CULVER LAKE WATER QUALITY MONITORING AND ZOOPLANKTON STOCKING PROGRAM 2012 END OF YEAR REPORT

Prepared for:

Normanoch Association, Inc.
P.O. Box 477
Branchville, New Jersey 07826

Prepared by:

Princeton Hydro, LLC

1108 Old York Road, Suite 1
P.O. Box 720
Ringoes, New Jersey 08551
(P) 908.237.5660
(F) 908.237.5666
www.princetonhydro.com
Christopher L. Mikolajczyk
cmiko@princetonhydro.com

January 2013

Executive Summary

Over the course of the growing season (May – September) of 2012, Culver Lake met the minimum standards set for phosphorus levels and for the most part, the minimum standards set for clarity. However, the lake's thermal/dissolved oxygen profiles were not always optimal with regard to trout hold–over habitat or zooplankton refuge habitat. Additionally, the lake's phytoplankton community was characterized for the growing season by the predominance of blue-green algae. The density and number of large-bodied zooplankton increased overall in 2012 relative to 2011, with the number of large-bodied zooplankton highest in the critical mid and late summer portions of the growing season. Overall the lake's water quality conditions can be summarized as follows:

- ***Dissolved Oxygen (DO)*** - Data collected from late-May through late-September document that the aeration system did not consistently maintain positive dissolved oxygen concentrations throughout the entirety of the lake's water column. In late-May, DO concentrations were within the desired range from surface to a depth of approximately 10 meters. By mid-July, a DO sag had developed, resulting in anoxic DO concentrations below a depth of 8 meters. By late September the anoxia in the deep-water continued, with anoxic conditions again at depths greater than 8 meters. Usually, anoxic conditions in the lake's deep hypolimnion (water deeper than 10 meters) are not an especially significant concern as this water remains segregated from the upper, sunlit epilimnetic waters. However low or no DO in the metalimnion (water depths of 5 – 10 meters) has the potential to significantly impact water quality. **As compared to the data collected in the more recent monitoring years, lower dissolved oxygen concentrations were measured in the metalimnetic layer in the mid to latter part of the summer. As noted under temperature, anoxic conditions were observed at times in the metalimnion and overall growing season DO concentrations were not considered ideal with respect to trout holdover habitat.**

- ***Secchi Transparency*** - The targeted lake management Secchi transparency depth for Culver Lake is 1 meter. **In 2012 the lake's Secchi depth dropped below this target depth; and the 2012 average Secchi depth, as measured by Princeton Hydro at mid-lake, was 1.35 meters, which is substantially less than the 1.8 meter average measured in 2011.** However, an annual average clarity of 1.35 meters is still considered good for most lakes in northern New Jersey. Appendix E documents the Secchi depths and water clarity conditions on each of the three Princeton Hydro monitoring dates. Of significance is that 2012 was a much drier year in New Jersey overall as compared to 2011, however heavy nutrient influx conditions to Culver Lake existed locally in 2012, especially in the latter part of the growing season.

- ***Temperature*** - **The lake became thermally stratified by mid-May and remained so through late-September. As has historically been the case, three distinct thermal layers**

developed, coinciding with the following approximate water depths: 0 - 5 m, 5 m - 10 m, and 10 m to bottom. For the purpose of this report, the epilimnion, metalimnion and hypolimnion will be defined by these depth intervals. The metalimnetic portion of the lake had corresponding dissolved oxygen concentrations that ranged from 7.75 mg/l in the mid-spring to anoxic conditions in late-summer. This cool thermal layer (metalimnion) should be providing midsummer trout habitat and refuge habitat for large zooplankton. Although from the perspective of temperature, adequate conditions were maintained for the most part, however the DO concentrations measured in the metalimnion were not always adequate to support trout. The data show that trout holdover habitat existed only in the late spring, and for the remainder of the summer, particularly in the late summer, was marginal at best. **Also with respect to the lake's thermal properties, algal densities, as interpreted from Chlorophyll *a* data, increased over the summer at or near the lake's thermocline. However this algal buildup is most likely the result of the concentration of settled algal cells, rather than the result of a mid-water column algae bloom.**

- ***Phosphorus*** - Phosphorus concentrations were measured over the 2012 growing season at each of the lake's thermal layers. In the late spring, phosphorus concentrations were somewhat elevated (0.03 mg/L and 0.05 mg/L, respectively) in the epilimnion and metalimnion, but were especially elevated in the hypolimnion (0.29 mg/L). In the middle of the summer, the TP concentration measured in the epilimnion and metalimnion had decreased to a lab detected minimal concentration of 0.02 mg/L or less, and had also decreased in the hypolimnion from the spring concentration of 0.29 mg/L to 0.16 mg/L. **By late summer (21 September), TP concentrations in the epilimnion and metalimnion had increased to 0.04 mg/L, while the hypolimnetic concentration of TP increased significantly to 0.32 mg/L from the 0.16 mg/L measured in July.**

  The lake's TP concentrations appear in part to have been influenced by the prevailing weather pattern that characterized the summer of 2012. The low frequency of storms in the mid summer timeframe decreased both the influx of nutrients and the flushing rate of the lake. While a decrease in the amount of phosphorus loading to the lake is a positive, the lake's reduced flushing rate increases the opportunity for available inorganic phosphorus to be assimilated. As a result, surface concentrations of TP remained consistent over the early to middle part of the growing season as available inorganic phosphorus was assimilated by algae. The storms that then occurred in early September were likely responsible for the increase in surficial TP measured during the last part of the growing season.

  Overall the observed seasonal and depth related changes in TP concentrations documented in 2012 followed a pattern somewhat similar to that observed in Culver Lake during the previous years. Additionally, the documented increases in TP in the late summer, as supported by the lake's Secchi data, did not have a large negative

impact on the lake's overall perceived condition.

- ***Ammonia*** – An increase in the concentration of ammonia was observed over the course of the growing season in the lake's hypolimnion. **As was somewhat similar with phosphorus, the general trend for the growing season of 2012 was an increase in ammonia concentrations over time and with increasing depth. This is the same pattern as observed in the past seven growing seasons, and is a trend that we expect to observe in Culver Lake as long as the hypolimnion is anoxic.** The buildup of ammonia in the deep layers of a stratified lake is largely due to the bacteriological breakdown of organic material under anoxic conditions.

- ***Chlorophyll a*** - Chlorophyll *a* is a photosynthetic pigment present in all algae. It is used as a surrogate to evaluate and quantify algal community development in Culver Lake. The acceptable maximum threshold concentration for chlorophyll *a* in Culver Lake is 20 mg/m^3. **In May, before the lake's algal community began to fully bloom, the concentration of chlorophyll *a* in the epilimnion was 9.9 mg/m^3. In July, a surface algal bloom was present and the epilimnion concentration of chlorophyll *a* had increased to 46.9 mg/m^3. By late summer, the bloom had somewhat dissipated and the epilimnetic concentration of chlorophyll *a* had decreased to 27 mg/m^3.**

  The chlorophyll *a* concentrations measured in the lake's metalimnion peaked in the late spring. This may have been the result of late April/early May rain storms driving the upwelling of phosphorus rich water into the metalimnion (which would potentially stimulate a mid-depth water bloom) or could reflect the simple settling and accumulation of surficial algae at the lake's thermocline. We expect the former, given the concentration of DO and TP measured in the deeper reaches of the lake at this time of year, relative to that measured at the surface.

- ***Phytoplankton*** **–** The phytoplankton community was monitored both at the surface and at the lake's metalimnion. Blue-green algae were found to the dominant phytoplankton community over the entire course of the 2012 growing season (May through September), especially from the mid-summer point onward. **It is important to note that the abundance and density blue-green algal species measured in 2012 was elevated compared to what was observed in 2011. Thus, even though the lake continues to be characterized by relatively low epilimnetic concentrations of TP at times, it is still clearly dominated by blue-green algae.**

- ***Macrophyte Growth and Management*** **–** Macrophyte growth in the Stehr Tract section of the lake once again continued to pose an overall management problem in 2012. Mechanical harvesting of this area effectively addressed the problems caused by the density of weed growth. **Data provided by Aquatic Technologies, Inc. estimated that approximately 182-195 tons of wet plant material was removed from Culver Lake in 2012. This is approximately 40-55 tons <u>more</u> than what was removed in 2011.** In terms of species composition, weed density, weed distribution, and overall weed growth, conditions remained fairly stable relative to those observed in 2011. Specifically, the species removed were Eurasian watermilfoil, Coontail, Curly-leaf pondweed, Elodea, Tapegrass and both White and Yellow Waterlilies.

- ***Inlets –*** Stream sampling was again conducted in 2012. This was limited to the collection of key water quality parameters at the lake's two main tributaries (Owassa Brook and Causeway Cove Brook) under non-storm flow conditions. **This sampling showed that the concentration of TP in the stream discharging from Lake Owassa peaked in the mid-summer at 0.06 mg/L. This concentration is approximately three times the concentration that was measured at the same time in the lake's surface waters. These data show this stream being a problematic source of phosphorus.** It must be emphasized that these are <u>baseflow</u> measured conditions. It is possible that due to the late summer storm event conditions experienced in the 2012 growing season, the concentration of TP entering the Culver Lake via the Owassa Inlet was much higher than normal. This assumption is justified given the types of land use that dominate the watershed adjacent to this stream and the likelihood of roadway runoff entering the stream during storm events. We also expect the TP concentrations entering the lake from this location were far greater when storm runoff was flowing off of the adjacent roadways.

  The Causeway Cove Inlet TP concentrations did not display the variability observed with the Owassa Inlet data. The Causeway Cove Inlet TP was not consistent over the course of the 2012 sampling program; with concentrations ranging from a high of 0.06 mg/L in late May to a low of 0.03 mg/L in mid-summer. However, these concentrations are still elevated relative to the TP concentrations measured in the lake. With the exception of the July sampling event, these concentrations were also higher than those measured at the Owassa Inlet station. **Nutrient loading via the Causeway Cove Inlet may be tied to the release of nutrients from the large upstream wetland complex, particularly during long timeframes of low precipitation and low water levels. As is the case for the Owassa Inlet, these data show inflow from the Causeway Cove inlet being a problematic source of phosphorus. It should be noted that these are baseflow concentrations, thus Causeway Cove Inlet TP concentrations maybe far greater under storm conditions.**

Introduction

This report reviews the findings of the 2012 water quality monitoring program, and discusses the data with respect to the overall management of Culver Lake. The water quality of Culver Lake has been monitored continuously since the early 1990's by Princeton Hydro. The objective of the monitoring program basically revolves around the need to objectively and quantitatively evaluate the water quality status of the lake as it applies to recreational use and the ability to support a healthy fishery. The data are also used to evaluate the effectiveness of various lake management activities, including the operation of the Layer Air system. Supplementing Princeton Hydro's data are data collected by Ecosystem Consulting Services and Aquatic Technologies, Inc. The data collected by the former focus mostly on the performance of the aeration system, while the data collected by the latter pertains exclusively to issues related to weed (macrophyte) growth and weed harvesting. Finally, Princeton Hydro also utilized *in-situ* data collected by Culver Lake community volunteers on a weekly basis over the course of the growing season.

The combination of the data collected and supplied by all these parties increases the diversity and robustness of the database, thereby increasing the Association's ability to make informed assessments and decisions on the management of the lake. To gain further insight into those factors that may be stimulating algae blooms and declines in water quality, in 2008 an inlet stream sampling program was initiated by Princeton Hydro as a supplement to the in-lake program. Particular emphasis was placed on the use of the resulting data to better understand the role of external nutrient and sediment loading on the lake's water quality. The inlet sampling program involves the collection of key water quality parameters at the lake's two main tributaries; Owassa Brook and Causeway Cove Brook. This sampling was conducted only under non-storm, "baseflow" conditions.

Methodology

During the 2012 growing season Princeton Hydro monitored the water quality of Culver Lake on three dates; 24 May, 17 July and 21 September. The selected sampling dates enabled us to collect data during critical periods over the course of the growing season, and to make timely observations of weed growth, weed management and thermal stratification processes. During each sampling event, data pertaining to the lake's water chemistry, water clarity and the dynamics of the lake's zooplankton community were collected. In addition, on each date, observations were made of the lake's weed growth and algal (phytoplankton) community. Information was also obtained and reviewed regarding the Association's weed control and any fishery management efforts. As in past monitoring efforts, three stations were monitored in 2012; mid-lake, Stehr Tract and Causeway Cove. The North Shore was also observed for macrophyte growth. As noted above, to obtain a better understanding of the role of external nutrient and sediment loading on lake water quality, inlet stream sampling was also conducted in 2012 as a supplement to the in-lake monitoring program. This involved the collection of key water quality parameters at the lake's two main tributaries;

Owassa Brook and Causeway Cove Brook. The following details the procedures followed in the collection of the in-lake and inlet water quality data.

In-Lake

On each sampling date, Princeton Hydro conducted both *in-situ* and discrete water quality monitoring within the lake. At each station the following data were collected in profile, at one-meter intervals from the surface to bottom of the lake:

- Dissolved oxygen
- Temperature
- pH
- Specific Conductivity

In addition, the lake's clarity was measured at each station by means of a Secchi disk. Data pertaining to the occurrence and density of aquatic macrophytes (plants) were recorded on each sampling date. At the mid-lake station only, water samples were collected from the surface, mid and bottom depths and analyzed for the following parameters:

- Total Phosphorus (TP)
- Nitrate-nitrogen (NO_3)
- Ammonia-nitrogen (NH_3)

Lastly, samples were also collected from the surface and mid-depth for chlorophyll *a* analysis, and from the surface and mid-depth for the quantitative analysis of both phytoplankton and zooplankton.

Inlet Tributaries

On each sampling date, Princeton Hydro conducted both *in-situ* and discrete water quality monitoring within the tributaries. At each tributary, the following *in-situ* data were collected:

- Dissolved oxygen
- Temperature
- pH
- Specific Conductivity

The grab water samples collected at each inlet on each date were analyzed for the following parameters:

- Total Phosphorus (TP)

- Nitrate-nitrogen (NO_3)
- Ammonia-nitrogen (NH_3)
- Total Suspended Solids (TSS)

Results and Discussion:

1. In-Lake Water Quality

Water Temperature, Thermal Stratification and Dissolved Oxygen

The winter of 2011-12 was unseasonably mild, with many lakes in the northern NJ region never achieving an iced-over condition. Furthermore, the growing season of 2012 was unseasonably dry and generally warmer than average overall statewide. However, for precipitation patterns local to Culver Lake this was not the case. In fact, in May, June and July, the Culver Lake area received above average rainfall totals. However, in August and September, pronounced differences in actual versus average monthly rainfall values were measured (Table 1) both above and below average totals. The temperatures in the Culver Lake area were above average for every month of the growing season, from April though to October.

Table 1 – Actual vs. Average Rainfall and Temperature Data for Sussex County 2012*

Month	Precipitation		Temperature	
	Actual (in.)	Average (in.)	Actual (°F)	Average (°F)
April	2.51	4.44	49.3	47.2
May	5.41	4.46	63.0	57.7
June	5.31	4.57	66.7	66.1
July	4.74	4.22	74.2	71.2
August	1.93	4.23	71.1	69.4
September	8.88	4.45	62.9	61.4
October	5.50	3.72	54.0	50.0

*www.climod.nrcc.cornell.edu

The surface waters of the lake steadily increased in temperature through June and July then began to rapidly cool in September with the aid of several heavy rainfall events early in the month. The heating of the lake's upper layers (epilimnion) that began in the spring, after a mild winter, resulted in the lake's defined thermal stratification by mid-May. Similar to previous monitoring years, by mid-summer the thermocline was present strongly at a depth of approximately four (4) to five (5) meters (approximately 13-16 feet) below the lake's surface. The lake remained stratified and the depth of the thermocline persisted throughout the remainder of the growing season. As would be expected, both weather patterns and the operation of the lake's aeration system were responsible for the lake's observed thermal gradients. For Culver Lake, it is critical to keep the thermocline as deep as possible. We know that that the shallower the thermocline, the more likely is it for algae that accumulate at the thermocline to be re-circulated into the lake's epilimnion. Maintenance of the thermocline at a depth of 4-5 meters tends to avoid this problem, thus aiding in the maintenance of the lake's clarity.

Similar to previous monitoring years, as the growing season progressed, dissolved oxygen (DO) measured in the deeper reaches of the lake declined. However, in 2012, the seasonal DO sag was first observed in the metalimnetic reach as opposed to the hypolimnetic zone of the lake. Specifically, by mid-summer, the concentration of DO measured in the lake's metalimnetic zone (4-7 meters below the surface) was significantly depressed, although not fully anoxic. As will be discussed in further detail in the nutrient sub-section of this report, reduced DO conditions within this zone can potentially increase the opportunity for phosphorus recycling into the sunlit, epilimnetic zone as a result of upwelling (metalimnetic erosion). This condition may also have a carry-over effect that results in greater algal densities the following spring. Lower DO in the lake's metalimnion is especially relevant to the maintenance of the lake's cold-water (trout) and zooplankton communities. Typically, lack of sufficient DO in the cool middle layers of the lake impacts its ability to provide much-needed trout habitat during the summer months. Lack of sufficient summer hold over habitat can create a stress on the trout that affects their survival. As evidenced by the 17 July 2012 *in-situ* data, this was the case as insufficient DO (> 5.0 mg/L) was present in the metalimnion. The volunteer/ECS *in-situ* data, also reveals this condition of the metalimnion possessing reduced DO concentrations. Lack of sufficient DO in the metalimnion also reduces the amount of refuge habitat available for large bodied zooplankton. This impacts their ability to avoid predation, thus impacting their ability to survive in high numbers over the course of the growing season. A decline in herbivorous zooplankton in turn decreases the amount of grazing pressure exerted by these organisms on the lake's applicable phytoplankton communities, thus limiting the amount of biological control exerted on algae blooms.

With respect to the DO data, from July through September, metalimnetic DO concentrations were unacceptable with respect to the maintenance of summer hold-over trout habitat. In July, a metalimnetic DO concentration dropped below 5 mg/L at a depth of 4 meters and was consistent to the bottom. These data indicate that as of mid-July, the lake's hold-over trout habitat was minimal at best, and most likely stayed at such for a short term. Similar to DO conditions observed in the past, the mid-depth DO concentrations measured in 2012 were somewhat similar to those observed in 2011. When examined relative to the DO/depth data collected over the past ten years, the 2012 data show that DO concentrations decline from spring through summer in the metalimnion, resulting in minimal summer hold-over trout habitat at best. Between the July and September sampling events the lake's hypolimnetic DO concentrations significantly increased, and in fact reversed the near anoxic state observed in the mid summer (Appendix A). The existence of depressed DO levels in the lake's hypolimnion is acceptable, as long as the anoxic portion of the hypolimnion remains well below the lake's thermocline and suitability separated form the metalimninon. It is also acceptable, if the lake's aeration operations are manipulated such that any released phosphorus is not allowed to mix into the epilimnion either as a result of some form of mid-summer upwelling or during the lake's fall turn over. The lake's DO and thermal properties as measured in July are reason for caution. However, as documented by the phosphorus data collected during this same time period, the depressed DO conditions that characterized the majority of the lake's hypolimnion in July did not appear to be severe enough to impact the lake's phosphorus dynamics as this is when the lowest TP concentrations were observed in 2012.

pH

As the summer progressed, the lake's pH changed consistently with depth. In late-May, the pH of the epilimnion was moderately alkaline (7.64 to 7.88). Once below the thermocline, the pH was reduced slightly, ranging from 7.29 to 7.55. In July, the pH of the epilimnion was neutral to alkaline (7.04 to 9.17). Once below the thermocline, the pH decreased to essentially a slightly alkaline level. The pH levels in September were much less prominent than those observed in July, as epilimnetic pH levels had again returned to a more neutral status, similar to what was observed in May. These reduced pH levels were the direct result of reduced algal productivity and photosynthesis, as a result of the extremely wet weather experienced in late August and early September. Once below the metalimnetic thermocline, the pH of the lake continued to decline and was moderately acidic nearest bottom. Overall, the pH values of the lake suggest the existence of season-long algal bloom conditions in the upper water column. The alkaline conditions measured in the epilimnion in mid-July were indicative of a bloom perhaps stimulated by the drier and warmer normal conditions experienced in June and July of 2012. These conditions are typically observed in the mid summer. Additionally, the lake's chlorophyll a concentration at the surface was elevated at this time (46.9 mg/M^3), suggesting that there was indeed a bloom.

Clarity

The lake's Secchi disk transparency, as measured by Princeton Hydro, remained above the target Secchi depth of 1 meter throughout most of the growing season. In May, the lake's Secchi clarity was 1.9 meters. It dipped in July to 0.9 meters, but in September had recovered to a depth of 1.3 m. Although the Secchi depth was 0.9 meters during the July monitoring event, the volunteer collected data show that approximately one week prior to (July 21, 2012) and one week after (August 1, 2012) the July monitoring event, the Secchi depth was greater than 1 meter. Thus, the reduced Secchi depth observed in July was the result of a short-lived intense algal bloom.

Nutrients

The results of the 2012 discrete laboratory analysis data are presented in Table 2. The 2012 and long-term nutrient data are also presented is graph format in the figures contained in Appendices B and C, respectively.

Table 2 - Culver Lake 2012 Discrete data

Sample ID		Chl A (mg/M3)	NH3-N (mg/L)	NO3-N (mg/L)	TP (mg/L)	TSS (mg/L)
24-May-12	Surface	9.9	0.03	0.16	0.03	-
	Mid-Depth	18.4	0.03	0.15	0.05	-
	Deep	-	0.55	0.29	0.29	-
	Causeway Inlet	-	-	0.20	0.06	14
	RT. 206 Inlet	-	-	0.24	0.05	ND <3
17-Jul-12	Surface	46.9	0.10	ND <0.02	0.02	-
	Mid-Depth	17	0.06	ND <0.02	0.02	-
	Deep	-	0.58	ND <0.02	0.16	-
	Causeway Inlet	-	-	ND <0.02	0.03	5
	RT. 206 Inlet	-	-	0.09	0.06	ND <3
21-Sep-12	Surface	27	ND <0.01	0.04	0.04	-
	Mid-Depth	9.5	0.06	0.04	0.04	-
	Deep	-	1.7	0.10	0.32	-
	Causeway Inlet	-	-	0.15	0.04	2
	RT. 206 Inlet	-	-	0.14	0.03	2

Phosphorus concentrations were measured over the 2012 growing season at each of the lake's three thermal layers. The epilimnetic and metalimnetic phosphorus concentrations were divergent in the spring. That is, there was already a large difference between the concentrations measured in the lake's upper layers (0.03 mg/L and 0.05 mg/L) and that measured in the hypolimnion (0.29 mg/L). As expected, by mid-summer, the deep water concentration of TP (0.16 mg/L) remained higher than the TP concentrations measured in either the epilimnion or metalimnion (both 0.02 mg/L). In late summer, the concentration of TP in the lake's deeper waters had increased to 0.32 mg/L and was still much higher than the concentrations measured in the lake's surface and mid-depth layers (both 0.04 mg/L).

Spikes in the mid to late summer hypolimnetic concentrations of TP are relatively common in the lake as evidenced by data going back to 2004. These spikes are in part related to declines in bottom water DO concentrations that lead to the sediment release of phosphorus (internal TP loading). The increase in hypolimnetic concentration of TP observed in September 2012 is similar to that observed during the same corresponding time periods in recent years. This may be a function of both the extremely large late summer storm events, as well as changes in the seasonal operation of the lake's aeration system during the late summer periods.

In May, ammonia concentrations were minimal at the surface and mid-depth layers (0.10 mg/L or less). However the deep water concentration (0.55 mg/L) was elevated. In July, ammonia concentrations displayed the same pattern from surface to bottom, ranging from a low of 0.06 mg/L to a maximum of 0.58 mg/L. In September, ammonia concentrations were the most variable from surface to bottom, ranging from a low of ND <0.01 mg/L to a maximum of 1.70 mg/L. The observed changes in depth in the concentration of ammonia are tied directly to the changes in the water column profile of DO and the more DO depleted conditions that existed below the 5-meter thermocline as the summer progressed. Typically, ammonia concentrations increase dramatically in the lake's deeper waters under DO diminished or anoxic conditions, and typically increase markedly in Culver Lake over the course of the summer.

Unlike ammonia, the lake's nitrate concentrations remained somewhat consistent over the 2012 growing season. As the growing season progressed, nitrate concentrations increased slightly in the deepest waters of the lake (depth >14 meters) relative to the concentrations measured at the surface and at the thermocline earlier in the year. This is expected, and is due to bacterial decomposition occurring near the bottom of the lake. The conversion of ammonia, in the presence of oxygen, to nitrate is through nitrification. By the end of the summer, nitrate concentrations had again decreased near the bottom and were somewhat more consistent with late spring concentrations. In addition, by the late summer, nitrate concentrations had decreased at both the surface and mid-depth layers. These upper layer decreases are largely the result of photosynthetic uptake of the nitrate occurring in the upper layers of the lake.

Chlorophyll *a*

For Culver Lake, the established maximum chlorophyll *a* concentration threshold is 20 mg/M^3. It has been determined, on the basis of past data and the consensus of lake users that when concentrations are below this value, the lake, although greenish in color, is aesthetically acceptable. As the concentration of chlorophyll *a* exceeds this target value however, there is an increase in lake user complaints and lower satisfaction with the appearance of the lake. It has been our experience that a concentration of 20 mg/M^3 typically coincides with the development of an algae bloom, especially the blue-green algae blooms. As such, we can use this target value to both gauge user satisfaction with the lake as well as identify the onset or existence of an algal bloom.
In May 2012, the concentration of chlorophyll *a* was 9.9 mg/M^3 at the surface and 18.4 mg/m^3 at the thermocline. These are acceptable concentrations as they are obviously below the target concentration. Although the mid-depth concentration was higher than in recent spring seasons, this concentration would be expected in the late spring because of the lake's cooler water temperature, limited duration and intensity of sunlight and the predominance of non-surface blooming algal forms.

