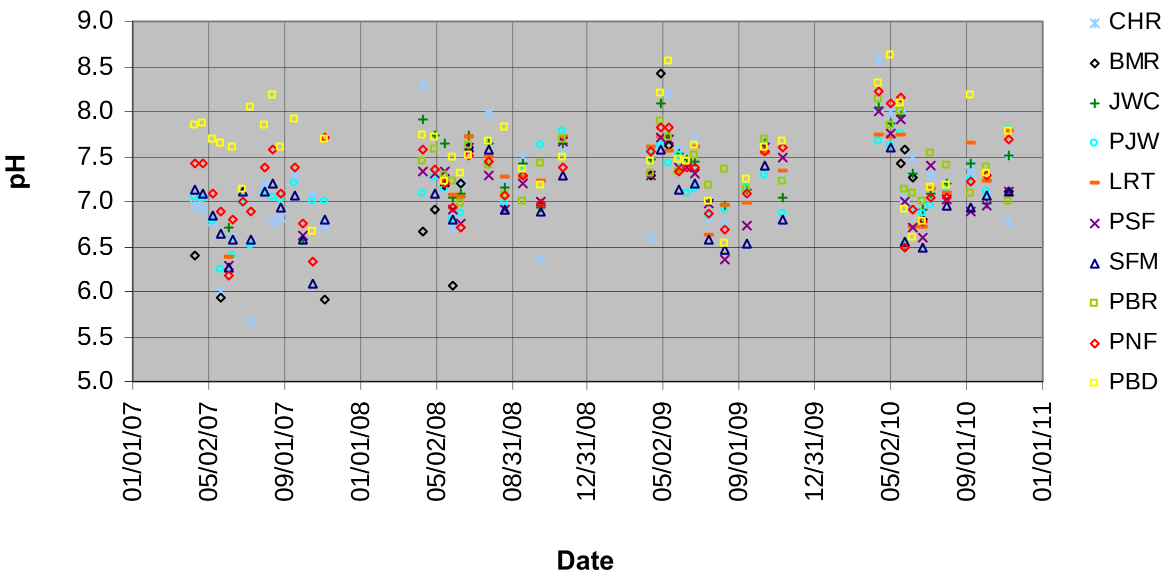


Figure 4.b. pH on the North Fork CLP

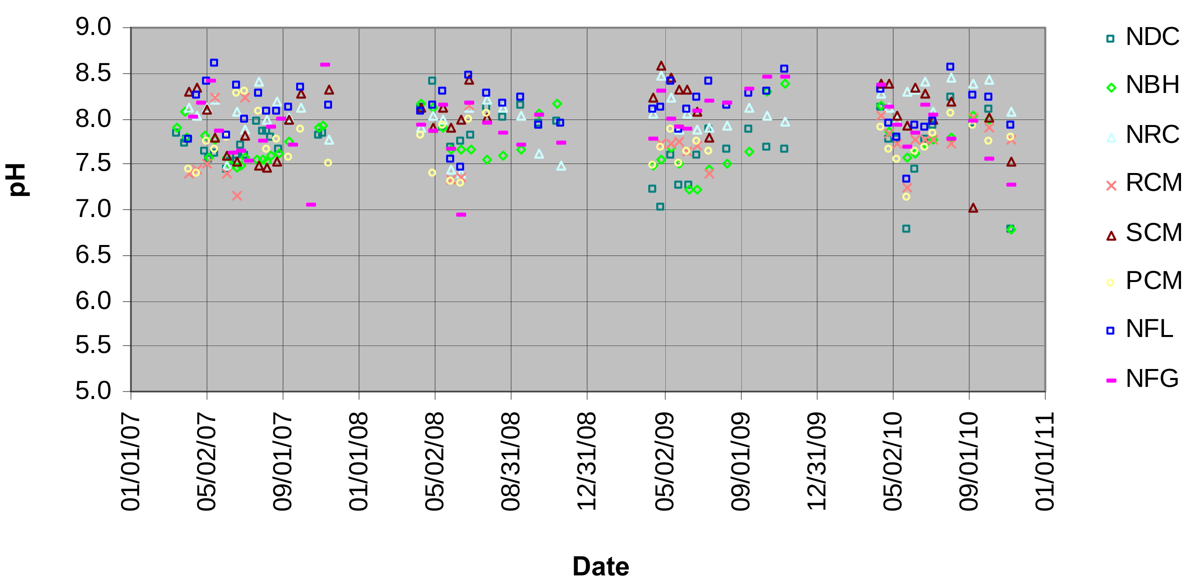


Figure 5 (a & b). Specific Conductance

Figure 5.a. Specific Conductance **o**n the Mainstem CLP

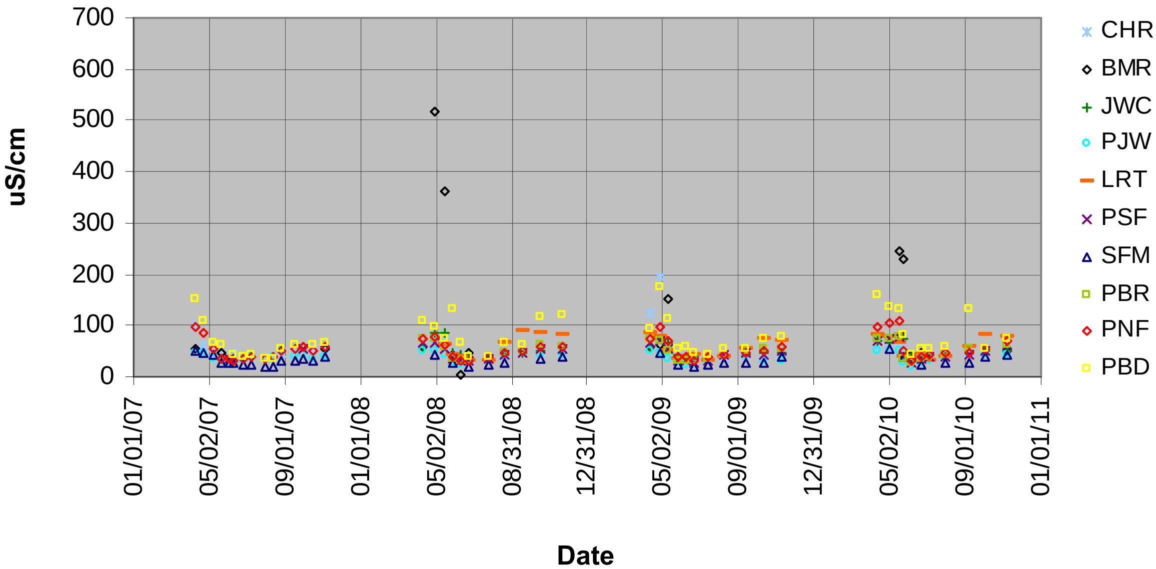


Figure 5.b. Specific conductance on the North Fork CLP

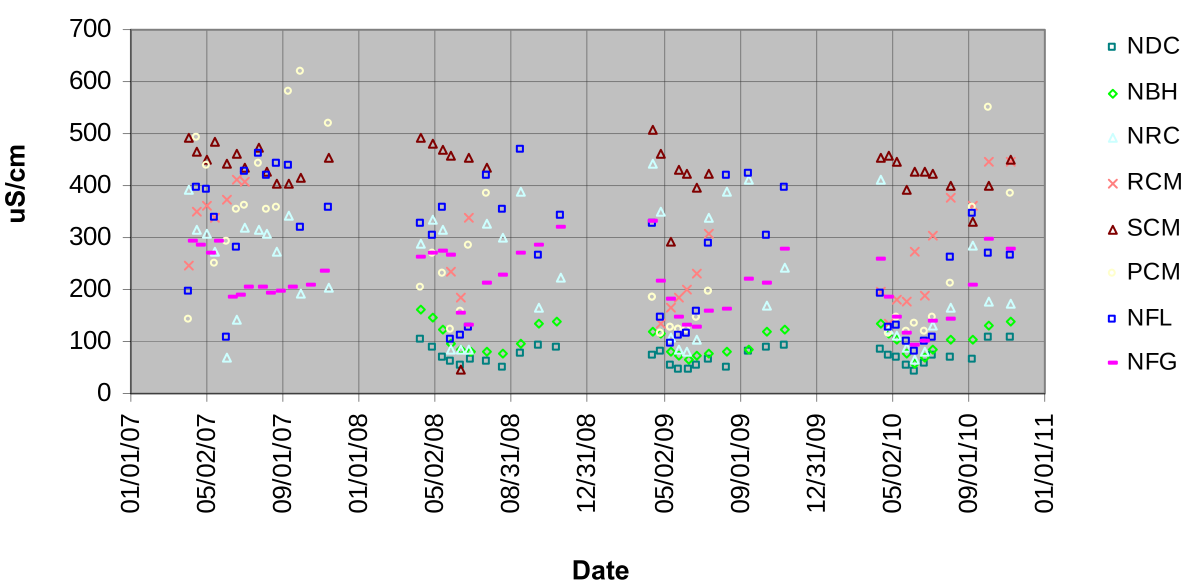


Figure 6 (a & b). Hardness

Figure 6.a. Hardness on the Mainstem CLP

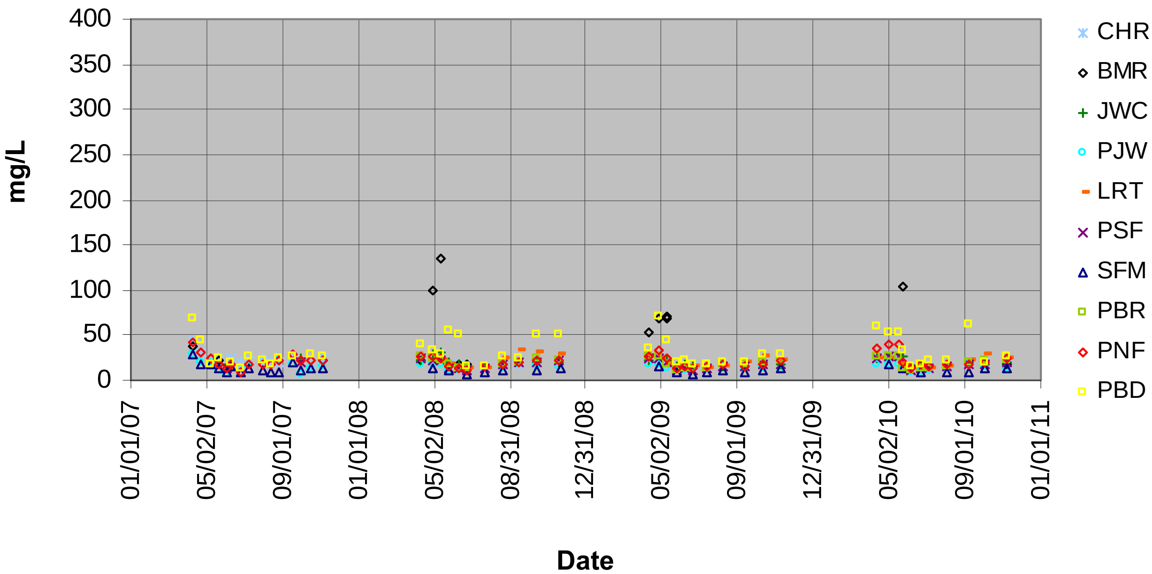


Figure 6.b. Hardness on the North Fork CLP

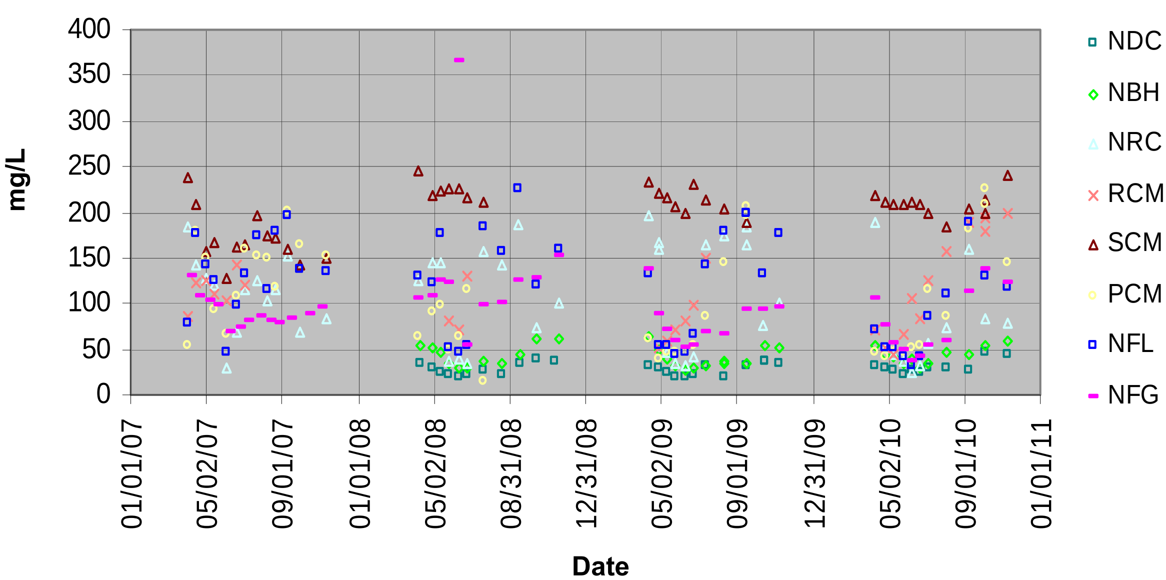


Figure 7 (a & b). Alkalinity

Figure 7.a. Alkalinity on the Mainstem CLP

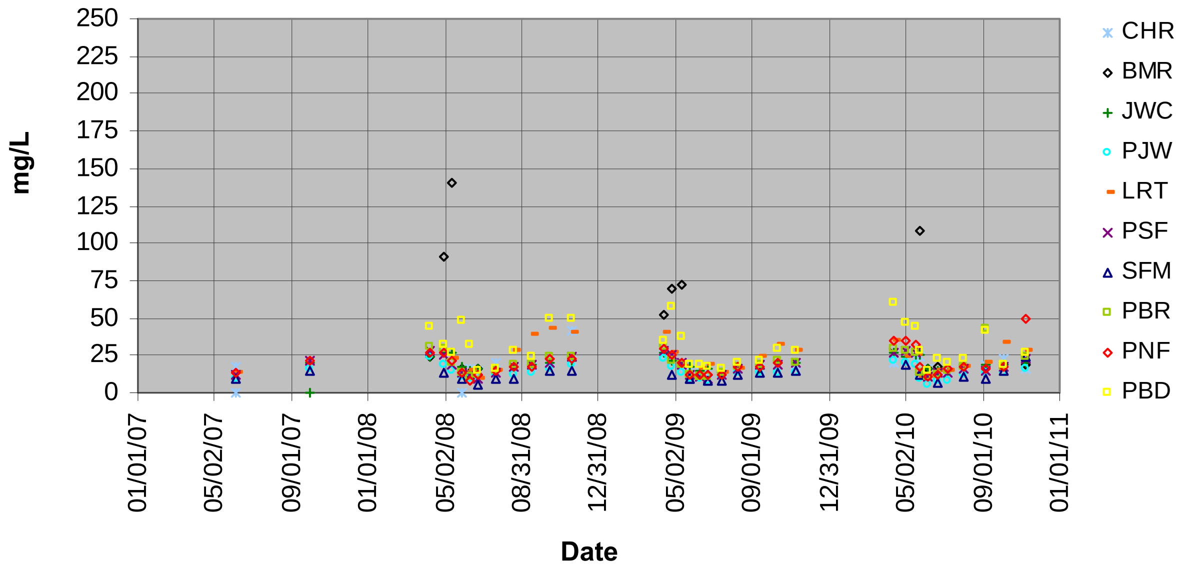


Figure 7.b. Alkalinity on the North Fork CLP

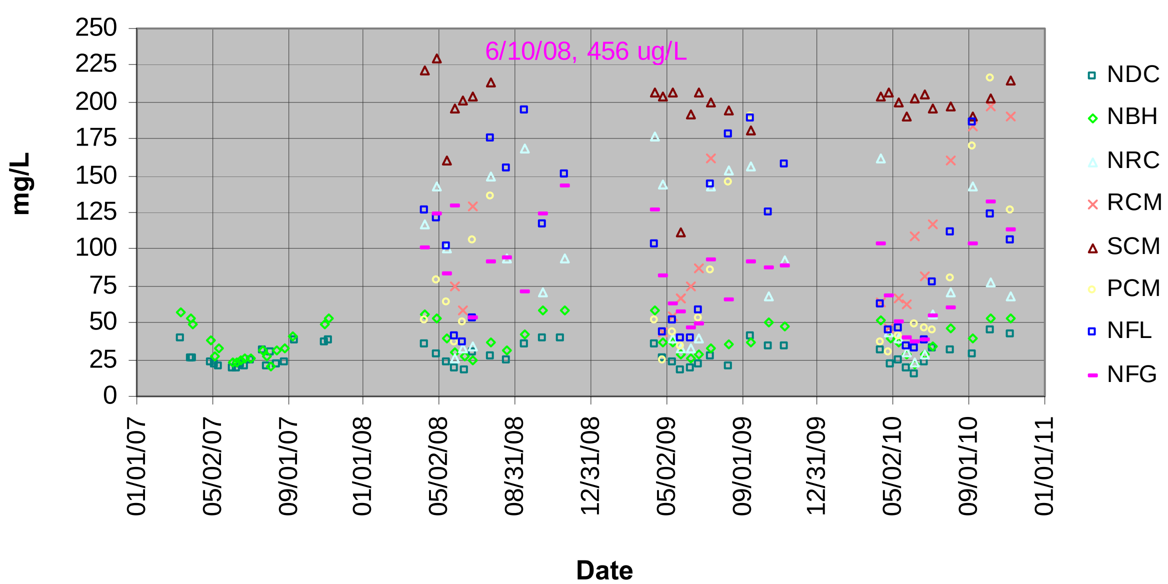


Figure 8 (a & b). Turbidity

Figure 8.a. Turbidity on the Mainstem CLP

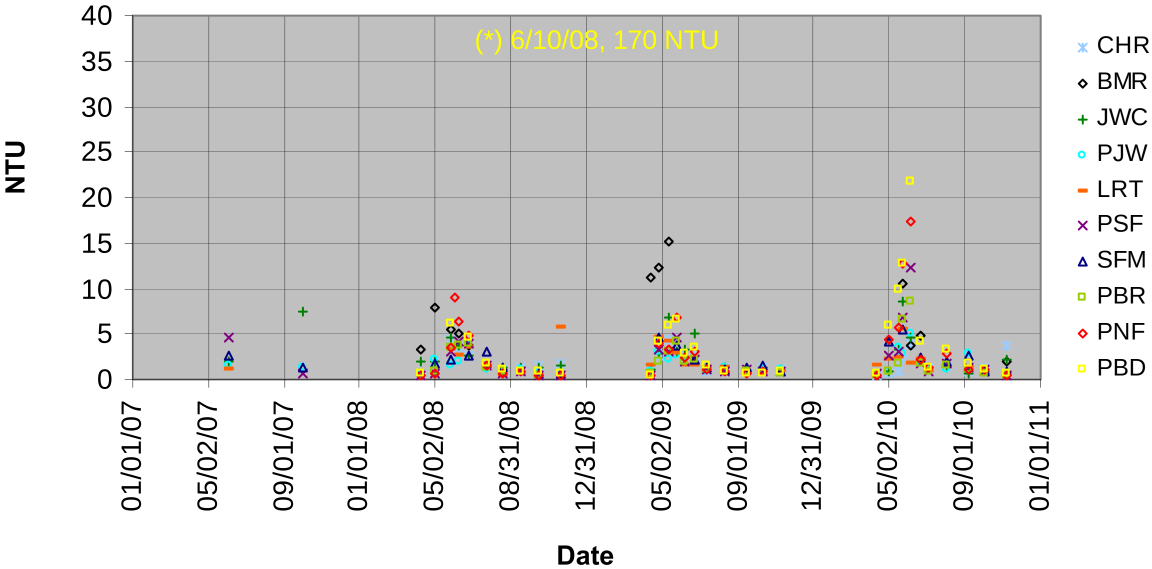


Figure 8.b. Turbidity on the North Fork CLP

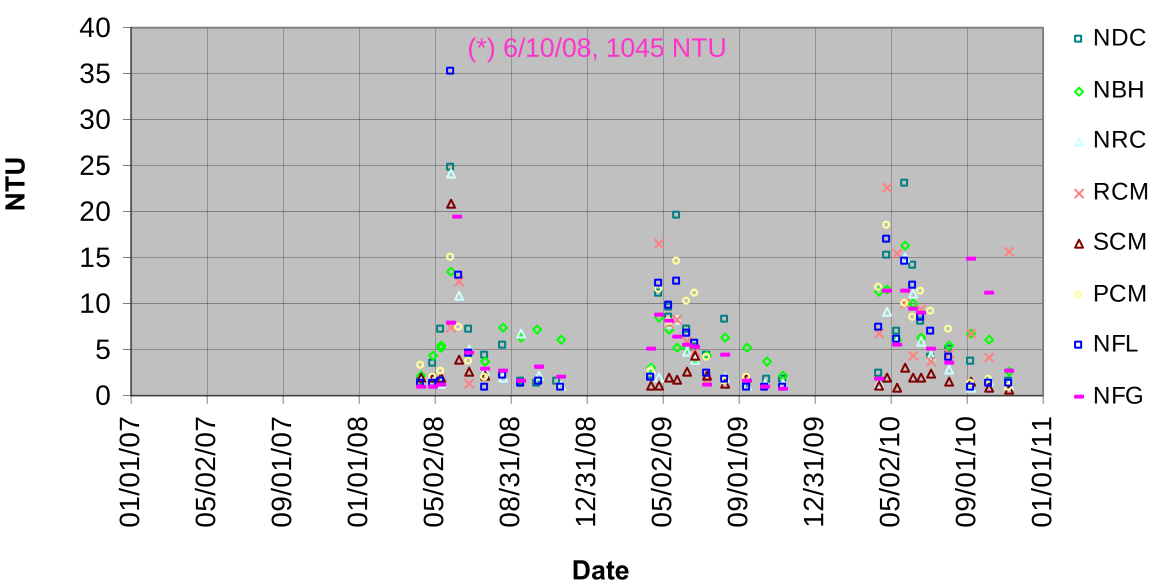
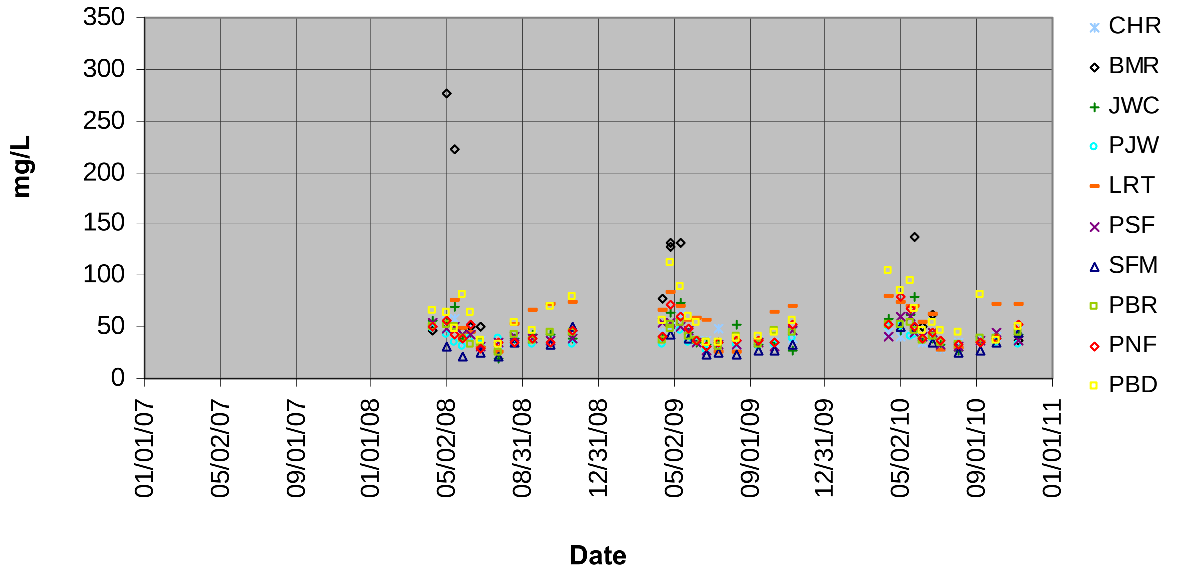


