# 2008 Annual Report

# Upper Cache la Poudre River

# Collaborative Water Quality Monitoring Program

**Prepared for:**

**City of Fort Collins Utilities**

**City of Greeley**

**Tri-Districts**

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# EXECUTIVE SUMMARY

## Scope of 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, 2008 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 sampling parameters are outlined in Attachment 3 of this report and the 2008 Sampling Plan is included as Attachment 4.

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 2008 Annual Report

The 2008 annual report summarizes the hydrologic and water quality data collected during the first year of the Upper CLP Collaborative Water Quality Monitoring Program and provides a comparison with water quality information from the years 2005 – 2007. Data for the three years preceding 2008 were obtained from the historic City of Fort Collins and City of Greeley sampling program records.

Six key sites were identified that are considered representative of conditions on the Mainstem and North Fork CLP. The discussion of results focuses on these 6 key sites as well as Seaman Reservoir; however, 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

- Seaman Reservoir Drawdown

  On 6/3/08, the City of Greeley initiated a 9-day drawdown of Seaman Reservoir to address mechanical problems associated with the outlet gates. Water releases into the North Fork ranged between 483 – 1350 cfs daily. From 6/5/08 - 6/6/08, a large rainfall event occurred on the North Fork drainage above Seaman Reservoir. These coincident events, at a time of already high seasonal runoff, significantly affected the flow volume as well as hardness, alkalinity, turbidity and nutrient concentrations at sites downstream of Seaman Reservoir (NFG and PBD).

## Significant Results

- 2008 flows on the Mainstem were similar to years 2005 through 2007. The North Fork experienced considerably higher peak runoff than in the previous three years.

- In general, hardness, conductivity and alkalinity increased with decreasing elevation. Across all sites, minimum values occurred during periods of high flow.
- Turbidity peaked at all sites during spring run-off. North Fork sites experienced much higher peak turbidity values than Mainstem sites.
- Peak TOC concentrations occurred during peak runoff across the watershed. The North Fork exhibited persistently elevated TOC concentrations during periods of low flows, as seen in previous years.
- The North Fork had higher nutrient concentrations than on the Mainstem. Nitrate, total phosphorus, and ortho-phosphate concentrations at NFG increased from 2005 to 2007, but decreased in 2008.
- Mainstem nutrient concentrations were generally low, as in previous years. Poudre above Joe Wright Creek (PJW), consistently experienced higher nitrate concentrations than other Mainstem sites.
- *Giardia* is more abundant than *Crypotsporidium* on both the Mainstem and the North Fork. *Giardia* concentrations at North Fork above Dale Creek (NDC) showed an increase from 2006 through 2008, with an exceptionally high spike on 10/7/08.
- *E.coli* and total coliform concentrations were similar to previous years on the Mainstem (PNF).
- The North Fork below Seaman Reservoir (NFG) experienced higher *E.coli* concentrations than other Upper CLP sites, including Seaman Reservoir. There is no discernible relationship between NFG and Seaman Reservoir *E.coli* concentrations.
- Geosmin concentrations on the Mainstem were consistently below the taste and odor threshold of 5 ppt.
- Thermal stratification in Seaman Reservoir was only weakly established following the drawdown and subsequent refilling; however, near-anoxic conditions were observed below 8m by 8/19/08.
- Spikes in turbidity, nitrate, TKN, ortho-phosphate and total phosphorus also occurred in Seaman Reservoir on 8/19/08, and were similar to late season spikes observed in 2007.
- Geosmin concentrations in Seaman Reservoir were consistently at or above the taste and odor threshold, as in previous years; the maximum measured geosmin concentration at the top of Seaman Reservoir was 34 ppt on 9/15/08.
- Suggested changes to the Upper CLP Collaborative Water Quality Monitoring Program for 2009 include: 1) adding algae identification at Seaman Reservoir that was omitted in 2008, and 2) collecting samples at site NFL (North Fork above Livermore) for total coliform and *E.coli* analysis to better understand the relationships between pathogen concentrations on the North Fork and Seaman Reservoir.

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# 1.0 INTRODUCTION

## 1.1 Monitoring Program Development and Reporting

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, the City of Greeley-Bellvue Water Treatment Plant, and the Tri-Districts Soldier Canyon Filter Plant. 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 2006 to design the Upper Cache la Poudre River Collaborative Water Quality Monitoring Program. 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.

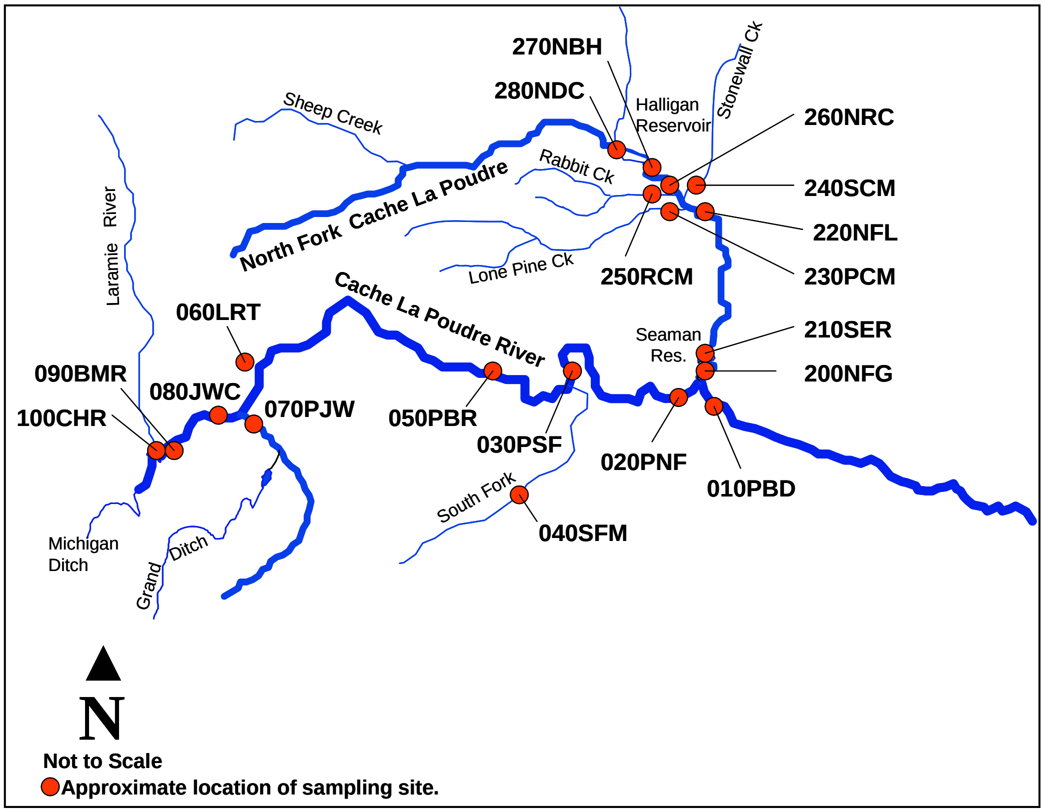
Annual and five-year reports for the collaborative program are prepared by City of Fort Collins staff to keep participants abreast of current issues and trends in water quality of the Upper CLP. The purpose of annual reports is to summarize hydrologic and water quality information for the current water year, describe notable events, and provide a comparison with water quality from the preceding three years. 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 were 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 (Fig. 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

Sampling frequency 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 2008 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 and City of Greeley collected 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. Analytical methods and detection limits are included in Attachment 5.

### 1.5 Scope of 2008 Annual Report

This 2008 annual report summarizes the hydrologic and water quality data collected during the first year of the Upper CLP collaborative monitoring program and provides a comparison with water quality information from the years 2005-2007. Data for the three years preceding 2008 were obtained from the historic City of Fort Collins and City of Greeley sampling program records.

# 2.0 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 sites; however, data from all sites were reviewed and analyzed and any notable events and trends are included in the discussion. A full set of data summary graphs is contained in Attachment 6; raw data are available upon request from the City of Fort Collins.

## 2.1 Hydrology

Discharge was measured during sampling at two sites on the Mainstem CLP and four sites on the North Fork CLP. These sites included:

South Fork Poudre (SFM; Mainstem)

Poudre above Joe Wright Creek (PJW; Mainstem)

North Fork at Rabbit Creek (NRC; North Fork)

Rabbit Creek Mouth (RCM; North Fork)

Stonewall Creek Mouth (SCM; North Fork)

Lone Pine Creek Mouth (PCM; North Fork)

Discharge at these sites was not continuously monitored; values presented for these sites represent instantaneous discharge measurements collected on the specified sampling dates. Continuous stream flow data at other key locations were obtained from USGS and CDWR online reporting sites for flow gauging stations and 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 (Fig. 2). Spring runoff for the year 2008 began in early May with peak flows occurring on June 6th and June 9th for the lower Mainstem and North Fork sites, respectively (Fig. 3).

**Figure 2. 2005 – 2008 Daily average stream flow at key Upper CLP monitoring sites.**

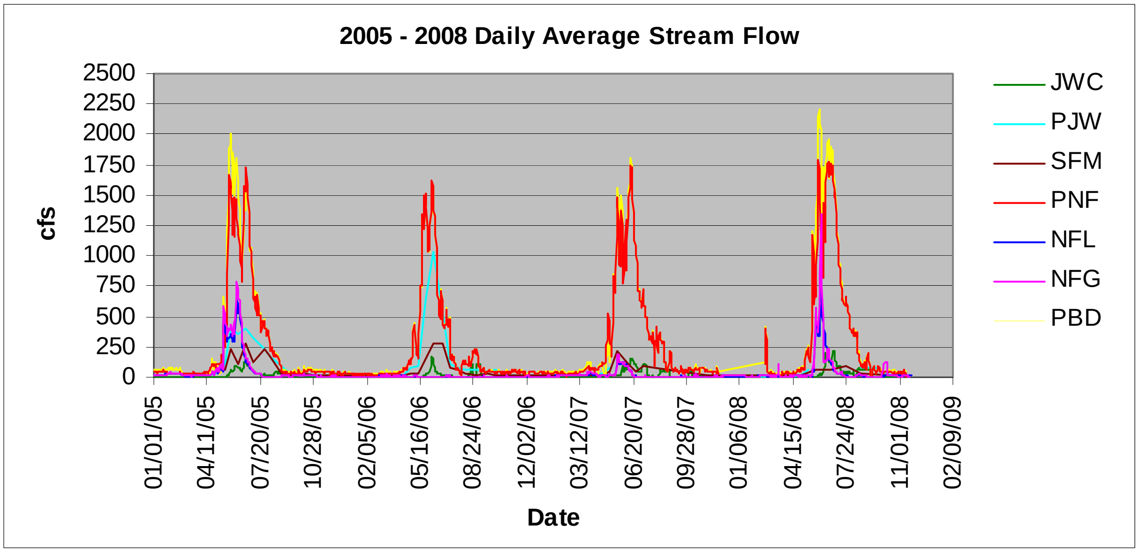
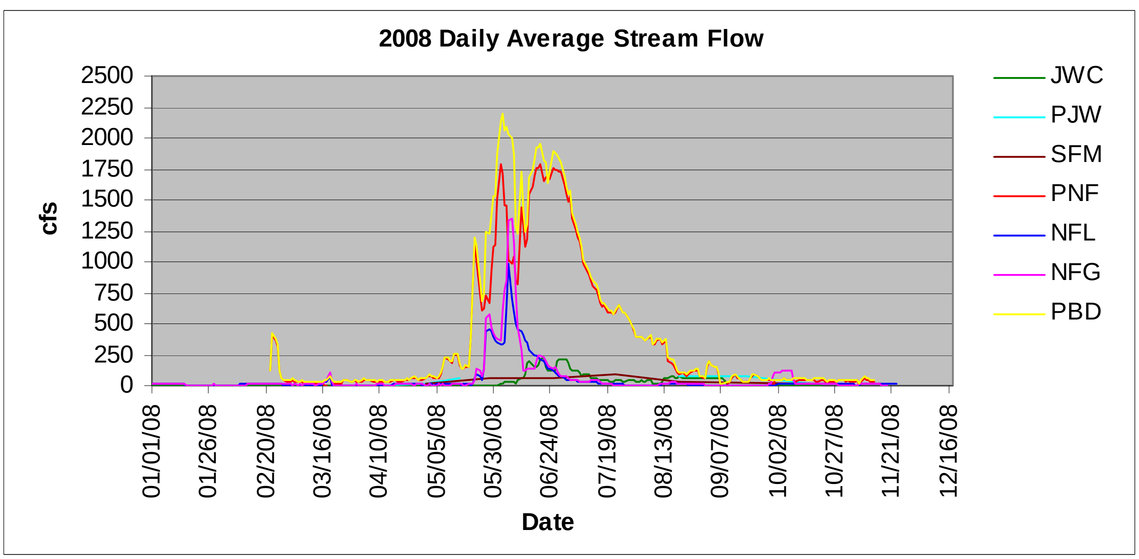



**Figure 3**. **2008 Daily Average Stream Flow at key Upper CLP monitoring sites.**




Despite smaller peak daily average flows in two of the largest headwater sources to the Mainstem Poudre, PJW and SFM, the lower Mainstem (PNF) recorded slightly higher peak daily average flows for 2008 (1740 cfs) than in the previous three years. Peak daily average stream flow at JWC (215 cfs) was higher than years 2005-2007, whereas, at

PJW, 2008 peak flow (105 cfs) was considerably lower than in both 2005 and 2006 (year 2007 data were not included in the PJW time-comparison due to a large number of missing flow measurements). In addition, peak stream flows on the South Fork (SFM), another major tributary to the upper Mainstem, have consistently declined since 2005.

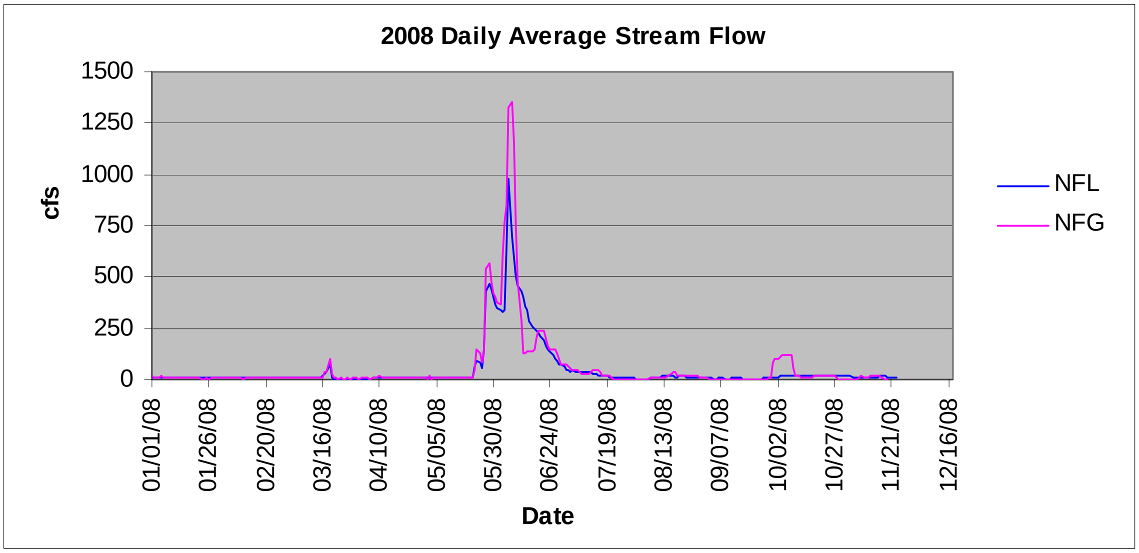
The North Fork at NFG experienced a significantly higher peak daily average flow (1350 cfs) than in all previous years, including the substantial peak of 2005 (843 cfs). It is important to note that stream flow measurements at NFG are largely controlled by Seaman Reservoir operations and the associated water releases. During a typical spring runoff season, North Fork flows to Seaman Reservoir are matched in large part, by outflow over the spillway back into the North Fork. In this situation, it is expected that the hydrograph at NFG would closely resemble that of NFL, located above Seaman Reservoir. However, in situations where incoming flows are used to fill the reservoir or when additional reservoir releases are necessary to meet downstream needs, the hydrographs as well as water quality at NFG and NFL can differ substantially.

During June 2008, a series of coincident events on the lower North Fork CLP resulted in exceptionally high peak flows at NFG. In late May, the City of Greeley discovered mechanical problems with the gates on Seaman Reservoir, impacting their ability to effectively control water releases. In response, the decision was made to drain the reservoir and fix the gates (details provided through personal communications with J. McCutchan, 2008). The subsequent 9-day reservoir drawdown began on June 3, 2008, during which time between 483 and 1350 cfs of water was released daily. On June 5$^{th}$ and 6$^{th}$, a large precipitation event occurred within the North Fork basin, at a time when flows were already increasing in response to spring-runoff. On June 11$^{th}$, the decision was made to refill Seaman Reservoir because the high volume of incoming North Fork stream flow had prevented sufficient drawdown to address the mechanical issues. During this time, the peak daily average flow observed at NFG was 1350 cfs, which occurred approximately 3 days after Mainstem peak flows.

In this case, the comparison of NFG and NFL data was useful for understanding whether resulting trends in discharge and water quality at NFG were related to spring runoff and the large precipitation event or to Seaman Reservoir operations. Based on this comparison, it appears that flow patterns at NFG closely match those of NFL (Fig. 4). This suggests that although Seaman Reservoir drawdown contributed to the higher than normal peak-flows, spring snow-melt and precipitation events within the North Fork basin were the largest influences on the magnitude and timing of NFG peak-flows.

At PBD, the majority of measured stream flow can be attributed to Mainstem sources and as expected, the hydrographs of PBD and PNF track closely, except in years which NFG contributes higher than normal flow. This is best exemplified in 2005 and 2008, during which maximum daily average flows of 2,010 cfs and 2,200 cfs, respectively, were recorded at PBD (Fig. 2).

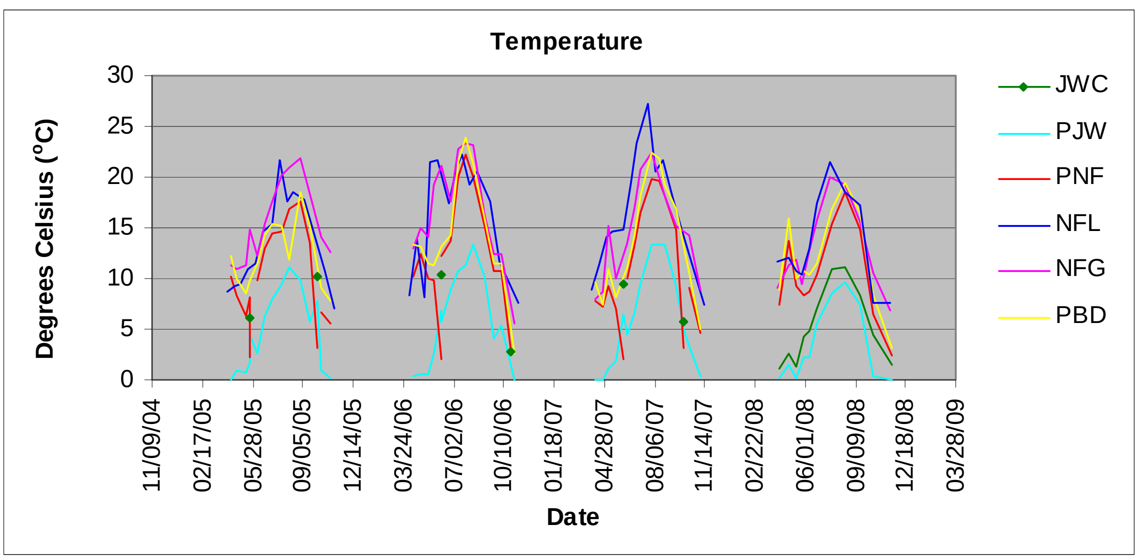
**Figure 4. 2008 Daily Average Stream Flow at NFL and NFG**




## 2.2 Water Temperature

Water temperature increases with decreasing elevation throughout the watershed (Fig.5). Peak temperatures occurred mid-summer, with North Fork sites peaking a few days earlier than the Mainstem sites due to the influence of the warmer temperatures within this lower elevation drainage. Seaman Reservoir did not have any discernible influence on North Fork water temperature.

**Figure 5. Water temperature at key Upper CLP monitoring sites.**



## 2.3 General Parameters: Conductivity, Hardness, Alkalinity, pH and Turbidity

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 ($OH^-$). 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 (Figures 6.a – 6.d).

In general, conductivity, hardness and alkalinity increased with decreasing elevation. Accordingly, North Fork sites showed consistently higher values for these parameters than Mainstem sites, which reflect the combined influences of differing geology and elevation. On the Mainstem, water releases from Barnes Meadow Reservoir, a high-elevation reservoir situated above JWC, are infrequent, and do not typically display extreme conductivity or hardness; however, water released on 4/30/08 showed relatively high conductivity (518 us/cm) and hardness (136 mg/L). In this case, the only effects on downstream water quality were small increases in conductivity and hardness at JWC where conductivity increased from 59 to 86 us/cm and hardness increased from 23 to 31mg/L. The duration and volume of the release were not sufficient to result in persistently elevated readings at any downstream location.

Strong spikes in hardness and alkalinity were also observed at NFG (365 mg/l and 456 mg/l, respectively) on 6/10/2008, but occurred in the absence of a spike in conductivity. The accuracy of data related to this unusual occurrence was verified using independent calculations and comparisons of field and lab measurements, but the available data did not explain the low conductivity values. Because this event did not have any persistent impact on water quality and the data appear to be reliable, it was determined that no further investigation is needed at this time.

Spikes in hardness and alkalinity at NFG coincided with peak spring-runoff and the end of the Seaman Reservoir draw-down period. A coincident peak in turbidity values (1045 NTU; Fig. 6.e) suggests that high hardness values are likely caused by the large amount of sediments discharged with the deep waters of Seaman Reservoir. The sediment-laden water release resulted in observable downstream peaks in hardness, alkalinity and turbidity at PBD, although the magnitude of the peaks was reduced by the dilution effect of Mainstem flows.

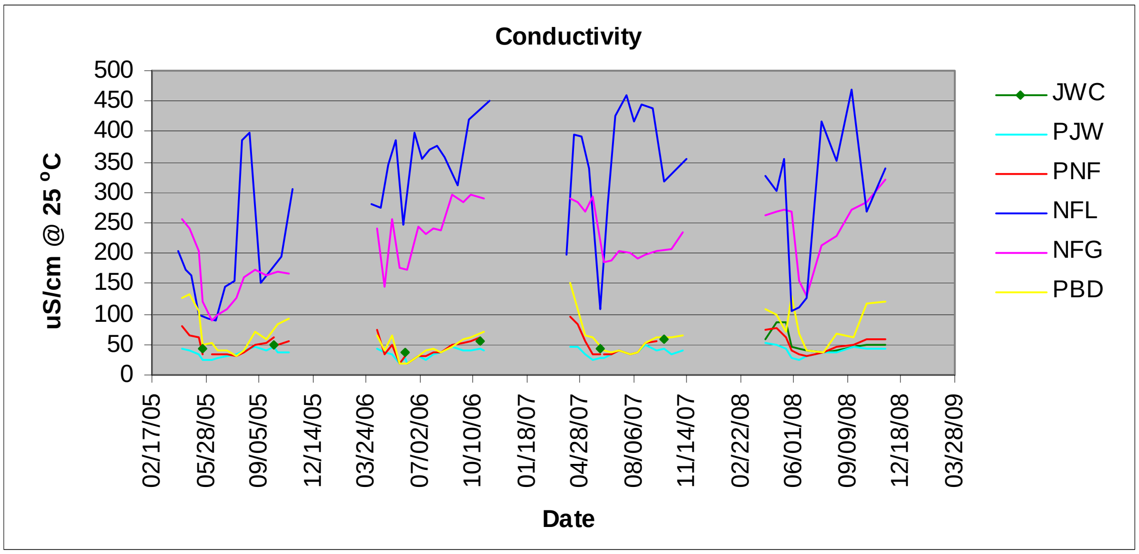
In 2008, the pH of the Upper CLP waters followed similar patterns related to season and elevation as alkalinity, conductivity and hardness (Fig. 6.d). In particular, the North Fork exhibited higher pH than the Mainstem, with all sites experiencing annual minimum values during spring runoff. 2008 pH values ranged from 6.7 – 7.8 on the Mainstem and from 6.9 – 8.5 on the North Fork; all values were within the ranges observed in previous years.

Turbidity peaked at all sites during spring run-off, with the North Fork showing much higher peaks than Mainstem sites. High turbidities at NFG and PBD occurred during the

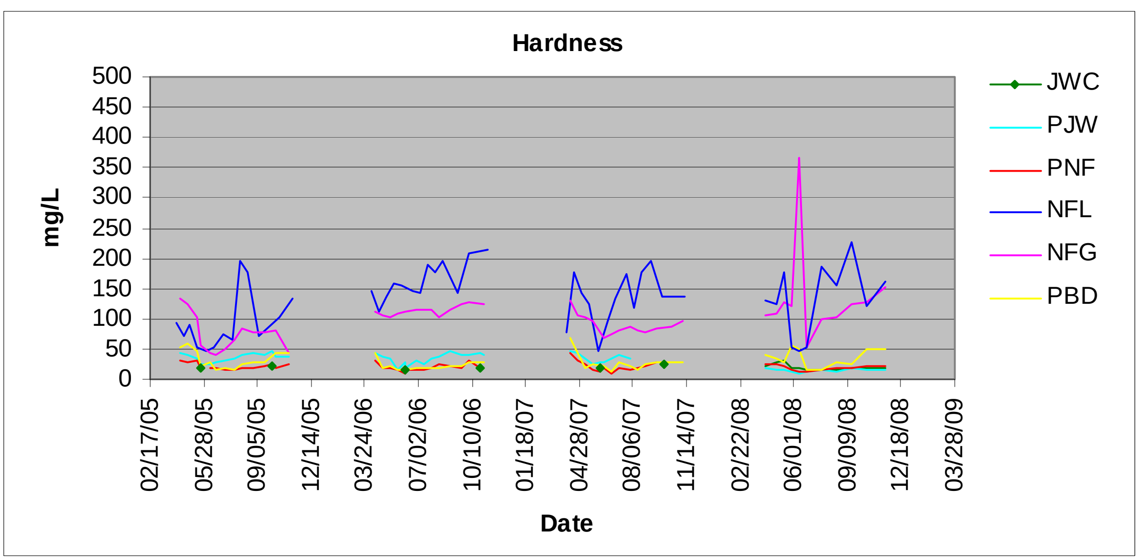
Seaman Reservoir drawdown. However, during this period, turbidity at NFL upstream of Seaman Reservoir was approximately three times greater than at PNF due to snowmelt and rainfall runoff (Fig.6.e). In periods of lower flow, turbidity decreased considerably and values on the Mainstem and North Fork were similar.

**Figure 6 (a –e). General water quality parameters at key Upper CLP monitoring sites: Conductivity, Hardness, Alkalinity, pH and Turbidity**

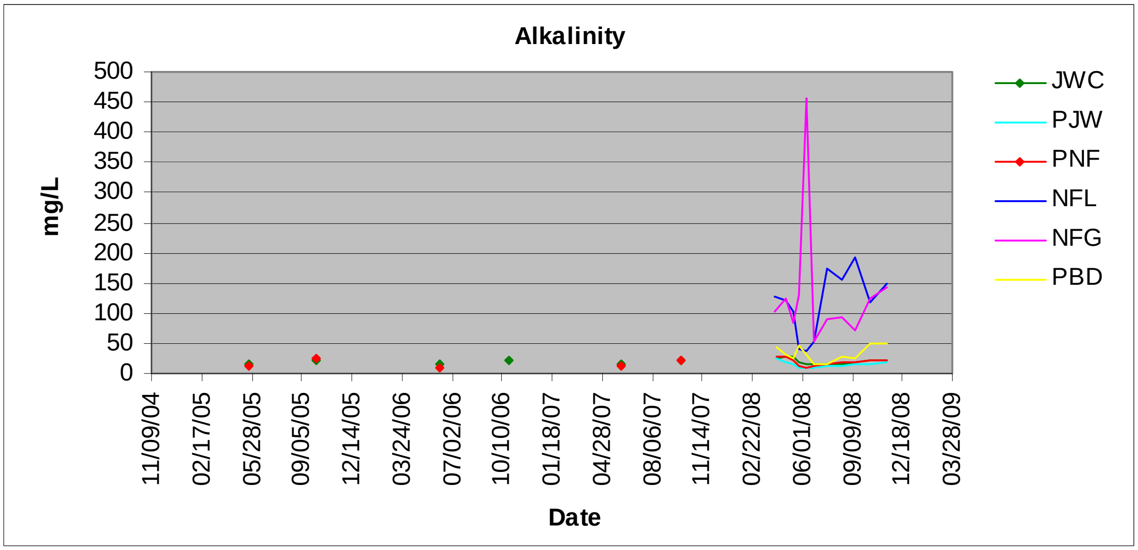
**6.a. Conductivity**



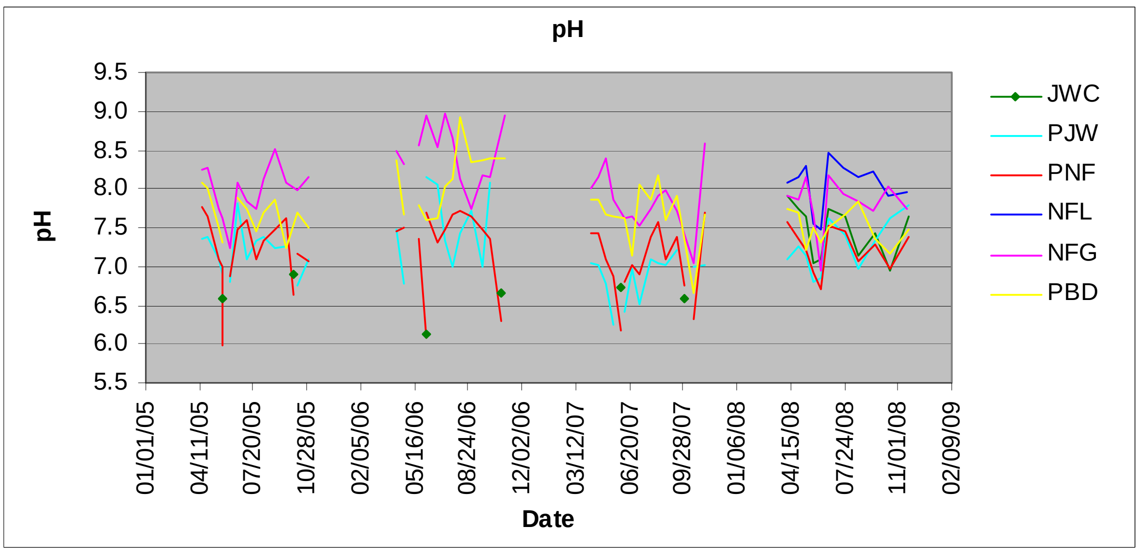

**6.b. Hardness**



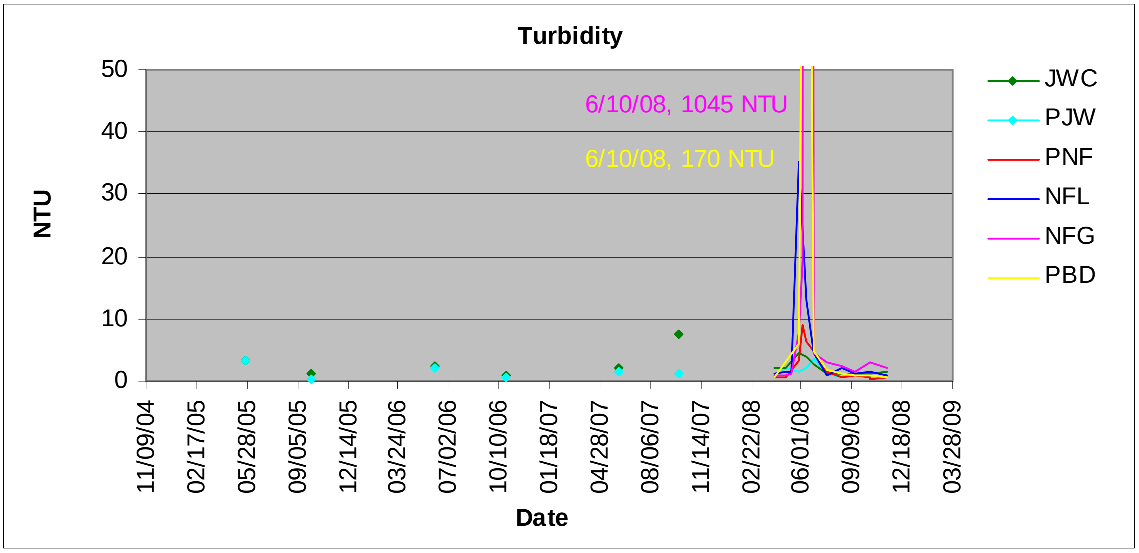
### 6.c. Alkalinity




### 6.d. pH



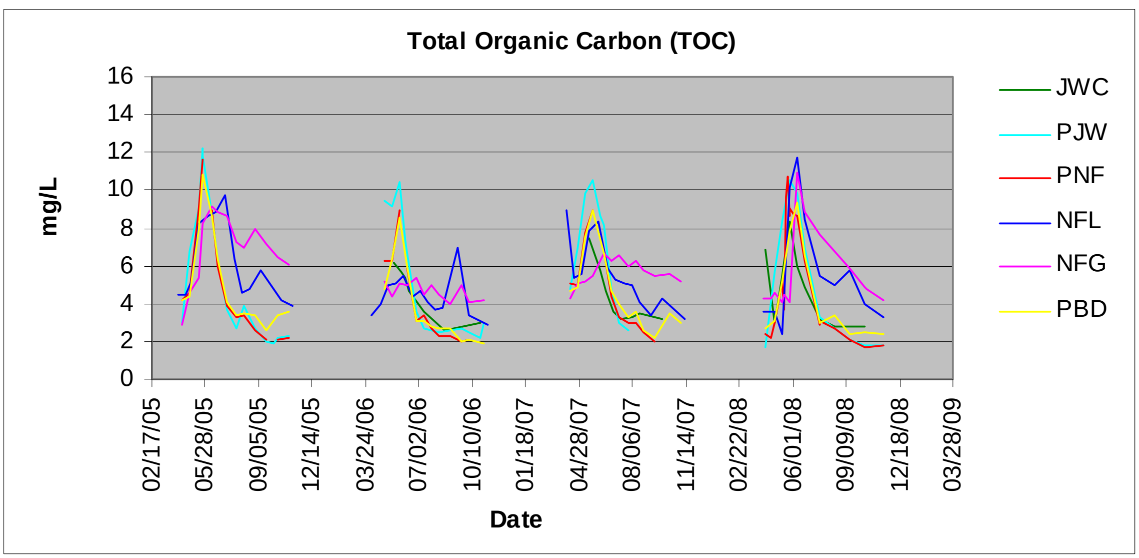
**6.e. Turbidity**




## 2.4 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 spring snowmelt runoff period. This trend was evident in years 2005 through 2008, with Mainstem sites generally peaking several days earlier than North Fork sites (Fig. 7).

**Figure 7. TOC concentrations at key Upper CLP monitoring sites.**

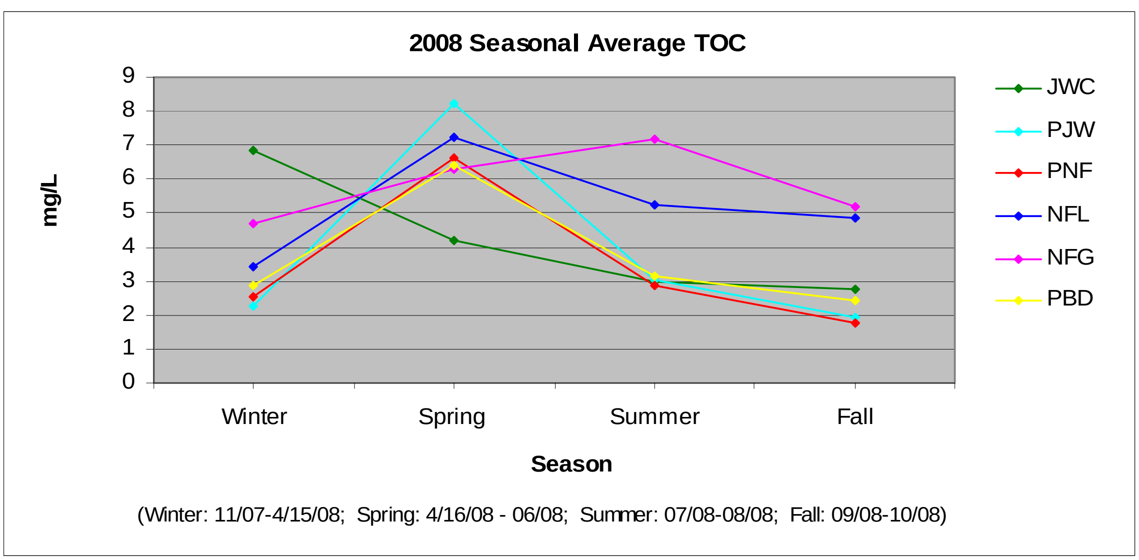


In general, the highest Mainstem TOC concentrations were observed at the high-elevation site, PJW, an occurrence that is likely related to the high proportion of runoff occurring as snowmelt near the Mainstem headwaters. Water released from Barnes Meadow Reservoir (BMR) during spring runoff has historically 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 2005 – 2008, peak TOC concentrations at BMR were between 10-14 mg/l and often surpassed TOC concentrations at PJW. However, releases from BMR were infrequent and short duration, and their impact on source water supplies at PNF and PBD was minimal. In 2008, an exceptionally large spike in TOC also occurred in the incoming waters diverted through the Laramie River Tunnel (LRT). The average peak value of 14.25 mg/L on 5/27/08 represented a large increase over peak TOC values recorded in 2006 or 2007, which were 8.75 and 8.82 mg/L, respectively.

In 2008, all North Fork sites had peak TOC values above 10 mg/L, with the small tributaries, Rabbit Creek Mouth (RCM) and Pine Creek Mouth (PCM) reporting the highest TOC concentrations (13.0 and 13.8 mg/L, respectively). NFL and NFG reported slightly lower peak values of 11.7 mg/L and 10.9 mg/l, respectively, both which were higher than values reported in 2005-2007. Concentrations on the North Fork are higher than on the Mainstem; however, higher volume flow results in greater loads on the Mainstem.

Seasonal differences in TOC concentrations were also observed between Mainstem and North Fork sites. On the North Fork, the higher TOC levels persisted 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 average TOC values at NFL and NFG (Fig. 8).

**Figure 8. 2008 Seasonal Average TOC concentrations at key Upper CLP monitoring sites.**



The persistence of elevated TOC levels on the North Fork during periods of low flow suggests the presence of an additional source or sources of TOC other than that mobilized during spring snowmelt. Possible sources of this additional TOC include water released from Halligan and Seaman Reservoirs, and runoff from agricultural land within the North Fork basin. A study was conducted in 2008 by Dr. Mel Suffet at UCLA to evaluate the characteristics of TOC in the source waters of the Fort Collins Water Treatment Facility, the Tri-Districts Soldier Canyon Filter Plant and the City of Greeley-Bellvue Water Treatment Plant. Results of this study may provide additional information about the origins of TOC at NFG; however, this information was not available at the time of this report.

## 2.5 Nutrients

A complete comparison of 2008 data with years 2005- 2008 was not possible for several nutrient parameters due to differences in reporting limits between the former monitoring programs. Those parameters include ammonia, nitrite, nitrate, total phosphorus and ortho-phosphate. 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.

