CULVER LAKE
WATER QUALITY MONITORING
AND
ZOOPLANKTON STOCKING PROGRAM
2007 END OF YEAR REPORT

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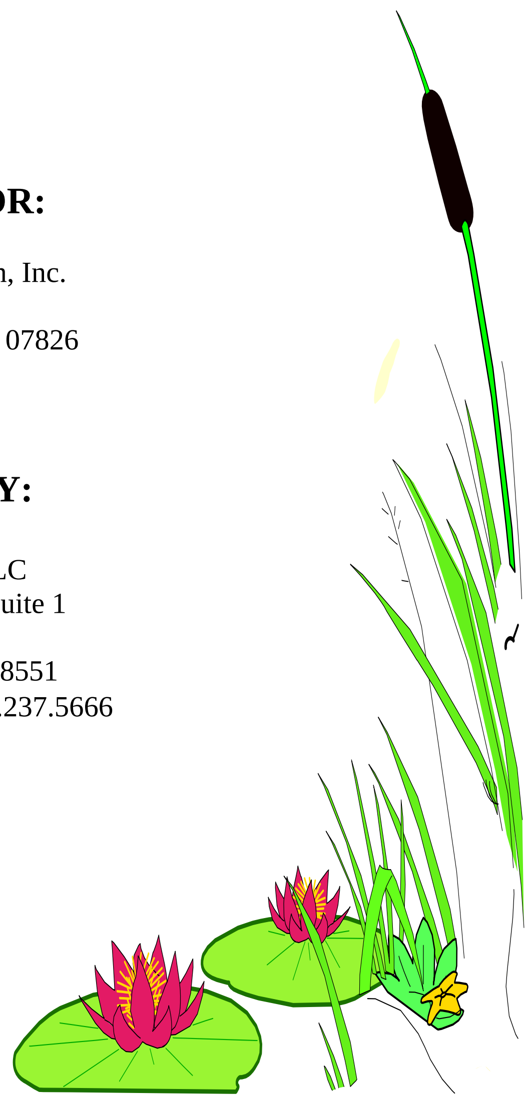

Executive Summary

- ***Dissolved Oxygen (DO)*** - Data collected from early July through mid-September document that the aeration system did not consistently maintain positive dissolved oxygen concentrations throughout the entirety of the lake's water column. In the early part of the season, specifically mid-May, DO concentrations were acceptable and within the desired range from surface to bottom at the mid-lake station. However, by mid-July, a DO sag had occurred, resulting in reduced conditions at depths greater than 7 meters. This DO depletion continued throughout the summer and into the late summer, resulting in anoxic conditions at depths greater than 7 meters. Usually anoxic conditions in the deep hypolimnion (water deeper than 8 meters) are not an especially significant concern at this time of year, however low or no dissolved oxygen within the metalimnion layer of the lake has the potential to significantly impact water quality. The data show that increased dissolved oxygen concentration conditions were present within the metalimnetic layer over the course of the later part of the summer as compared to previous monitoring years.

- ***Secchi Transparency*** - The desired target Secchi transparency depth established for Culver Lake is 1 meter. In the summer of 2007, the lake's Secchi depth consistently met or exceeded 1.9 meters, well above the target depth. The 2007 average Secchi depth for the mid-lake station was 1.9 meters.

- ***Temperature*** - The Lake became thermally stratified by mid May and remained so through late-September. As has been the case historically, three distinct thermal layers were once again present over the course of the summer of 2007. These approximately coincided with the following 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 11.0 mg/l in the mid-spring to anoxic in late summer. This cool thermal layer (metalimnion) should be providing midsummer brown trout habitat. However, the data suggests that the trout "hold over" habitat was only acceptable for the late spring, then marginal at best for the remainder of the summer. Once again, the lake's thermal layering also appeared to affect the development and concentration of algae at or near the lake's thermocline.

- ***Phosphorus*** - Phosphorus concentrations were measured over the 2007 growing season at each of the lake's thermal layers. Phosphorus concentrations were elevated in the late spring when all three layers (surface, mid-depth and bottom) were 0.06 mg/L or higher. During the mid-summer monitoring event, the TP concentrations measured in each layer had lessened to at or below 0.02 mg/L. By late summer, the surface and mid-depth layers were still minimal at 0.02 mg/L; however the deep water concentration had risen to 0.29 mg/L. The consistently dry weather that was observed during the second half of the summer of 2007 allowed the lake to experience a much lower flushing rate then normal, somewhat similar to what was observed in 2005 and 2006. Thus, with the exception of the elevated initial late spring concentrations, the 2007 TP levels were somewhat similar to those measured the previous two years.

- ***Ammonia*** - A build up of ammonia was observed in the lake's hypolimnion during the monitoring of 2007. Similar to phosphorous, this was also similar to conditions previously observed during the summer of 2006. This again supports the observation that the persistent dry weather and the subsequent non-flushing of the lake in the second half of the summer of 2007 allowed the nutrient buildup, based on the anoxic conditions.

- ***Chlorophyll a*** - Chlorophyll *a* is a photosynthetic pigment present in all algae. It is commonly used to evaluate and quantify algal community development. For Culver Lake, we have established an acceptable maximum concentration of chlorophyll *a* of 20 mg/m^3. In May, as the lake's algal community is blooming, the concentration of chlorophyll *a* was *6.6* mg/m^3. In July, the epilimnetic concentration of chlorophyll *a* had decreased to 6.0 mg/m^3. By late summer, the concentration of chlorophyll *a* had increased to 13.4 mg/m^3. The metalimnetic chlorophyll *a* concentrations mirrored the surface concentration, although slightly less in concentration. Given the consistency of dry weather experienced in the second half of the summer of 2007, and the decreased flushing rates, the ability of algae to truly bloom may have been the reason for the observed increase in surface chlorophyll *a* concentrations recorded from late spring to late summer.

- ***Phytoplankton*** **–** The phytoplankton community was monitored both at the surface and at the lake's metalimnion. The blue-green algae where the dominant algae for the majority of the sampling season. The abundances and biomass densities of the blue-greens were considerably higher than observed in 2007.

- ***Macrophyte Growth and Management*** – Macrophyte (weed) growth in the Stehr Tract section of the lake once again continued to pose a significant management problem. Overall, weed growth remained relatively stable as compared to the pattern and densities of weeds recorded during the 2006-growing season.

Introduction

The water quality of Culver Lake has been monitored continuously since the early 1990's by Princeton Hydro. The objective of the annual growing season monitoring program has been two fold; collect and review the data needed to evaluate improvements in the lake's water quality and collect the data needed to evaluate the performance and operation of the lake's Layer Air aeration system. Supplementing Princeton Hydro data are data collected by Ecosystem Consulting Services and Aquatic Analysts. 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 weed harvesting results. The combination of the data collected and supplied by all three consultants increases the diversity and robustness of the database, thereby increasing the Association's ability to make informed decisions on the management of the lake. This report reviews the findings of the 2007 data, and the implications of these data with respect to management options for Culver Lake.

Methodology

During the 2007 growing season Princeton Hydro monitored the water quality of Culver Lake on three dates; 11 May, 10 July and 17 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 phytoplankton community were collected. In addition, on each data, observations were made of the lake's weed growth and algal community. Information was also obtained and reviewed regarding the Association's weed control and fishery management efforts. As in past monitoring efforts, three stations were monitored in 2007; mid-lake, Stehr Tract and Causeway Cove. The North Shore was also observed for macrophyte growth.

On each sampling date, Princeton Hydro conducted both *in-situ* and discrete water quality monitoring. 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
- 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)

In addition, 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 phytoplankton and zooplankton.

Results and Discussion:

1. Water Quality

Temperature/Stratification and Dissolved Oxygen

Somewhat similar to 2006, the summer of 2007 was unseasonably warm and dry from the mid-summer to late summer timeframe. As would be expected, the surface waters of the lake steadily increased in temperature through July and August, then cooled into September, and as a result reached conditions of thermal stratification early on. Similar to previous monitoring years, by mid-summer the thermocline had formed at a depth of approximately five (5) meters (approximately 16 feet). This depth of stratification persisted throughout the summer. It once again appears that weather patterns, and the operation of the aeration system, were responsible for the lake's observed thermal properties. This is significant for Culver Lake, as past data have shown that the shallower the thermocline, the more likely for algae that accumulate at the thermocline to be re-circulated into the lake's epilimnion.

Similar to previous monitoring years, measurable amounts of dissolved oxygen (DO) were not present within the lake's metalimnetic zone (Appendix 1). As will be discussed in further detail in the nutrient sub-section of this report, anoxic conditions within this zone increase the opportunity for phosphorus recycling and an increase in the lake's overall phosphorus budget. It also impacts the lake's ability to sustain acceptable brown trout habitat over the summer months.