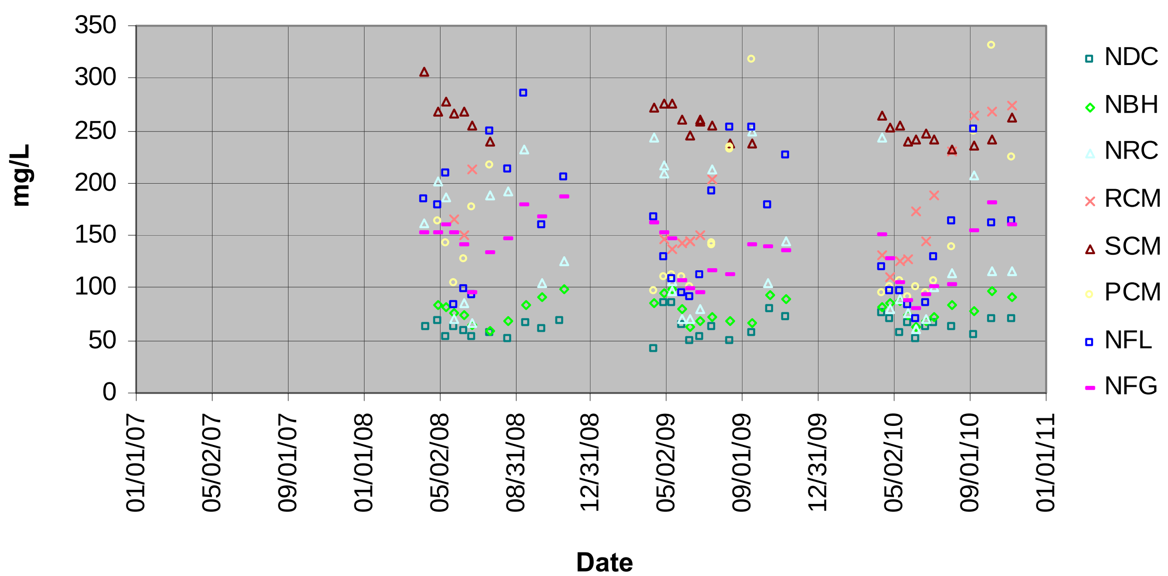
Figure 9 (a & b). Total Dissolved Solids (TDS)

Figure 9.a. TDS on the Mainstem CLP



(EPA Secondary Drinking Water Standard: 500 mg/l)

Figure 9.b. TDS on the North Fork CLP



(EPA Secondary Drinking Water Standard: 500 mg/l)

Figure 10 (a & b). Total Organic Carbon (TOC)

Figure 10.a. TOC on the Mainstem CLP

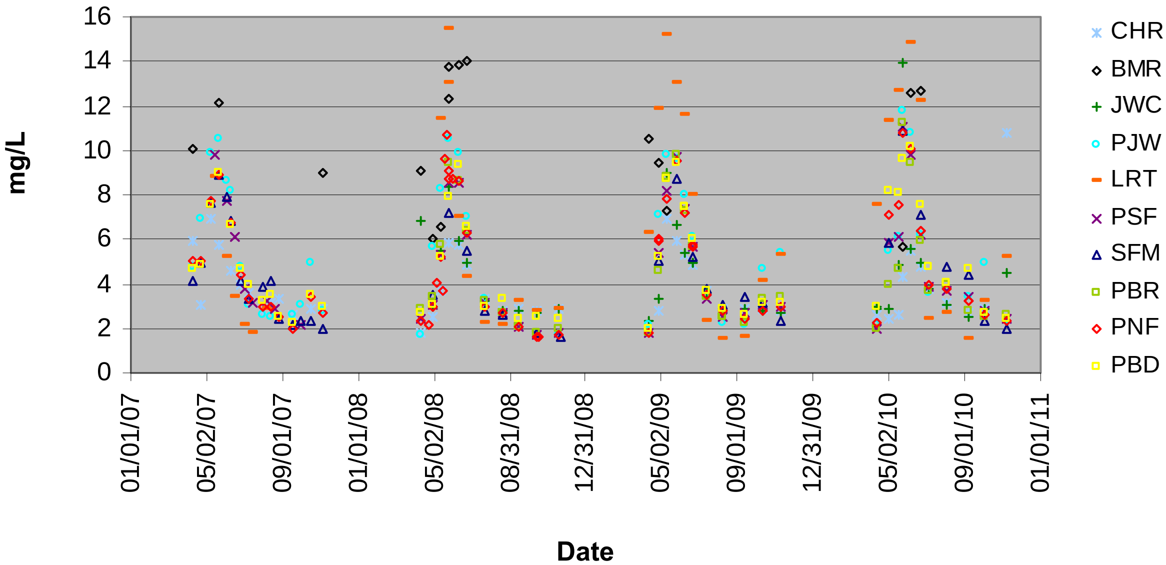
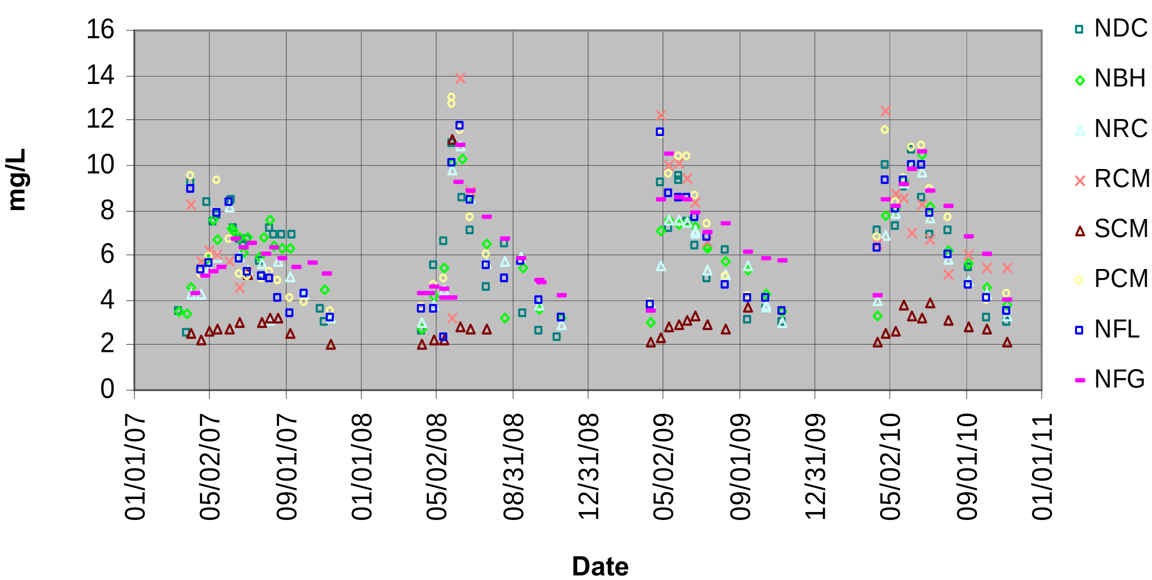


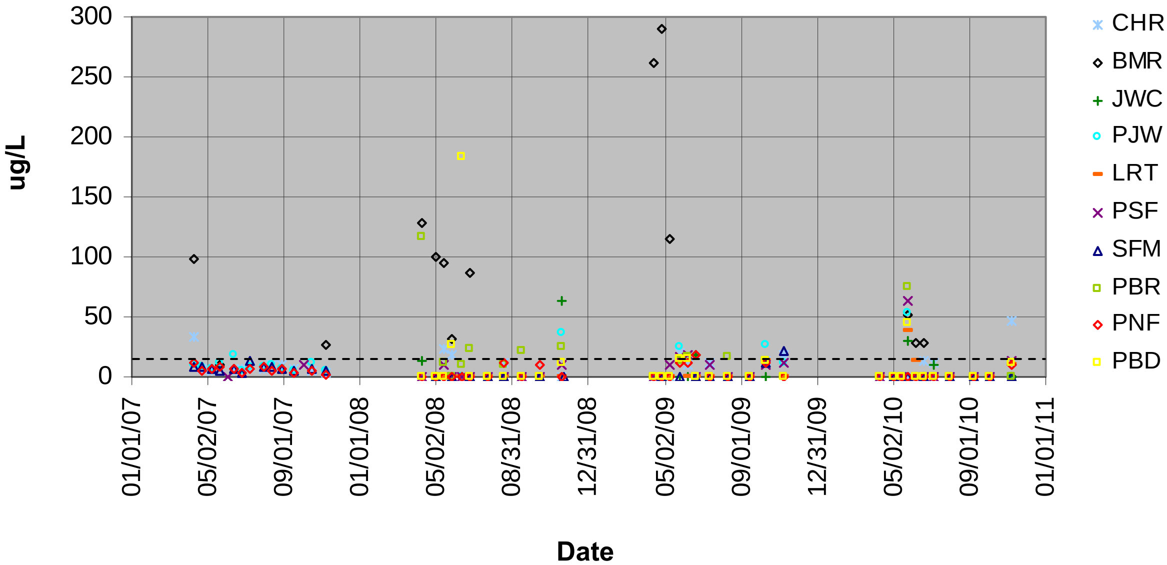
Figure 10.b. TOC on the North Fork CLP



Mainstem and North Fork CLP:
Nutrients

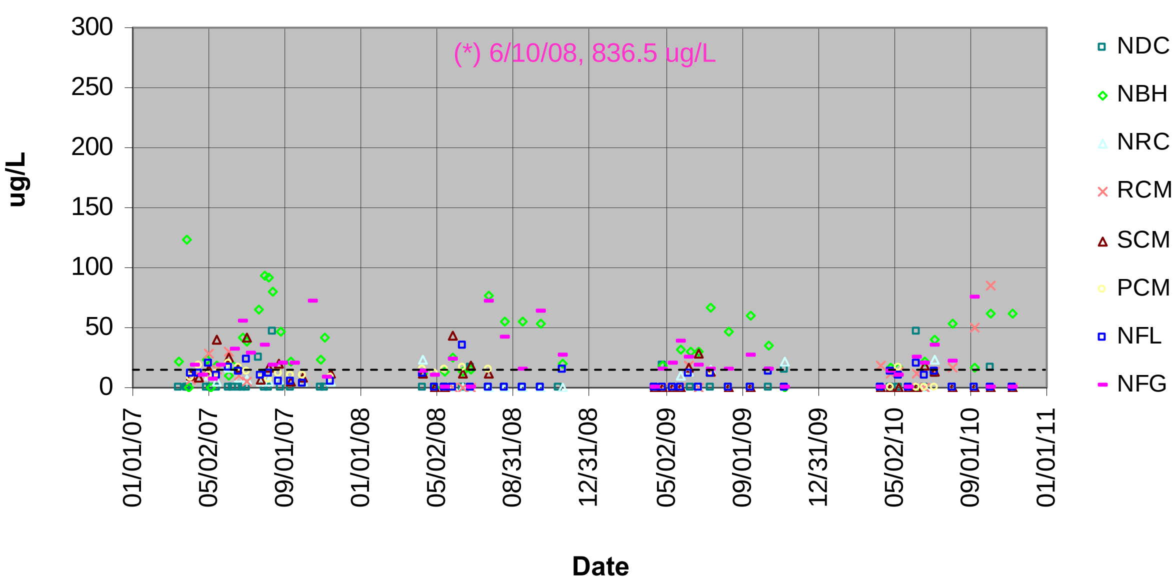
Figure 11 (a & b). Ammonia (NH_3)

Figure 11.a. Ammonia (NH_3) on the Mainstem CLP



(------- FCWQL Reporting Limit: 10 ug/L)

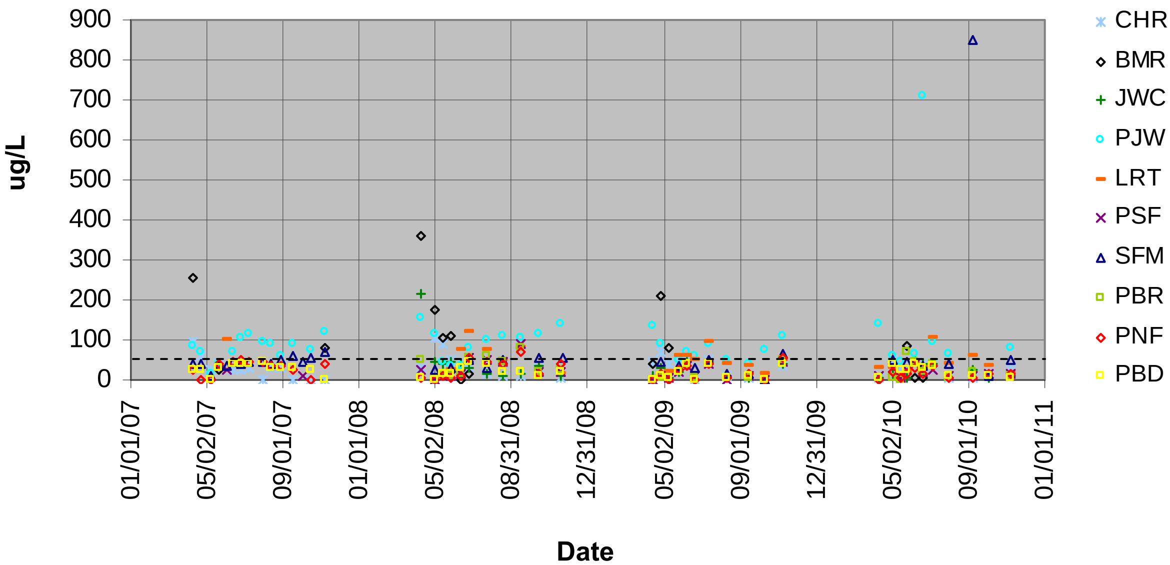
Figure 11.b. Ammonia (NH_3) on the North Fork CLP



(------- FCWQL Reporting Limit: 10 ug/L)

Figure 12 (a & b). Nitrate (NO_3)

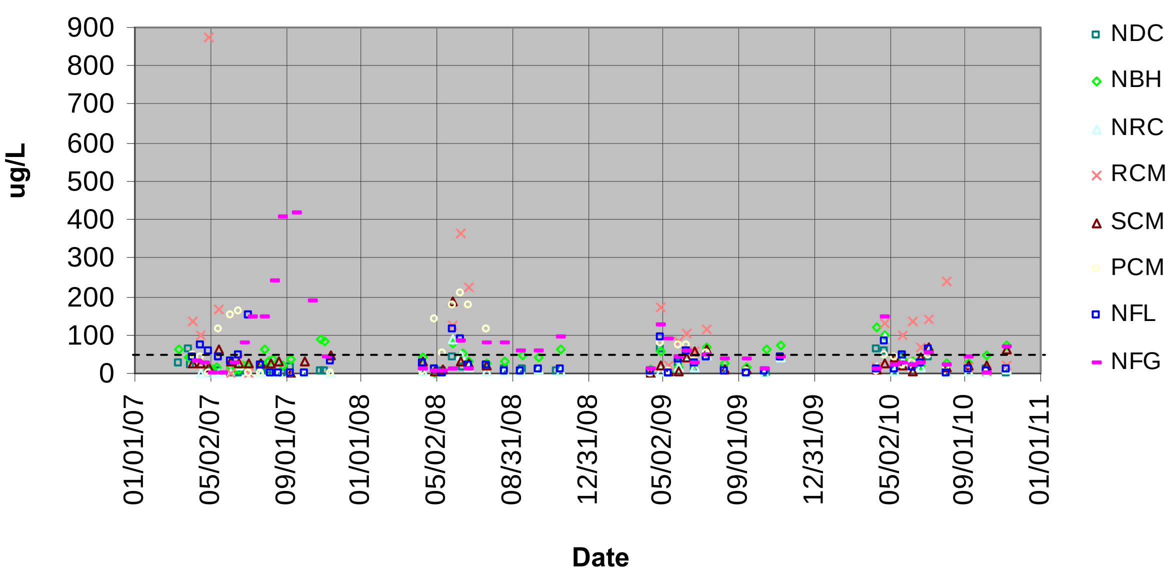
Figure 12.a. Nitrate (NO_3) on the Mainstem CLP



(------- FCWQL Reporting Limit: 40 ug/L)

(EPA Maximum Contaminant Level: 10,000 ug/L as N)

Figure 12.b. Nitrate (NO_3) on the North Fork CLP

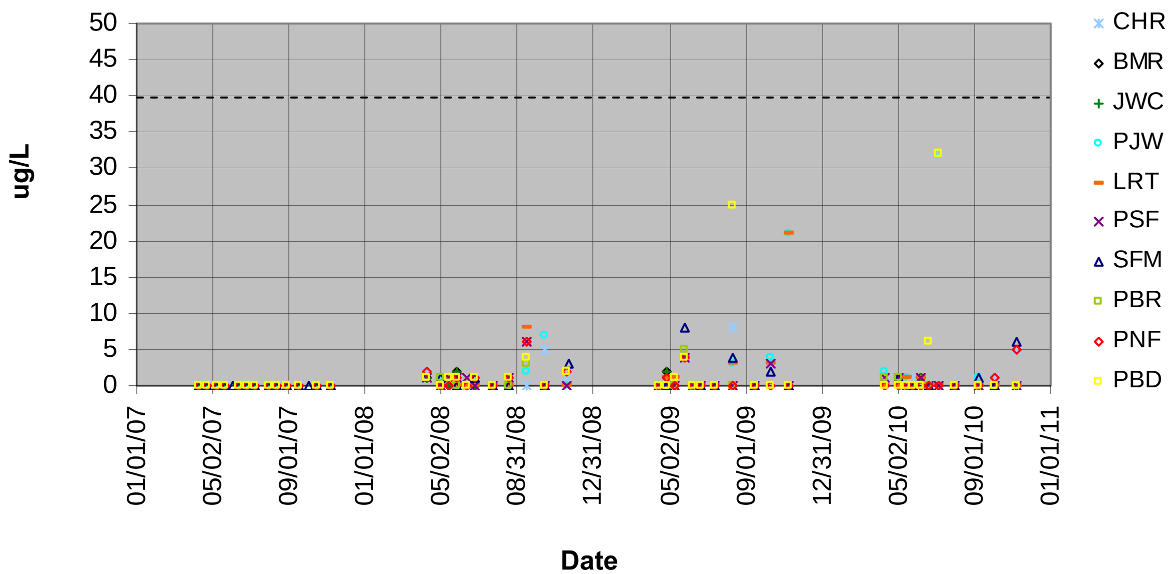


(------- FCWQL Reporting Limit: 40 ug/L)

(EPA Maximum Contaminant Level: 10,000 ug/L as N)

Figure 13 (a & b). Nitrite (NO_2)

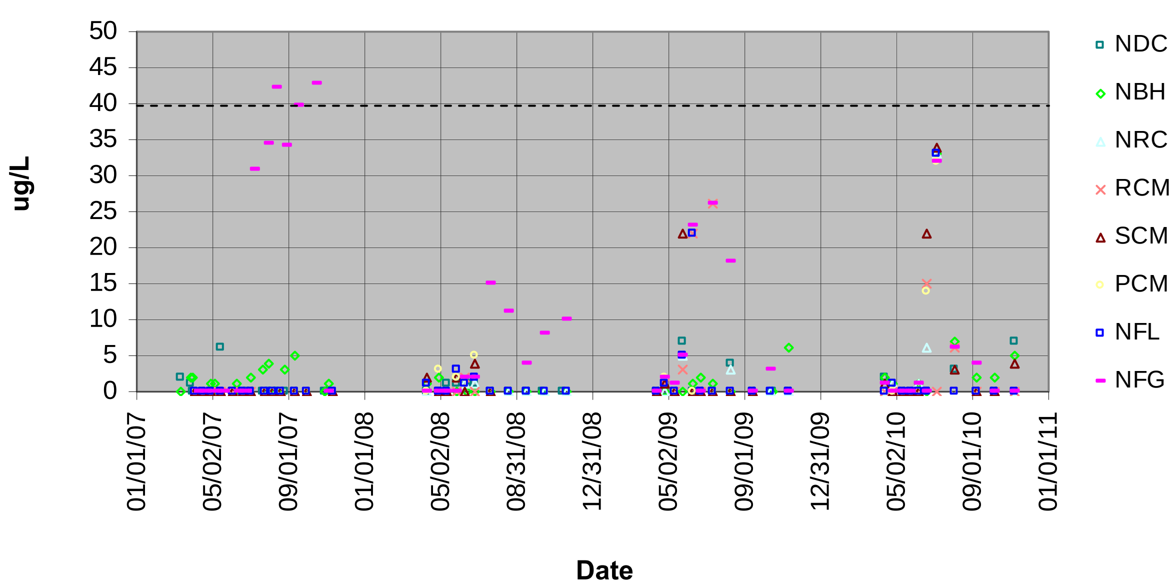
Figure 13.a. Nitrite (NO_2) on the Mainstem CLP



(------- FCWQL Reporting Limit: 40 ug/L)

(EPA Maximum Contaminant Level: 1,000 ug/L as N)

Figure 13.b. Nitrite (NO_2) on the North Fork CLP

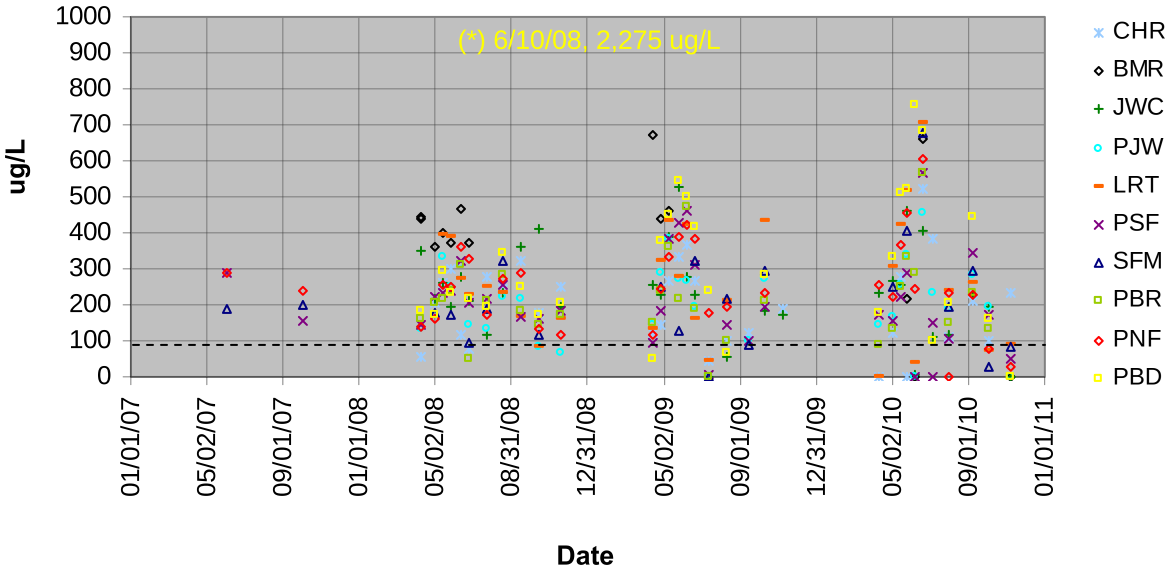


(------- FCWQL Reporting Limit: 40 ug/L)