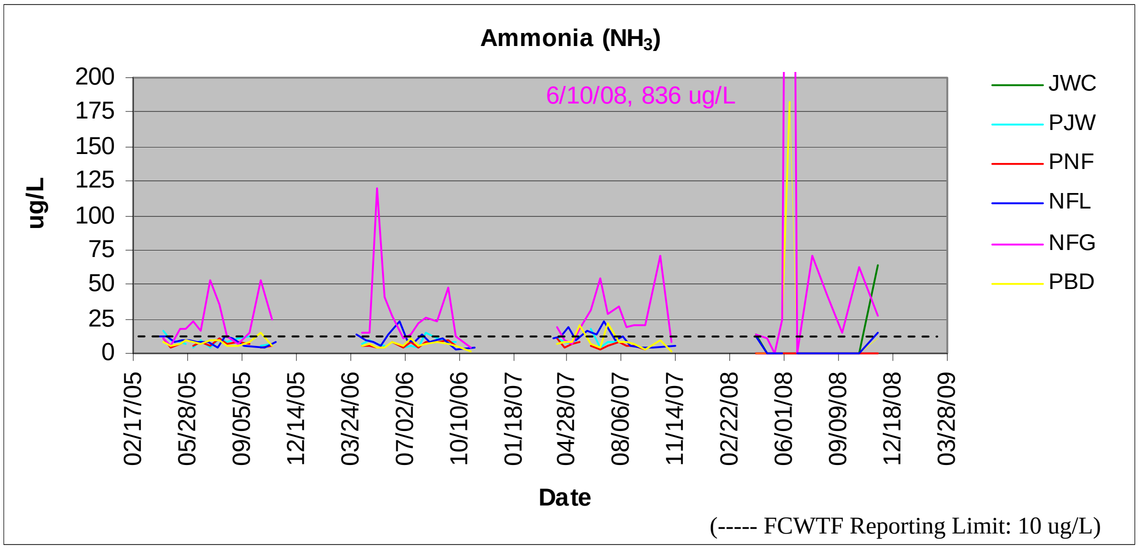
Current reporting limits are 5 ug/L for ortho-phosphate, 10 ug/L for ammonia and total phosphorus, and 40 ug/L for nitrate and nitrite, and are considerably higher than those used by Dr. Lewis in years 2005- 2007. Analysis of Total Kjeldahl Nitrogen (TKN) began in 2008.

**North Fork.** In general, higher nutrient concentrations were observed on the North Fork than at Mainstem sites, as reflected by values at NFL and NFG (Figures 9). These sites were characterized by frequent spikes in ammonia, nitrate, total phosphorus and ortho-phosphate from 2005 through 2008; however, 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 EPA drinking water quality standards for nutrients.

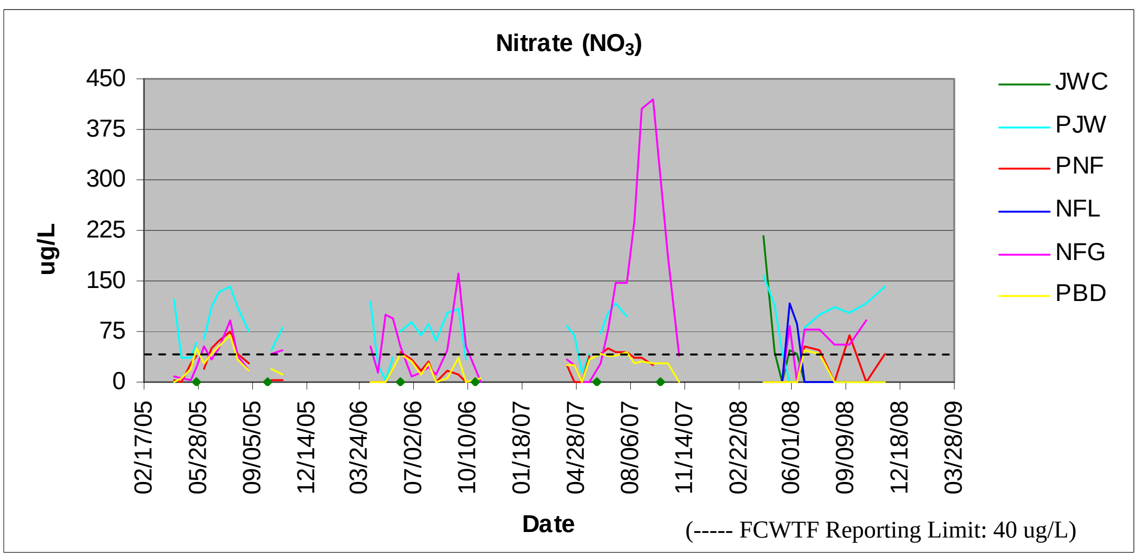
From 2005 through 2007, consistent increases in nitrate, total phosphorus and ortho-phosphorus were observed at NFG, followed by decreasing concentrations in 2008. In 2008, summer and fall releases from Halligan reservoir resulted in high concentrations of ammonia at NBH, and both PCM and RCM exhibited high concentrations of nitrate and total phosphorus, but these spikes did not correspond well to spikes observed at NFL. Nitrite was non-detectable throughout the watershed in 2008.

**Figure 9 (a-f). Nutrient concentrations at key Upper CLP monitoring sites.**

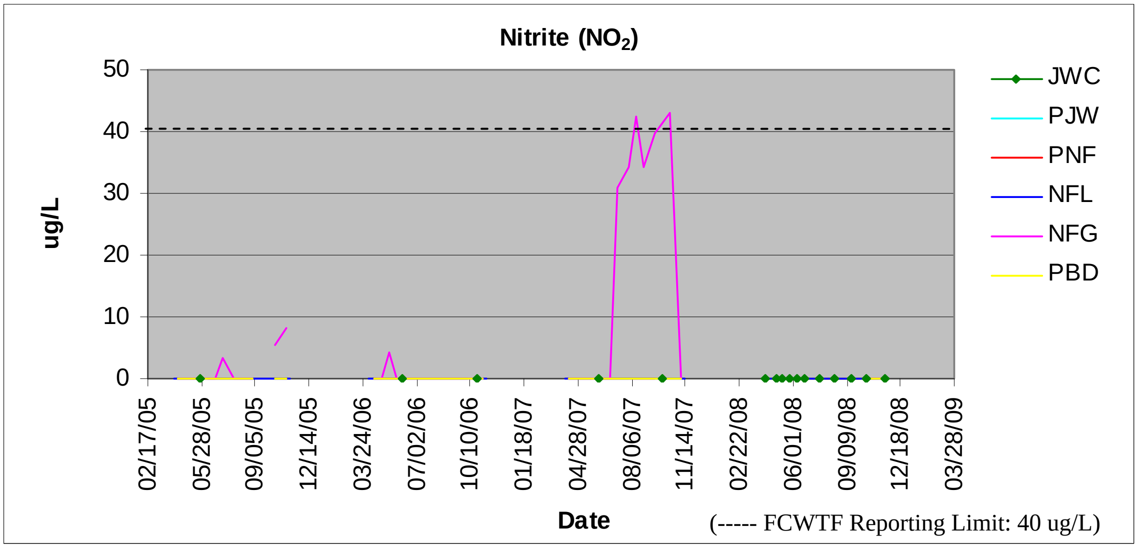
**9.a. Ammonia ($NH_3$)**



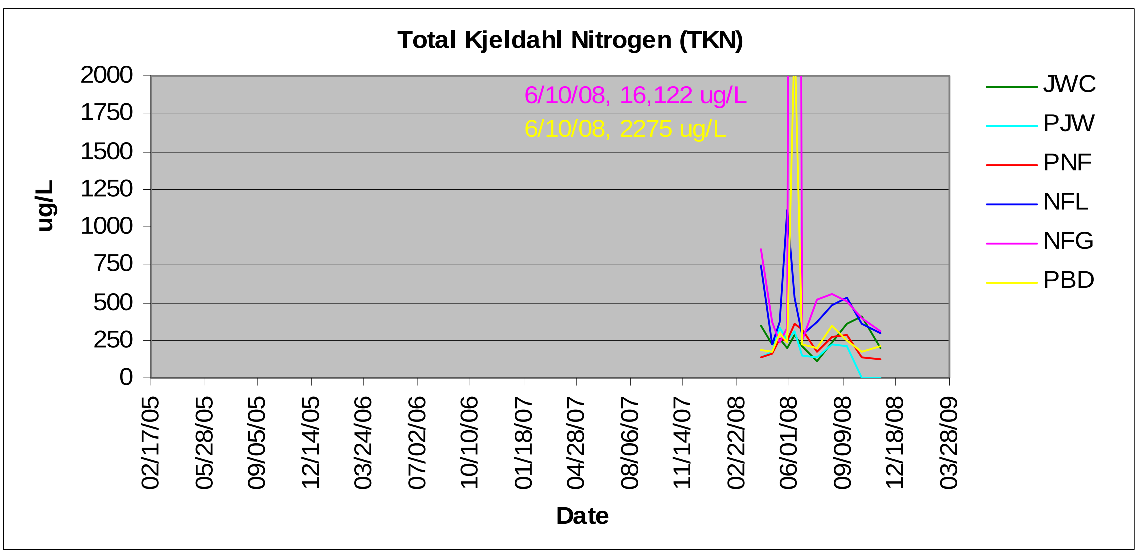

**9.b. Nitrate ($NO_3$)**



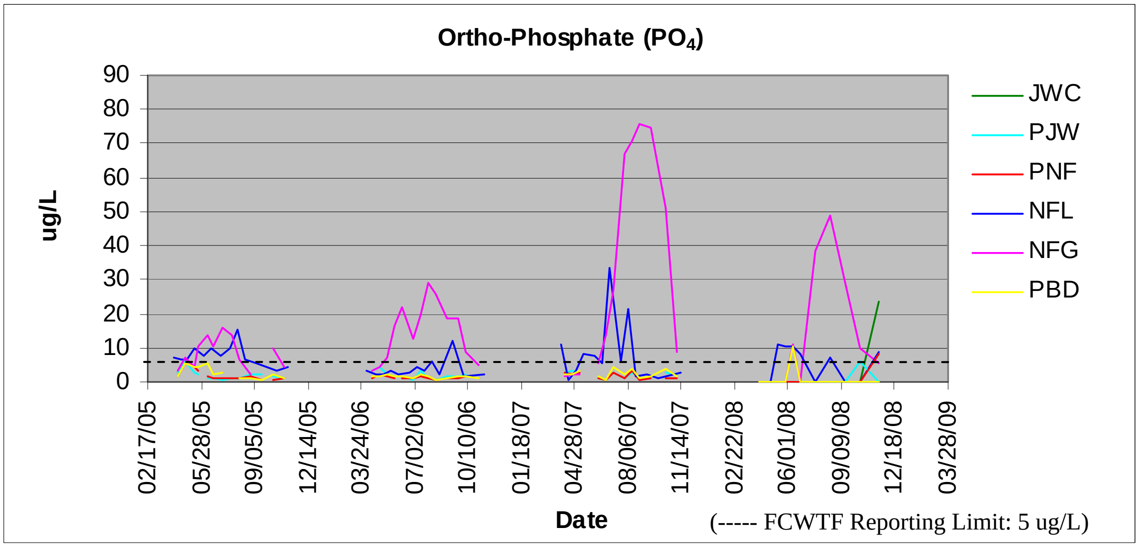
**9.c. Nitrite ($NO_2$)**



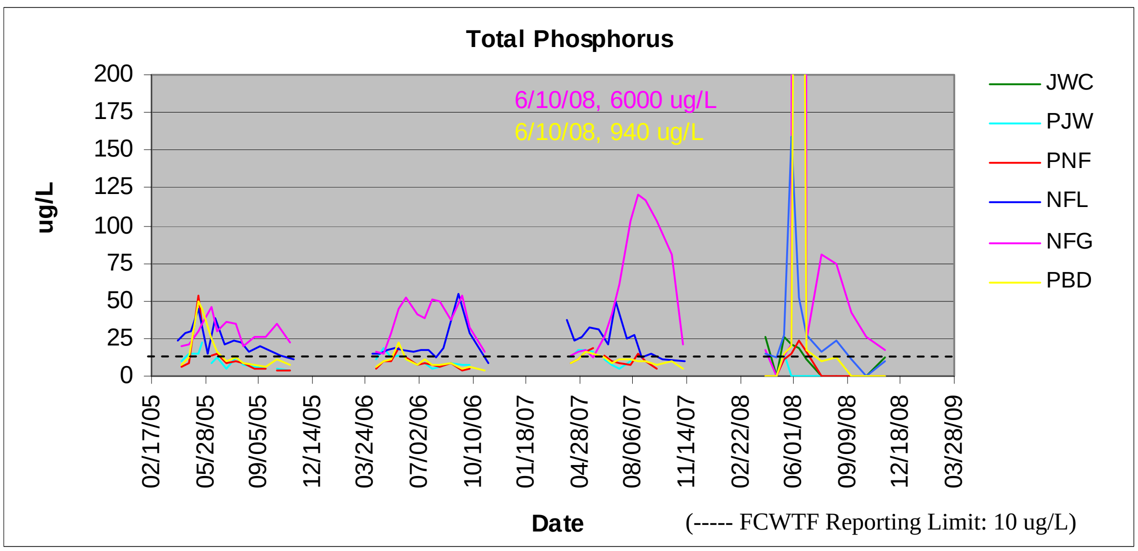

**9.d. Total Kjeldahl Nitrogen (TKN)**



**9.e. Ortho-phosphate ($PO_4$)**




**9.f. Total Phosphorus**



**Seaman Drawdown**. During the 2008 drawdown of Seaman Reservoir, significant concentrations of TKN, total phosphorus and ammonia were observed at NFG, while nitrate and ortho-phosphate were not detected. The dilution effect of the high flows accounts for the non-detectable concentrations of dissolved nutrients (nitrate and ortho-phosphate). Because TKN and total phosphorus include non-soluble nitrogen and phosphorus fractions bound within sediments and organic matter, their concentrations increased dramatically as the deep, sediment-laden waters were released from the reservoir. Large nutrient spikes on the North Fork were typically reflected at PBD, although the magnitudes of the events were smaller than at NFG due to the dilution effect of Mainstem flows.

**Mainstem.** Nitrite and ortho-phosphate were generally not detected on the Mainstem. The exception was JWC, which had detectable levels of ortho-phosphate in 2008. Total phosphorus concentrations were similar to previous three years during which PNF experienced the highest values.

Nitrate concentrations were generally low at all sites, consistent with the previous three years, and displayed a seasonal pattern of highest concentrations prior to spring runoff followed by a decrease during the high flow period and a return to higher values in the late summer. Highest Mainstem concentrations were consistently observed at PJW, although much higher nitrate concentrations were occasionally seen in water released from BMR, JWC and LRT. For example, in 2008, peak nitrate values from 141-156 ug/L were observed at PJW, while water released from BMR and LRT had maximum nitrate concentrations of 359 ug/L and 121ug/L, respectively. The timing of peak concentrations of nitrate at the lower elevation site, PNF, generally corresponded to upstream peaks at PJW. TKN concentrations were fairly constant throughout the year with the highest concentrations occurring at PNF.

## 2.6 Metals

Metals are sampled twice annually at two sites, PNF and NFG. All metals are analyzed for dissolved fractions except iron (Fe), which is analyzed for both total and dissolved fractions. In 2008, dissolved concentrations of silver (Ag), cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb) and zinc (Zn) were not detected.

Due to analytical error, dissolved iron fractions were not determined in 2008, but will be analyzed in future years for all sampling dates. Total iron concentrations at PNF were 146 ug/L and 513 ug/L on 5/27/08 and 11/19/08, respectively. At NFG, total iron was not detected on 5/27/08, but was measured at 1,233 ug/L on 11/19/08. Total concentrations at both sites on 11/19/08 exceeded the EPA secondary drinking water maximum contaminant level (MCL) for iron of 300 ug/L. 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 supplies.

## 2.7 Pathogens: *Cryptosporidium* and *Giardia*

*Cryptosporidium* and *Giardia* testing on the North Fork sites above and below Halligan Reservoir 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 (Fig. 10 and 11). From 2005- 2008, *Giardia* was present at levels ranging from 0 to 35 cysts/L, whereas *Cryptosporidium* was frequently not detected, with no observed values exceeding 0.7 oocysts/L.

The Mainstem had higher concentrations of both *Giardia* and *Cryptosporidium* than the North Fork in 2006 and 2007, with peak values occurring in 2007. NBH consistently had the lowest *Giardia* concentrations. 2008 differed from previous years, in that NDC showed increases in concentrations of both protozoa that were higher than the Mainstem. *Cryptosporidium* was also higher at NBH than on the Mainstem.

*Cryptosporidium* and *Giardia* both show an increase over time at NDC, however, due to the change in sampling site location, it is not possible to determine whether the trend is due to changes occurring within the watershed, or is a response to site-specific conditions. There was, however, a general seasonal increase at NDC with a strong peak on 10/7/08 of 35.1 cysts/L of *Giardia* and 0.69 oocysts/L of *Cryptosporidium*, the highest values on record.

**Figure 10. Concentrations of *Giardia* on Mainstem and North Fork CLP.**

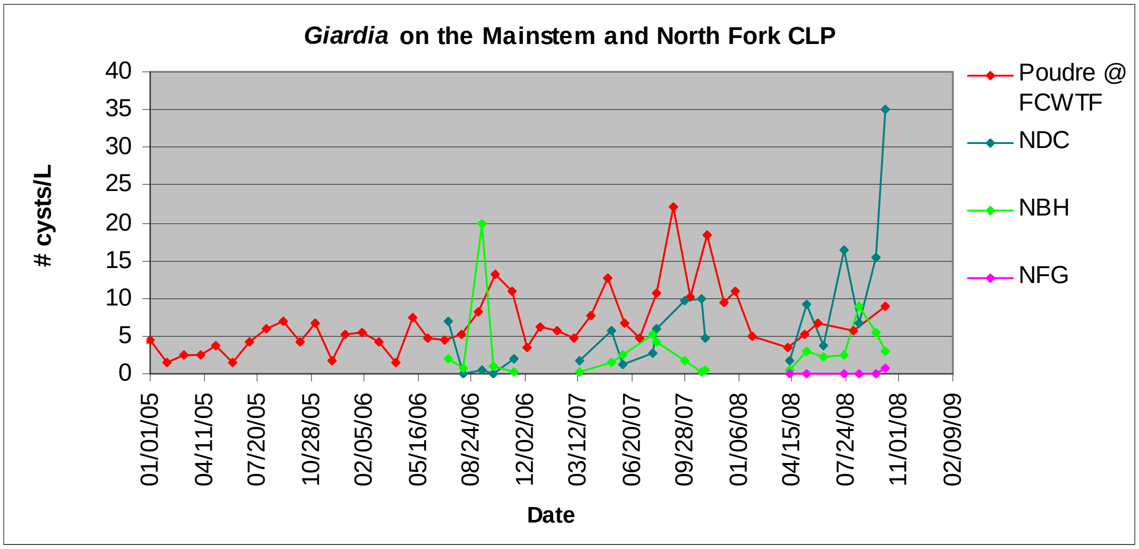
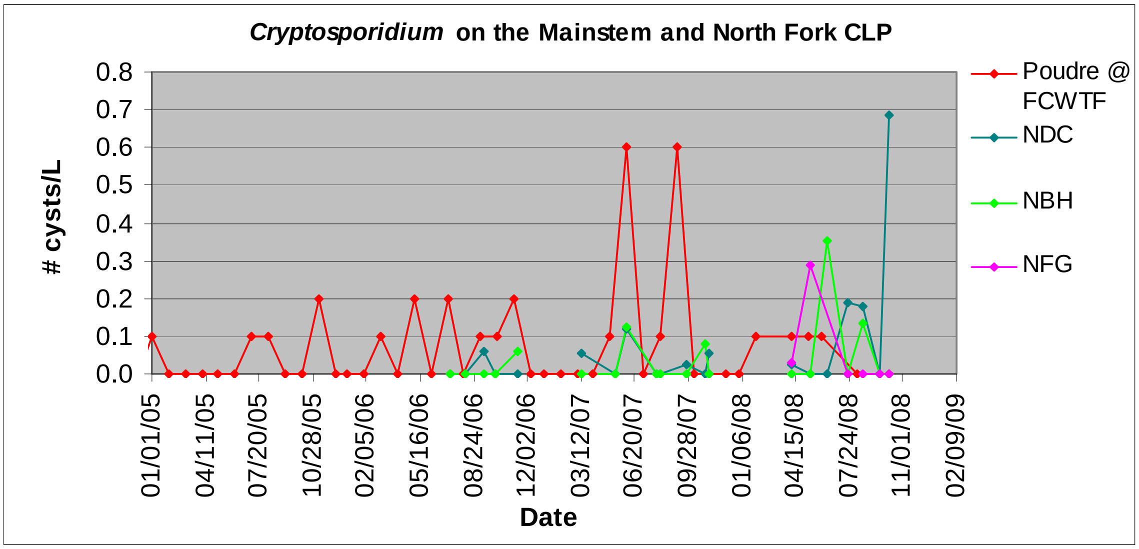


**Figure 11. Concentrations of *Cryptosporidium* on Mainstem and North Fork CLP.**




## 2.8 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 2005 – 2008. In 2008, values for *E. coli* and total coliforms were within the range of values observed from the previous three years (Fig. 12 & 13). PBD had similar concentrations of total coliforms as PNF, but *E. coli* concentrations differed at the two sites.

In 2008, the highest total coliform and *E. coli* concentrations were measured at NFG. Despite the lack of comparable data between 2008 and previous years, the agricultural (animal grazing) activities within the North Fork watershed likely result in higher loads of these constituents compared to the Upper Mainstem. In order to gain a better understanding of these sources within the North Fork watershed, it is recommended that the North Fork at Livermore (NFL) site be sampled for total coliform and *E.coli* in 2009.

**Figure 12. Concentrations of total coliforms at key Upper CLP monitoring sites**

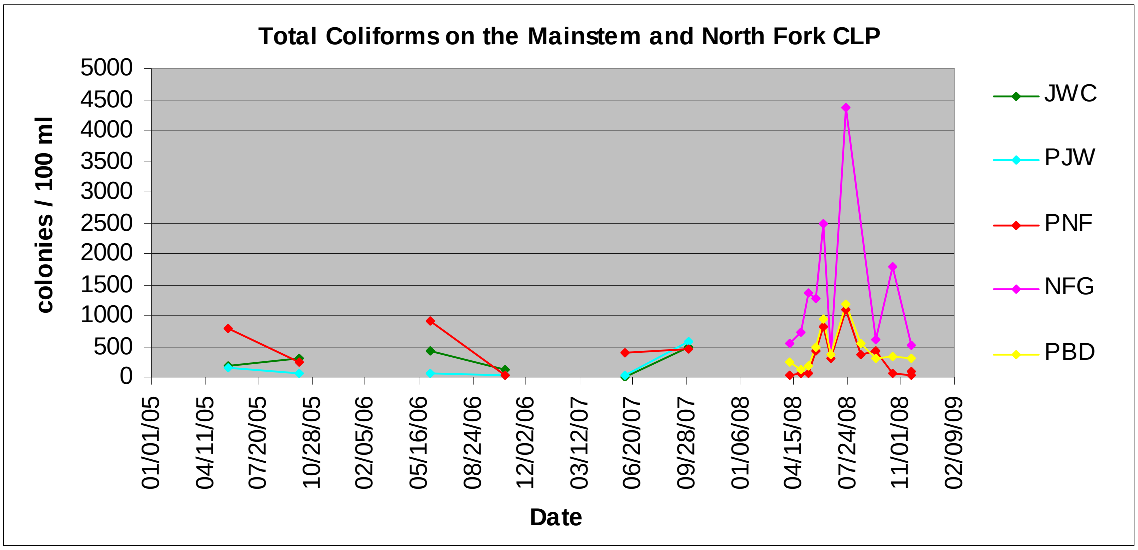
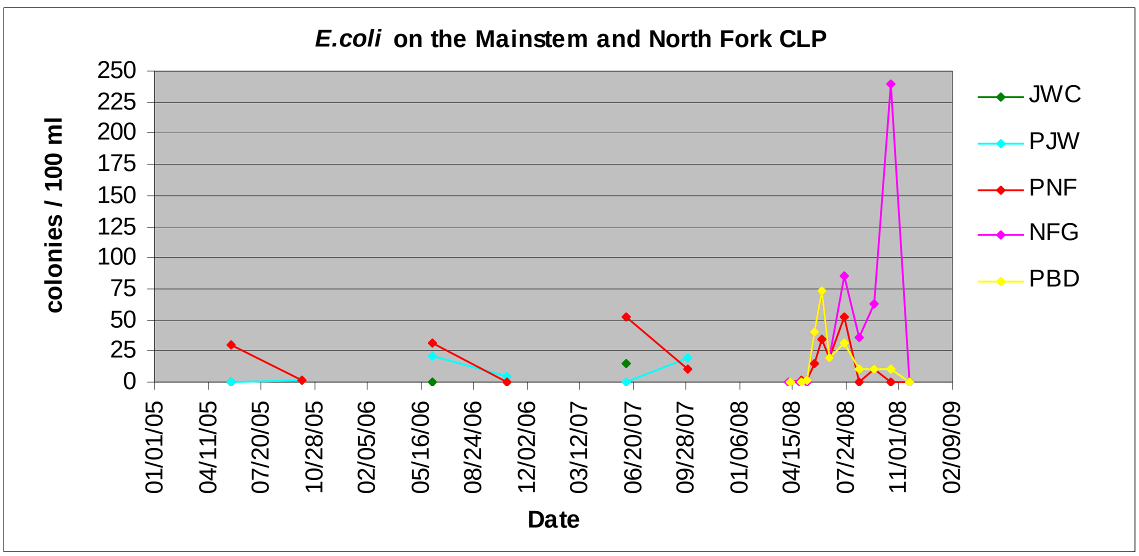


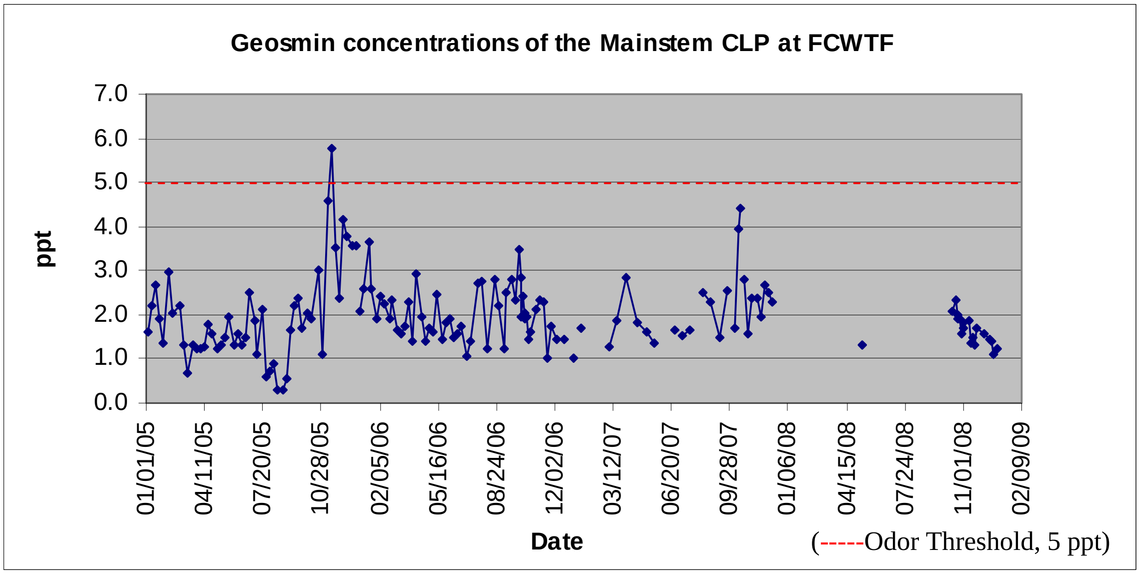

**Figure 13. Concentrations of *E. coli* at key Upper CLP monitoring sites.**




## 2.9 Geosmin

Geosmin samples for the Upper CLP Mainstem were collected from October through December at the FCWTF raw Poudre sample station. Concentrations of all samples were below the 5 parts per trillion (ppt) odor threshold; values ranged from 1.1 to 2.3 ppt. The 2008 values were similar to 2005 – 2007 concentrations (Fig. 14).

**Figure 14. Geosmin concentration of the Mainstem CLP, sampled at the FCWTF.**



## 3.0 SEAMAN RESERVOIR RESULTS

### 3.1 Temperature, Dissolved Oxygen, pH, and Conductivity Profiles

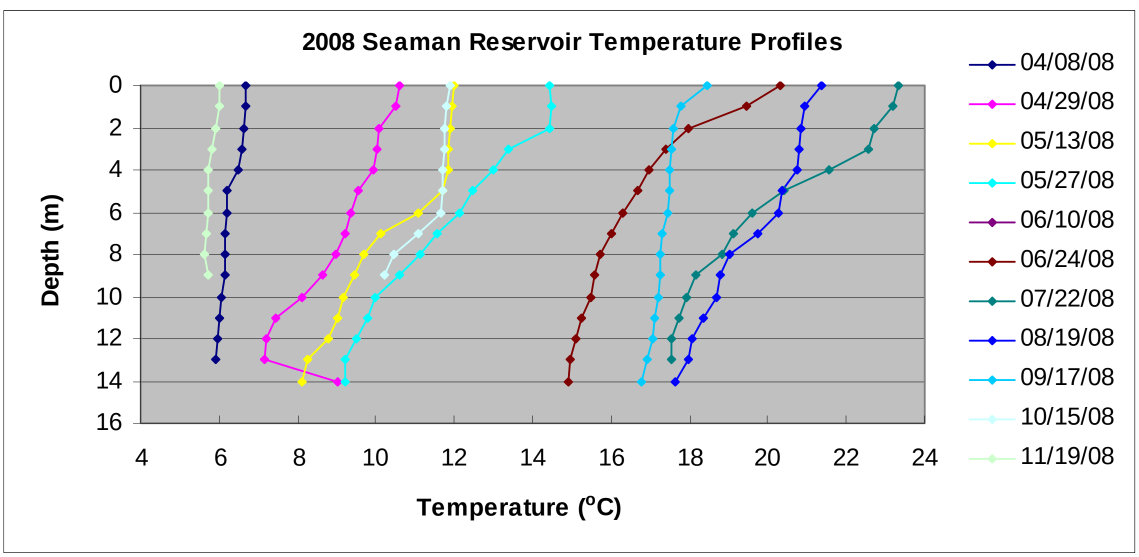
The onset of thermal stratification in Seaman Reservoir began in May, prior to the reservoir draw-down (Fig.15.a). Following the draw-down and subsequent refilling of the reservoir, stratification was again detectable by 6/24/08 and progressed through July. Because the usual progression of thermal stratification was interrupted by reservoir operations, the thermocline was only weakly established. As a result, the water column began to mix after the mid-August sampling date, which was much earlier than usual (Lewis, 2007). The earlier than usual mixing of the reservoir may be due, in part, to the lower overall depth of the reservoir than in previous years. At the time of turnover, the reservoir was 15 meters deep, which was approximately 2 meters lower than average for that time of year.

Despite the limited thermal stratification, the bottom waters still reached near-anoxic conditions with dissolved oxygen (D.O.) concentrations of 1 to 2 mg/L by the August sampling date (Fig 15.b). However, the period of low D.O. at the reservoir bottom was shorter and less severe than in the previous three years (Figure 16). The D.O. oxygen generally falls to zero at the bottom of Seaman Reservoir and remains there for a period of time. The release of manganese and phosphorus from the bottom sediments can occur during this time.

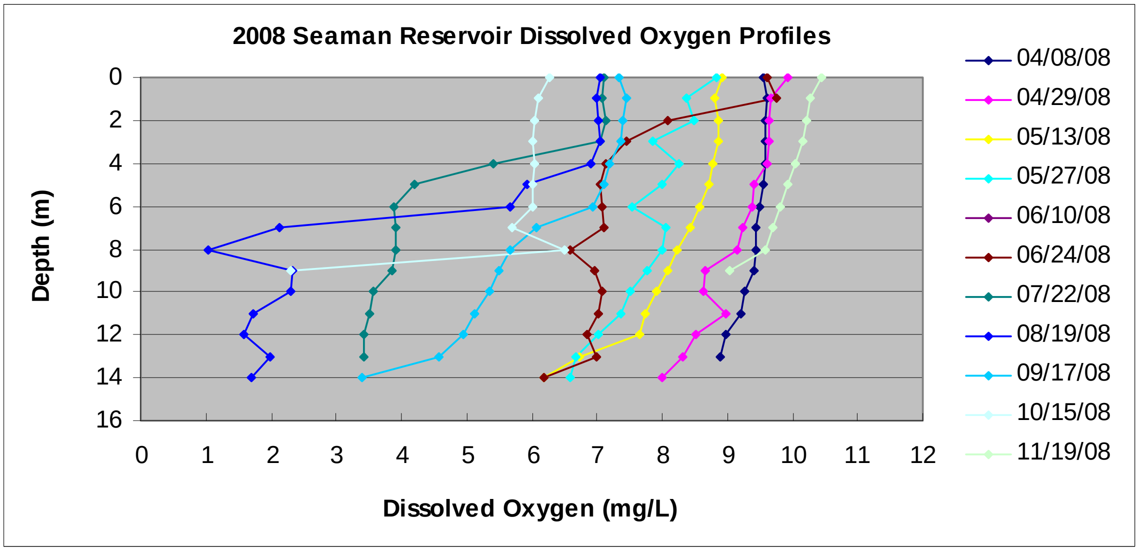
pH tracked closely with D.O. concentrations, with pH values ranging from 7.6 to 9.0 at the surface and 7.1 to 7.7 at the bottom (Fig.15c). Conductivity values were higher under well-mixed conditions, with lower values occurring from June through August (Fig. 15d). In general, conductivity did not vary substantially with depth for a given sampling date.

**Figure 15 (a-d). 2008 Seaman Reservoir Profiles**

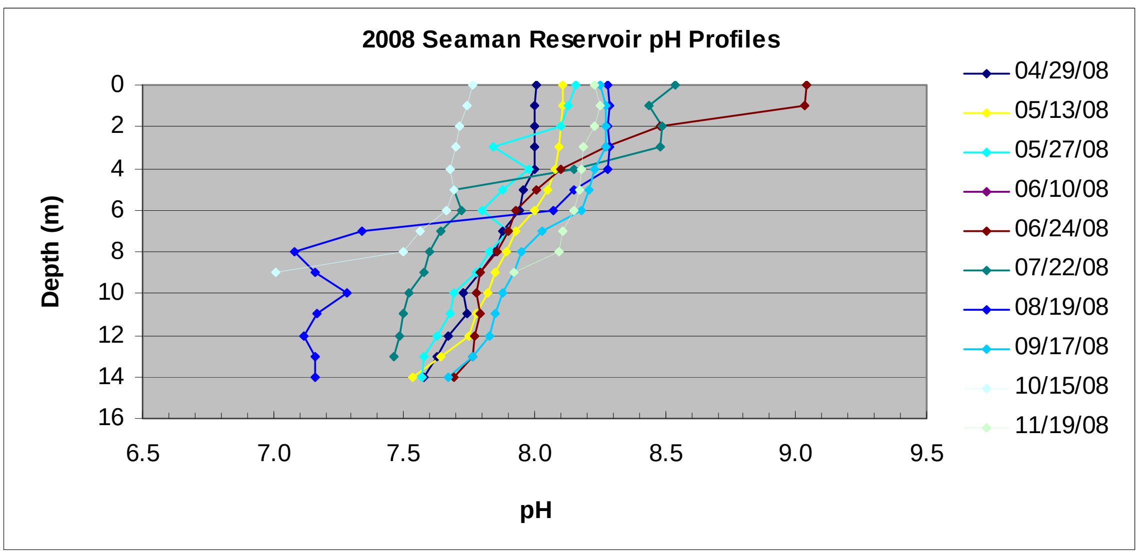
**15.a Temperature**



### 15.b. Dissolved Oxygen




### 15.c. pH



**15.d. Conductance**

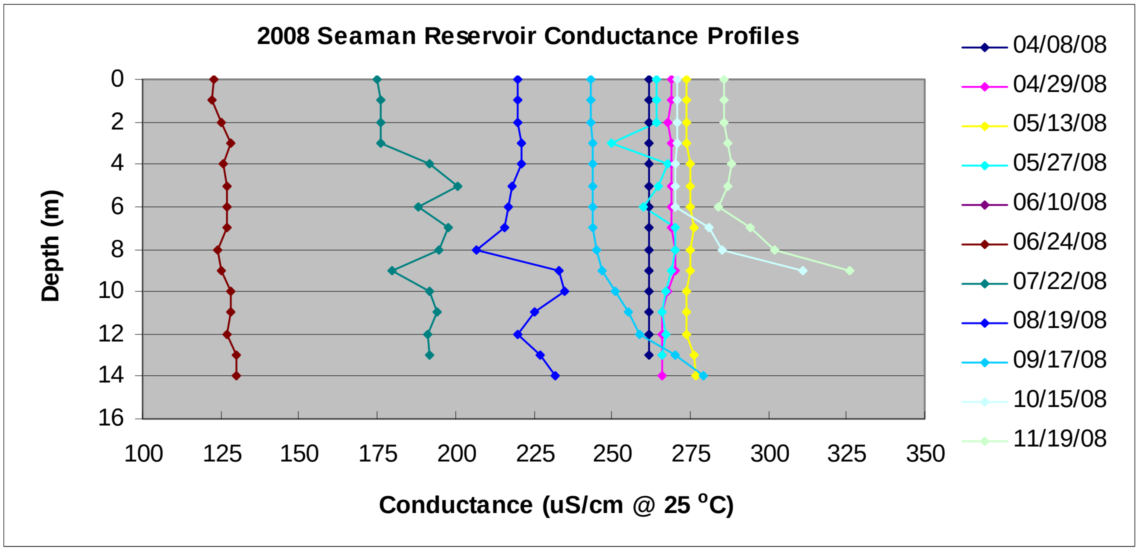
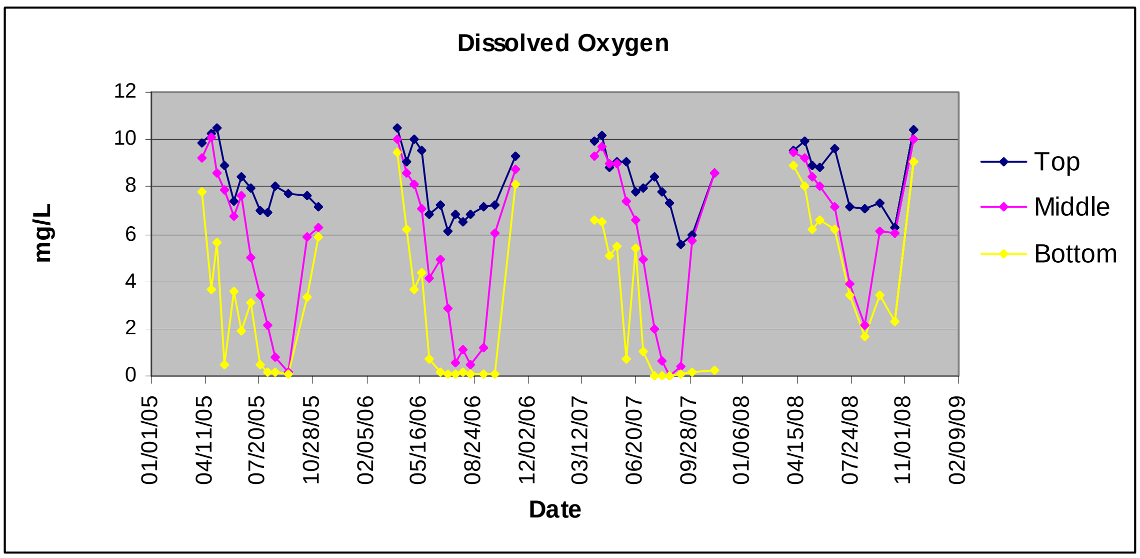



**Figure 16. Dissolved oxygen concentrations at the top, middle and bottom of Seaman Reservoir.**



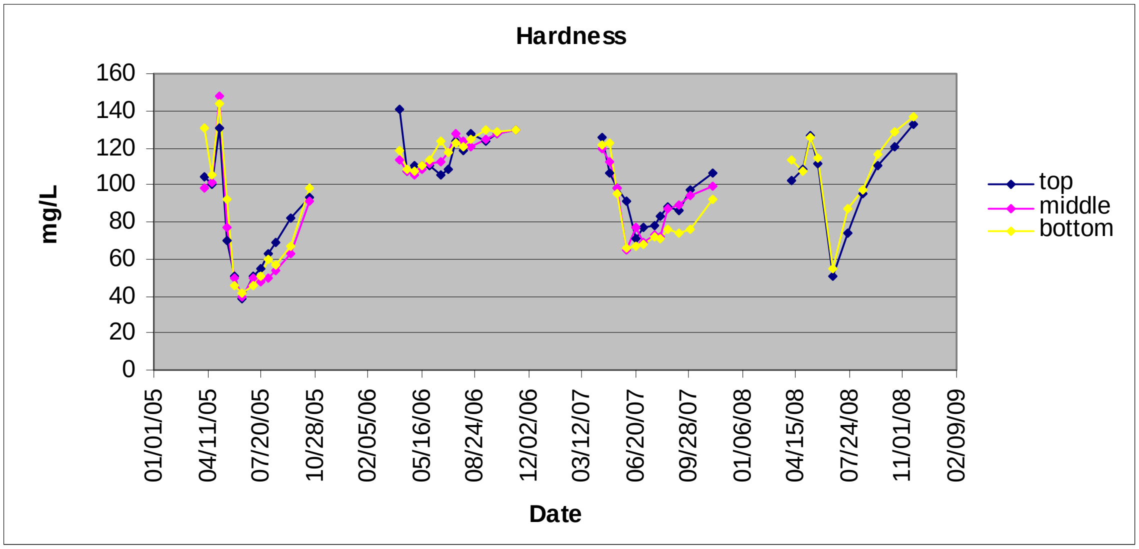

## 3.2 General Parameters: Hardness, Alkalinity and Turbidity

Hardness and alkalinity values were similar; both parameters track closely on top and bottom (Fig. 17.a and 17.b). In 2008, the seasonal trend in hardness was similar to 2005 and 2007 during which a strong spring decrease in hardness was observed, followed by a steady return to early spring values. 2006 hardness values exhibited a much smaller decrease than other years.