With respect to the DO data, from the July through September monitoring dates, metalimnetic DO concentrations were minimal to unacceptable with respect to the maintenance of summer hold-over trout habitat. In July, metalimnetic DO concentrations declined below 2 mg/L at corresponding depths greater than 5 meters. This pattern also held true even in the cooler waters of the lake greater than 13 meters, with DO concentrations holding steady below the 1 mg/L range, anoxia. These data indicate that as of mid-July the lake's hold-over trout habitat was borderline acceptable. This was similar to the conditions observed in the past. For at least the past eight years, the data showed that although some hold-over trout habitat existed, the total volume of summer hold-over trout habitat was once again minimal. Over the course of the summer, the lake's hypolimnion remained anoxic or close to anoxic. This is an acceptable condition and consistent with the management objectives of the lake. The key however, is to ensure that the anoxic portion of the hypolimnion remains well below the lake's thermocline.

pH

The lake's pH changed dramatically with depth (Table 1). In mid-May, the pH of the epilimnion was slightly acid (6.91 to 6.59). Once below the thermocline, the pH decreased to slightly basic levels. In July, the pH of the epilimnion was again alkaline (7.70 to 8.35). Once below the thermocline, the pH increased to essentially neutral levels. The pH levels in September were more prominent in September than observed in July, as slightly elevated epilimnetic pH levels persisted. These elevated pH levels were the direct result of algal productivity and photosynthesis, especially during the dry warm mid to late summer period. The pH values suggest the existence of an algal bloom, and this was further confirmed by the highest measured chlorophyll a concentrations of the 2007 monitoring program. However, once below the metalimnetic thermocline, the pH of the lake declined somewhat and was close to neutral, as was the case in May and July.

Clarity

The lake's transparency, as measured by Secchi disk remained consistently high from the beginning of the season through the end. In May the lake's Secchi clarity was 2.0 meters; well above the target Secchi depth of 1 meter. In July the lake's clarity had remained consistent at 2.0 meters, again well above the target depth. A slight decrease in clarity was observed toward the close of the season, as in September the clarity had decreased to 1.9 m.

Nutrients

Phosphorus concentrations were measured over the 2007 growing season at each of the lake's thermal layers. Phosphorus concentrations were somewhat consistent from the surface to the bottom of the lake throughout the summer, until the late summer event. Phosphorus concentrations were similar at all three depths in the early summer, with all the depths at either 0.06 mg/L or 0.07 mg/L. These concentrations are somewhat elevated relative to what is normally observed in the spring. This may have been due to two things, the unusually warm winter of 2007 (which altered the freezing regime of the lake) and the influx of nutrients with the spring rains, which were a greater than normal. During the mid-summer monitoring event, all of the phosphorus concentrations had been reduced to 0.02 mg/L. By late summer, the deep water concentration was significantly higher than the remaining depths. The surface and mid-depth concentrations were 0.02 mg/L while the deep water concentration had risen to 0.29 mg/L. The consistently dry weather that was observed during the second half of the summer of 2007 allowed the lake to experience a much lower flushing rate then normal, somewhat similar to what was observed in 2005 and 2006. Thus, TP levels in the latter part of the 2007 growing season were somewhat similar to those observed in 2005 and 2006.

In May, ammonia concentrations were variable from surface to bottom, ranging from a low of 0.03 mg/L to a maximum of 0.16 mg/L. In July, ammonia concentrations were more consistent from surface to bottom, ranging from a low of 0.02 mg/L to a maximum of 0.08 mg/L. Lastly, in September, ammonia concentrations were again variable from surface to bottom, ranging from a low of 0.17 mg/L to a maximum of 0.41 mg/L. This is consistent with the fact that anoxic conditions (measurable DO) were present below the 5-meter thermocline, specifically at depths greater than 10 meters. Typically, ammonia concentrations increase dramatically under anoxic conditions. This can be seen in the September data, when the hypolimnion was in a continued anoxic condition, an increase in the concentration of ammonia from the early summer concentration was observed in the lake's deepest reaches. Overall, the lake's ammonia concentrations were higher than those measured during the 2006 season, especially in the upper reaches of the water column. The reasons for this may be the patterns of the lake's thermal and dissolved oxygen profile or the late summer algae bloom, which will be discussed below.

Unlike ammonia, the lake's nitrate concentrations remained relatively consistent over the 2007 growing season. As the summer progressed, nitrate concentrations increased markedly 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 suggests that a significant amount of bacterial decomposition was 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 more consistent with late spring concentrations. This decrease is largely the result of photosynthetic uptake of the nitrate.

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 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. 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 2007, the concentration of chlorophyll *a* was 6.6 mg/M^3 at the surface and 8.4 mg/m^3 at the thermocline. These are very acceptable concentrations as they are obviously well below the target concentration. This 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, however this is not reflected in the chlorophyll *a* concentrations measured in 2007. At the lake's surface in July the concentration was 6.0 mg/M^3, while at the thermocline it was 1.4 mg/M^3. Again, these conditions are considered acceptable and were well below the target concentration. The fact that the mid-depth concentration was 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. Given that such conditions did not exist in the lake as late as the middle to end of July is a very positive indicator.

Later in the summer, due to the dryer, warmer conditions that persisted during most of August and September an increase in the concentration of chlorophyll *a* was then observed as reported in the September data. At that time the lake's surface chlorophyll *a* concentration was 13.4 mg/M^3. This is still well below the established target concentration. It should be noted at this same time the chlorophyll *a* concentration measured at the thermocline was only 12.7 mg/M^3. In examining the 2007 to the data collected over previous years it was noted that the 2007thermocline chlorophyll *a* concentrations were similar to those measured over the most recent years; that is relatively low from spring through the end of the summer. This year, much unlike what was observed in 2006, the surface chlorophyll *a* concentrations although increasing as the year progressed, never actually exceed the threshold value.

Two important conclusions can be drawn from these data. First, the 2007 data shows that the algae present in the mid-layers of the lake were not responsible for the late summer slight surface bloom. The maintenance of low concentrations at the thermocline supports a conclusion that the transport of deep water algae to the surface was not a primary factor in the September bloom. Second, as based on the analysis of the 2007 chlorophyll *a* with the other discrete and *in-situ* data, and especially the phytoplankton data (Section 2, below), it appears that prevailing (dry, warm) late-summer weather conditions were the driving factor behind the September bloom. As observed in both 2005 and 2006, such conditions allow for the significant growth and development of blue-green algae, leading to the bloom conditions (as reflected in the chlorophyll *a* concentrations) measured at the lake's surface in September. So although the density of algae never reached nuisance levels (concentrations greater than 20 mg/M^3), there was a sizable (approximately 2 fold) increase in chlorophyll *a* concentrations between the beginning and the end of the summer.

2. Biota

Phytoplankton

During the 11 May 2007 sampling event, a high diversity of green algae, several chrysophytes, a cryptomonad and a blue-green alga were identified in Culver Lake. In the surface waters the green algae were the dominant group and the single dominant genus was the chrysophyte *Dinobryon*. The sole blue-green alga identified in the surface waters was *Pseudoanabaena*. In May 2007, mid-depth algal abundance and biomass values were lower than the respective surface water values. However, similar to the surface waters, the green algae were the dominant group and *Dinobryon* was single dominant genus in the mid-depth waters. No blue-green algae were identified in the mid-depth May sample.

During the 10 July 2007 sampling event, the green algae remained the dominant group in the surface waters of Culver Lake in terms of abundance. However, the blue-green algae were the dominant group in terms of biomass. The blue-green algae that were identified in the surface waters included *Pseudoanabaena*, *Anabaena* and *Chroococcus*. Mid-depth abundance and biomass values were substantially lower the respective surface water values. No blue-green algae were identified in the mid-depth sample and the dominant alga in terms of both abundance and biomass was the chrysophyte *Synura*.

Surface water phytoplankton samples taken in September were characterized by a similar community assemblage with blue-greens again accounting for the majority of the community in terms of abundance and biomass. The dominant algae in terms of abundance shifted from the blue-green *Anabaena* to the blue-green *Coelosphaerium*. The dominant algae in terms of biomass were again the blue-green *Anabaena*. Although total abundance was only slightly elevated and this is reflected in the chlorophyll *a* concentrations of 6.0 µg/L to 13.4 µg/L. Mid depth phytoplankton samples again showed a significantly lower abundance and biomass than concomitant surface water samples. The mid depth community assemblage was similar to that of surface waters with the blue-green *Anabaena* exerting dominance terms of abundance and biomass. Along with the decreased phytoplankton abundance was an increase in chlorophyll *a* concentration with a measured concentration of 1.4 µg/L in July to 12.7 µg/L in September.

The phytoplankton data thus show the increased pervasiveness of the blue-green algal forms in the lake as the summer progressed. In 2007, these blue-greens tended to be composed mostly of species know to create surface blooms and scums. Although the densities of these species never attained nuisance densities, they did achieve a mass great enough to impact the aesthetics of the lake. However, on a relative scale the impacts were not as great as observed in the past. This is evident by examining the lake's Secchi clarity data for 2007.

Zooplankton

Zooplankton diversity, densities and biomass were moderate during the 11 May 2007 sampling event. Surface and mid-depth zooplankton values were similar to each other during the 11 May 2007 sampling event. In contrast to conditions observed in May of 2004 – 2006, herbivorous zooplankton were rare in Culver Lake during the May 2007 sampling event. Only one herbivore, the cladoceran *Ceriodaphnia*, was identified in the surface waters, while no herbivores were identified in the mid-depth waters. Rotifers were the most abundant group of zooplankton in the surface and mid-depth samples of Culver Lake in May 2007.

During the July 2007 sampling event, no herbivorous zooplankton were identified in the surface waters of Culver Lake while four herbivores, the copepod *Diaptomus* and the cladocerans *Daphnia*, *Diaphniosoma* and *Diaptomus*, were identified in the mid-depth sampling event. In the surface waters the rotifers were the dominant zooplankton group in terms of both abundance and biomass. While the rotifers were also the dominant group in the mid-depth waters in terms of abundance, the copepods were the dominant group in terms of biomass. In fact, the single most abundant genus in the mid-depth July sample in terms of biomass was the herbivorous copepod *Diaptomus*. The herbivores accounted for 17% of the total zooplankton abundance in the mid-depth July 2007 sample. In contrast, the herbivores accounted for 10% of the total zooplankton abundance in the mid-depth July 2006 sample.