(EPA Maximum Contaminant Level: 1,000 ug/L as N)

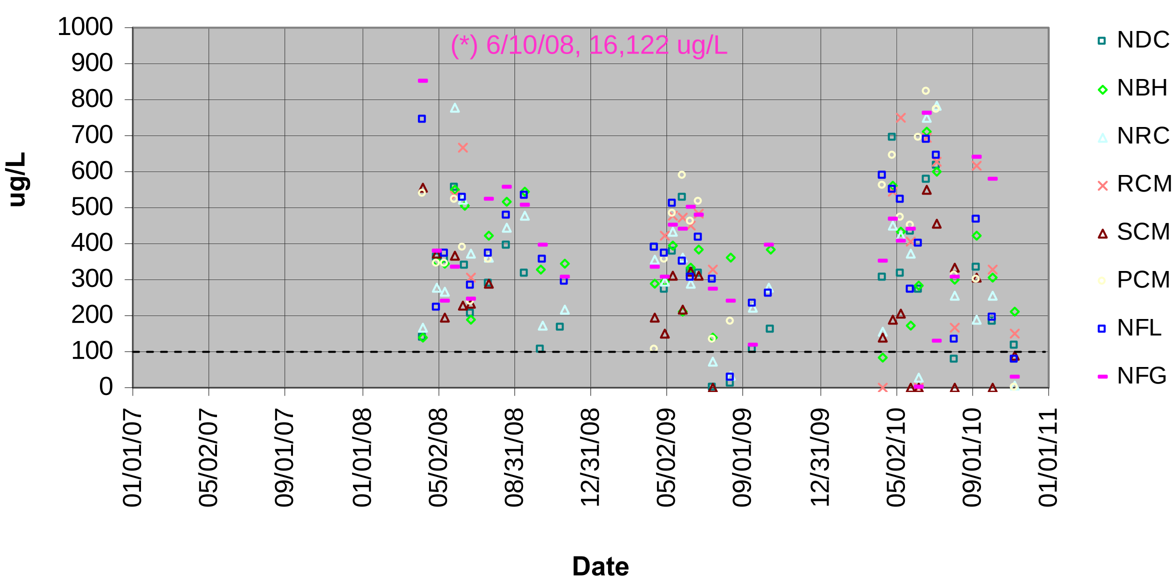
Figure 14 (a & b). Total Kjeldahl Nitrogen (TKN)

Figure 14.a. TKN on the Mainstem CLP



(------- FCWQL Reporting Limit: 100 ug/L)

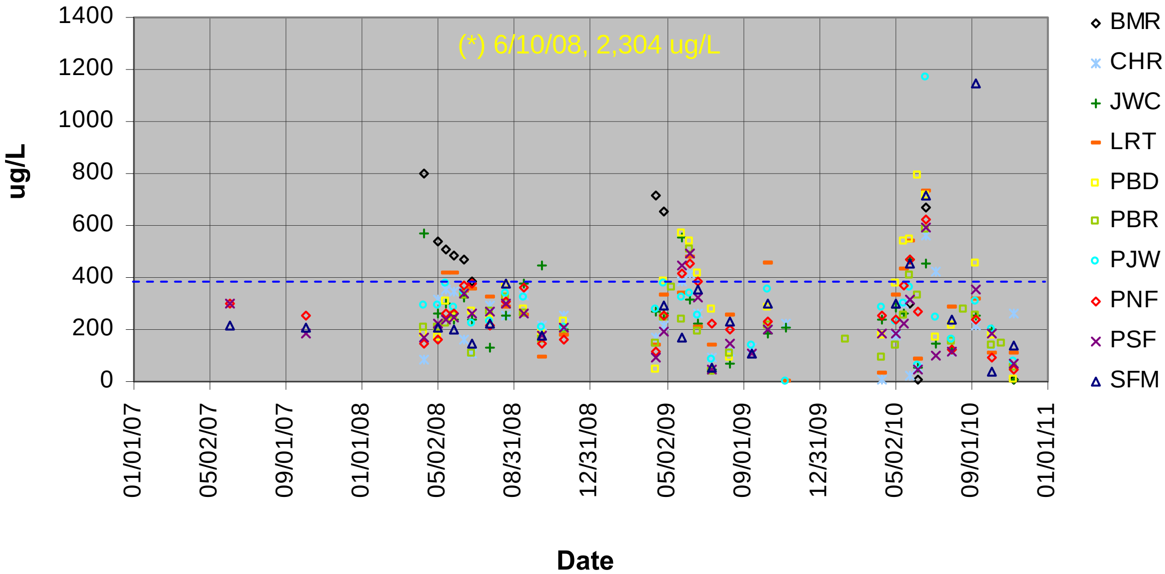
Figure 14.b. TKN on the North Fork CLP



(------- FCWQL Reporting Limit: 100 ug/L)

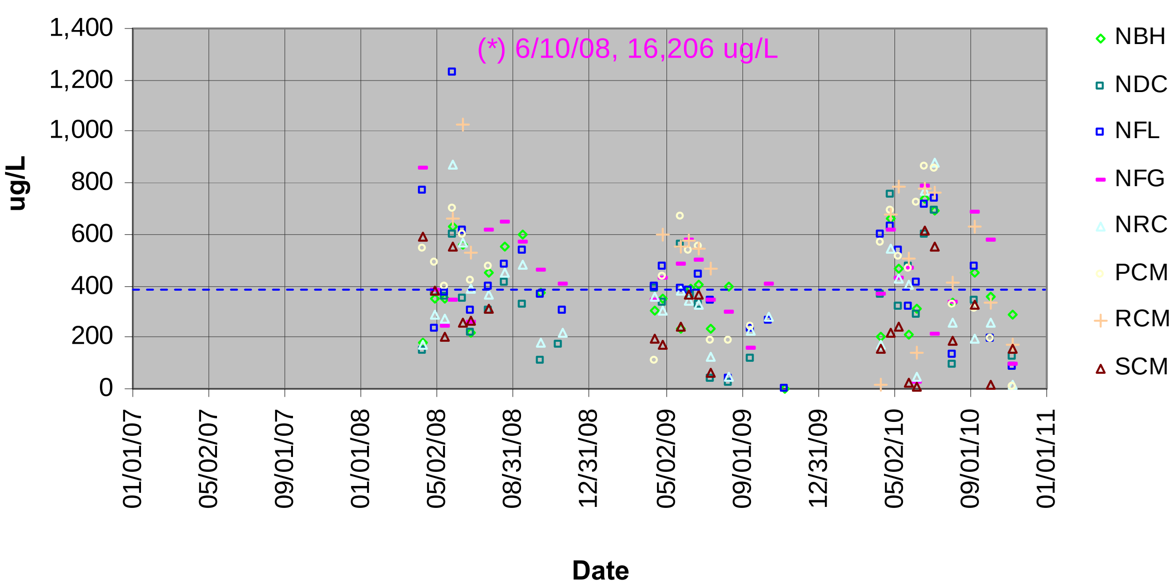
Figure 15 (a & b). Total Nitrogen (TKN+NO_3+NO_2)

Figure 15.a. Total N on the Mainstem CLP



(------- 2010 CDPHE/WQCD proposed cold water stream standard for Total N: 400 ug/L)

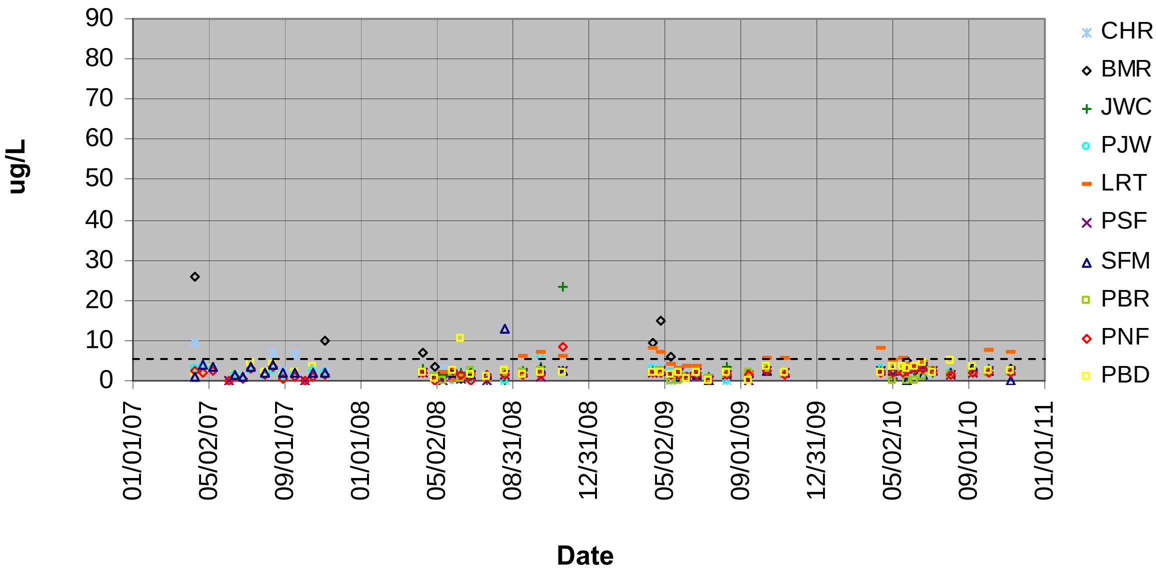
Figure 15.b. Total N on the North Fork CLP



(------- 2010 CDPHE/WQCD proposed cold water stream standard for Total N: 400 ug/L)

Figure 16 (a & b). Ortho-phosphate (PO_4)

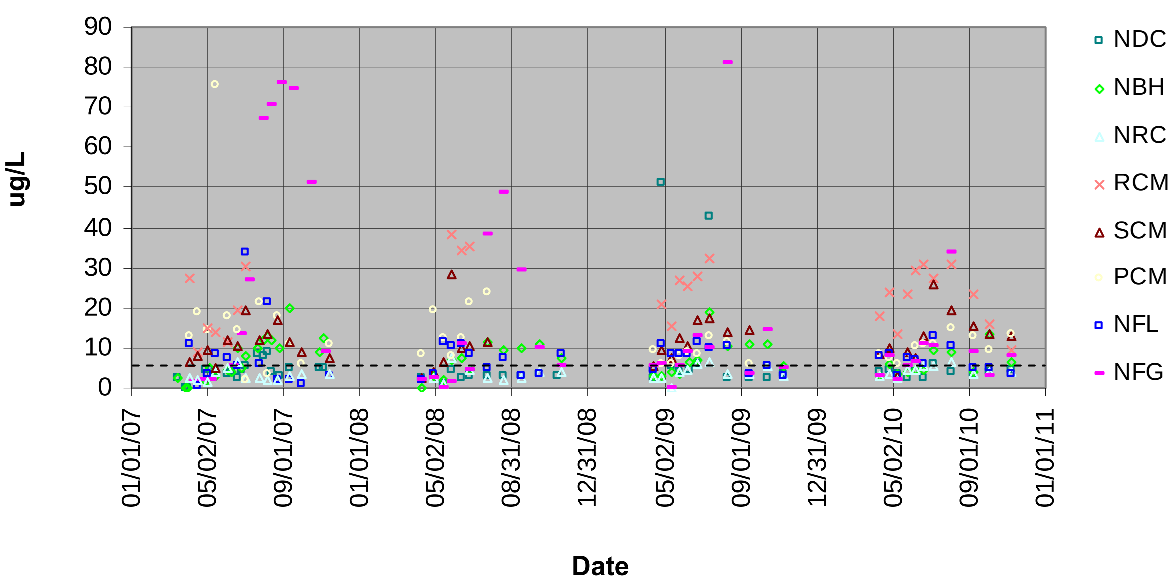
Figure 16.a. Ortho-phosphate (PO_4) on the Mainstem CLP



(------- FCWQL Reporting Limit: 5 ug/L)

* 2007 values reported as Soluble Reactive Phosphorus (SRP)

Figure 16.b. Ortho-phosphate (PO_4) on the North Fork CLP

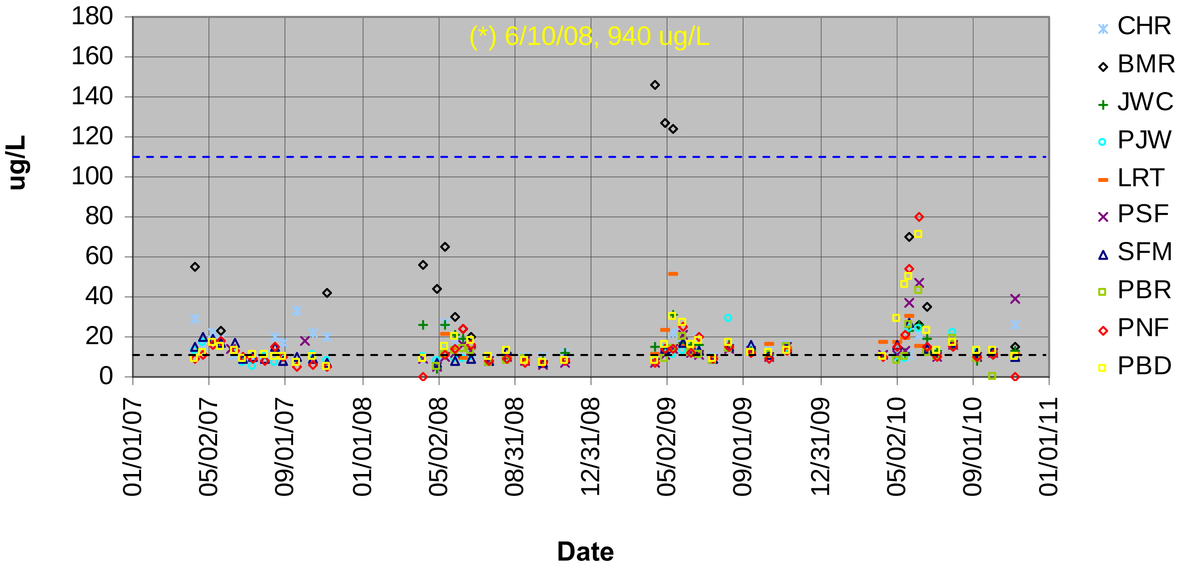


(------- FCWQL Reporting Limit: 5 ug/L)

* 2007 values reported as Soluble Reactive Phosphorus (SRP)

Figure 17 (a & b). Total Phosphorus (P)

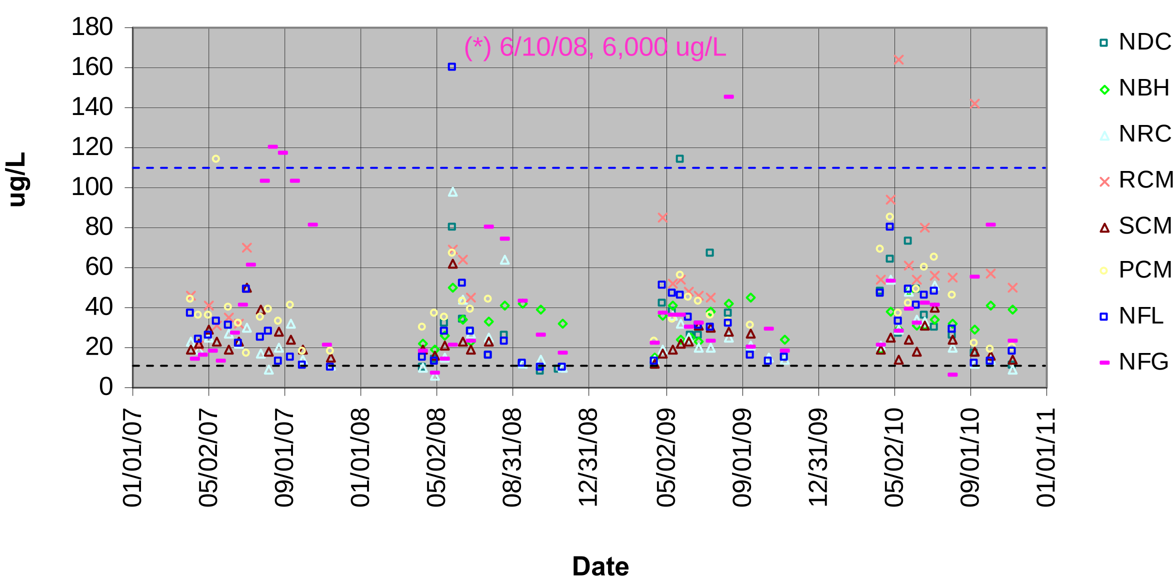
Figure 17.a. Total P on the Mainstem CLP



(------- FCWQL Reporting Limit: 10 ug/L)

(------- 2010 CDPHE/WQCD proposed cold water stream standard for Total P: 110 ug/L)

Figure 17.b. Total P on the North Fork CLP

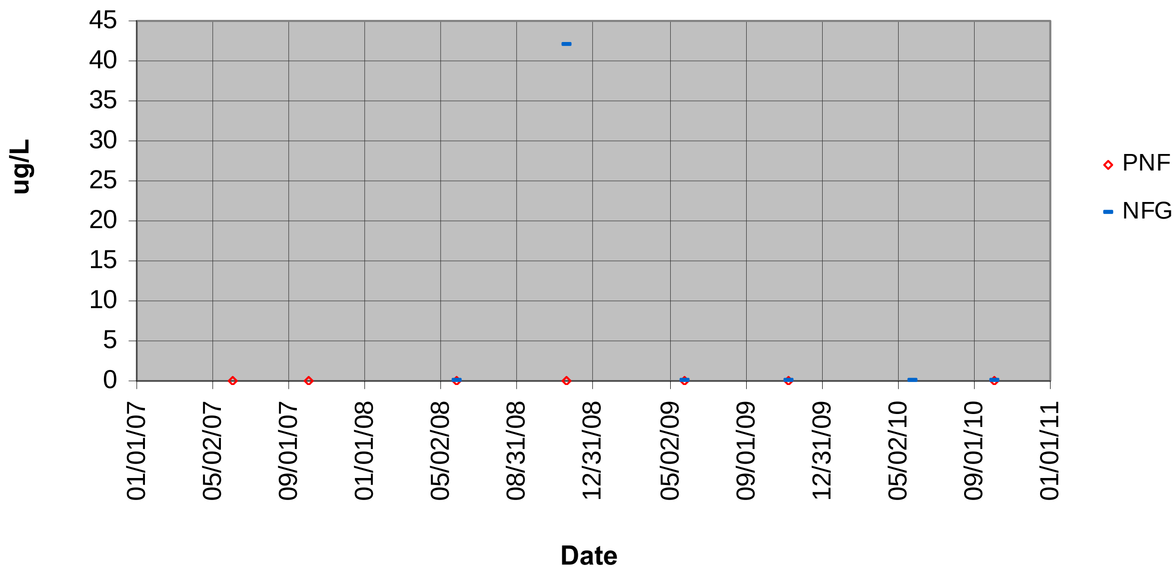


(------- FCWQL Reporting Limit: 10 ug/L)

(------- 2010 CDPHE/WQCD proposed cold water stream standard for Total P: 110 ug/L)

Mainstem and North Fork CLP: Metals

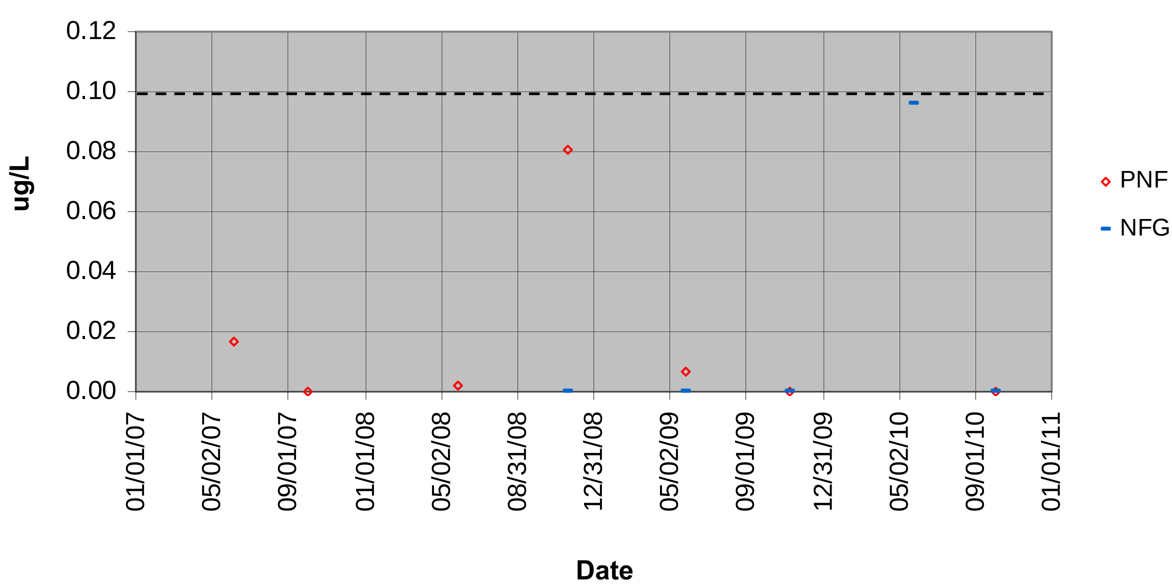
Figure 18. Dissolved silver (Ag) on the Mainstem and North Fork CLP



(------- FCWQL Reporting Limit: 0.5 ug/L)

(EPA Secondary Drinking Water Standard: 100ug/L)

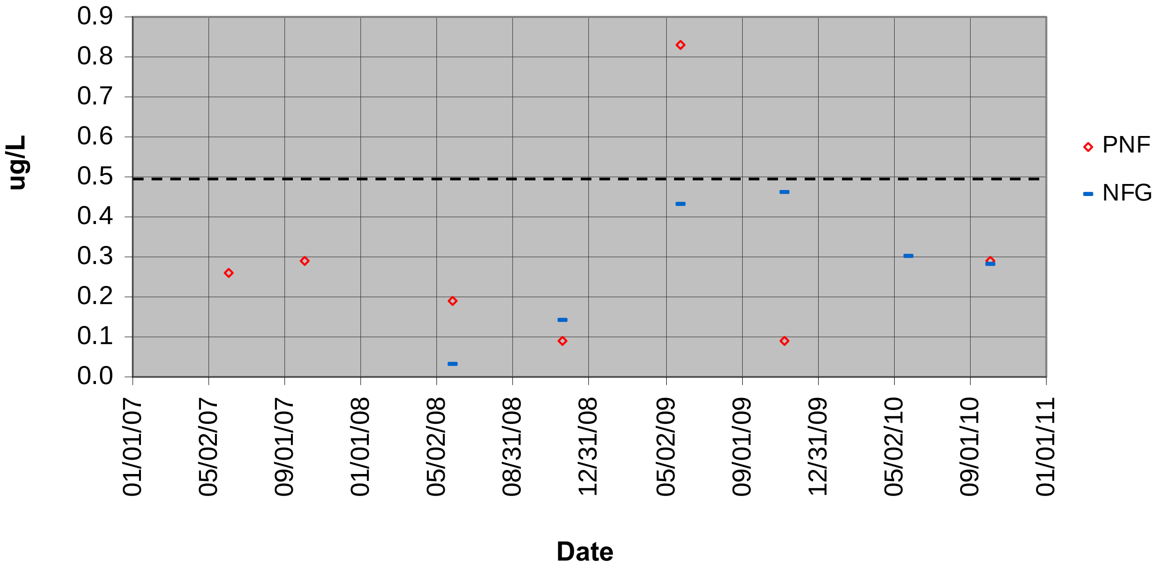
Figure 19. Dissolved cadmium (Cd) on the Mainstem and North Fork CLP



