Prepared For:

TOWN OF EAST HAMPTON, CONNECTICUT

LAKE POCOTOPAUG LAKE AND WATERSHED RESTORATION EVALUATION EAST HAMPTON, CONNECTICUT

Prepared By:

ENSR INTERNATIONAL

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LAKE POCOTOPAUG
LAKE AND WATERSHED
RESTORATION EVALUATION

Prepared for:

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LAYPERSON'S SYNOPSIS

Lake Pocotopaug covers 512 acres in East Hampton, CT. Its watershed is less than five times as large as the lake. As a consequence, limited water is delivered to the lake and the lake is flushed relatively infrequently. This means that pollutants entering the lake stay there a long time and can have the maximum impact on lake condition. Although the watershed is mostly forest, areas that have been developed as residential and recreational areas are mostly near the lake and have negative impacts on the lake by adding nutrients, bacteria and other pollutants. Over the long term, these inputs have caused a build up of contaminants in the lake that support algal blooms and low water clarity. The alum treatment of 2000-2001 inactivated these contaminants over the most critical part of the lake, but inputs associated with bigger rain events and possibly recycling of contaminants in untreated parts of the lake can still support algal blooms and low water clarity. Additional watershed management is therefore needed.

An unusual aspect of the Lake Pocotopaug system is that it supports algal blooms at a relatively low fertility level. This means that management that might be adequate at other area lakes may not eliminate undesirable conditions in Lake Pocotopaug. Watershed management must therefore be especially effective in reducing pollutant inputs to achieve the desired results. A variety of options have been reviewed, including minimizing sources of contaminants and trapping contaminants as they move toward the lake. Sources of major concern include lawn care products; education and possible local ordinances are recommended to reduce their use in this watershed. Methods to trap contaminants include systems that detain storm water, with passage into the ground wherever possible. Natural processes will reduce the amount of pollutants reaching the lake through such systems.

Adding predatory fish (such as walleye) to the lake may also improve conditions, as these fish eat smaller fish that eat small invertebrates that eat algae. In other words, by increasing the biomass of predatory fish, grazing pressure on algae can be increased and less algae will build up in the lake. This strategy may not be sufficient by itself, but can supplement a strong watershed management program that reduces overall fertility in the lake.

Some additional monitoring in the lake and watershed is needed to address some unanswered questions and to track progress. This is a complicated system with no easy solution to existing problems, but Town actions to date are moving the lake in the right direction, and careful continued management is expected to continue and expand this improvement.

1.0 EXECUTIVE SUMMARY

Lake Pocotopaug has a surface area of approximately 512 acres and is a major resource for recreation and aquatic life in East Hampton. The watershed is small relative to the size of the lake (<5:1 watershed:lake area ratio). The land use within the watershed is mostly forested area. However, near-shore land use is heavily developed. Soils within the watershed consist mainly of glacial till that is well drained.

Although the watershed area is small, the majority of lake water comes from surface runoff from the watershed. The lake flushes a little more than once per year. In-lake water quality is therefore highly dependent on the quality of surface water runoff from the watershed. The highly developed area surrounding the lake contributes to poor water clarity, which has been documented since 1974. Lake Pocotopaug suffers from severe algal blooms and high sediment loading that reduces water clarity. A fishkill in 1999 prompted accelerated activity toward lake improvement.

Poor water clarity is likely the result of a combination of algal density and non-algal turbidity. Lake Pocotopaug is unusual in that it suffers from algal blooms even though total surface phosphorus concentrations are fairly low. Reducing watershed phosphorus load by 60%, the maximum probable percentage achievable, may not prevent algal blooms in this lake, although other lakes in this region cannot typically support high algal densities at this low concentration. Reducing the phosphorus input to Lake Pocotopaug will decrease the probability of blooms, reducing their frequency and/or severity, so such management is still advised.

Internal recycling has been reduced through the application of alum, but future treatment may still be necessary. Non-algal turbidity is likely the result of inadequate watershed management practices resulting in heavy sediment loading and internal resuspension of lake sediment in the shallow basin to the south. Sediment inputs should be controllable. The “Storm Water Renovation and Management Plan for Lake Pocotopaug” prepared by WMC in 1995 outlines many techniques for sediment input reduction. Techniques for controlling internal resuspension of sediment are expensive on a large scale. A more cost effective but highly experimental approach would be an alum treatment of the southern area. This treatment may both congeal the sediments to limit resuspension and inactivate any phosphorus that does get entrained in the water column.

Lake Pocotopaug has a large panfish population, which may be contributing to low zooplankton densities and individual size. Increasing piscivore (fish eating fish) populations could improve zooplankton populations and thereby increase grazing on phytoplankton. This “top-down” control is a form of biomanipulation in which biological components of an aquatic system are altered to create a cascading effect within the food web that results in increased water clarity.

The stocking of walleye in Lake Pocotopaug could have the desired effect. Realistically, it may take 3-5 years for an observable effect to become manifest, but this is an approach that virtually all groups can support.

The cause of the fishkill that occurred in late 1999 and early 2000 remains a mystery. No toxic algae have been encountered during the time when perch school in the tributaries, and algal densities at that time (December-January) have not been especially high anyway. Contact with over 30 fishery professionals has not revealed a similar situation elsewhere. While many plausible explanations for the schooling and fishkill have been offered, no proof has yet been documented.