Similar to past monitoring years, mean total lengths of the herbivorous zooplankton in July were less than 1.0 mm, indicating that they were under grazing pressure by forage and/or young gamefish. To continue long-term efforts to facilitate the development of a zooplankton community dominated by large-bodied herbivorous genera in Culver Lake, approximately 500,000 herbivorous zooplankton were stocked in Culver Lake during the July 2007 sampling event. More specifically, these stocked zooplankton were *Daphnia*, varying in size between 0.9 and 1.5 mm, with an estimated population mean of 1.38 mm.

During the September 2007 sampling event, no herbivorous zooplankton were identified in the surface waters of Culver Lake while three herbivores, the copepods *Diaptomus* and *Cyclops* and the cladocerans *Bosmina* were identified in the mid-depth sampling event. In the surface waters the copepods were the dominant zooplankton group in terms of both abundance and biomass. The copepods were also the dominant group in the mid-depth waters in terms of abundance and biomass. In fact, the single most abundant genus in the mid-depth September sample in terms of biomass was the herbivorous copepod *Cyclops*. The herbivores accounted for 64% of the total zooplankton abundance in the mid-depth September 2007 sample. In contrast, the herbivores accounted for 17% of the total zooplankton abundance in the mid-depth July 2007 sample. September zooplankton stocking again consisted of approximately 500,000 herbivorous zooplankton, thus completing the stocking density of the 2007 monitoring season.

The zooplankton stocking program again proved useful in controlling excessive amounts of phytoplankton, namely the green algae. Green algae densities, on average, were comparable in 2007 to 2006. The abundance of blue-green algae seems to have limited 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.

The distribution of the zooplankton, especially the 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 is less than optimal, thus creating additional stress for these organisms.

Aquatic Macrophytes

In May of 2007, approximately 90%-100% of the Stehr Tract section of the lake was impacted by weed growth. Large amounts of Eurasian water milfoil were observed growing to a point near the lake's surface. Weed densities were nominal in the Causeway Cove section of the lake. However, in the Causeway Cove section, unlike past years, Eurasian water milfoil was the only macrophyte observed. The North Shore of the lake also possessed scattered patches of Curly-leaf pondweed.

In July of 2007, the Stehr Tract Cove remained impacted by weed growth, especially Eurasian water milfoil and water lilies. Weed growth in the other sections of the lake continued to be much more sporadic and patchy, both with respect to that observed in Stehr Tract Cove and that observed throughout the lake in previous years. However, it should be noted that again only Eurasian watermilfoil was observed in the Causeway Cove portion of the lake, a place where tapegrass has been dominant in the past. Minimal numbers of yellow and white water lily, tapegrass and Eurasian water milfoil were observed along the North Shore.

In September of 2007, the Stehr Tract Cove showed the presence and growth of water milfoil, lilies and tapegrass, with a fairly even mix of all observed. In addition, the Eurasian water milfoil plants that were observed appeared to be brown and decaying. Throughout the summer, both yellow and white water lilies, Eurasian water milfoil and tapegrass were observed in sporadic patches along the North Shore. The Causeway Cove portion of the lake possessed Eurasian water milfoil and tapegrass with an approximate even mix of each.

3. Summary

- Between mid May and late July, the lake became strongly stratified. Once again, the thermocline was established at a depth of approximately five (5) meters. This timing of the onset of stratification was 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 consistent with that measured in recent past years (Appendix C), and remained consistent into in the later part of the summer. The lake's clarity in September was higher than that observed in the past few years, even in the presence of a late summer algal bloom that was dominated by blue-green algae forms.

- The cause for this bloom was concluded to be weather related and a direct function of the dry, warm conditions and subsequent lack of flushing experienced from mid through late summer. Likewise review of the DO, temperature and TP data do not suggest it was a function of the lake's late-summer destratification and turnover.

- The mean Secchi depth in 2005 was 2.4 meters and in 2006 it was 1.9 meters. In 2007, the lake's mean clarity remained at 1.9 meters. While there was no decrease in average clarity, this is still a cause for concern. It is again possible that the overall dry climatic conditions of the latter portion of 2007 are in part responsible for this value. The mid to late summer's overall dry and warm conditions could be considered favorable for the development of algal blooms. As noted although the bloom never exceeded threshold concentrations (20 mg/M^3) it did result in a doubling of chlorophyll *a* concentrations and significant increases in blue-green algae densities.

- As has consistently been the case in the past, midsummer, dissolved oxygen concentrations at or exceeding saturation were measured in the epilimnion. However, DO concentrations declined rapidly at the thermocline and anoxic conditions were experienced throughout the deeper portions of the lake's profile. Into the latest part of the summer, the hypolimnion once again remained anoxic. Although this condition did result in the internal release of phosphorus, the released phosphorus remained segregated near the bottom of the lake over the entire course of the 2007 growing season. This was physically achieved by the maintenance of strong thermal profiles into late September. Without a breakdown in stratification, it was possible (as evidenced by the TP data) to contain the phosphorus rich water near the lake bottom.

- With regard to the extent and the maintenance of summer hold-over trout habitat, the lake's thermal and DO properties were less than optimal from the early summer onward. It appears from mid-July through late-September, the DO concentrations measured at or below the thermocline were less than that desired for the maintenance of brown trout.

· Total phosphorus concentrations were higher than normal in the spring but deceased into the summer months. TP concentrations then remained relatively consistent from surface to bottom from mid-summer to late-summer. The late-summer deep water concentrations of TP were significantly elevated; 0.29 mg/L. However, although there significant phosphorus release occurred in the hypolimnion, none of the phosphorus migrated into the metalimnion or the epilimnion. Thus although internal phosphorus release did occur, the maintenance of the lake's thermal properties through the growing season resulted in the segregation of this phosphorus rich water at the bottom of the lake. Thus in essence the lake's internal phosphorus load was controlled.

· Although the annual mean TP concentration measured in 2007 was somewhat similar than that observed in 2006, it was higher than concentrations measured from 1993 to 2004 (Appendix B and C).

· <u>In general</u> (Appendix B and C) mean summer chlorophyll *a* concentrations have declined since 1995. The chlorophyll *a* concentration measured in late summer 2007 is the lowest chlorophyll a concentration measured in the last three years. This appears to be a function of a number of factors including weather patterns, lack of any significant mid-summer and external loading, and the control of internally released phosphorus.

· From the middle to the end of the summer of 2007, Culver Lake's phytoplankton community was generally dominated by blue-green algae. This is not a positive indicator. The density of blue-greens measured in September was very high and equated to bloom conditions. However, at no time did the concentrations reach densities high enough to violate the lake's Secchi or chlorophyll *a* threshold levels.

· Although the mean annual Secchi depth clarity exceeded the 1.0m threshold, the 2007 mean was far below the means measured in 2004 and 2005. Obviously this decline was strongly influenced by the overall decline in clarity attributable to the lake summer algae bloom.

· Nutrient and chlorophyll *a* concentrations were very low at the thermocline from the spring through the late summer. The data suggest the absence of a 2007 mid-water bloom. It does show that the lake experience instead a late summer surface water bloom. The algal and chlorophyll data do not suggest that very much of the algae that developed at or near the thermocline were transported into the epilimnion or were the cause for the late summer surface bloom.

- A review of the lake's nitrogen to phosphorous ratios showed that low N:P ratios continue to persist. Such ratios favor the development of blue-green algae. Altering this ratio will be difficult given the lake's overall low TP concentrations.

- An increase in the densities of herbivorous zooplankton was again observed. The lake's zooplankton community continues to show a positive effect as a result of the zooplankton stocking effort, the maintenance of zooplankton refuge habitat and the control of alewife densities. These are positive indicators. A shift in the phytoplankton further away from the blue-green algae would prove beneficial to the zooplankton as the blue-green algae are poor food sources.

- The Stehr Tract section of the lake continued to be impacted by excessive weed growth and continued to be that area of the lake in need of the greatest amount of weed control. Harvesting strategies in this section of the lake were intensified in 2007 to include hydro-raking. The resulting program proved to be very successful. A large amount of weeds and biomat material were removed through the operation. This resulted not only in improved access through this area but also aided in water circulation and improved the area's general aesthetics.

- 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 tend to be as impacted by weed growth as Stehr Tract Cove, each is impaired to some extent with weed densities at times impeding access and usage. As such, they continue to require maintenance. It should also be noted that again Eurasian watermilfoil was observed in the Causeway Cove section of the lake in 2007. The spread or density of this weed needs to continue to be tracked. Although rocks and subsurface impediments are more common here than in Stehr Tract Cove, a continued increase in the density of this weed in the Causeway Cove area may in the future warrant the implementation of a hydro-raking effort.

4. Conclusions and Recommendations:

The data collected during the 2007 season shows that for the most part the Association's management efforts are working. The September algae bloom, the predominance of blue-green algae in the lake from July through September and the less than optimal hold over habitat provided in the metalimnion for brown trout were negative conditions observed in 2007. The Association needs to continue to track algal species composition and algal densities in both the epilimnetic and metalimnetic regions of the lake. However, with the exception of the late summer algae bloom, the lake's overall conditions were relatively satisfactory. It can be concluded, based on the bulk of the 2007 data, and the relationship of these data to the long-term database, most of the water quality problems documented in the summer of 2007 were again weather induced and a function of external loading patterns.