With the onset of the summer, the lake's overall productivity is expected to increase, and this is reflected in the chlorophyll *a* concentrations measured in 2012. At the lake's surface in July the concentration was 46.9 mg/M^3, while at the thermocline it was 17.0 mg/M^3. Based on the targeted goals, this surface condition is considered unacceptable. These concentrations are an increase than those that were measured in the mid-summer in 2011. However, the fact that the mid-depth concentration was significantly lower than the surface concentration was deemed a positive. Although one would typically expect higher chlorophyll *a* concentrations at the lake's surface due to more favorable light intensity and warmer water temperatures, this has not always been the case in Culver Lake. At times, the blue-green algae *Oscillatoria* has developed to bloom densities near the thermocline. The subsequent upwelling of these algae to the surface has at times in the past caused significant water quality problems, as was the case in 2009. However, this condition was not observed in the mid-summer of 2012.

Later in the summer, due to the intense rain event conditions that persisted during the storms of August and September one would expect an increase in the concentration of chlorophyll *a* then was observed in the mid-summer, however this was not the case. In the late summer, the lake's surface chlorophyll *a* concentration had decreased to 27 mg/M^3; but was still above the established target concentration. In addition, at this same time the chlorophyll *a* concentration measured at the thermocline was 9.5 mg/M^3. This decrease in surface concentration is most likely the result of the extreme wet spell experienced in the region in August and September. This weather pattern allowed for heavy amounts of rain, and the subsequent flushing associated with it. These periods of heavy rain most likely increased the flushing that had previously been absent during the long dry spell that occurred in the overall growing season in June and July. However, it is important to note that these storms may have very well had the ability to fuel fall algal blooms, especially if mixed with the TP rich bottom waters had the lake turned over as a result of the heavy winds associated with these types of storms.

In examining the 2012 data to the data collected over previous years it was noted that the 2012 thermocline chlorophyll *a* concentrations were similar to those measured over the most recent years; that is the concentrations are relatively low from spring through the end of the summer. This year, similar to what was observed in the most recent growing season of 2011, the surface chlorophyll *a* concentrations increased as the growing season progressed, and exceeded the established threshold value in the mid and late summer.

Two important conclusions can be drawn from these data. First, the 2012 data shows that the algae present in the mid-layers of the lake were not responsible for the surface bloom. The maintenance of lower concentrations at the thermocline supports a conclusion that the transport of deep water algae to the surface was not a primary factor in the overall bloom. Second, as based on the analysis of the 2012 chlorophyll *a* with the other discrete and *in-situ* data, and especially the phytoplankton data (Section 2, below), it appears that prevailing mid-summer dry conditions followed by extraordinarily wet late summer conditions were the driving factor behind the overall blooms exceeding the chlorophyll threshold value in July and September. The wet conditions of early to mid 2012, followed by the dry mid-summer conditions allowed for the storm based influx of nutrients to remain and therefore significant growth and development of blue-green algae, thus leading to the observed intense bloom conditions (as reflected in the chlorophyll *a* concentrations) measured at the lake's surface in the mid-summer. However, the density of algae did reduce with the late summer's flushing storms, yet still remained at nuisance levels (concentrations greater than 20 mg/M^3). A sizable increase in chlorophyll *a* concentrations between the beginning and endpoint of the summer of 2012 was again observed.

2. Biota

Phytoplankton

During the May sampling event, a high diversity of green algae, diatoms, cryptomonads and blue-green alga were identified in Culver Lake. In the surface waters the blue-greens were the dominant group and the single dominant genus was *Anabaena*. In May, mid-depth algal abundance and biomass values were lower than the respective surface water values. However, unlike the surface waters, the diatoms were the dominant group, with *Synedra* the single dominant genus in the mid-depth waters.

During the July sampling event, the blue-green algae were again the dominant group in the surface waters of Culver Lake in terms of abundance, as well as the dominant group in terms of biomass. The blue-green algae that were identified in the surface waters included *Aphanizomenon, Anabaena, Chroococcus* and *Coleosphaerium.* Total abundance at the surface was elevated when compared to May, and this is reflected in the mid-summer chlorophyll *a* concentration of 46.9 µg/L. Mid-depth abundance and biomass values were actually higher than the respective surface water values, with the abundance and biomass groups also represented by the same blue-green algae groups observed at the surface. However, the mid-depth chlorophyll a concentration remained similar to May (18.4 µg/L to 17 µg/L).

Surface water phytoplankton samples taken in September were characterized by a similar community assemblage with blue-greens again accounting for the overall majority of the community in terms of abundance and biomass, with levels actually higher than that observed in July. The dominant algae at the surface in terms of abundance was the blue-green alga *Anabaena*. Mid depth phytoplankton samples however showed a significantly lower abundance and biomass than the associated surface water samples. The mid depth community assemblage was similar to that of surface waters, with the blue-green alga *Anabaena* continuing to exert dominance in terms of abundance and biomass. Along with the decreased phytoplankton abundance was a decrease in chlorophyll *a* concentration with a measured concentration of 17 µg/L in July to 9.5 µg/L in September.

The phytoplankton data documents the occurrence of blue-green algal forms in the lake over the entire growing season and their increased incidence as the summer progressed. In 2012, the blue-green assemblage was composed mostly of species known to create surface blooms and scums. In fact, the development of such surface scums intensified to the point that the lake's clarity dropped below 1 meter, albeit for a short time. Although, the clarity and aesthetic impacts were not as great as had been observed in past years (Figure 9).

Zooplankton

Zooplankton diversity, densities and biomass were moderate during the May sampling event. Mid-depth zooplankton values were similar in value to the surface during the May sampling event. In contrast to conditions observed in May 2004 – May 2006, herbivorous zooplankton were somewhat rare in Culver Lake as documented by the May 2012 sampling event. This continues a trend previously observed in recent years. The only herbivores present in the lake in May were the cladoceran *Bosmina* and the copepods *Cyclops and Diaptomus*; all identified in the surface waters and the mid-depth waters. No herbivorous C*eriodaphnia* were present in the May sample. The copepods were the most abundant group of zooplankton in the surface and mid-depth samples of Culver Lake in May.

During the July sampling event, the herbivorous zooplankton identified in the surface and mid-depth waters of Culver Lake were, *Bosmina*, *Diaptomus*, *Ceriodaphnia* and *Cyclops*. In the surface waters the rotifers were the dominant zooplankton group in terms of abundance, but in biomass the cladocerans dominated. The rotifers were also the dominant group in terms of abundance in the mid-depth waters; however the cladocerans again achieved the highest biomass. In fact, the single most abundant genus in the mid-depth July sample was the rotifer *Conochilus*. The herbivores accounted for approximately 42% of the total zooplankton abundance in the mid-depth July sample. This is an increase from the 2011 mid-depth July samples where herbivores accounted for approximately 35% of the total zooplankton abundance in the mid-depth sample. However, as documented in previous monitoring years, the mean total lengths of the herbivorous zooplankton sampled in July were less than 1.0 mm. This indicated that these zooplankton were under grazing pressure by forage and/or young gamefish.

During the September sampling event, several herbivorous zooplankton species were identified in the surface waters of Culver Lake. Specifically the copepods *Diaptomus* and *Cyclops* and the cladocerans *Daphnia and Ceriodaphnia* were identified. In the mid-depth waters the same species of herbivores were also identified. In the surface waters the copepods were the dominant zooplankton group in terms of both abundance and biomass. The rotifers were the dominant group in the mid-depth waters in terms of abundance, while the copepods were the dominant group in terms of biomass. In fact, the single most abundant genus in the mid-depth September sample was the rotifer *Keratella*. The herbivores accounted for approximately 51% of the total zooplankton abundance in the mid-depth September sample. This is a large increase from the same total zooplankton abundance observed in the mid-depth July sample.

Based upon the stable presence of the herbivores in the mid and late summer mid-depth samples, the zooplankton stocking program again assisted in controlling excessive amounts specific phytoplankton types, namely the chlorophytes (green algae). Green algae densities, on average, were overall much less in 2012 to those observed in 2011. However, the continued abundance of blue-green algae seems to have continued influence on in-lake herbivore concentrations to some extent. As previously mentioned the blue-green algae are not a preferential food source and are therefore only lightly grazed upon by the herbivores. To facilitate the development of a denser zooplankton community dominated by large-bodied herbivorous genera, a combined total of approximately 275,000 total herbivorous zooplankton (*Bosmina*, *Diaptomus*, *Daphnia* and *Ceriodaphnia*) were stocked in Culver Lake in May and September.

The distribution of the zooplankton, especially the minimal number of larger herbivorous forms, emphasizes the need to maintain a well oxygenated metalimnion. These organisms use the mid-water reaches of the lake as refuge habitat from predators, especially zooplanktivorous fish. Without ample DO in the mid-water depths of the lake, the habitat conditions conducive for the support of these large body zooplankton are less than optimal, thus creating additional stress for these organisms.

Aquatic Macrophytes

In May of 2012, approximately 40% - 50% of the Stehr Tract section of the lake was impacted by weed growth. Sporadic amounts of curly-leaf pondweed (P*otamageton crispus*) and Eurasian watermilfoil (*Myriophyllum spicatum*) were observed. Weed densities were minimal in the Causeway Cove section of the lake with Eurasian watermilfoil, curly-leaf pondweed and coontail (*Ceratophyllum demersum*) sporadically observed in this area as well. The North Shore of the lake also was characterized by low weed densities. In this area scattered patches of Eurasian watermilfoil and curly-leaf pondweed were encountered again.

Mechanical weed harvesting had occurred in late June, prior to our July 2012 sampling of the lake, with approximately 94-100 tons of wet plant material removed between 11 June 2012 and 19 June 2012. Even so, the Stehr Tract Cove remained impacted by sporadic weed growth, especially stands of tapegrass (*Valisneria americana*) as well as stands of curly-leaf pondweed, Eurasian watermilfoil and Elodea (*Elodea Canadensis*). Weed growth in the other sections of the lake remained intermittent and patchy, as compared to that observed throughout the lake in previous years. Only Eurasian watermilfoil and tapegrass were observed in the Causeway Cove portion of the lake. Additionally in July, minimal numbers of yellow and white water lily were observed scattered throughout areas along the North Shore and along the perimeters of the island present in the Stehr

Tract.

Similar to July, mechanical weed harvesting had occurred prior to our September 2012 sampling of the lake (approximately 88-95 tons of wet plant material removed between 30 July 2012 and 9 August 2012), In September, the Stehr Tract Cove was populated by tapegrass, coontail, elodea and Eurasian water milfoil, with a mix of all constituting the overall weed composition. In September, sporadic yellow and white water lilies, and tapegrass were observed along the North Shore. This same condition was observed in the Causeway Cove area of the lake in September as well as well as the scattered presence of Eurasian watermilfoil and tapegrass.

3. Inlet Water Quality

In order to obtain a better understanding of the role of external loading to the lake, inlet stream sampling was also conducted as a supplement to the in-lake program. The inlet stream sampling was added to the overall monitoring program in 2008 and involves the collection of key water quality parameters at the points where the lake's two main tributaries, Owassa Brook and Causeway Cove, discharge into Culver Lake. Owassa Brook (also known as Culvers Creek) is fed by discharge from Lake Owassa and enters Culver Lake via a culvert that runs under State Route 206. The Causeway Cove inlet enters Culver Lake via a culvert that drains the marsh/swamp area located directly to the northeast of Culver Lake. All sampling was conducted under base flow conditions, and consisted of the laboratory assessment of the concentrations of TP, TSS, NH_3-N and NO_3-N (Table 2), as well as the *in-situ* measurement of dissolved oxygen, temperature, pH, and conductivity (Appendix 2).

<u>In-Situ</u>

Temperature

Water temperature has great influence on aquatic life. Colder water can hold more dissolved oxygen and thus may support a greater variety or density of organisms, while warmer temperatures generally give rise to higher rates of biological activity (photosynthesis, respiration, etc.) As expected, based on their forested corridors, influence by groundwater and overall flowing characteristic, the water temperatures of the inlets were relatively consistent throughout the year. The inlets' water temperatures were cooler in July than the lake's surface water temperatures. However, the inlets' spring and late summer temperatures were slightly warmer than the lake's surface waters. This is more apparent for Owassa Brook than the Causeway Cove Inlet.

Dissolved Oxygen

The amount of dissolved oxygen (DO) measured in a stream is one of the best indicators of its health. Oxygen levels in water are a function of that which diffuses directly from the atmosphere and produced by the photosynthetic activities of macrophyte (aquatic plants) and algae. This "inputs" are offset by the amount of oxygen consumed or respired by the chemical and biological processes occurring in the stream. In fact DO may at times become depleted due to the respiratory demands of resident aquatic organisms (including bacteria). At least 5-6 mg/l of DO is needed to support a healthy diverse fishery.

The DO concentrations measured in both inlet streams were well above the NJDEP surface water standard of 5.0 mg/L. Over the course of the growing season, in-stream DO concentrations peaked in the fall when plant respiration is high and water temperatures are cooling from their summer peaks.

Specific Conductivity

Specific conductivity is a measurement of the amount of dissolved substances (i.e. nutrients, minerals, salts) in water. The higher the conductivity, the more dissolved substances are present in the water. Throughout the growing season, each stream's specific conductivity was consistent. There were however some differences in the specific conductivity of the inlet streams as compared to the specific conductivity of the lake, as measured in the epilimnion. Generally, the Owassa Inlet stream was approximately 25% lower in specific conductivity as compared to either the lake or the Causeway Cove inlet, most likely the result of undeveloped forested sources and overall cooler waters contributing to streamflow. Thus, under baseline conditions, the inlet streams do not appear to be transporting any excessive amounts of dissolved solids into the lake. It should be noted that this can change in the winter (due to road salts) or during storms (as a result of the mobilization of sediments and other pollutants).

pH

The pH of water can have a profound effect on the chemical and biological components of an aquatic ecosystem. Therefore, it is an extremely important ecological parameter. The pH measured at the inlet streams tended to be well within the surface water standards established by the NJDEP (6.5 to 8.5). Overall, the pH values that were observed were nearly neutral (6.5 – 7.0). This is somewhat different than observed in the lake where alkaline conditions tended to persist in the epilimnion. The difference is likely a function of the greater amount of photosynthetic activity that occurs in the generally still lake relative to the flowing streams. Increased photosynthetic activity will push the pH into the alkaline range.

Nutrients

Phosphorus

As stated earlier, phosphorus is the primary limiting nutrient in most freshwater waterbodies within the Mid-Atlantic section of the United States. In other words, it takes very little phosphorus to stimulate large amounts of algal and/or aquatic plant growth; as phosphorus concentrations increase, the amount of algal and/or aquatic plant biomass will also increase. Thus, reducing current phosphorus loads, as well as controlling future loads, is an effective, long term strategy in improving and preserving the water quality of a lake or pond. It has been well documented that in-lake TP concentrations greater than 0.03 mg/L can stimulate high levels of algal and/or aquatic plant growth. Under such conditions, a lake or pond is described as being eutrophic, meaning it is highly productive. Thus, such water bodies have the potential to experience algal blooms and excessive densities of aquatic plants. As part of the 2012 monitoring program, a single form of phosphorus was measured in the two inlet streams. This form of phosphorus is total phosphorus (TP), which measures all the phosphorus in the water; inorganic and organic, particulate and dissolved. Most water quality models are based on TP concentrations, since rates of phosphorus recycling is extremely fast in lakes and ponds.

The Owassa Inlet TP concentrations varied from 0.03 mg/L to 0.06 mg/L, with concentrations peaking in the mid-summer. The Causeway Cove Inlet TP concentrations also varied from 0.03 mg/L to 0.06 mg/L, with concentrations peaking in the late spring. These concentrations are greater than the TP concentrations measured in the lake's surface waters at the same time. This shows that the inlets are at times a source of phosphorus to Culver Lake. However, it should be noted that throughout the course of the growing season, a large amount of aquatic vegetation die-off was experienced. A large portion of the phosphorus measured in the Causeway Cove inlet water, especially during the late summer, may have been from the accumulation and/or decomposition of this plant biomass. In any event, the inlet streams function as phosphorus sources of concern for the lake.

Nitrogen

While phosphorus is the primary nutrient limiting relative to algal and aquatic plant growth, nitrogen is another extremely important nutrient. Nitrogen occurs in the environment in a variety of forms; particulate and dissolved, inorganic and organic. The two forms most easily assimilated by algae and aquatic plants are ammonia-N and nitrate-N. Both are dissolved, inorganic forms of nitrogen. Nitrate-N tends to be more mobile in surface and groundwater relative to ammonia-N and can be generated through microbial activities, such as nitrification. However, bacterial decomposition of organic matter tends to generate reduced forms of nitrogen such as ammonia-N and not nitrate-N. As a result of rapid assimilation by algae and aquatic plant of nitrate-N, the concentration of this nutrient tends to be relatively low in lakes and ponds. For sources of potable water, the Federal and State concentration limit for nitrate-N is 10 mg/L. While no ecological standard exists for nitrate-N, concentrations greater than 1 mg/L will support excessive amounts of algal and aquatic plant biomass. We have found that concentrations of nitrate as low as 0.3 mg/L are associated with streams displaying evidence of eutrophication (algae buildup on rocks, excessive weed growth, etc.). Therefore it does not take a lot of nitrate-N to result in algae and plant related problems.

For the inlet stations only nitrate-N (NO_3-N) was measured. The Owassa Inlet NO_3-N concentrations varied from 0.09 mg/L to 0.24 mg/L, with concentrations peaking in the late spring. The Causeway Cove Inlet NO_3-N concentrations varied from ND <0.02 mg/L to 0.20 mg/L, with concentrations also peaking in the late spring. Thus, under baseline conditions the NO_3-N levels in either the Causeway Cove or Owassa inlets are not considered elevated with respect to algae and plant growth.

Total Suspended Solids

Total suspended solids (TSS) are a measure of the amount of particulate matter suspended in the water column. The State limit for TSS is 40 mg/L. TSS concentrations greater than 40 mg/L, under baseline (non-storm event) conditions, can negatively impact aquatic habitats. Some of these negative impacts include in-filling of wetlands, lakes and waterways, the destruction of spawning habitat, and added physiological stress on fish through suspended sediments entering their gills. In addition, TSS concentrations greater than 40 mg/L are perceived by the layperson as being “dirty” or “muddy”. It is also important to note as some forms of phosphorus are bound to particulate material, especially clays and silts and fine organic debris. Such material can be carried into the lake from the inlet streams under both baseflow and storm conditions.

The Owassa Inlet TSS concentrations were very low (<3 mg/L) throughout the entire growing season. The Causeway Cove Inlet TSS concentrations were also low, but varied from 2 mg/L to 14 mg/L. The highest TSS concentration measured in the Causeway Cove Inlet occurred during the May event. It must be stressed that all sampling was conducted under baseline conditions. During storm events there is a considerable amount of TSS loading to the lake, not only from these streams but from direct discharge stormwater outfalls located all along the lake’s shoreline. Although the low concentrations of TSS measured under base flow conditions do not suggest any sedimentation problem, this is not the case during storm events as has been presented in volunteer photographs. The various deltas that have formed at the mouth of many of the direct discharge stormwater outfalls and in proximity to the Owassa and Causeway Cove inlets confirm that sediment loading to the lake is problematic. The data show that the extent and severity of storm based TSS (and likely TP and nitrate) loading needs to be more aggressively investigated and cannot be evaluated only by sampling the inlet streams under baseflow conditions.

4. Overall Summary

- By late May, the lake became strongly stratified. The thermocline established at a depth of approximately five (5) meters. The depth of the thermocline and the timing of the onset of stratification are similar to that observed in past years. The lake remained strongly stratified through late September.

- Lake clarity during the beginning of the growing season was exceptional (1.9 meters at mid-lake). This is relatively consistent with early season Secchi readings measured in recent years. Clarity declined by mid-summer, dropping to 0.9 m, but the lake's clarity in September increased relative to that measured in July (1.3 meters vs. 0.9 meters). Again, although a relatively small increase, such an increase in late-summer clarity is consistent with data collected over the past few years.

- Blue-green algae dominated the lake's phytoplankton community throughout 2012. In fact, the densities of blue-green algae reached a level that impacted the lake's clarity in the mid-summer, dropping it below the 1.0 meter threshold.

- Mid-summer algal densities were problematic given the greater than normal late spring rains which likely transported more nutrients that usual into the lake. The warmer and drier than normal mid-summer weather conditions then facilitated the uptake of the nutrients by phytoplankton. The July algae bloom was caused by an increase in blue-green algae densities, with the chlorophyll *a* threshold concentration (20 mg/M^3) being exceeded at this same time.

- The July DO, temperature and TP data show there was minimal internal phosphorus recycling as a result of bottom water anoxic conditions.

- The lake's mean Secchi depth in 2012 was 1.35 meters. In comparison the 2006, 2007, 2008, 2009 and 2010 means were respectively 1.9 meters, 1.9 meters, 1.8 meters, 2.0 meters, and 1.95 meters. As such, regardless of whether it was a wet or dry year, the lake's average clarity displayed relatively little inter-annual differences. However, from year to year the intra-annual differences in clarity as measured over the course of the growing season can be significant. This is illustrated in Figure 9 in Appendix C.

- Consistent with recent data trends, in 2012 the mid-summer dissolved oxygen concentrations measured in the lake's epilimnion were at or exceeded 100% saturation. DO concentrations declined rapidly at the thermocline and anoxic conditions (as per the volunteer/ECS data) were experienced throughout the deeper portions of the lake's profile. The hypolimnion's DO concentrations remained depressed and, as per the volunteer/ECS data, near anoxic for the majority of the latter part of the summer. Even so, as a result of the operation of the aeration system the phosphorus rich waters of the hypolimnion remained segregated from the epilimnion. Thus, we did not see any evidence of internally driven increases in lake productively over the majority of the 2012 growing season. With the aeration system operating at peak efficiency, there appeared to be no breakdown in stratification, and it was therefore possible (as evidenced by the TP data) to retain the phosphorus rich water near the bottom of the lake.

- In terms of hold-over trout habitat, the lake's DO properties were minimal at best from the early summer onward. It appears from mid-July through late-September, the DO concentrations and temperatures measured at or below the thermocline were less than that desired and necessary for the maintenance of trout.

- Total phosphorus concentrations as measured at the lake's surface, though somewhat variable, remained well below the 0.05 mg/L threshold for the entire growing season. However, the deep water concentrations of TP were significantly elevated relative to those measured in the epilimnion or metalimninon and peaked in the late summer at a concentration of 0.32 mg/L. However, the phosphorus rich waters of the hypolimnion did not migrate into the metalimnion or the epilimnion. Thus, although internal phosphorus release was experienced, the maintenance of the lake's thermal stratification fully segregated this phosphorus rich water to the bottom of the lake for a majority of the summer. Thus, in essence the lake's internal phosphorus load was controlled.

- <u>In general</u> (Appendix B and C) summer chlorophyll *a* concentrations have declined since 1995. The chlorophyll *a* concentration measured in mid-summer 2012 is higher, yet consistent, with the chlorophyll *a* concentrations measured since 2007. This appears to be a function of a number of factors associated with the overall management of the lake.

- Throughout the summer of 2012, Culver Lake's phytoplankton community was dominated by blue-green algae. The density of blue-greens measured in 2012, especially in the mid-summer was high and equated to bloom conditions. In fact, the lake's mid-summer chlorophyll *a* concentration also exceeded the lake's threshold level. Additionally, the bloom was great enough to impact the lake's Secchi threshold of 1.0 meter for a short time. Thus in the summer of 2012, even though blue-green algae were present and did bloom, the bloom was relatively short-lived and did not significantly impact the lake's Secchi clarity or aesthetics for an extended period of time.

- Nutrient and chlorophyll *a* data show there was no significant mid-depth algae bloom in 2012. The algal and chlorophyll data suggest little of the algae that developed at or near the thermocline was transported into the epilimnion and these algae were not responsible for the lake's mid-summer surface bloom.

- A good overall increase in the density of herbivorous zooplankton was observed in 2012. Overall, the lake's zooplankton community continues to show the positive effects attributable to the zooplankton stocking effort, the continued maintenance of zooplankton refuge habitat and the control of lake's alewife densities. A shift in the phytoplankton community further away from blue-green dominance would prove beneficial to the zooplankton as the blue-green algae are a poor food sources for herbivorous zooplankton.

- The Stehr Tract section of the lake continued to be impacted by excessive weed growth and continues to be the area of the lake in need of the greatest amount of weed control activity. Harvesting strategies in this section of the lake in 2012 proved to be successful. A large amount of weeds and biomat material (195± tons) were removed through the implemented harvesting operation. This resulted not only in improved boat access through this area, but also aided in water circulation and improved the general aesthetics of this area of the lake.

- Overall, weed growth in the <u>entire</u> lake continues to be sporadic and patchy. Weed densities in the Owassa Inlet and Causeway Cove sections of the lake and the along the lake's North Shore were consistent with the conditions documented in these areas in previous years. Although none of these areas tended to be as impacted by weed growth to the extent experienced in the Stehr Tract Cove, each is impaired to some extent by weed densities that impede access and usage. As such, these areas continue to require maintenance. It should also be noted that Eurasian watermilfoil densities in the Stehr Tract and Causeway Cove sections of the lake continued to be less dense in 2012. Tracking of the distribution and density of this weed needs to be continued, with the resulting data used to evaluate the need for additional hydroraking and/or harvesting efforts.

- *In-situ* data collection and TP, TSS, and NO_3-N sampling was conducted under base flow conditions at the Owassa and Causeway inlet stream stations. The *in-situ* data did not reveal any evidence of impairment or conditions that would be considered impactful to the lake. However, the concentrations of nutrients, in particular TP, were elevated in the inlet streams relative to the lake. Specifically, the Owassa Inlet TP concentrations varied from 0.03 mg/L to 0.06 mg/L, with concentrations peaking in the mid-summer. Overall, the concentration of TP measured at this station was at least double that measured on the corresponding date at the center of the lake. The Causeway Cove Inlet TP concentrations were also elevated relative to the in-lake concentrations, with concentrations varying from 0.03 mg/L to 0.06 mg/L, with concentrations peaking in the late spring. The elevated nature of the nutrient levels measured in either stream compared to that measured in the lake, documents the streams as important sources of phosphorus loading to Culver Lake. It should be noted that the data are baseflow values. Typical storm event concentrations are likely to be much greater and can therefore represent an even greater impairment to the lake.