Active management of Lake Pocotopaug and its watershed should continue, but certain aspects of this system deserve further study to allow the most effective management program to be implemented and to answer questions that remain from work done to date. Future investigations should focus on:

- watershed wet and dry weather sampling,
- determination of the total phosphorus concentration that limits algal growth in Lake Pocotopaug,
- investigating the effect of internal resuspension of lake sediment
- fish assays to determine if there are toxicity effects on fish resulting in observed schooling behavior and death.

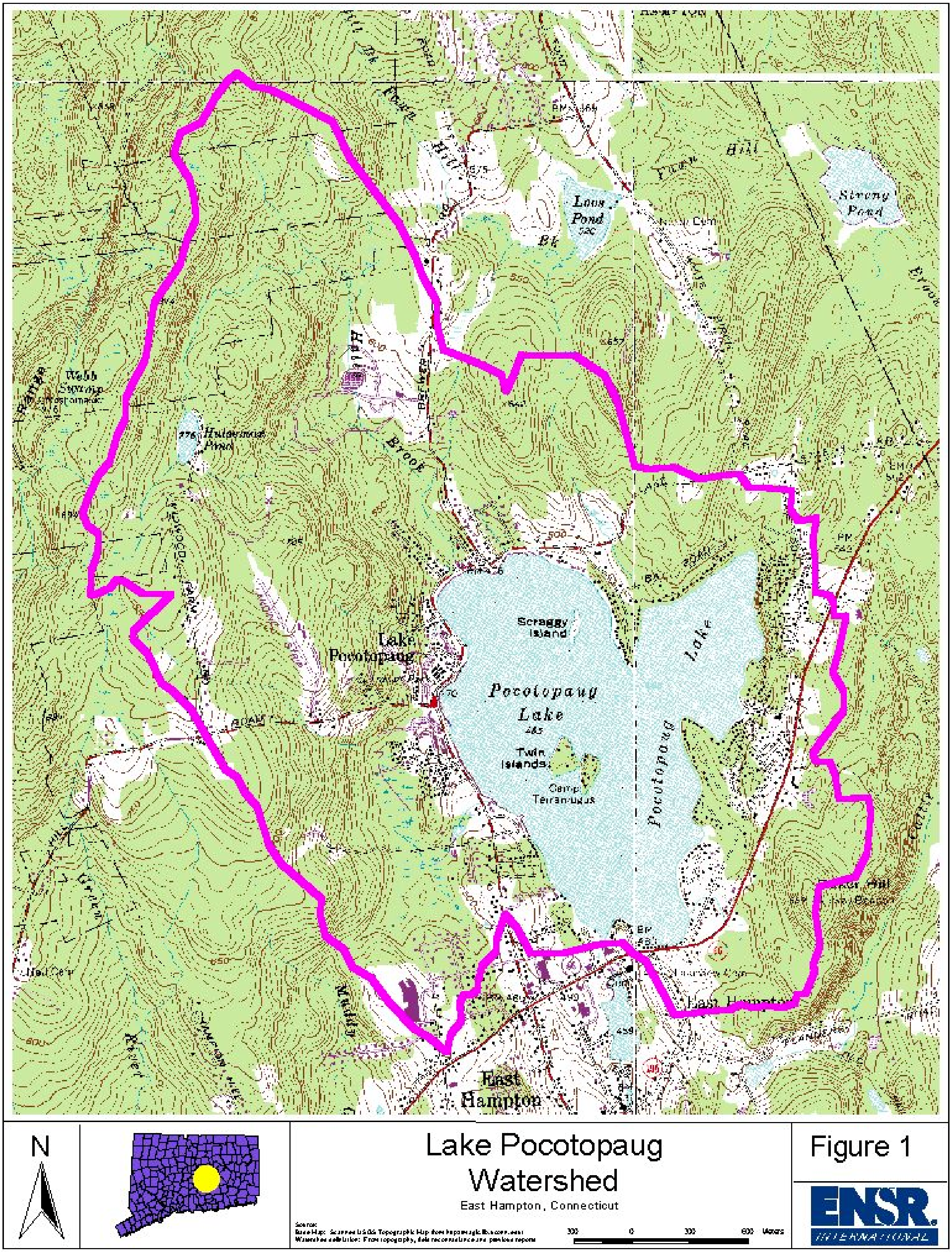
2.0 INTRODUCTION

Lake Pocotopaug is located in the Town of East Hampton, Connecticut (Figure 1). It is the largest freshwater lake in the State of Connecticut (511.7 acres) and serves as a major resource for boating, fishing and swimming.

Lake Pocotopaug, meaning “clear water”, was named by the Wagunk during mid 1600’s (Dynia 1999, Umba 2000). The lake and surrounding land was sold to early colonist. Industry was prevalent by mid 1700’s. Industry included iron forging, bell making, and sawmilling. Lake Pocotopaug became a popular tourist destination by the 1870’s. Tourism increased with road improvements and railroad construction. Permanent residents became widespread by mid 1900’s. Today the lakeshore area is highly developed. However, much of the 2,381-acre watershed remains as wooded area (65 – 77%, Ad Hoc 1995 and CT DEP 1994).