(------- FCWQL Reporting Limit: 0.1 ug/L)

(EPA Maximum Contaminant Level: 5 ug/L)

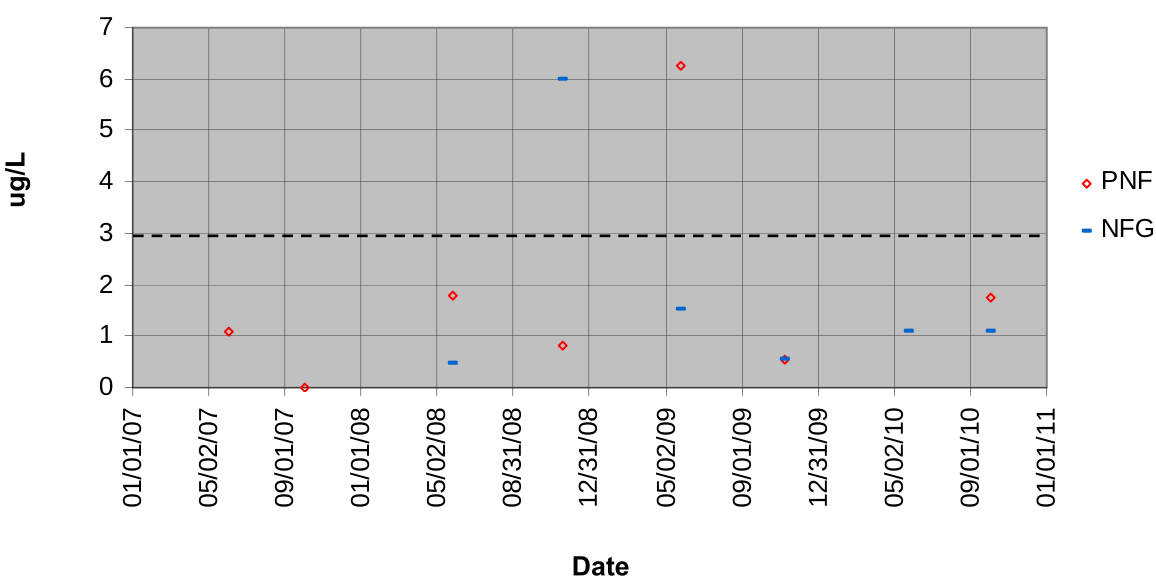
Figure 20. Dissolved chromium (Cr) on the Mainstem and North Fork CLP



(------- FCWQL Reporting Limit: 0.5 ug/L)

(EPA Maximum Contaminant Level: 100ug/L)

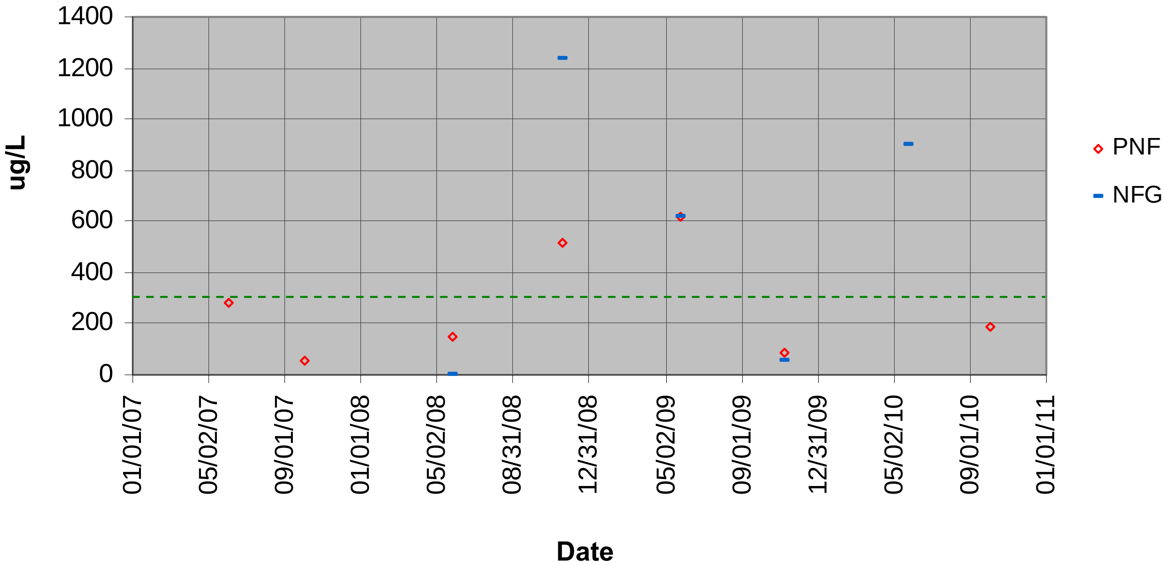
Figure 21. Dissolved copper (Cu) on the Mainstem and North Fork CLP



(------- FCWQL Reporting Limit: 3.0 ug/L)

(EPA Maximum Contaminant Level: 1,300 ug/L)

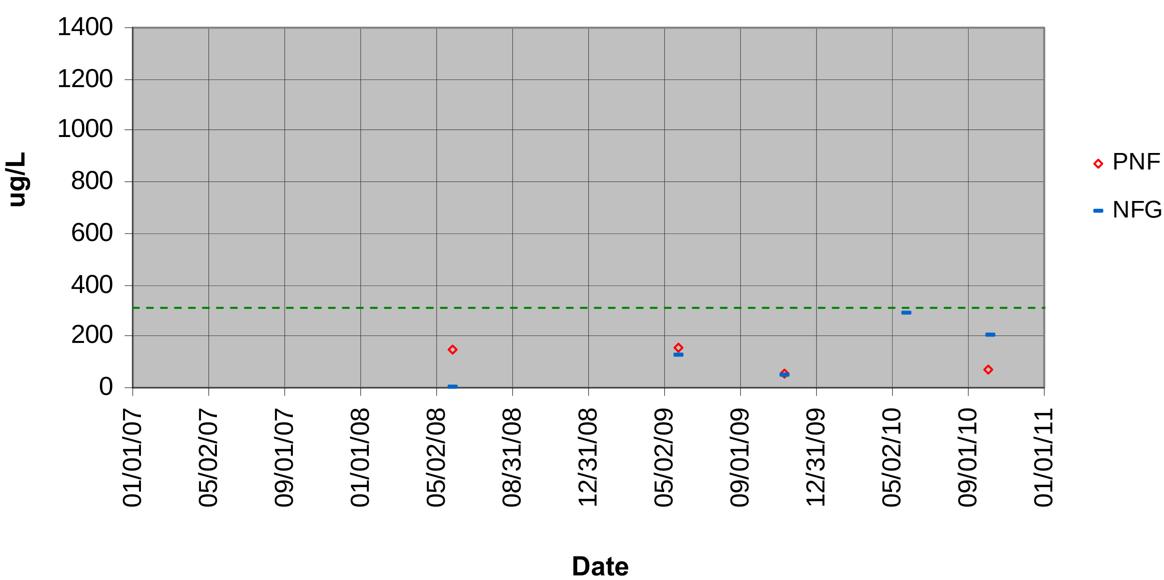
Figure 22. Total iron (Fe) on the Mainstem and North Fork CLP



(----- FCWQL Reporting Limit: 0.5 ug/L)

(----- EPA Secondary Drinking Water Standard: 300 ug/L)

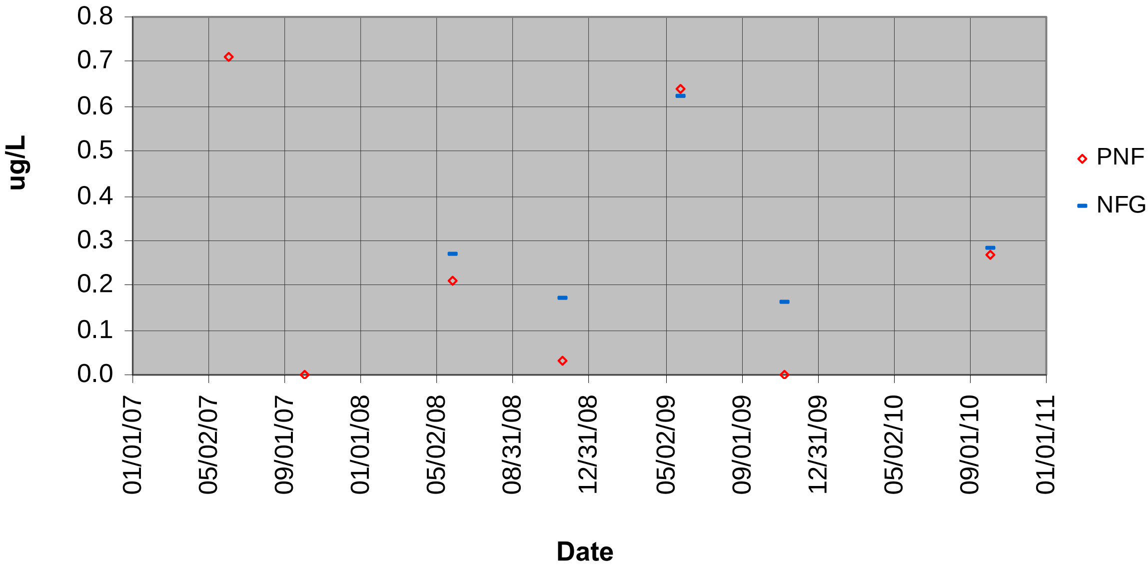
Figure 23. Dissolved iron (Fe) on the Mainstem and North Fork CLP



(----- FCWQL Reporting Limit: 0.5 ug/L)

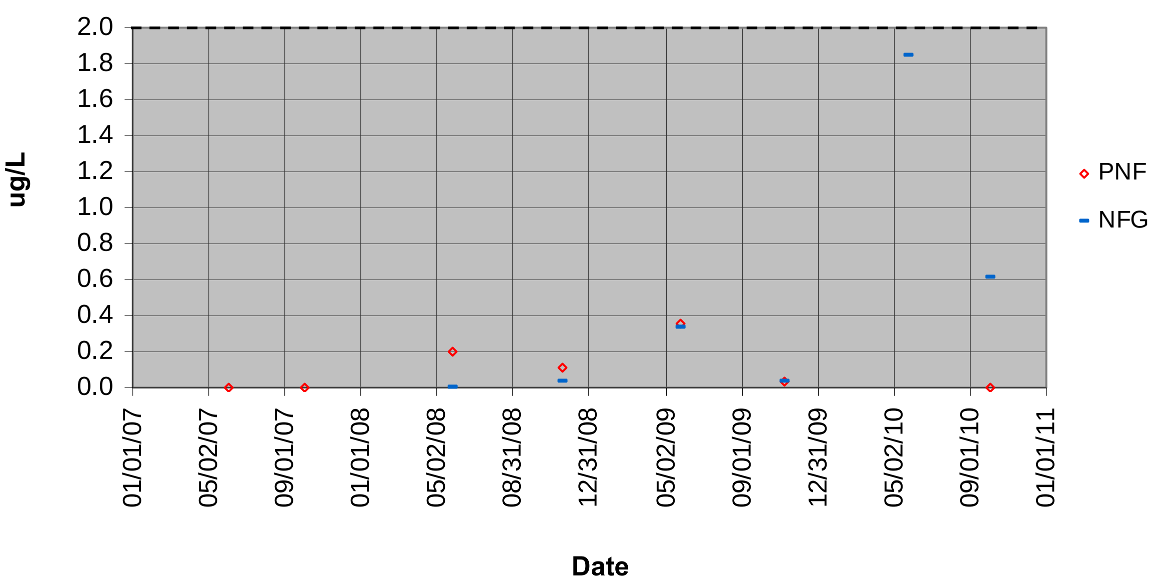
(----- EPA Secondary Drinking Water Standard: 300 ug/L)

Figure 24. Dissolved nickel (Ni) on the Mainstem and North Fork CLP



(------- FCWQL Reporting Limit: 2.0 ug/L)

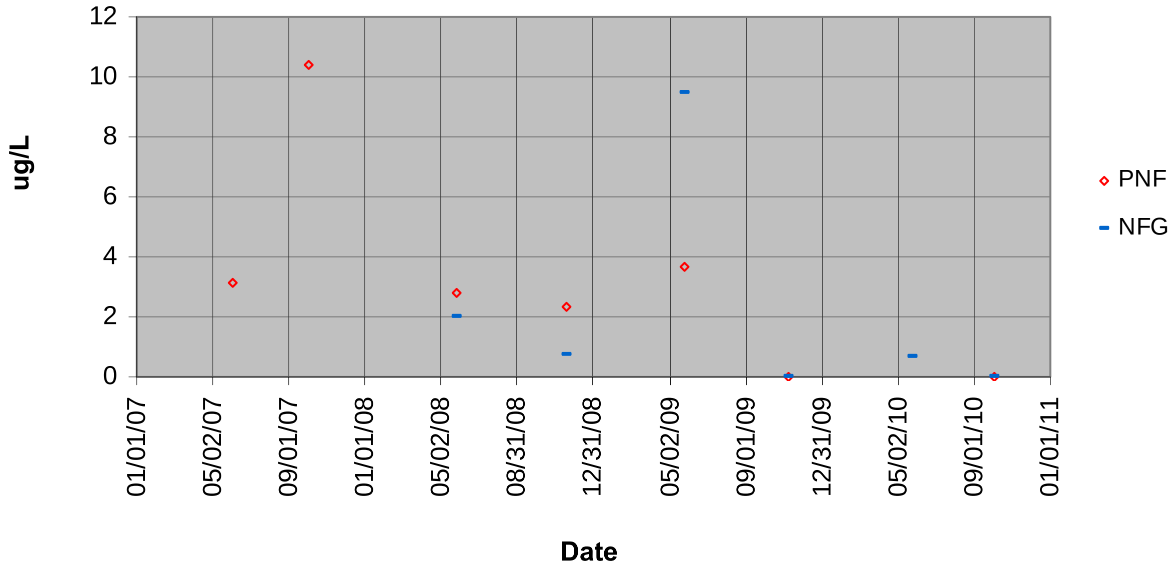
Figure 25. Dissolved lead (Pb) on the Mainstem and North Fork CLP



(------- FCWQL Reporting Limit: 2.0 ug/L)

(EPA Maximum Contaminant Level: 15 ug/L)

Figure 26. Dissolved Zinc (Zn) on the Mainstem and North Fork CLP



(------- FCWQL Reporting Limit: 50 ug/L)

(EPA Secondary Drinking Water Standard: 5,000 ug/L)

Mainstem and North Fork CLP:
Major Ions

Figure 27 (a & b). Calcium (Ca)

Figure 27.a. Calcium (Ca) on the Mainstem CLP

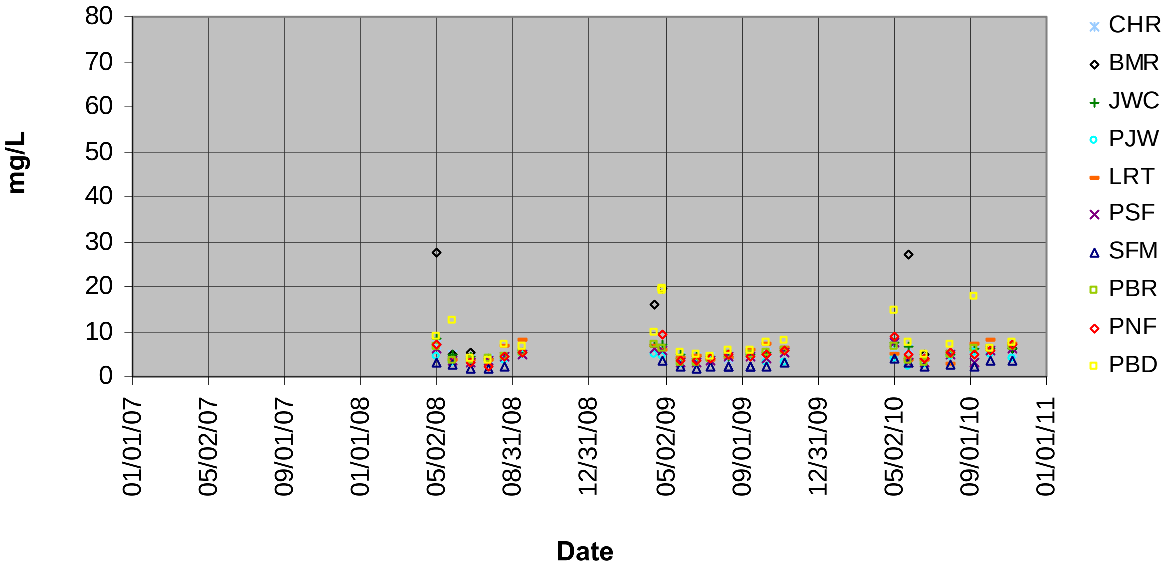


Figure 27.b. Calcium (Ca) on the North Fork CLP

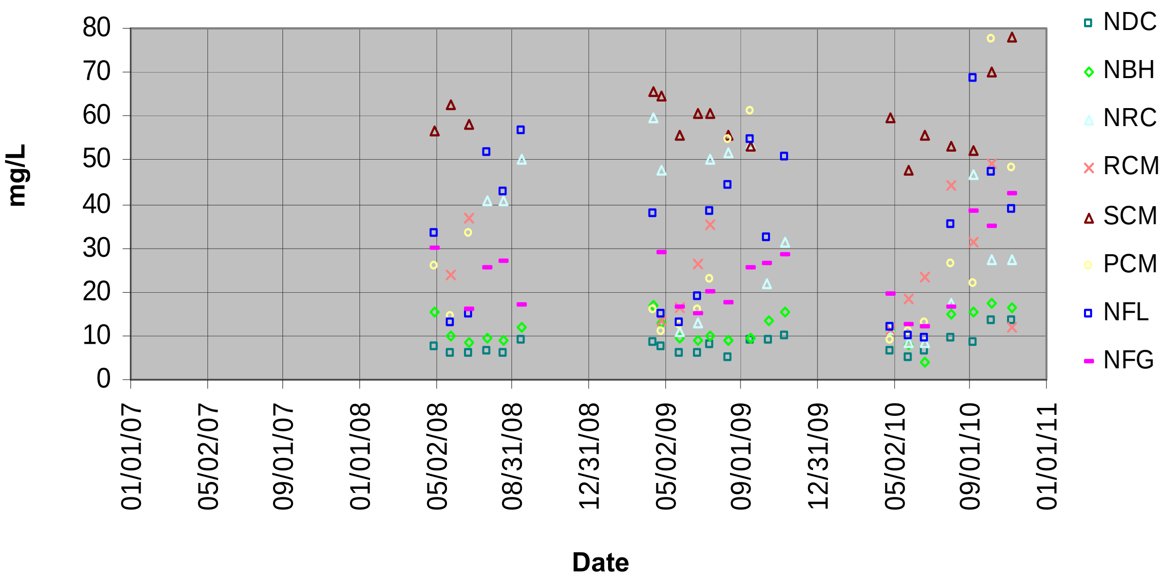


Figure 28 (a & b). Magnesium (Mg)

Figure 28.a. Magnesium (Mg) on the Mainstem CLP

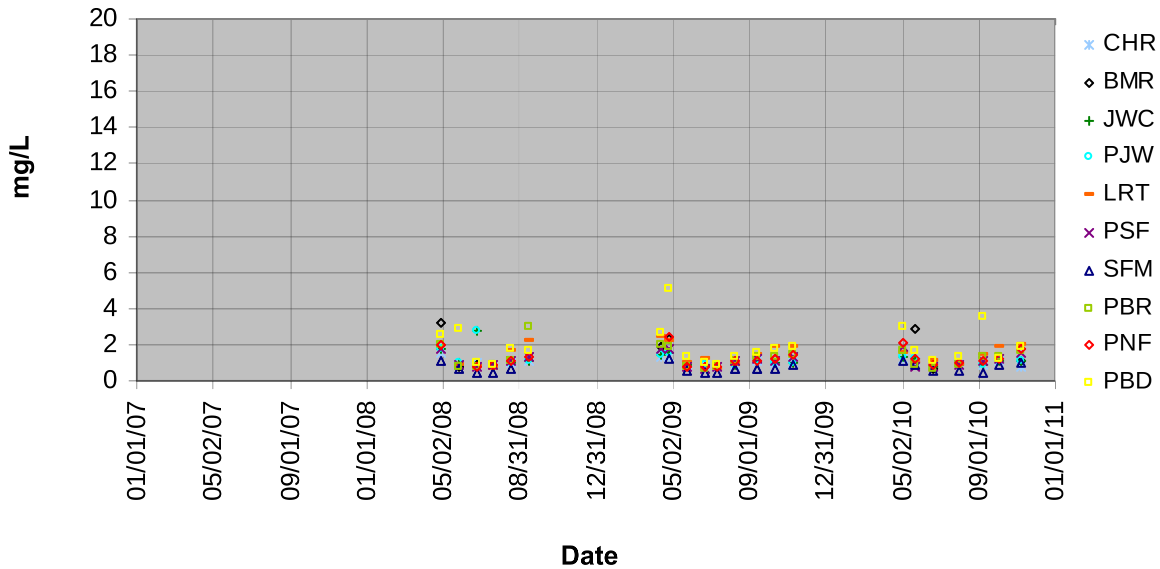


Figure 28.b. Magnesium (Mg) on the North Fork CLP

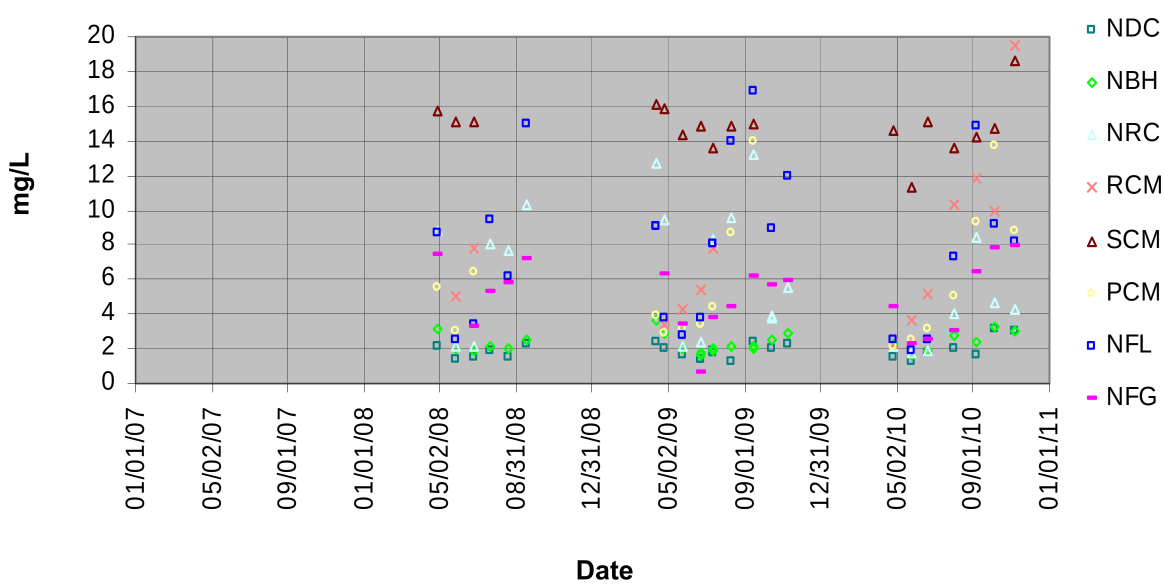


Figure 29 (a & b). Potassium (K)