5. Overall Conclusions and Recommendations:

The data collected during 2012 confirms that the lake's management efforts are working. For the most part, the lake's water quality met or exceeded the surface phosphorus concentration and water transparency threshold values. This is not to say that the lake was without problems. The 2012 data, when analyzed independently and with respect to the long-term database, show that the majority of the lake's water quality issues can be weather induced and very likely a function of increased external loading further enhanced by precipitation. Even though clarity was for the most part satisfactory, the lake's algal community was predominantly represented throughout the growing season by blue-green algae. Additionally, summer trout hold-over habitat was less than optimal, as based on the lake's metalimnetic mid- and late-summer thermal profile and DO concentrations.

Thus, although the lake continued for the most part to meet the community's recreational demands, the Association needs to continue to track the lake's water quality attributes. In particular, monitoring of algal species composition and algal densities in both the epilimnetic and metalimnetic regions of the lake must be continued. We also feel that additional attention needs to be given to external loading dynamics, the management of the lake's overall nitrogen and phosphorus balance (as related to the nitrogen:phosphosus ratios that do not favor blue-green algae) and the creation and/or maintenance of conditions that better support a zooplankton community that is consistently represented by a large percentage of herbivorous, large-bodied species.

With regard to the latter, data collected since 2007 shows that the stocking of herbivorous zooplankton is having a positive impact on restructuring the lake's zooplankton community. Observations in the recent years have not yielded quite the same results. However, the overall densities of herbivorous zooplankton did increase significantly in 2012 as compared to 2011, reversing the recent trend. The continued abundance of blue-green algae is limiting the success of herbivorous zooplankton. As previously mentioned, the blue-green algae are not a suitable food source for herbivorous zooplankton.

We continue not to support the stocking of any trout species for any other purpose than to augment the lake's fishery on a "put and take" basis. Any fish stocking done by the Association should focus only on species that can continue to exert predatory pressure on the lake's zooplanktivorous fish such as alewives and golden shiner. The limited suitable trout habitat, combined with hybrid Striped Bass predation, limits how much carry over and natural recruitment can be expected through the stocking of trout. The introduction of a few large trophy trout simply for the benefit of anglers is fine. However, it appears that it would be better from a biomanipulation standpoint to give some attention to the introduction of other piscivorous species such as Walleye (*Stizostedion vitreum*) or Tiger Muskellunge (*Esox masquinongy x Esox lucius*) to further control alewife and perhaps apply pressure on other pan and forage fish that school or congregate in the lake's weedy littoral areas. Our fishery data from 2007 suggested that the hybrid striped bass may be over stocked in the lake.

Hybrid striped bass weight / length data should therefore be continuously reviewed to confirm whether these fish are over abundant. Over the course of the 2009 season, observations by resident fisherman suggested that the alewife population was on the rise. Based on this observation and the date of the previous stocking, Princeton Hydro agreed with the decision of the Normanoch Association to re-introduce the hybrid striped bass stocking program on a limited basis. This stocking restarted in 2009 and continued through to the summer of 2012. Specifically, 1,700 hybrid striped bass 10-12 inches in length were stocked in the summer of 2012. At this point, Princeton Hydro suggests no further stocking be conducted until some quantification is made of the effects that these newly introduced hybrid striped bass are having on the lake's alewife population.

Lake-wide harvesting efforts continued to provide relief from use impairment caused by excessive weed growth. Data provided by Aquatic Technologies, Inc. estimated that approximately 195± tons of wet plant material was removed from Culver Lake in 2012. This is approximately 55 tons more than what was harvested in 2011. However, management of the weed growth in the Stehr Tract section of the lake should continue to include hydro-raking as a supplement to the conventional weed harvesting efforts. Overall, the 2012 harvesting project was successful. Thus, based on the success of this effort, a 2013 harvesting program should again be conducted in the Stehr Tract section of the lake. In addition, based on the continued trend of a reduction in the presence of Eurasian watermilfoil observed in the Stehr Tract and Causeway Cove portions of the lake, the management technique of harvesting and possibly hydro-raking in these specific areas should be continued.

Princeton Hydro still remains guarded in terms of the use of herbicides to control weed growth as long as the lake is a water source to shoreline community residents. We strongly suggest the Association consider starting an annual mapping program of the lake's weed community. This would involve using a combination of both aerial photographic analysis and in-lake surveys. These would be done in early May and again in late August. The data would be used to as document the species community assemblage of weeds, changes in the distribution and density of weed species, the spread of different weed species, and area-specific or lake-wide changes in weed composition and density attributable to weed management efforts. The data derived through such a survey could be used to continue to direct weed harvesting, hydro-raking or alternative control strategies to problem areas and quantitatively track the resulting improvements.

As such, for 2013 we recommend the following be conducted:

1. The Association should continue with the existing monitoring program and the collection of key water quality parameters over the course of the 2013 growing season. Along with the in-lake data collection, the collection of data at the Owassa Inlet and Causeway Inlet under baseflow conditions, as conducted this past year, should be continued.
2. However, the monitoring program needs to be expanded to include data collected from the

major inflow sources under storm conditions. The TP concentrations measured at both inlets are higher than that measured in the lake, and these data only reflected baseflow conditions. Specifically we feel that it would be prudent to measure inflow nutrient (TP and NO_3-N) and sediment (TSS) concentrations during 3-4 major storm events. The storm event sampling can be conducted by the Association with assistance from Princeton Hydro. This sampling should occur between June and mid-September. The lab analysis can be limited to TP, NO_3-N and Total Suspended Solids. The resulting data would be used to evaluate the effect of nutrient loading from the surrounding watershed on triggering algae-blooms or shifting N:P ratios to favor different algal forms. Storm water data for Culver Lake and its watershed have not been collected for approximately 20 years. With continued positive steps being made in the control of the lake's internal nutrient loading processes, attention needs to be placed on better understanding of the impacts of watershed storm based related loading.

3. In concert with the additional sampling noted above, the Association should update the 1990 Diagnostic Study. This would entail the updated modeling and computation of the watershed pollutant loads to the lake. This update is warranted due to the changes in land use and development (growth, intensity and in-fill development), the Association's septic management efforts and the new stormwater management, as well as fertilizer rules that have occurred over the past 22+ years. Based on observations made over the past seven years, external loading dynamics are having a larger impact on lake water quality than are internal loading dynamics. Computing the lake's watershed based pollutant load will enable us to better determine how best to manage the lake. When we conducted the original lake assessment we demonstrated that the driving factors controlling the lake's water quality were dominated by internal processes. It would be useful to redo this analysis to ensure that proper attention is being given to those factors having the greatest impact on the lake's water quality.

4. Continue the aquatic weed harvesting program and avoid the use of herbicides in the management of the lake's weed growth.

5. Consider the implementation of a weed tracking/mapping program that uses both aerial reconnaissance and in-lake field surveys. These data would enable the Association to both better allocate and assess weed control (hydroraking or harvesting) efforts.

6. Limit any trout stocking to "put and take". An evaluation of the weight/length data of the lake's hybrid striped bass population should be conducted to ensure that these fish are not overstocked. Similarly, the stocking of other game fish should only be occurring with the knowledge that there is an ample and appropriate forage base of these fish. It is also important to evaluate prior to stocking if the fish species being proposed for introduction will negatively compete with either the hybrid striped bass or any of the stocked trout.

7. The Normanoch Association must continue to play a prominent role in the education of the lake community. The residents of Culver Lake need to be provided with guidance regarding proper septic system maintenance. Phosphorus and nitrogen loading from septic systems (even those that are not failing) represent a substantial source of nutrient loading to the lake. Thus anything that residents can do to limit such loading through proper septic management, the use of alternative wash products and water conservation is important.

   Residents should also be provided with information and guidance concerning the creation and maintenance of vegetated lakeside buffers. Naturalized shorelines help to reduce erosion, filter out pollutants transported with stormwater runoff, and help limit passage of geese to and from the lake.

   Residents also need to be supplied with information concerning the new State-wide regulations regarding the over-the-counter lawn fertilizers. As of November 2012, not only is it illegal for a homeowner to purchase and apply phosphorus –containing lawn fertilizers, but there are seasonal limitations when any lawn fertilizer can be applied.

   Finally, public education materials regarding measures that can be taken to prevent the introduction and spread of invasive plant and animal species in the lake need to be disseminated to the community. Non-native plants and animals (e.g., zebra mussel) pose an ecological threat to the lake. The public education materials should not only increase public awareness of these potential problems, but clearly identify the consequences of such infestations on the ecological balance and water quality of Culver Lake.

Appendix A

2012 *In-Situ* Water Quality Data

In-Situ Monitoring for Culver Lake 5/24/12								
Station	**DEPTH (meters)**			**Temperature**	**Conductivity**	**Dissolved Oxygen**	**pH**	**Dissolved Oxygen**
	Total	**Secchi**	**Sample**	**(^{0}C)**	**(mmhos/cm)**	**(mg/L)**	**(units)**	**(%)**
Mid-Lake	**14.9**	**1.9**	**Surface**	20.15	0.188	8.76	7.88	96.5
			1.0	20.14	0.187	8.8	7.86	97.2
			2.0	20.03	0.186	8.95	7.82	98
			3.0	18.4	0.186	9.11	7.74	90.1
			4.0	16.15	0.186	8.72	7.64	87.7
			5.0	13.71	0.186	7.75	7.55	73.1
			6.0	12.5	0.187	7.32	7.49	66.2
			7.0	11.85	0.188	6.67	7.42	60.9
			8.0	11.22	0.189	6.62	7.38	60.6
			9.0	10.84	0.188	6.93	7.33	63
			10.0	10.61	0.189	6.56	7.29	58.1
			11.0	10.34	0.19	5.73	7.25	49.4
			12.0	10.01	0.194	3.7	7.14	31.8
			13.0	9.84	0.195	1.7	7.05	14.9
			14.0	9.72	0.201	<1.0	6.97	7.3
			14.5	9.63	0.201	<1.0	6.83	3.2
Stehr Tract	**1.5**	**1.5+**	**Surface**	21.77	0.152	7.67	7.68	87.4
			1.0	21.23	0.139	6.07	7.49	70.5
			1.5	19.54	0.185	2.79	7.34	33.1
Causeway Cove	**1.5**	**1.5+**	**Surface**	19.68	0.19	8.76	7.89	95.5
			1.0	19.21	0.187	8.62	7.83	91.1
			1.5	18.98	0.189	7.24	7.69	78.6
Inlet (RT. 206)	**N/A**	**N/A**	**Surface**	20.27	0.12	6.2	7.36	68.5
Inlet (Causeway)	**N/A**	**N/A**	**Surface**	21.53	0.186	6.22	7.58	68.3

***In-Situ* Monitoring for Culver Lake 7/17/12**								
Station	**DEPTH (meters)**			**Temperature**	**Conductivity**	**pH**	**Dissolved Oxygen**	**Dissolved Oxygen**
	Total	**Secchi**	**Sample**	**(^{0}C)**	**(µmhos/cm)**	**(units)**	**(mg/L)**	**(%)**
Mid-Lake	**14**	**0.9**	**Surface**	27.39	202.6	9.17	9.68	125.9
			1.0	27.27	202.3	9.12	9.67	125.4
			2.0	26.71	200.2	8.78	9.17	117.7
			3.0	25.35	197.5	7.47	6.77	84.8
			4.0	20.73	192.9	7.04	5.1	58.6
			5.0	15.38	189.7	6.77	2.73	28
			6.0	13.59	189	6.62	1.78	17.6
			7.0	13.14	189.2	6.51	1.22	11.9
			8.0	12.88	189.3	6.47	1.01	9.8
			9.0	12.58	189.1	6.43	0.86	8.3
			10.0	11.91	188.7	6.43	0.83	7.9
			11.0	11.44	191.6	6.4	0.56	5.3
			12.0	11.01	193.1	6.41	0.42	3.9
			13.0	10.71	198.8	6.48	0.12	1.1
			13.5	10.23	215.5	6.49	0.09	0.8
Stehr Tract	**1**	**1**	**Surface**	27.55	200.1	7.71	7.46	97.3
			1.0	26.76	200.1	7.27	7.05	90.6
Causeway Cove	**1.5**	**1.2**	**Surface**	28.54	204.4	8.56	8.44	112
			1.0	27.98	206.3	8.08	8.02	105.4
			1.5	27.2	210.4	7.07	6.56	84.9
Inlet (RT. 206)	**N/A**	**N/A**	**Surface**	25.16	154.7	6.58	7.66	95.7
Inlet (Causeway)	**N/A**	**N/A**	**Surface**	30.85	223.9	6.36	7.53	103.9

***In-Situ* Monitoring for Culver Lake 9/21/12**								
Station	**DEPTH (meters)**			**Temperature**	**Conductivity**	**pH**	**Dissolved Oxygen**	**Dissolved Oxygen**
	Total	**Secchi**	**Sample**	**(^{0}C)**	**(mmhos/cm)**	**(units)**	**(mg/L)**	**(%)**
Mid-Lake	**14.5**	**1.3**	**Surface**	19.98	187.3	6.41	8.46	95.7
			1.0	19.94	187.2	6.62	8.42	95.1
			2.0	19.84	187.4	6.72	8.28	93.4
			3.0	19.64	187	6.78	8.13	91.2
			4.0	19.5	187	6.79	7.95	89
			5.0	19.01	185.5	6.76	7.64	84.7
			6.0	18.39	183.8	6.57	5.8	63.5
			7.0	15.87	198.5	6.35	3.64	37.8
			8.0	14.91	198.3	6.29	2.25	22.9
			9.0	14.13	199.2	6.29	0.86	8.6
			10.0	13.35	200.4	6.29	0.5	4.9
			11.0	12.91	202.9	6.3	0.27	2.7
			12.0	12.4	204.6	6.31	0.16	1.6
			13.0	11.59	214.7	6.33	0.11	1
			14.0	11.18	225.3	6.34	0.07	0.6
			14.5	11.2	232.8	6.34	0.05	0.5
Stehr Tract	**1.8**	**1.3**	**Surface**	19.99	186	6.82	8.52	96.3
			0.5	19.97	185.9	6.96	8.54	96.5
			1.0	19.95	185.7	7	8.54	96.5
			1.5	19.28	183.8	6.99	8.39	93.5
			1.8	19.26	190.7	6.61	0.43	4.8
Causeway Cove	**1.9**	**1.4**	**Surface**	20.06	184.6	6.3	7.95	90.1
			0.5	20.06	184.5	6.49	7.83	88.7
			1.0	19.67	178.6	6.51	7.84	88.1
			1.5	18.12	144.5	6.11	6.15	67
			1.8	17.77	144.1	5.92	5.05	54.6
Inlet (RT. 206)	**N/A**	**N/A**	**Surface**	17.56	105.7	6.22	7.71	82.9
Inlet (Causeway)	**N/A**	**N/A**	**Surface**	19.81	162.4	5.85	8.65	97.5

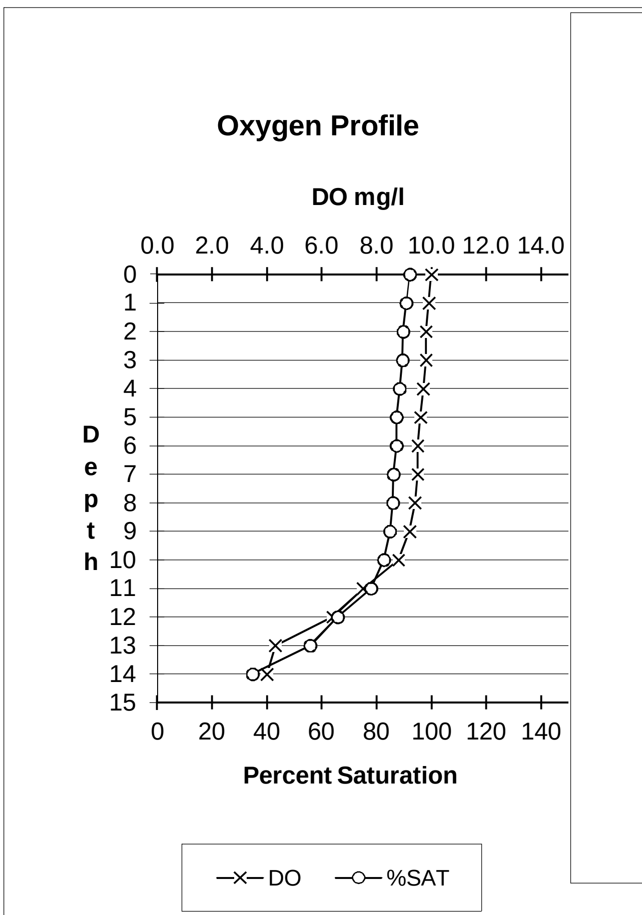
Culver Lake

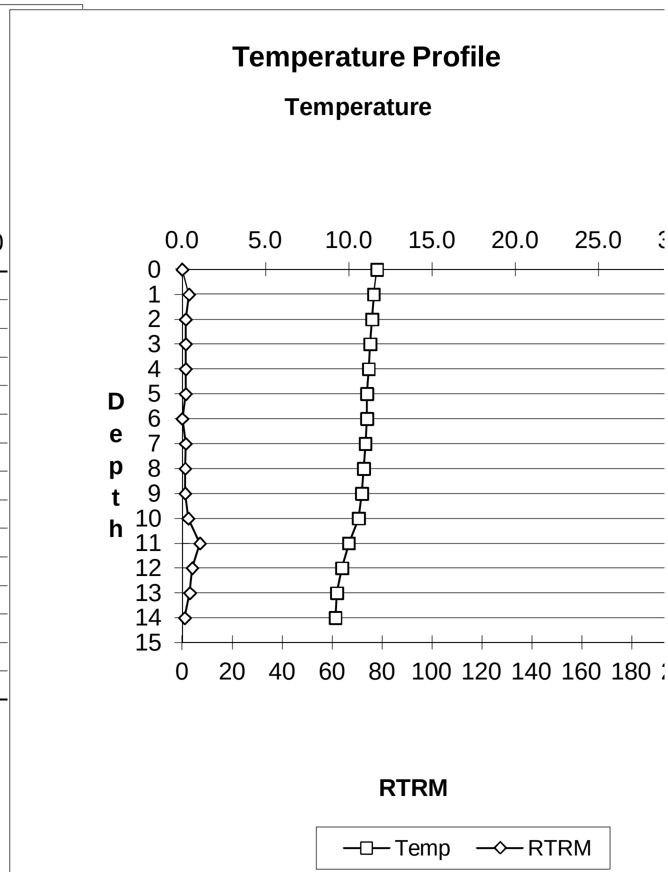
900 N

Date	4/29/2012		48°
SECCHI	7.0	*Feet*	Clear, breezy
Anoxic Boundry	3.50	*meters*	Lauren, John, Roy
Sum RTRM	29		11am

Normanoch Associa
Data Services Divisi

Depth	Temp	DO	%SAT	RTRM	RVG	ORP
0	11.7	10.0	92	0	0	
1	11.5	9.9	91	3	17	
2	11.4	9.8	90	1	9	
3	11.3	9.8	89	1	9	
4	11.2	9.7	88	1	9	
5	11.1	9.6	87	1	9	
6	11.1	9.5	87	0	0	
7	11.0	9.5	86	1	9	
8	10.9	9.4	86	1	9	
9	10.8	9.2	85	1	9	
10	10.6	8.8	83	2	17	
11	10.0	7.5	78	7	51	
12	9.6	6.4	66	4	34	
13	9.3	4.3	56	3	26	
14	9.2	4.0	35	1	9	





Legend	
DO	Dissolved Oxygen Concentration
RTRM	Relative Thermal Resistance to Mixing
%SAT	DO Saturation as a function of Temperature
RVG	Relative Viscosity Gradient

Culver Lake

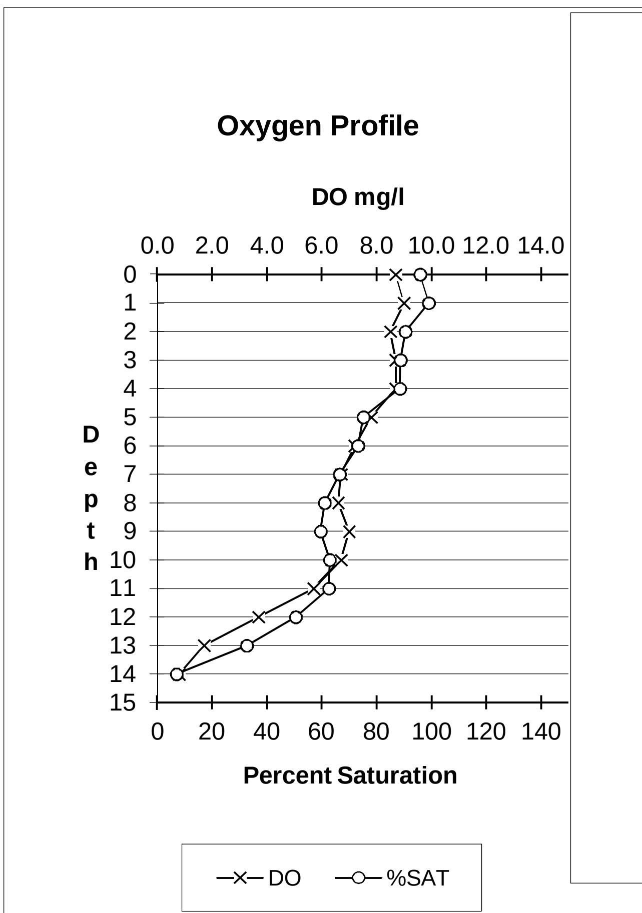
900 N

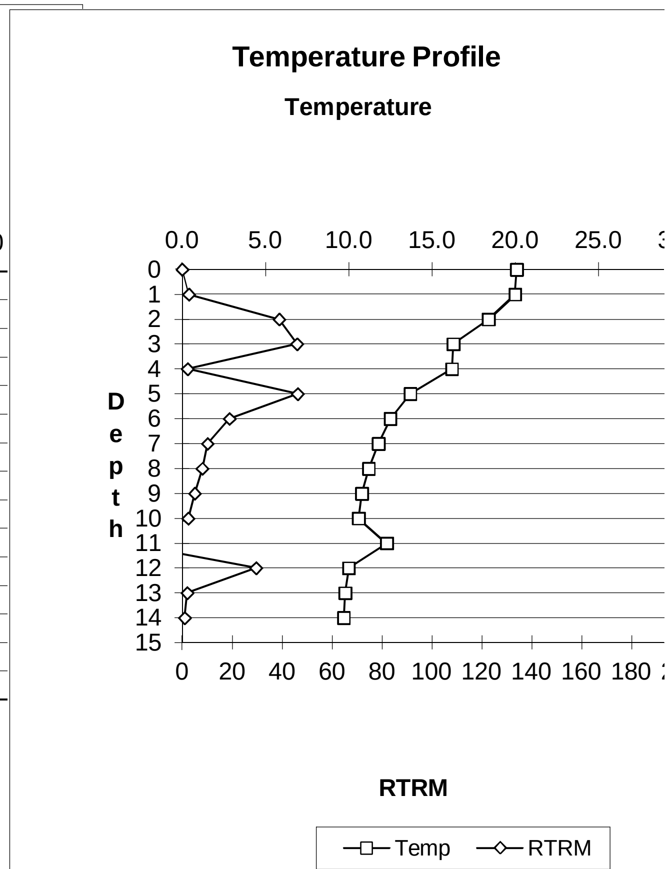
Date	5/24/2012		68°
SECCHI	6.0	*Feet*	Cloudy, sl. breezy
Anoxic Boundry	13.78	*meters*	John
Sum RTRM	190		1

Normanoch Associa
Data Services Divisi

Rain 2 inches 2 da

Depth	*Temp*	*DO*	*%SAT*	*RTRM*	*RVG*	ORP
0	20.1	8.7	96	0	0	
1	20.0	9.0	99	3	4	
2	18.4	8.5	91	39	64	
3	16.3	8.7	89	46	84	
4	16.2	8.7	89	2	4	
5	13.7	7.8	75	46	160	
6	12.5	7.2	73	19	103	
7	11.8	6.7	67	10	60	
8	11.2	6.6	61	8	51	
9	10.8	7.0	60	5	34	
10	10.6	6.7	63	2	17	
11	12.3	5.7	63	-23	-146	
12	10.0	3.7	50	30	197	
13	9.8	1.7	33	2	17	
14	9.7	0.8	7	1	9	





Legend	
DO	Dissolved Oxygen Concentration
RTRM	Relative Thermal Resistance to Mixing
%SAT	DO Saturation as a function of Temperature
RVG	Relative Viscosity Gradient