The lake has suffered from reduced water clarity associated with severe algal blooms and non-algal turbidity. Poor water clarity has been document since 1974 (Frink and Norvell 1984). A group of concerned citizens formed a Lake Study Group to investigate the water quality problems of Lake Pocotopaug after a severe algal bloom in 1990. Several studies conducted by the Volunteer Lake Study Group (VLSG), Town of East Hampton Ad Hoc Lake Advisory Committee (AHLAC), and an Environmental Consulting firm (Fugro-McClelland – now ENSR) have followed. The lake also experiences a strange phenomenon in which fish school in the two major tributaries during the winter shortly after ice formation on the lake. The lake has experienced fish kills in the past. A chronology of events is provided in the next section to summarize previous investigations and major events relating to Lake Pocotopaug.

The Town of East Hampton contracted ENSR International (ENSR) for a Lake and Watershed Restoration Evaluation. The restoration evaluation is a yearlong lake and watershed sampling program and management alternative investigation in an effort to increase lake water clarity and to help determine the cause of fish kills. The Lake and Watershed Restoration Evaluation began in spring of 2001, with in-lake water sampling concluding in December 2001. Results of the monthly water sampling and restoration evaluation are the subject of this document.



Lake Pocotopaug Watershed

East Hampton, Connecticut

Figure 1

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3.0 BACKGROUND INFORMATION

3.1 Previous Studies and Major Event Chronology

The Town of East Hampton and the Volunteer Lake Study Group provided copies of previous reports. Scientific information and major events relating to Lake Pocotopaug presented in those reports are summarized here. All publications are listed in the Reference section of this report. Readers are encouraged to obtain original documents for further details, as only short summaries are provided below. Raw data from select previous reports are summarized for comparison purposes throughout the document.

Publication: Frink and Norvell (1984)

Period Covered: 1973 – 1974 & 1979 – 1980

Lake Pocotopaug chemical and physical properties were documented as part of an assessment of the fertility of 23 Connecticut Lakes. Results of these and 47 other lakes were used to develop a predictive model based on land use. The model predicts future conditions based on land use changes. Frink and Norvell classified Lake Pocotopaug as mesotrophic. Mean values for total phosphorus (TP), total nitrogen (TN), chlorophyll a, and Secchi disk transparency (SDT) are provided in Table 1. This information was not used in subsequent section of this.

Table 1. Mean Lake Pocotopaug Water Quality in 1973, 1974, 1979 and 1980.

	1973 -1974	1979-1980*
TP (ug/L)	21	25
TN (ug/L)	420	420
Chl a (ug/L)	4	7
SDT (m)	3.6	3.6

*Summer values only

Publication: Fugro-McClelland (1993)

Period Covered 1977

- A "mild" bloom of *Anabaena* and *Aphanocapsa* occurred in June 1977.
- The bloom coincided with a fish kill of approximately 50 small yellow perch.

Period Covered 1987

- Pollution from the Baker Hill sub-division was documented (15 ac. cleared for development)
- East Hampton Board of Selectman established Lake Area Task Force to investigate the pollution report

<u>Period Covered 1988</u>

- Pollution from the sub-division continued, although an abatement order was issued
- A reported "oil slick" on the lake was determined to be a diatom bloom of *Asterionella* and *Tabellaria*

<u>Period Covered 1989</u>

- Pollution from Baker Hill sub-division continued to be documented

<u>Period Covered 1990</u>

- A severe algal bloom occurred in late summer and fall (SDT <1 m on 9/28/90)
- CT DEP and CT Department of Health Services (CT DHS) Lab identified *Anabaena* as dominant alga in September.

<u>Period Covered 1991-1992</u>

- VLSG documented monthly nutrient concentrations, turbidity, and SDTs. A summary of these findings are documented in the Diagnostic and Management Study (Fugro 1993) and are provided in Table 2.
-

Table 2. Median Lake Pocotopaug Water Quality in 1973, 1974, 1979 and 1980.

	1991 and 1992 Median	
	East Basin	**West Basin**
TP (ug/L)	18.5	18
Ammonium-N (ug/L)	47	49.5
Nitrate-N (ug/L)	20	20
Organic-N (ug/L)	84.5	77
Turbidity (NTU)	2.3	2.1
SDT (m)	1.8	1.6

- Phytoplankton data concluded
  - *Staurastrum*, *Tabellaria*, and *Dinobryon* were dominant in April 1991.
  - A severe algal bloom occurred in September/October 1991 (minimum SDT 0.6 m on 9/21/91).
  - *Mougeotia*, *Zygnema*, and *Staurastrum* were identified in May 1992.
  - *Anabaena*, *Asterionella*, and three genera of filamentous green algae were identified in June 1992.
  - A severe bloom occurred from mid-July through mid-September 1992 (minimum SDT 0.45 m on 8/15/92).
  - *Anabaena* was the dominant alga in July and August 1992. *Zygnema* was also identified in July.
  - *Scenedesmus* and *Zygnema* were identified in October 1992.

Period Covered 1992-1993

Fugro-McClelland, Inc (Fugro) prepared a Diagnostic and Management Study (D/M) for Lake Pocotopaug. The results of seven sampling events from December 1992 until September 1993 were summarized, and management recommendations were provided.