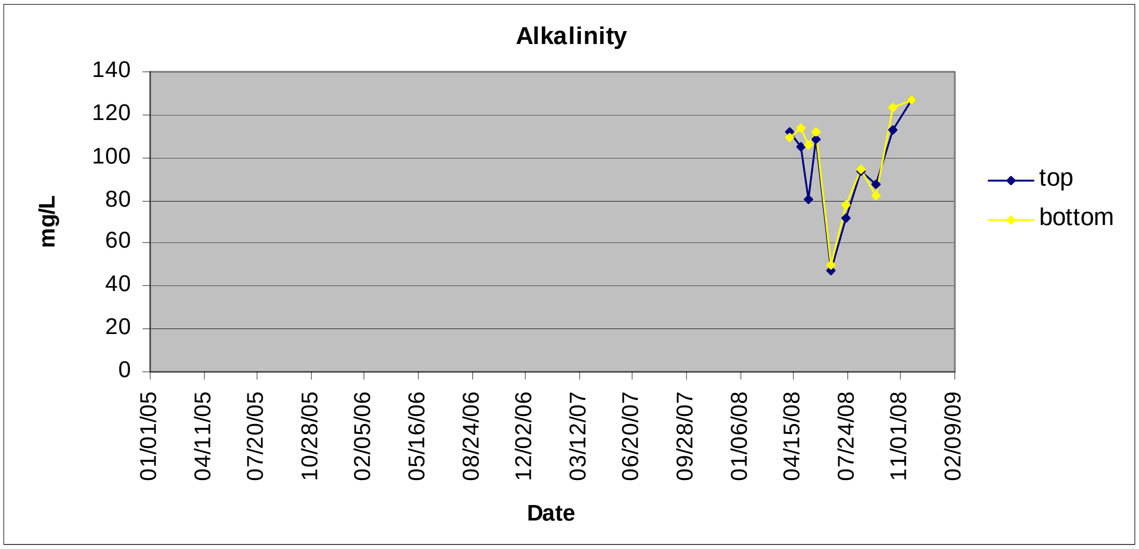
The 2008 alkalinity data followed a similar seasonal pattern as hardness; data were not available for previous years. For both parameters, minimum values occurred on 6/24/08. In general, turbidity did not differ on the top and bottom of the reservoir, with the exception of a strong top peak (8.62 NTU) on 8/19/08 (Fig.17.c).

**Figure 17 (a-c). General water quality parameters at Seaman Reservoir: Hardness, Alkalinity and Turbidity.**

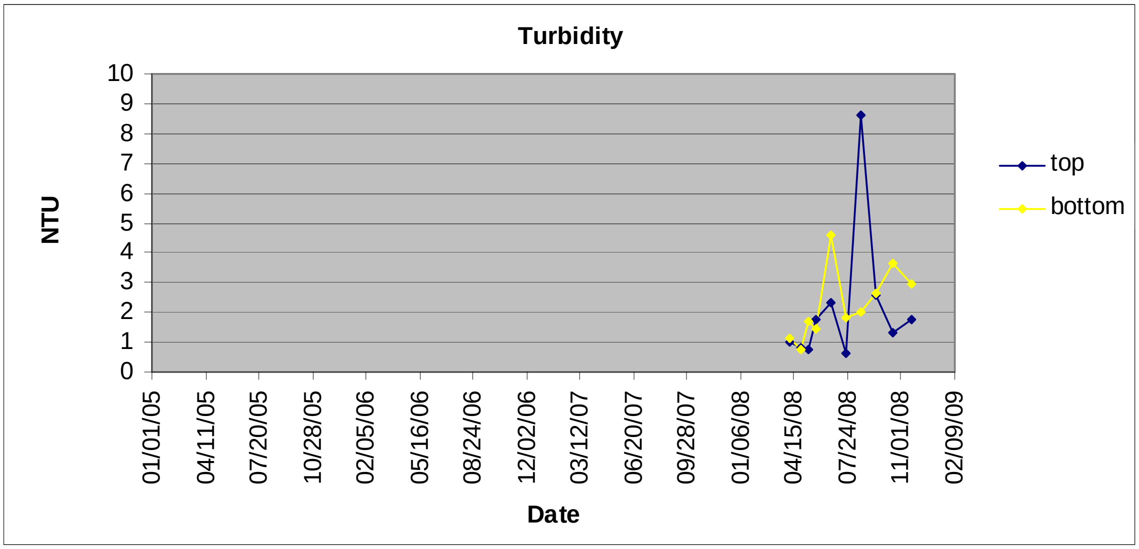
**Turbidity 17.a. Hardness**




**17.b. Alkalinity**



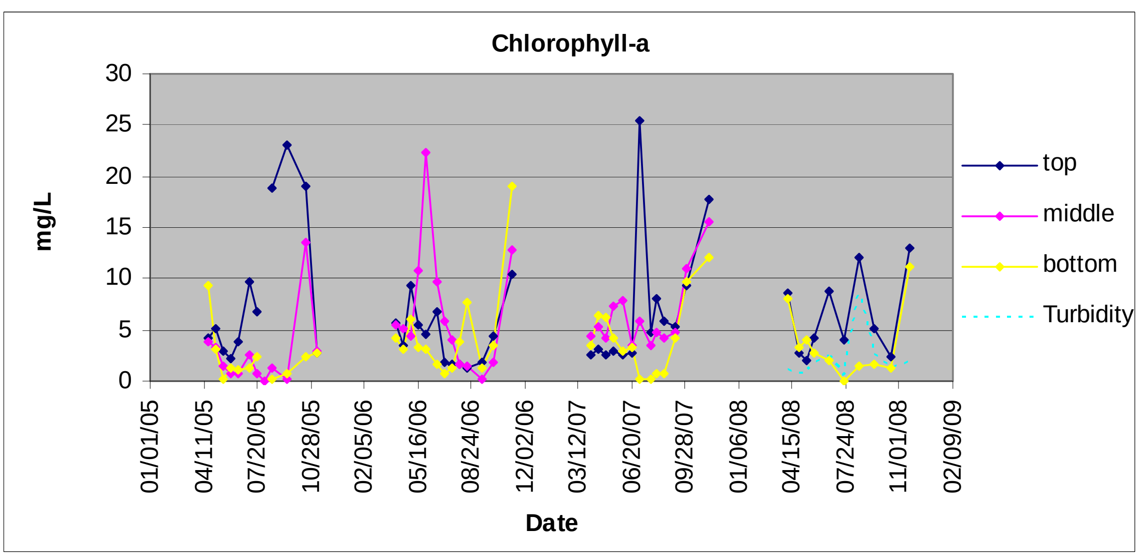
**17.c. Turbidity**




## 3.3 Chlorophyll-a and Secchi depth

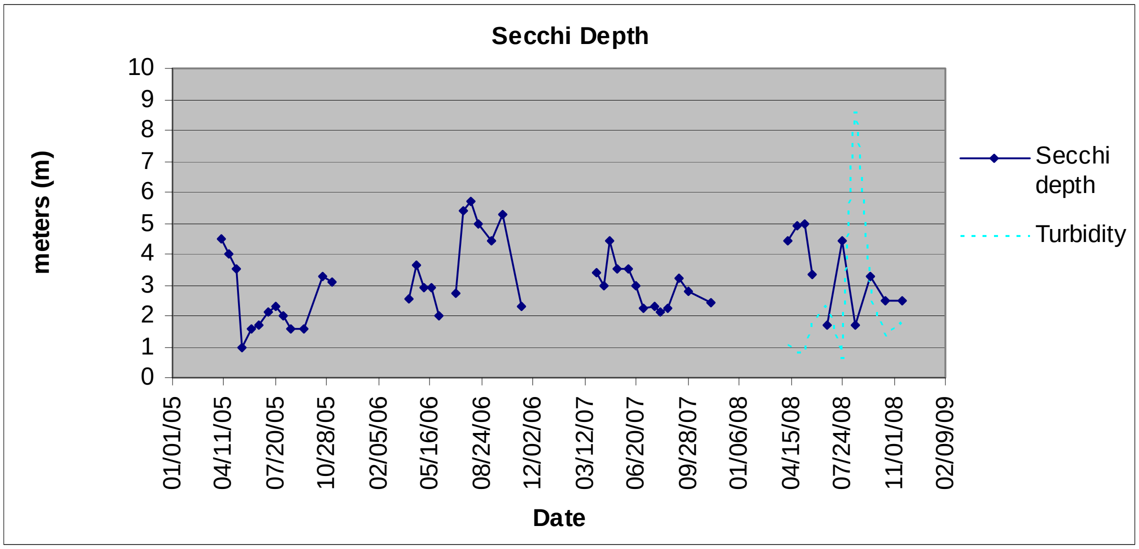
Chlorophyll-a concentrations in Seaman Reservoir were within the range observed for the previous three years, although maximum values were lower in 2008 (Fig. 18). Chlorophyll-a was consistently higher on the top than on the bottom, with the exception of a late season spike in bottom concentrations which occurred in 2006. Changes in chlorophyll-a and turbidity tracked closely, suggesting that algal growth is an important contributor to turbidity, especially from mid-summer through fall. There were no apparent long-term or seasonal trends in chlorophyll-a concentrations over time.

**Figure 18. Chlorophyll-a concentrations in Seaman Reservoir.**



Secchi depth, a measure of water clarity, varied between 1.7 and 5 meters throughout 2008 and values were comparable to the previous three years (Fig.19). Visual inspection of Figure 19 indicates that the 2008 Secchi depth data were generally inversely related to the turbidity data: when turbidity goes up, the Secchi depth goes down; when turbidity goes down, Secchi depth goes up.

**Figure 19. Secchi depth in Seaman Reservoir.**



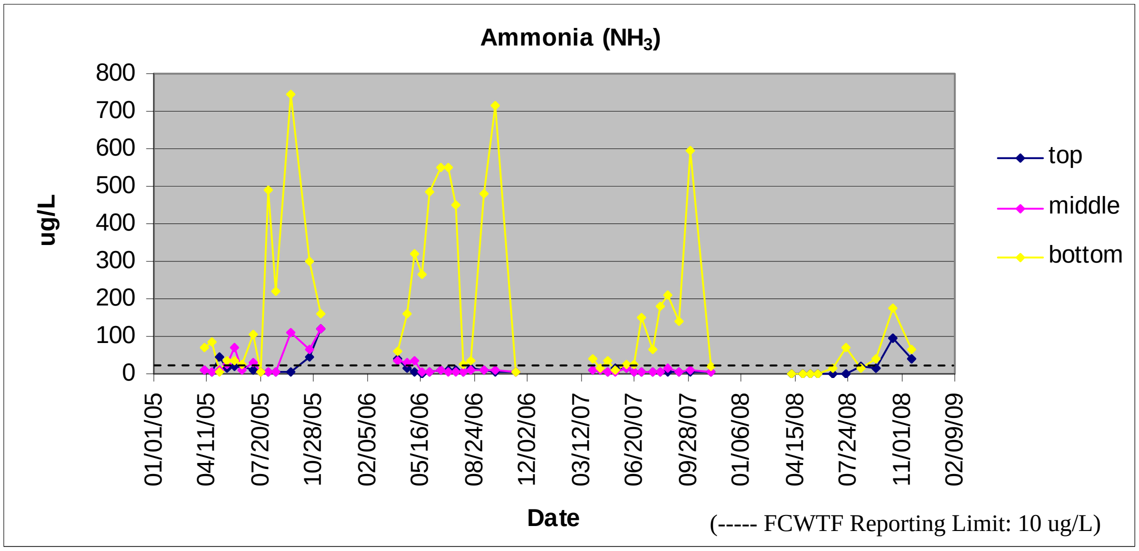

## 3.4 Nutrients

Concentrations of nitrate, ortho-phosphate and total phosphorus at the bottom of Seaman Reservoir peaked on August 19 (Fig. 20), coincident with the lowest observed pH and D.O. values in the hypolimnion. Phosphorus is released from the bottom sediments during periods of anoxia. Similarly, high ammonia concentrations can also occur at the bottom of Seaman Reservoir due to anoxic conditions, although this was not observed on the August 19 sampling date. The late season peaks in ammonia, ortho-phosphate and total phosphorus at the reservoir bottom were significantly lower in 2008 than in the previous three years because of the short period of low dissolved oxygen and the early reservoir turnover.

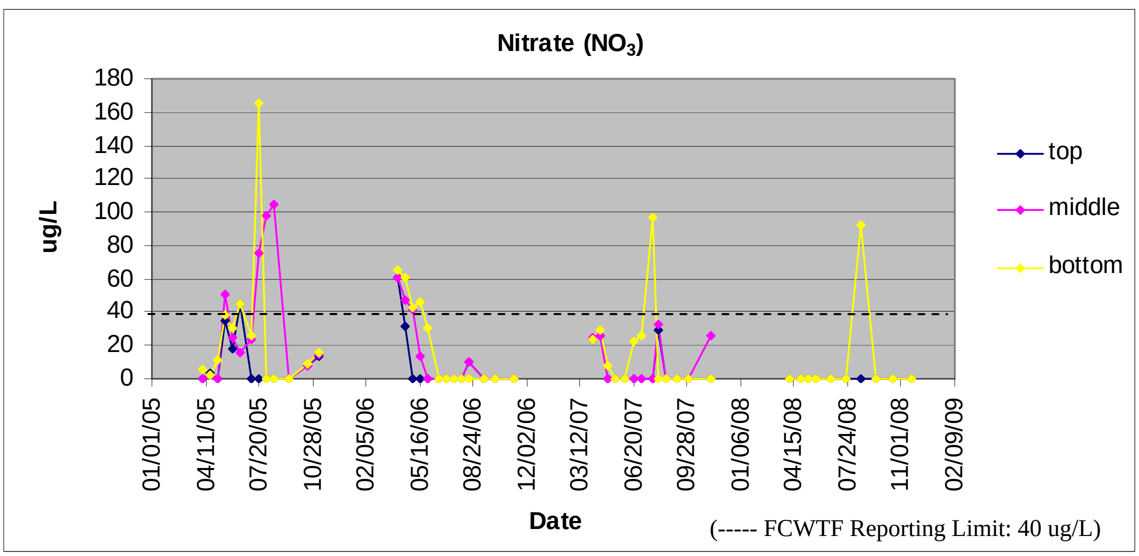
In general, ortho-phosphate, nitrate and nitrite concentrations were very low or not detected at the top of the reservoir in 2008. The TKN concentration at the top of the reservoir peaked on August 19 and was significantly higher than the TKN concentration at the reservoir bottom on that day. Concentrations of ammonia and total phosphorus at the top of the reservoir increased in the fall, likely due to reservoir mixing.

**Figure 20 (a-f). Nutrient concentrations in Seaman Reservoir.**

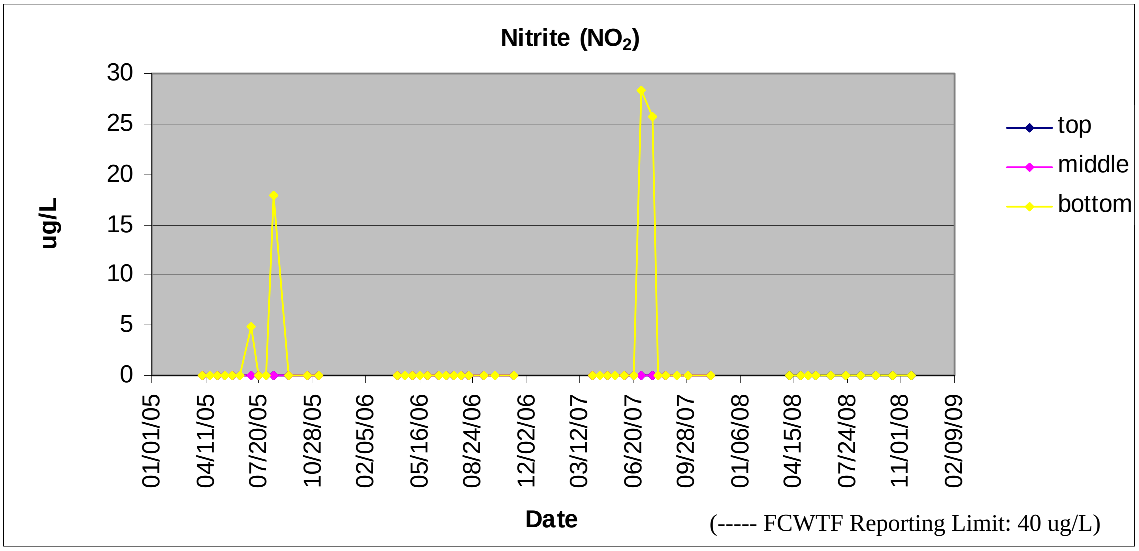
**20.a. Ammonia ($NH_3$)**



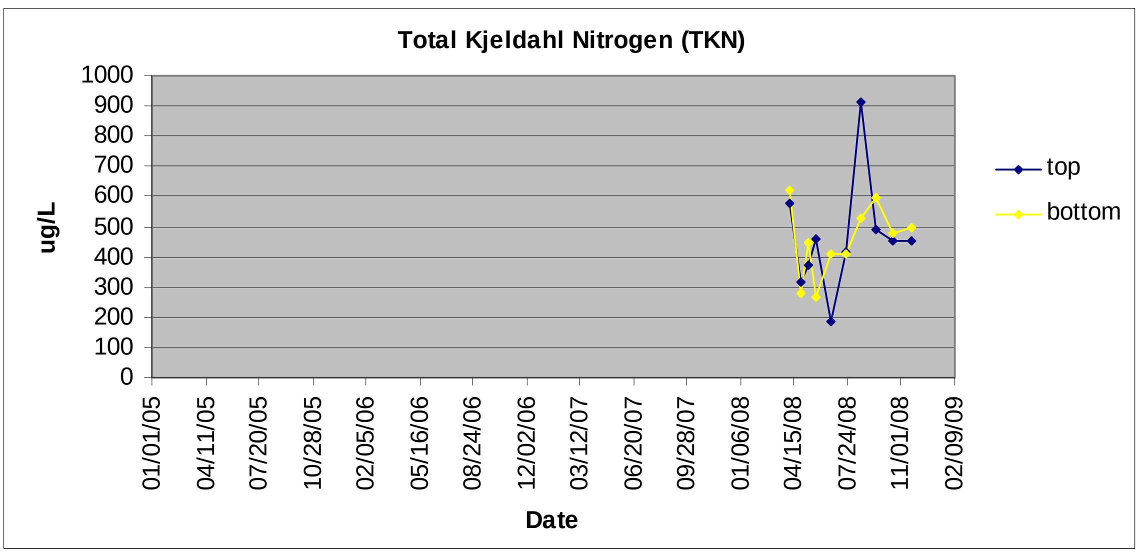

**20.b. Nitrate ($NO_3$)**



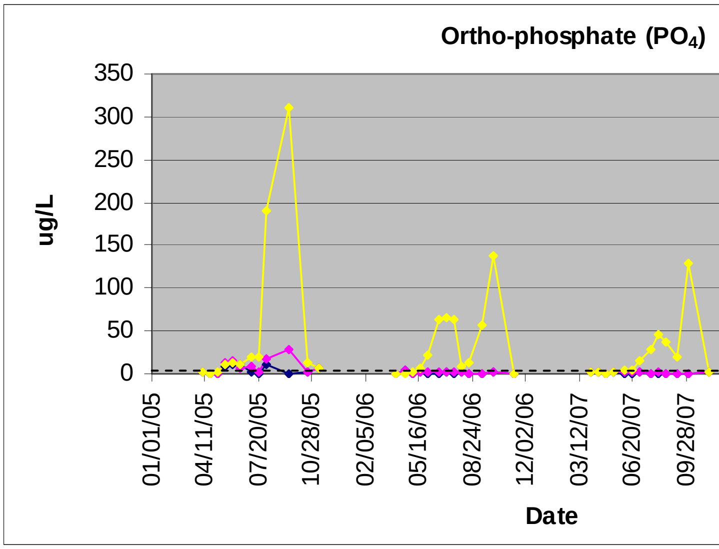
**20.c. Nitrite ($NO_2$)**




**20.d. Total Kjeldahl Nitrogen (TKN)**

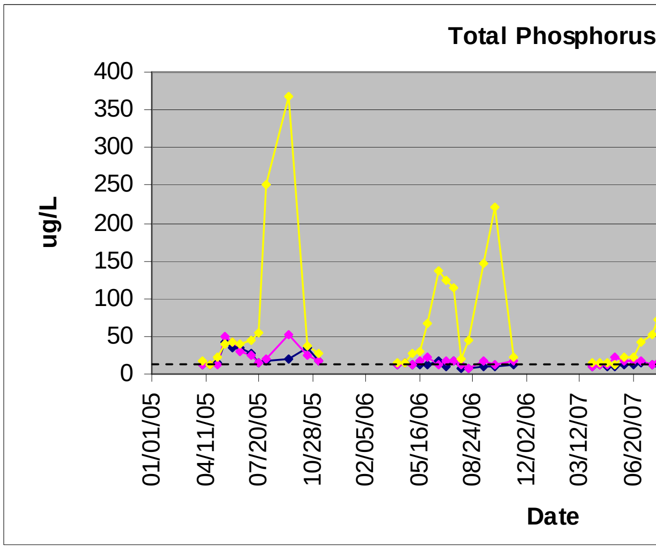


**20.e Ortho-phosphate ($PO_4$)**




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

**20.f. Total Phosphorus (P)**

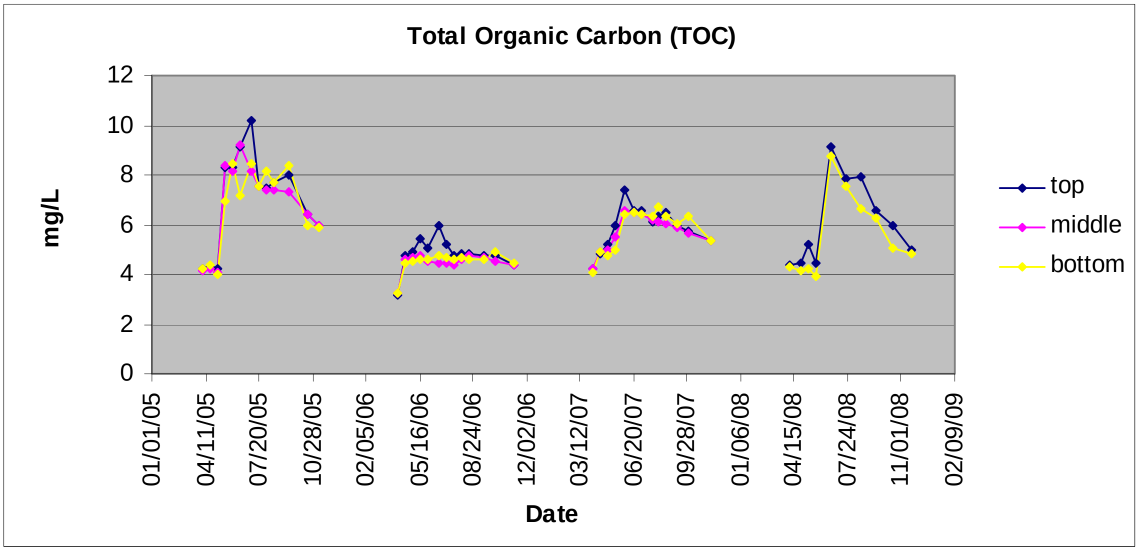



(----- FCWTF Reporting Limit: 10 ug/L)

## 3.5 Total Organic Carbon (TOC)

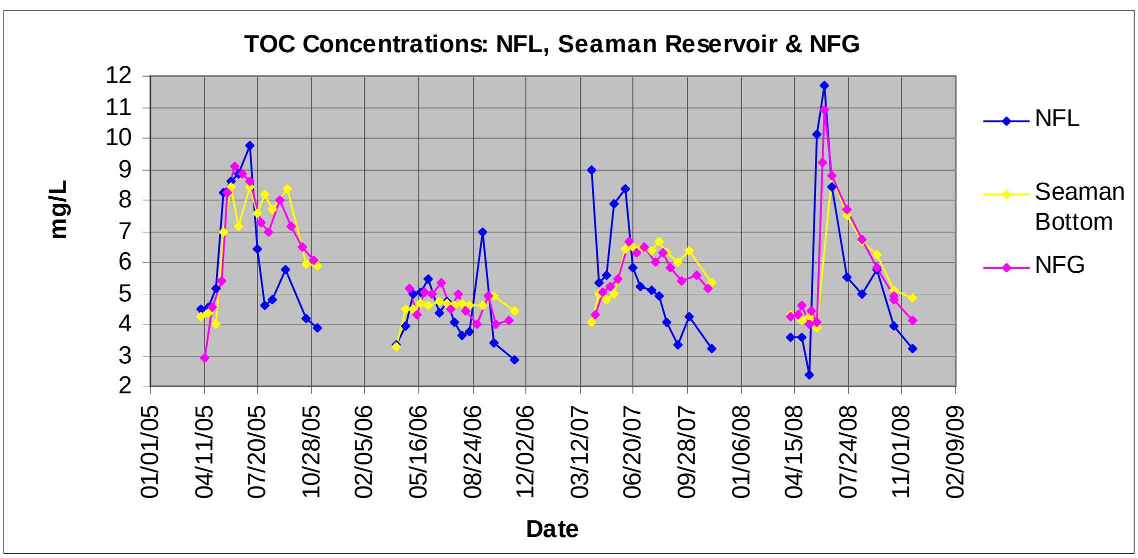
TOC values were comparable to previous years (Fig. 21) and generally did not differ between the top and bottom of the reservoir. In 2008, the peak measured TOC values were approximately 9 mg/l and occurred on 6/24/08, just prior to the refilling of the reservoir. A subsequent decline in TOC was observed throughout the summer and fall. Peak values in 2008 were considerably higher than in 2006 and 2007 (7.4 and 5.9 mg/L, respectively), but slightly less than 2005 (10.2 mg/L).

**Figure 21. TOC concentrations in Seaman Reservoir.**




The TOC concentrations on the North Fork below Seaman Reservoir (as measured at the NFG site) are generally similar to the TOC concentrations at the bottom of Seaman Reservoir (Fig. 22). After the spring runoff period, TOC concentrations at both of these locations are higher than the TOC in waters entering Seaman Reservoir (as measured at the NFL site). The TOC concentrations in Seaman Reservoir and in waters below Seaman Reservoir may be higher due to in-reservoir production of TOC from algal growth. Also, the reservoir stores high-TOC spring runoff water that is blended with lower TOC inflows and released over the course of the year.

**Figure 22. Comparison of TOC concentrations at NFL, Seaman Reservoir, and NFG.**



### 3.6 Total Coliforms and *E. coli*

Total coliforms peaked in late summer, with top and bottom concentrations of 1732 and 3654 colonies/100ml, respectively. *E. coli* concentrations were consistently very low. A comparison of NFG with Seaman Reservoir values shows that NFG often had higher total coliforms and *E. coli* than the top or bottom of the reservoir (Fig. 23 & 24). Furthermore, since there is not a clear relationship between NFG and in-reservoir values, there may be an additional bacteria source downstream of the reservoir, above the gage at NFG.

**Figure 23. Total Coliforms in Seaman Reservoir and at NFG**

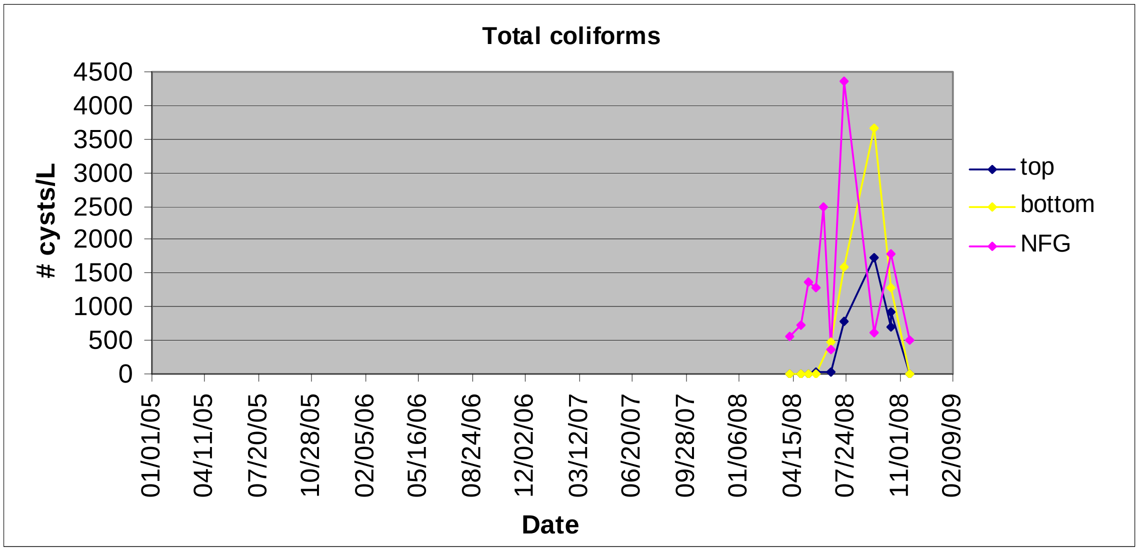
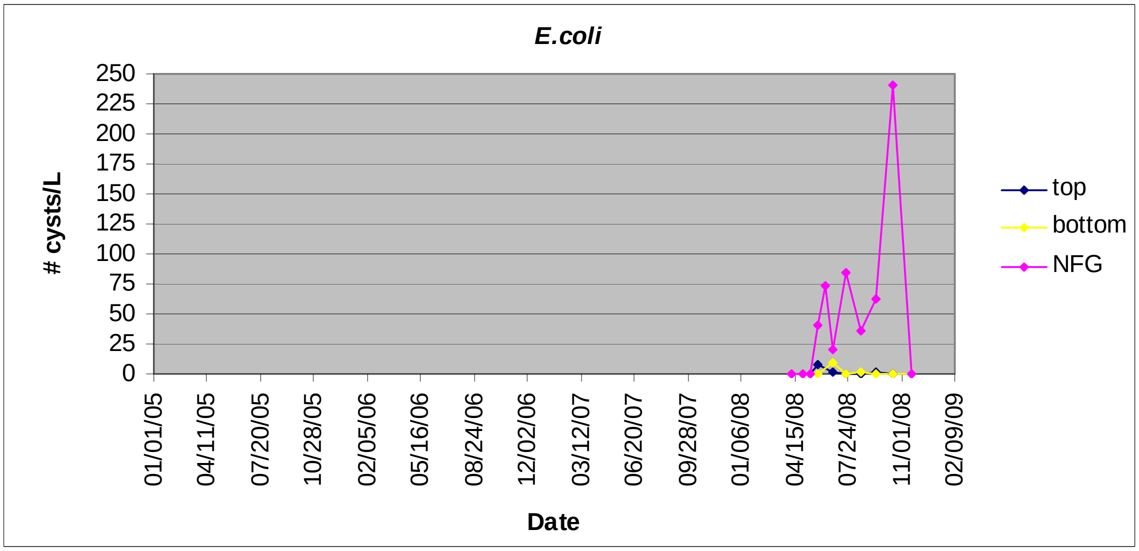


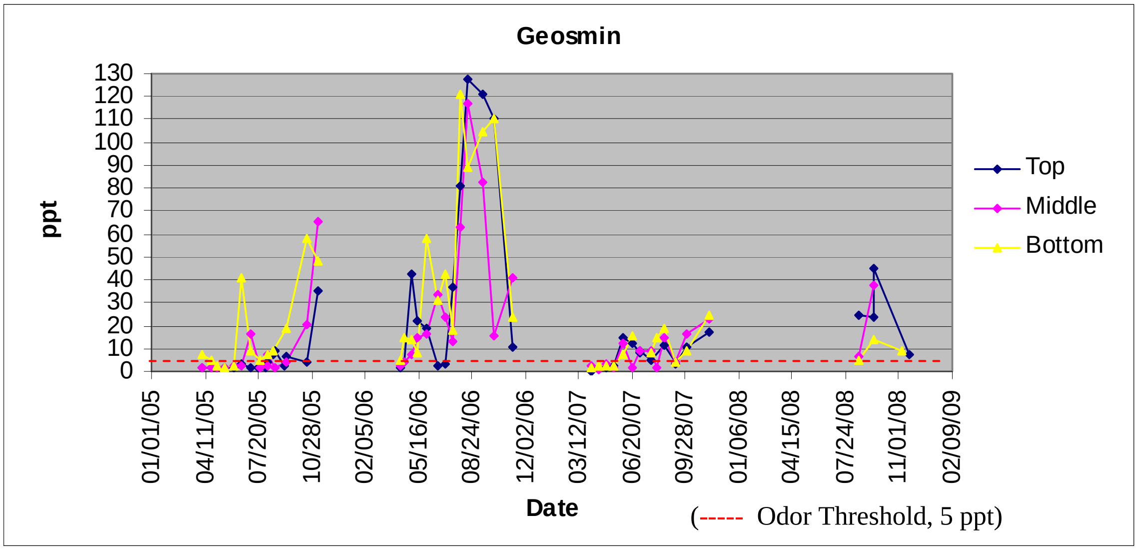

**Figure 24. Concentrations of *Escherichia coli* (*E. coli*) in Seaman Reservoir and at NFG**



## 3.7 Geosmin

In 2008, geosmin was sampled at the top, middle and bottom of the reservoir profile on three occasions between August and December. All reported values were at or above the odor threshold of 5 ppt. Maximum concentrations for top, middle and bottom occurred on 9/15/08 and were 34.17 ppt, 36.67 ppt and 13.64 ppt, respectively (Fig. 25). Peak concentrations for the previous three years ranged from 24 ppt (2007) to 128 ppt (2006).

**Figure 25. Geosmin concentrations in Seaman Reservoir.**




## 3.8 Algae

Algae sample collection was mistakenly omitted from the 2008 sampling routine. 2009 samples will be collected and analyzed according to the Upper CLP monitoring plan (Billica, Loftis and Moore, 2008).

# 4.0 SUMMARY

Review of the 2008 Upper CLP Collaborative Water Quality Monitoring Program data indicated that the program adequately captured the seasonal trends in water quality and provided a spatial context for examining notable events, such as the large precipitation event that occurred on the North Fork drainage on June 5$^{th}$ and 6$^{th}$.

The Mainstem and the North Fork, as expected, exhibited different water quality characteristics, resulting from differences in geology and elevation. In general, no significant concerns related to water quality were identified for either the Mainstem or North Fork CLP. 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.

Seaman Reservoir exhibited near-anoxic conditions in the bottom waters during the summer months. In the previous three years, the period of anoxia has been longer and more severe. The usual progression of thermal stratification was interrupted by the nine-day reservoir drawdown that occurred in early June. This resulted in a weakly established thermocline, early turnover, and a short period of near-anoxic conditions at the reservoir bottom.

The 2008 drawdown of Seaman Reservoir demonstrated the fact that reservoir releases into North Fork CLP can significantly alter the water quality at downstream locations, but the influence of these releases on the water quality at the Bellvue Diversion (PBD) is highly dependent on the time of year and volume of release.

Samples will continue to be analyzed for all parameters in 2009. Suggested changes to the Upper CLP Collaborative Water Quality Monitoring Program for 2009 include adding the algae identification that was omitted in 2008, and adding North Fork above Livermore (NFL) to the site list for total coliform and *E.coli* sampling to better understand the relationships between pathogen concentrations on the North Fork and Seaman Reservoir.

# 5.0 REFERENCES

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

Lewis Jr., W.M., 2007. Studies of Water Quality for the Water Supply to the Bellvue Water Treatment Plant: Presentation and Interpretation of Monitoring Data for Year 2006. City of Greeley, CO, March 1, 2007.