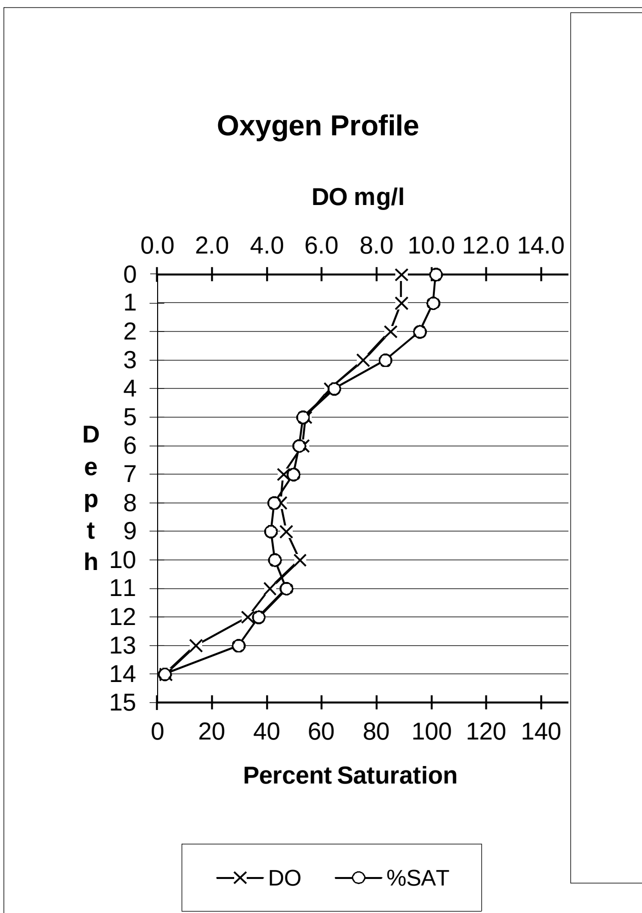
Culver Lake

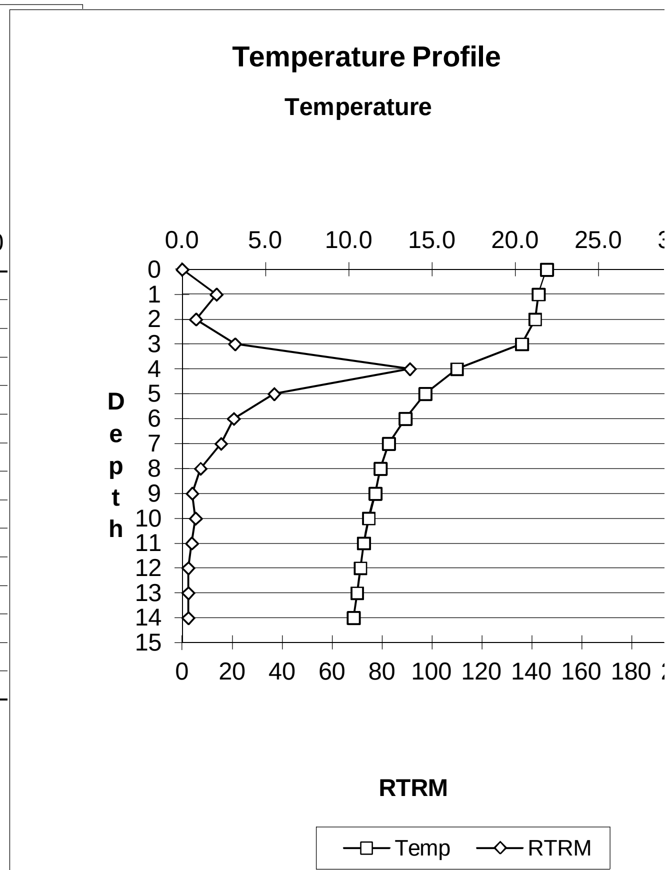
900 N

Date	6/3/2012		68°
SECCHI	5.0	*Feet*	Cloudy, sl. breezy
Anoxic Boundry	13.36	*meters*	John /Roy
Sum RTRM	232		1

Normanoch Associa
Data Services Divisi

Depth	*Temp*	*DO*	*%SAT*	*RTRM*	*RVG*	ORP
0	21.9	8.9	102	0	0	
1	21.4	8.9	101	14	20	
2	21.2	8.5	96	5	8	
3	20.4	7.5	83	21	32	
4	16.5	6.3	64	91	156	
5	14.6	5.4	53	37	95	
6	13.4	5.3	52	21	103	
7	12.4	4.6	50	15	86	
8	11.9	4.5	43	7	43	
9	11.6	4.7	41	4	26	
10	11.2	5.2	43	5	34	
11	10.9	4.1	47	4	26	
12	10.7	3.3	37	2	17	
13	10.5	1.4	30	2	17	
14	10.3	0.3	3	2	17	





Legend	
DO	Dissolved Oxygen Concentration
RTRM	Relative Thermal Resistance to Mixing
%SAT	DO Saturation as a function of Temperature
RVG	Relative Viscosity Gradient

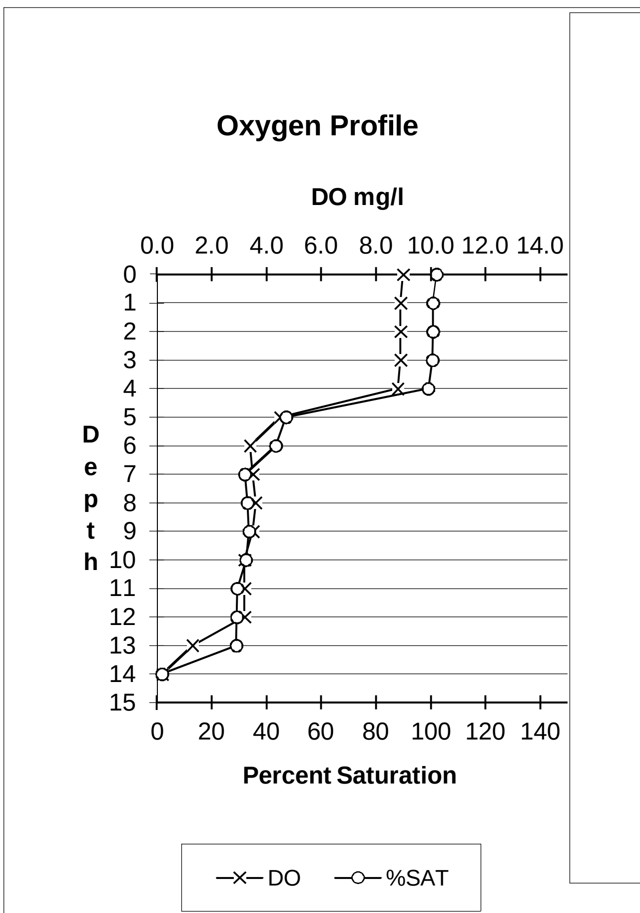
Culver Lake

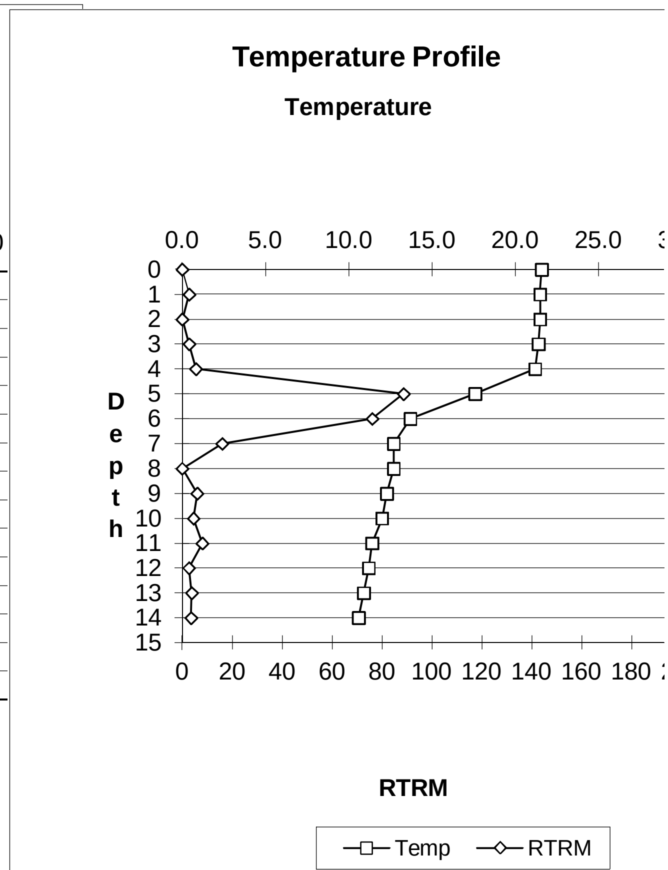
900 N

Date	6/13/2012		72°
SECCHI	4.0	*Feet*	clear, sunny, gusts to 15 mph
Anoxic Boundry	13.27	*meters*	John /Barry
Sum RTRM	220		1 rain 1 day ago about 2 inches

Normanoch Associa
Data Services Divisi

Depth	*Temp*	*DO*	*%SAT*	*RTRM*	*RVG*	**ORP**
0	21.6	9.0	102	0	0	
1	21.5	8.9	101	3	4	
2	21.5	8.9	101	0	0	
3	21.4	8.9	101	3	4	
4	21.2	8.8	99	5	8	
5	17.6	4.5	47	89	144	
6	13.7	3.4	43	76	216	
7	12.7	3.5	32	16	86	
8	12.7	3.6	33	0	0	
9	12.3	3.5	34	6	34	
10	12.0	3.2	32	4	26	
11	11.4	3.2	29	8	51	
12	11.2	3.2	29	3	17	
13	10.9	1.3	29	4	26	
14	10.6	0.2	2	4	26	





Legend	
DO	Dissolved Oxygen Concentration
RTRM	Relative Thermal Resistance to Mixing
%SAT	DO Saturation as a function of Temperature
RVG	Relative Viscosity Gradient

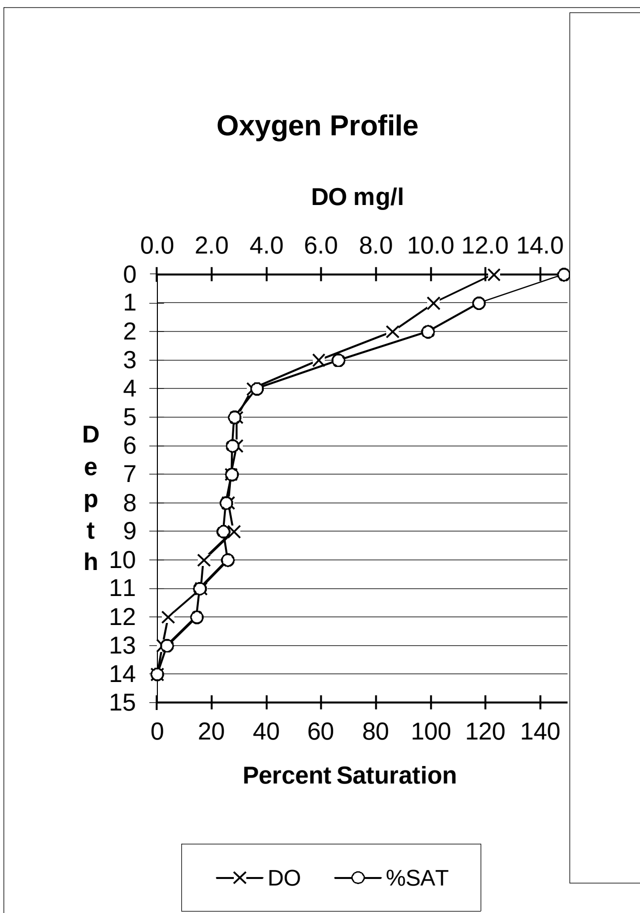
Culver Lake

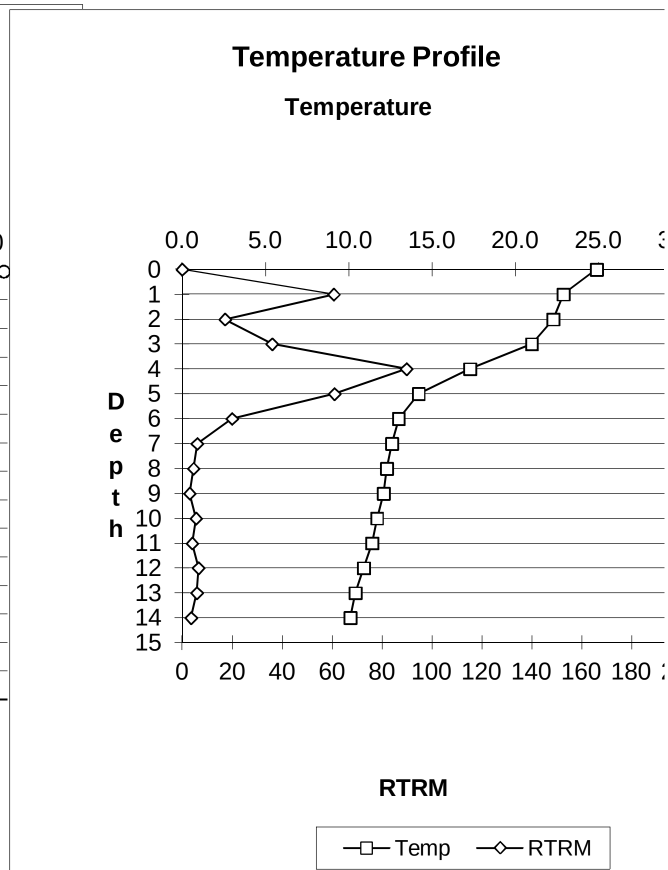
900 N

Date	6/21/2012		92°
SECCHI	3.0	*Feet*	hot, sunny
Anoxic Boundry	11.50	*meters*	John /roy
Sum RTRM	323		1 no rain 6 days

Normanoch Associa
Data Services Divisi

Depth	*Temp*	*DO*	*%SAT*	*RTRM*	*RVG*	ORP
0	24.9	12.3	149	0	0	
1	22.9	10.1	118	61	80	
2	22.3	8.6	99	17	24	
3	21.0	5.9	66	36	52	
4	17.3	3.5	36	90	148	
5	14.2	2.9	28	61	161	
6	13.0	2.9	28	20	103	
7	12.6	2.7	27	6	34	
8	12.3	2.6	25	4	26	
9	12.1	2.8	24	3	17	
10	11.7	1.7	26	5	34	
11	11.4	1.6	16	4	26	
12	10.9	0.4	14	7	43	
13	10.4	0.2	4	6	43	
14	10.1	0.0	0	4	26	





Legend	
DO	Dissolved Oxygen Concentration
RTRM	Relative Thermal Resistance to Mixing
%SAT	DO Saturation as a function of Temperature
RVG	Relative Viscosity Gradient

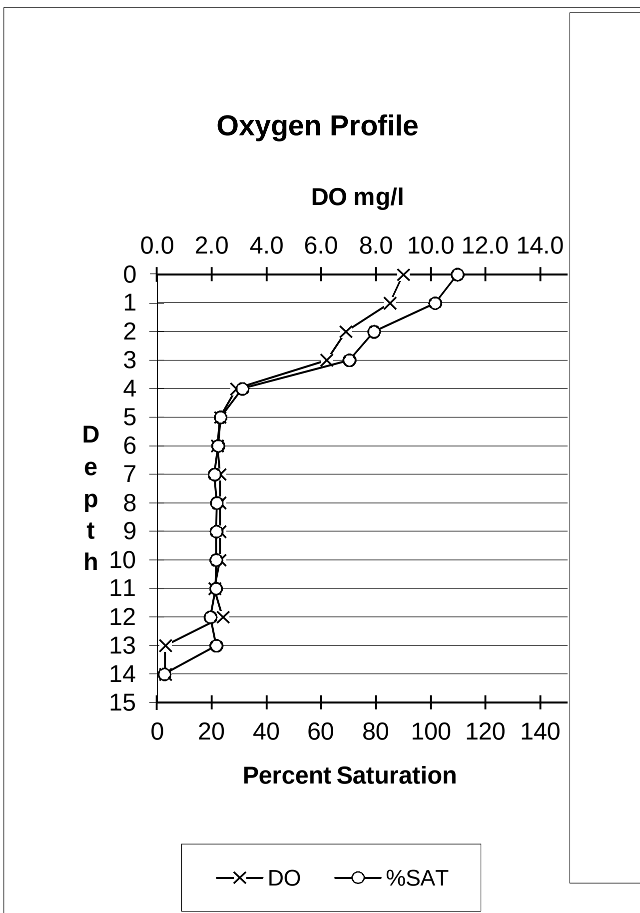
Culver Lake

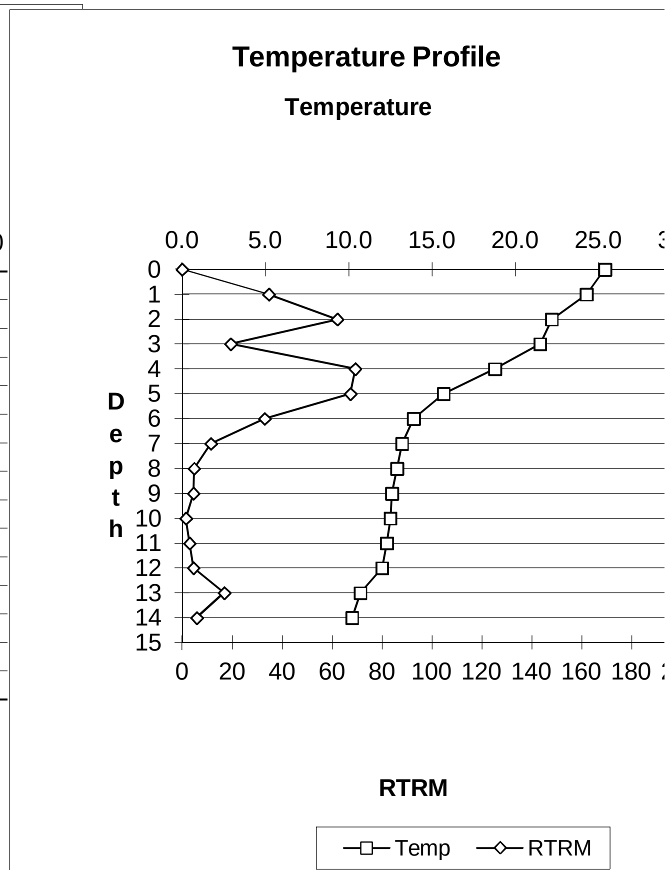
900 N

Date	6/29/2012		88°
SECCHI	4.0	*Feet*	hot, sunny
Anoxic Boundry	12.67	*meters*	John /roy
Sum RTRM	338		1 some rain days ago, not as green

Normanoch Associa
Data Services Divisi

Depth	Temp	DO	%SAT	RTRM	RVG	ORP
0	25.4	9.0	110	0	0	
1	24.3	8.5	102	35	44	
2	22.2	6.9	79	62	84	
3	21.5	6.2	70	19	28	
4	18.8	2.9	31	69	108	
5	15.7	2.3	23	67	124	
6	13.9	2.2	22	33	123	
7	13.2	2.3	21	11	60	
8	12.9	2.3	22	5	26	
9	12.6	2.3	22	4	26	
10	12.5	2.3	22	1	9	
11	12.3	2.1	21	3	17	
12	12.0	2.4	19	4	26	
13	10.7	0.3	22	17	111	
14	10.2	0.3	3	6	43	





Legend	
DO	Dissolved Oxygen Concentration
RTRM	Relative Thermal Resistance to Mixing
%SAT	DO Saturation as a function of Temperature
RVG	Relative Viscosity Gradient

Culver Lake

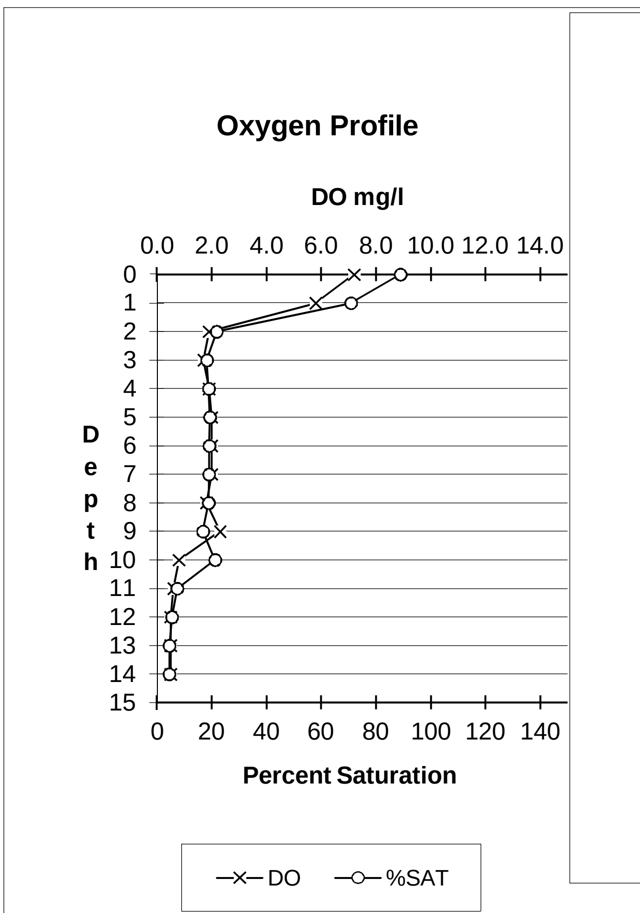
900 N

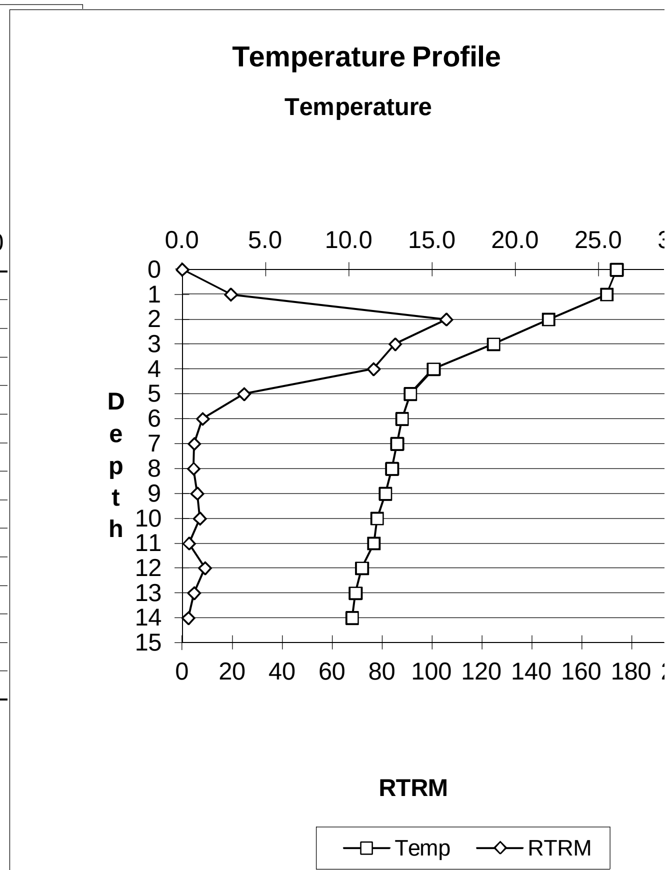
g equipment

Date	7/6/2012		83
SECCHI	4.0	*Feet*	hot, sunny
Anoxic Boundry	9.87	*meters*	John /roy
Sum RTRM	361		1 shower 3 days ago, other than th

Normanoch Associa
Data Services Divisi

Depth	Temp	DO	%SAT	RTRM	RVG	ORP
0	26.1	7.2	89	0	0	
1	25.5	5.8	71	19	24	
2	22.0	1.9	22	106	140	
3	18.7	1.7	18	85	132	
4	15.1	1.9	19	77	144	
5	13.7	2.0	19	25	116	
6	13.2	2.0	19	8	43	
7	12.9	2.0	19	5	26	
8	12.6	1.8	19	4	26	
9	12.2	2.3	17	6	34	
10	11.7	0.8	21	7	43	
11	11.5	0.6	7	3	17	
12	10.8	0.5	5	9	60	
13	10.4	0.5	4	5	34	
14	10.2	0.5	4	2	17	





Legend	
DO	Dissolved Oxygen Concentration
RTRM	Relative Thermal Resistance to Mixing
%SAT	DO Saturation as a function of Temperature
RVG	Relative Viscosity Gradient

g equipment

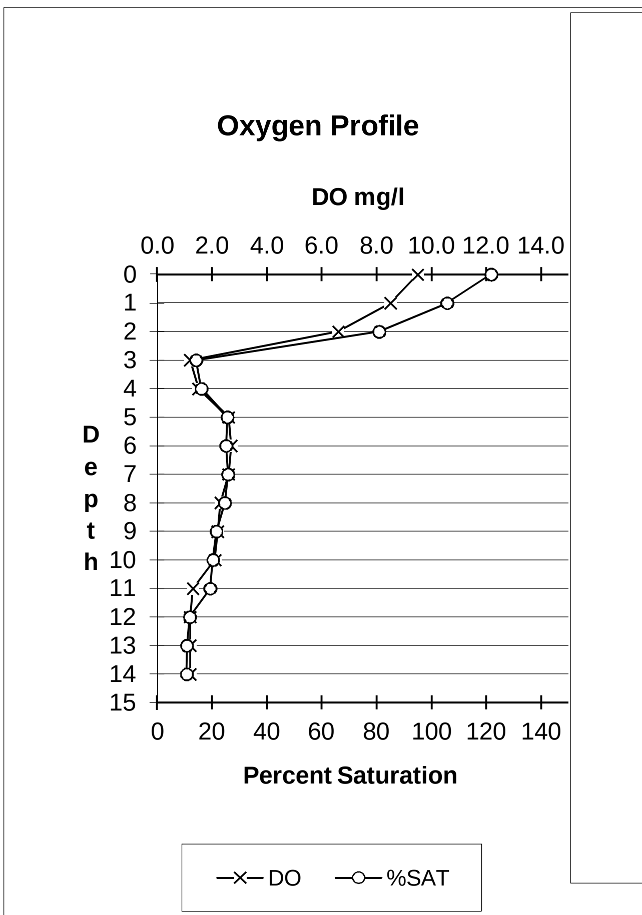
Culver Lake

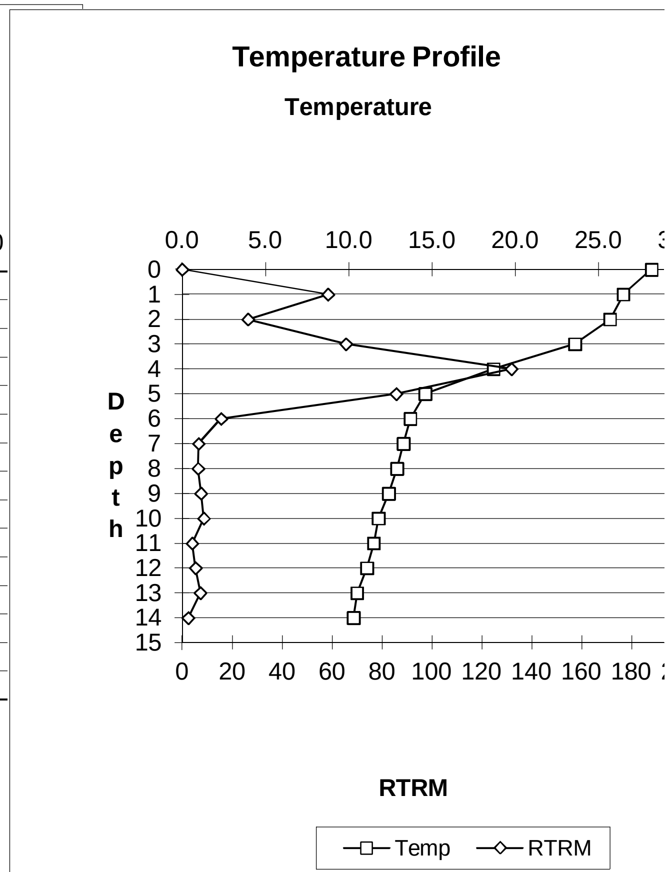
900 N

Date	7/13/2012		83
SECCHI	4.0	*Feet*	overcast hot,humid
Anoxic Boundry	11.67	*meters*	John /roy
Sum RTRM	431		1 no rain 2weeks +