The report compared 1992-1993 sampling results to previous studies. Water clarity was greater in 1993 in comparison to 1991-1992. An algal bloom in July did not occur. However, an algal bloom did occur in September. Dominant algae were *Staurastrum* and *Anabaena*. It was hypothesized that September blooms were the result of increase phosphorus released from the sediment during periods of anoxia. Differences in mean phosphorus concentrations from 1993 to 1991-1992 could not be made due to a questionable laboratory measurement reported in 1993. Median surface values for ammonium nitrogen and nitrate nitrogen were comparable to 1991-1992 values. Median surface organic nitrogen concentrations were higher in 1992-1993 than in 1991-1992. Median SDT was lower in 1991-1992. Median turbidity values were higher in 1991-1992 than in 1992-1993. A hydrologic budget was prepared and is provided in Table 3.

A phosphorus loading analysis was performed based previous values presented in an unpublished work titled "Land Use and Phosphorus Input to Lake Pocotopaug" by the AHLAC, Land Use Subcommittee. This report was later published in 1995. Results from the Fugro analysis are provided below.

Areal Phosphorus Loading Includes watershed, waterfowl, and atmosphere	1263 lbs/yr (0.277 g/m^2 yr)	53% of total
Internal Loading	1099 lbs/yr (0.518 g/m^2 yr)	47% of total

Table 3. Diagnostic and Management Study Hydrologic Budget (Adapted from Fugro 1993).

Inputs	
a) Watershed runoff	6.63×10^6 m^3
b) Direct Precipitation	2.489×10^6 m^3
Losses	
a) Outlet	7.647×10^6 m^3
b) Evaporation	1.472×10^6 m^3
Residence Time	0.78 years
Flushing Rate	1.3 volumes/year

(Assumed no negligible inputs or losses of groundwater and no change in storage volume)

Information from this study was used for portions of the ENSR phosphorus loading analysis.

Recommendations included

- Algacide treatment for short-term relief
- Phosphorus inactivation treatment of alum (aluminum sulfate)
- Aeration
- Biomanipulation to supplement other techniques
- Watershed Management – specifically altering the small pool in Hales Brook to function as a sediment basin and follow through with the recommendations set forth by the Land Use Subcommittee of the Lake Advisory Committee. The AHLAC document was still in preparation at the time of the Diagnostic and Management Study completion.

Publication: WMC Consulting Engineers (1995)

Period Covered 1995

A Stormwater Renovation and Management Study was conducted to

- Document existing conditions of the stormwater drainage system around Lake Pocotopaug,
- Review current regulations and ordinances, and
- Recommend improvements and control measures to reduce sediment, nutrient and pollutant loading.

The Stormwater Renovation and Management Study provides an inventory of the existing drainage systems and a list of areas requiring improvement. ENSR agrees with their recommendation although the recommendations are focused more on sediment removal and flood control than phosphorus. The same principles for sediment removal, however, often apply to phosphorus reduction. Specific recommendations regarding phosphorus removal are provided in Section 11 of this report.

Publication: Ad Hoc Lake Advisory Committee (1995)

Period Covered –multiple years (phosphorus data from 1991-1992, zoning data from 1989, etc.)

Three reports were published in 1995 by the Ad Hoc Lake Advisory Committee

1. Land Use and Phosphorus Input to Lake Pocotopaug
2. Taxes and Water Quality
3. Lake Pocotopaug Management Recommendations

Land Use and Phosphorus Input to Lake Pocotopaug

The land use and phosphorus report:

- uses simple phosphorus loading and transparency models to demonstrate anthropogenic impacts to the lake,
- uses the models to predict trends in relation to changing land use, and
- suggests land use changes to reduce watershed impacts to the lake

The estimated phosphorus loading was as follows:

61% from the watershed (791 lbs/yr)
35% from the atmosphere (455 lbs/yr)
4 % from waterfowl (43 lbs/yr)

The phosphorus export value predicted for the future was 1,817 lbs/yr, resulting in a spring in-lake mean TP concentration of 31 ug/L. Predicted water transparency was 0.6 meters. Values in this report were used in ENSR calculations and for comparison purposes.

Taxes and Water Quality

The "Taxes and Water Quality" report pointed out that taxpayers with large quantities of undeveloped land (> 15 ac) were paying substantially more (72% more) in taxes than prior to 1991. The concern is that this increase would promote the development of open space land. Potential future development will substantially increase phosphorus loading to Lake Pocotopaug. An assessment of the applicability of the Open Space Provision of the Public Act 490 was made. The Open Space Provision, which is an optional component of the Public Act 490, would provide tax relief to open space landowners as defined in a the planning commissions "Plan of Development". Modification of the current "Plan of Development" to include additional open space in Lake Pocotopaug's watershed to be eligible for tax relief was recommended by the AHLAC, with hopes that this would discourage the development of open space.

Lake Pocotopaug Management Recommendations

The Lake Pocotopaug Management Recommendation report was prepared to "1), reduce current inputs of eutrophication causing material to the lake, and 2), minimize future increases from future land use changes in the lake basin." Three basic recommendations were outlined:

1. Develop a Lake Advisory Committee devoted to develop and implement water quality improvement programs,
2. Reduce nutrient and sediment inputs from the watershed through best management practices and reduce internal nutrient recycling, and
3. Develop and implement land use controls to reduce nutrient and sediment inputs

Each of these recommendations was described in detail within the report. ENSR agrees with their recommendations.