# 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, NFG, SER |
| Total Coliform | Indicator of human or animal waste contamination. | Only from Rustic downstream, 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 2008 Sampling Plan

| | 2008 Sampling Date | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | Apr 8- 9 | Apr 29- 30 | May 13-15 | May 27-28 | June 10-12 | June 24-26 | July 22-24 | Aug 19-20 | Sept 16-18 | Oct 14-15 | Nov 13,19 20 |
| North Fork | | | | | | | | | | | |
| 280NDC[3] | F,G,P | F,G,I | F,G,P | F,G,I | F,G,P | F,G,I | F,G,P | F,G,I,P | F,G,P | F,G,I,P | F,G,I |
| 270NBH[3] | F,G,P | F,G,I | F,G,P | F,G,I | F,G,P | F,G,I | F,G,P | F,G,I,P | F,G,P | F,G,I,P | F,G,I |
| 260NRC | 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 |
| 250RCM | G,D | F,G,I,D | F,G,D | F,G,I,D | F,G,D | F,G,I,D | | | | | |
| 240SCM | G,D | F,G,I,D | F,G,D | F,G,I,D | F,G,D | F,G,I,D | | | | | |
| 230PCM | G,D | F,G,I,D | F,G,D | F,G,I,D | F,G,D | F,G,I,D | | | | | |
| 220NFL | 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 |
| 200NFG | F,G,E,P[4] | F,G,I,E | F,G,E,P | F,G,I,M,E | F,G,E,P | F,G,I,E | F,G,E,P | F,G,I,E,P | F,G,E,P | F,G,I,M,E,P | F,G,I,E |
| Main Stem | | | | | | | | | | | |
| 100CHR | 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 |
| 090BMR[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 |
| 080JWC | 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 |
| 070PJW | 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 |
| 060LRT | 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 |
| 050PBR | 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 |
| 040SFM | | F,G,I,D | | F,G,I,D | | F,G,I,D | | F,G,I,D | | F,G,I,D | F,G,I,D |
| 030PSF | 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 |
| 020PNF | 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 |
| 010PBD | 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 | | | | | | | | | | | |
| 210SER[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] To be sampled by Fort Collins personnel; all other stations to be sampled by Dr. Bill Lewis' Team.
[4] *Giardia*/*Cryptosporidium* sampling to be conducted bv Fort Collins personnel.

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*.

## 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 | none | 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 | | none | 28 days |
| | Total Dissolved Solids | SM 2540 C | 10 mg/L | cool, 4C | 7 days |
| | Turbidity (NTU) | SM2130B,EPA180.1 | 0.01 units | none | 48 hrs |
| Nutrients | Ammonia - N | Lachat 10-107-06-2C | 0.02 mg/L | $H_2SO_4$ | 28 days |
| | Nitrate + Nitrite | EPA 300 (IC) | 0.2 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 as CaCO3 | SM 3500-Ca D | 2.0 mg/L | none | 28 days |
| | 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 | 5 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 | 3 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 | 100 ug/L | $HNO_3$ pH <2 | 6 mos |
| TOC | TOC | SM 5310 C | 0.5 mg/L | HCl 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

**(included as a separate pdf file)**

**2008 Upper CLP Collaborative Water Quality Monitoring Program**

**Graphical Summary**

# 2008 Upper Cache la Poudre River Cooperative Water Quality Monitoring Program

# Graphical Summary

Prepared for:

City of Fort Collins Utilities
City of Greeley
Tri-Districts

Prepared by:

Jill Oropeza, Watershed Specialist
City of Fort Collins Utilities

Judith A. Billica, P.E., Ph.D., Senior Process Engineer
City of Fort Collins Utilities

February 23, 2009

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## List of Figures (Continued)

# Mainstem and North Fork CLP: Daily Average Stream Flow

**Figure 1 (a & b). Daily average streamflow on Mainstem and North Fork CLP.**

**Figure 1.a.** 2008 Daily average streamflow on the Mainstem and North Fork CLP.

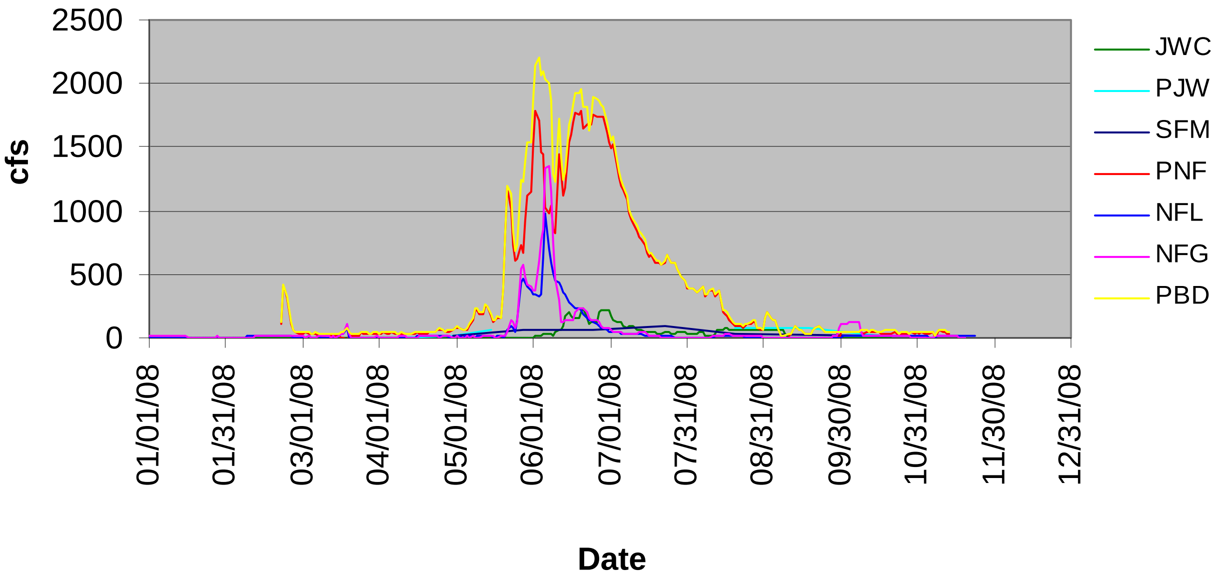



**Figure 1.b.** 2005 – 2008 Daily average streamflow on the Mainstem and North Fork CLP.

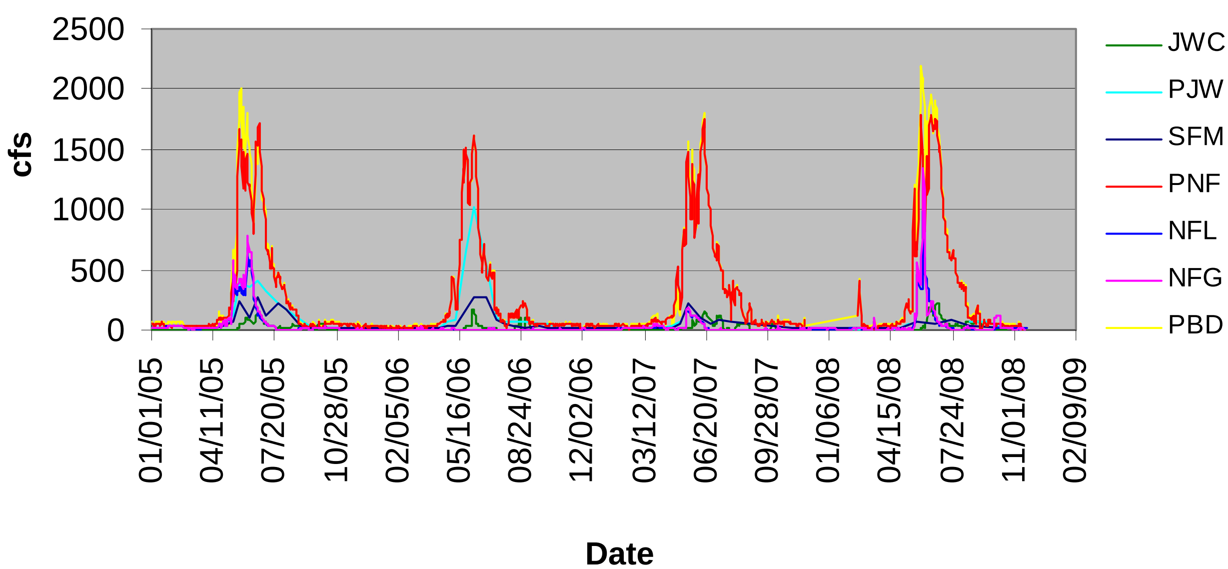


**Figure 2 (a & b). Daily average streamflow on the North Fork tributaries.**

**Figure 2.a.** 2008 Daily average streamflow on the North Fork tributaries.

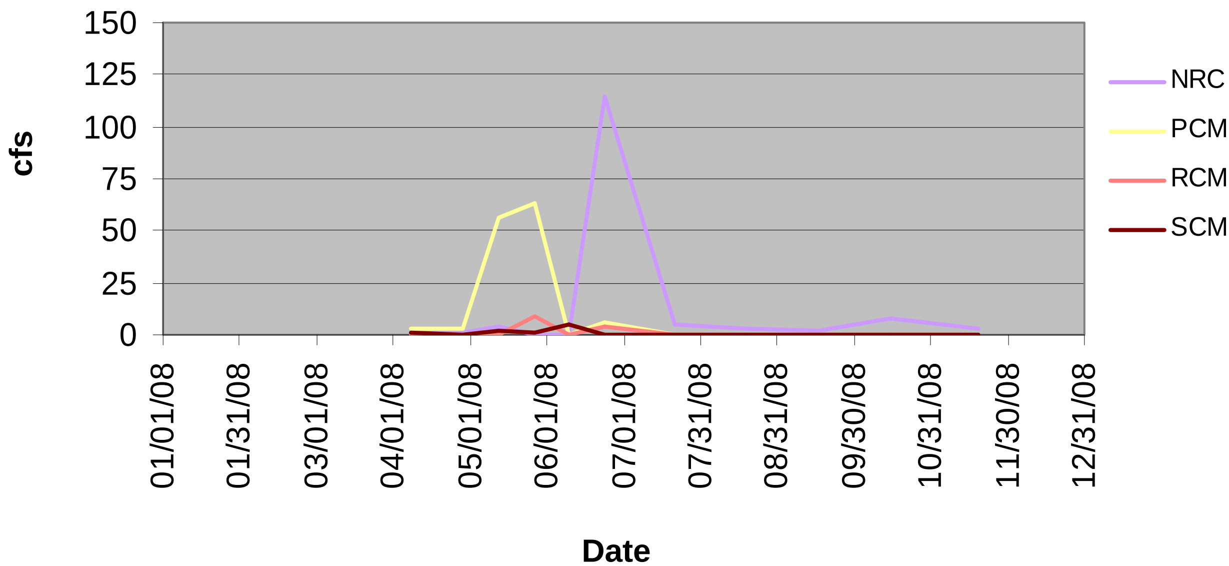
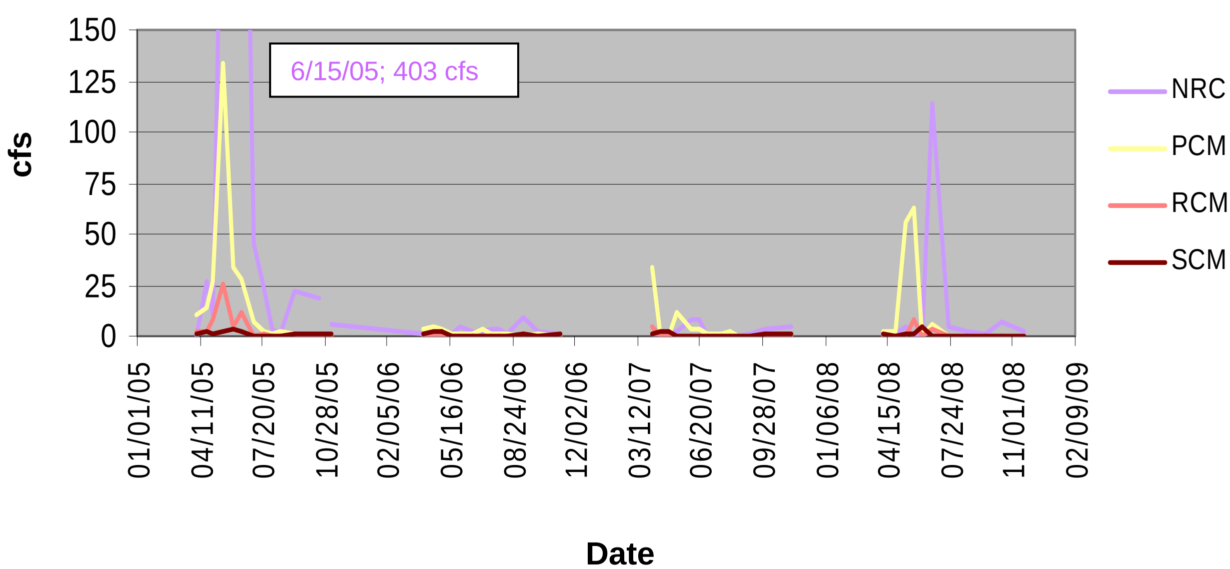



**Figure 2.b.** 2005 – 2008 Daily average streamflow on the North Fork tributaries.



# Mainstem and North Fork CLP: General Parameters

**Figure 3 (a & b). Water Temperature**

**Figure 3.a.** Water temperature on the Mainstem CLP.

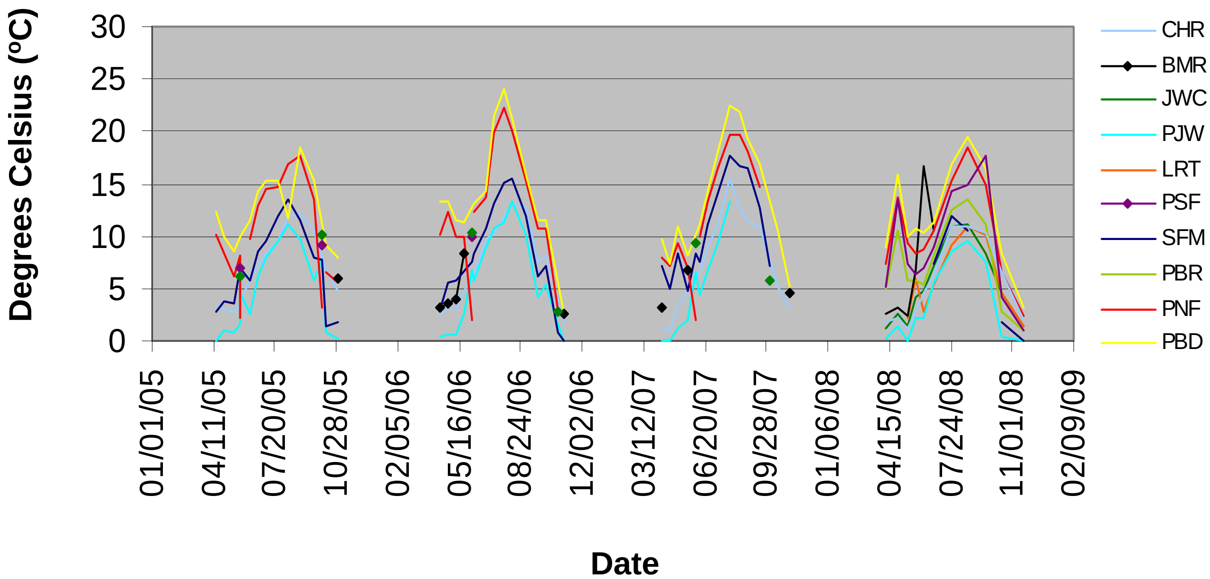



**Figure 3.b.** Water temperature on the North Fork CLP.

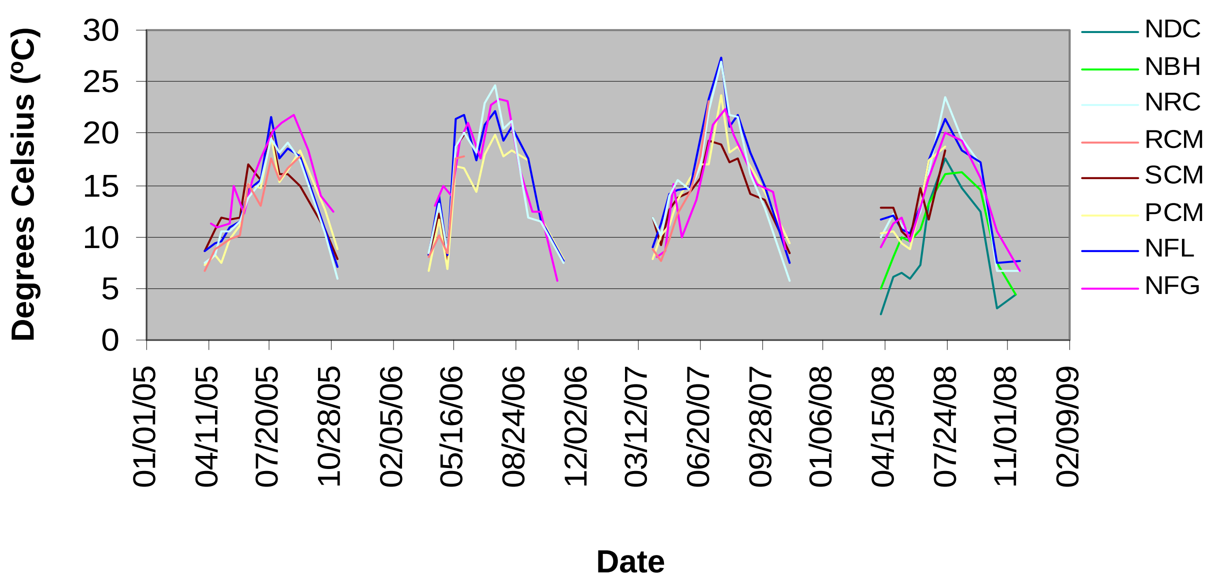


**Figure 4 (a & b). pH**

**Figure 4.a.** pH on the Mainstem CLP.

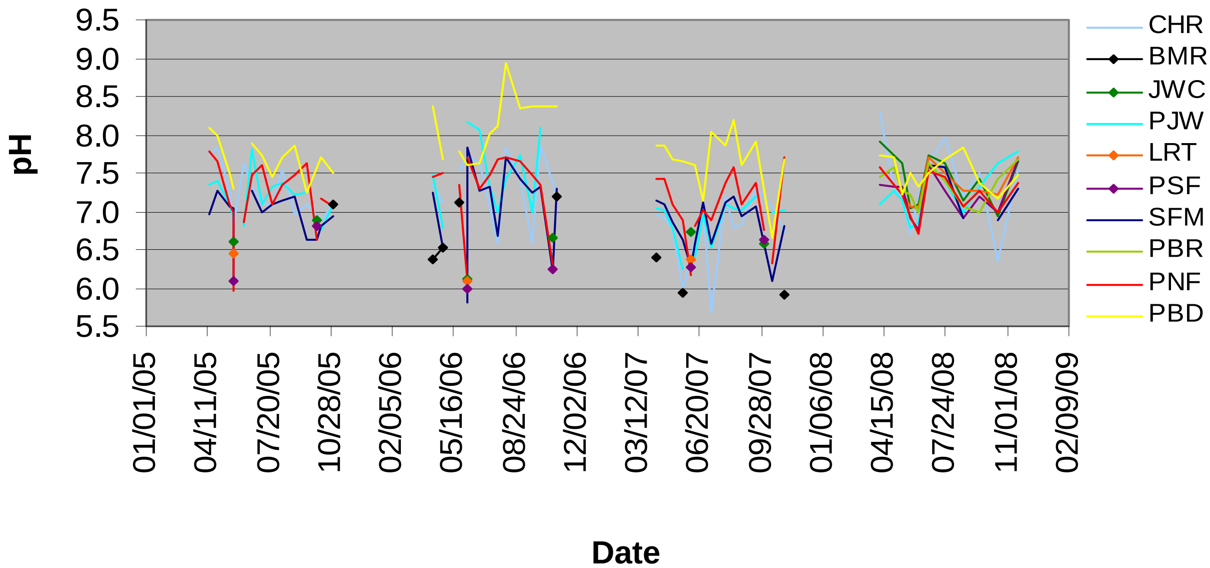



**Figure 4.b.** pH on the North Fork CLP.

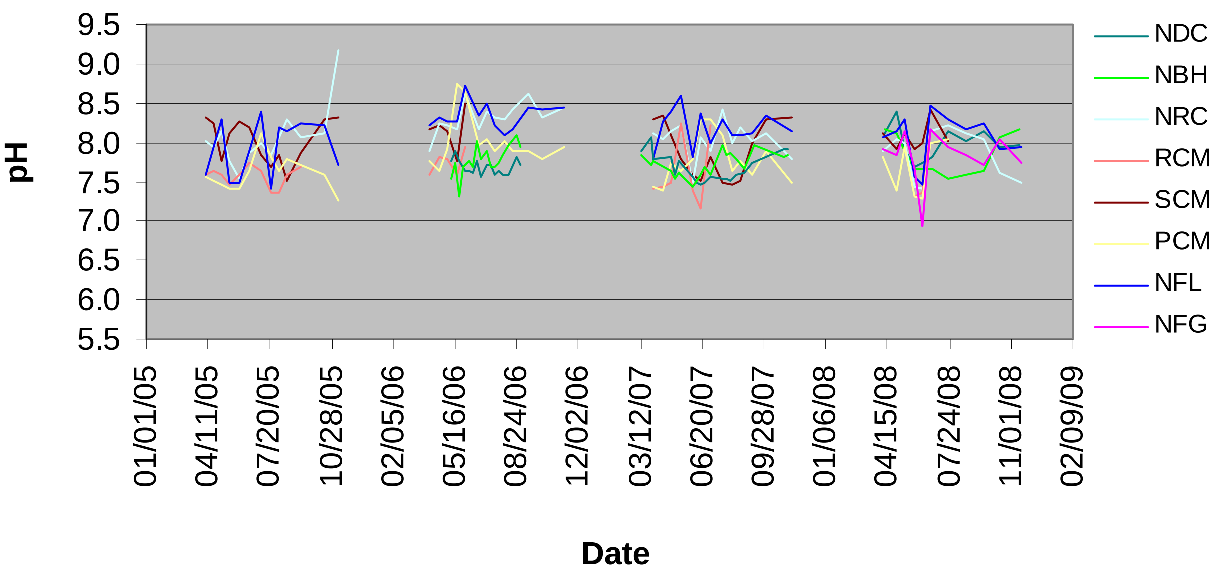


**Figure 5 (a & b). Conductivity**

**Figure 5.a.** Conductivity of the Mainstem CLP.

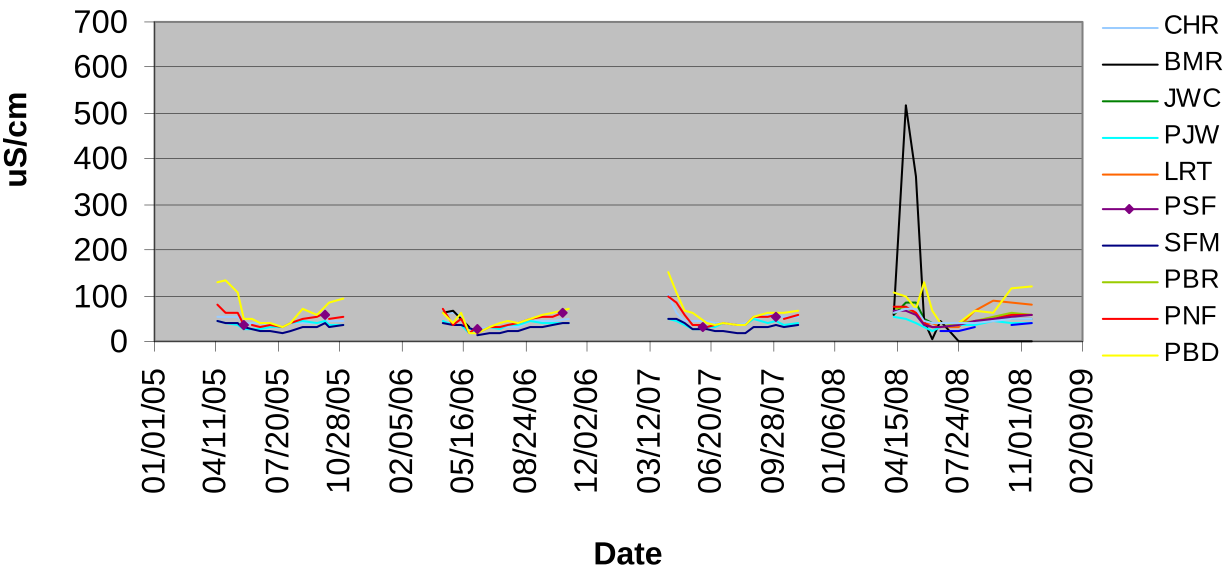



**Figure 5.b.** Conductivity of the North Fork CLP.

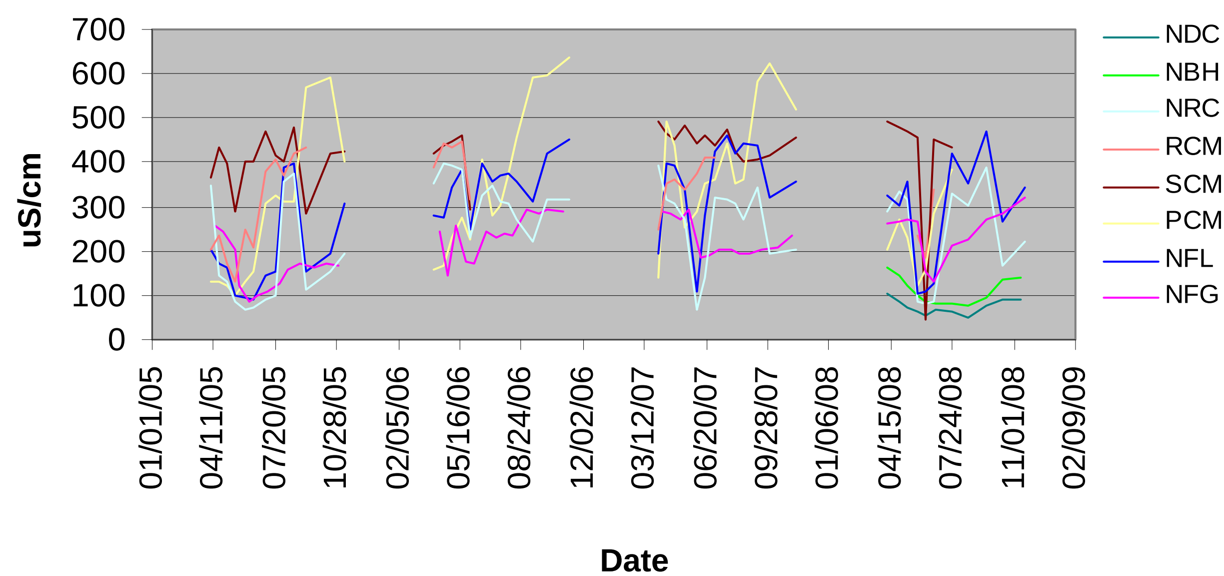


**Figure 6 (a & b). Hardness**

**Figure 6.a.** Hardness on the Mainstem CLP.

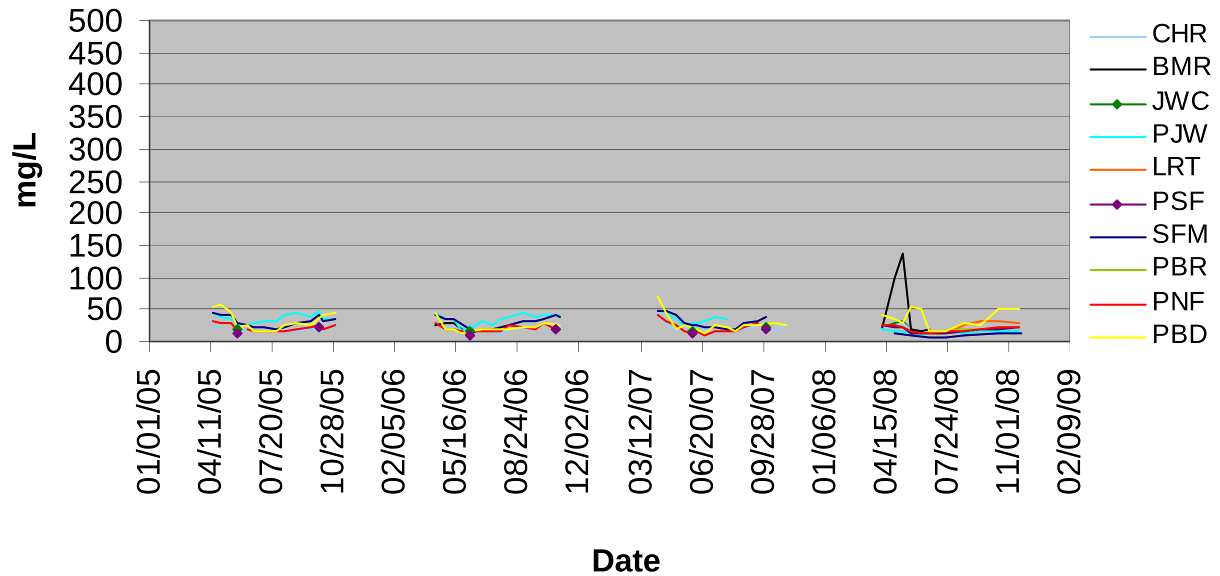



**Figure 6.b.** Hardness on the North Fork CLP.

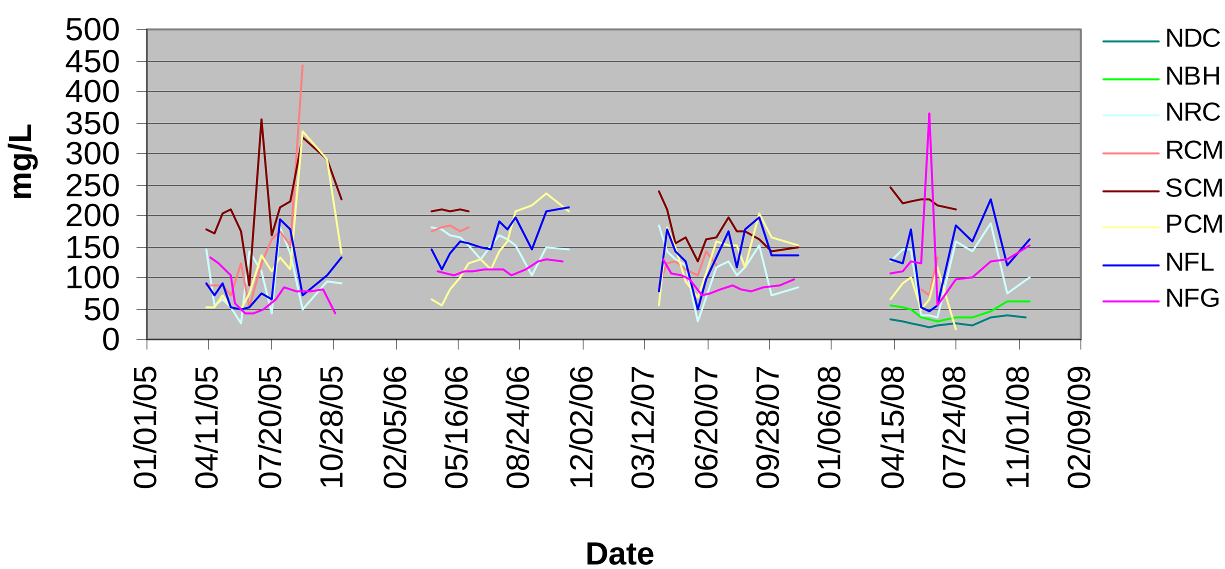


**Figure 7 (a & b). Alkalinity**

**Figure 7.a.** Alkalinity on the Mainstem CLP.

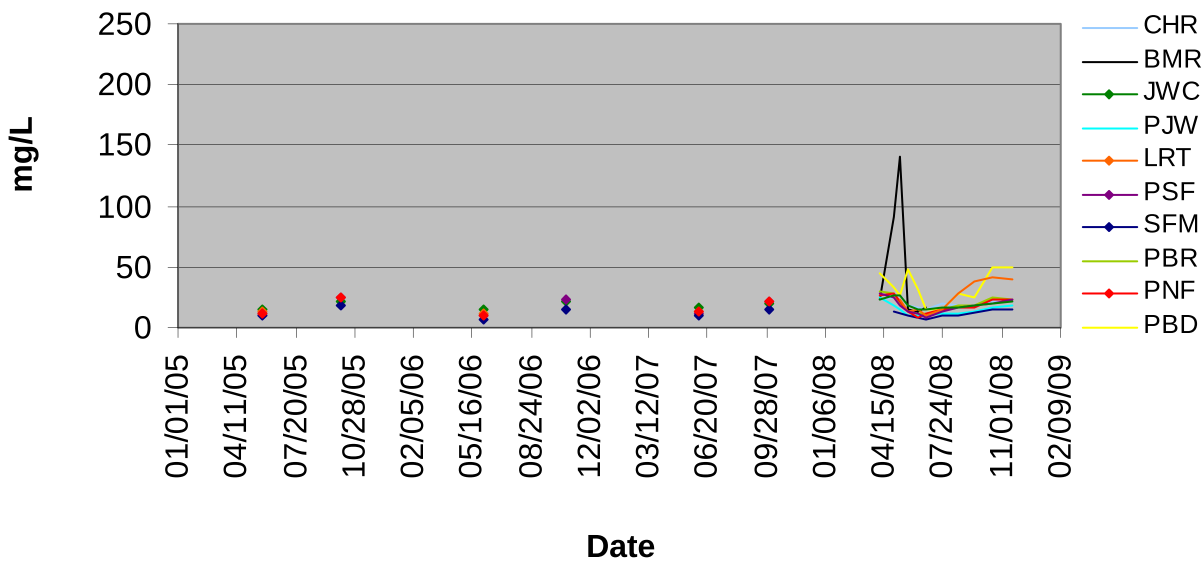



**Figure 7.b.** Alkalinity on the North Fork CLP.

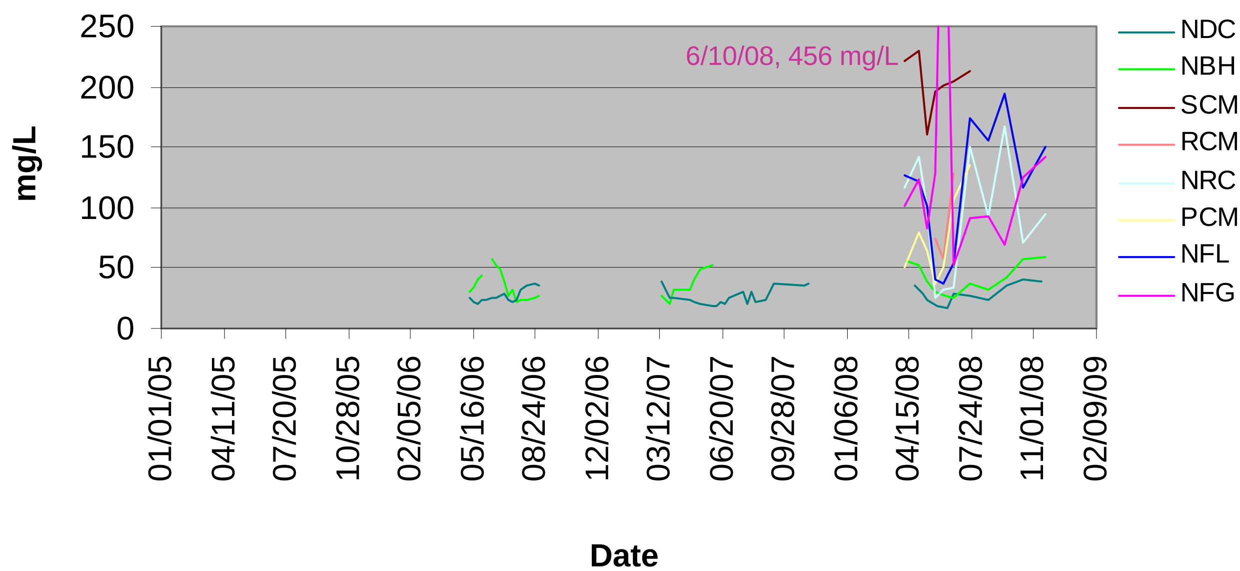


**Figure 8 (a & b). Turbidity**

**Figure 8.a.** Turbidity on the Mainstem CLP.

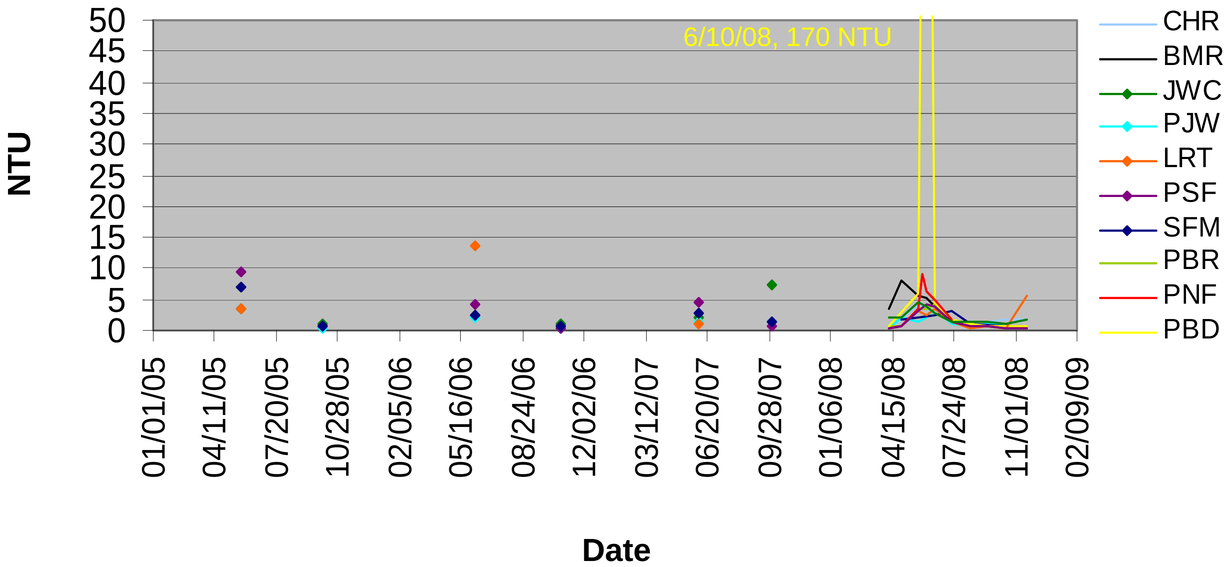
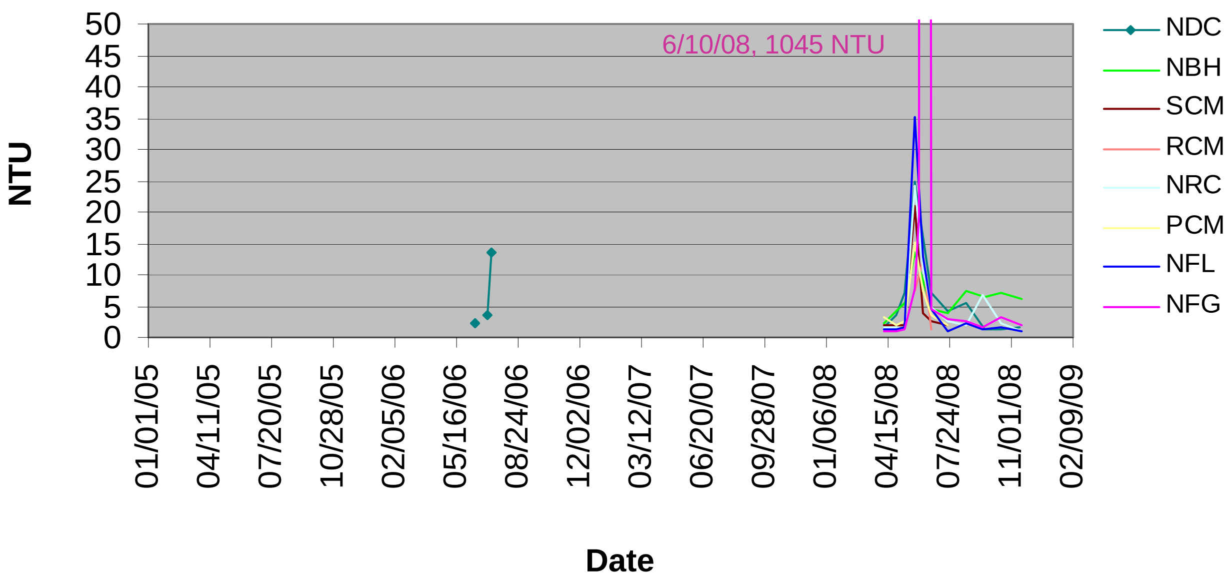