Normanoch Associa
Data Services Divisi

Depth	*Temp*	*DO*	*%SAT*	*RTRM*	*RVG*	ORP
0	28.2	9.5	122	0	0	
1	26.5	8.5	106	58	68	
2	25.7	6.6	81	26	32	
3	23.6	1.2	14	66	84	
4	18.7	1.5	16	132	196	
5	14.6	2.6	26	86	183	
6	13.7	2.7	25	16	77	
7	13.3	2.6	26	7	34	
8	12.9	2.3	25	6	34	
9	12.4	2.2	22	7	43	
10	11.8	2.1	20	9	51	
11	11.5	1.3	19	4	26	
12	11.1	1.2	12	5	34	
13	10.5	1.2	11	7	51	
14	10.3	1.2	11	2	17	





Legend	
DO	Dissolved Oxygen Concentration
RTRM	Relative Thermal Resistance to Mixing
%SAT	DO Saturation as a function of Temperature
RVG	Relative Viscosity Gradient

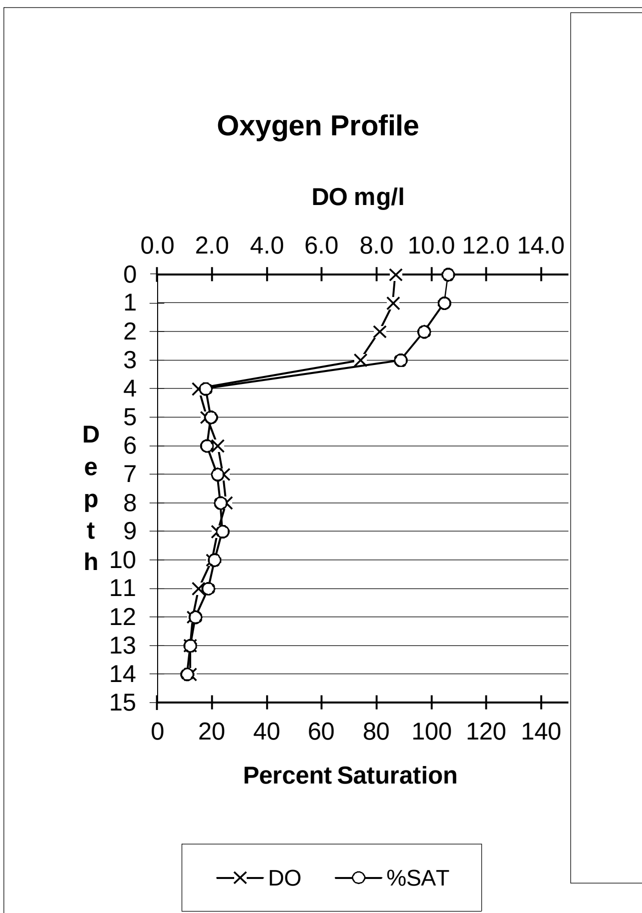
Culver Lake

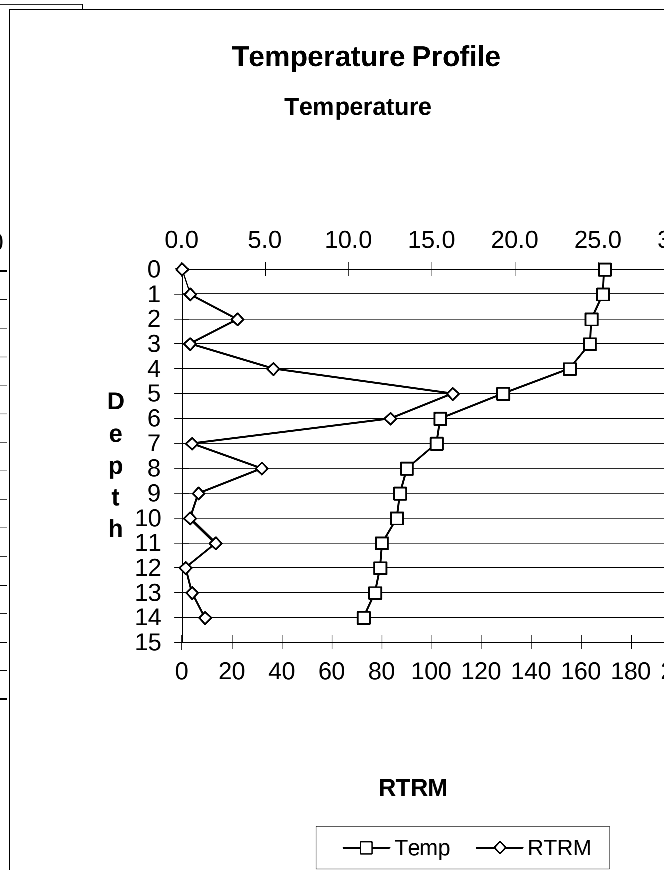
900 N

Date	7/21//2012		76
SECCHI	3.5	*Feet*	Sun, clear wind 10mph
Anoxic Boundry	11.67	*meters*	John /roy
Sum RTRM	330		1 aprox 3 in 1 day ago

Normanoch Associa
Data Services Divisi

Depth	Temp	DO	%SAT	RTRM	RVG	ORP
0	25.4	8.7	106	0	0	
1	25.3	8.6	105	3	4	
2	24.6	8.1	97	22	28	
3	24.5	7.4	89	3	4	
4	23.3	1.5	18	36	48	
5	19.3	1.8	20	108	160	
6	15.5	2.2	18	83	152	
7	15.3	2.4	22	4	8	
8	13.5	2.5	23	32	141	
9	13.1	2.2	24	7	34	
10	12.9	2.0	21	3	17	
11	12.0	1.5	19	13	77	
12	11.9	1.3	14	1	9	
13	11.6	1.2	12	4	26	
14	10.9	1.2	11	9	60	





Legend	
DO	Dissolved Oxygen Concentration
RTRM	Relative Thermal Resistance to Mixing
%SAT	DO Saturation as a function of Temperature
RVG	Relative Viscosity Gradient

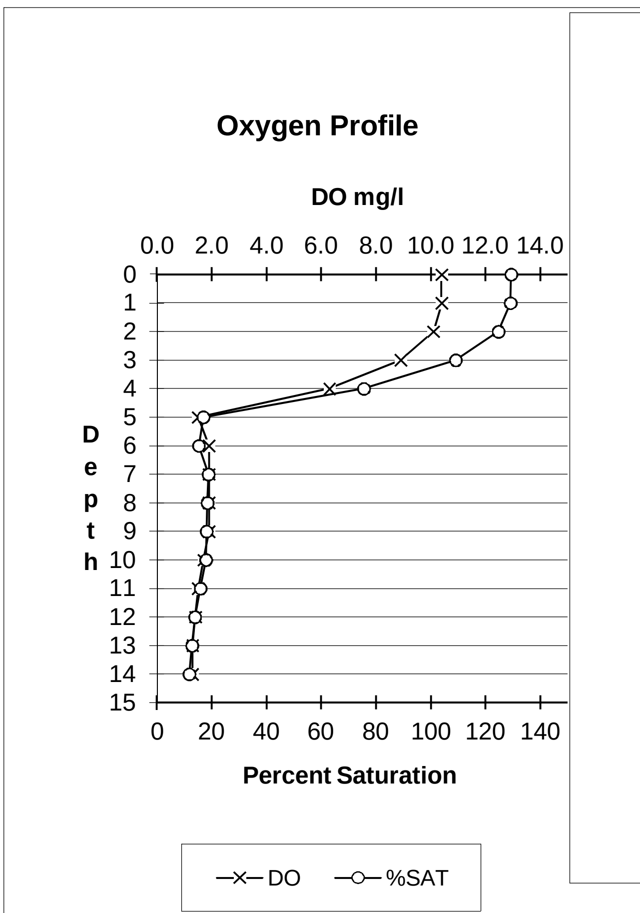
Culver Lake

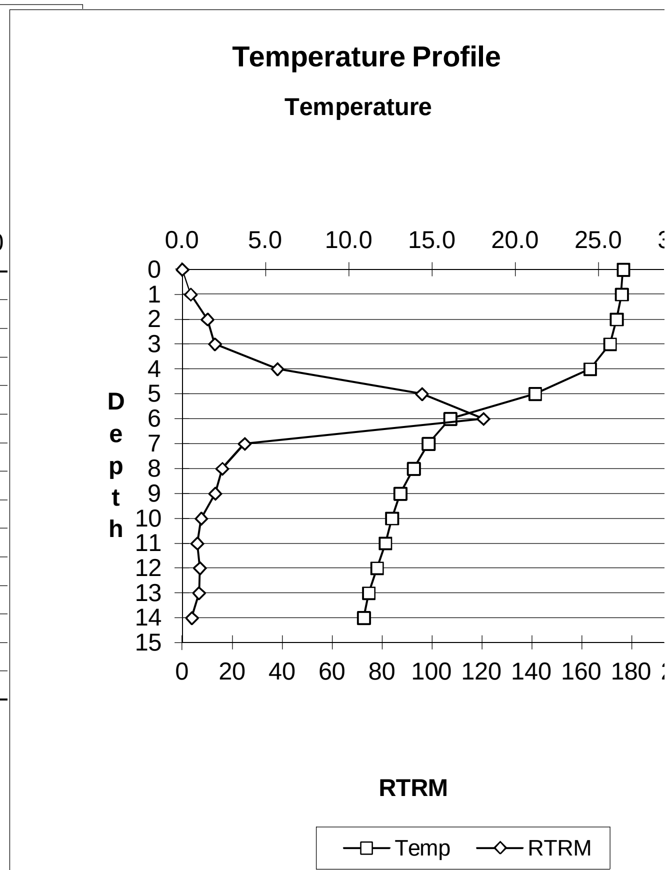
900 N

Date	7/27//2012		76
SECCHI	3.0	*Feet*	Sun, clear wind 10mph
Anoxic Boundry	10.77	*meters*	John /roy
Sum RTRM	366		1 1 day ago 3 t-storms

Normanoch Associa
Data Services Divisi

Depth	*Temp*	*DO*	*%SAT*	*RTRM*	*RVG*	ORP
0	26.5	10.4	129	0	0	
1	26.4	10.4	129	3	4	
2	26.1	10.1	125	10	12	
3	25.7	8.9	109	13	16	
4	24.5	6.3	76	38	48	
5	21.2	1.5	17	96	132	
6	16.1	1.9	15	121	204	
7	14.8	1.9	19	25	62	
8	13.9	1.9	18	16	77	
9	13.1	1.9	18	13	68	
10	12.6	1.7	18	8	43	
11	12.2	1.5	16	6	34	
12	11.7	1.4	14	7	43	
13	11.2	1.3	13	7	43	
14	10.9	1.3	12	4	26	





Legend	
DO	Dissolved Oxygen Concentration
RTRM	Relative Thermal Resistance to Mixing
%SAT	DO Saturation as a function of Temperature
RVG	Relative Viscosity Gradient

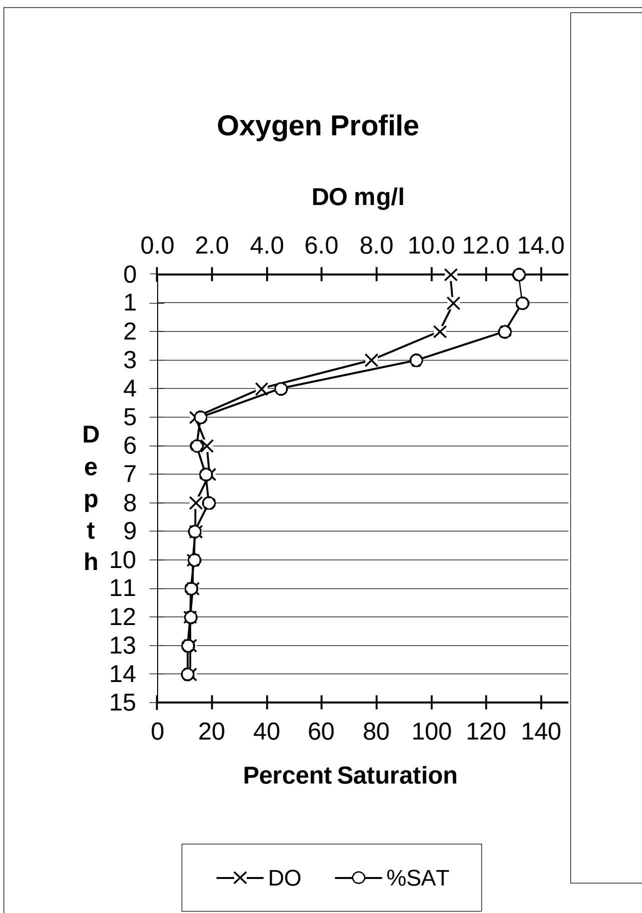
Culver Lake

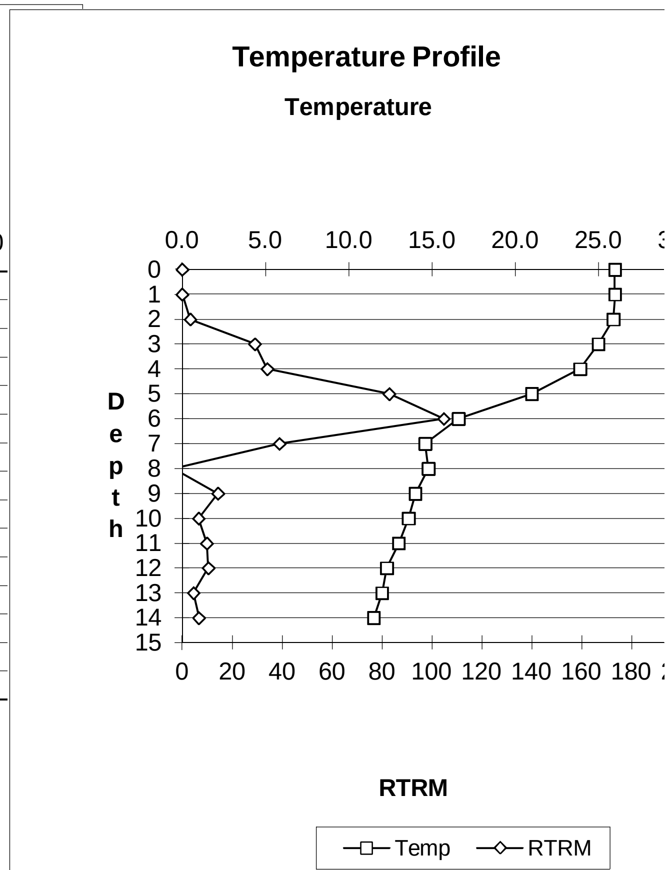
900 N

Date	8/1/2012		76	
SECCHI	3.5	*Feet*	Partly Cloudy	
Anoxic Boundry	11.67	*meters*	John /roy	
Sum RTRM	341		1	CMD shut down today

Normanoch Associa
Data Services Divisi

Depth	*Temp*	*DO*	*%SAT*	*RTRM*	*RVG*	**ORP**
0	26.0	10.7	132	0	0	
1	26.0	10.8	133	0	0	
2	25.9	10.3	127	3	4	
3	25.0	7.8	94	29	36	
4	23.9	3.8	45	34	44	
5	21.0	1.4	16	83	116	
6	16.6	1.8	14	105	176	
7	14.6	1.9	18	39	99	
8	14.8	1.4	19	-4	-17	
9	14.0	1.4	14	14	68	
10	13.6	1.3	13	7	34	
11	13.0	1.3	12	10	51	
12	12.3	1.2	12	10	60	
13	12.0	1.2	11	4	26	
14	11.5	1.2	11	7	43	





Legend	
DO	Dissolved Oxygen Concentration
RTRM	Relative Thermal Resistance to Mixing
%SAT	DO Saturation as a function of Temperature
RVG	Relative Viscosity Gradient

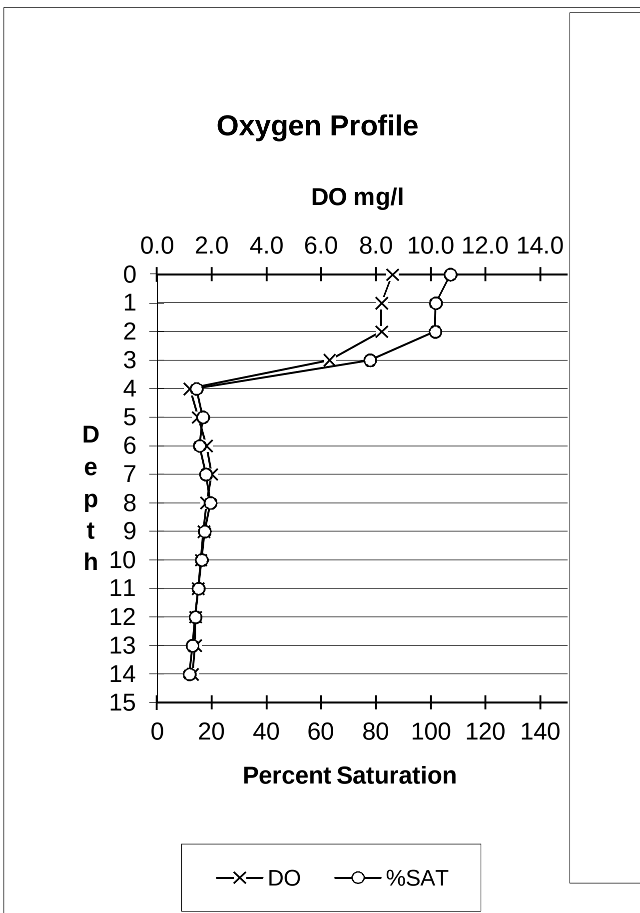
Culver Lake

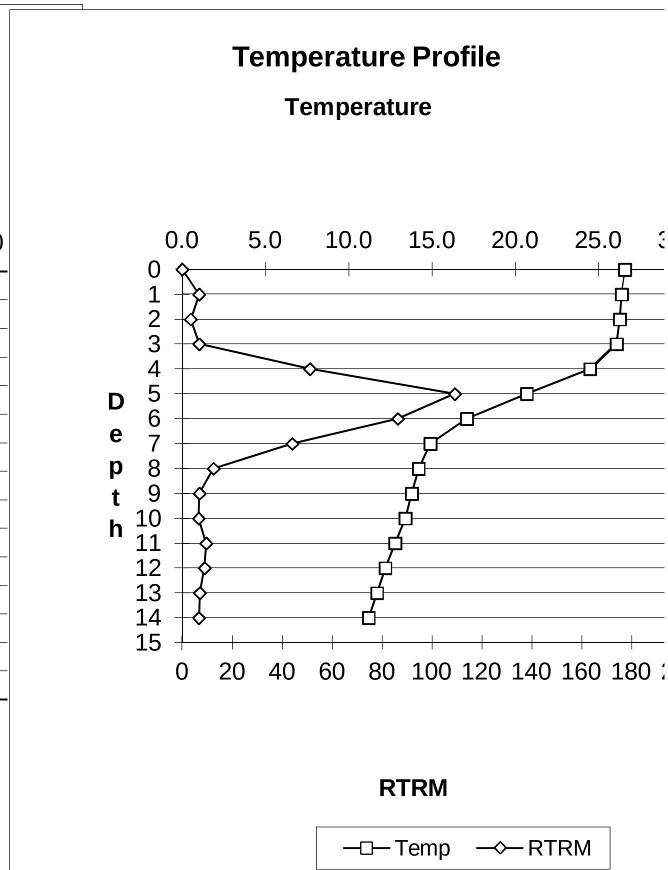
900 N

Date	8/11/2012		80
SECCHI	3.5	*Feet*	windy 5mph
Anoxic Boundry	10.77	*meters*	John /Jess
Sum RTRM	366		1 rain 1 day ago/2 inches

Normanoch Associa
Data Services Divisi

Depth	*Temp*	*DO*	*%SAT*	*RTRM*	*RVG*	ORP
0	26.6	8.6	107	0	0	
1	26.4	8.2	102	7	8	
2	26.3	8.2	102	3	4	
3	26.1	6.3	78	7	8	
4	24.5	1.2	14	51	64	
5	20.7	1.5	17	109	152	
6	17.1	1.8	16	86	144	
7	14.9	2.0	18	44	93	
8	14.2	1.8	19	13	60	
9	13.8	1.7	17	7	34	
10	13.4	1.6	16	7	34	
11	12.8	1.5	15	10	51	
12	12.2	1.4	14	9	51	
13	11.7	1.4	13	7	43	
14	11.2	1.3	12	7	43	





Legend	
DO	Dissolved Oxygen Concentration
RTRM	Relative Thermal Resistance to Mixing
%SAT	DO Saturation as a function of Temperature
RVG	Relative Viscosity Gradient

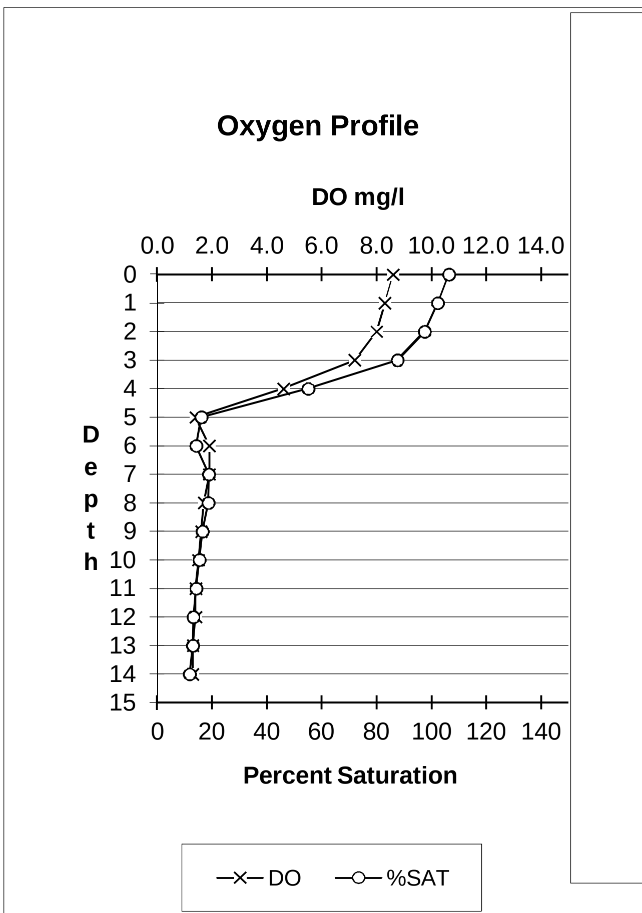
Culver Lake

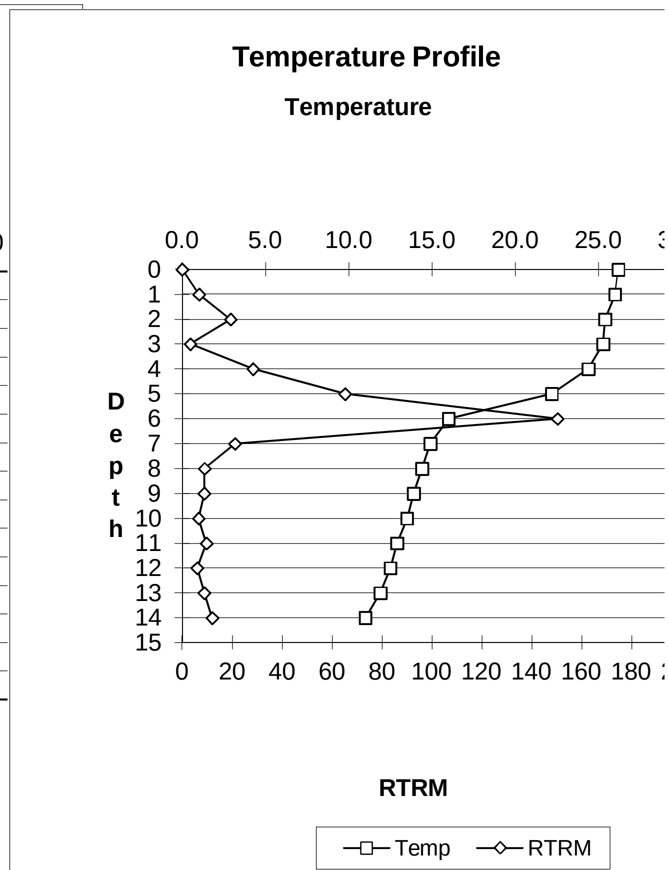
900 N

Date	8/17/2012		78	
SECCHI	4'4	*Feet*	windy 5mph	
Anoxic Boundry	10.77	*meters*	John /Joe	
Sum RTRM	355		1	rain 3 day ago/<1 inches

Normanoch Associa
Data Services Divisi

Depth	*Temp*	*DO*	*%SAT*	*RTRM*	*RVG*	ORP
0	26.2	8.6	106	0	0	
1	26.0	8.3	102	7	8	
2	25.4	8.0	98	19	24	
3	25.3	7.2	88	3	4	
4	24.4	4.6	55	28	36	
5	22.2	1.4	16	65	88	
6	16.0	1.9	14	150	248	
7	14.9	1.9	19	21	49	
8	14.4	1.7	19	9	43	
9	13.9	1.6	16	9	43	
10	13.5	1.5	15	7	34	
11	12.9	1.4	14	10	51	
12	12.5	1.4	13	6	34	
13	11.9	1.3	13	9	51	
14	11.0	1.3	12	12	77	





Legend	
DO	Dissolved Oxygen Concentration
RTRM	Relative Thermal Resistance to Mixing
%SAT	DO Saturation as a function of Temperature
RVG	Relative Viscosity Gradient