In reviewing the long-term data base it was determined that it is time to re-set the lake management water quality thresholds and objectives for Culver Lake. Specifically, the clarity, TP and chlorophyll *a* threshold values need to be reassessed and modified to account for the sustained improvements achieved over the past 6-7 years. Similar to 2006, more focus needs to be placed on external loading dynamics, the management of the lake's nitrogen loading (to create N:P ratios that do not favor blue-green algae) and create threshold values for the lake's zooplankton community.

The stocking of herbivorous zooplankton is having a positive impact on the restructuring of the lake's zooplankton community. We do not support the stocking of brown trout other than on a put and take basis. Any fish stocking done by the Association should focus only on species that can exert predatory pressure on the zooplanktivorous fish such as alewives and golden shiner. The limited suitable trout habitat, combined with hybrid Striped Bass predation, may indicate a need to stock larger trout or perhaps another species in its place such as Walleye (*Stizostedion vitreum*) to achieve the same predatory effects of the alewife.

The weed harvesting efforts throughout the lake continues to provide relief from use impairment caused by excessive weed growth. 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 2007 hydro-raking project was very successful. Thus, based on the success of this effort, a 2008 hydro-raking program should again be conducted in the Stehr Tract section of the lake. In addition, based on the continued larger presence of Eurasian watermilfoil in the Causeway Cove portion of the lake, the feasibility of managing weed growth in this area of the lake by means of hydro-raking should be seriously assessed.

Princeton Hydro still remains guarded in terms of the use of herbicides to control weed growth. We strongly suggest the Association consider implementing a monitoring effort of the lake's weed community using a combination of aerial photographic analysis and in-lake surveys as a means of documenting the spread of different weed species, lake-wide changes in weed composition and density, and the success of different weed management efforts. The data derived through such a survey could be used to direct weed harvesting, hydro-raking or alternative control strategies to problem areas and quantitatively track the resulting improvements.

As such, for 2008 we recommend the following be conducted:

1. Although the Association should continue with the existing monitoring program and the collection of key water quality parameters from over the course of the 2008 growing season data need to be collected from major inflow sources to the lake under both baseflow and storm conditions. Specifically we feel that it would be prudent to examine inflow (TP and NO_3-N) nutrient concentrations on each of the three in-lake sampling dates. In addition 3-4 of the major stormwater outfalls (to be selected with assistance from the Association) should be sampled during storm event conditions, with at least three events monitored between June and mid-September. The analysis could be limited to TP, NO_3-N and Total Suspended Solids. The resulting data could 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. Such data have not been collected for over 15 years. With continued positive steps being made in the control of the lake's internal nutrient loading processes, attention needs to be placed on understanding better the impacts or consequences of watershed related loading.
2. Conduct a through statistical review of the long-term data base starting with the 2000 data to new lake management water quality thresholds for Secchi clarity, TP and chlorophyll *a*.
3. Use the long-term database to create a new threshold value for nitrogen, specifically the lake's N:P ratios. We can then utilize these data and the resulting revised threshold levels to better track the environmental conditions favoring blue-green algae.
4. Create a threshold value for the lake's zooplankton community, emphasizing minimum surface and metalimnetic concentrations and size classes for the herbivorous zooplankton standing crops.
5. In concert with the additional sampling noted above (2), model and recompute the watershed pollutant loads to the lake accounting for changes in land development (growth, intensity and in-fill development), the Association's septic management efforts and the new stormwater management rules. Start a shift in focus from internal nutrient control to external nutrient control. Based on observations made over the past three years, external loading dynamics are beginning to have a larger impact on lake water quality than are internal loading dynamics. This is gaining more importance with the management efforts involved in the lake.
6. Implement again a hydro-raking effort in the Stehr Tract area and seriously consider the feasibility of a similar effort in the Causeway Cove area. Understanding that a successful project of this nature was completed on the wetland side of the causeway, expansion of such

an effort into the lake proper appears warranted given the consistency of weed growth related problems in this section of the lake. Continue the conventional harvesting program, and avoid the use of herbicides in the management of the lake's weed growth.

7. Consider the implementation of a weed tracking program that is based on aerial reconnaissance and backed by in-lake field surveys.
8. Limit any trout stocking to put and take and consider the introduction of larger brown trout so as to minimize predatory losses to hybrid striped bass. We do not recommend the introduction of additional hybrid striped bass, or other predatory fish, until another fishery survey is conducted.

Appendix A

2007 *In-Situ* Water Quality Data

***In-Situ* Monitoring for Culver Lake 5/11/07**							
Station	**DEPTH (meters)**			**Temperature**	**Conductivity**	**Dissolved Oxygen**	**pH**
	Total	**Secchi**	**Sample**	**(^{0}C)**	**(mmhos/cm)**	**(mg/L)**	**(units)**
Mid-Lake	**14**	**2**	**Surface**	18.93	0.176	10.14	6.59
			1.0	18.2	0.175	10.24	6.78
			2.0	16.75	0.174	10.8	6.89
			3.0	15.23	0.173	11.19	6.94
			4.0	13.32	0.172	11.32	6.91
			5.0	11.74	0.172	11.38	6.86
			6.0	10.91	0.172	11.15	6.8
			7.0	9.82	0.172	11.22	6.82
			8.0	8.71	0.172	10.82	6.86
			9.0	7.79	0.172	11.09	6.93
			10.0	7.35	0.172	10.9	7.01
			11.0	6.88	0.173	10.75	7.04
			12.0	6.6	0.173	10.6	7.08
			13.0	6.36	0.176	9.44	7.11
			14.0	6.31	0.176	9.01	7.14
Stehr Tract	**1.8**	**1.8**	**Surface**	19.13	0.176	10.49	7.65
			1.0	18.04	0.175	10.43	7.61
			1.5	17.7	0.175	10.03	7.58
Causeway Cove	**1.8**	**1.8**	**Surface**	19.28	0.175	11.01	8.09
			1.0	18.71	0.175	11.16	8.16
			1.5	16.82	0.175	11.5	8.23

In-Situ Monitoring for Culver Lake 7/10/07							
Station	**DEPTH (meters)**			**Temperature**	**Conductivity**	**Dissolved Oxygen**	**pH**
	Total	**Secchi**	**Sample**	**(°C)**	**(mmhos/cm)**	**(mg/L)**	**(units)**
Mid-Lake	**13.5**	**2**	**Surface**	26.45	0.187	8.84	8.81
			1.0	25.6	0.186	8.91	8.78
			2.0	24.95	0.186	9.14	8.65
			3.0	23.92	0.185	9.19	8.17
			4.0	22.61	0.184	7.96	7.37
			5.0	20.59	0.183	5.58	6.88
			6.0	13.73	0.177	2.4	6.75
			7.0	12.82	0.177	2.01	6.57
			8.0	11.85	0.176	2.09	6.53
			9.0	11.16	0.176	2.09	6.51
			10.0	10.62	0.175	2.18	6.52
			11.0	10.11	0.176	1.92	6.52
			12.0	9.02	0.177	1.96	6.53
			13.0	7.99	0.189	1.58	6.78
			13.5	8.04	0.231	0.66	7.01
Stehr Tract	**1.8**	**1.5**	**Surface**	26.62	0.186	8.93	8.56
			1.0	24.78	0.186	9.28	8.1
			1.5	24.24	0.188	8.3	7.63
Causeway Cove	**2**	**1.6**	**Surface**	27.64	0.188	9	8.74
			1.0	25.47	0.187	9.26	8.88
			1.5	24.87	0.188	9.25	9.52

***In-Situ* Monitoring for Culver Lake 9/17/07**							
Station	**DEPTH (meters)**			**Temperature**	**Conductivity**	**Dissolved Oxygen**	**pH**
	Total	**Secchi**	**Sample**	**(^{0}C)**	**(mmhos/cm)**	**(mg/L)**	**(units)**
Mid-Lake	**14.5**	**1.9**	**Surface**	19.59	0.191	7.09	7.57
			1.0	19.56	0.19	7.12	7.59
			2.0	19.38	0.19	7.15	7.58
			3.0	19.32	0.19	7.06	7.57
			4.0	19.29	0.191	7.02	7.5
			5.0	18.55	0.189	3.8	7.54
			6.0	17.55	0.186	2.1	7.37
			7.0	16.38	0.186	1.86	7.26
			8.0	15.53	0.189	1.75	7.12
			9.0	14.35	0.19	1.8	6.96
			10.0	13.23	0.192	1.6	6.89
			11.0	12.13	0.196	1.41	6.79
			12.0	11.28	0.197	1.3	6.74
			13.0	10.35	0.209	1.3	6.61
			14.0	9.81	0.218	1.21	6.5
			14.5	9.75	0.228	<1.0	6.4
Stehr Tract	**1**	**1**	**Surface**	19.27	0.189	7.37	7.63
			0.5	18.63	0.192	7.65	7.57
			1.0	17.99	0.192	7.08	7.49
Causeway Cove	**1.5**	**1.5**	**Surface**	19.98	0.189	6.75	7.75
			1.0	18.79	0.192	7.13	7.68
			1.5	18.05	0.195	6.4	7.62