**Figure 8.b.** Turbidity on the North Fork CLP.



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

**Figure 9.a.** TDS on the Mainstem CLP.

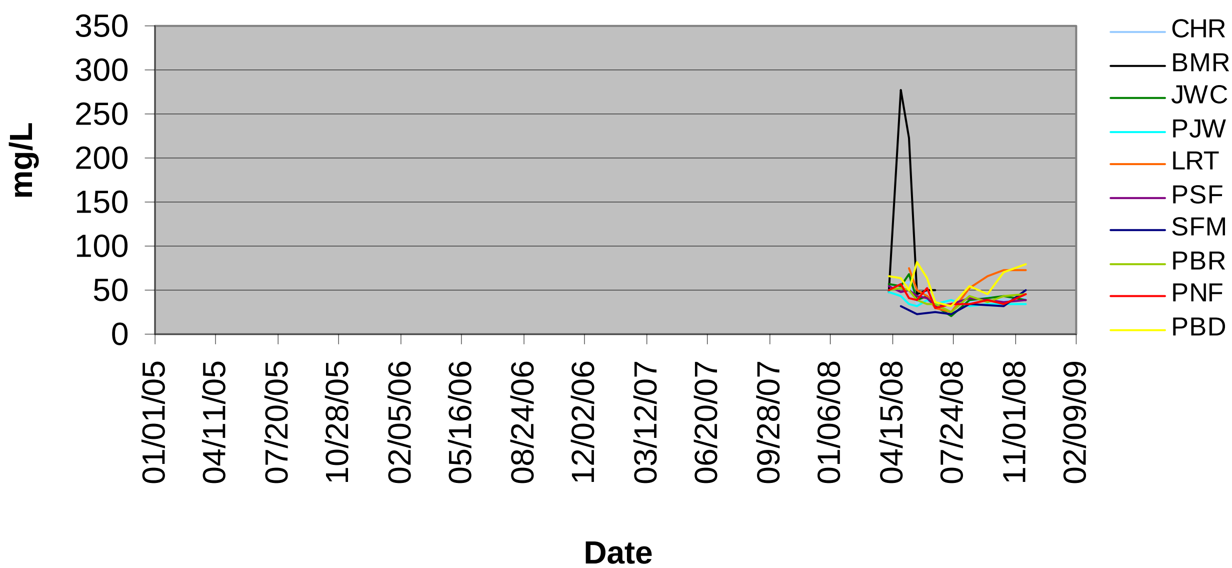



**Figure 9.b.** TDS on the North Fork CLP.

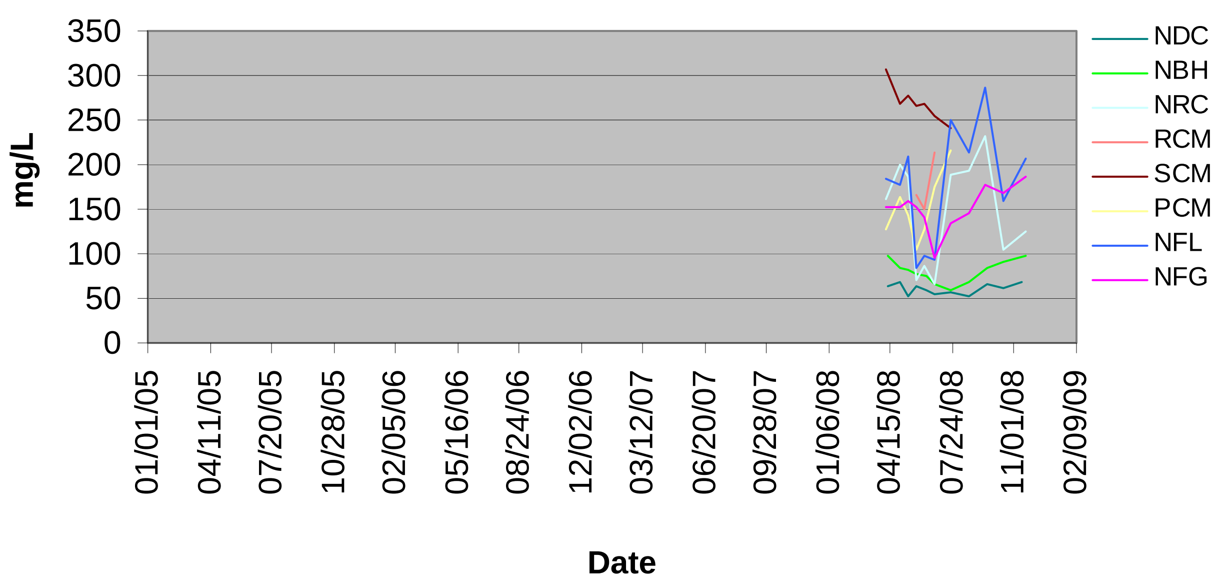


**Figure 10 (a & b). Total Organic Carbon (TOC)**

**Figure 10.a.** TOC on the Mainstem CLP.

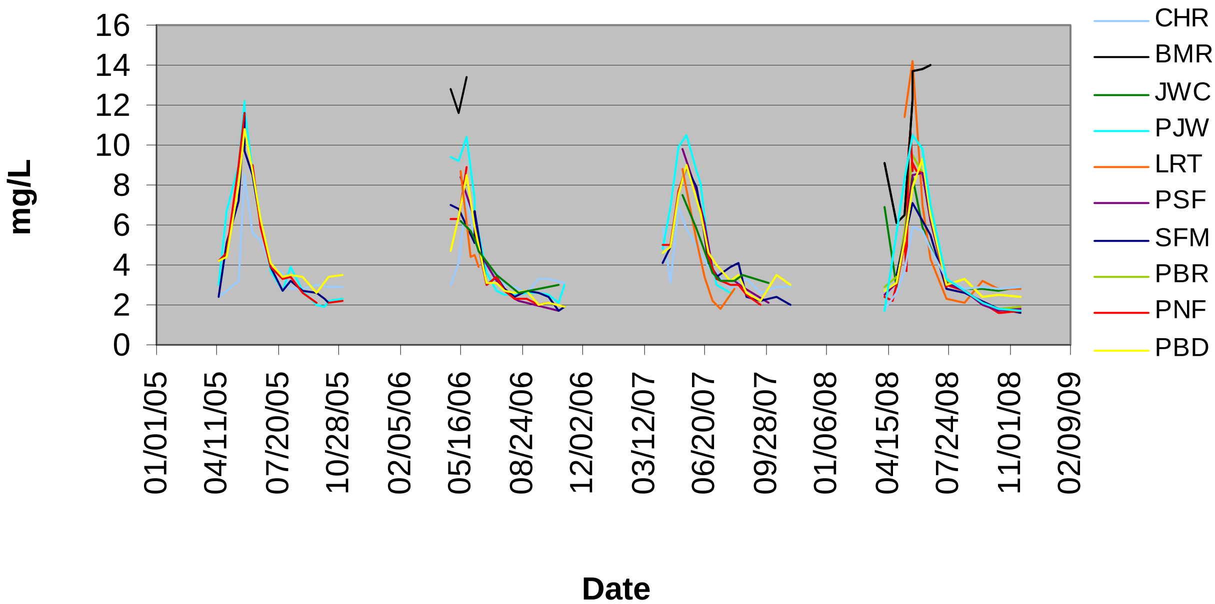
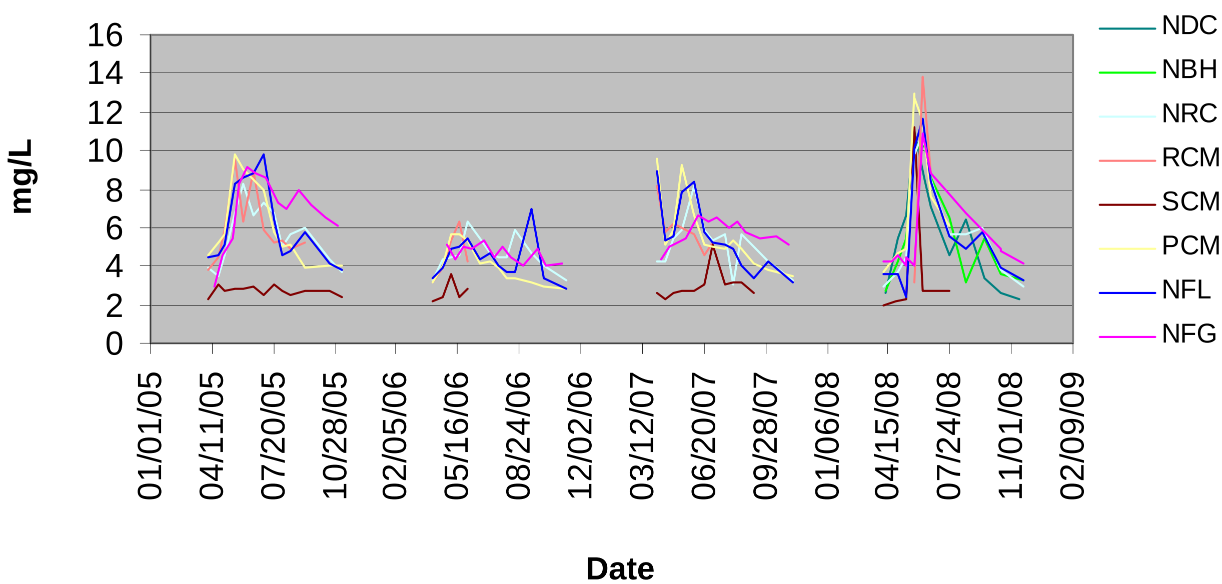


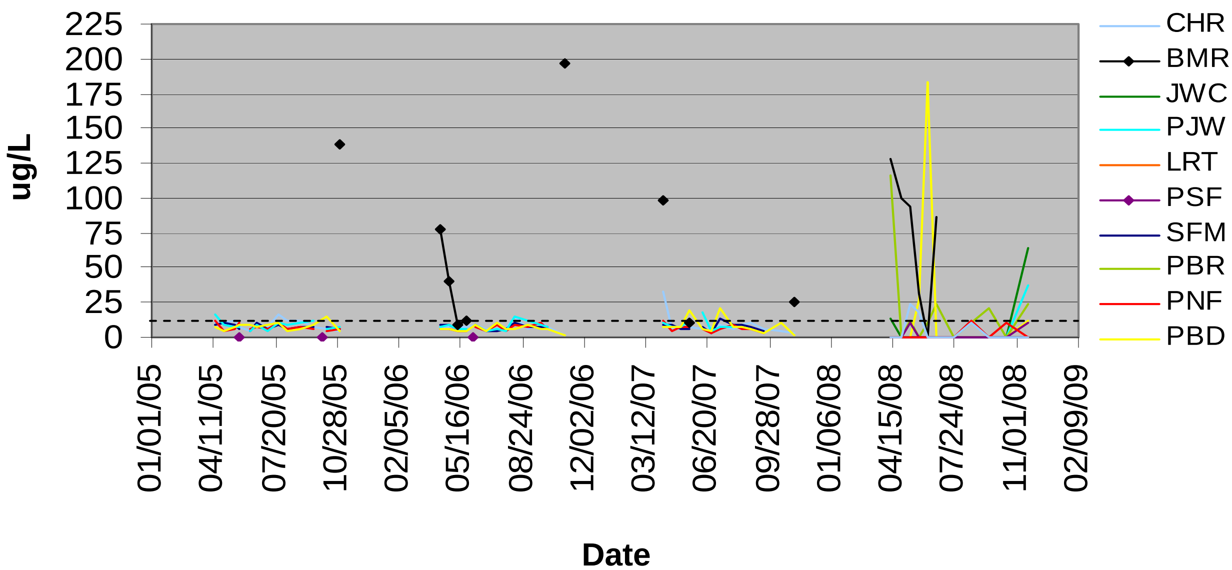

**Figure 10.b.** TOC on the North Fork CLP.



# Mainstem and North Fork CLP: Nutrients

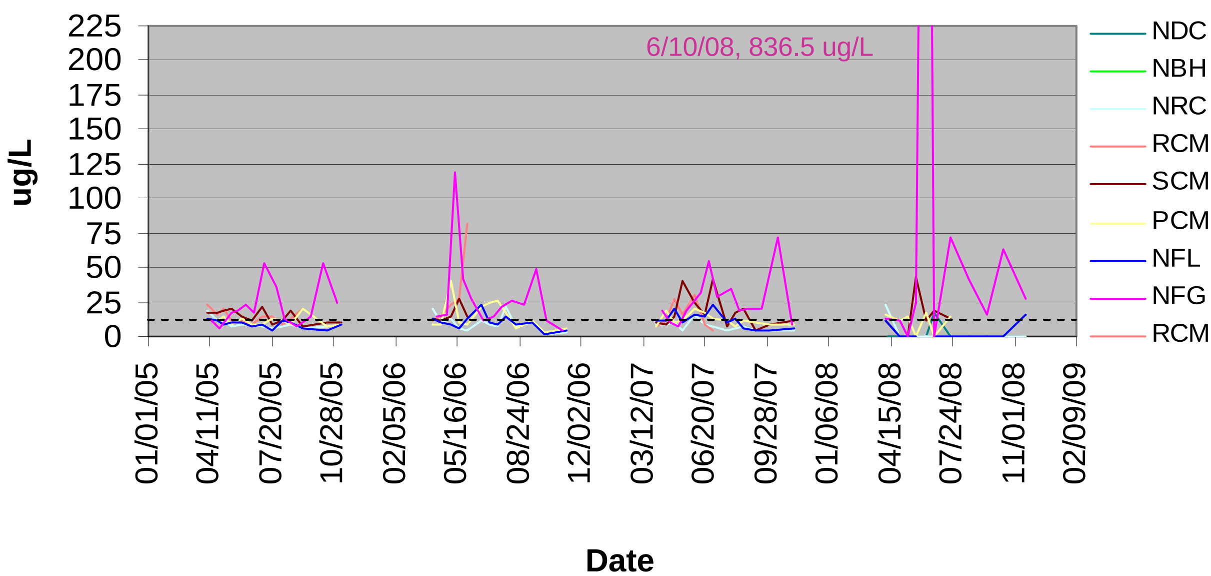
**Figure 11 (a & b). Ammonia ($NH_3$)**

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




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

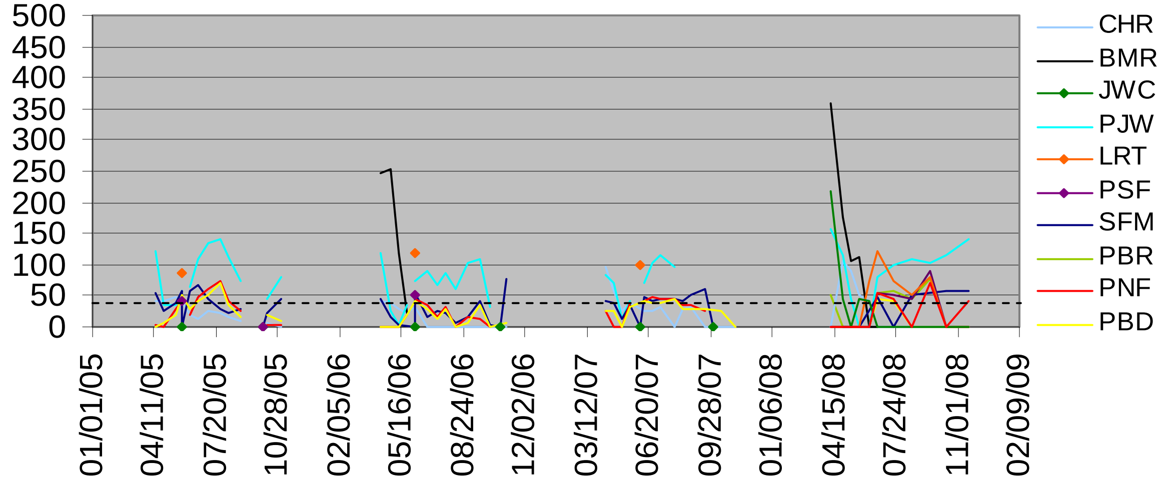
**Figure 11.b.** Ammonia ($NH_3$) on the North Fork CLP.




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

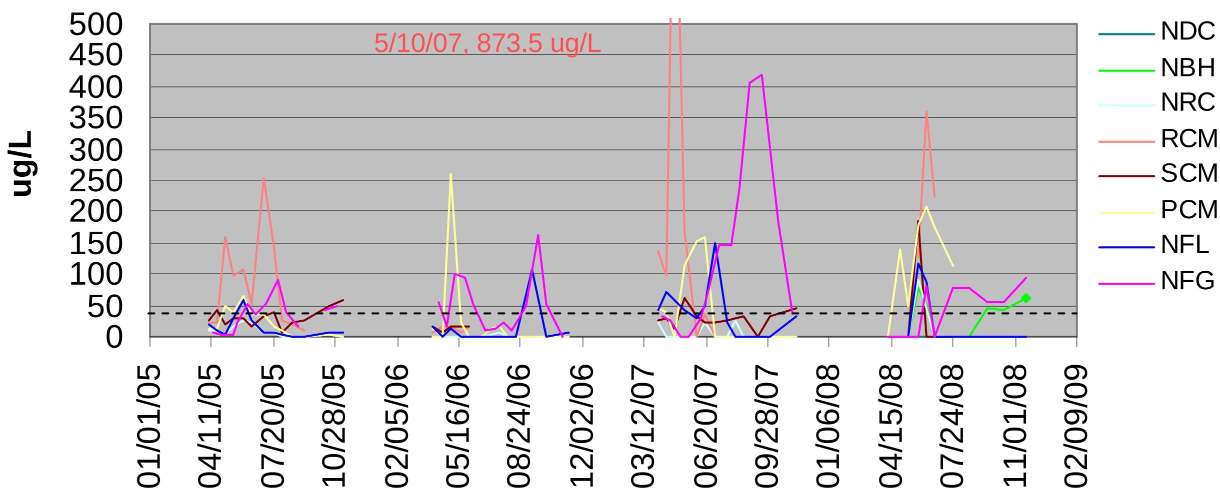
**Figure 12 (a & b). Nitrate ($NO_3$)**

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




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

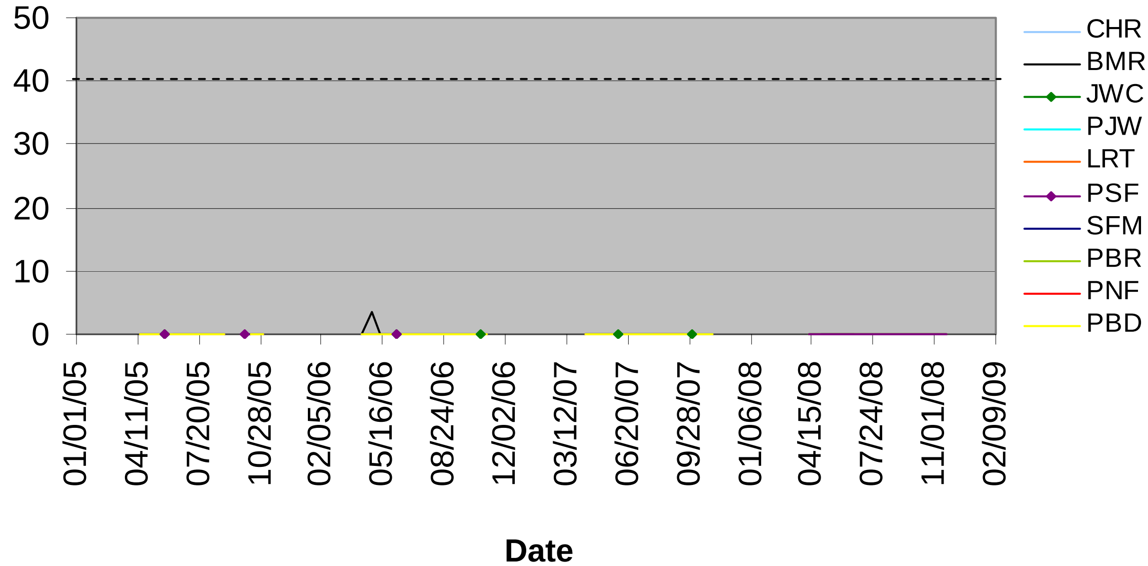
**Figure 12.b.** Nitrate ($NO_3$) on the North Fork CLP.




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

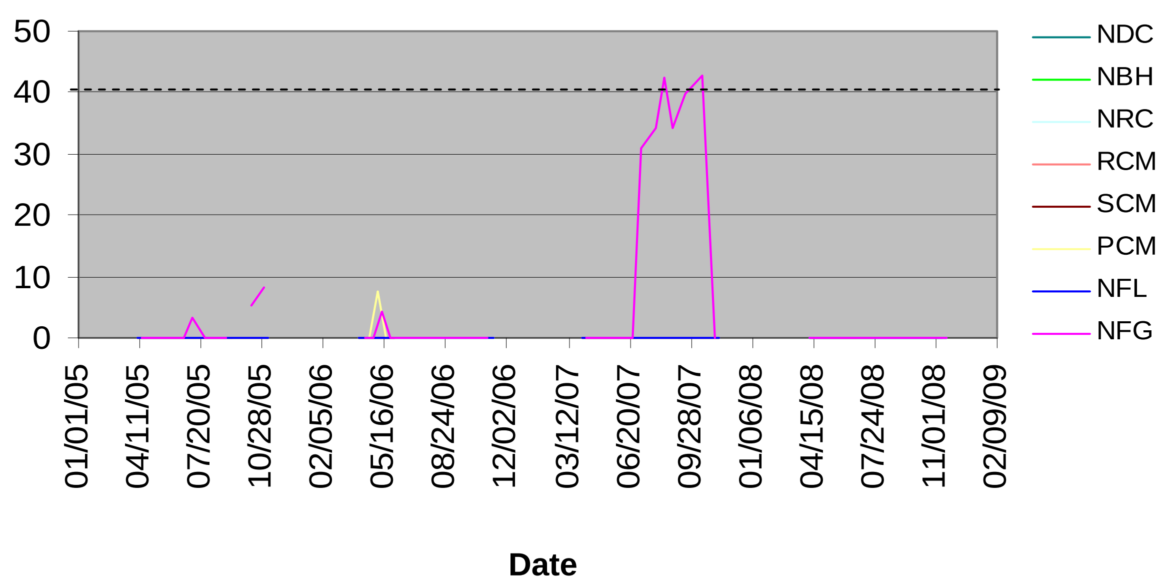
**Figure 13 (a & b). Nitrite ($NO_2$)**

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




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

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




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

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

**Figure 14.a.** TKN on the Mainstem CLP.

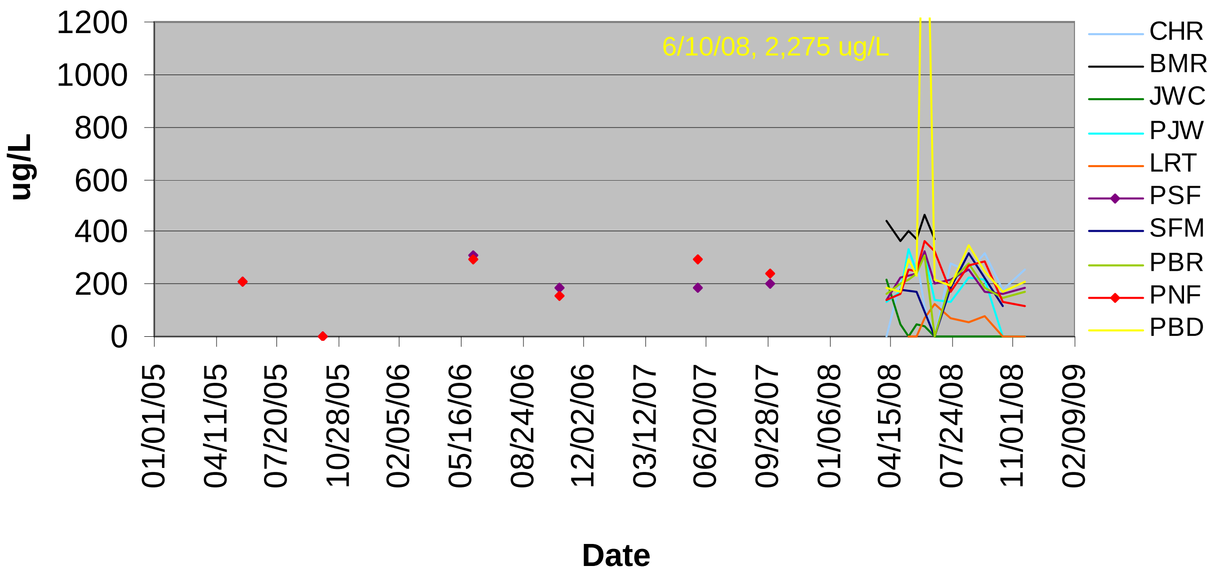



**Figure 14.b.** TKN on the North Fork CLP.

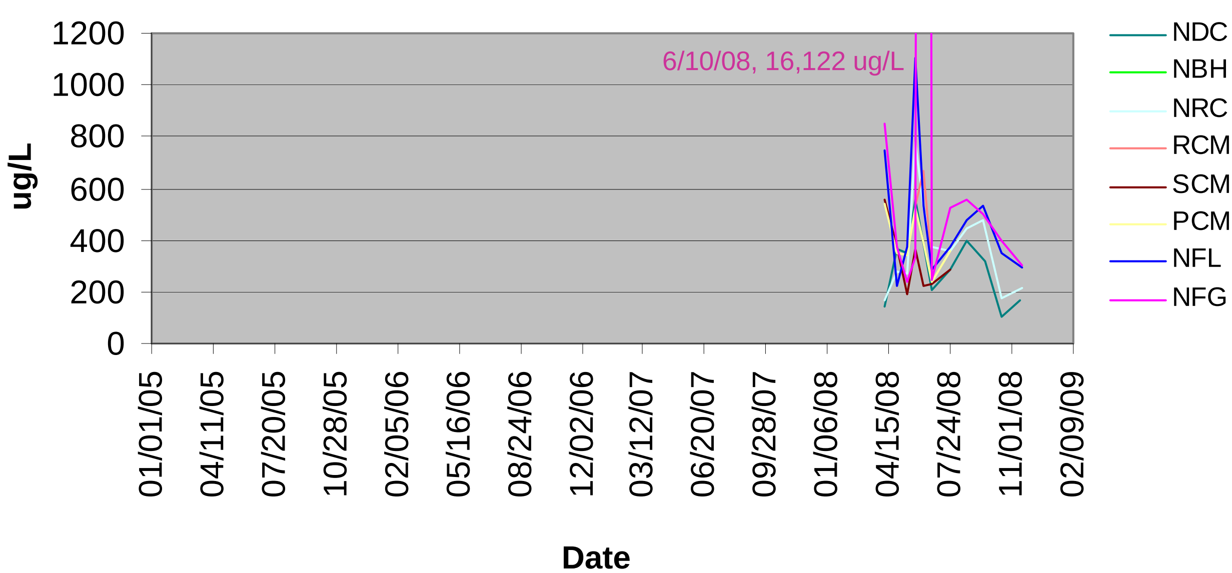
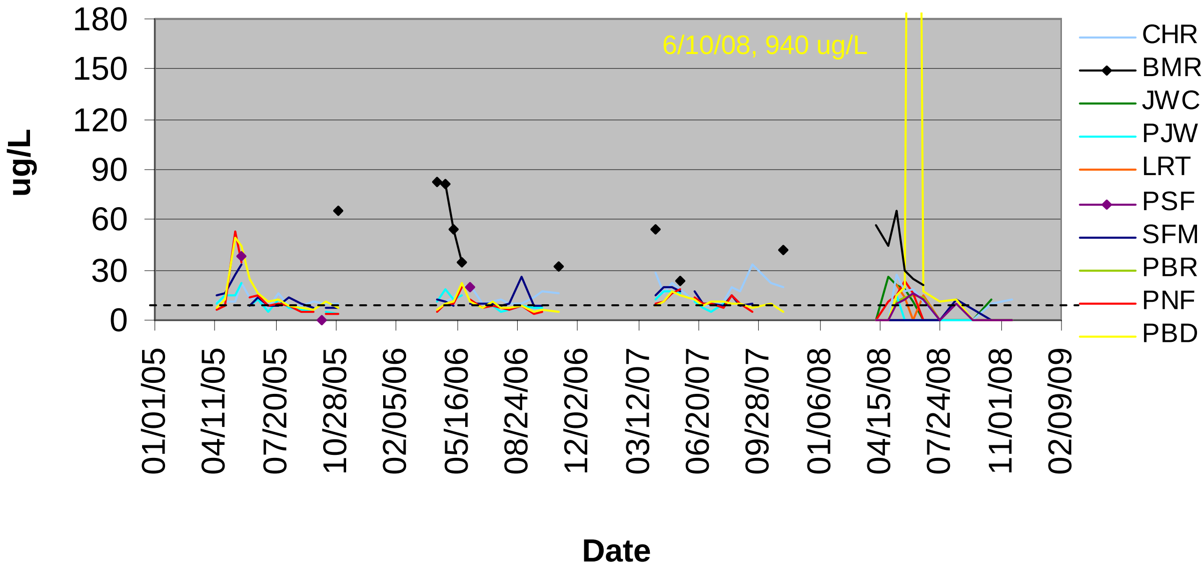


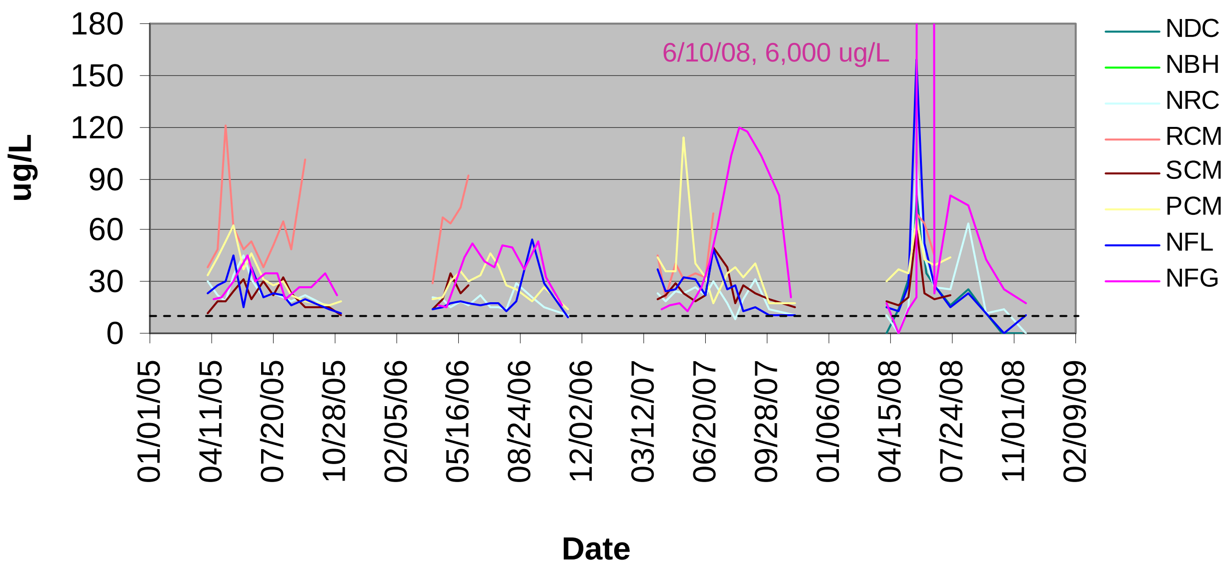
**Figure 15 (a & b). Total Phosphorus**

**Figure 15.a.** Total Phosphorus on the Mainstem CLP.




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

**Figure 15.b.** Total Phosphorus on the North Fork CLP.




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

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

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

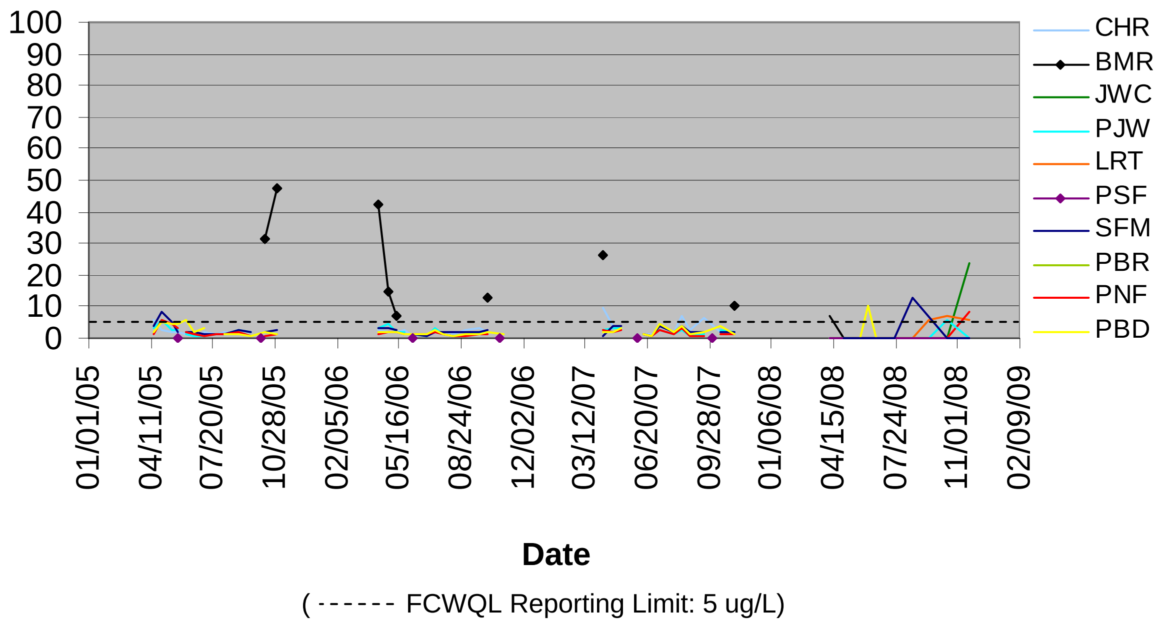
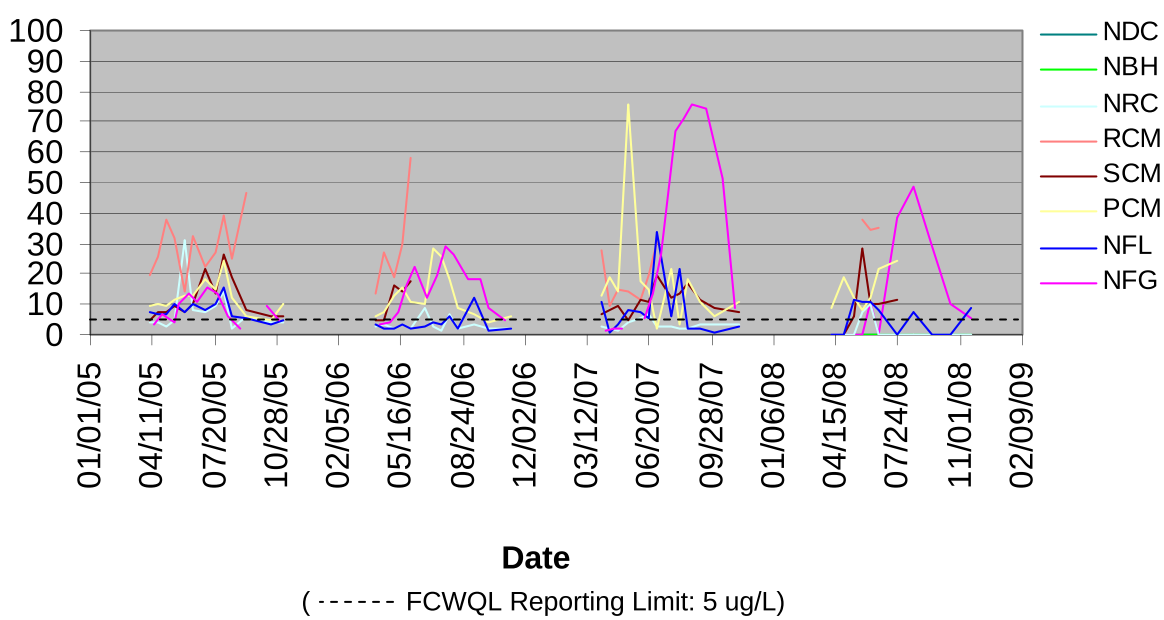