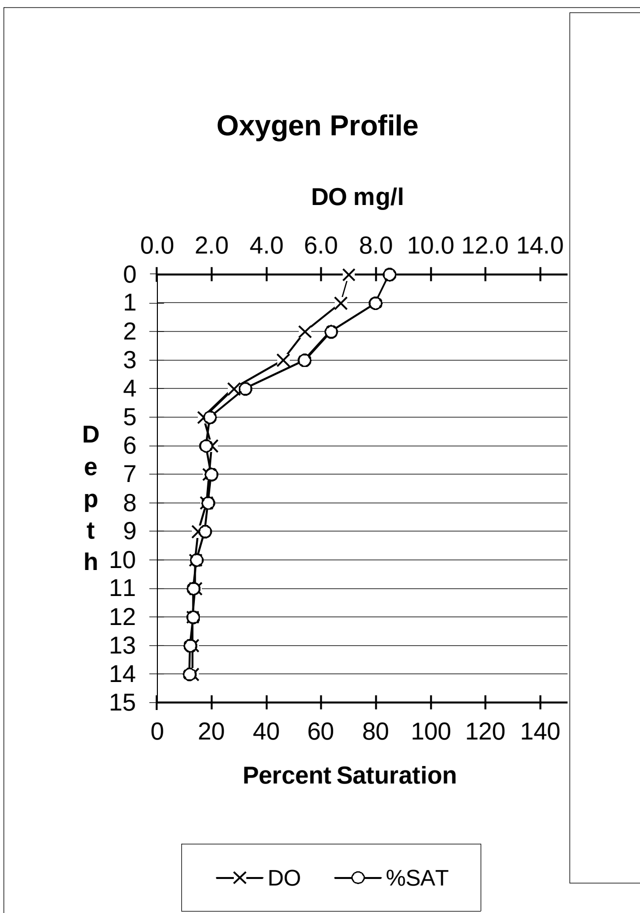
Culver Lake

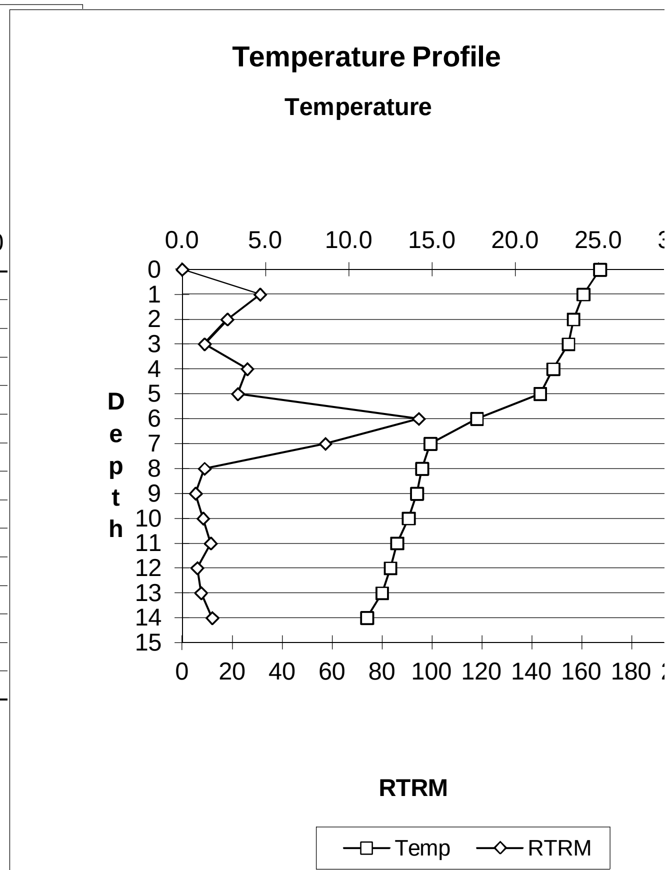
900 N

Date	8/24/2012		80
SECCHI	6'2	*Feet*	windy 5mph
Anoxic Boundry	10.77	*meters*	John /roy
Sum RTRM	318		1 rain 6-7 day ago

Normanoch Associa
Data Services Divisi

Depth	*Temp*	*DO*	*%SAT*	*RTRM*	*RVG*	ORP
0	25.1	7.0	85	0	0	
1	24.1	6.7	80	31	40	
2	23.5	5.4	64	18	24	
3	23.2	4.6	54	9	12	
4	22.3	2.8	32	26	36	
5	21.5	1.7	19	22	32	
6	17.7	2.0	18	95	152	
7	14.9	1.9	20	57	117	
8	14.4	1.8	19	9	43	
9	14.1	1.5	18	5	26	
10	13.6	1.4	14	8	43	
11	12.9	1.4	13	11	60	
12	12.5	1.3	13	6	34	
13	12.0	1.3	12	7	43	
14	11.1	1.3	12	12	77	





Legend	
DO	Dissolved Oxygen Concentration
RTRM	Relative Thermal Resistance to Mixing
%SAT	DO Saturation as a function of Temperature
RVG	Relative Viscosity Gradient

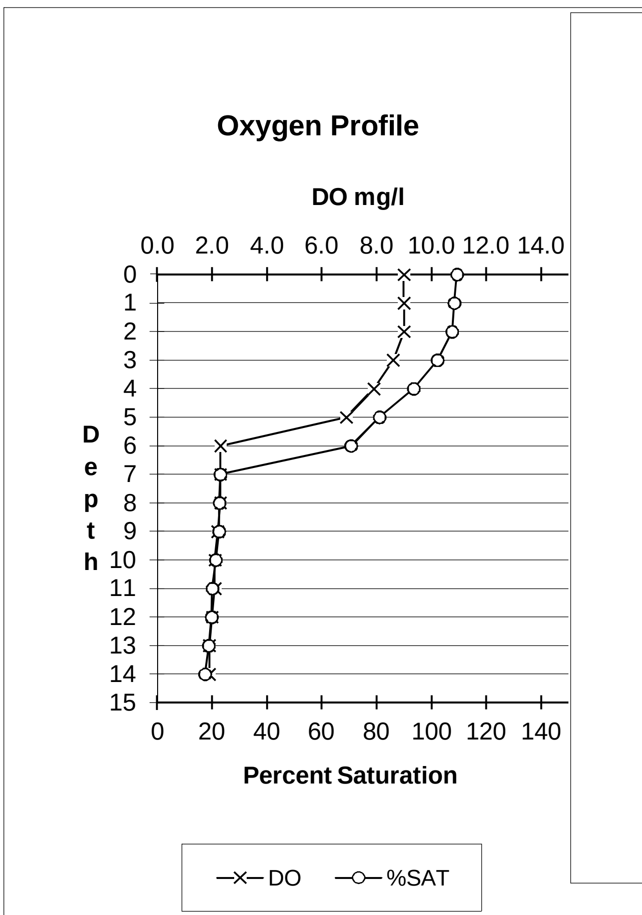
Culver Lake

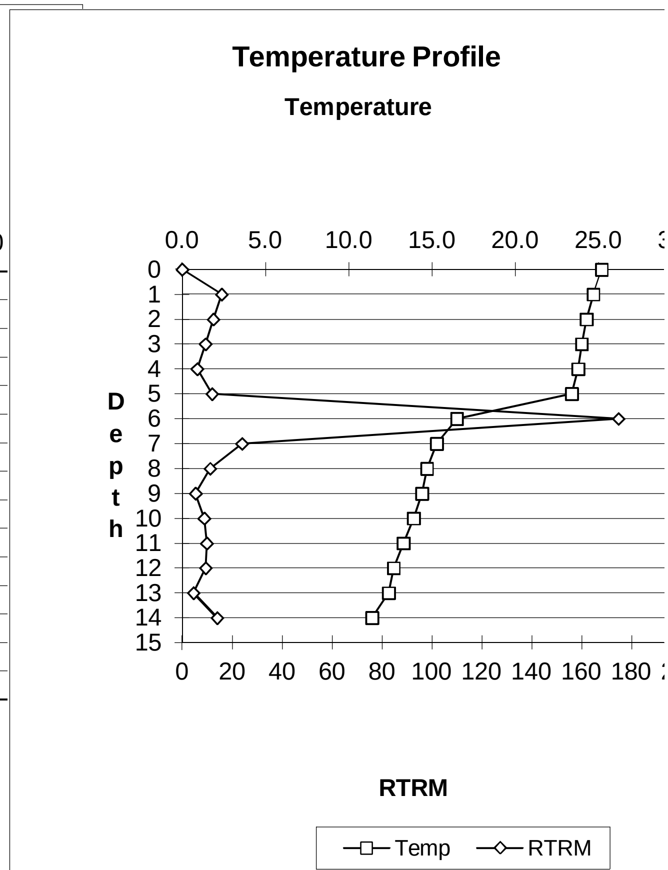
900 N

Date	8/30/2012		80
SECCHI	6.0	*Feet*	windy 5mph
Anoxic Boundry	7.37	*meters*	John /Ben
Sum RTRM	317		1 rain 6 day ago

Normanoch Associa
Data Services Divisi

Depth	*Temp*	*DO*	*%SAT*	*RTRM*	*RVG*	ORP
0	25.2	9.0	109	0	0	
1	24.7	9.0	108	16	20	
2	24.3	9.0	108	12	16	
3	24.0	8.6	102	9	12	
4	23.8	7.9	93	6	8	
5	23.4	6.9	81	12	16	
6	16.5	2.3	71	175	276	
7	15.3	2.3	23	24	48	
8	14.7	2.3	23	11	38	
9	14.4	2.2	23	5	26	
10	13.9	2.1	21	9	43	
11	13.3	2.1	20	10	51	
12	12.7	2.0	20	9	51	
13	12.4	1.9	19	4	26	
14	11.4	1.9	17	14	86	





Legend	
DO	Dissolved Oxygen Concentration
RTRM	Relative Thermal Resistance to Mixing
%SAT	DO Saturation as a function of Temperature
RVG	Relative Viscosity Gradient

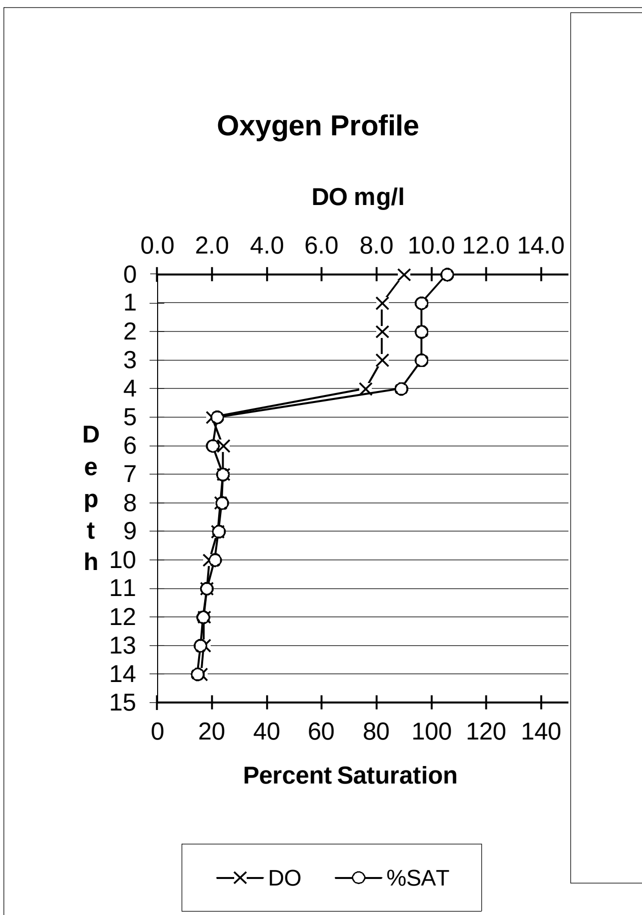
Culver Lake

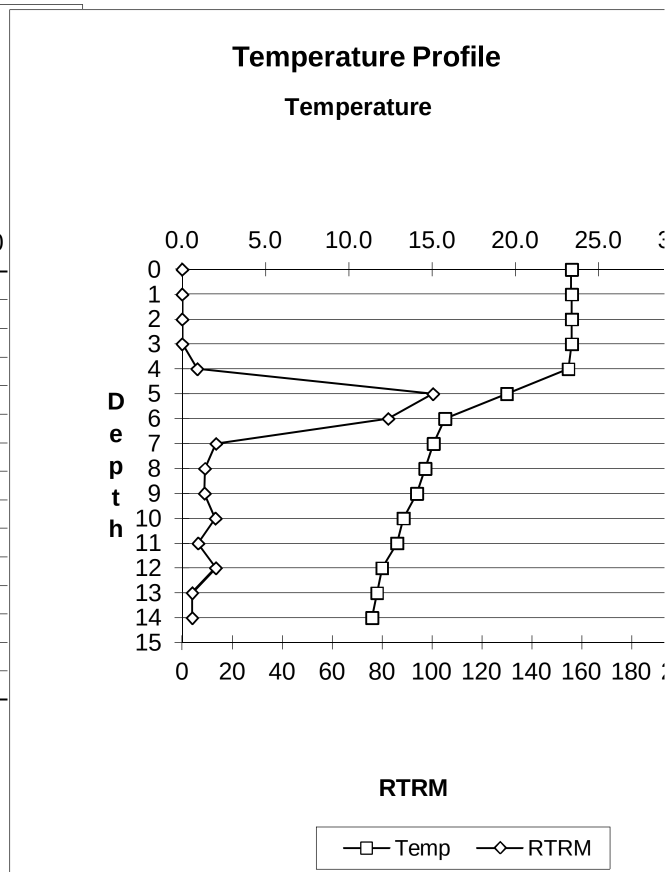
900 N

Date	9/9/2012		65
SECCHI	5.0	*Feet*	windy 5mph
Anoxic Boundry	8.75	*meters*	John /Roy
Sum RTRM	262		1 rain 1 day ago 6inches ?

Normanoch Associa
Data Services Divisi

Depth	*Temp*	*DO*	*%SAT*	*RTRM*	*RVG*	**ORP**
0	23.4	9.0	106	0	0	
1	23.4	8.2	96	0	0	
2	23.4	8.2	96	0	0	
3	23.4	8.2	96	0	0	
4	23.2	7.6	89	6	8	
5	19.5	2.0	22	100	148	
6	15.8	2.4	20	83	148	
7	15.1	2.4	24	14	28	
8	14.6	2.3	24	9	39	
9	14.1	2.2	22	9	43	
10	13.3	1.9	21	13	68	
11	12.9	1.8	18	6	34	
12	12.0	1.7	17	13	77	
13	11.7	1.7	16	4	26	
14	11.4	1.6	15	4	26	





Legend	
DO	Dissolved Oxygen Concentration
RTRM	Relative Thermal Resistance to Mixing
%SAT	DO Saturation as a function of Temperature
RVG	Relative Viscosity Gradient

Appendix B

Discrete Laboratory Data Figures

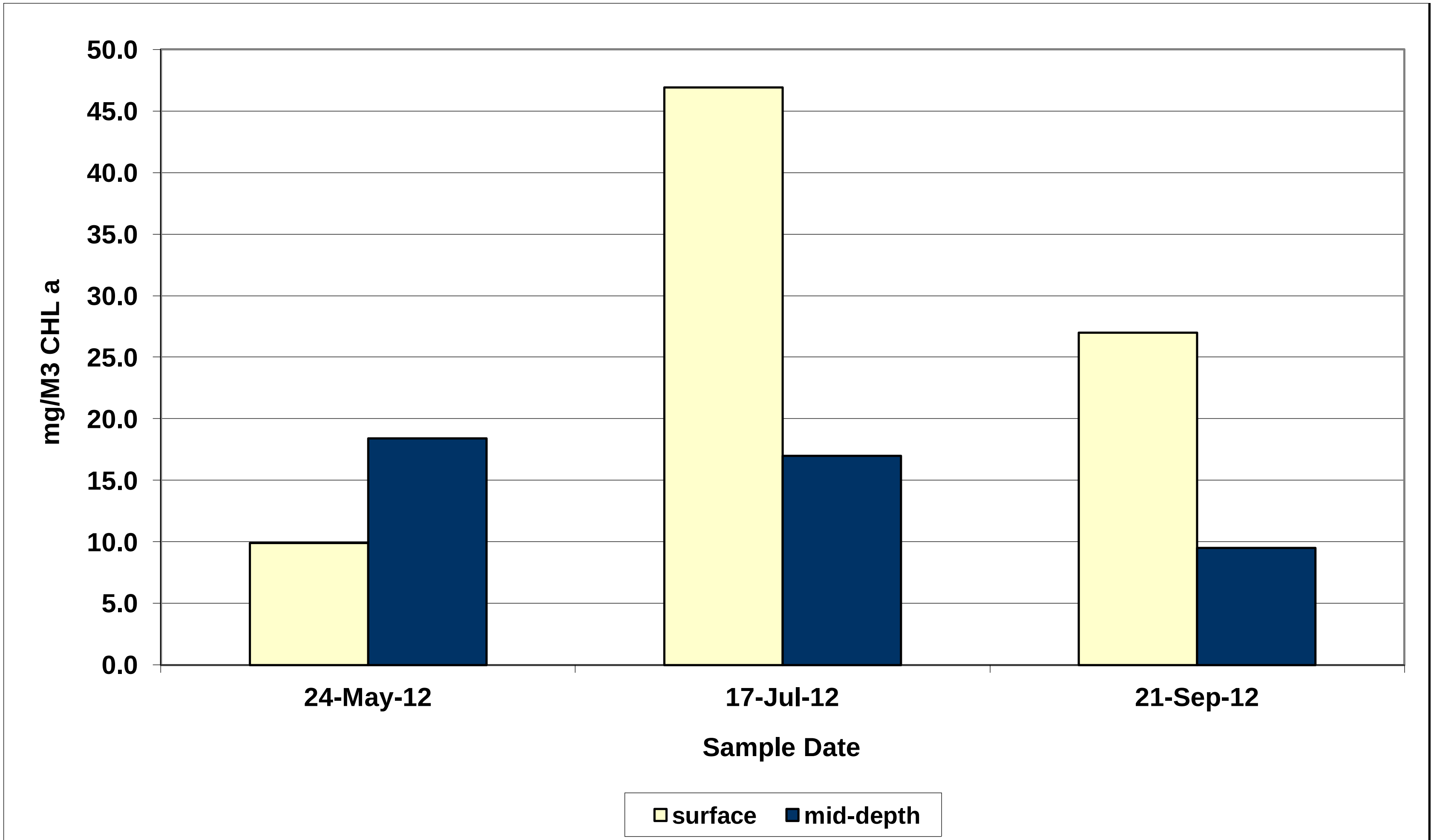


Figure 1 - Chlorophyll a concentrations at the Culver Lake mid-lake sampling station - 2012

Princeton Hydro, L.L.C.
1108 Old York Road
Ringoes, N.J. 08551

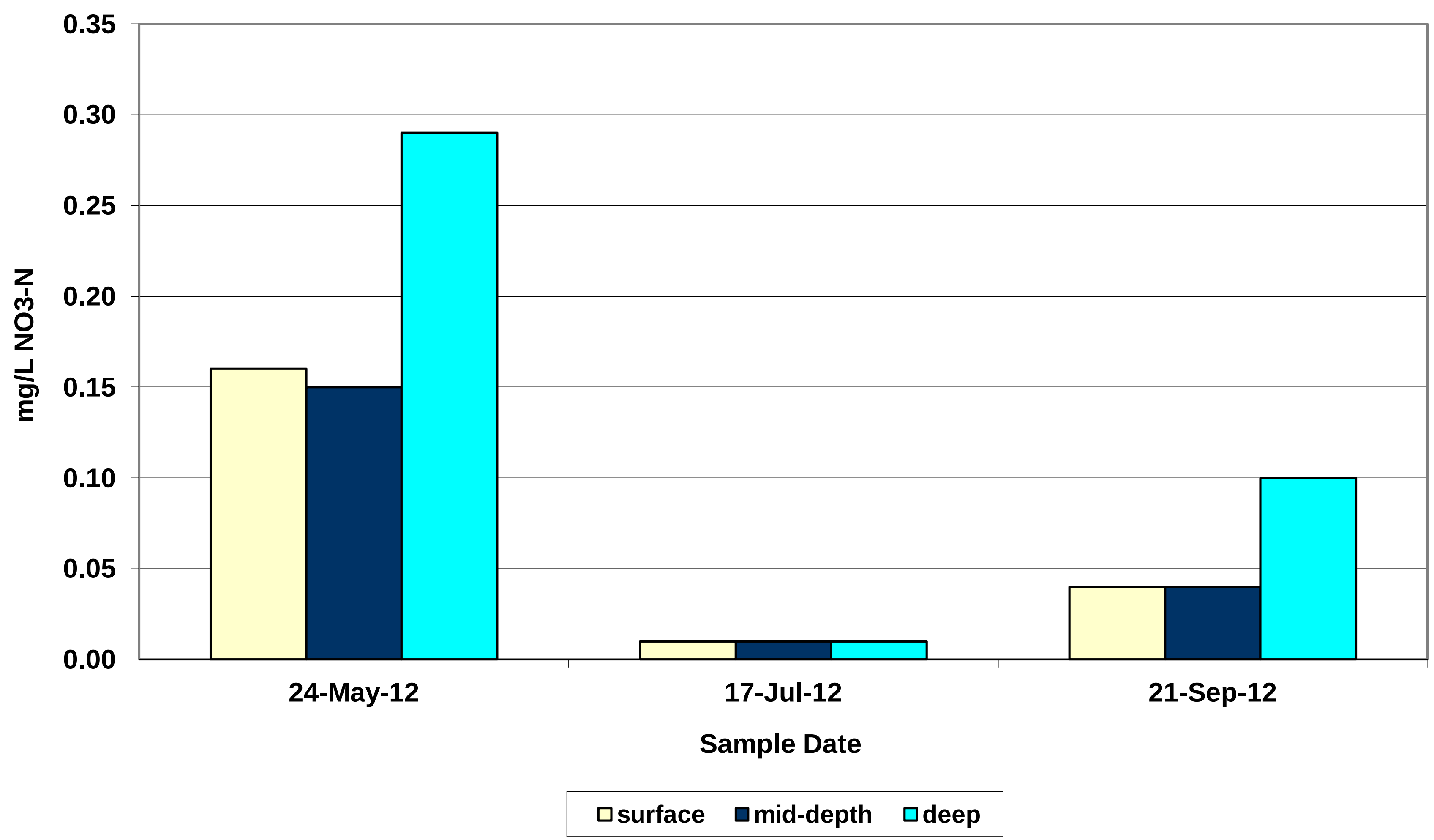


Figure 2 - Nitrate-N concentrations at the Culver Lake mid-lake sampling station - 2012

pH

Princeton Hydro, L.L.C.
1108 Old York Road
Ringoes, N. J. 08551

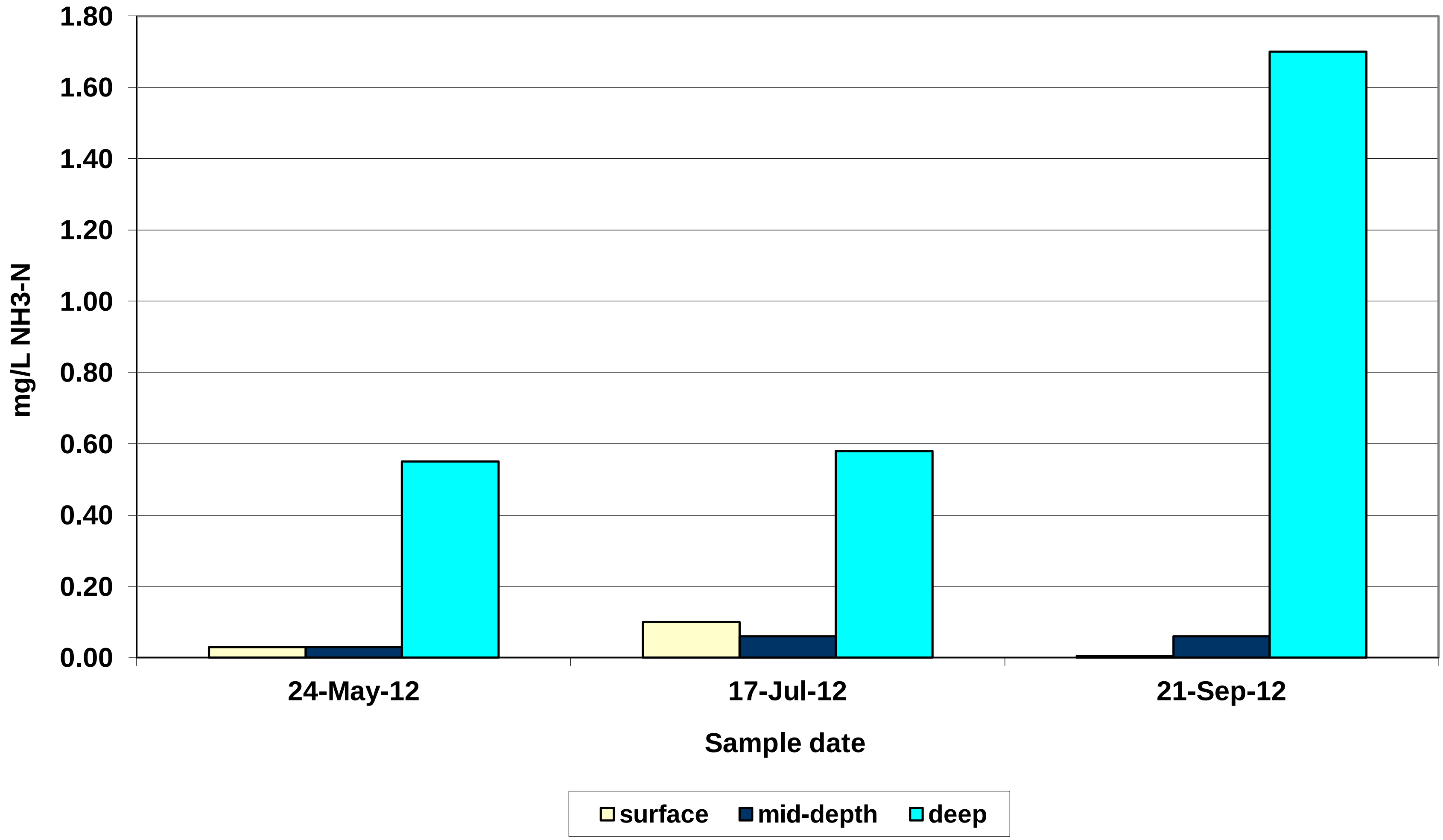


Figure 3 - Ammonia-N concentrations at the Culver Lake mid-lake sampling station - 2012