Appendix B

Discrete Laboratory Data Figures

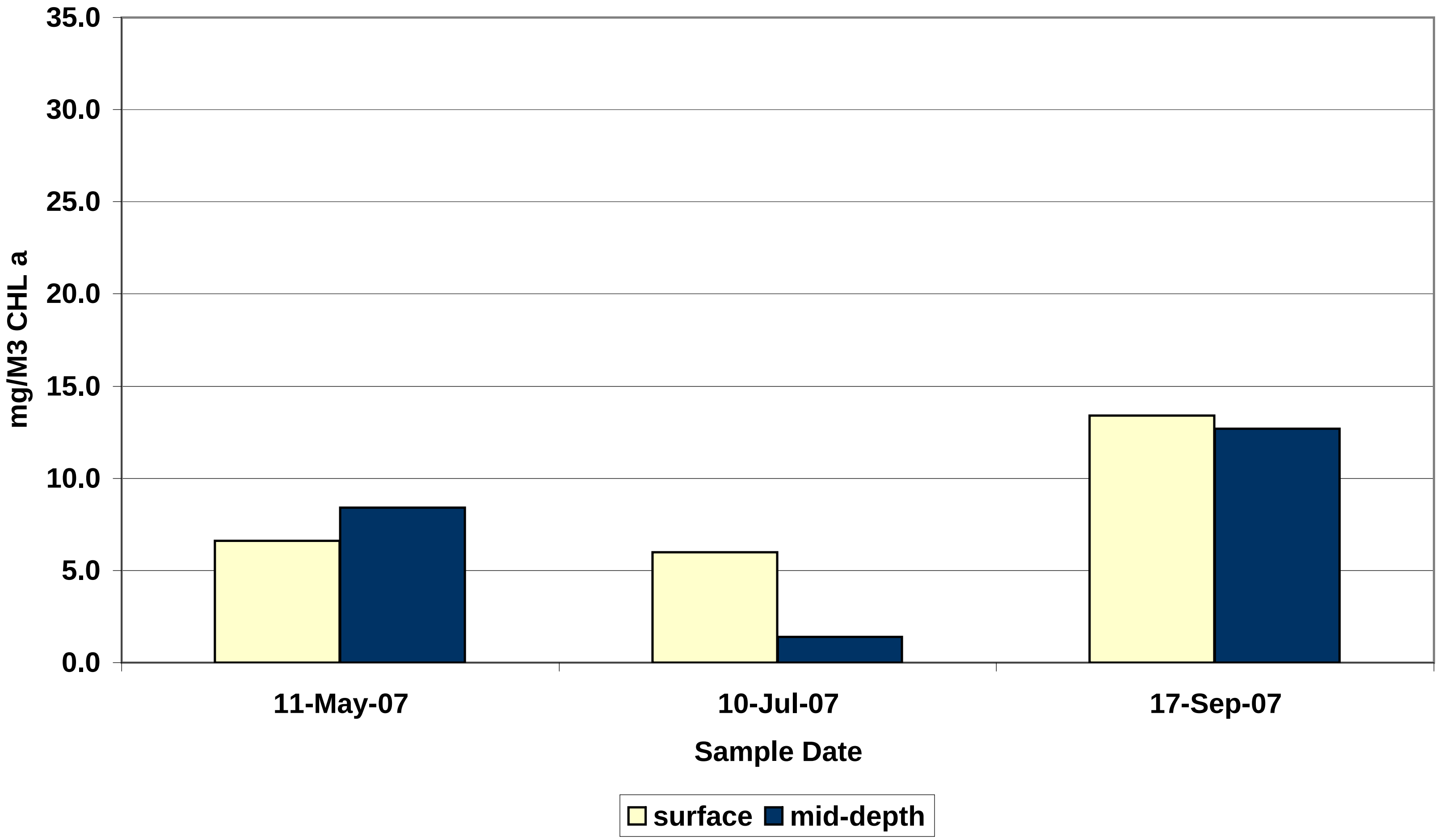

Figure 1 - Chlorophyll a concentrations at the Culver Lake mid-lake sampling station - 2007

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

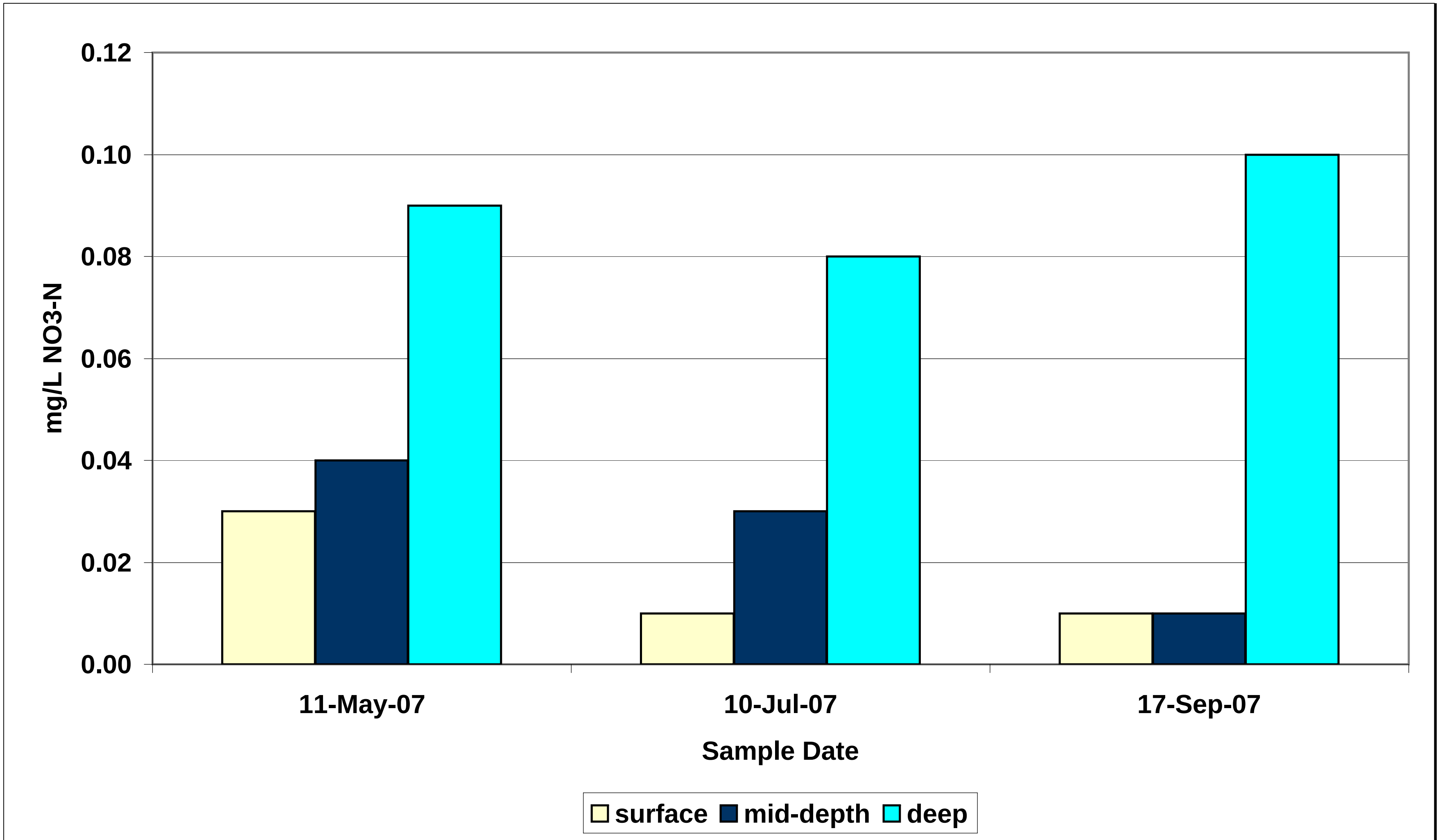

Figure 2 - Nitrate-N concentrations at the Culver Lake mid-lake sampling station - 2007