Figure 29.a. Potassium (K) on the Mainstem CLP

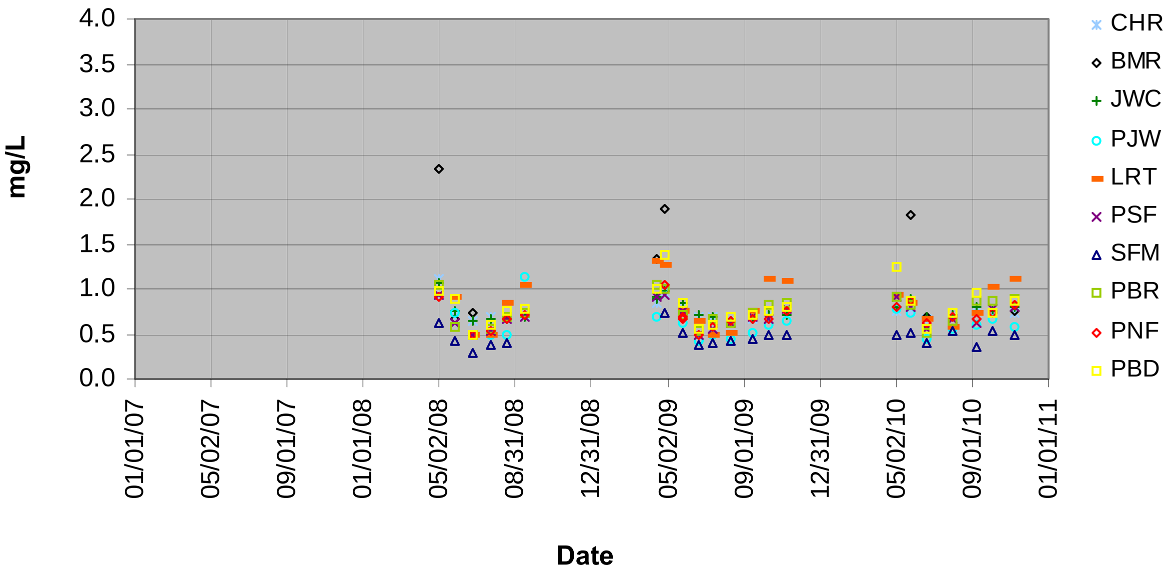


Figure 29.b. Potassium (K) on the North Fork CLP

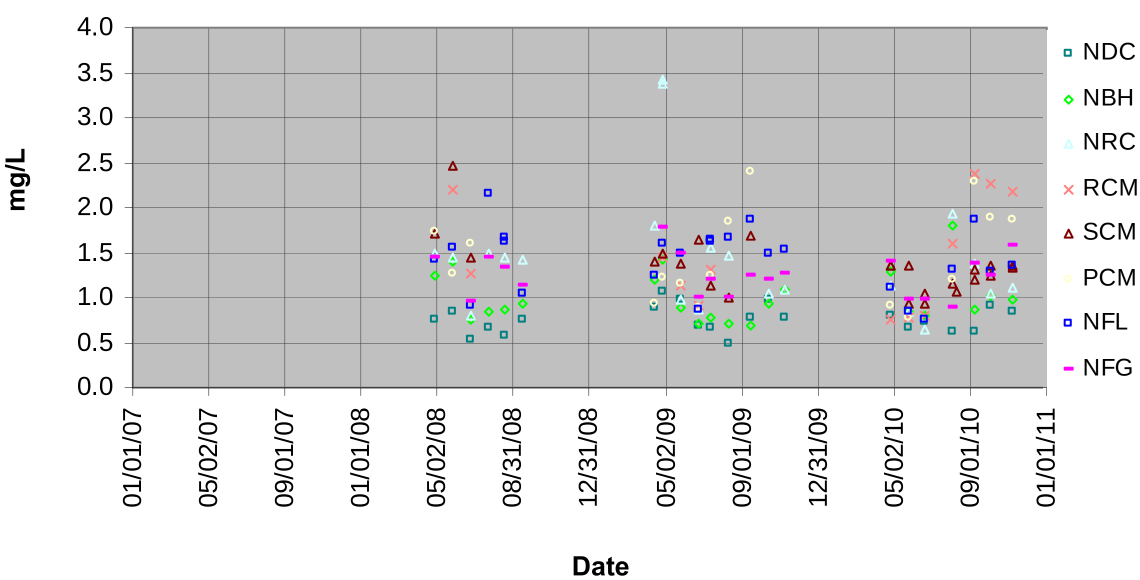


Figure 30 (a & b). Sodium (Na)

Figure 30.a. Sodium (Na) on the Mainstem CLP

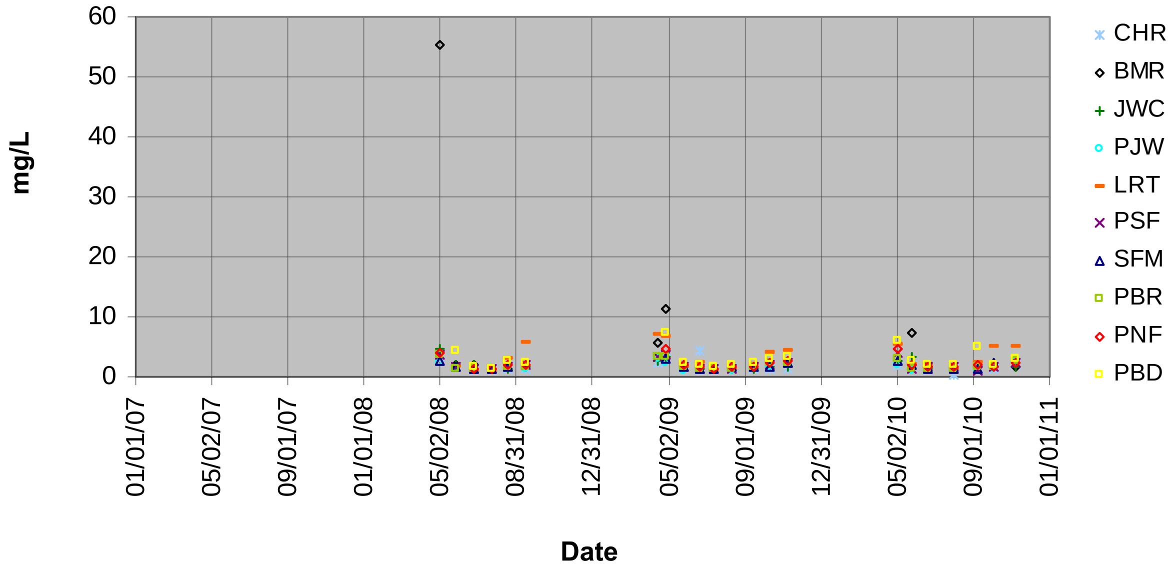


Figure 30.b. Sodium (Na) on the North Fork CLP

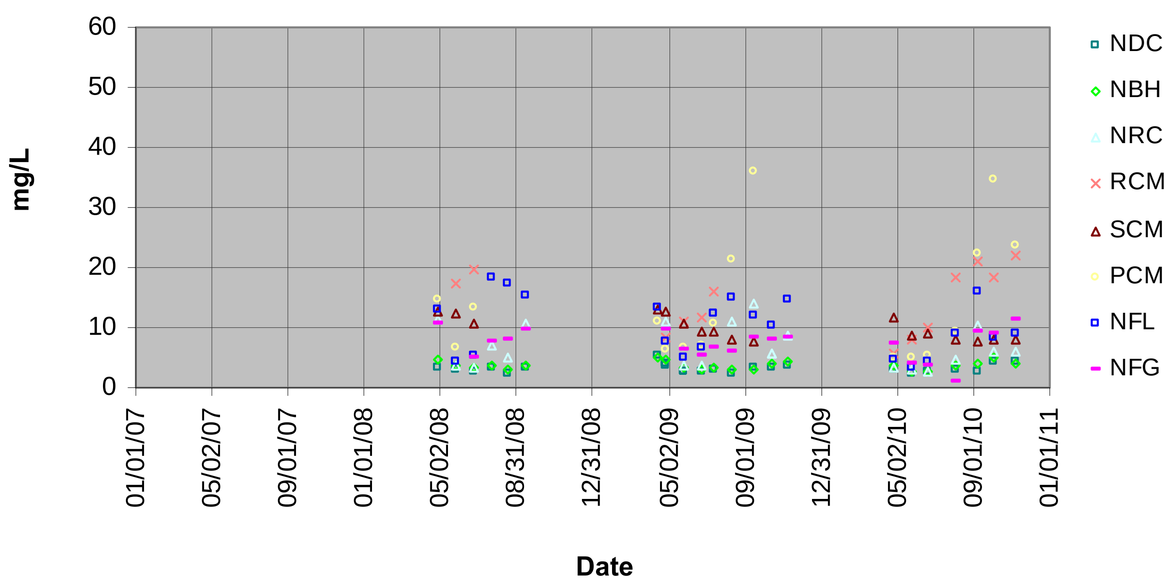


Figure 31 (a & b). Chloride (Cl)

Figure 31.a. Chloride (Cl) on the Mainstem CLP

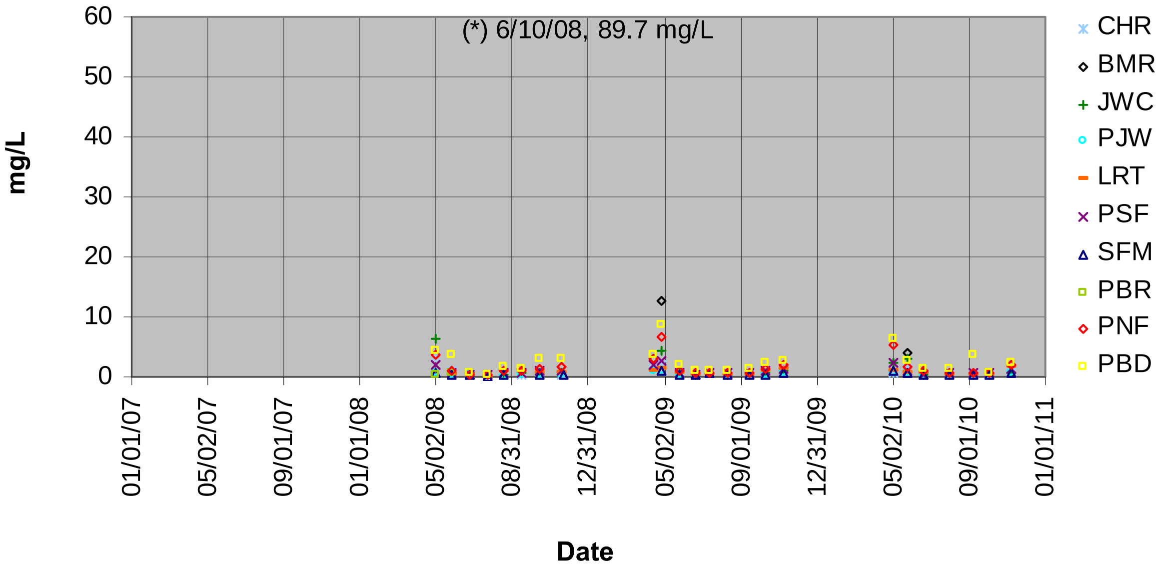


Figure 31.b. Chloride (Cl) on the North Fork CLP

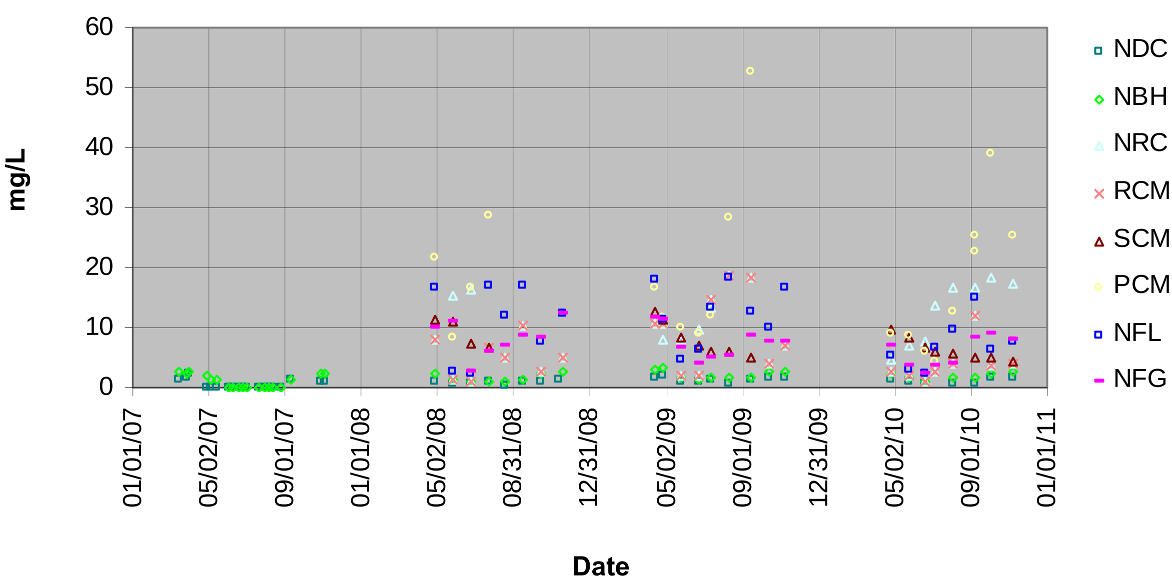
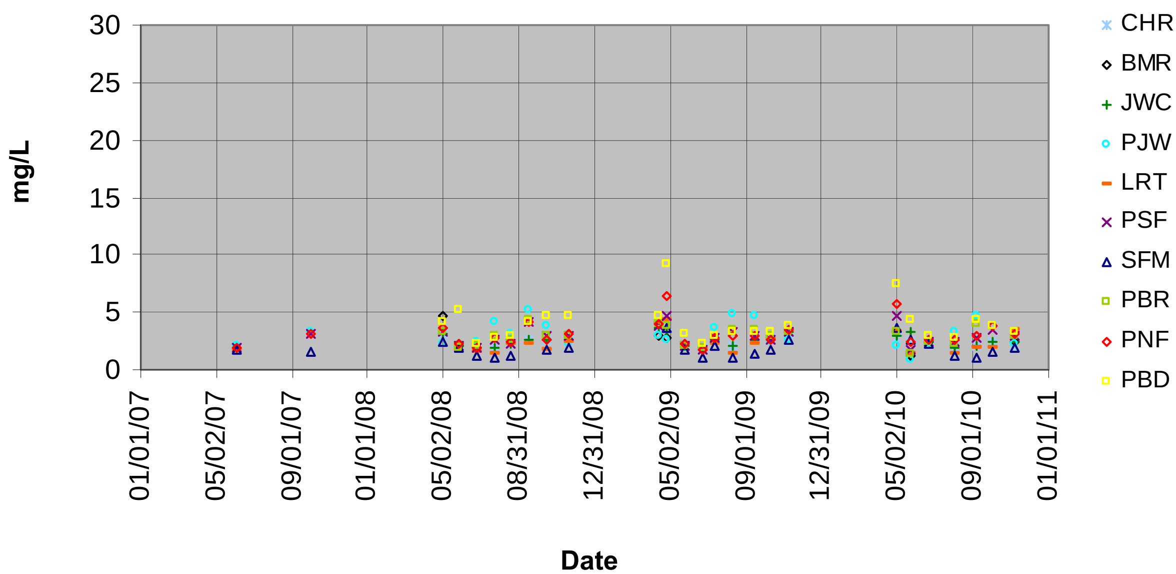


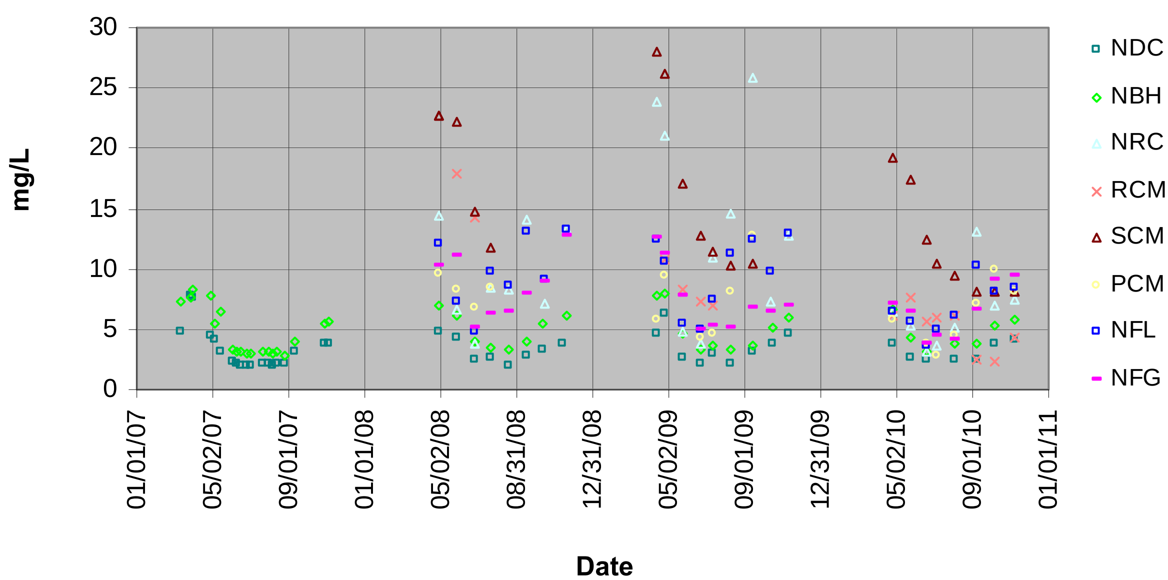
Figure 32 (a & b). Sulfate (SO_4)

Figure 32.a. Sulfate (SO_4) on the Mainstem CLP



(EPA Secondary Drinking Water Standard: 250 ug/L)

Figure 32.b. Sulfate (SO_4) on the North Fork CLP



(EPA Secondary Drinking Water Standard: 250 ug/L)

Mainstem and North Fork CLP: Microbiological Constituents

Figure 33. Total coliforms on the Mainstem and North Fork CLP

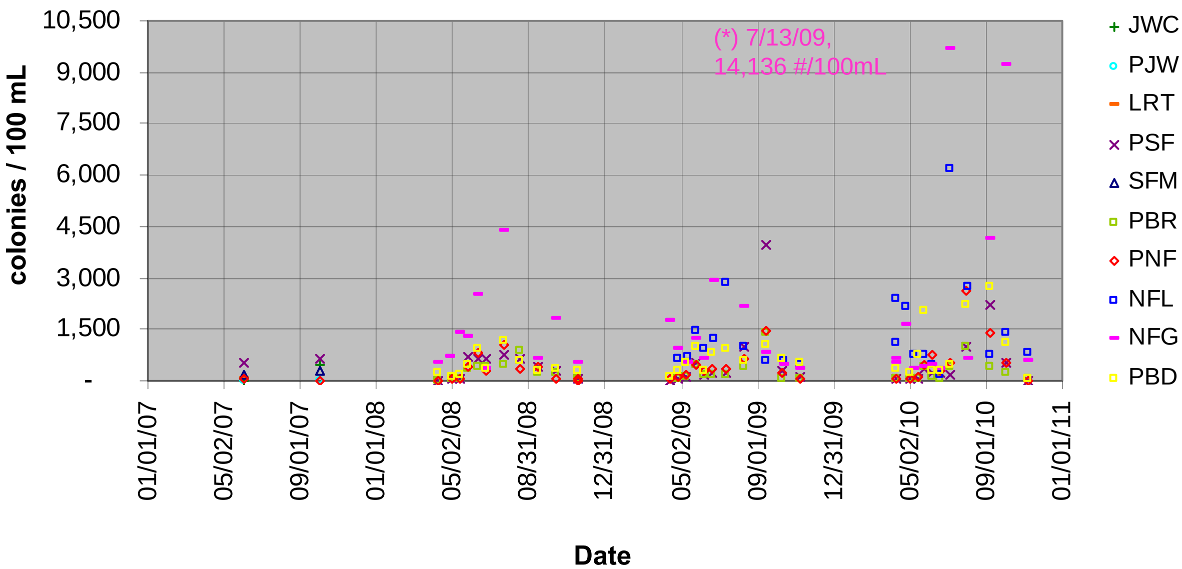
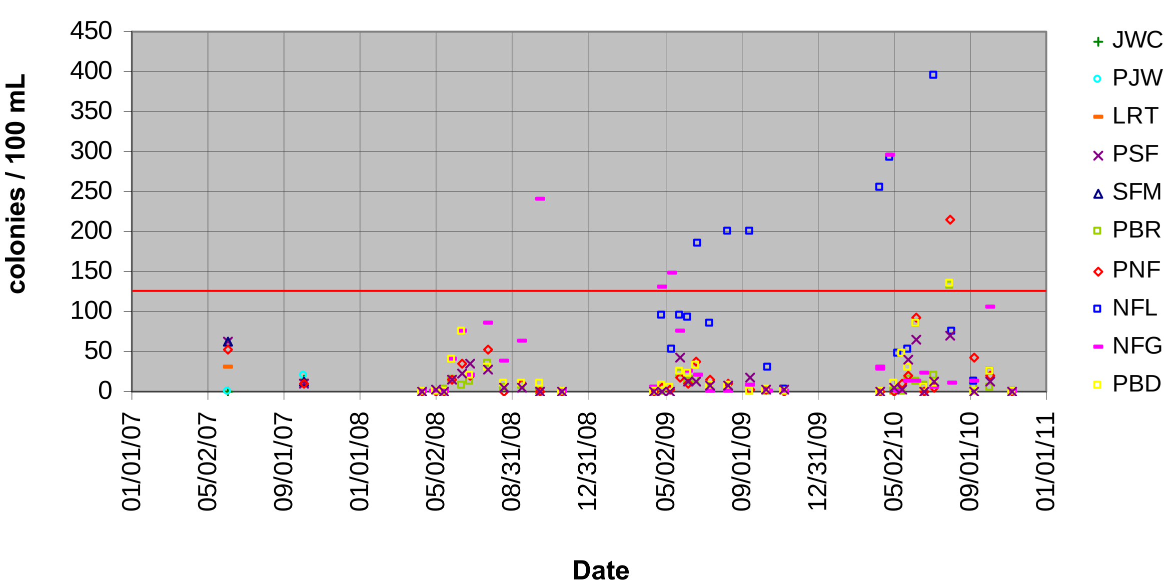