**Figure 16.b.** Ortho-phosphate ($PO_4$) on the North Fork CLP.



# Mainstem and North Fork CLP: Metals

**Figure 17.** Dissolved silver (Ag) on the Mainstem and North Fork CLP.

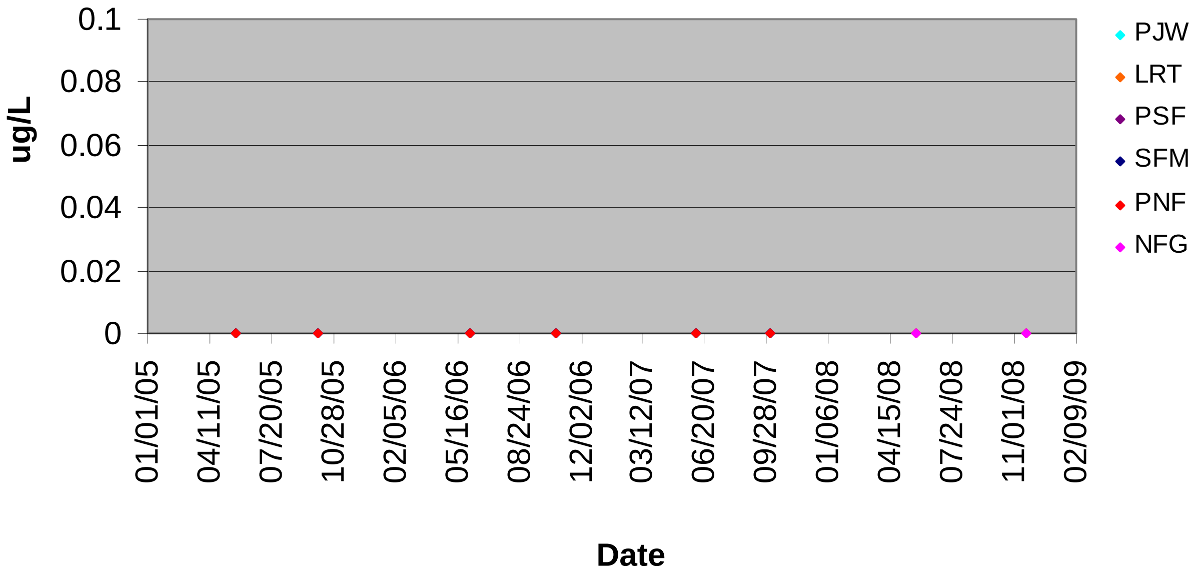



**Figure 18.** Dissolved cadmium (Cd) on the Mainstem and North Fork CLP.

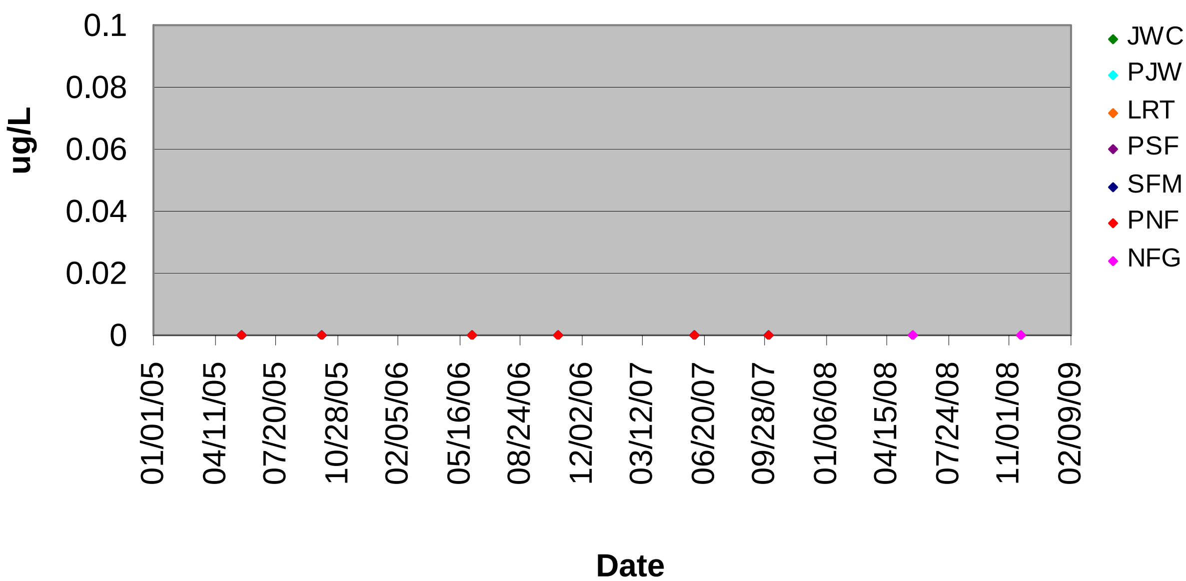


**Figure 19.** Chromium (Cr) on the Mainstem and North Fork CLP.

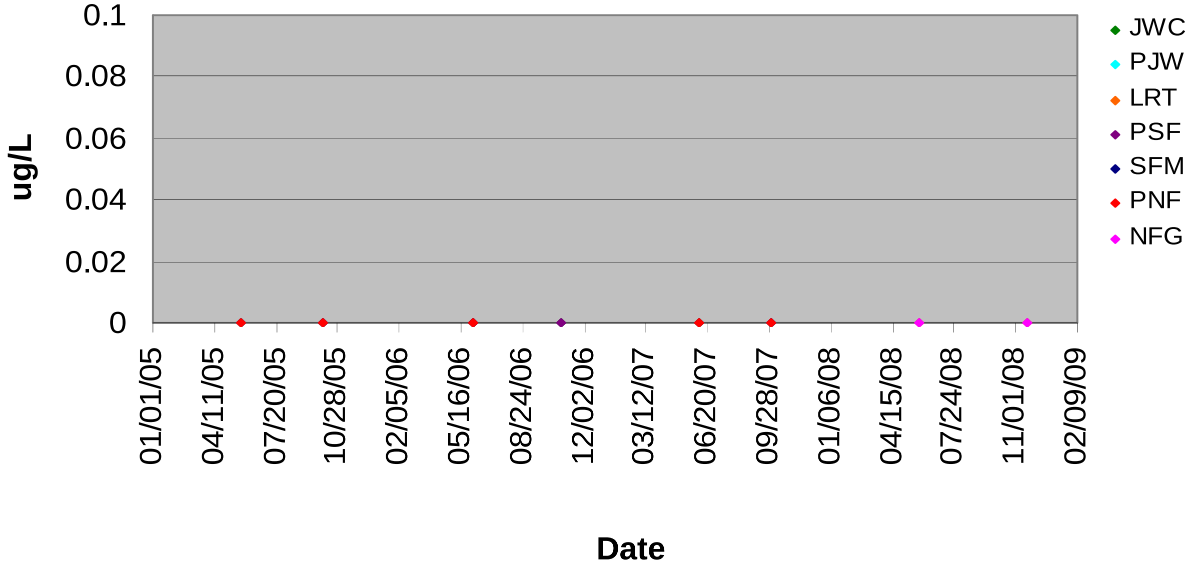



**Figure 20.** Dissolved copper (Cu) on the Mainstem and North Fork CLP.

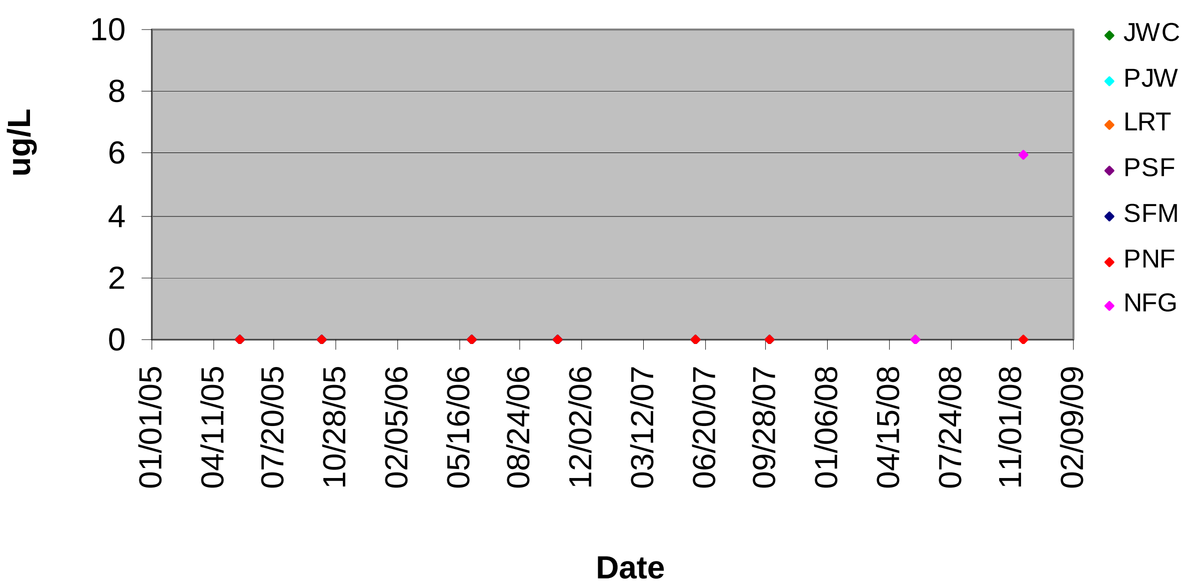


**Figure 21.** Total iron (Fe) on the Mainstem and North Fork CLP.

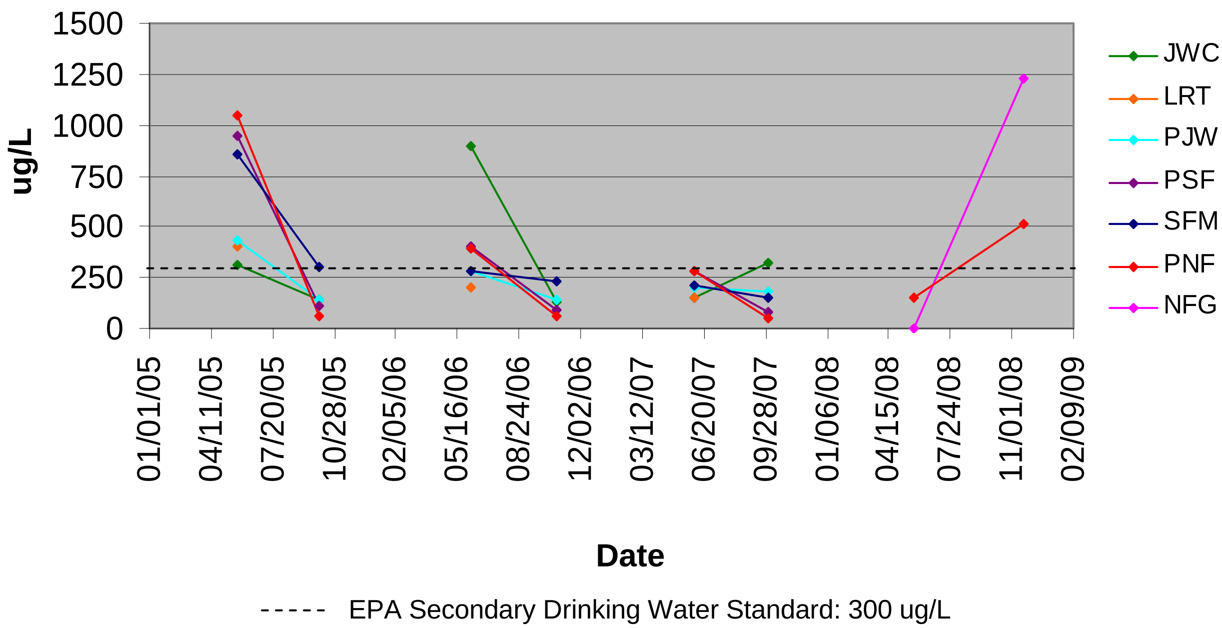



**Figure 22.** Dissolved nickel (Ni) on the Mainstem and North Fork CLP.

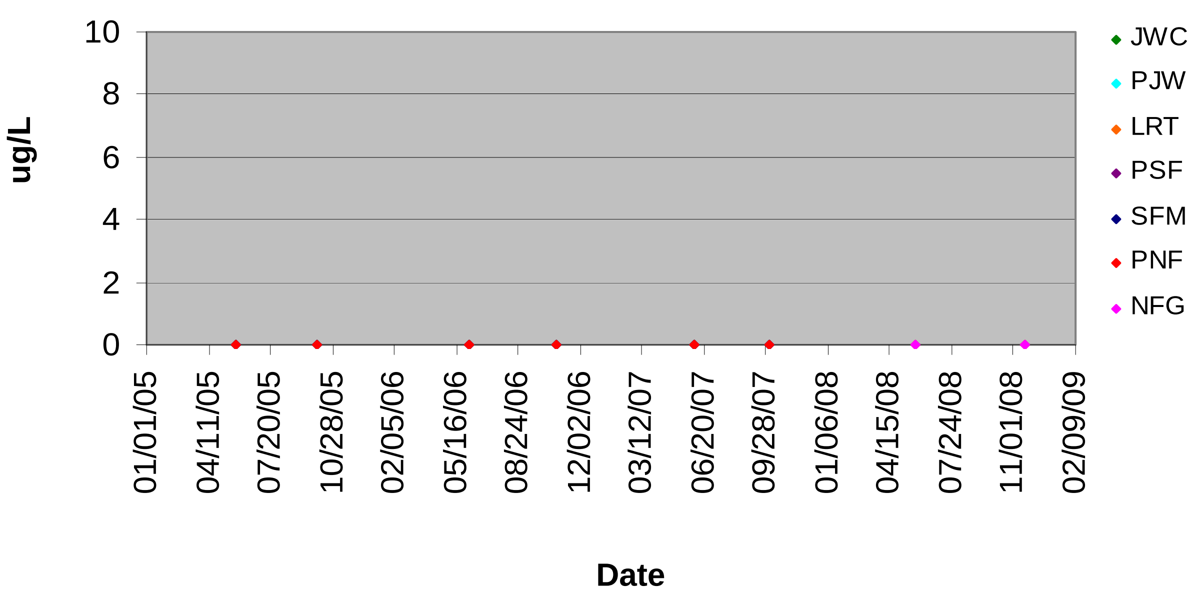


**Figure 23.** Dissolved lead (Pb) on the Mainstem and North Fork CLP.

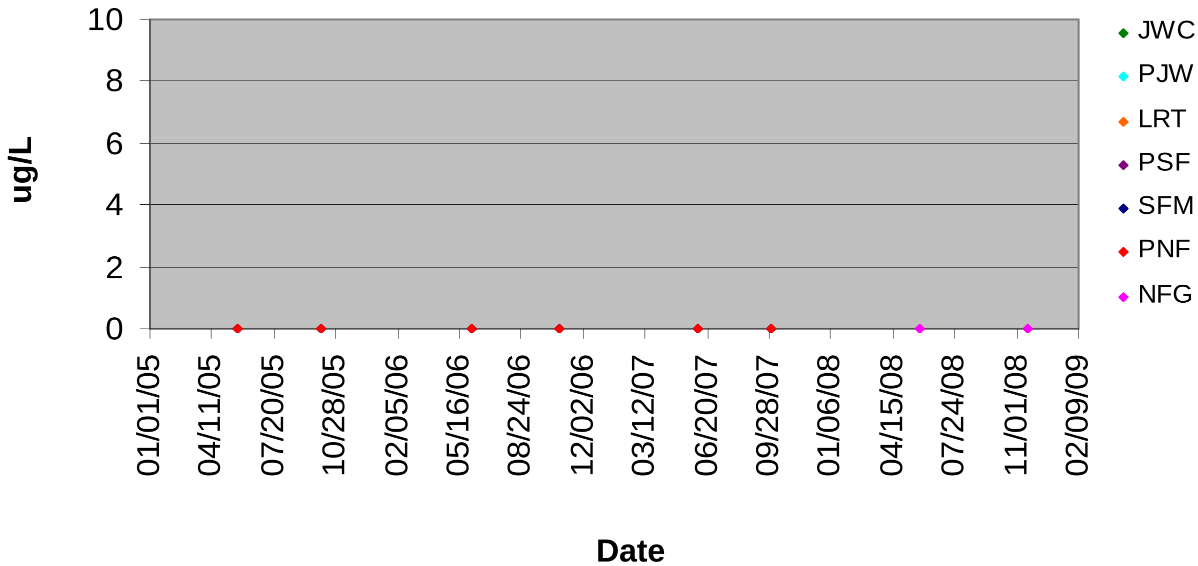
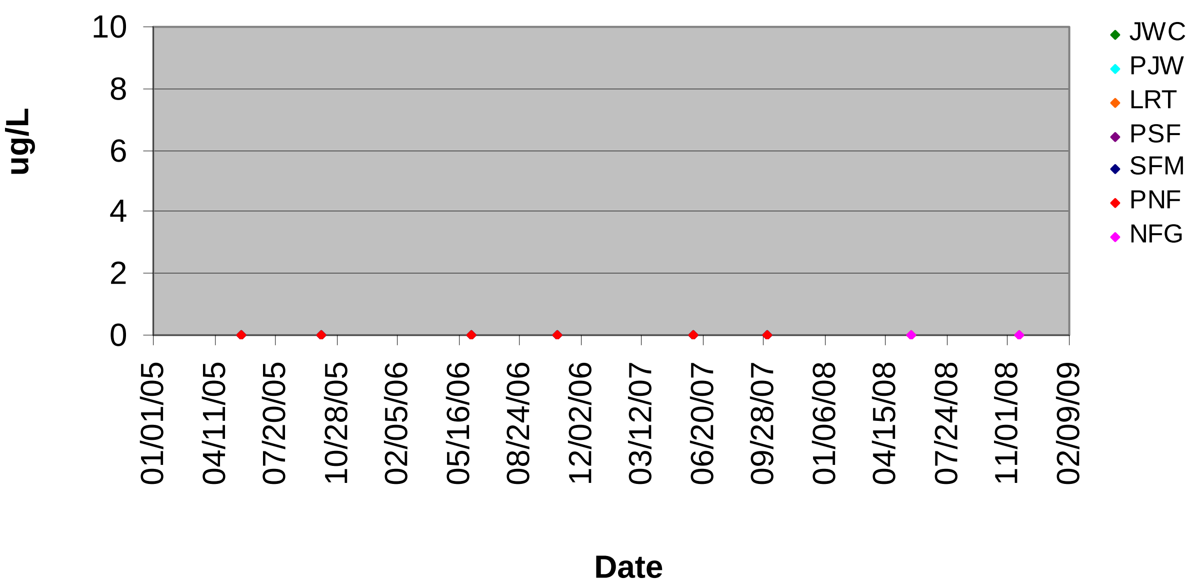



**Figure 24.** Dissolved zinc (Zn) on the Mainstem and North Fork CLP.



# Mainstem and North Fork CLP: Major Ions

**Figure 25 (a & b). Calcium (Ca)**

**Figure 25.a.** Calcium (Ca) on the Mainstem CLP.

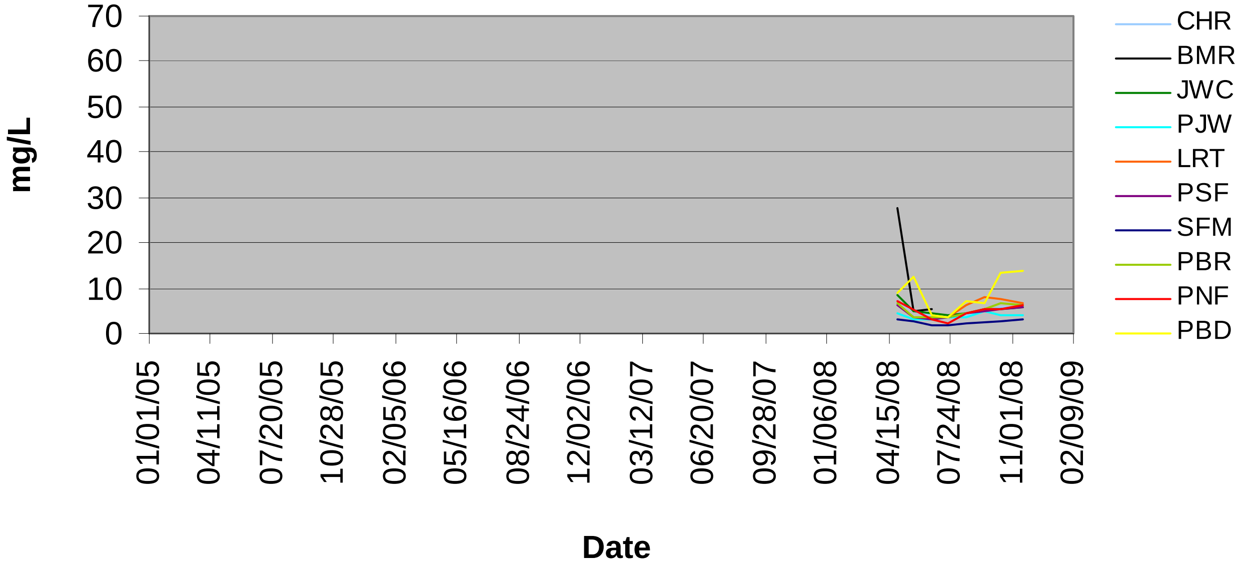



**Figure 25.b.** Calcium (Ca) on the North Fork CLP.

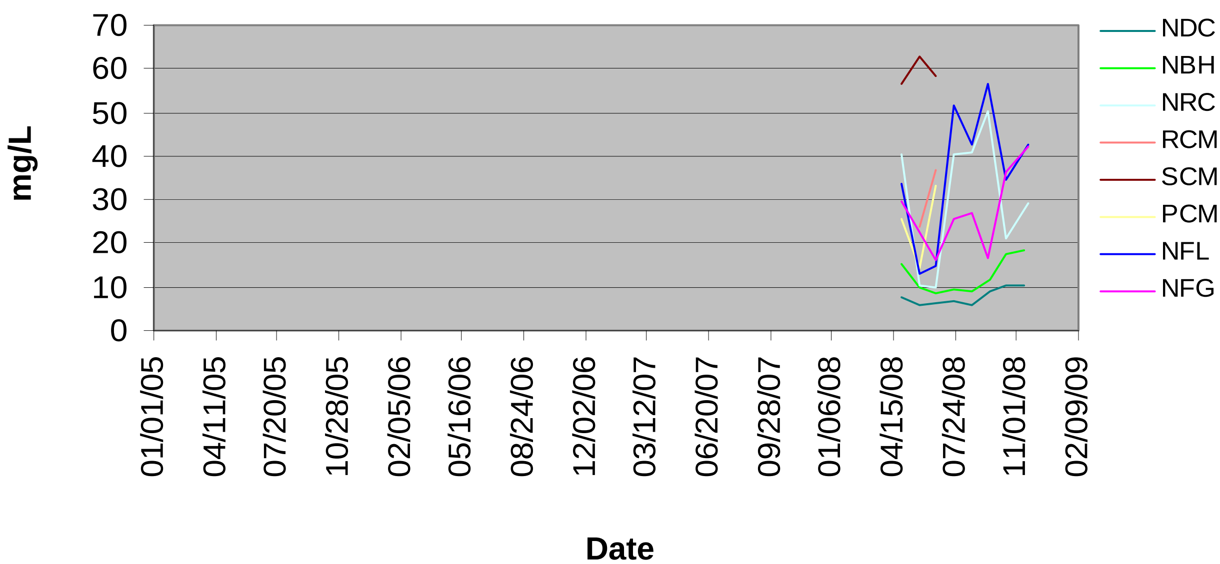


**Figure 26 (a & b). Potassium (K)**

**Figure 26.a.** Potassium (K) on the Mainstem CLP.

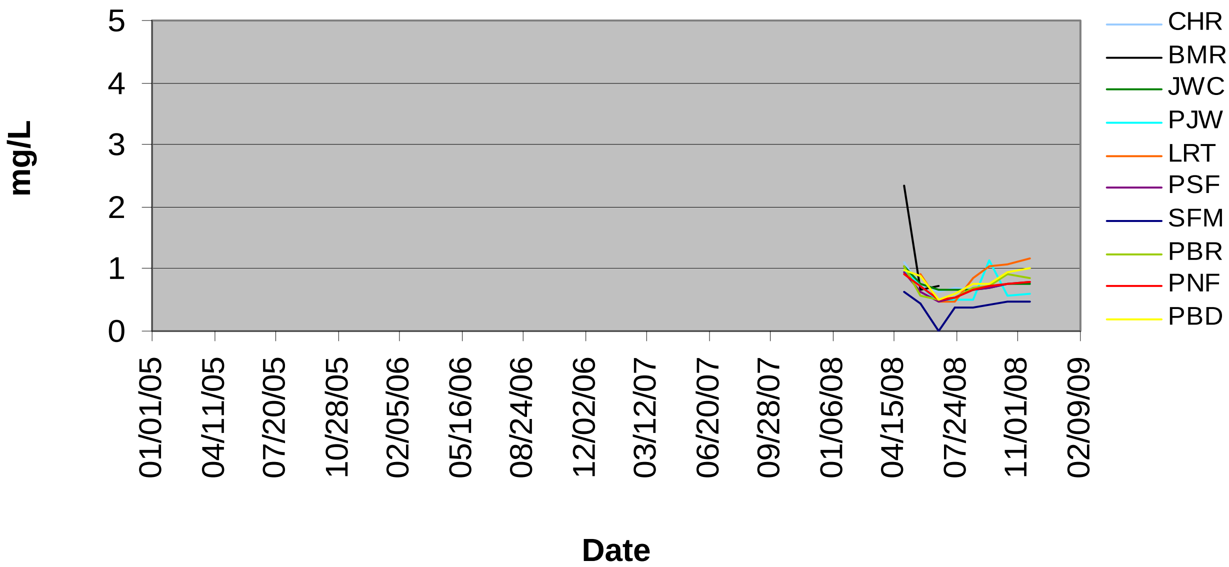



**Figure 26.b.** Potassium (K) on the North Fork CLP.

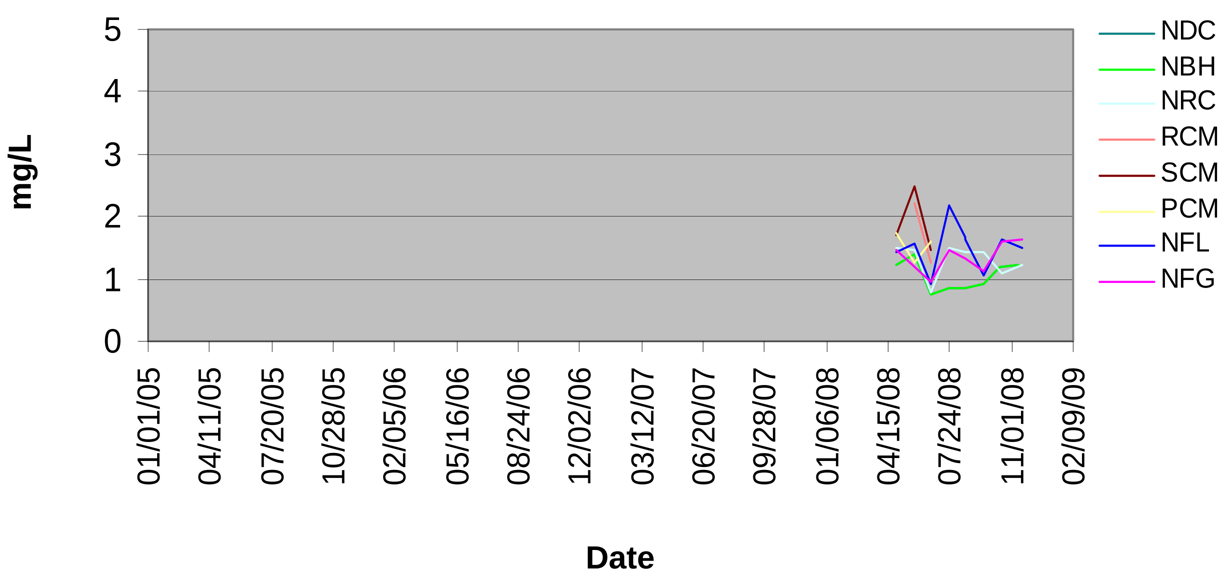


**Figure 27 (a & b). Magnesium (Mg)**

**Figure 27.a.** Magnesium (Mg) on the Mainstem CLP.

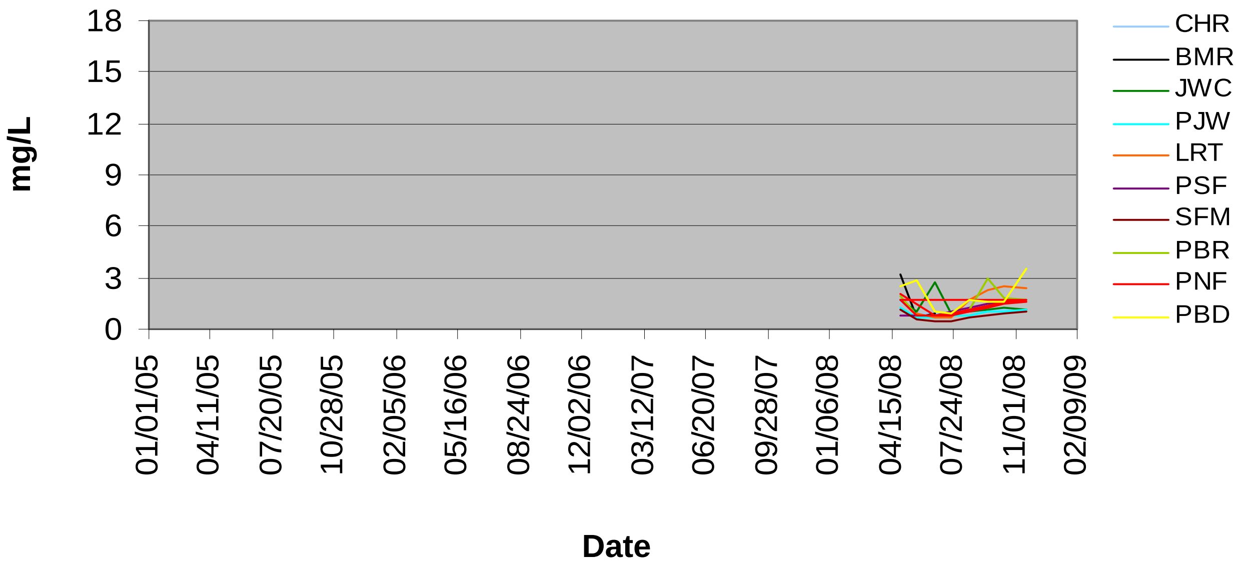



**Figure 27.b.** Magnesium (Mg) on the North Fork CLP.

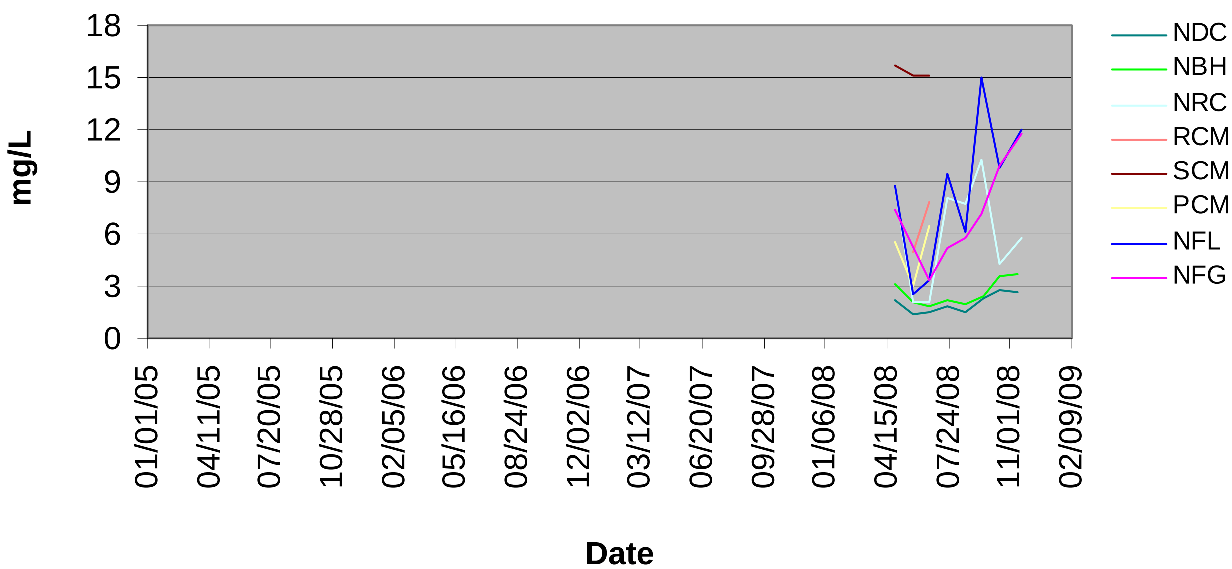


**Figure 28 (a & b). Sodium (Na)**

**Figure 28.a.** Sodium (Na) on the Mainstem CLP.

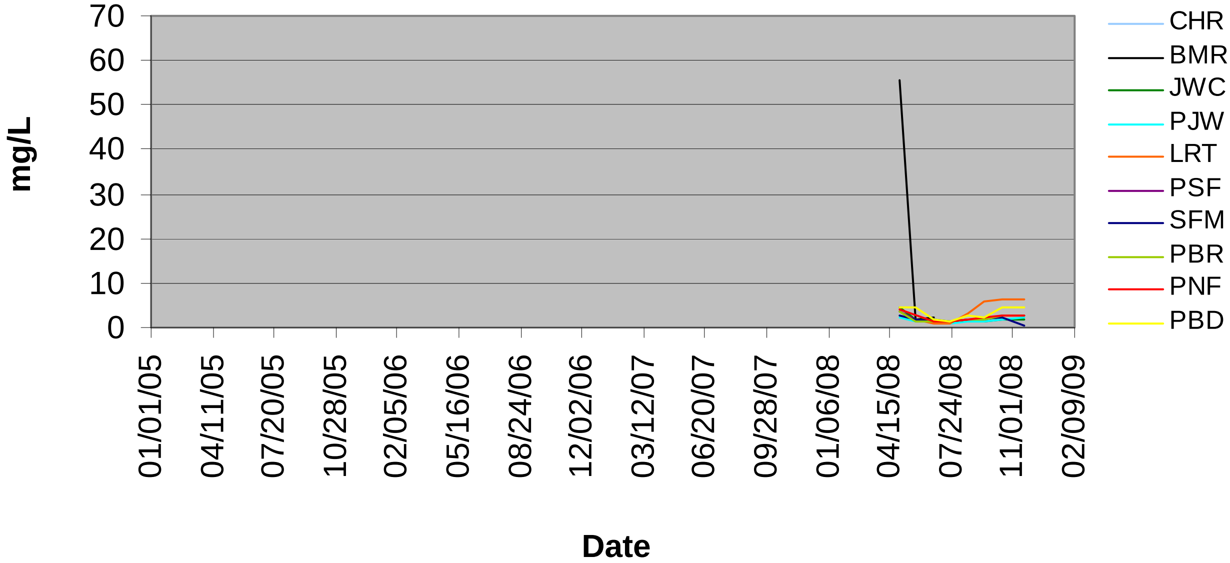



**Figure 28.b.** Sodium (Na) on the North Fork CLP.

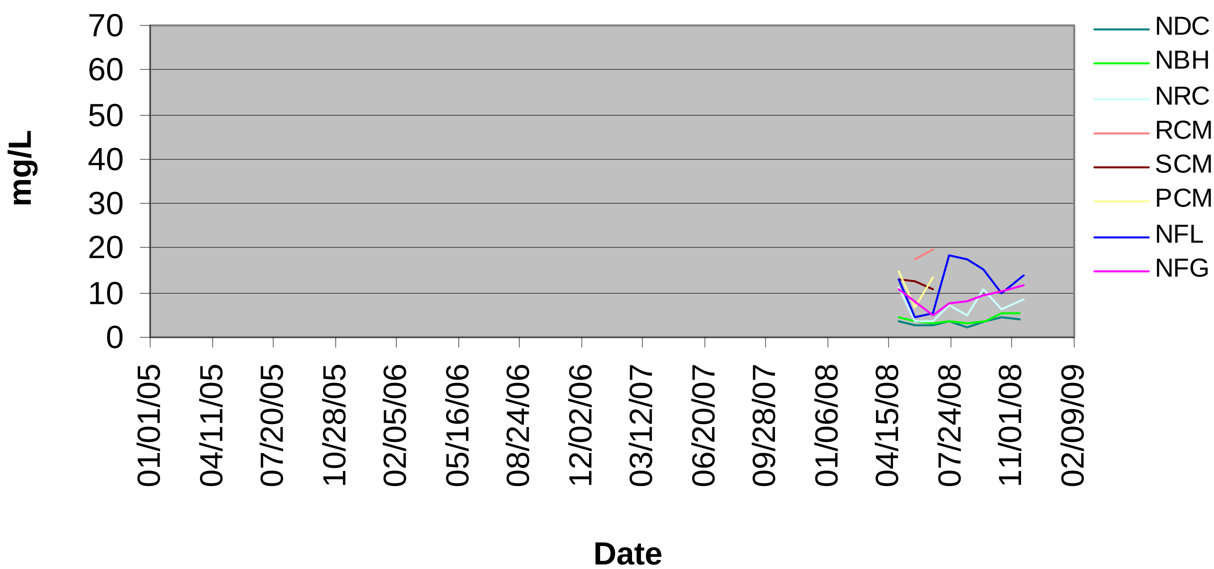


**Figure 29 (a & b). Chloride (Cl)**

**Figure 29.a.** Chloride (Cl) on the Mainstem CLP.

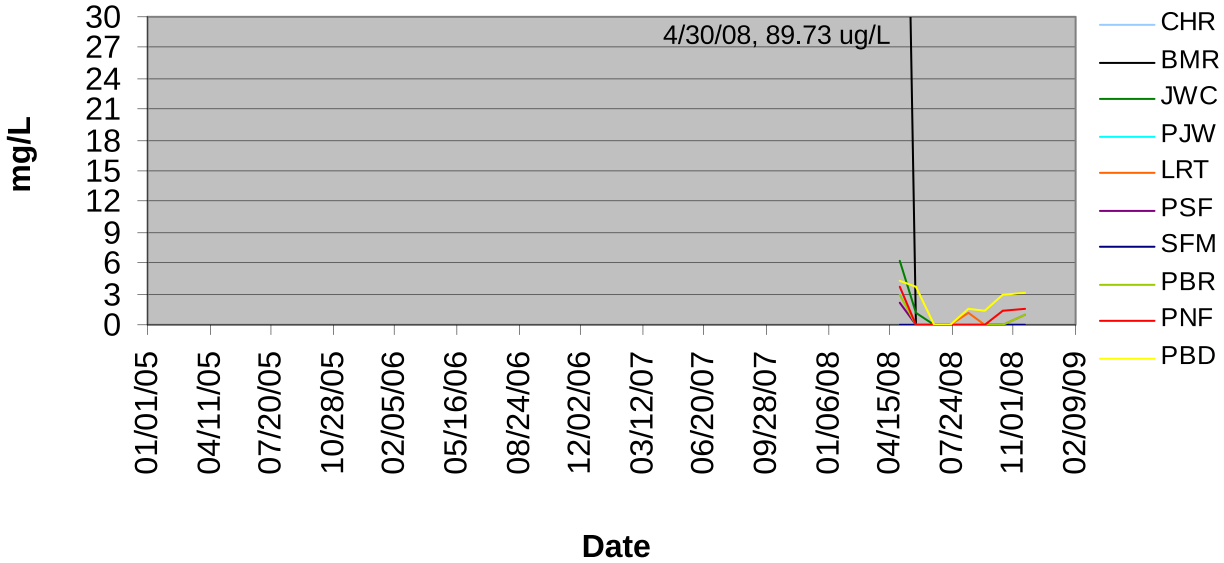



**Figure 29.b.** Chloride (Cl) on the North Fork CLP.

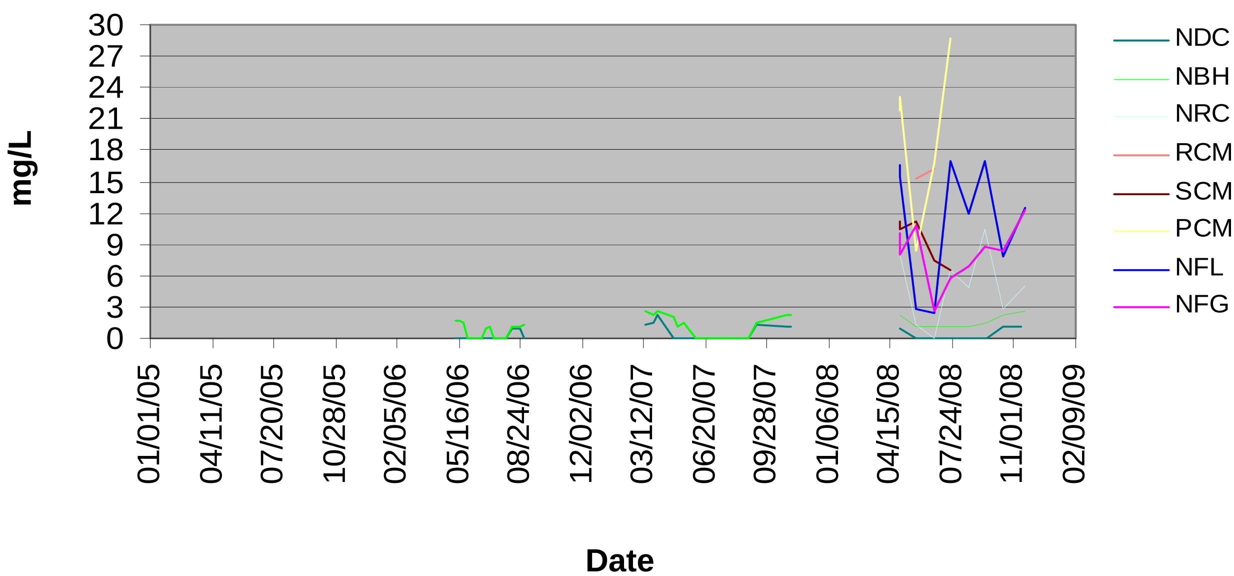


**Figure 30 (a & b). Sulfate ($SO_4$)**

**Figure 30.a.** Sulfate ($SO_4$) on the Mainstem CLP.

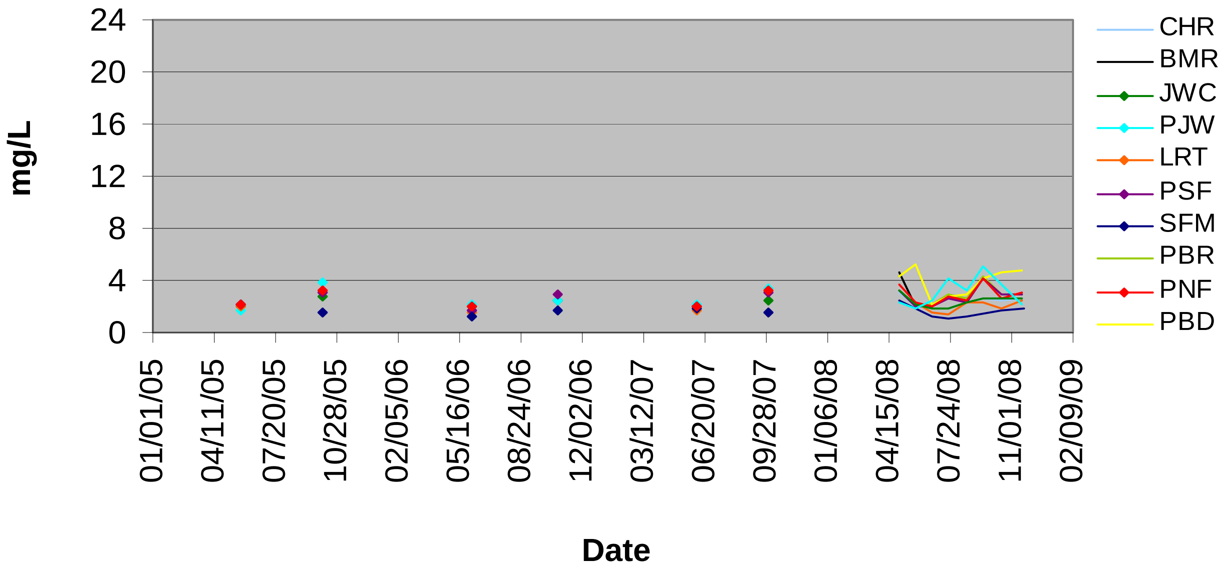
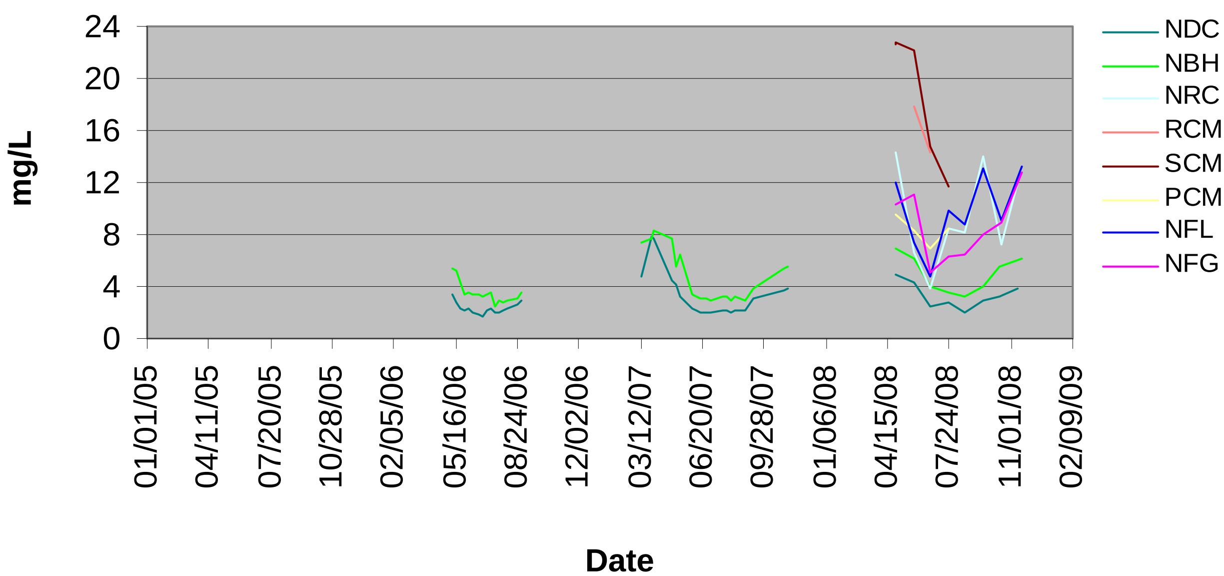