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

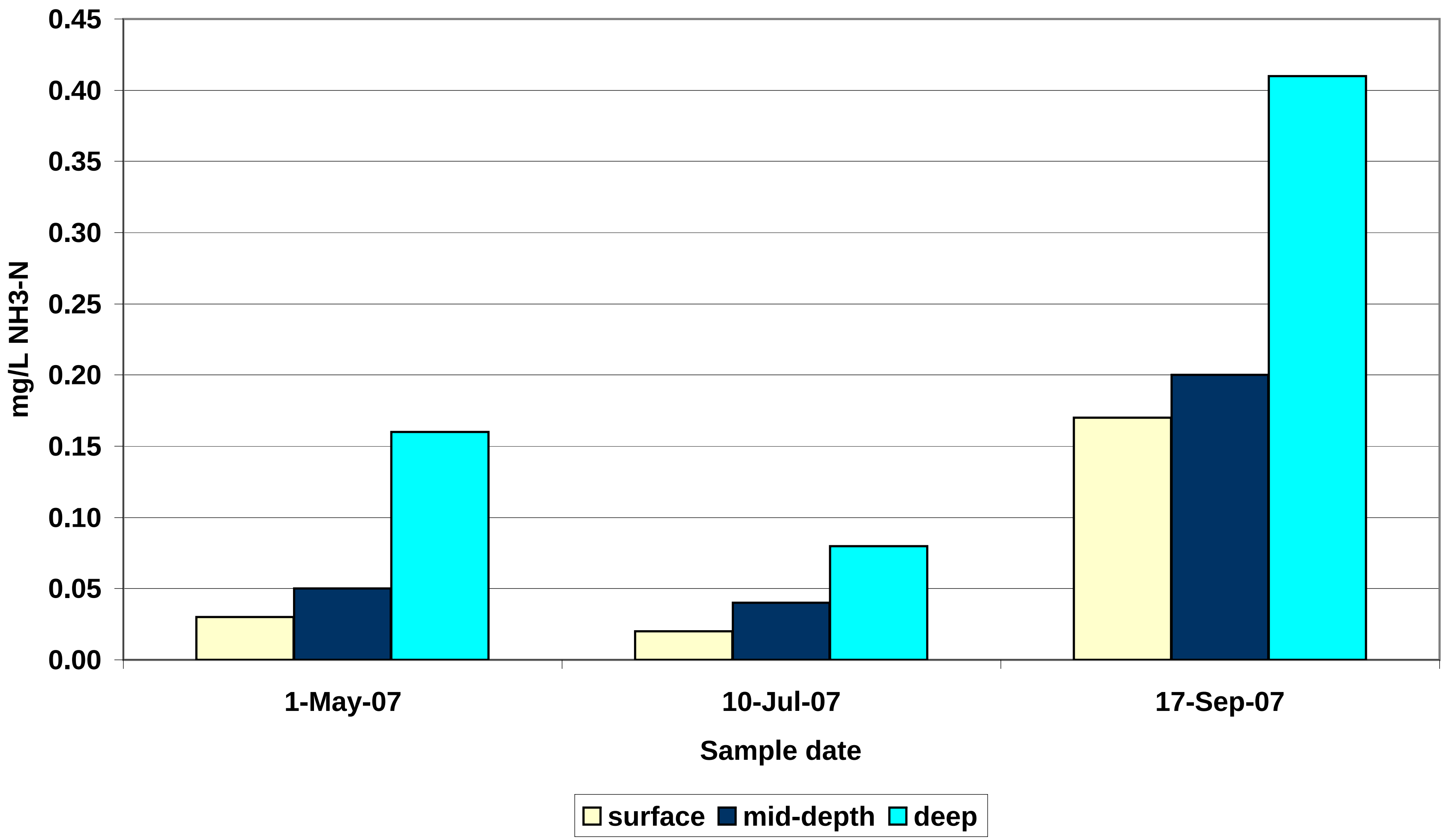

Figure 3 - Ammonia-N concentrations at the Culver Lake mid-lake sampling station - 2007

pH

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

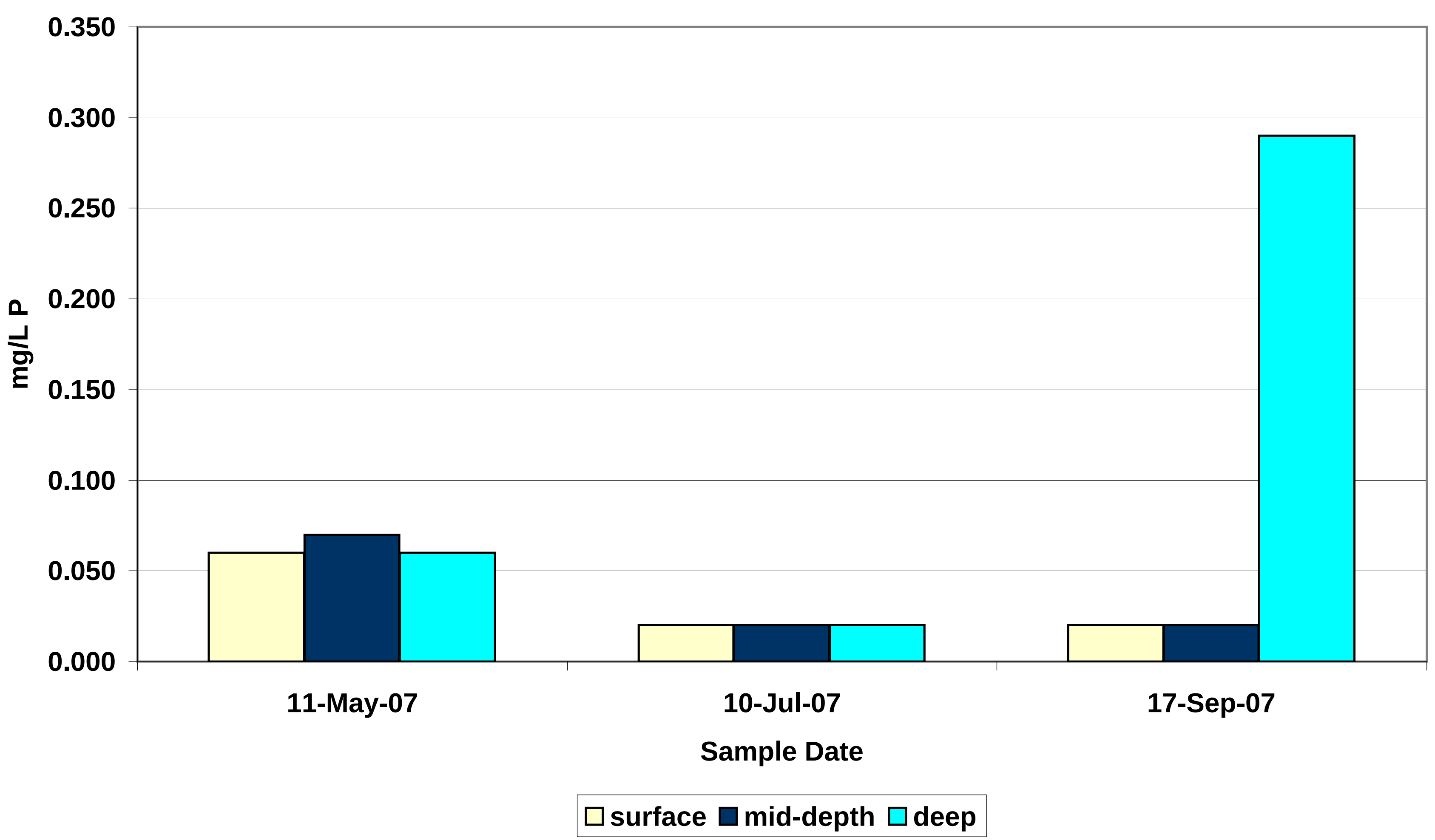

Figure 4 - Total Phosphate-P concentrations at the Culver Lake mid-lake sampling station - 2007

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

Appendix C

Discrete Laboratory Data Long Term Trend Figures

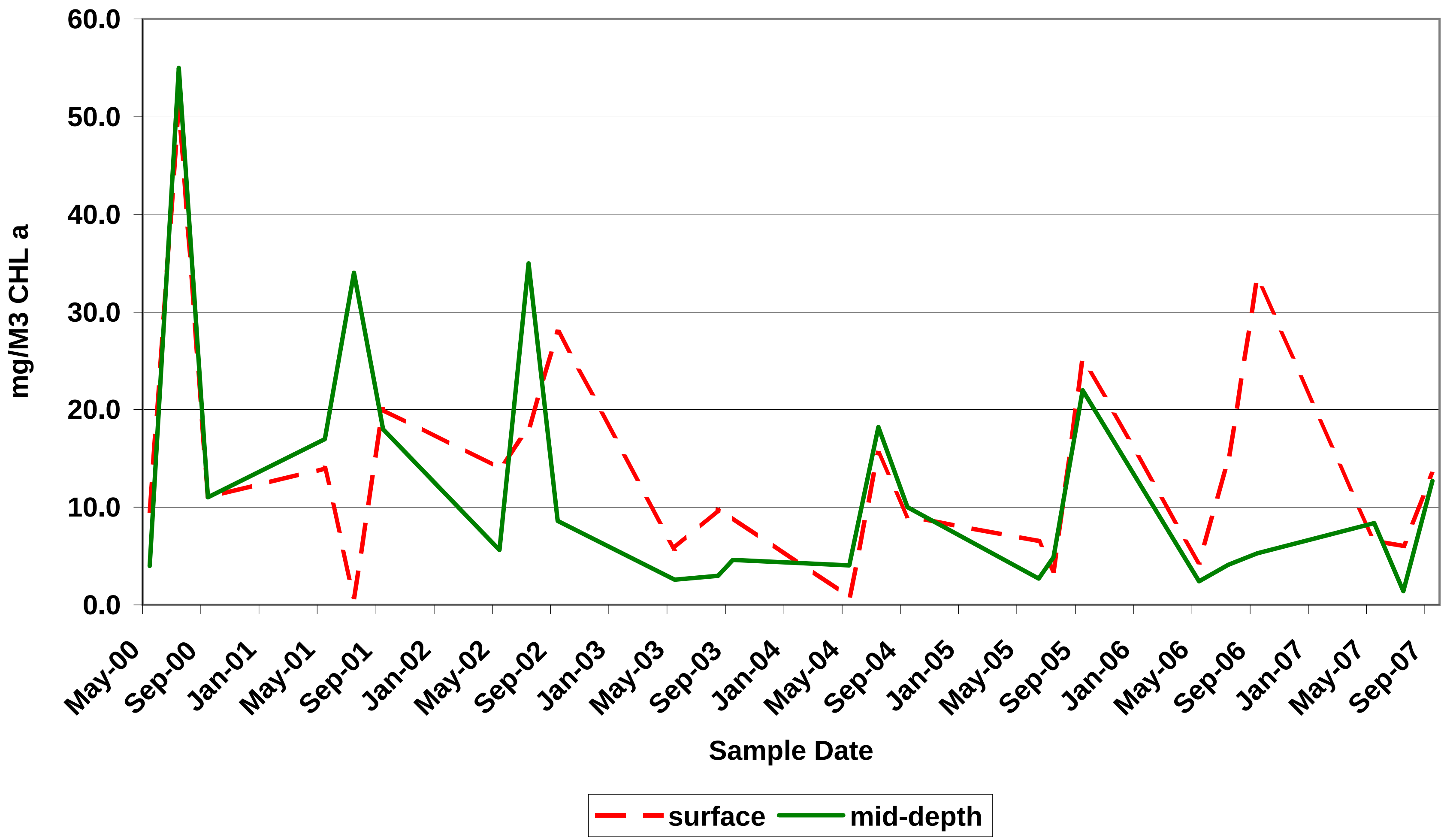

Figure 5 - Long-Term Trend of Chlorophyll a concentrations at the Culver Lake mid-lake sampling station