Figure 34. *E.coli* on the Mainstem and North Fork CLP



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

Figure 35. *Giardia* on the Mainstem and North Fork CLP

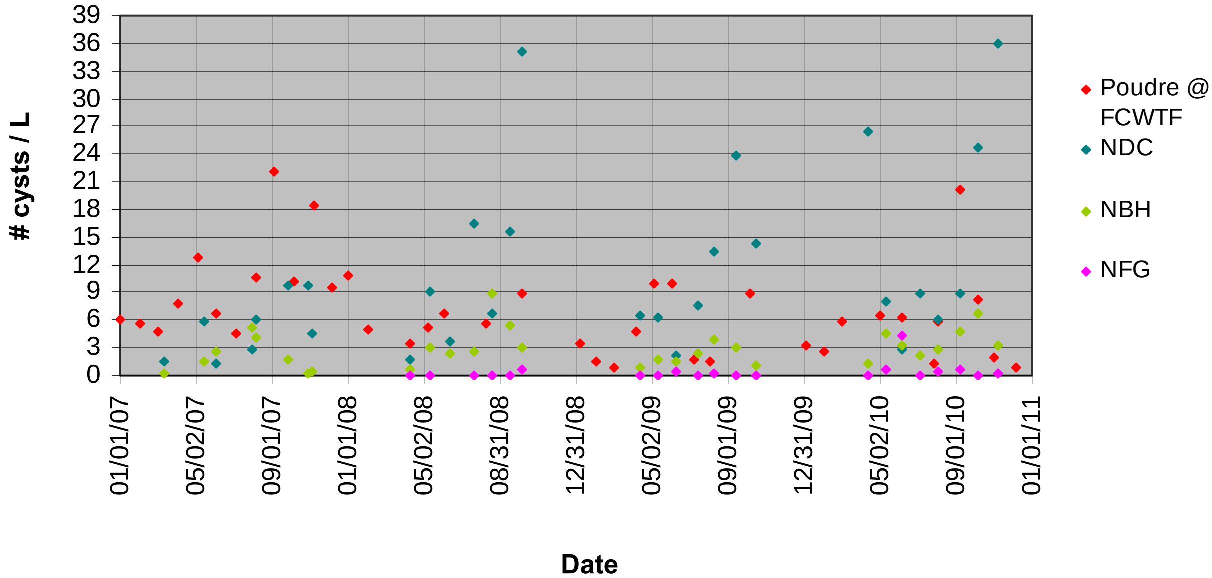
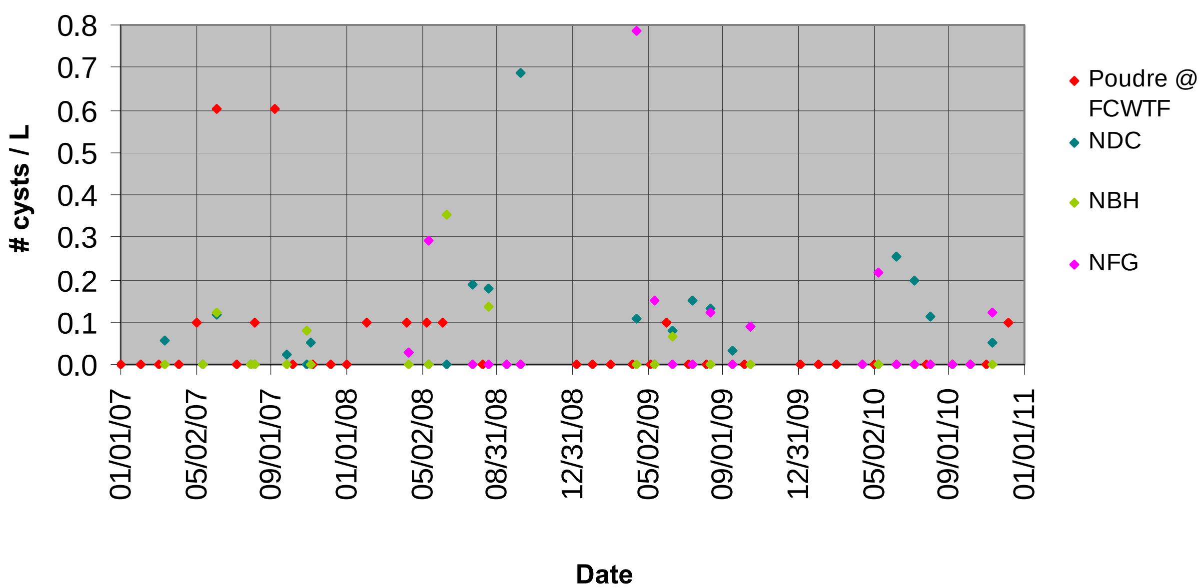
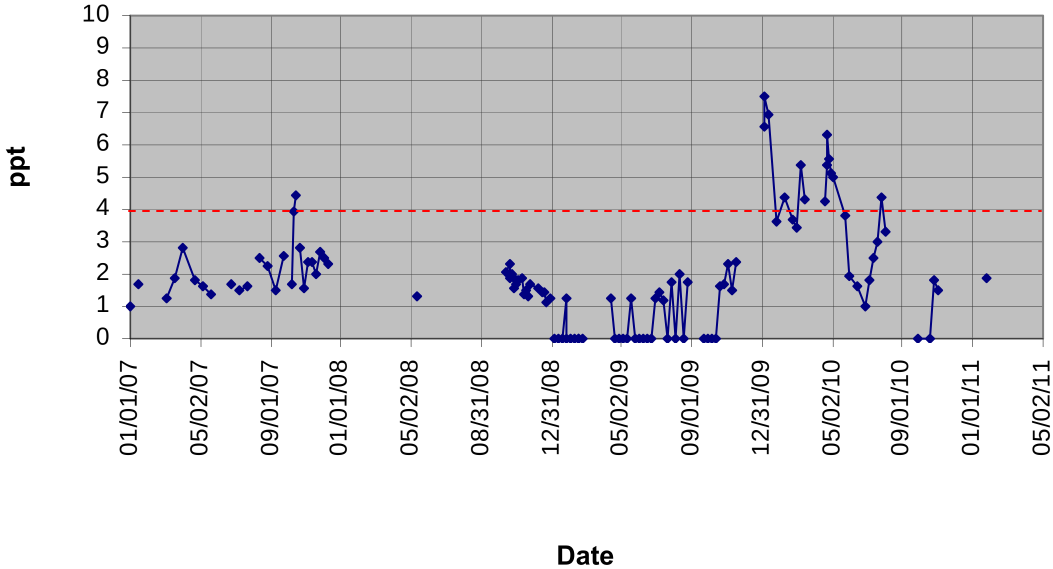


Figure 36. *Cryptosporidium* on the Mainstem and North Fork CLP



Mainstem and North Fork CLP:
Geosmin

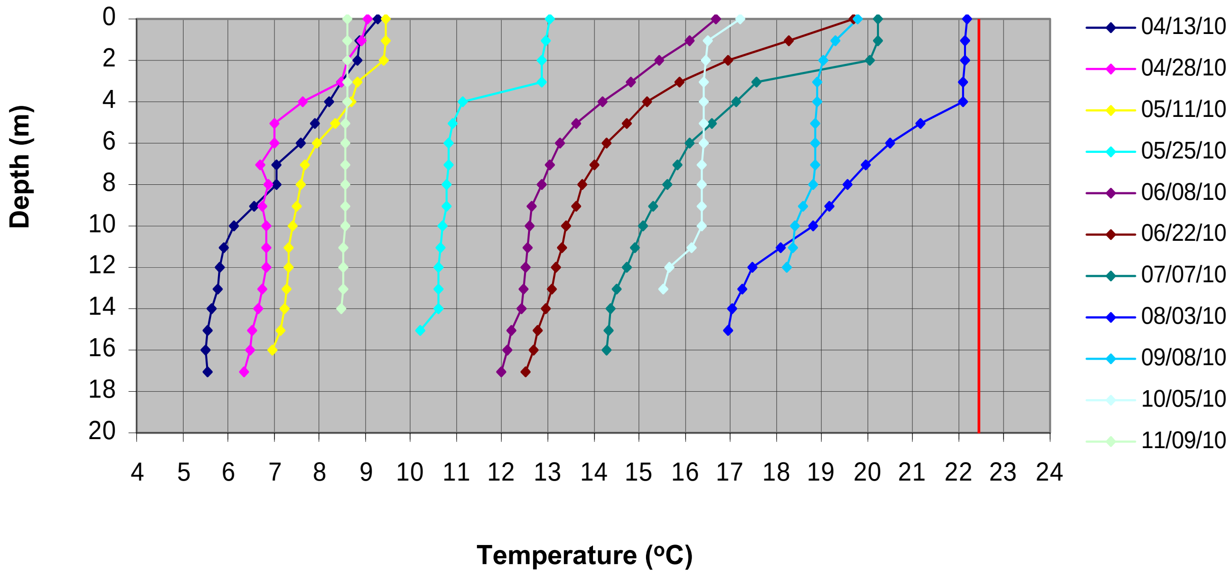
Figure 37. Geosmin on the Mainstem CLP collected at the FCWTF



(----- Odor threshold for geosmin: 4 ppt)

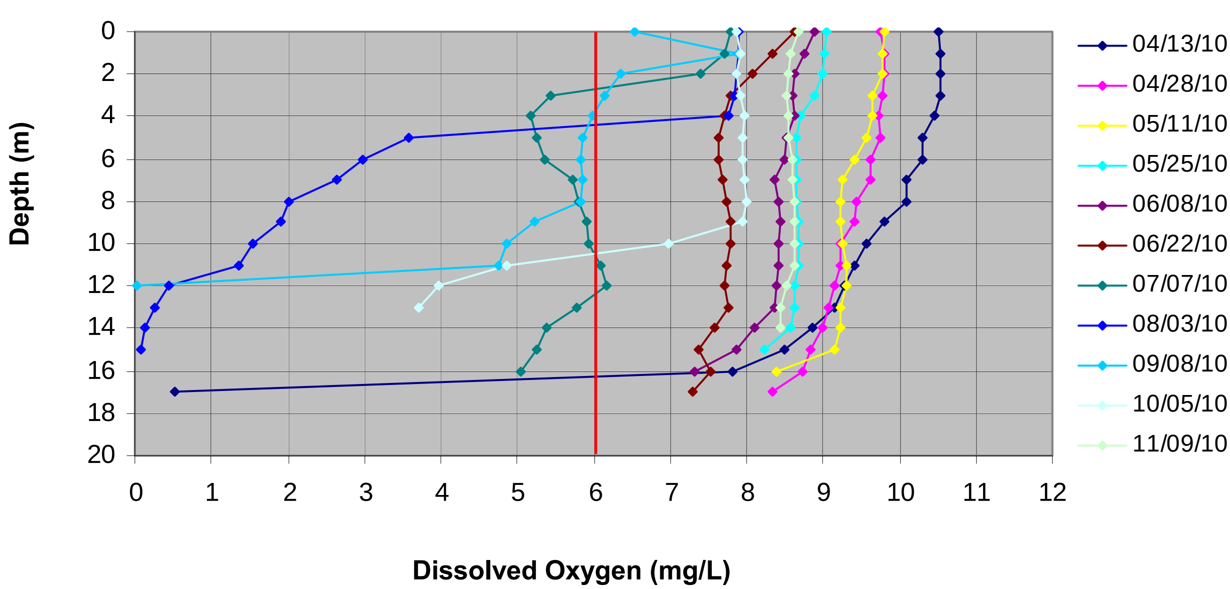
Seaman Reservoir:
Depth Profiles
(Temperature, D.O., pH & Conductance)

Figure 38. 2010 Seaman Reservoir temperature profiles



(—— Water quality standard for cold water aquatic life: 22.5ºC)

Figure 39. 2010 Seaman Reservoir dissolved oxygen (D.O.) profiles



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

Figure 40. 2010 Seaman Reservoir pH profiles

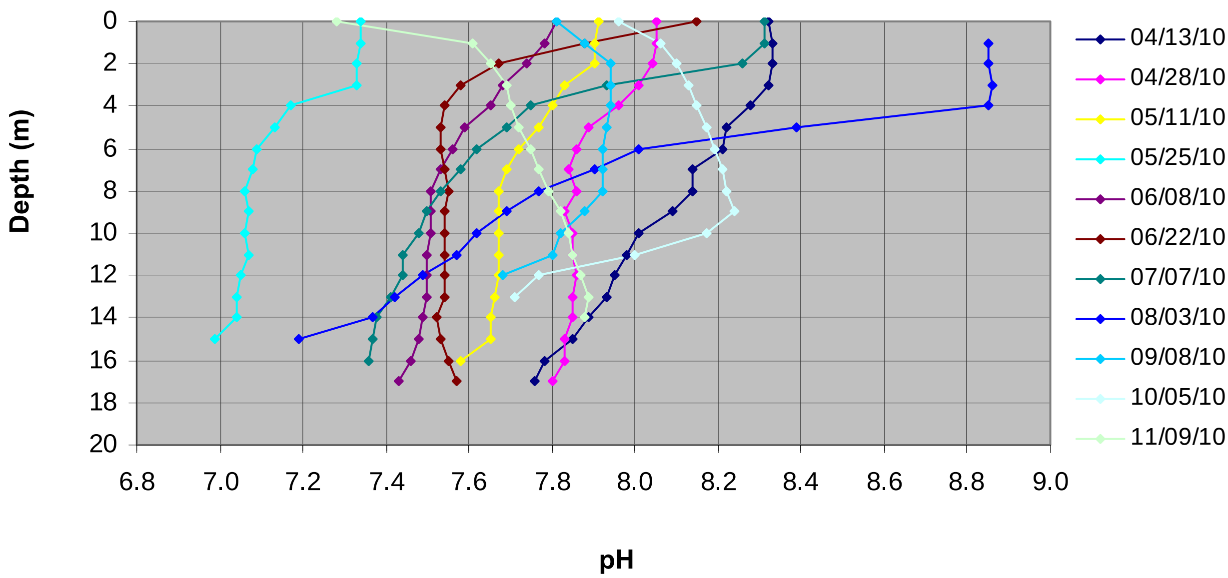
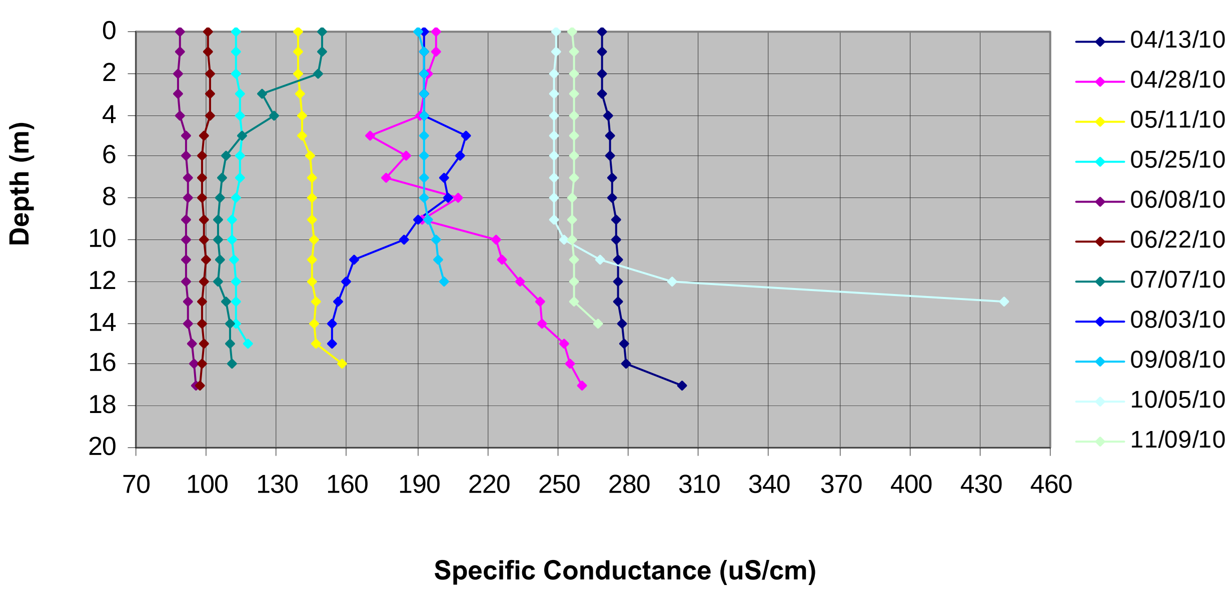