Princeton Hydro, L.L.C.
1108 Old York Road
Ringoes, N.J. 08551

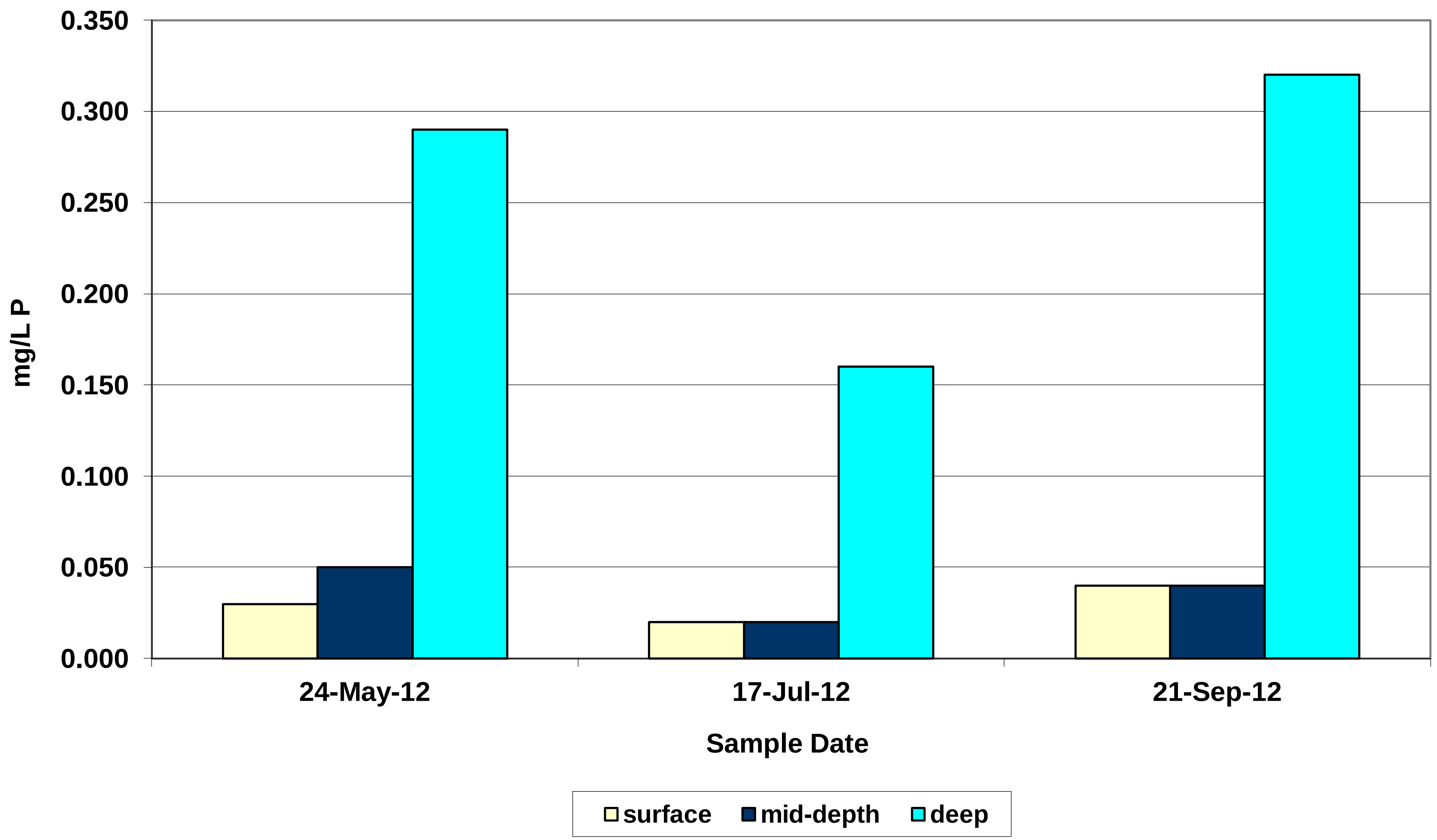


Figure 4 - Total Phosphate-P concentrations at the Culver Lake mid-lake sampling station - 2012

Princeton Hydro, L.L.C.
1108 Old York Road
Ringoes, N.J. 08551

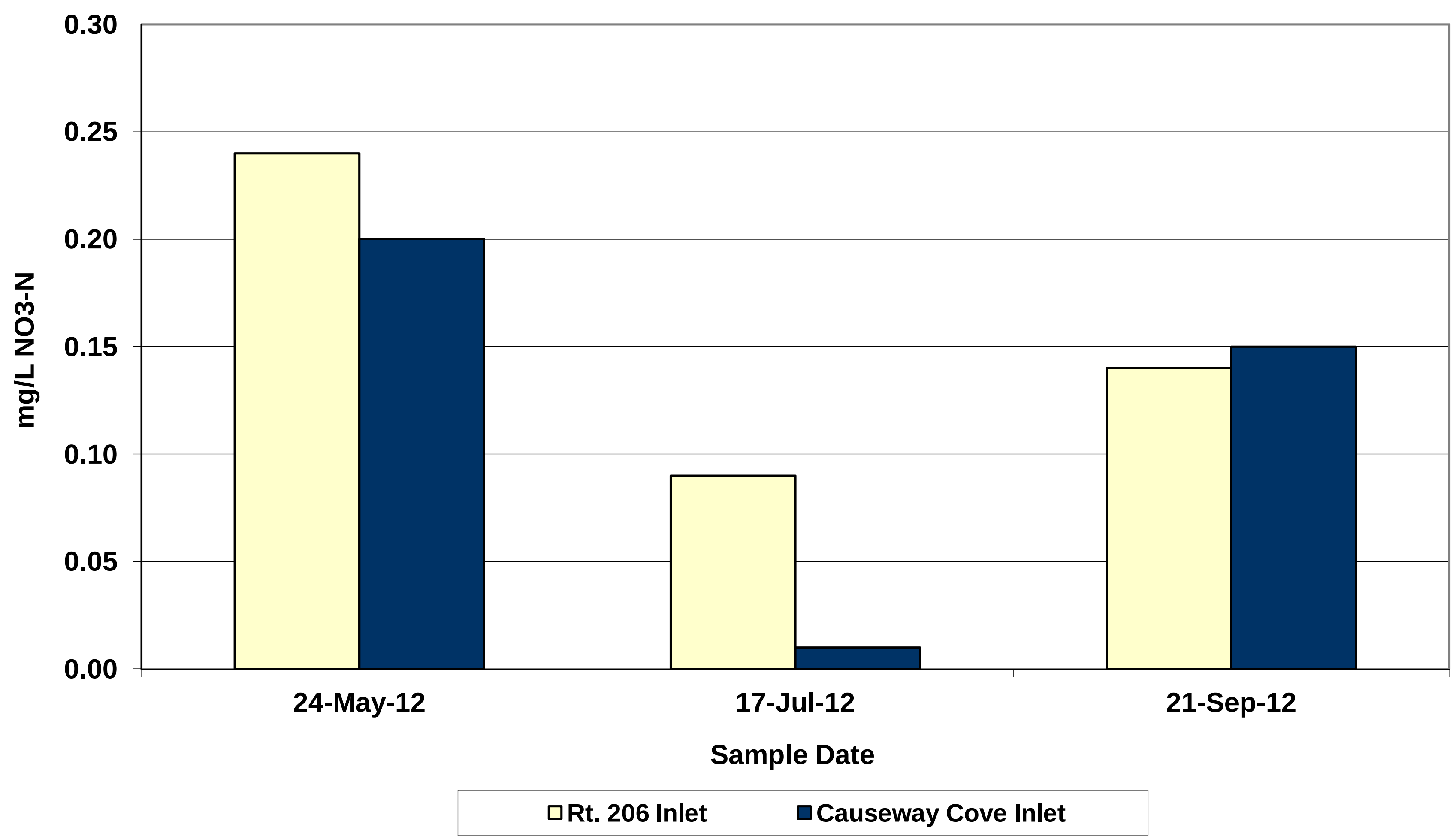


Figure 10 - Nitrate-N concentrations at Culver Lake Inlets - 2012

Princeton Hydro, L.L.C.
1108 Old York Road
Ringoes, N. J. 08551

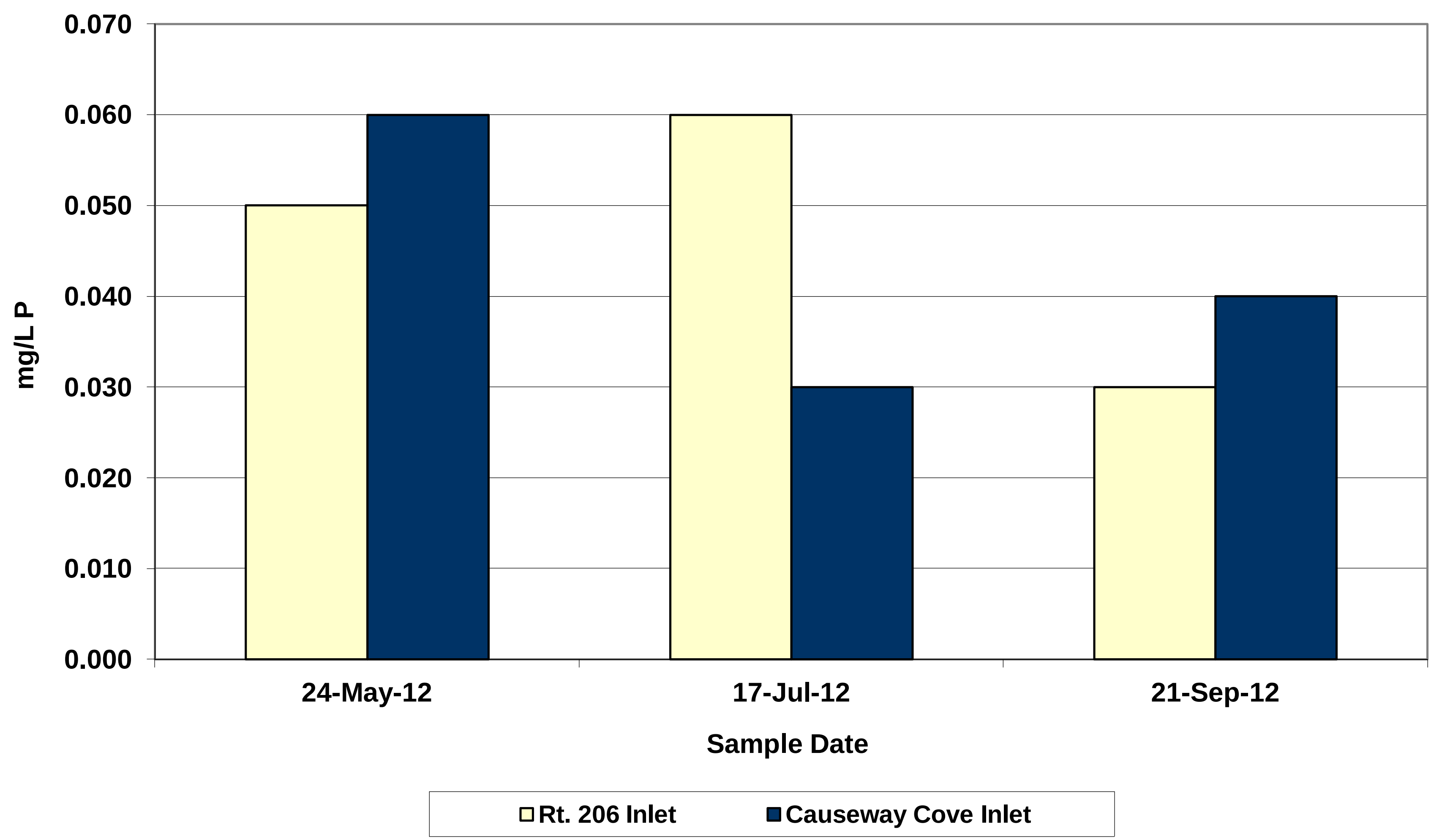


Figure 11 - Total Phosphate-P concentrations at Culver Lake Inlets - 2012

Princeton Hydro, L.L.C.
1108 Old York Road
Ringoes, N.J. 08551

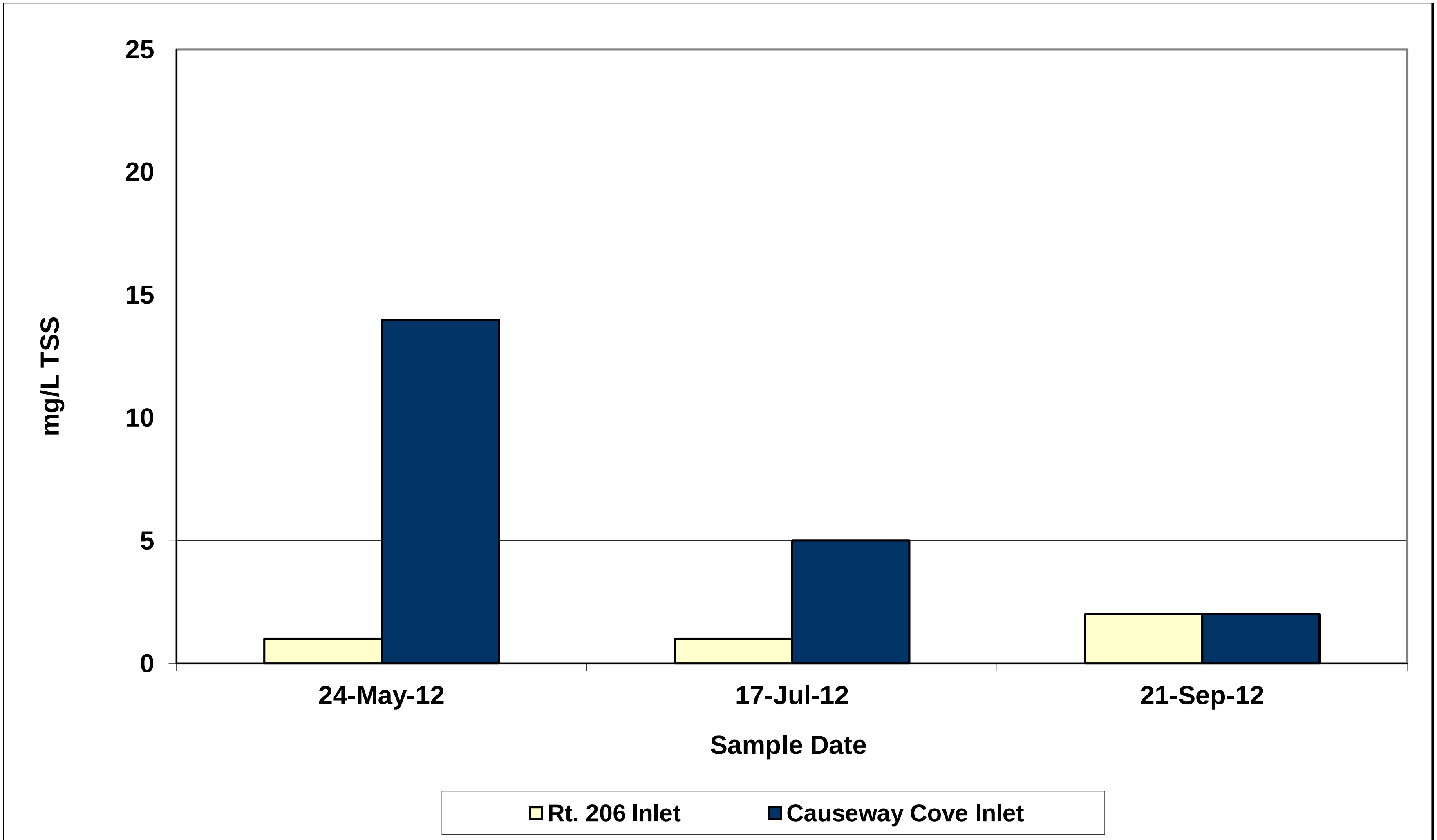


Figure 12 - Total Suspended Solids concentrations at Culver Lake Inlets - 2012

Princeton Hydro, L.L.C.
1108 Old York Road
Ringoes, N.J. 08551

Appendix C

Discrete Laboratory Data Long Term Trend Figures

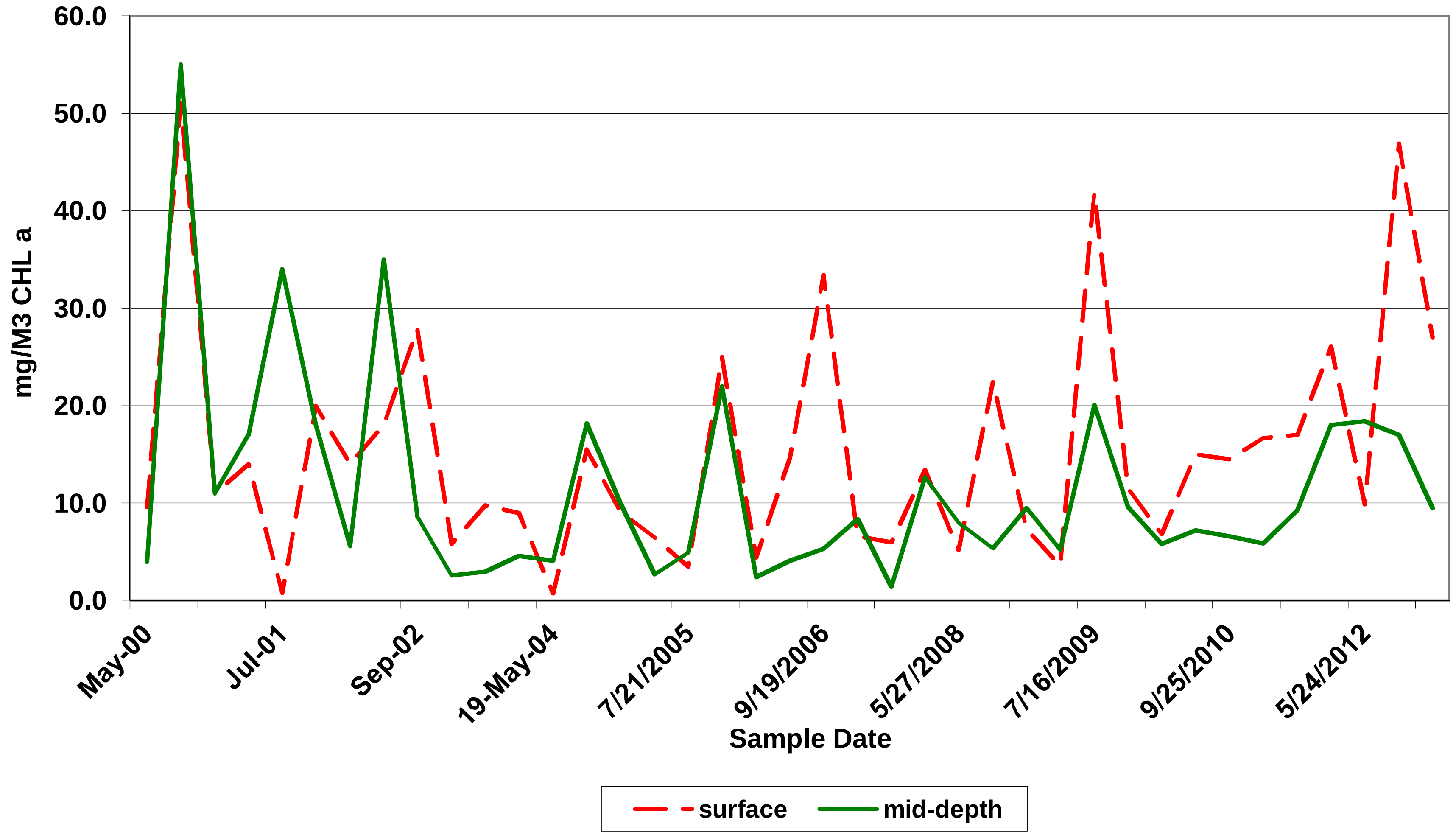


Figure 5 - Long-Term Trend of Chlorophyll a concentrations at the Culver Lake mid-lake sampling station

Princeton Hydro, L.L.C.
1108 Old York Road
Ringoes, N.J. 08551

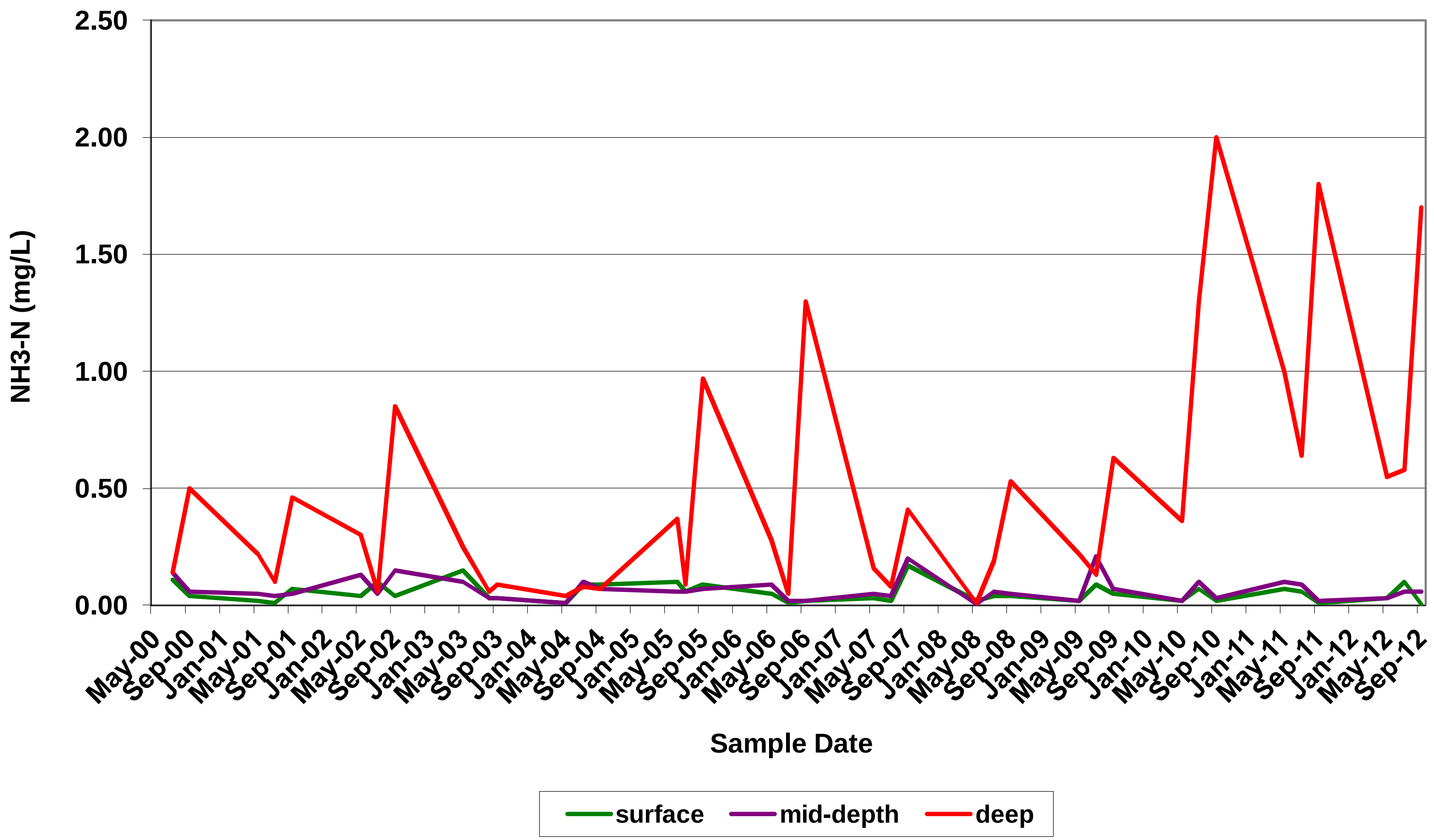


Figure 6 - Long Term Trend of Ammonia-N concentrations at the Culver Lake mid-lake sampling station	**pH** **Princeton Hydro, L.L.C.** **1108 Old York Road** **Ringoes, N.J. 08551**