Major Event

December 1999 – Fish kill

The cause of the kill is unknown. Several species of all sizes were affected. There was speculation of Haptophytes causing the kill, but phytoplankton counts did not reveal a population of Haptophytes large enough to result in fish death. Water samples from tributaries and within in the lake did not reveal the presence of toxic chemicals. Dead fish were collected and analyzed by the University of Connecticut (UCONN) and the United States Fish and Wildlife Survey. Toxicity results were non-conclusive.

Major Event

June 2000 – Alum Treatment/Fish Kill

Alum and sodium aluminate was applied to 22 acres beginning on June 2, 2000 to reduce the internal loading of phosphorus. Monitoring results indicated that pH and alkalinity values remained stable throughout the treatment and no stressed or dead fish were observed.

A significant number of dead perch were observed the following day. Water testing results indicated that pH and alkalinity levels were within desirable ranges. Analysis of the dead fish by the CT DEP and UCONN revealed elevated levels of aluminum in the fish gills.

Publication: ENSR (2001)

Period Covered 2000-2001

An analysis of the phosphorus inactivation issues at Lake Pocotopaug was performed by ENSR which included:

- An evaluation the alum treatment performed in June 2000,
- Fish bioassay with aluminum sulfate and sodium aluminate, and
- An evaluation of targeted aluminum dose

The laboratory fish bioassay was used to determine the acute impact of alum/aluminate ratios on fathead minnows (*Pimephales promulus*). Results suggested that fish mortality was likely due to aluminum toxicity, specifically from sodium aluminate. A 2:1 ratio of alum : sodium aluminate was suggested for future treatments, reducing the potential for aluminum toxicity in Lake Pocotopaug. The evaluation report is provided in Appendix A.

Major Event

June 2001 – Alum Treatment

The treatment of 150 acres occurred in June 2001 using the suggested 2:1 alum:sodium aluminate ratio and ½ the rate used in 2000. No stressed or dead fish were observed during or shortly after the alum treatment. Lake users reported clearer water up until August when an algal bloom occurred.

Major Event

January 2002– Fish Schooling

Fish, specifically white and yellow perch, were observed in large numbers (several thousand) in the two major tributaries (Christopher and Hales Brook) of Lake Pocotopaug. The fish were observed in tributaries shortly after ice had formed on the lake. Fish did not appear to be stressed (breathing rate appeared normal, no lesions or spots, etc). Fish were not collected for analysis. However water samples were taken from the lake and used in a biological assay. The assay involved toxicity testing with fathead minnows in Lake Pocotopaug water sampled on January 3, 2002. All fish exhibited normal behavior within the 48-hour test period. No fatalities were recorded. Water samples revealed ample oxygen (10.1 mg/L) and normal pH (6.8 SU).

Publication: Volunteer Lake Study Group (1992-2001)

The VLSG group has been sampling Lake Pocotopaug annually since 1991 and providing reports to the AHLAC. Raw data were used for comparisons in this report. Results of each year are summarized in Table 4 below.

Table 4. Summary of Volunteer Lake Study Group Data (from VLSG 2001).

	2000	1999	1998	1997	1996	1995	1994	1993	1992	1991
Minimum SDT, 5/15 – 9/15 (m)	0.5	1.2	1.3	0.8	1.0	1.7	1.3	1.0	0.4	0.5
Maximum SDT, 5/15 - 9/15 (m)	2.27	3.0	3.4	3.3	3.5	4.0	3.7	3.9	2.3	3.3
Average SDT 5/15 – 9/15 (m)	1.43	1.96	2.3	1.91	1.93	2.68	2.16	2.75	1.20	2.55
Late Summer Bloom Duration (wks)	12	11	5	10	11	9	9	4	13	4
Maximum Anoxic Area (ac)	141	136	122	87	93	162	80	56	127	68
Spring Turnover Phosphorus (ug/L)	26	18	17	13	12	19	5	21	25	18
Maximum Surface Phosphorus (ug/L)	23	18	35	24	23	27	24	---	36	27
Maximum Bottom Phosphorus (ug/L)	226	323	452	234	285	272	390	---	645	65