Figure 41. 2010 Seaman Reservoir specific conductance profiles



Seaman Reservoir:
General Parameters

Figure 42. Alkalinity concentrations in Seaman Reservoir

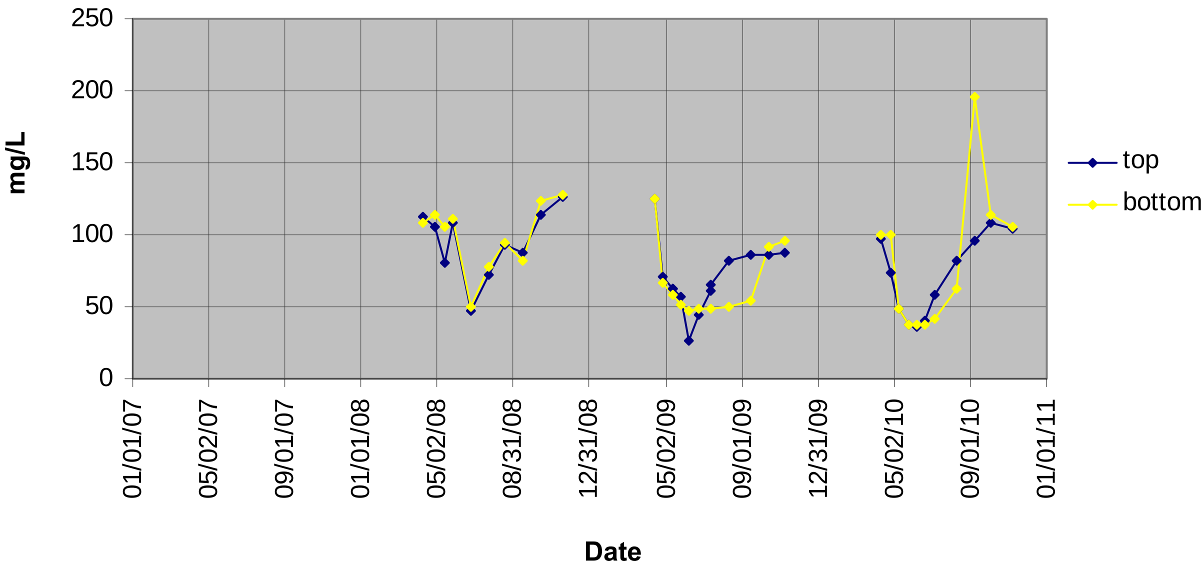


Figure 43. Hardness concentrations in Seaman Reservoir

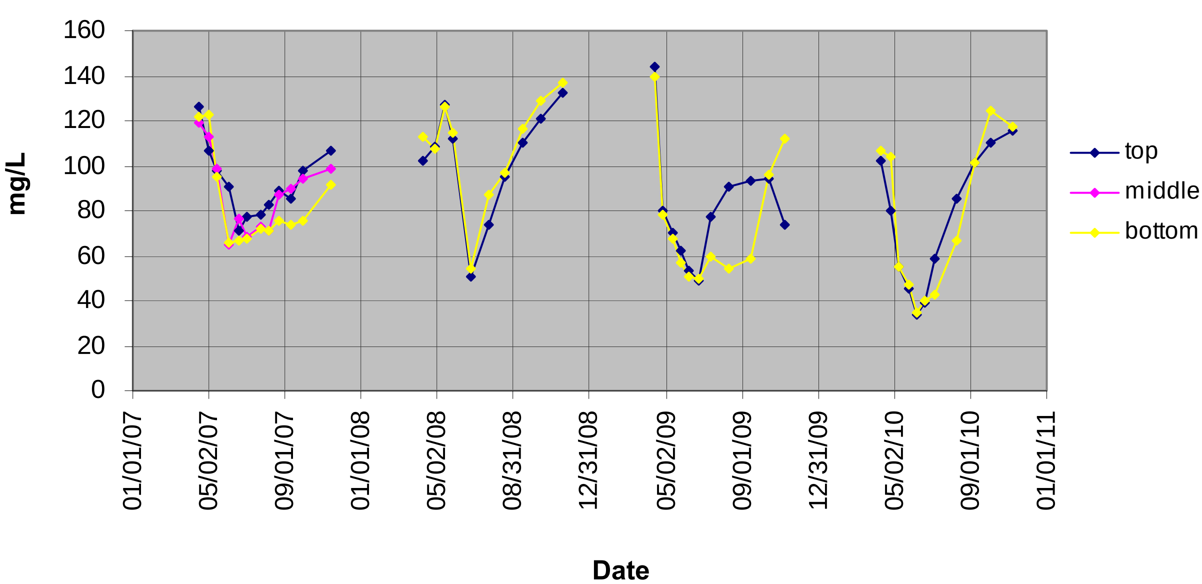


Figure 44. Turbidity in Seaman Reservoir

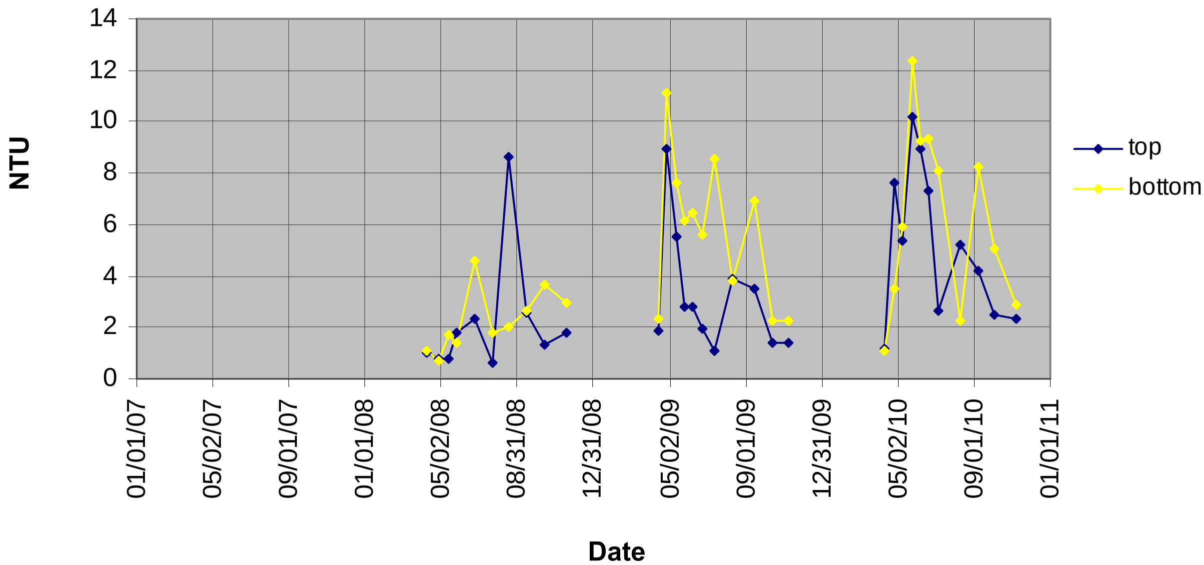
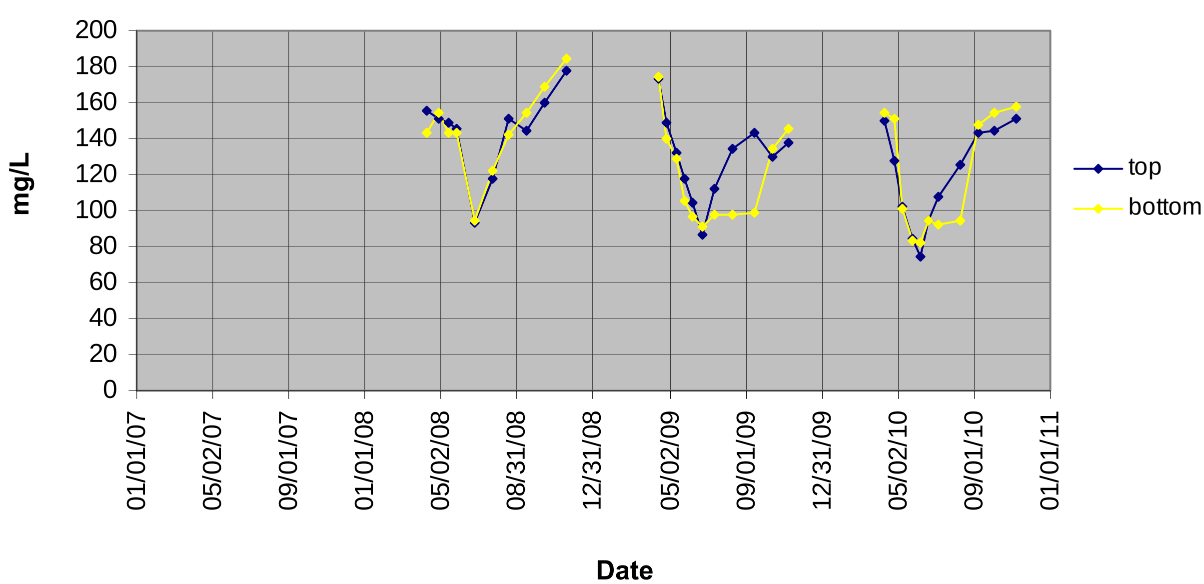
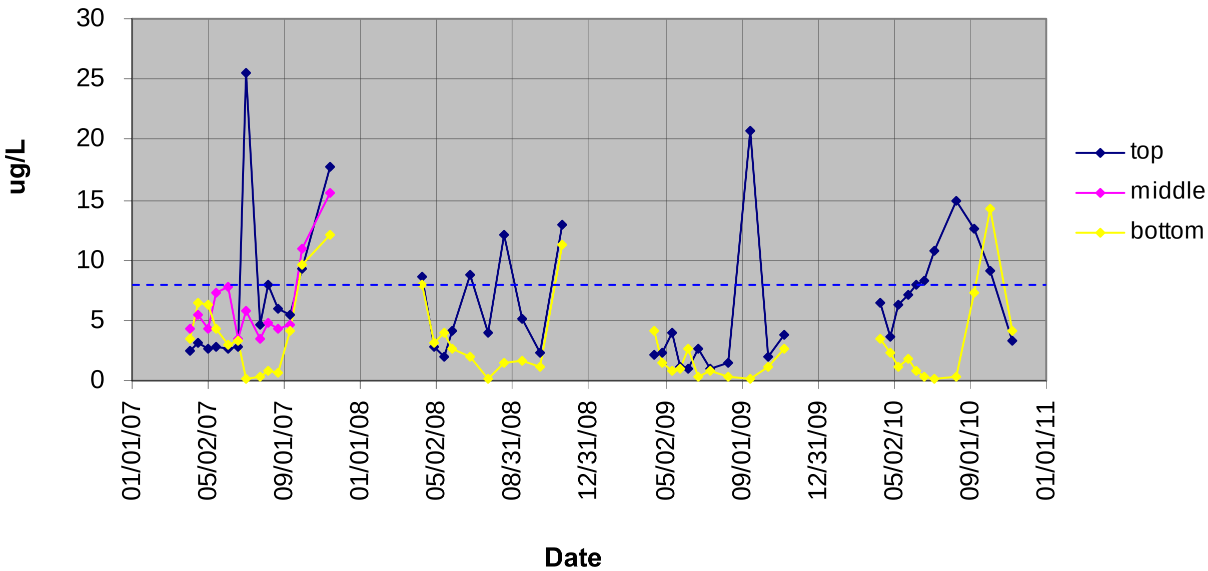


Figure 45. Total dissolved solids (TDS) in Seaman Reservoir



(EPA Secondary Drinking Water Standard: 500 ug/L)

Figure 46. Chlorophyll-a concentrations in Seaman Reservoir



(------- 2010 CDPHE/WQCD proposed cold water reservoir standard for chlorophyll-a: summer average of 8 ug/L in the mixed (top) layer)

Figure 47. Total organic carbon (TOC) in Seaman Reservoir

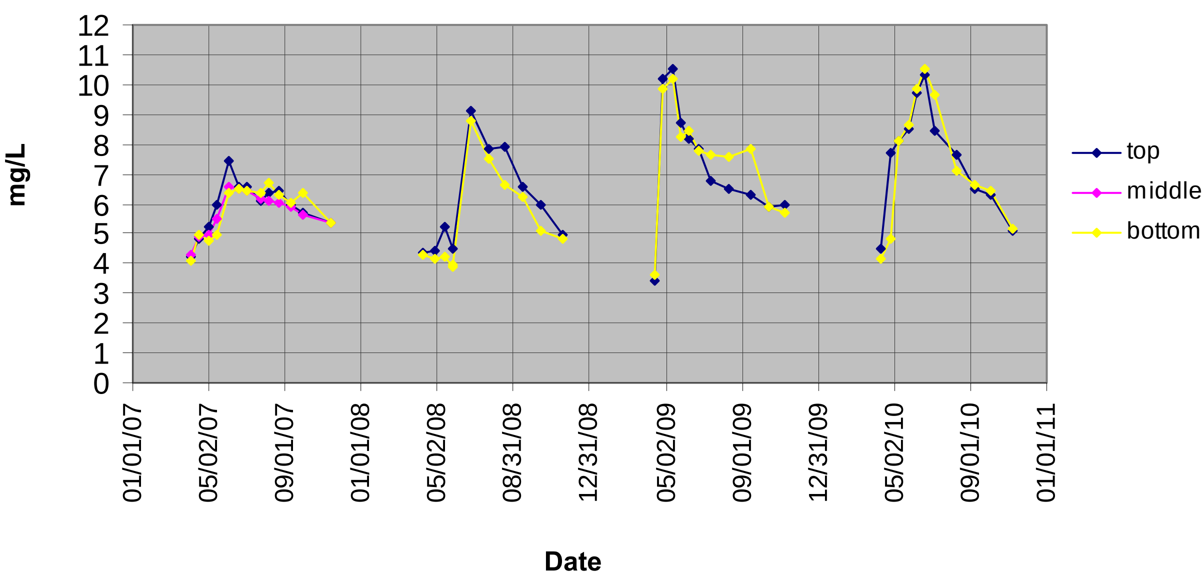
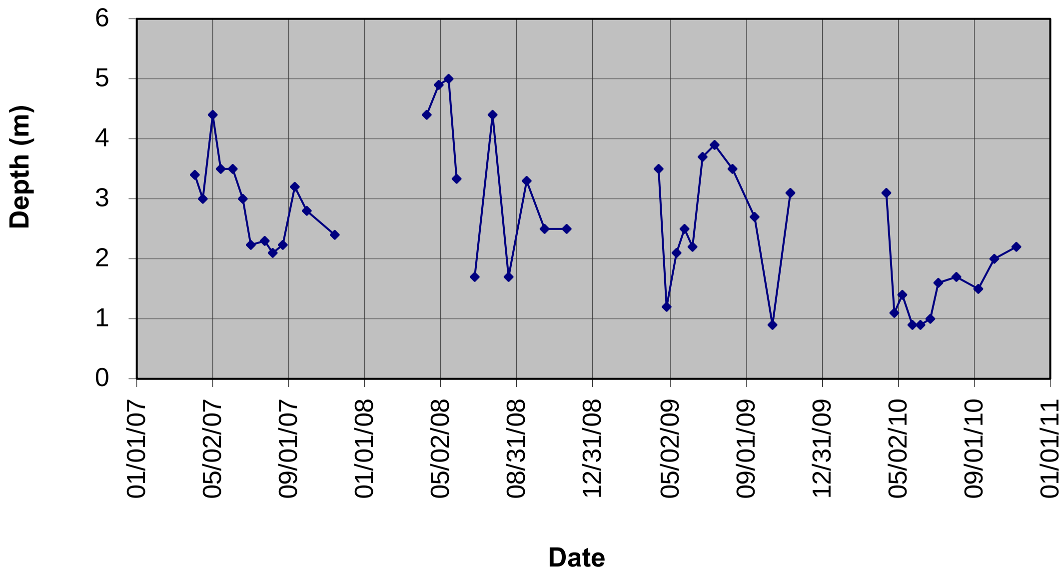
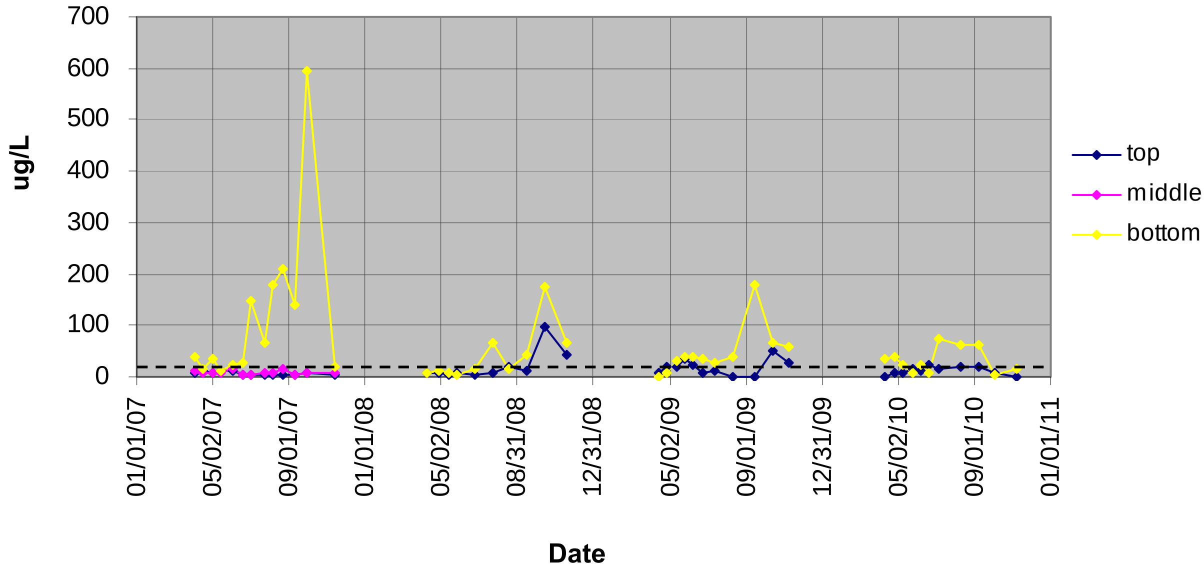


Figure 48. Secchi disk depth in Seaman Reservoir



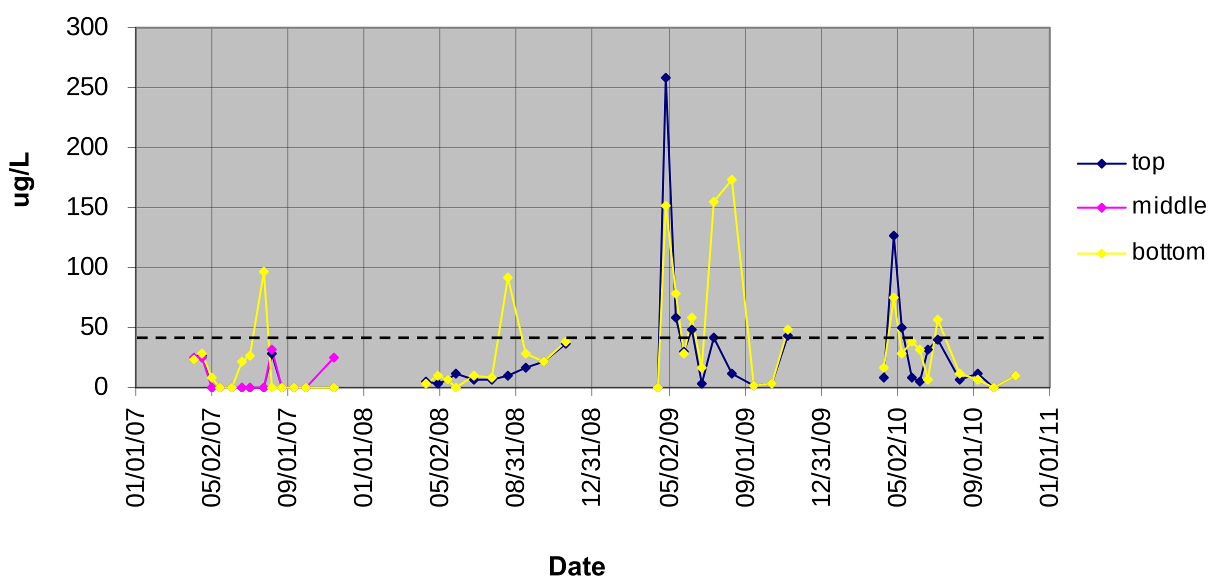
Seaman Reservoir:
Nutrients

Figure 49. Ammonia (NH3) concentrations in Seaman Reservoir



(----- FCWQL Reporting Limit: 10 ug/L)

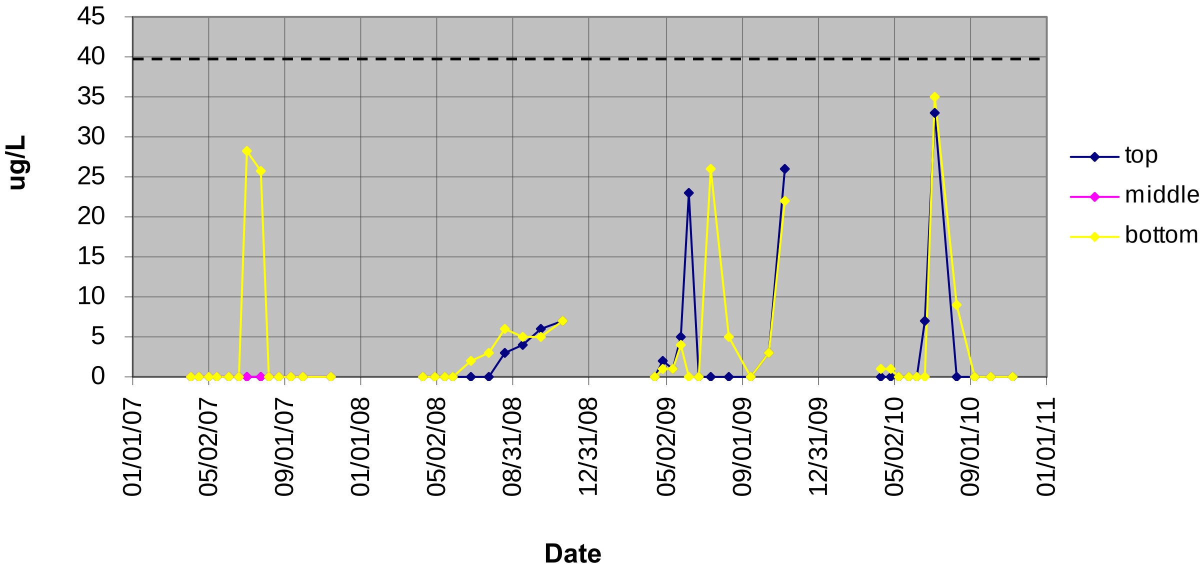
Figure 50. Nitrate (NO_3) concentrations in Seaman Reservoir



(----- FCWQL Reporting Limit: 40 ug/L)

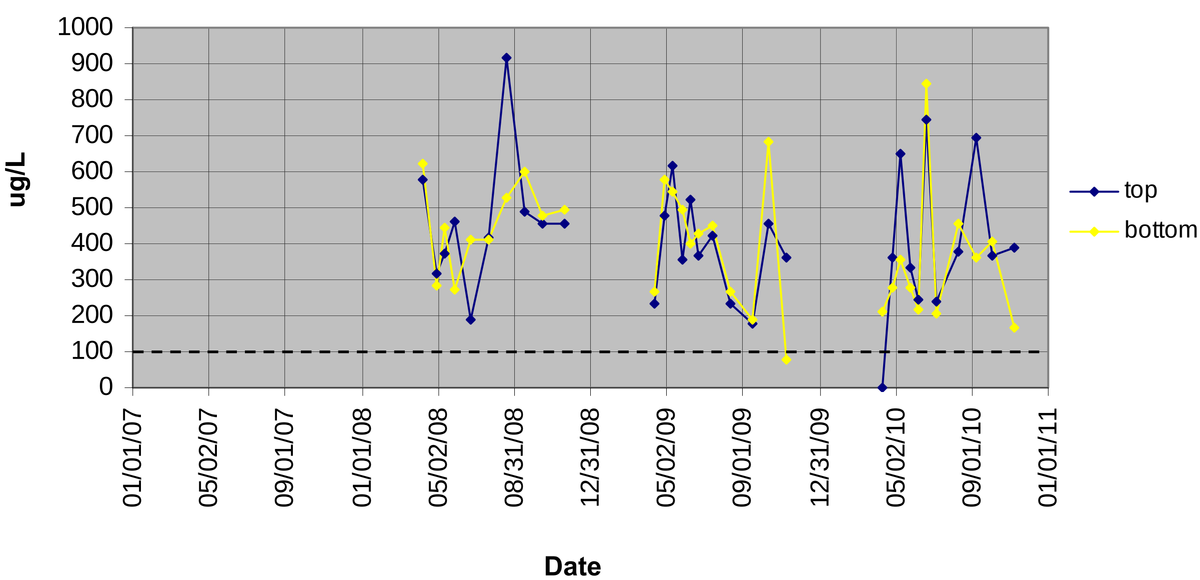
(EPA Maximum Contaminant Level: 10,000 ug/L)

Figure 51. Nitrite (NO_2) concentrations in Seaman Reservoir



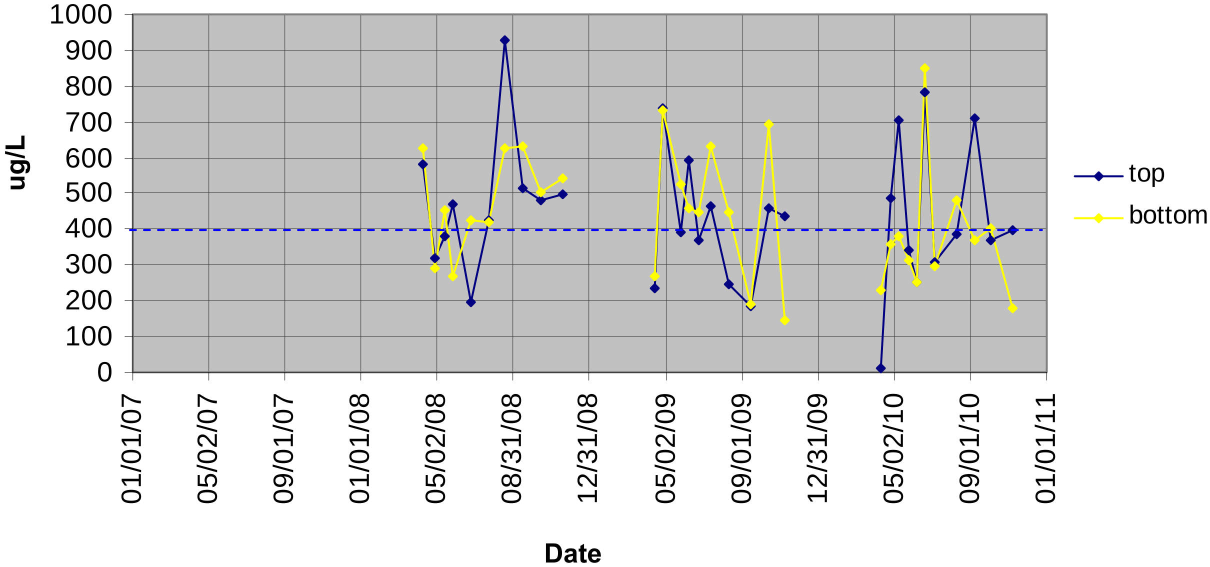
(----- FCWQL Reporting Limit: 40 ug/L)

Figure 52. Total Kjeldahl Nitrogen (TKN) concentrations in Seaman Reservoir



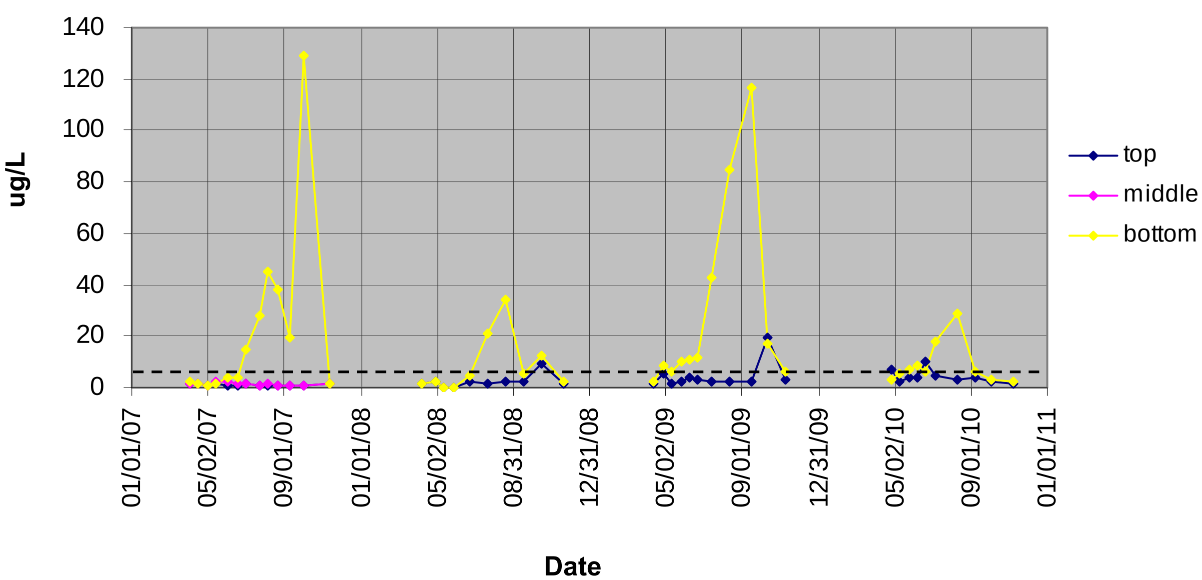
(----- FCWQL Reporting Limit: 100 ug/L)