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

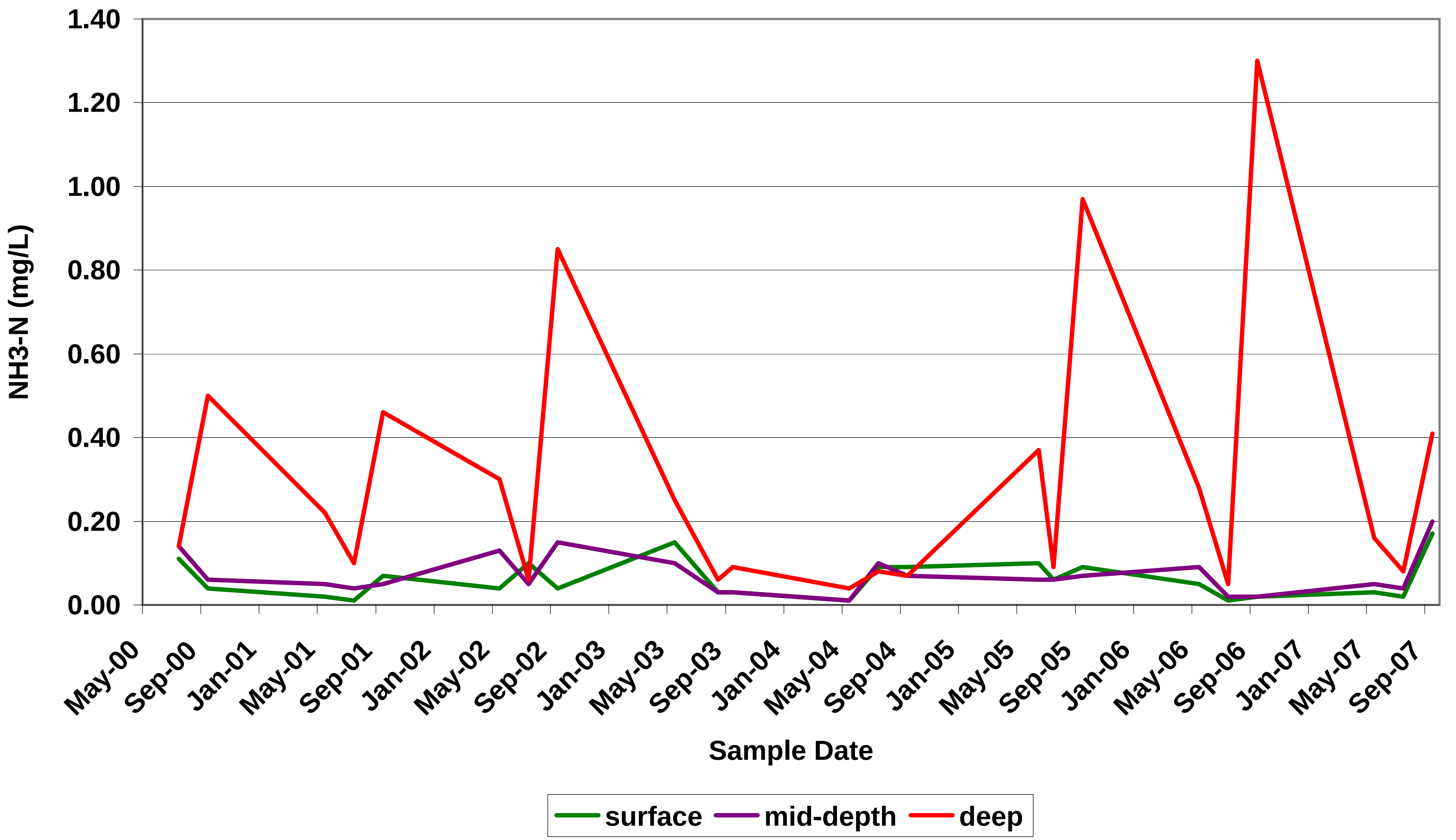

Figure 6 - long Term Trend of Ammonia-N concentrations at the Culver Lake mid-lake sampling station

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

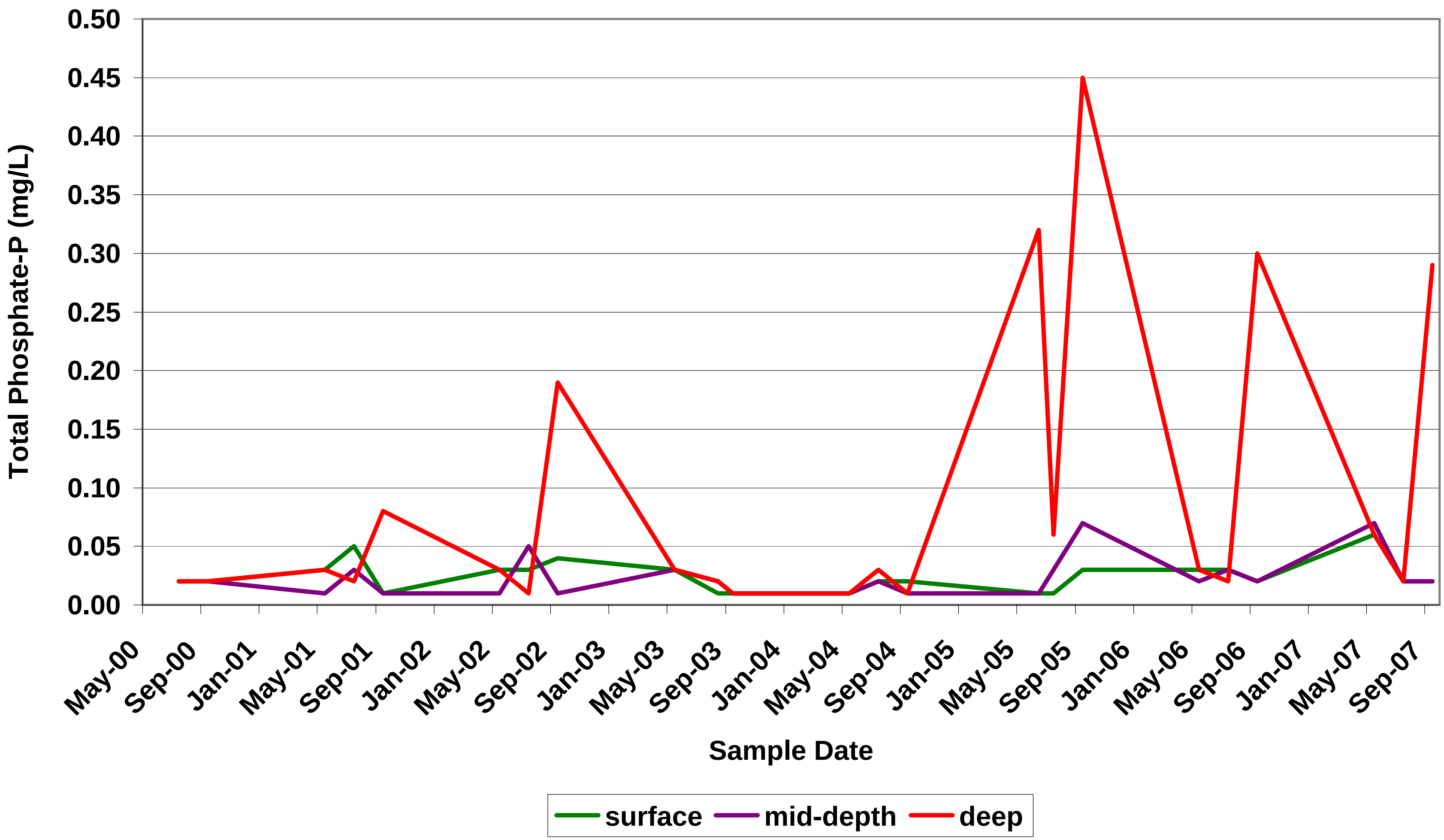

Figure 7 - Long Term Trend of Total Phosphate-P concentrations at the Culver Lake mid-lake sampling station