**Figure 301.b.** Sulfate ($SO_4$) on the North Fork CLP.



# Mainstem and North Fork CLP: Microbiological Constituents

**Figure 31.** Total coliforms on the Mainstem and North Fork CLP.

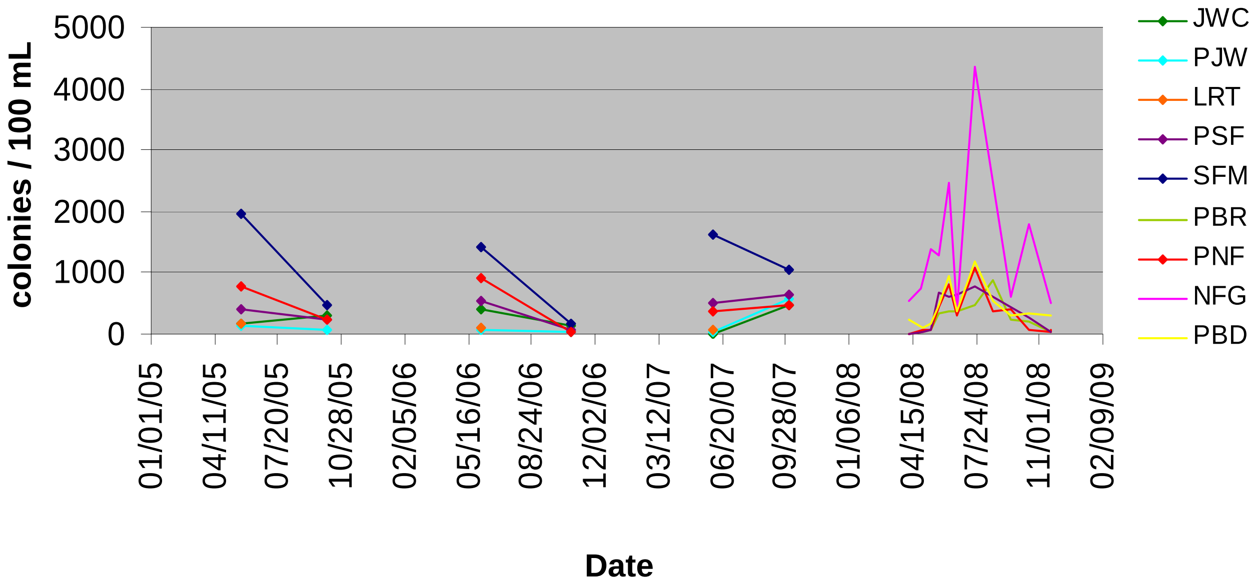



**Figure 32.** *E. coli* on the Mainstem and North Fork CLP.

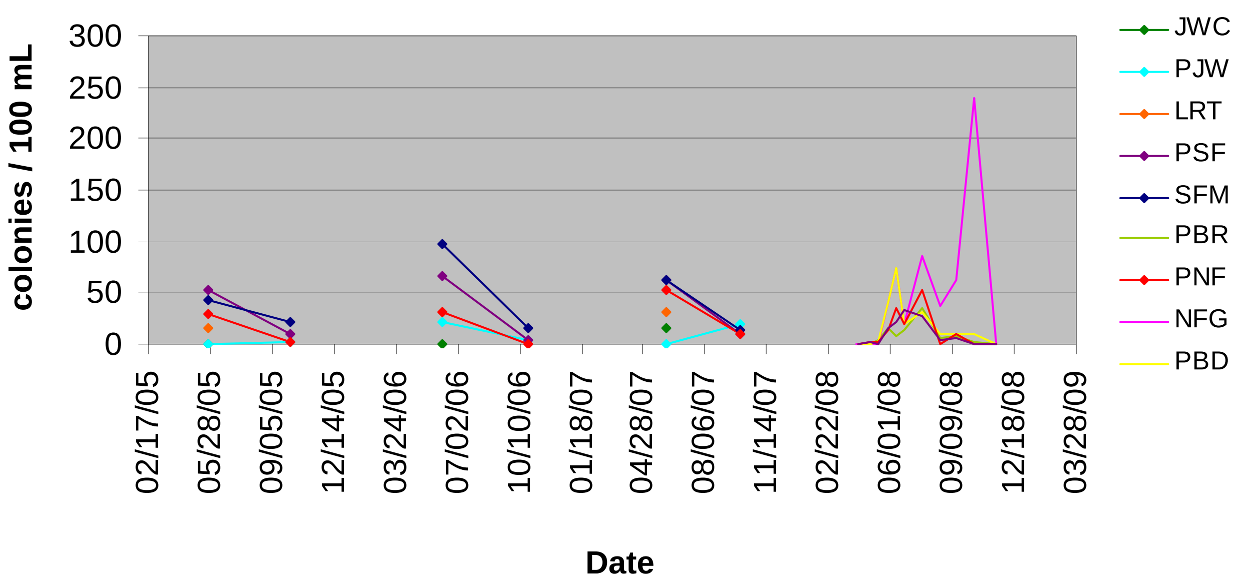


**Figure 33.** *Giardia* on the Mainstem and North Fork CLP.

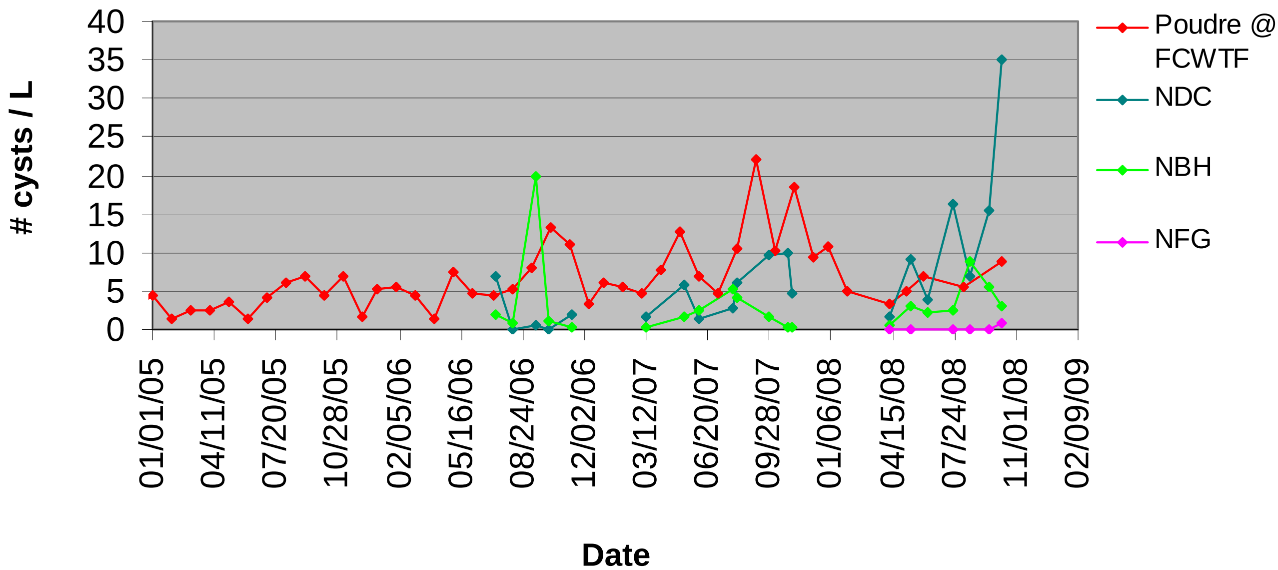
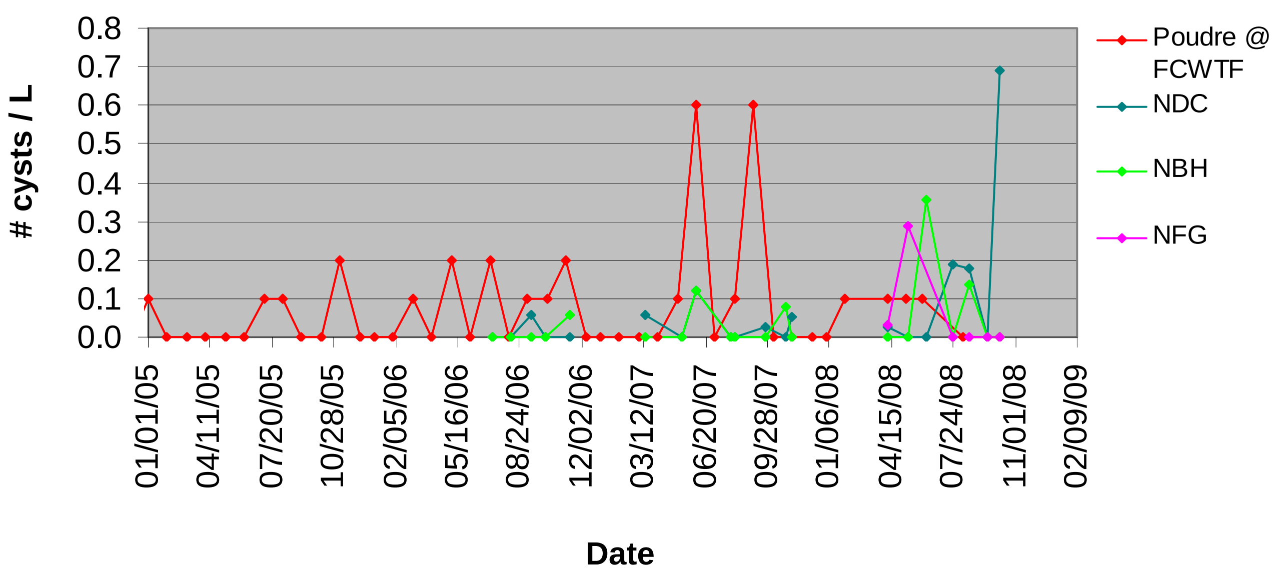
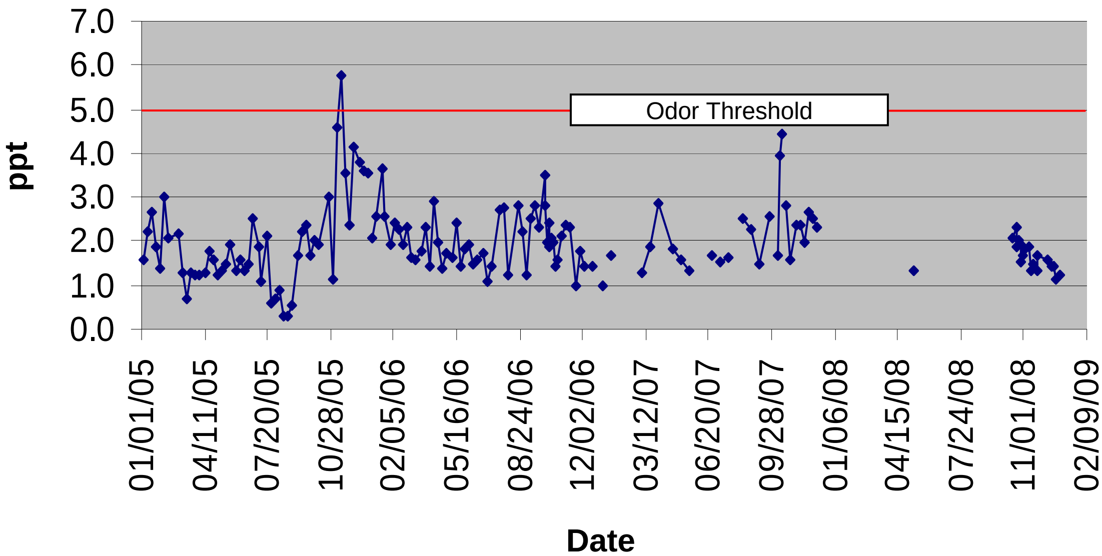



**Figure 34.** *Cryptosporidium* on the Mainstem and North Fork CLP.



# Mainstem and North Fork CLP: Geosmin

**Figure 35.** Geosmin concentrations of the Mainstem CLP collected at the FCWTF.



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

**Figure 36.** 2008 Seaman Reservoir temperature profiles.

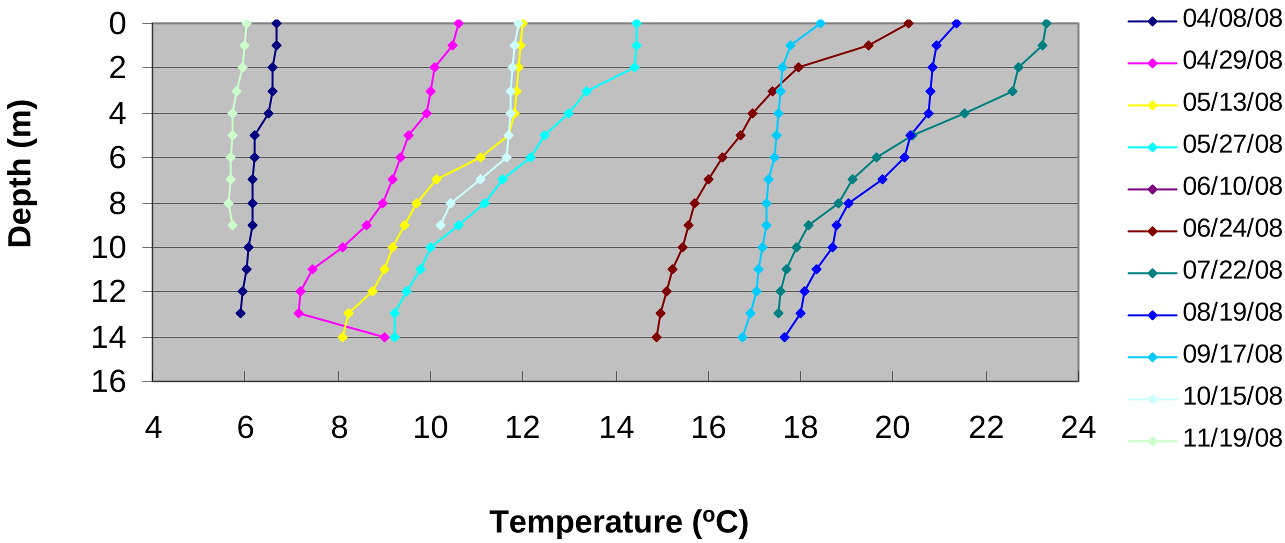



**Figure 37.** 2008 Seaman Reservoir dissolved oxygen (D.O.) profiles.

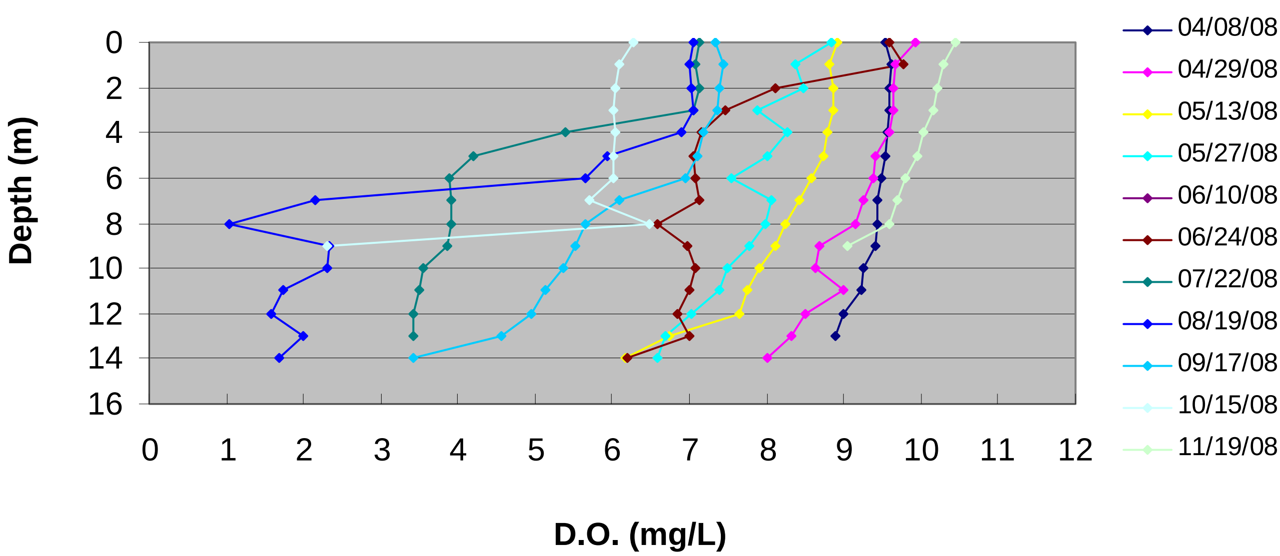


**Figure 38.** 2008 Seaman Reservoir pH profiles.

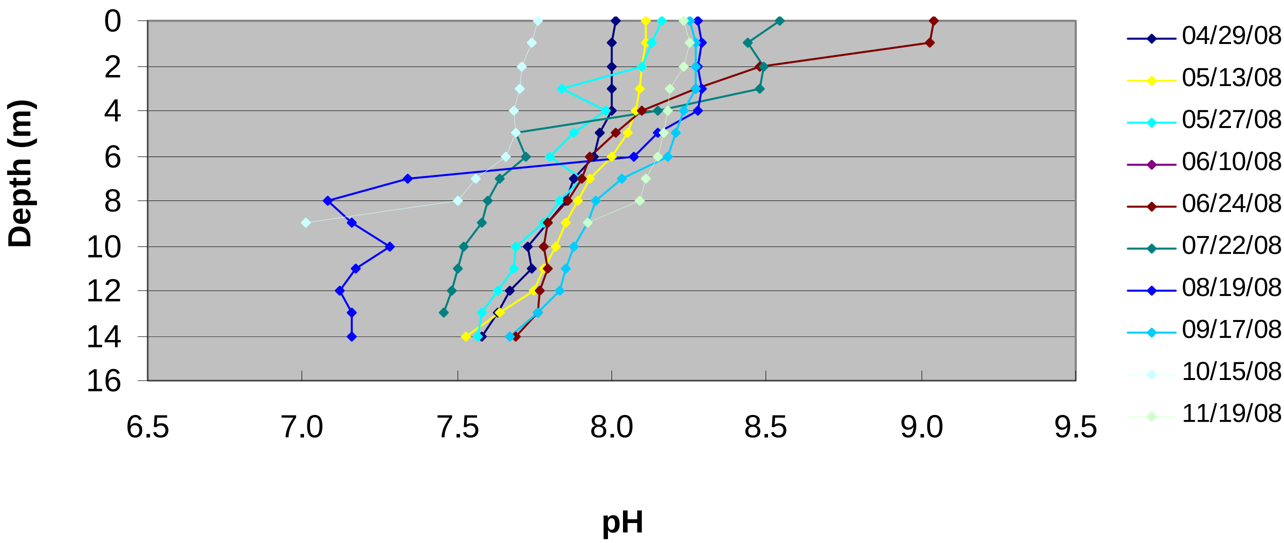
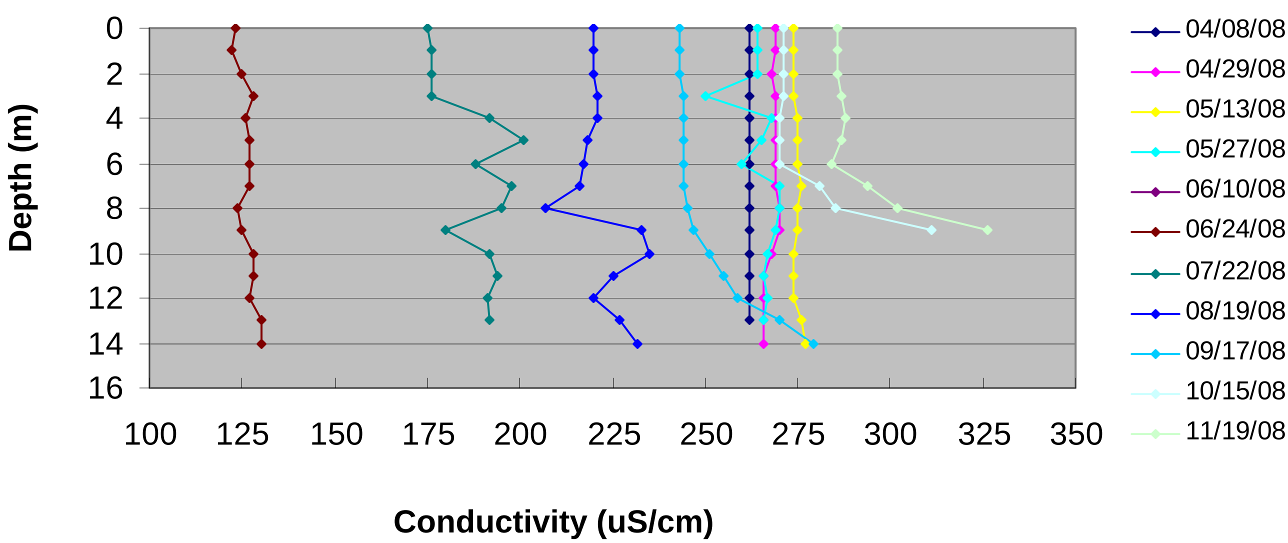