3.2 Watershed Features

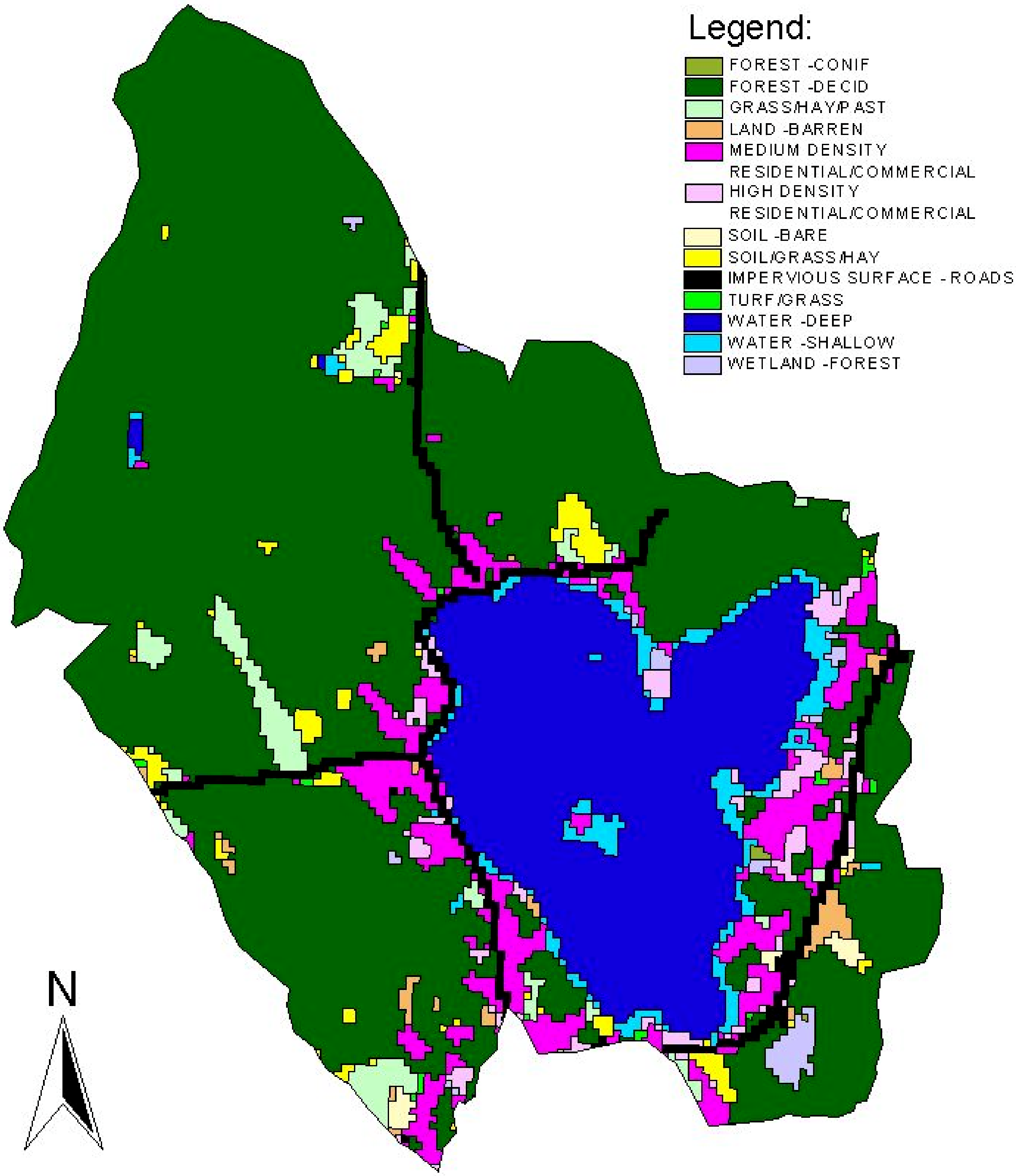
The Lake Pocotopaug watershed has a surface area of 2,381 acres. The entire watershed is located within the Town of East Hampton, Connecticut (Figure 1). Most of the watershed area is located north and west of the lake.

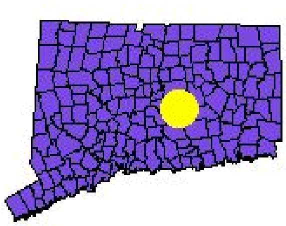
Land use in the Lake Pocotopaug watershed is mostly forested area (Table 5). However, shoreline land use is comprised of medium and high-density residential area (Figure 2).

Table 5. Land Use from the CT DEP GIS and from VLSG (1992).

	CT DEP		VLSG	
	Area (ac)	**% Total**	**Area (ac)**	**% Total**
Forest	1792	77.2%	1547	64.9%
High Density Residential/Commercial	45	2.0%	177	7.4%
Medium Density Residential	172	7.4%	400	16.8%
Low Density Residential			51	2.1%
Commercial			29	1.2%
Agriculture			63	2.6%
Grass/Pasture	118	5.1%		
Wetland	66	2.9%	115	4.8%
Forested Wetland	20	0.9%		
Barren Land	31	1.3%		
Road/impervious	74	3.2%		
Water	2	0.1%		
Total	2322	100%	2382	100%

Canton, Charlton, Paxton and Montauk soil types are dominant in the Lake Pocotopaug watershed (WMC 1995 & USDA 1995). These soils are loamy unstratified sand, silt, and rock (glacial till). These soils are well drained and have high erosion potential. Lake Pocotopaug watershed soils are illustrated on Figure 3.





Lake Pocotopaug Watershed Land Use

East Hampton, Connecticut

Source: Connecticut Department of Environmental Protection
http://magic.lib.uconn.edu/

300 0 300 600 Meters

Figure 2.