pH

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

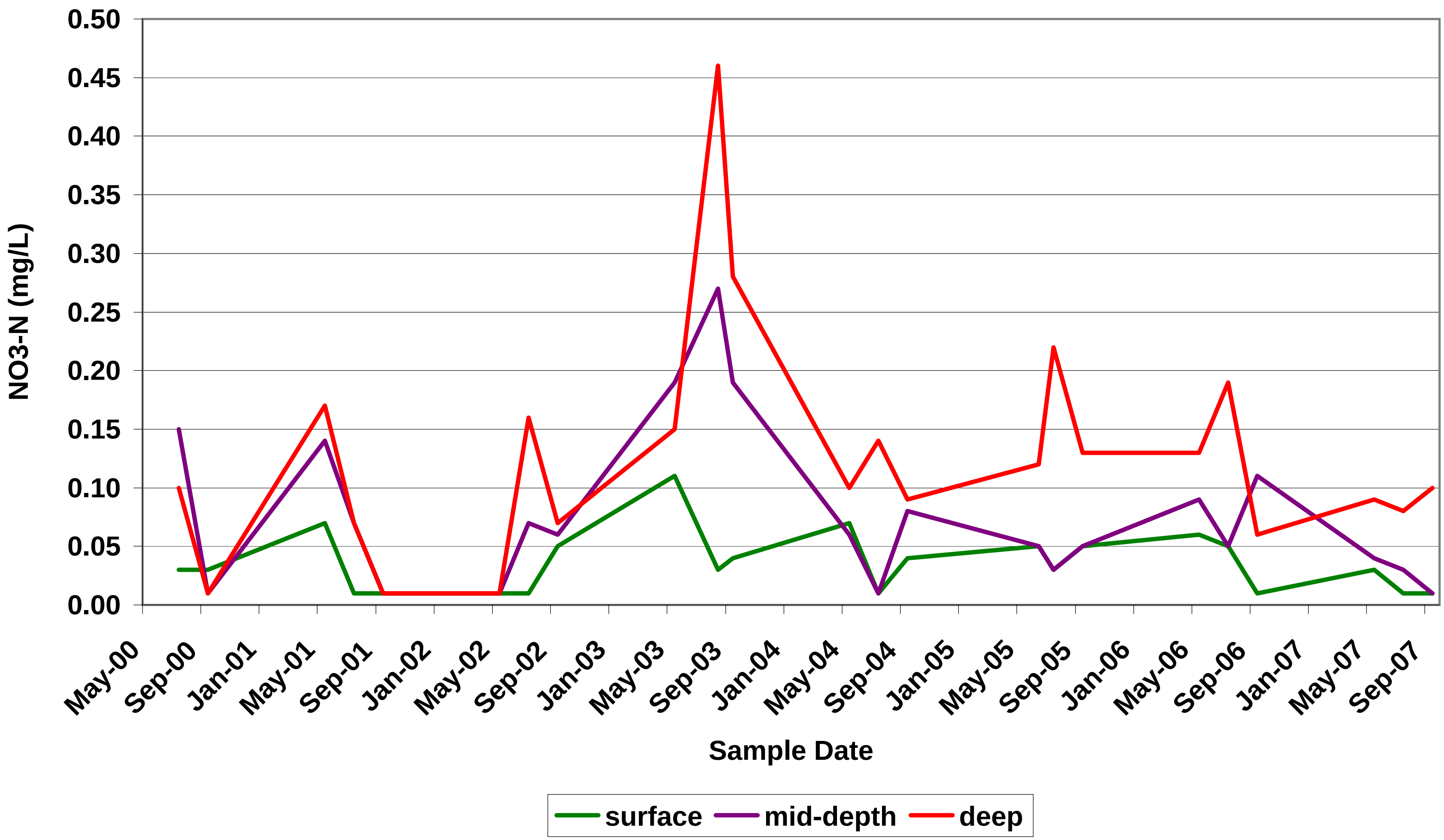

Figure 8 - Long Term Trend of Nitrate-N concentrations at the Culver Lake mid-lake sampling station

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

Appendix D

2007 and Long Term Zooplankton Population Data

Culver Lake Surface
11-May-07

Organism	Cells / ml	ug per Liter
Green Algae		
Chlamydomonas	302	31.52
Chlorella	181	143.61
Micractinium	484	50.43
Oocystis	484	67.24
Scenedesmus	484	22.69
Oedogonium	302	453.56
Total	**2238**	**769.05**
Chrysophyta		
Dinobryon	1270	446.80
Ochromonas	423	91.93
Total	**1693**	**538.73**
Cryptophyta		
Rhodomonas	181	35.49
Blue-green Algae		
Pseudoanabaena	605	141.84
Total	**4717**	**1485.11**

Culver Lake

Mid-depth

11-May-07

Organism	Cells / ml	ug per Liter
Green Algae		
Chlamydomonas	164	17.10
Gonium	328	34.21
Micractinium	205	21.38
Oocystis	492	68.41
Gloeocystis	123	68.41
Total	**1313**	**209.51**
Chrysophyta		
Dinobryon	1025	360.77
Chrysosphaera	82	17.82
Total	**1107**	**378.58**
Cryptophyta		
Cryptomonas	82	79.36
Rhodomonas	41	8.02
Total	**123**	**87.38**
Total	**2543**	**675.47**

Culver Lake Surface Waters
10-Jul-07

Organism	Cells / ml	ug per Liter
Green Algae		
Chlamydomonas	1738	181.15
Chlorella	28	21.84
Closterium	28	2.93
Xanthidium	28	11.03
Scenedesmus	276	12.93
Gloeocystis	221	122.69
Quadrigula	110	18.39
Total	**2427**	**370.97**
Chrysophyta		
Chromulina	690	161.75
Dinoflagellates		
Peridinium	28	82.19
Blue-green Algae		
Pseudoanabaena	690	161.75
Anabaena	662	1578.08
Chroococcus	110	263.01
Total	**1462**	**2002.85**
Total	**4607**	**2617.75**

Culver Lake
Mid-depth

10-Jul-07

Organism	Cells / ml	ug per Liter
Green Algae		
Chlamydomonas	51	5.32
Chrysophyta		
Synura	821	798.78
Mallomonas	17	42.13
Chromulina	17	3.99
Total	**855**	**844.90**
Diatoms		
Melosira	17	31.15
Stephanodiscus	17	93.44
Total	**34**	**124.59**
Dinoflagellates		
Ceratium	34	306.00
Total	**974**	**1280.81**

Culver Lake - Surface Waters
17-Sep-07

Organism	**Cells / ml**	**ug per Liter**
Green Algae		
Crucigenia	85	0.014
Cosmarium	592	0.171
Selenastrum	85	0.002
Chlorella	338	0.268
Chlamydomonas	507	0.053
Scenedesmus	338	0.016
Total	**1945**	**0.524**
Chrysophyta		
Mallamonas	254	0.629
Total	**254**	**0.629**
Dinoflagellate		
Peridinium	85	0.503
Total	**85**	**0.503**
Blue-green Algae		
Anabaena	10482	24.986
Psuedoanabaena	10144	0.497
Aphanizomenon	9637	0.564
Coelosphaerium	15216	16.919
Total	**45479**	**42.966**
Cryptophyta		
Rhodomonas	254	0.049
Cryptomonas	507	0.491
Total	**761**	**0.540**
Diatom		
Fragilaria	85	0.338
Total	**85**	**0.338**
Total	**48609**	**46**

Culver Lake - MidDepth
17-Sep-07

Organism	Cells / ml	ug per Liter
Green Algae		
Gloeocystis	2744	1.526
Cosmarium	445	0.129
Tetraedron	148	0.030
Chlorella	668	0.528
Asterococcus	148	0.148
Total	**4153**	**2.361**
Chrysophyta		
Mallamonas	223	0.551
Total	**223**	**0.551**
Blue-green Algae		
Anabaena	28777	68.594
Aphanocapsa	2225	0.158
Aphanizomenon	1113	0.065
Total	**32115**	**68.817**
Cryptophyta		
Rhodomonas	74	0.015
Cryptomonas	74	0.072
Total	**148**	**0.086**
Diatom		
Cyclotella	74	0.034
Total	**74**	**0.034**
Total	**36713.000**	**71.849**

Culver Lake
Surface
Zooplankton

11-May-07

Cladocerans	Number per Liter	ug / L
Ceriodaphnia	20	4.7
Bosmina	280	282.7
Total	**300**	**287.4**
Copepods		
Cyclops	10	2.0
nauplii	50	39.1
Total	**60**	**41.1**
Rotifers		
Keratella cochlearis	550	18.3
Kellicottia	300	30.0
Asplanchna	7	9.3
Total	**857**	**57.6**
Total	**1217**	**386.1**

Culver Lake
Mid-depth
Zooplankton

11-May-07

Cladocerans	Number per Liter	ug / L
Bosmina	100	101.0
Copepods		
Cyclops	100	20.3
Mesocyclops	10	21.7
nauplii	150	117.2
Total	**260**	**159.2**
Rotifers		
Keratella cochlearis	400	13.3
Kellicottia	230	23.0
Asplanchna	20	26.7
Total	**650**	**63.0**
Total	**1010**	**323.14**

Culver Lake
Surface
Zooplankton

10-Jul-07

Cladocerans	Number per Liter	ug / L
Chydorus	11	8.0
Copepods		
Cyclops	33	6.7
nauplii	87	68.0
Total	**120**	**74.7**
Rotifers		
Keratella cochlearis	513	17.1
Polyarthra	76	73.6
Trichocerca pilla	22	16.5
Total	**611**	**107.2**
Total	**742**	**189.9**

Culver Lake
Mid-depth
Zooplankton

10-Jul-07

Cladocerans	Number per Liter	ug / L
Daphnia	6	13.3
Diaphniosoma	6	26.0
Ceriodaphnia	19	13.6
Chydorus	13	9.4
Total	**44**	**62.3**
Copepods		
Cyclops	38	7.7
Diaptomus	19	73.8
nauplii	32	25.0
Total	**89**	**106.5**
Rotifers		
Keratella cochlearis	152	5.1
Trichocerca pilla	6	2.5
Polyarthra	5	4.8
Total	**163**	**12.4**
Total	**296**	**168.8**

Culver Lake
Surface
Zooplankton

17-Sep-07

Cladocerans	Number per Liter	ug / L
Bosmina	31	31.3
Total	**31**	**31.3**
Copepods		
Cyclops	21	4.2
nauplii	72	56.5
Total	**93**	**60.7**
Total	**124**	**92.0**

Culver Lake
Mid-Depth
Zooplankton

17-Sep-07

Cladocerans	Number per Liter	ug / L
Bosmina	73	73.7
Total	**73**	**73.7**
Copepods		
Diaptomus	73	123.8
Cyclops	85	17.3
nauplii	85	66.5
Total	**243**	**207.6**
Rotifers		
Trichocerca	61	20.2
Total	**61**	**20.2**
Total	**377**	**301.5**