**Figure 39.** 2008 Seaman Reservoir conductivity profiles.



# Seaman Reservoir:
# General Parameters

**Figure 40.** Alkalinity concentrations in Seaman Reservoir.

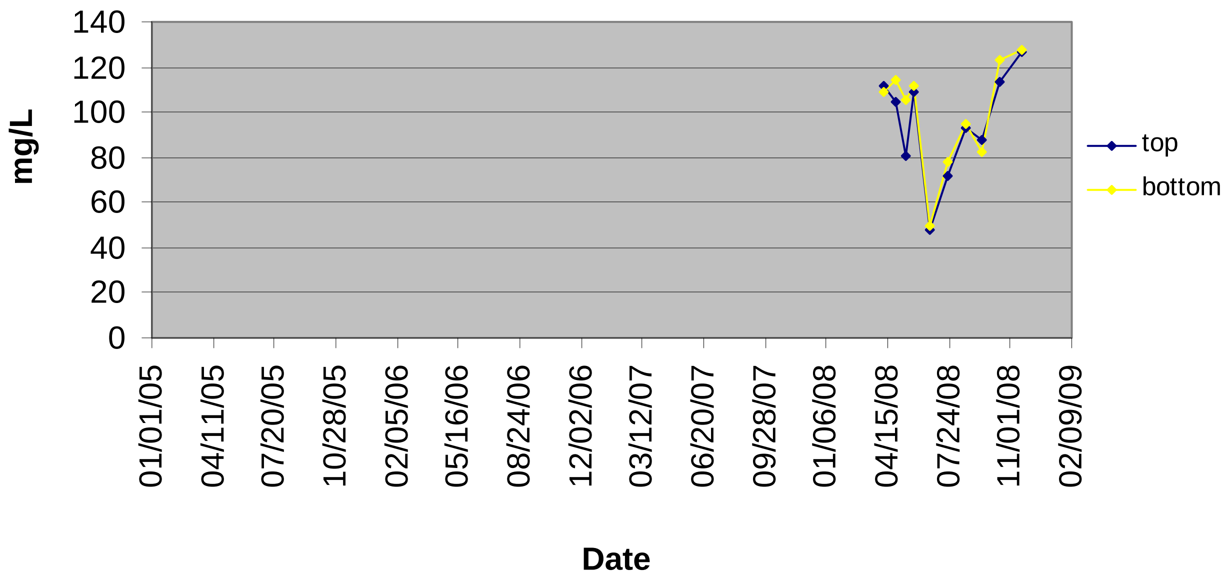



**Figure 41.** Hardness concentrations in Seaman Reservoir.

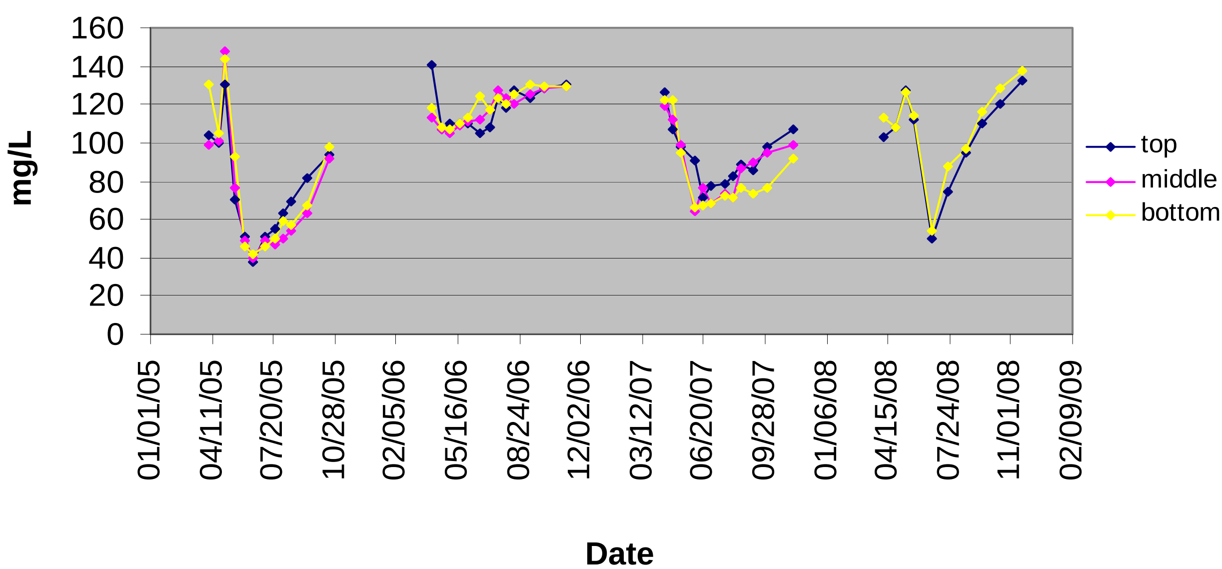


**Figure 42.** Conductivity of Seaman Reservoir.

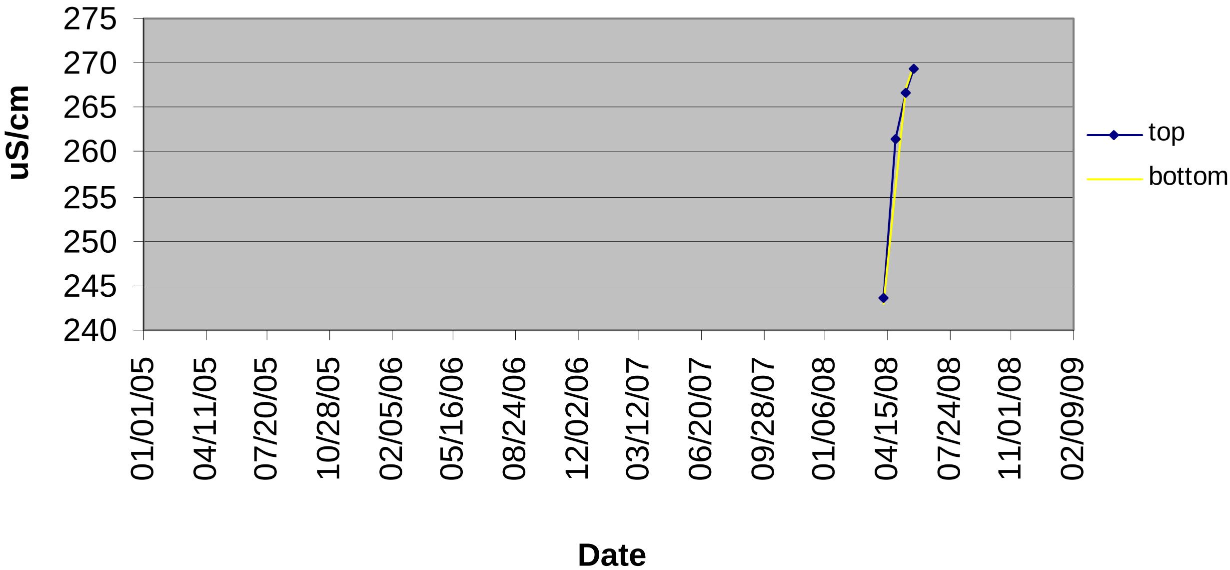



**Figure 43.** pH in Seaman Reservoir.

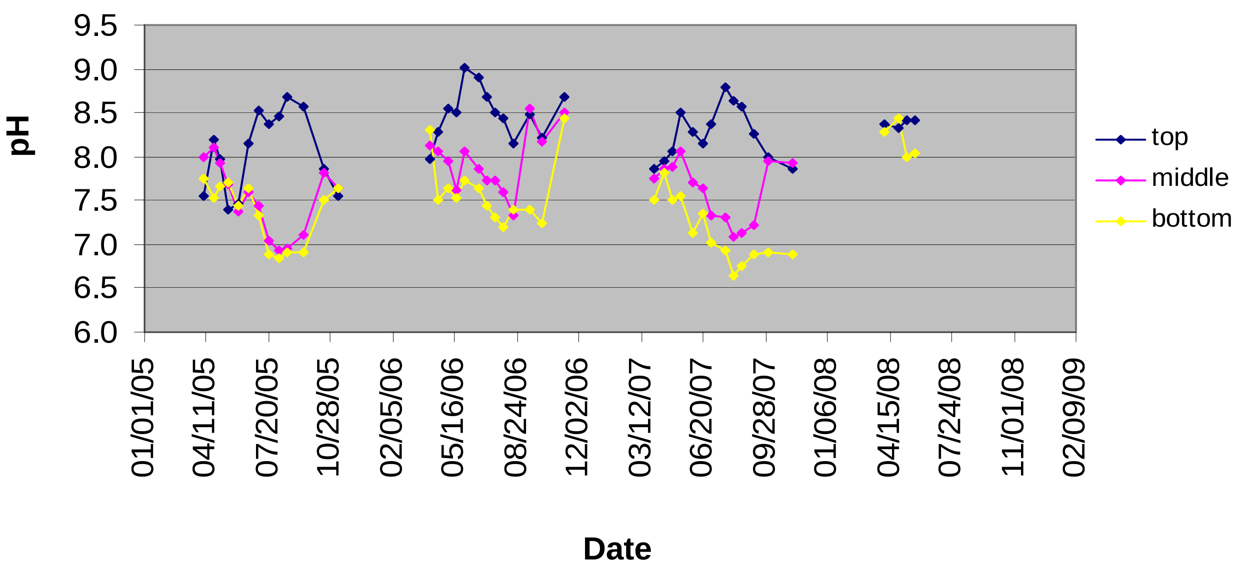


**Figure 44.** Turbidity in Seaman Reservoir.

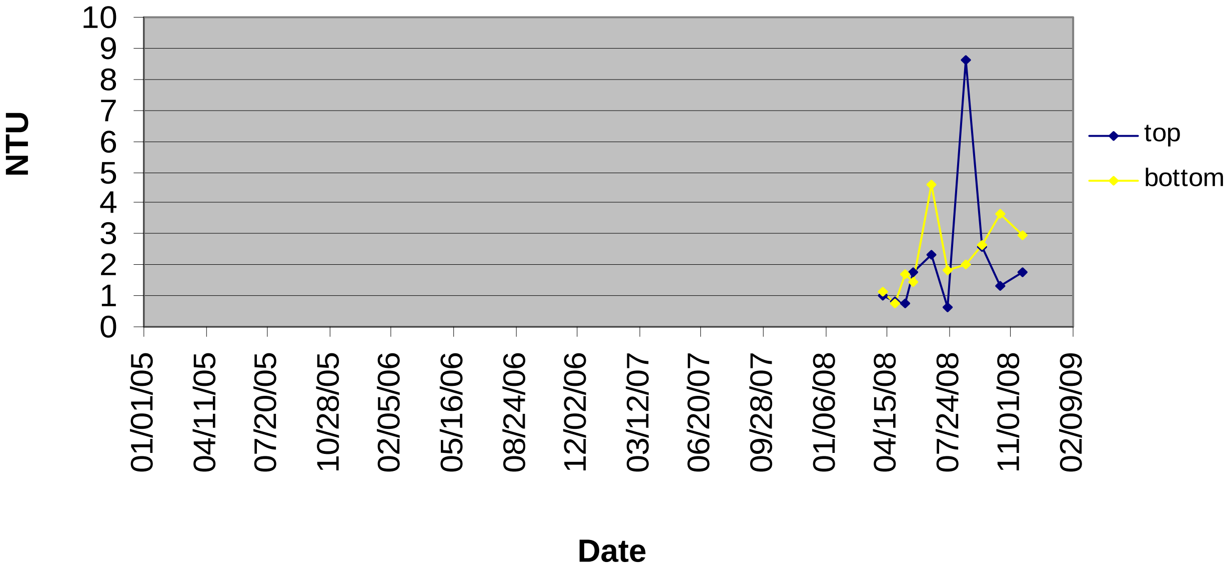



**Figure 45.** Chlorophyll-a concentrations in Seaman Reservoir.

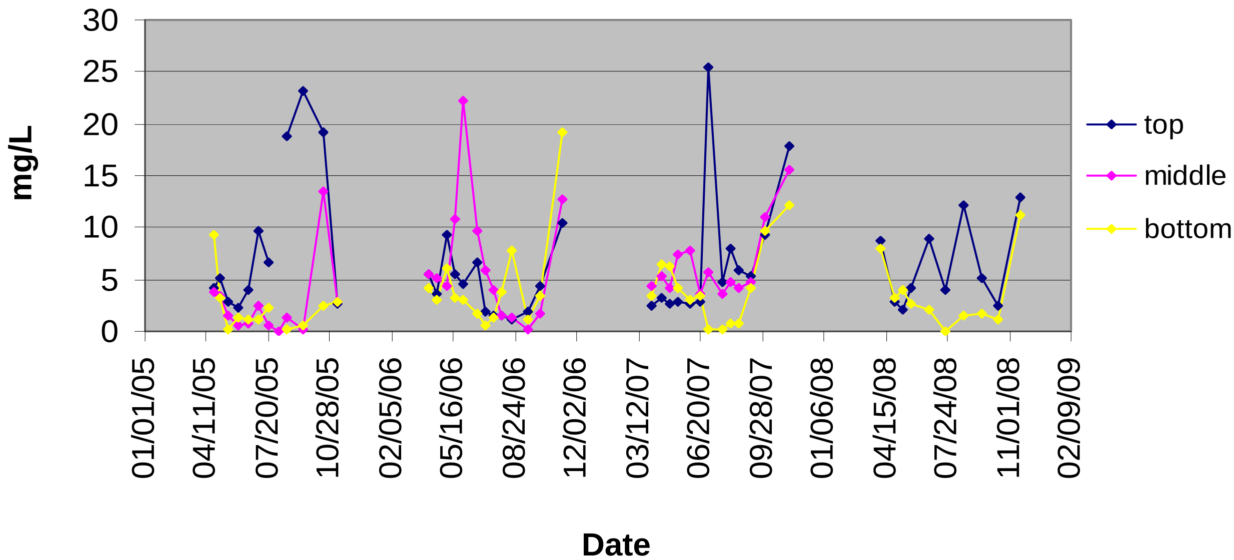


**Figure 46.** Total Dissolved Solids (TDS) in Seaman Reservoir.

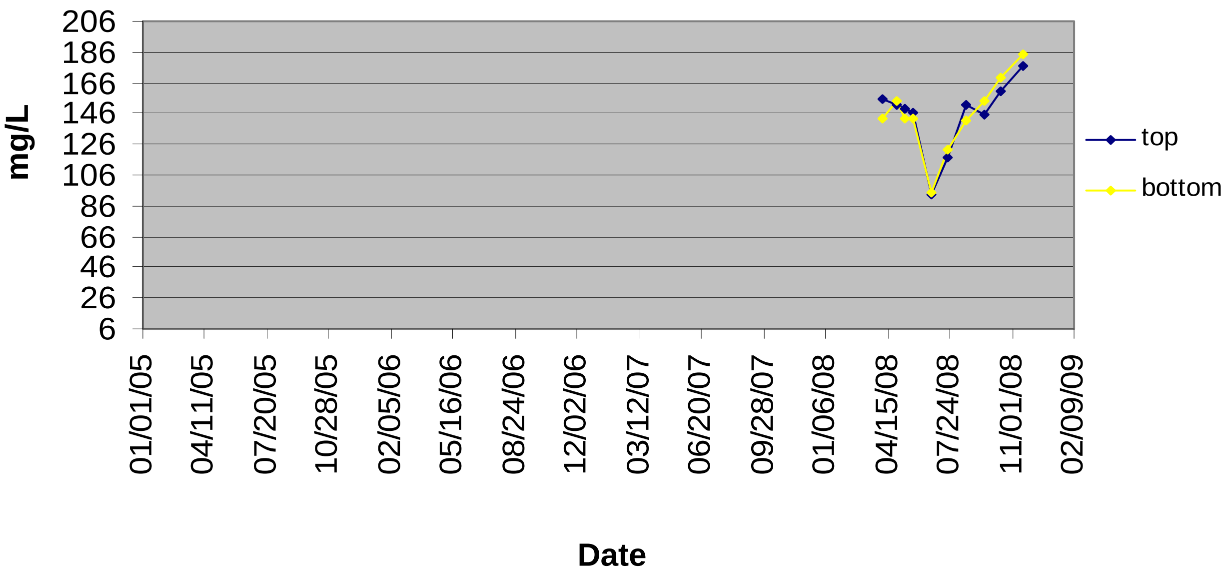



**Figure 47.** Total Organic Carbon (TOC) concentrations in Seaman Reservoir.

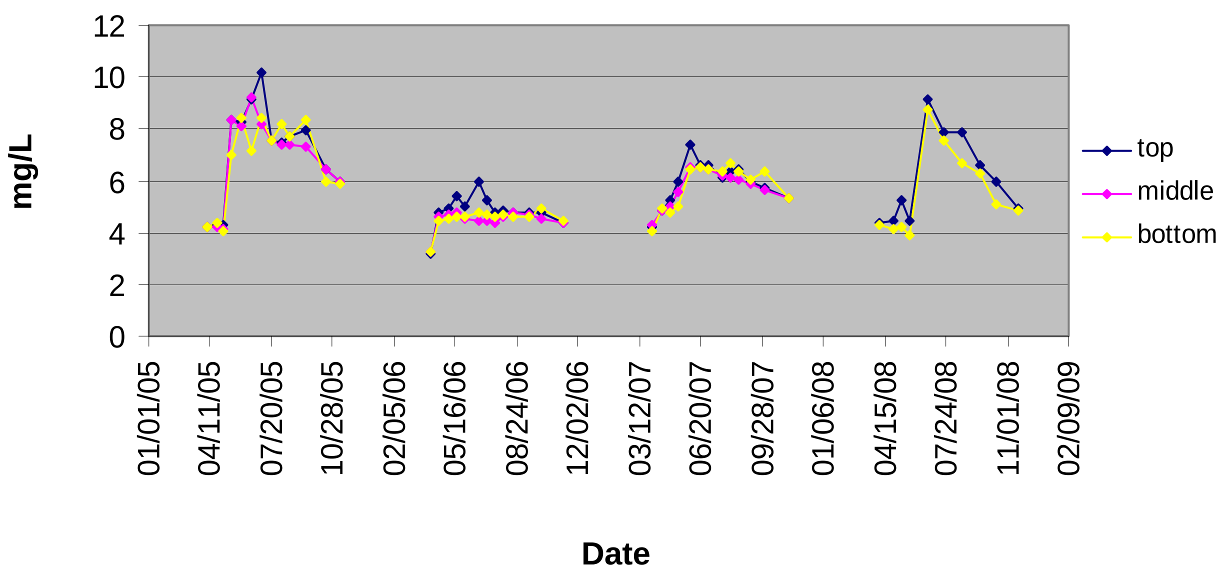
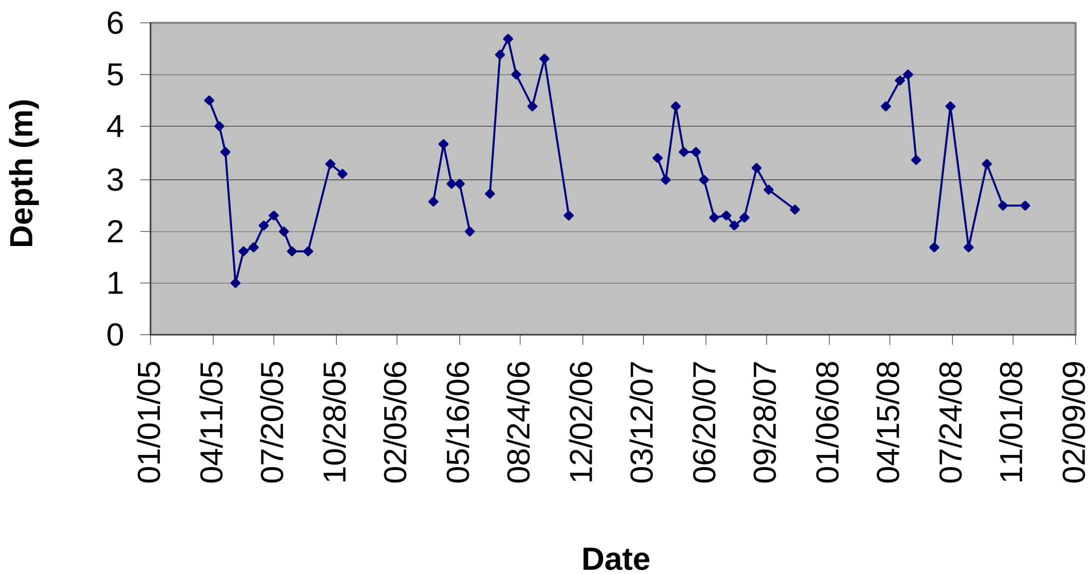
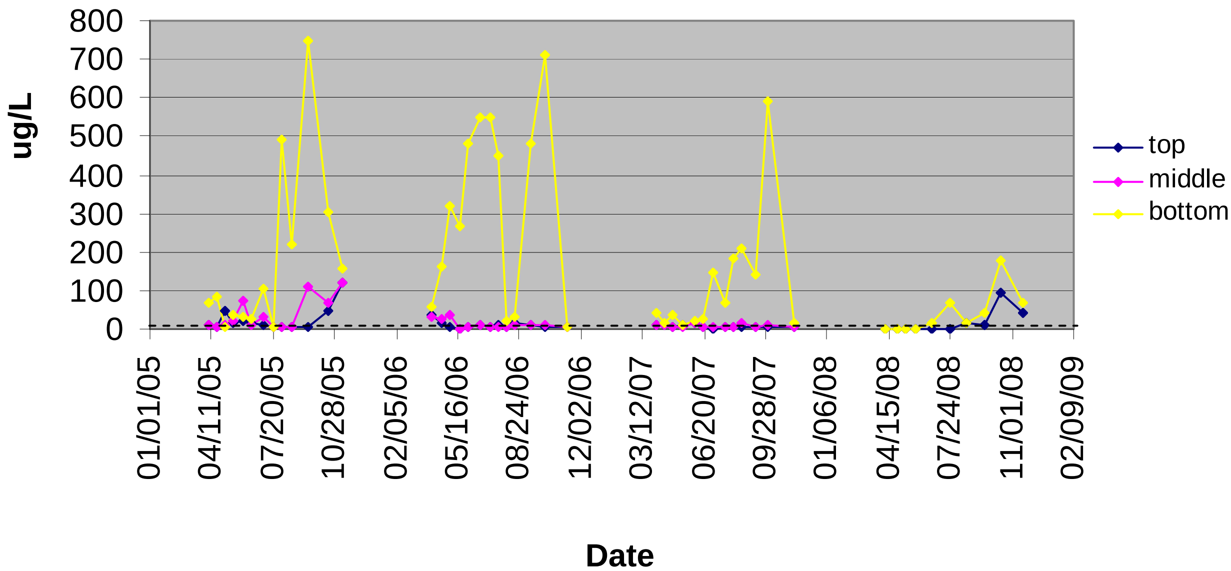


**Figure 48.** Secchi disk depth in Seaman Reservoir.



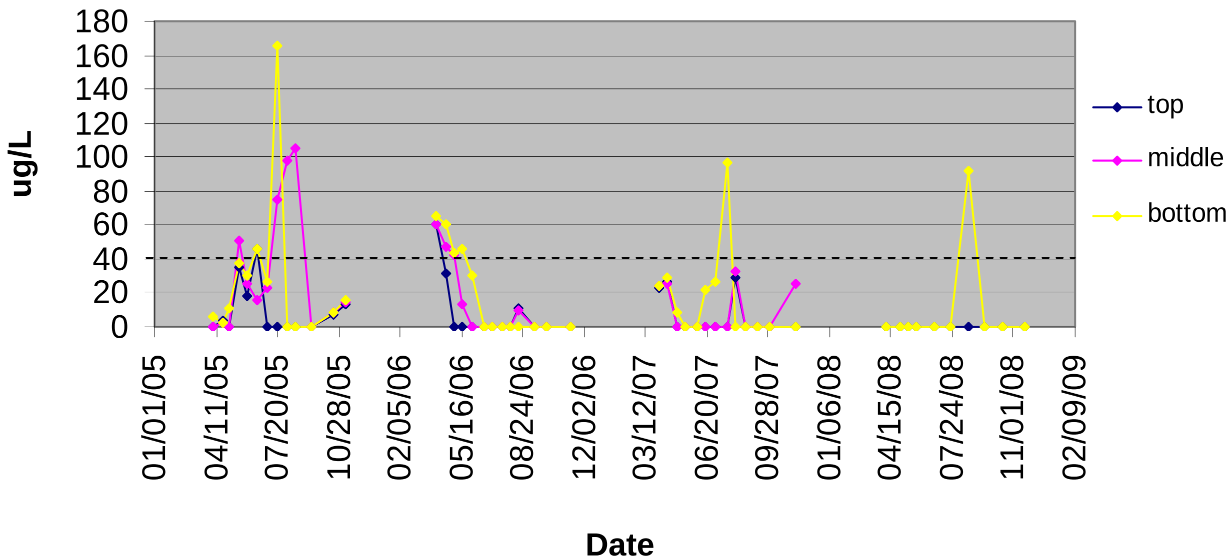
# Seaman Reservoir: Nutrients

**Figure 49.** Ammonia ($NH_3$) 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)

**Figure 51.** Nitrite ($NO_2$) concentrations in Seaman Reservoir.

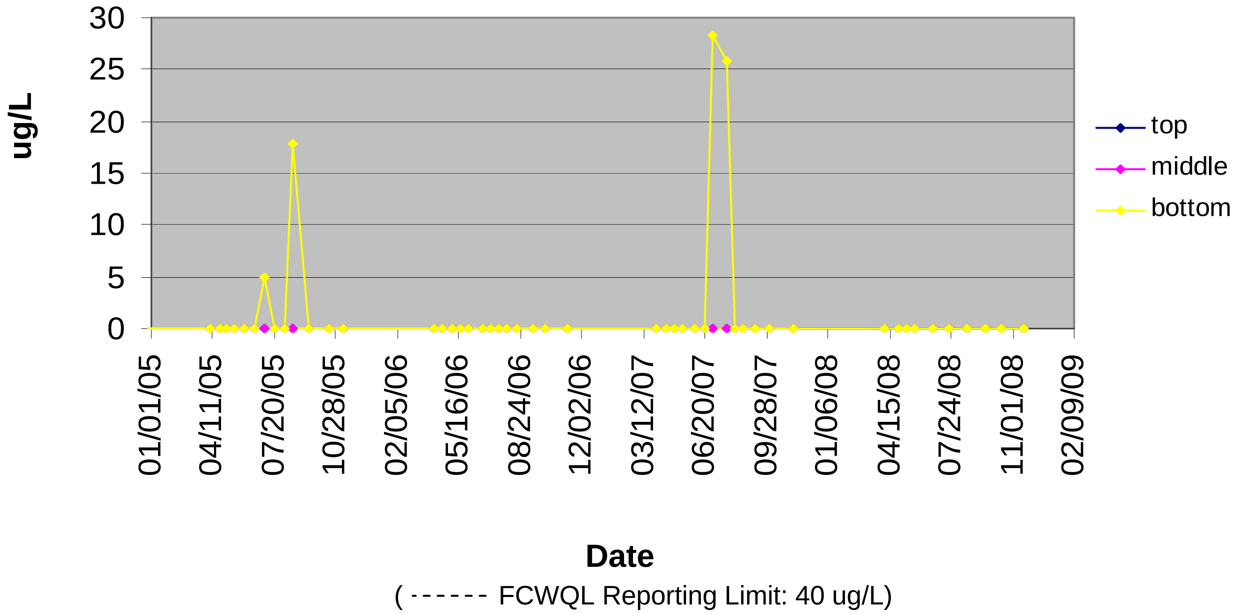



**Figure 52.** Total Kjeldahl Nitrogen (TKN) concentrations in Seaman Reservoir.

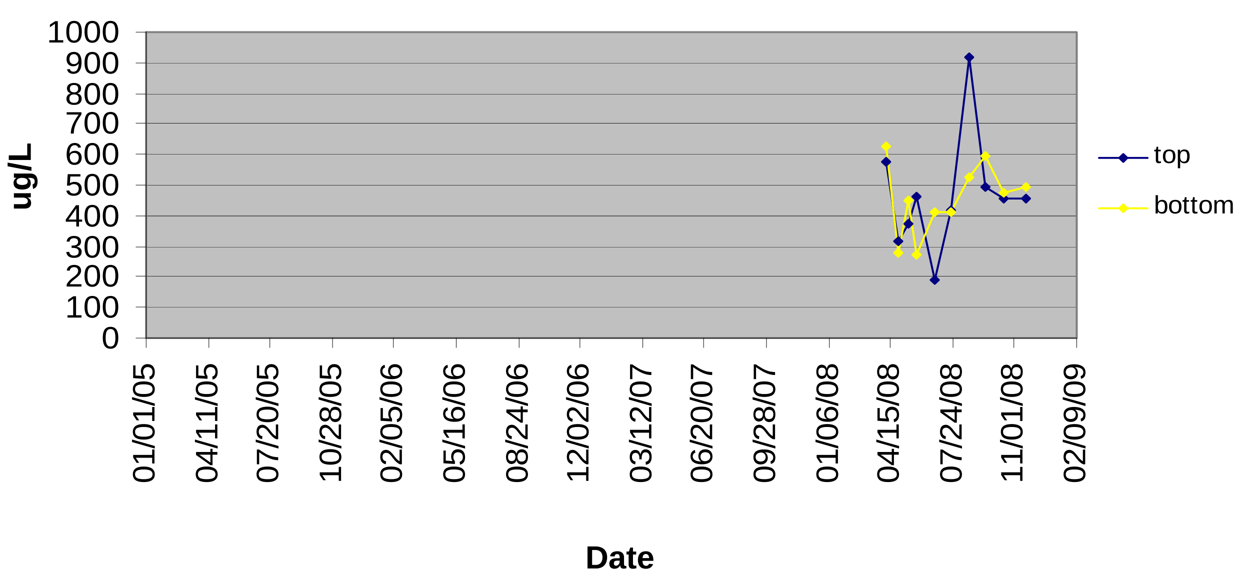


**Figure 53.** Ortho-phosphate ($PO_4$) concentrations in Seaman Reservoir.

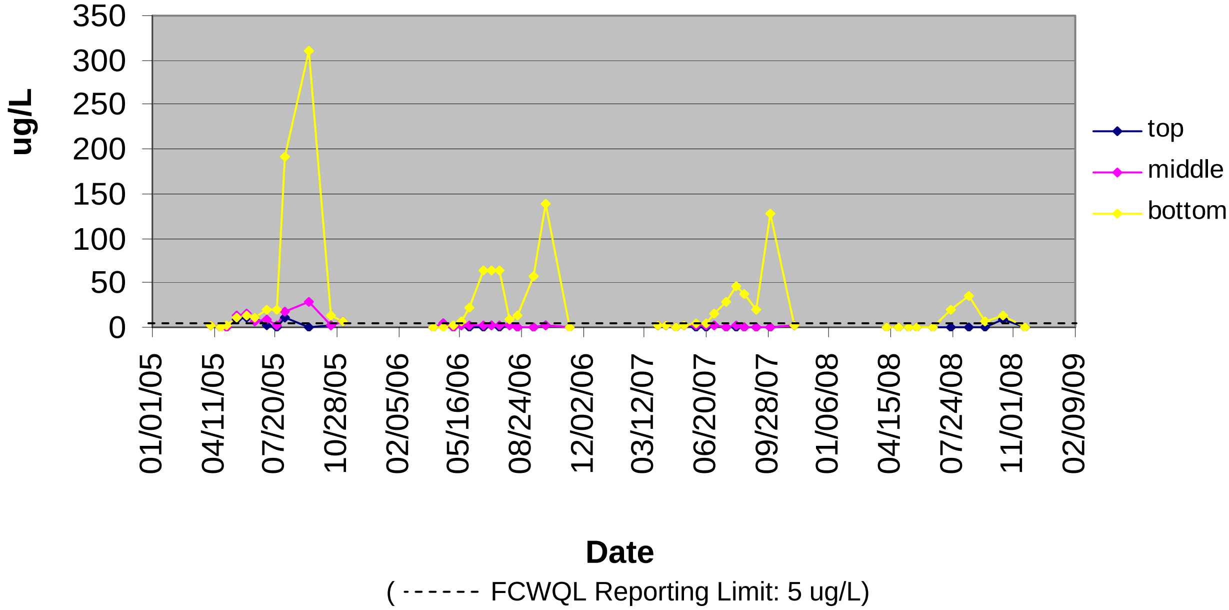
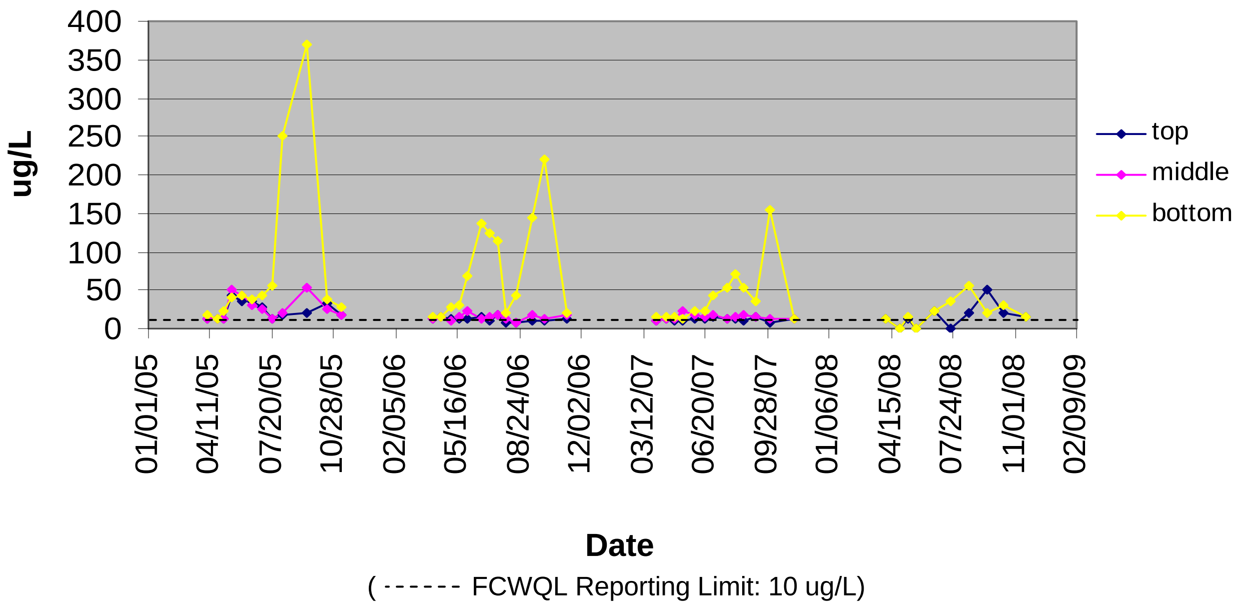



**Figure 54.** Total phosphorus concentrations in Seaman Reservoir.



# Seaman Reservoir: Major Ions

**Figure 55.** Calcium (Ca) concentrations in Seaman Reservoir.

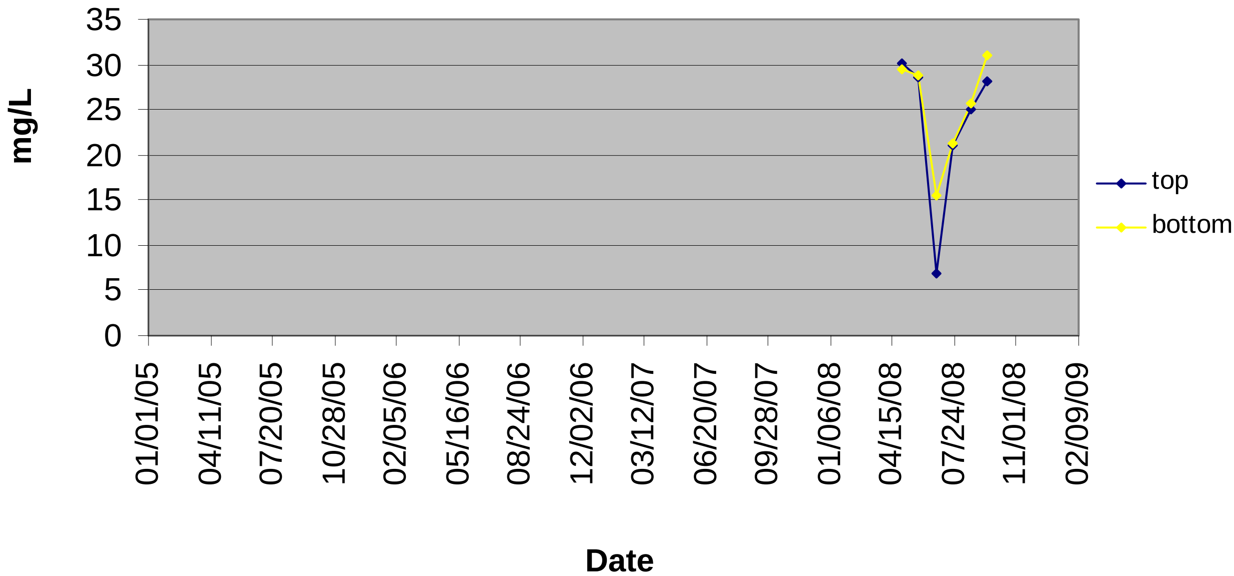



**Figure 56.** Potassium (K) concentrations in Seaman Reservoir.

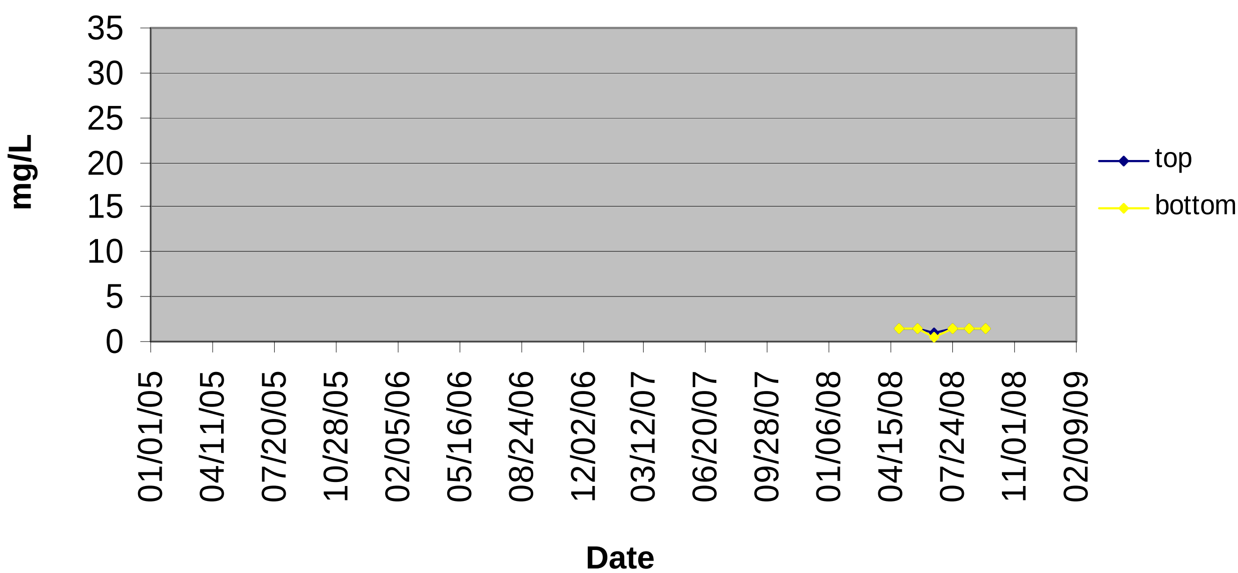


**Figure 57.** Magnesium (Mg) concentrations in Seaman Reservoir.

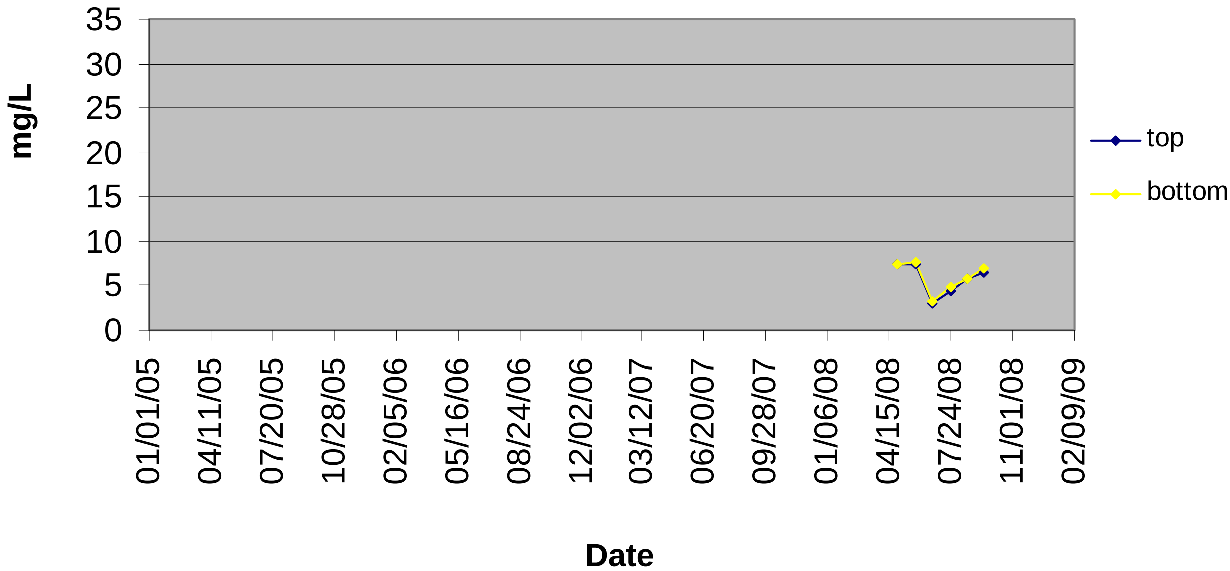



**Figure 58.** Sodium (Na) concentrations in Seaman Reservoir.

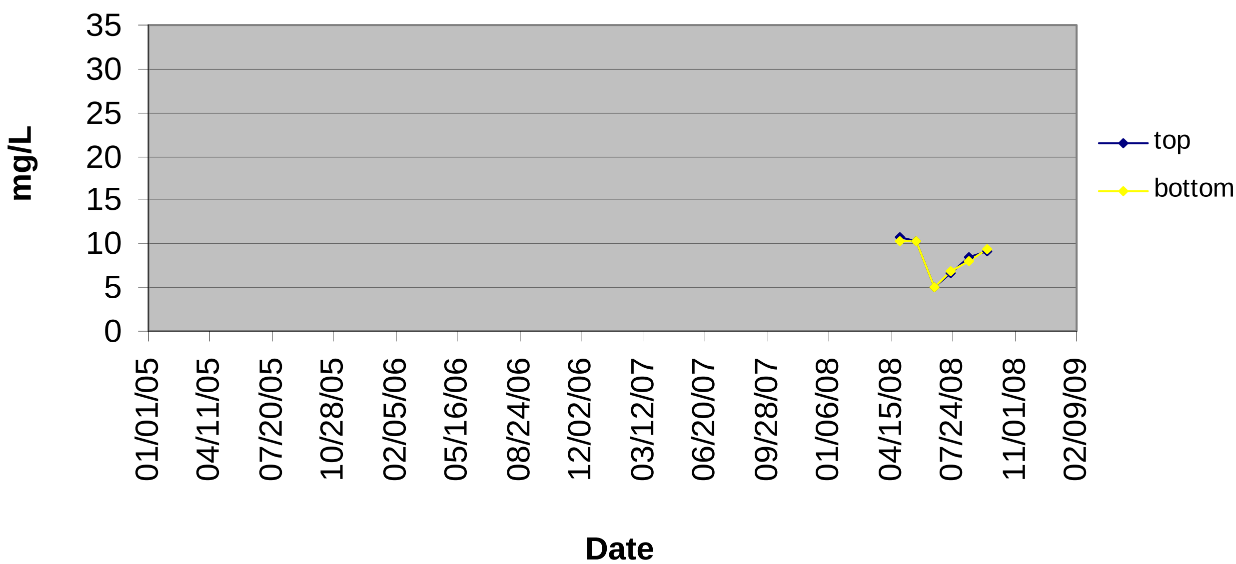


**Figure 59.** Chloride ($Cl^-$) concentrations in Seaman Reservoir.

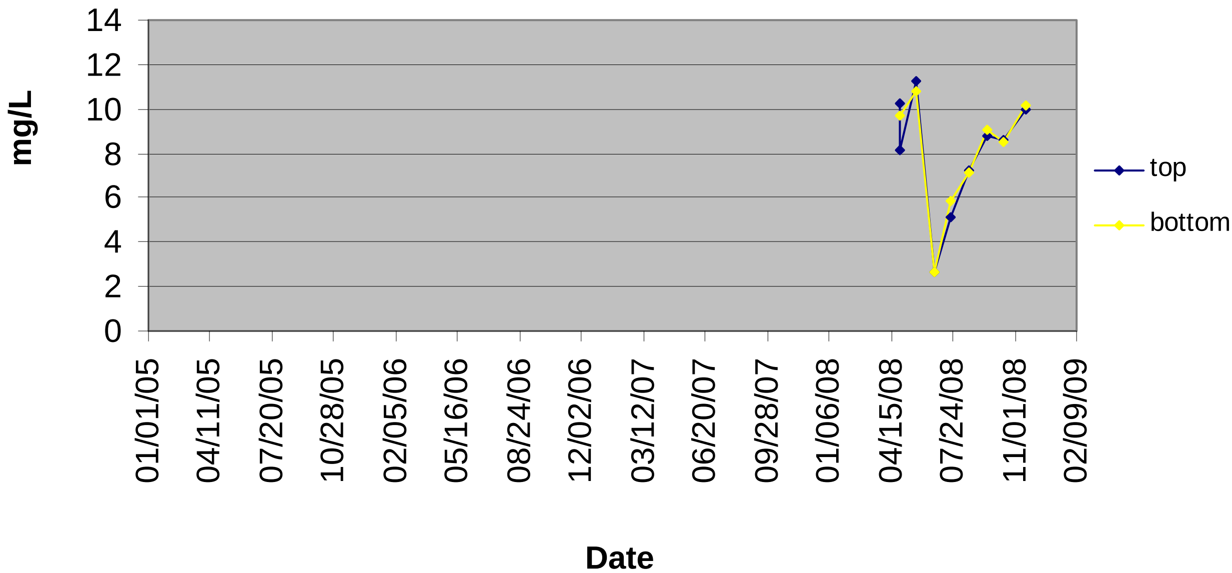
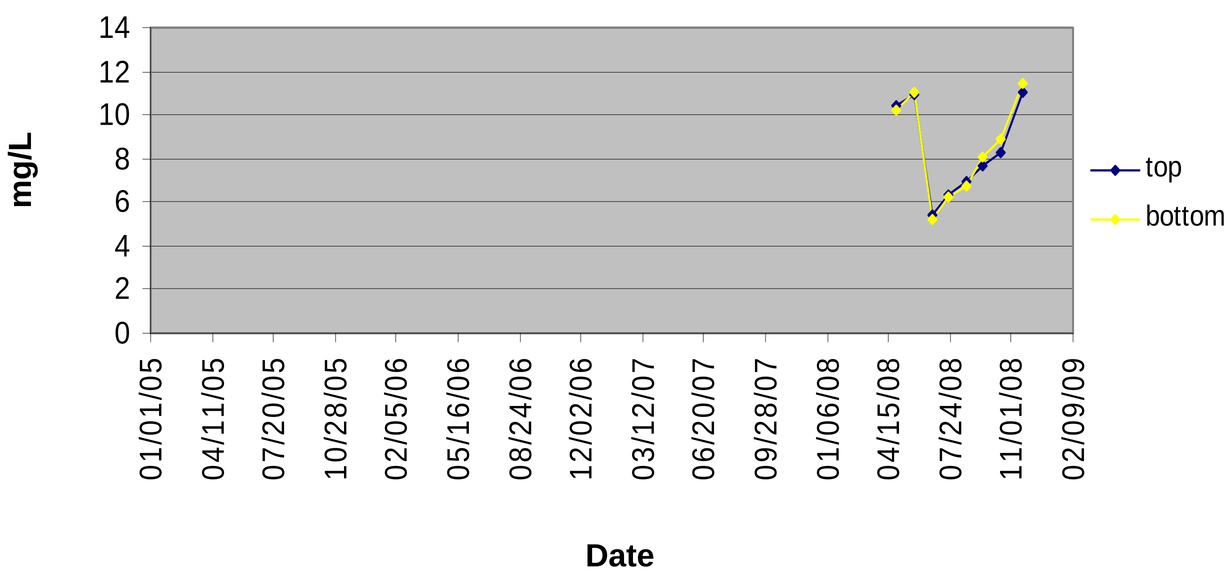



**Figure 60.** Sulfate ($SO_4$) concentrations in Seaman Reservoir.



# Seaman Reservoir: Microbiological Constituents

**Figure 61.** *E.coli* concentrations in Seaman Reservoir.

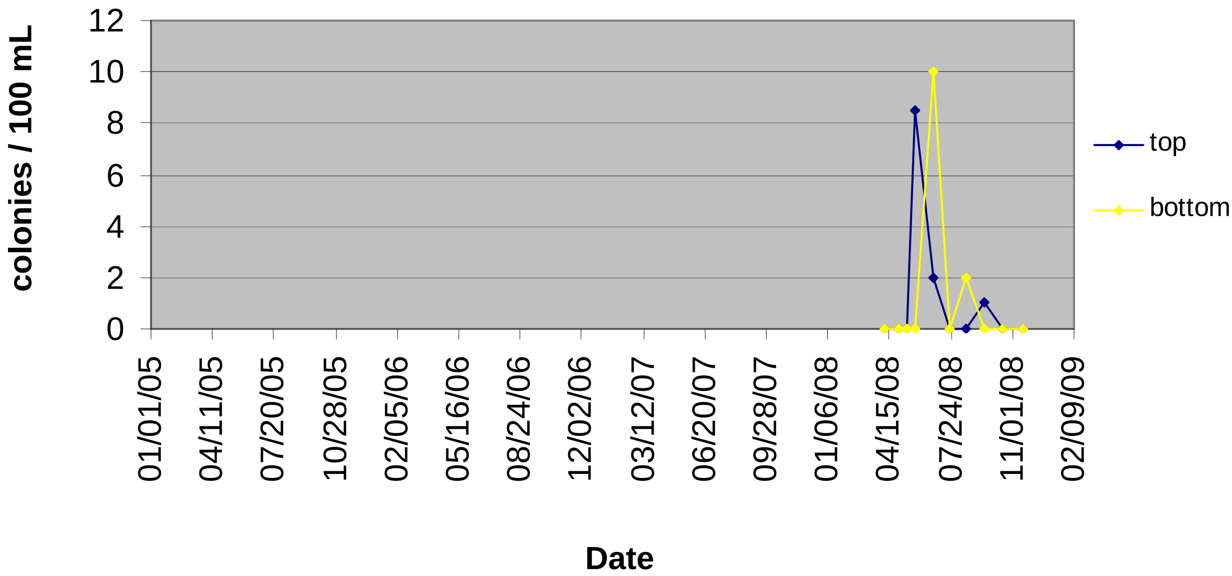
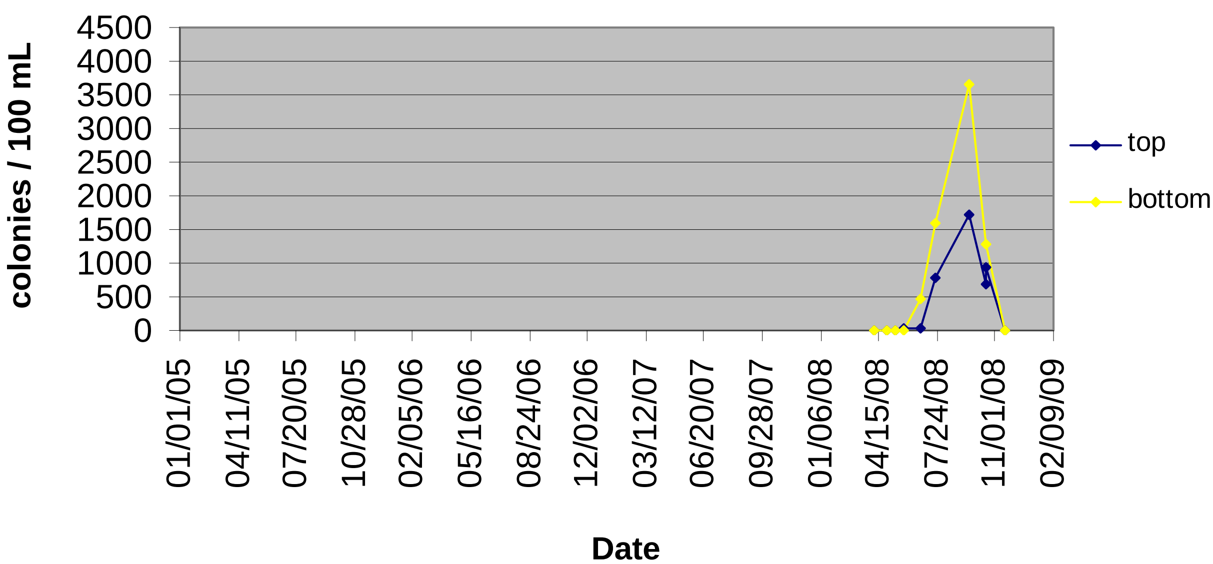



**Figure 62.** Total coliform concentrations in Seaman Reservoir.



# Seaman Reservoir:
# Geosmin

**Figure 63.** Geosmin concentrations in Seaman Reservoir.