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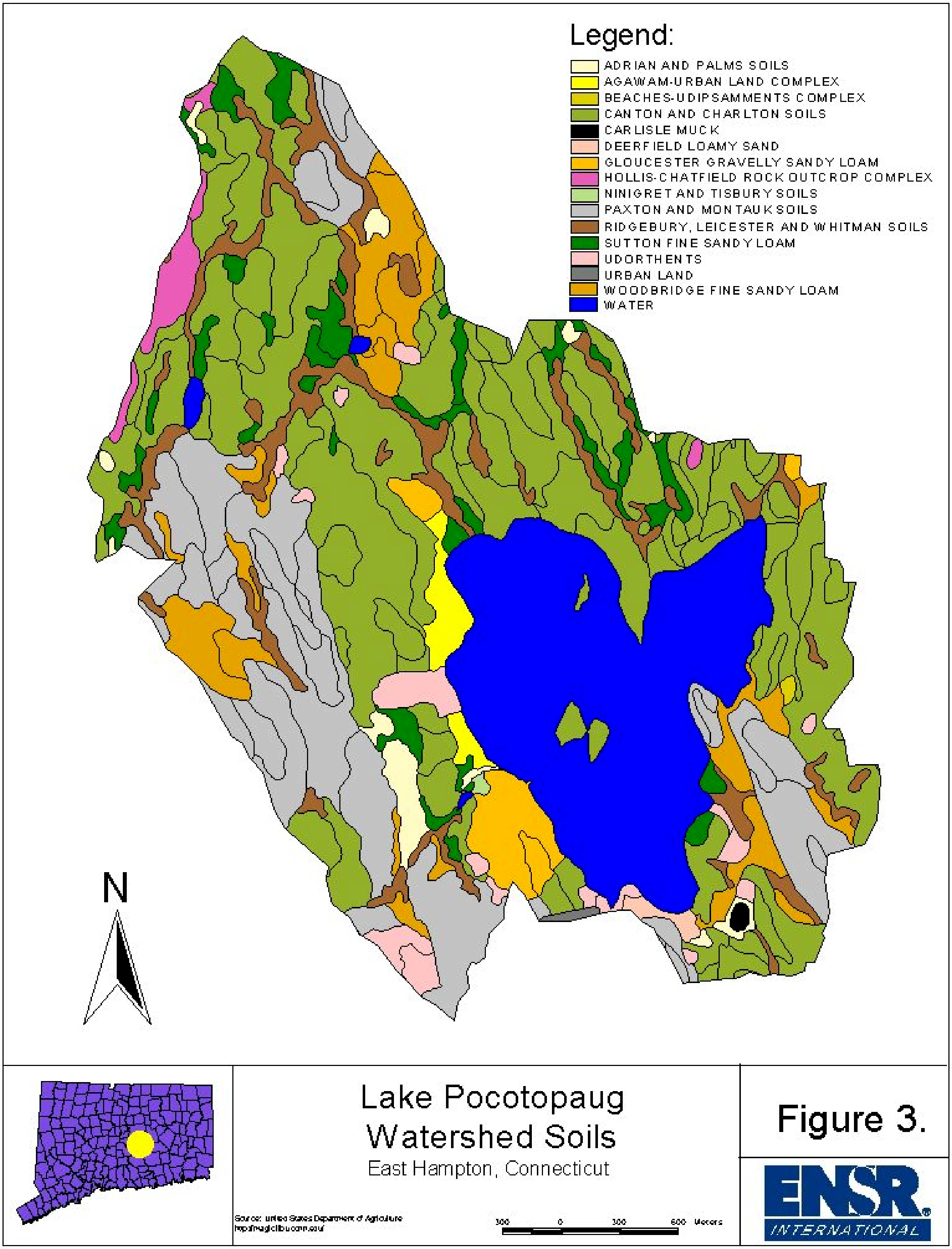


Lake Pocotopaug Watershed Soils

East Hampton, Connecticut

Figure 3.

3.3 Lake Features

Lake Pocotopaug is an enlarged pond resulting from the construction of a dam in the 1700's (Loomis 2002). Lake Pocotopaug has a surface area of 511.7 acres (Fugro 1993). The watershed:lake surface area ratio is 4.7:1.

There are two deep basins located in the northern portion of the lake. The western basin, Oakwood, has a maximum depth of approximately 11 meters. The eastern basin is approximately nine meters in depth. The latest bathymetric map, published in the Frink and Norvell (1984) report, is provided in Figure 4. The southern portion of the lake is relatively shallow. Mean depth of Lake Pocotopaug is 3.4 meters. Lake volume varies depending on the reference publication. Fugro (1993) shows a lake volume of 7,131,805 m^3, whereas the VLSG shows 7,132,239 m^3 (7,132,000 m^3 was used in calculations for this report).

Lake bathymetry is irregular due to islands, shoals and large rock outcrops. Boating can be difficult for lake users not familiar with these areas. Slopes are steep within the Oakwood basin and moderate in the Markham basin. The shallow area to the south likely contributes to lake turbidity due to wind mixing. The littoral area is mostly composed of rock, sand, and gravel with muck dominating in the deeper areas.

Recreational use of Lake Pocotopaug is extensive and varied. Boating of all kinds is very popular. Motorized watercraft is the preferred method of transportation on the lake. There is a public boat launch along the western shore. There are sandy beaches located on both the eastern and western shore for public and private use. Fishing is also popular at Lake Pocotopaug, and is generally practiced from boats. A Connecticut Trophy Award winning channel catfish was caught in Lake Pocotopaug in 1999. Lake Pocotopaug was stocked with fingerling walleye in 2001 as part of a project to expand sport fishing diversity in the State of Connecticut. Although a recent fishery study has not been performed in Lake Pocotopaug, the current fish community is likely dominated by panfish (perch, bluegills, etc.). Recreational activities continue throughout the winter months with ice fishing, sailing, and skating. Aside from human uses, Lake Pocotopaug provides an ideal habitat for aquatic life. Plankton, vascular plants, amphibians, reptiles, invertebrates, fish, birds (both permanent and migrating species) and mammals depend on the lake as part of their habitat.