Figure 53. Total Nitrogen (TKN+NO_3+ NO_2) concentrations in Seaman Reservoir



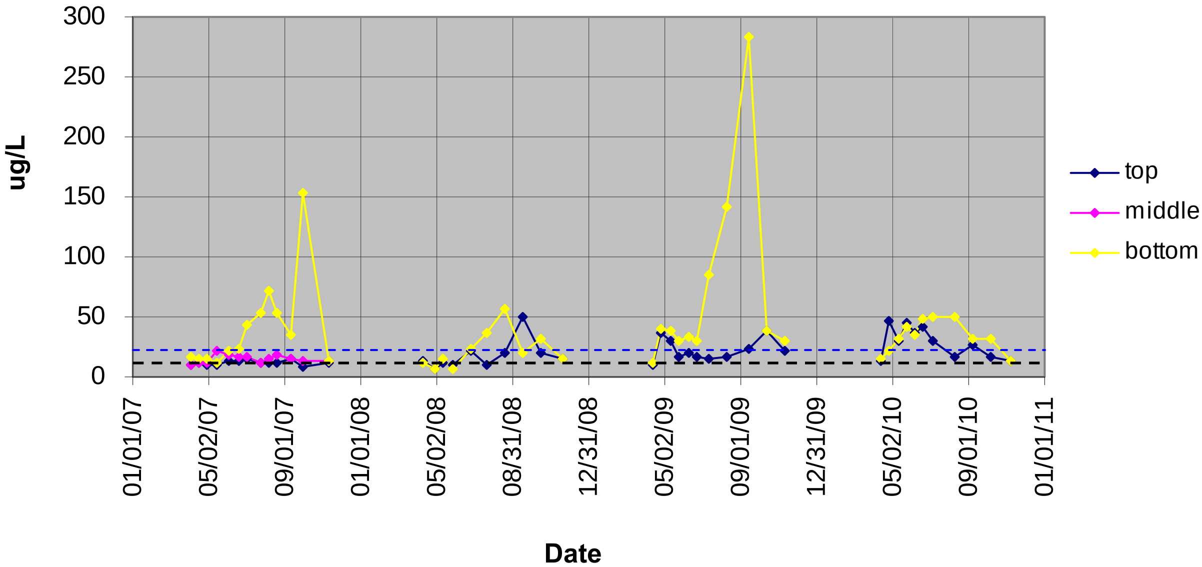
(------- 2010 CDPHE/WQCD proposed cold water reservoir standard for Total N: summer average of 410 ug/L in the mixed (top) layer)

Figure 54. Ortho-phosphate (PO_4) concentrations in Seaman Reservoir



(----- FCWQL Reporting Limit: 5 ug/L)

Figure 55. Total phosphorus (P) concentrations in Seaman Reservoir



(----- FCWQL Reporting Limit: 10 ug/L)

(------- 2010 CDPHE/WQCD proposed cold water reservoir standard for Total P: summer average of 20 ug/L in the mixed (top) layer)

Seaman Reservoir:
Major Ions

Figure 56. Calcium (Ca) concentrations in Seaman Reservoir

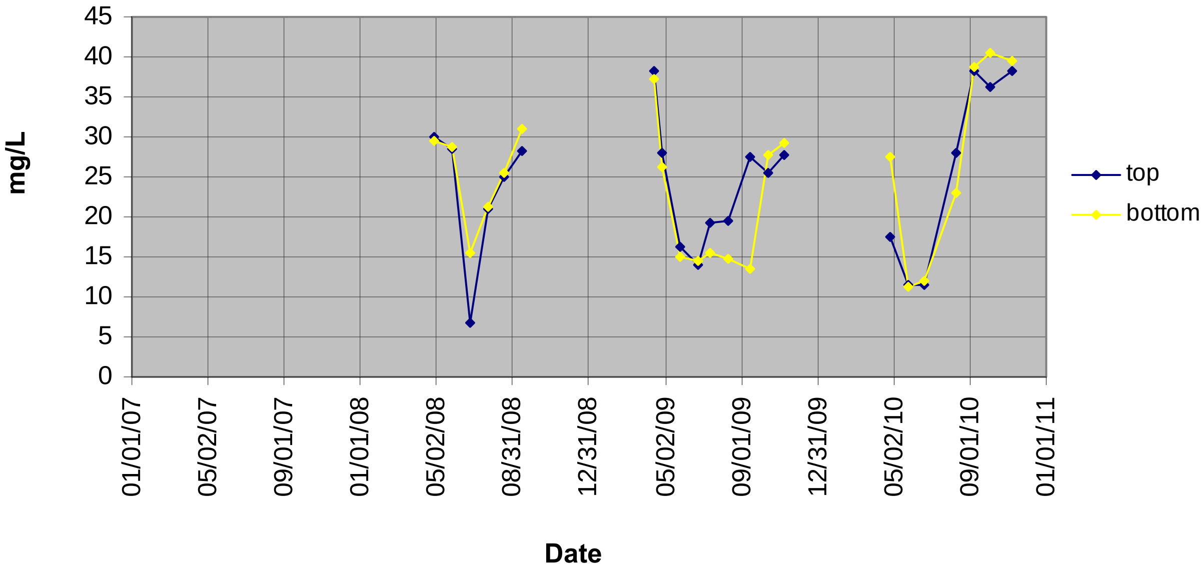


Figure 57. Magnesium (Mg) concentrations in Seaman Reservoir

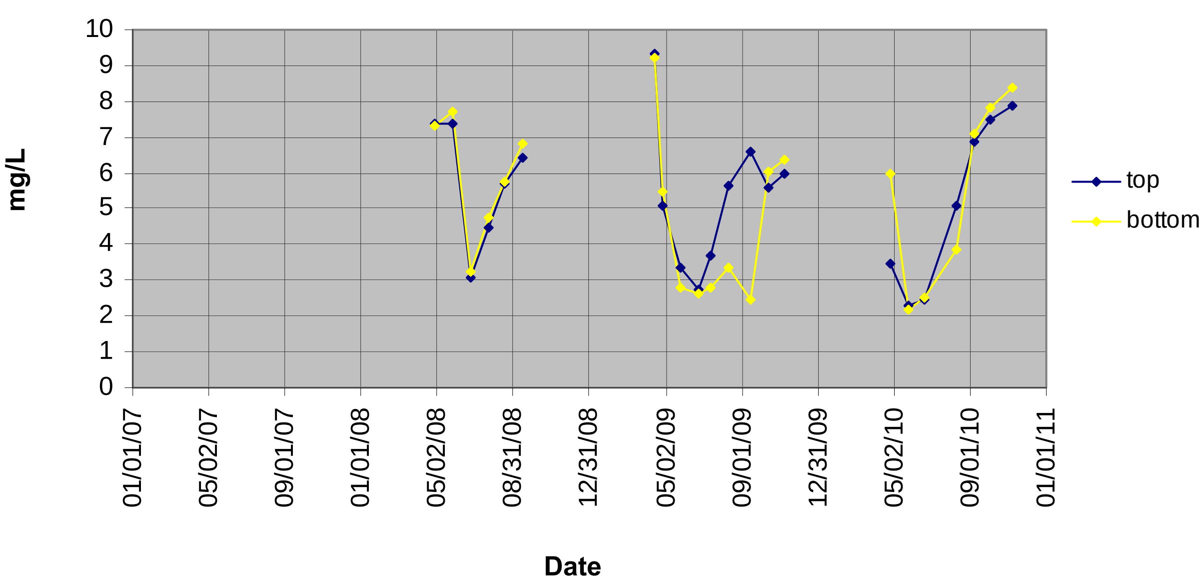


Figure 58. Potassium (K) concentrations in Seaman Reservoir

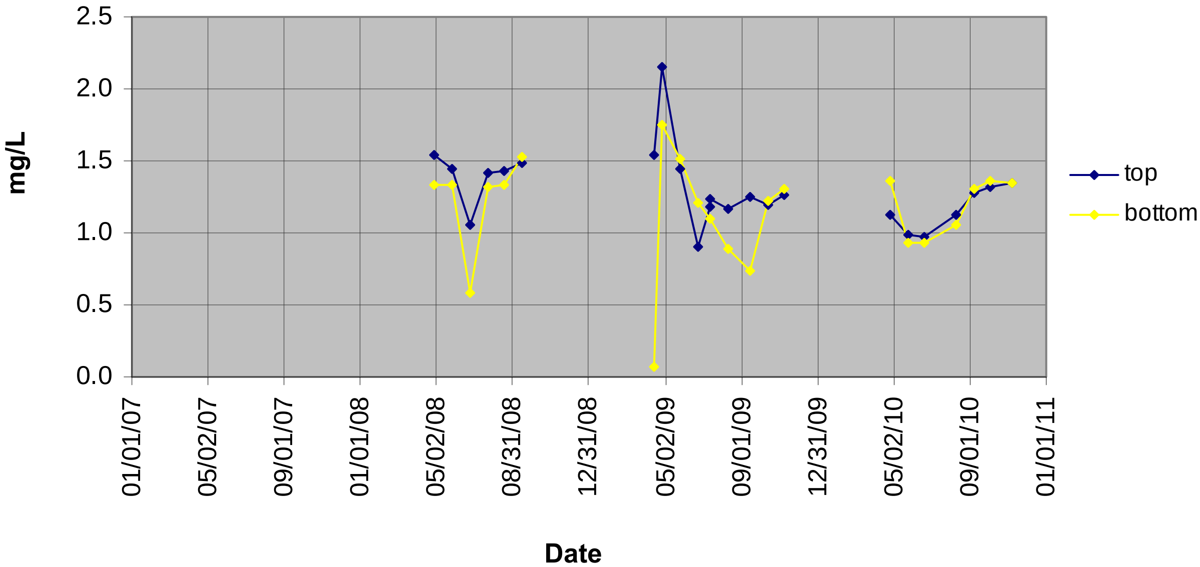


Figure 59. Sodium (Na) concentrations in Seaman Reservoir

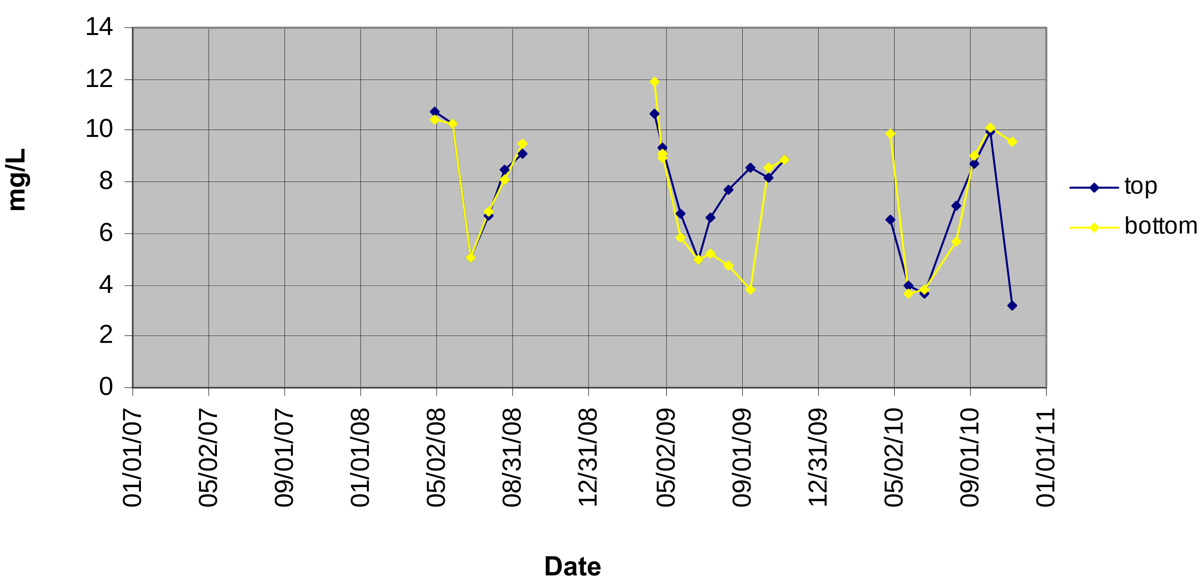


Figure 60. Chloride (Cl) concentrations in Seaman Reservoir

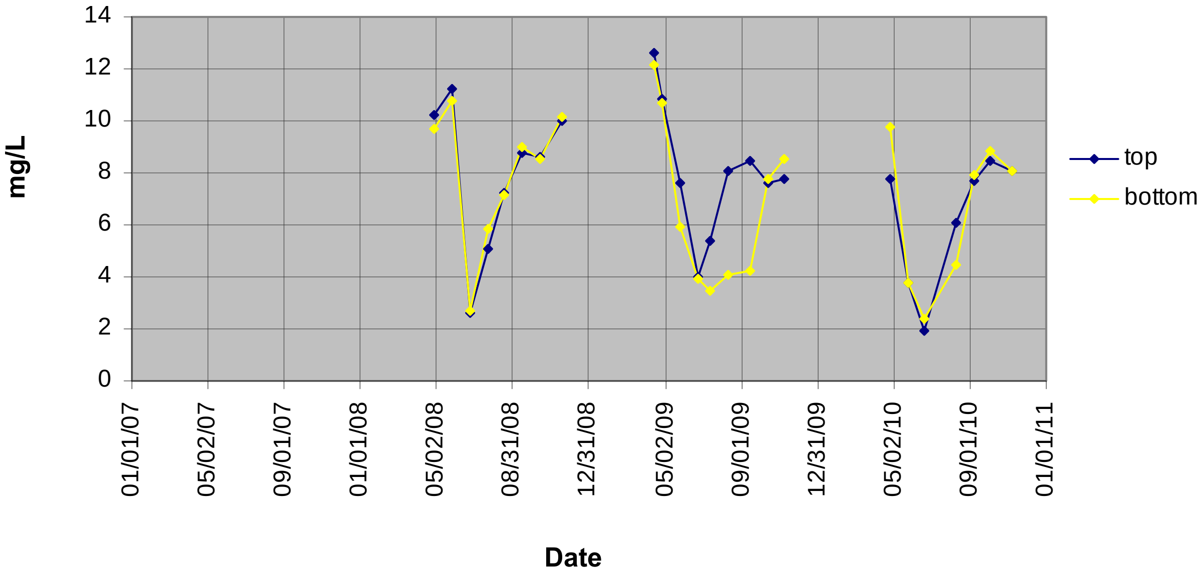
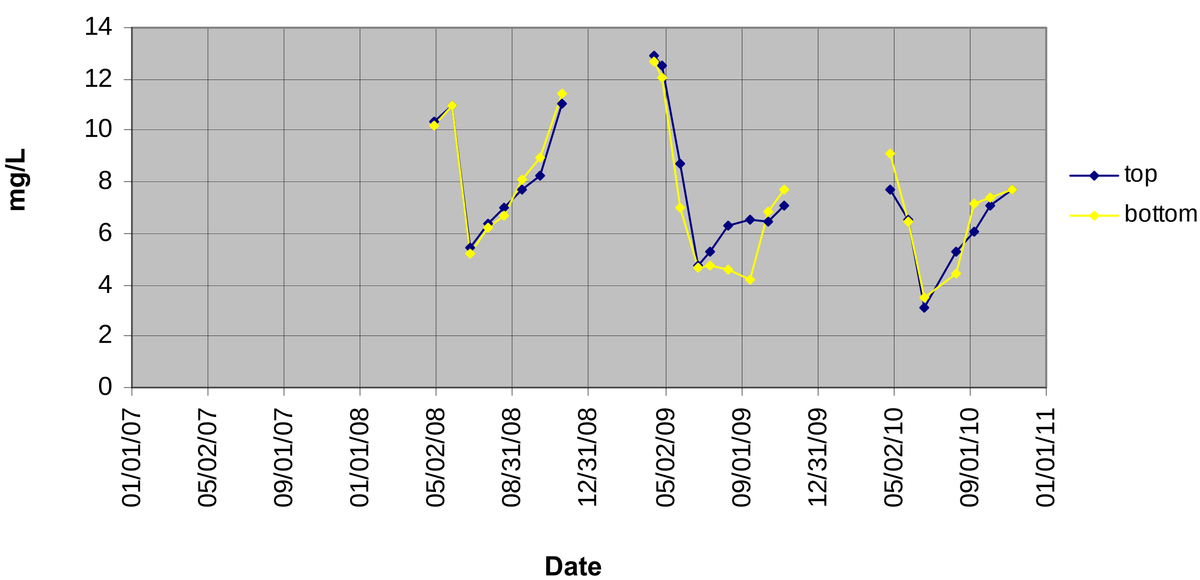


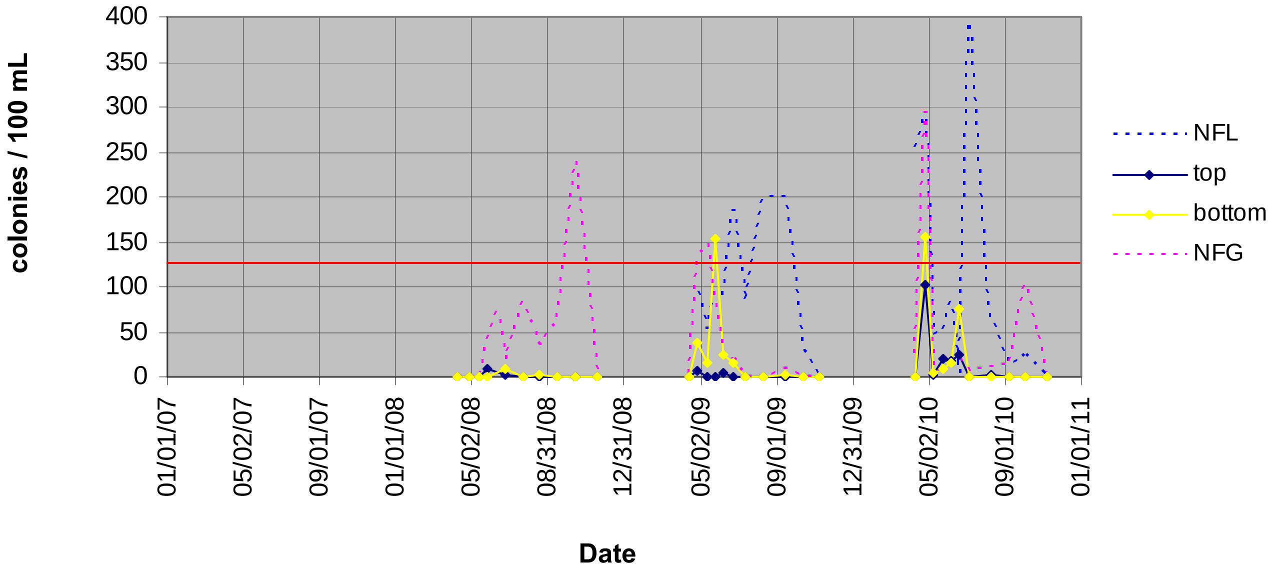
Figure 61. Sulfate (SO_4) concentrations in Seaman Reservoir



(EPA Secondary Drinking Water Standard: 250 mg/L)

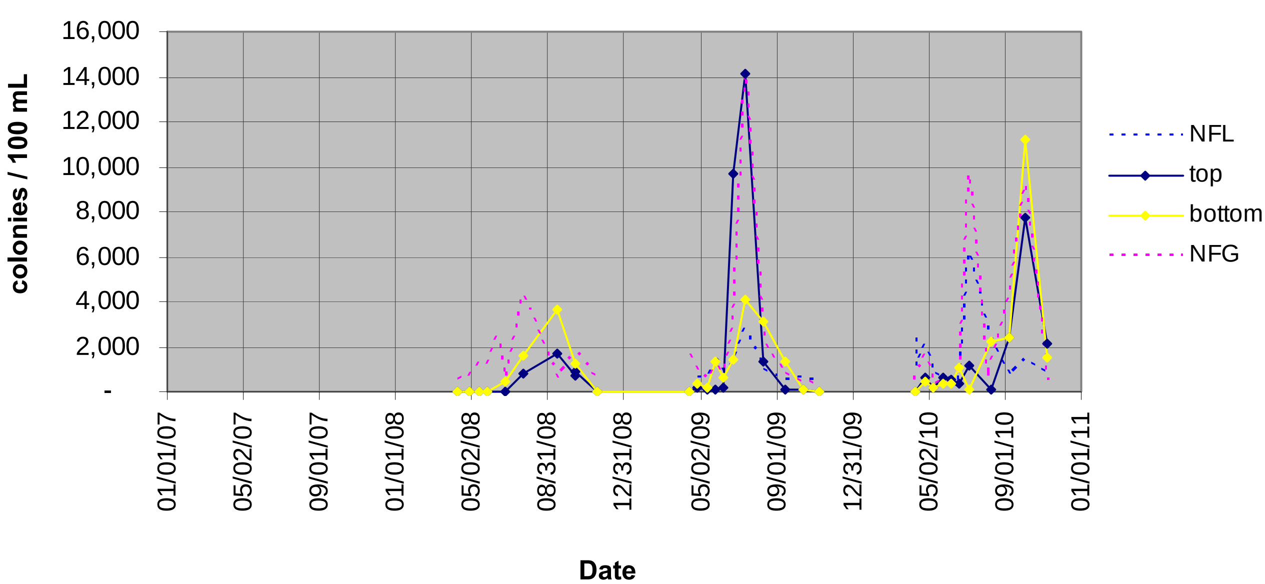
Seaman Reservoir: Microbiological Constituents

Figure 62. *E. coli* concentrations in Seaman Reservoir



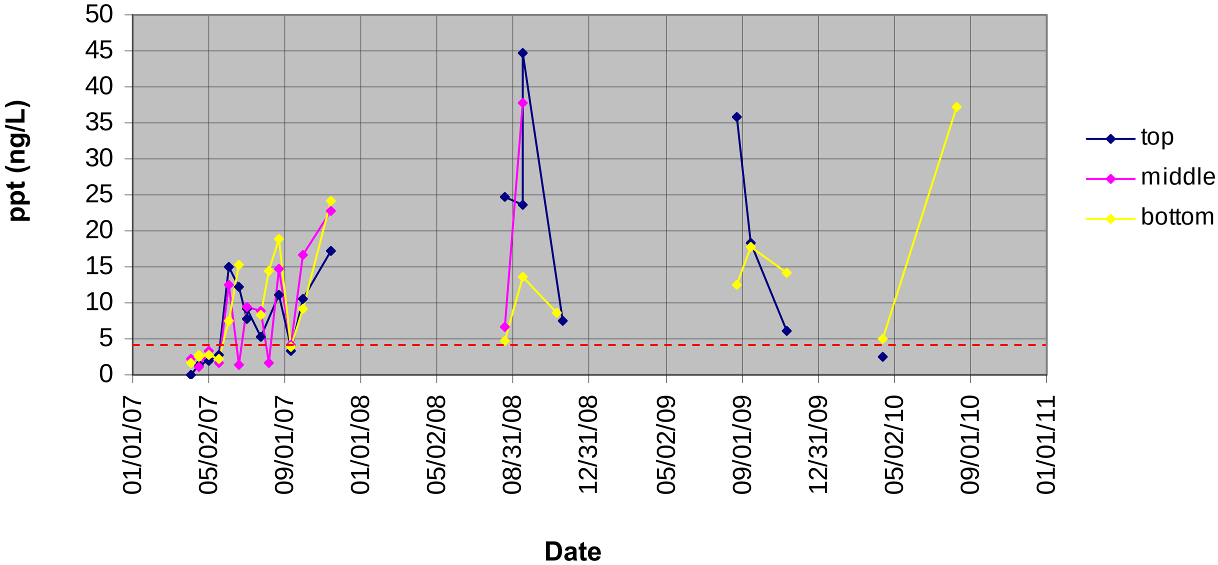
(—— Recreational water quality standard: 126 colonies/100 mL)

Figure 63. Total coliform concentrations in Seaman Reservoir



Seaman Reservoir:
Geosmin

Figure 64. Geosmin concentrations in Seaman Reservoir



(----- Odor threshold for geosmin: 4 ppt)