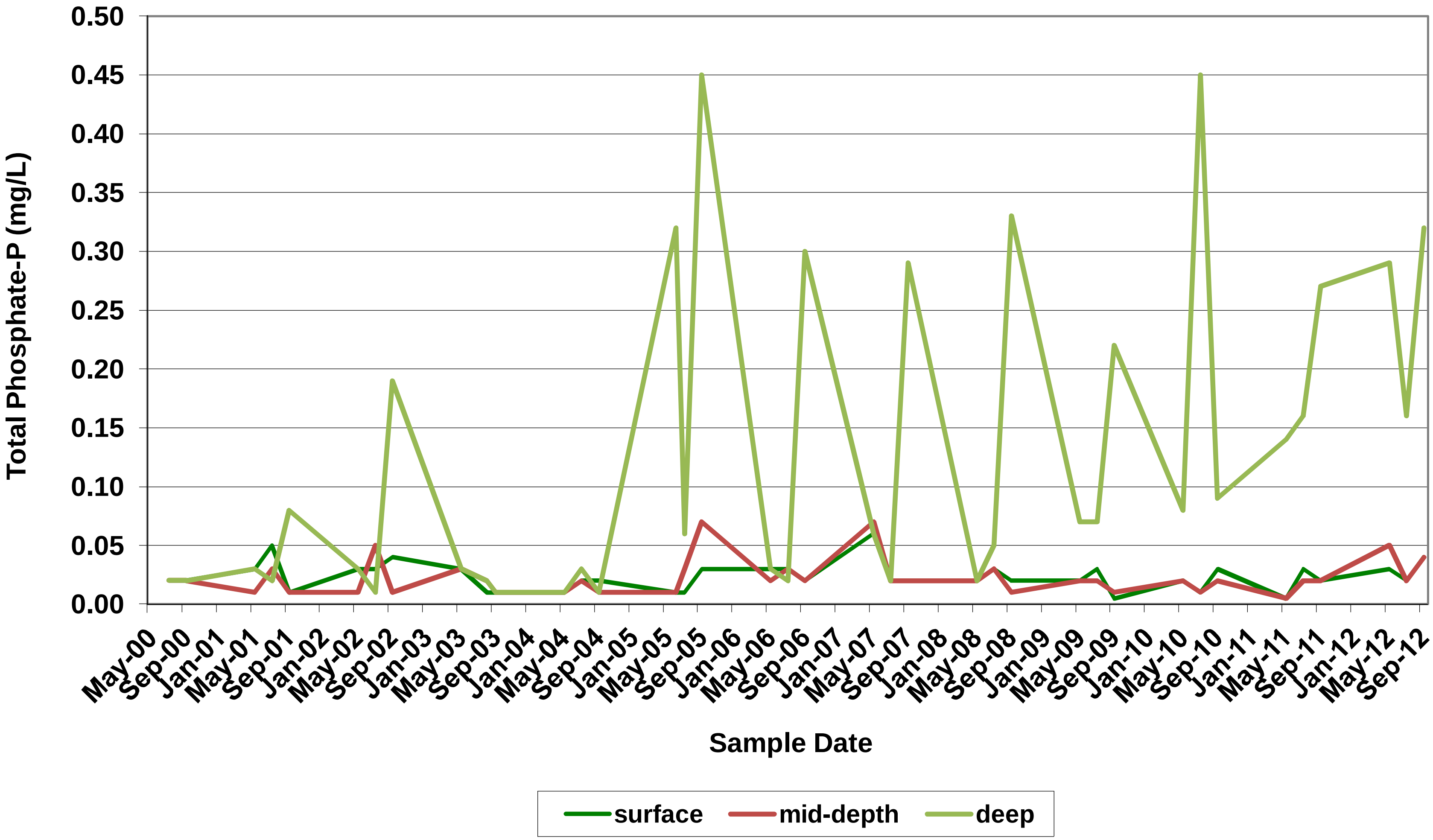


Figure 7 - Long Term Trend of Total Phosphate-P concentrations at the Culver Lake mid-lake sampling station

Princeton Hydro, L.L.C.
1108 Old York Road
Ringoes, N.J. 08551

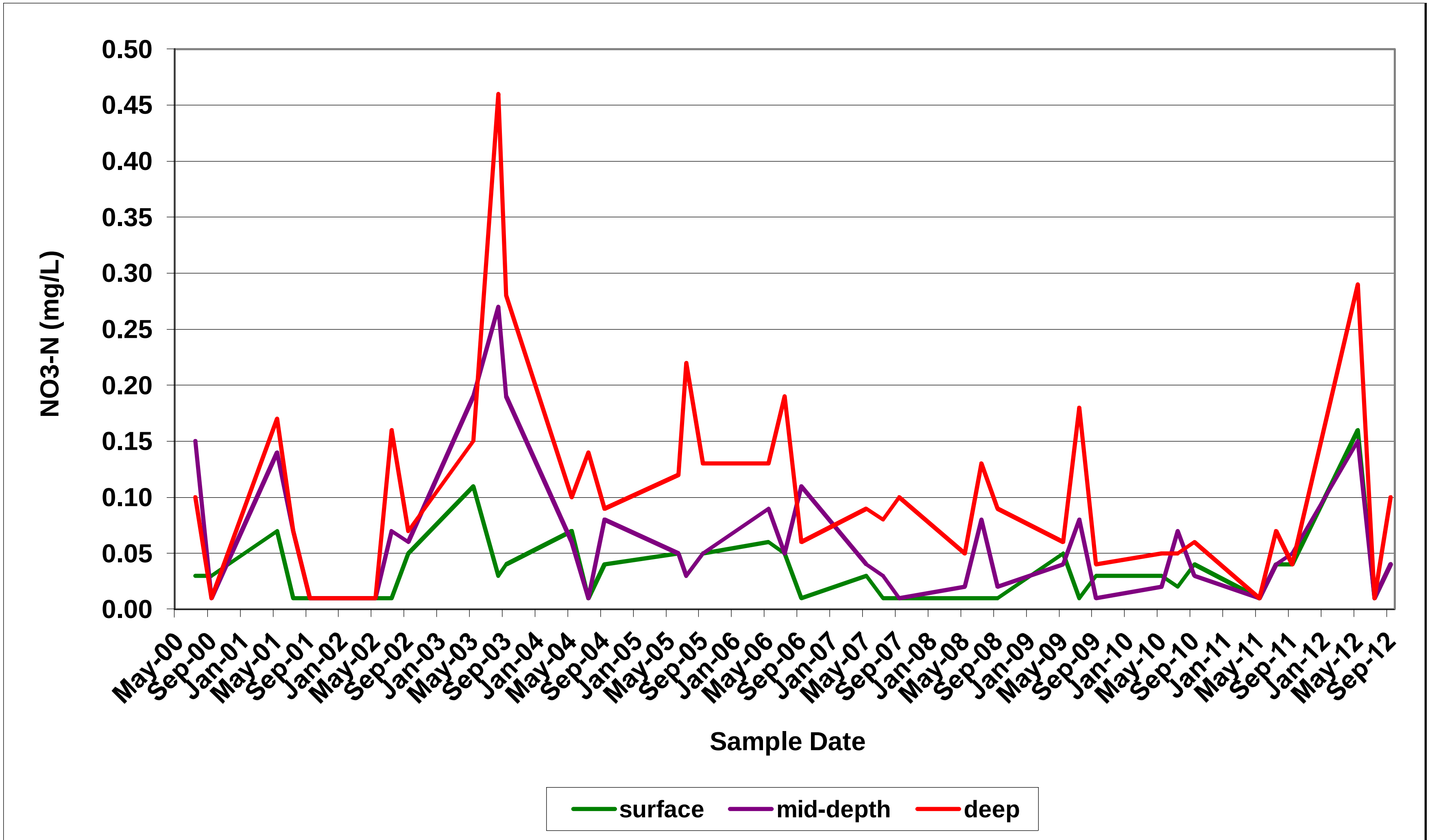


Figure 8 - Long Term Trend of Nitrate-N concentrations at the Culver Lake mid-lake sampling station	**Princeton Hydro, L.L.C.** **1108 Old York Road** **Ringoes, N.J. 08551**

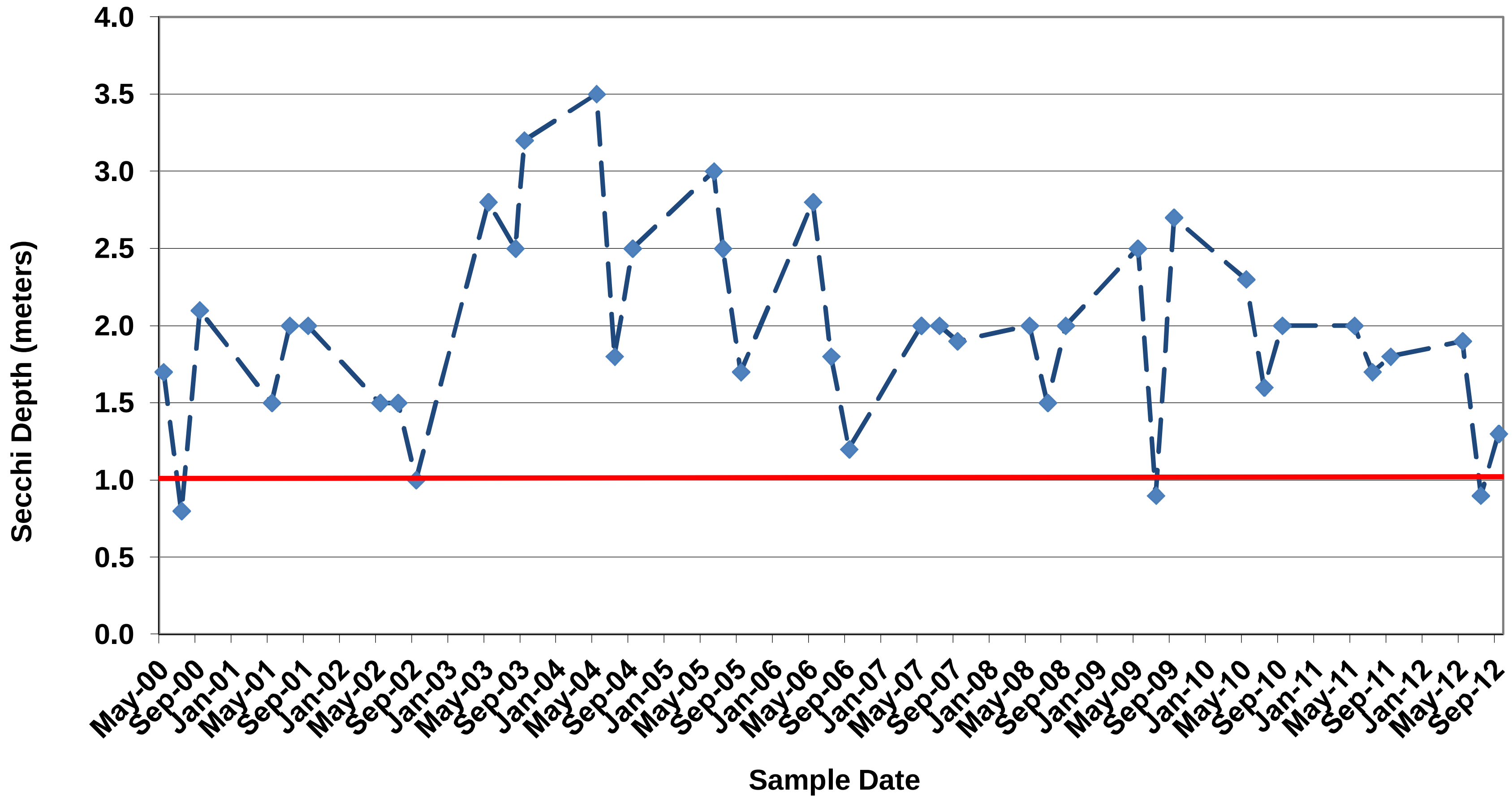


Figure 9 - Long-Term Trend of Secchi Disk values at the Culver Lake mid-lake sampling station	**Princeton Hydro, L.L.C.** **1108 Old York Road** **Ringoes, N.J. 08551**

Appendix D

2012 Plankton Population Data

Phytoplankton

Culver Lake

Mid-Lake, Surface

24-May-12

Organism	**Cells/ml**	**µg per liter**
Cyanophyta		
Anabaena	3,797	9,051
Green Algae		
Chlamydomonas	190	20
Chrysophyta		
Chromulina	759	178
Ochromonas	285	62
Chrysosphaera	285	226
Total	**1,329**	**466**
Cryptophyta		
Cryptomonas	759	735
Diatoms		
Tabellaria	949	2,853
Cyclotella	95	44
Total	**1,044**	**2,896**
Total	**7,119**	**13,167**

Phytoplankton

Culver Lake

Mid-Lake, Mid-Depth

24-May-12

Organism	**Cells/ml**	**µg per liter**
Cyanophyta		
Aphanizomenon	3,797	222
Chrysophyta		
Ochromonas	111	24
Chrysosphaera	111	88
Mallomonas	111	275
Total	**333**	**387**
Diatoms		
Asterionella	334	484
Synedra	334	1,147
Total	**668**	**1,631**
Total	**4,798**	**2,241**

Phytoplankton

Culver Lake

Mid-Lake, Surface

17-Jul-12

Organism	Cells/ml	µg per liter
Cyanophyta		
Aphanizomenon	33,962	1,989
Anabaena	14,927	35,581
Chroococcus	922	730
Coleosphaerium	16,771	18,648
Total	**66,582**	**19,378**
Green Algae		
Chlamydomonas	1,845	192
Pediastrum	84	532
Eudorina	2,683	268
Total	**4,612**	**800**
Chrysophyta		
Chromulina	419	98
Cryptophyta		
Cryptomonas	335	324
Euglenoids		
Trachelomonas	84	250
Total	**72,032**	**20,851**

Phytoplankton

Culver Lake

Mid-Lake, Mid-Depth

17-Jul-12

Organism	Cells/ml	µg per liter
Cyanophyta		
Aphanizomenon	816	48
Anabaena	2,122	5,058
Coleosphaerium	24,487	27,228
Total	**27,425**	**32,286**
Green Algae		
Chlamydomonas	326	34
Chlorella	82	65
Total	**408**	**99**
Chrysophyta		
Chromulina	571	134
Cryptophyta		
Cryptomonas	163	158
Total	**28,567**	**32,677**

Phytoplankton

Culver Lake

Mid-Lake, Surface

Sampling Date

400X

Organism	Cells/ml	µg per liter
Blue-Green Algae		
Anabaena	10,325	24,612
Coleosphaerium	7,518	8,359
Aphanocapsa	5,012	346
Pseudoanabaena	6,015	352
Total	**28,870**	**33,669**
Green Algae		
Chlamydomonas	2,907	303
Chlorella	100	79
Pediastrum	100	633
Oocystis	401	56
Scenedesmus	200	9
Total	**3,708**	**1,081**
Chrysophyta		
Chromulina	601	141
Ochromonas	301	65
Total	**902**	**206**
Total	**33,480**	**34,956**

Phytoplankton

Culver Lake

Mid-Lake, Mid-depth

Sampling Date

400X

Organism	Cells/ml	µg per liter
Blue-Green Algae		
Anabaena	776	1,850
Green Algae		
Chlamydomonas	1,320	138
Chlorella	78	62
Staurastrum	78	782
Oocystis	311	43
Scenedesmus	155	7
Total	**1,942**	**1,032**
Chrysophyta		
Chromulina	388	91
Dinobryon	78	27
Total	**466**	**118**
Total	**3,184**	**3,000**

Culver Lake

Surface

Zooplankton

24-May-12

Organism	**Number per Liter**	**µg/L**
Cladocera		
Bosmina	65	66
Chydorus	9	7
Total	**74**	**72**
Copepods		
Cyclops	37	8
nauplii	185	145
Total	**222**	**152**
Rotifers		
Conochilus	9	1
Polyarthra	9	9
Asplanchna	19	25
Total	**37**	**35**
Grand Total	**333**	**259**

Culver Lake

Mid-depth

Zooplankton

24-May-12

Organism	Number per Liter	µg/L
Cladocera		
Bosmina	30	30
Chydorus	10	7
Total	**40**	**38**
Copepods		
Diaptomus	10	17
Cyclops	61	12
nauplii	40	31
Total	**111**	**61**
Rotifers		
Conochilus	91	11
Keratella	131	4
Total	**222**	**16**
Grand Total	**373**	**114**

Culver Lake

Surface

Zooplankton

17-Jul-12

Organism	Number per Liter	µg/L
Cladocera		
Bosmina	284	287
Chydorus	53	38
Ceriodaphnia	74	130
Total	**411**	**456**
Copepods		
Diaptomus	21	36
Mesocyclops	11	24
Cyclops	95	19
nauplii	410	320
Total	**537**	**399**
Rotifers		
Conochilus	1218	150
Polyarthra	42	41
Asplanchna	11	15
Keratella	21	1
Trichocerca pilla	11	4
Total	**1,303**	**210**
Grand Total	**2,251**	**1,064**

Culver Lake

Mid-depth

Zooplankton

17-Jul-12

Organism	Number per Liter	µg/L
Cladocera		
Bosmina	232	234
Chydorus	43	31
Ceriodaphnia	60	106
Total	**335**	**371**
Copepods		
Diaptomus	17	29
Mesocyclops	9	20
Cyclops	77	16
nauplii	335	262
Total	**438**	**326**
Rotifers		
Conochilus	1502	185
Polyarthra	9	9
Asplanchna	9	12
Keratella	223	7
Trichocerca pilla	17	6
Total	**1,760**	**219**
Grand Total	**2,533**	**915**

Culver Lake

Surface

Zooplankton

21-Sep-12

Organism	**Number per Liter**	**µg/L**
Cladocera		
Daphnia	16	37
Chydorus	184	134
Ceriodaphnia	24	42
Total	**224**	**213**
Copepods		
Diaptomus	168	285
Cyclops	144	29
nauplii	160	125
Total	**472**	**439**
Rotifers		
Conochilus	56	7
Polyarthra	88	85
Keratella	240	8
Total	**384**	**100**
Grand Total	**1,080**	**753**

Culver Lake

Mid-depth

Zooplankton

21-Sep-12

Organism	Number per Liter	µg/L
Cladocera		
Daphnia	15	35
Bosmina	15	15
Chydorus	173	126
Ceriodaphnia	8	14
Total	**211**	**190**
Copepods		
Diaptomus	128	217
Cyclops	60	12
nauplii	113	88
Total	**301**	**318**
Rotifers		
Conochilus	60	7
Polyarthra	30	29
Keratella	233	8
Trichocerca pilla	75	25
Total	**398**	**69**
Grand Total	**910**	**577**

Appendix E

2012 Secchi Clarity Photographs

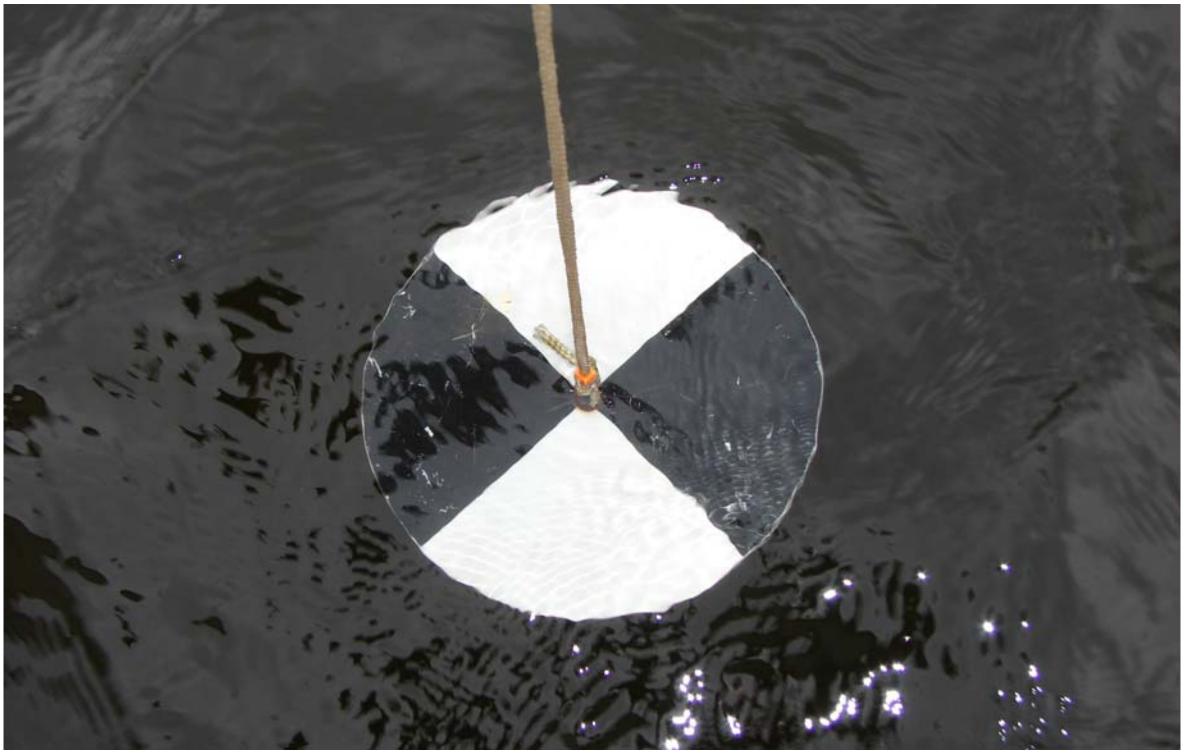


Photo 1: 24 May 2012 surficial view of the secchi disk.

Photo 2: 24 May 2012 view of the secchi disk at a depth of 1 meter.

2012 Water Quality Monitoring Program
Normanoch Association
Culver Lake
Township of Branchville, Sussex County, New Jersey
Project # 0013.020

Princeton Hydro

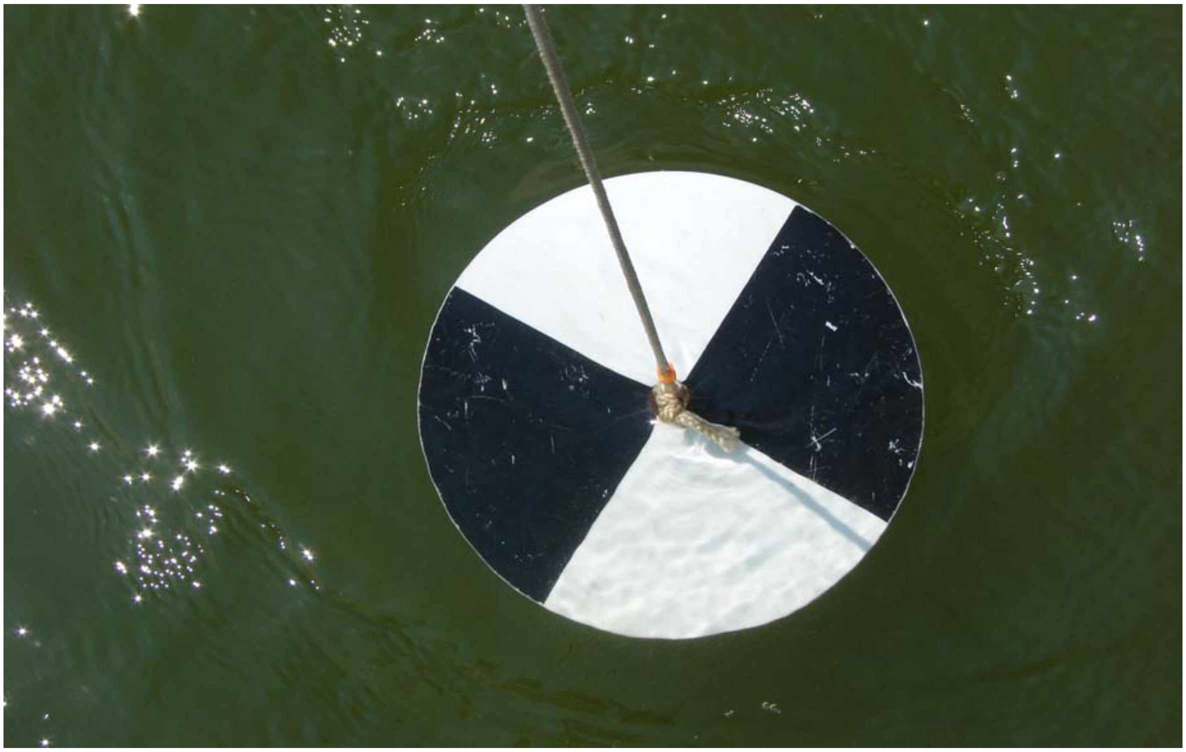


Photo 3: 17 July 2012 surficial view of the secchi disk.

Photo 4: 17 July 2012 view of the secchi disk at a depth of approximately 0.5 meters.

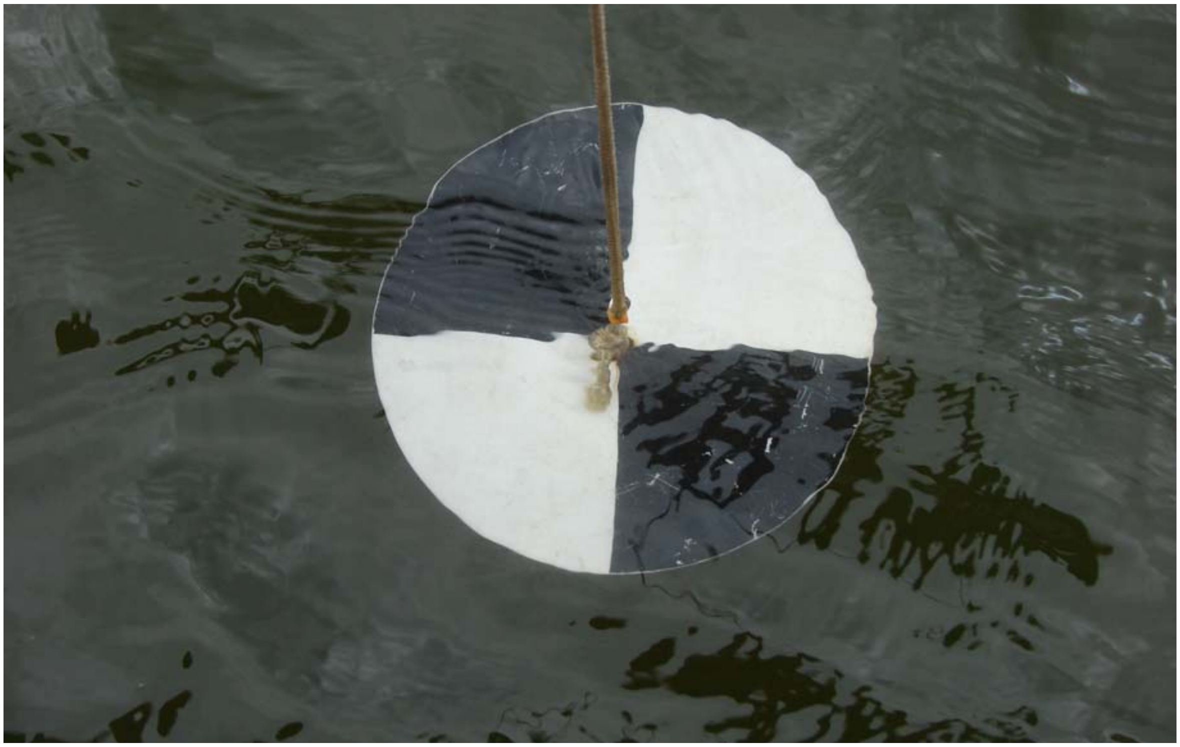


Photo 3: 21 September 2012 surficial view of the secchi disk.

Photo 4: 21 September 2012 view of the secchi disk at a depth of approximately 1.0 meters.