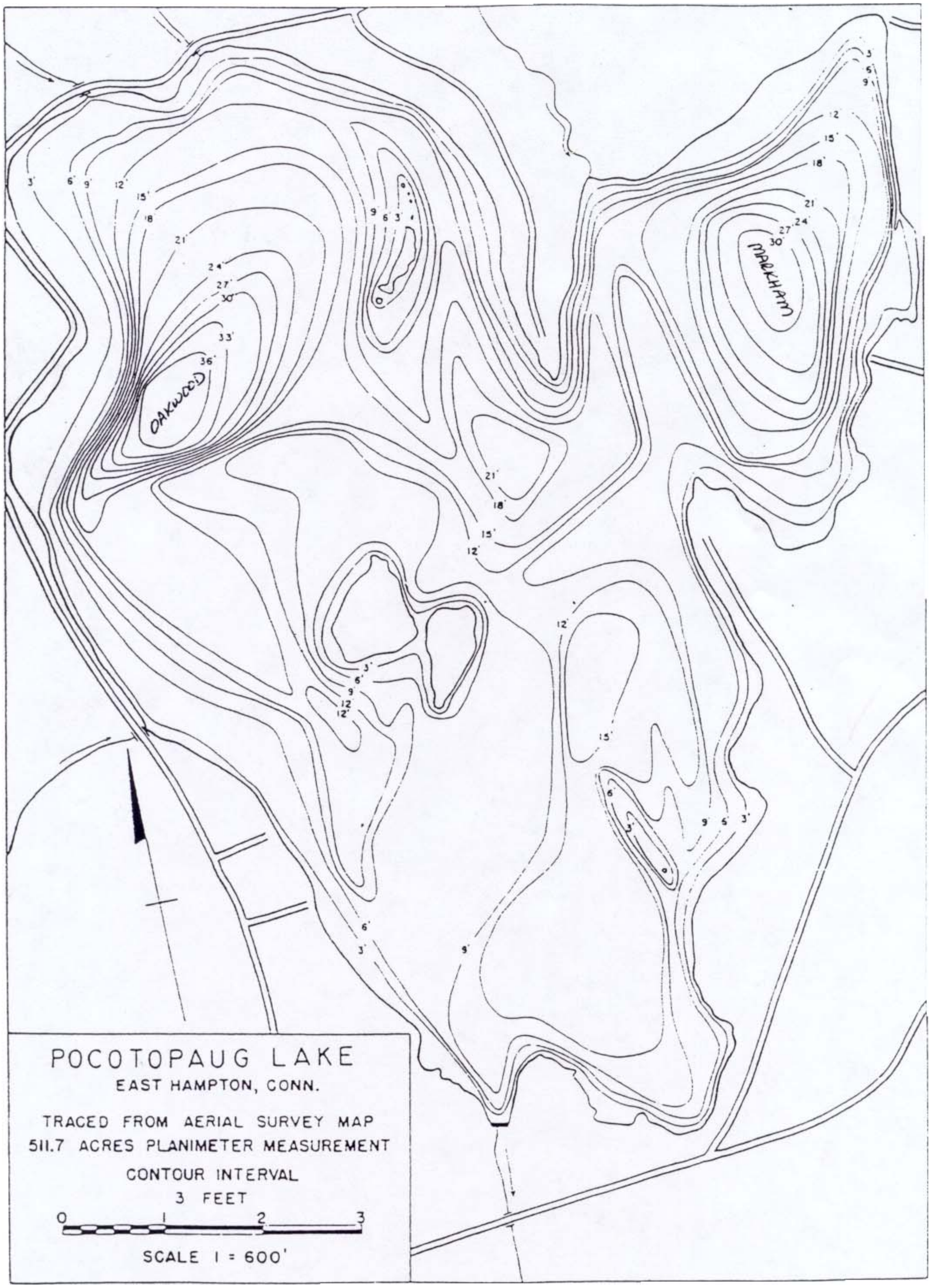


Figure 4. Lake Pocotopaug Bathymetry (Frink and Norvell 1984).

4.0 METHODS AND APPROACH

4.1 Quality Control and Quality Assurance

This Section presents the organization and objectives of the sampling activities and procedures associated with the Lake Pocotopaug, Lake and Watershed Restoration Evaluation. Specific protocols for sampling, sample handling and storage, and laboratory and field analyses are described. All QA/QC procedures were structured in accordance with applicable technical standards.

All sampling was carried out in order to assure sample precision, accuracy, completeness, and representativeness. Precision is a measure of the degree to which two or more measurements are in agreement, and was assessed through the determination of duplicate samples, collected or measured randomly, representing about 10% of the actual number of samples. Precision was measured as the relative percent difference (*RPD*) between sets of values:

$$RPD = \frac{(Amount\ in\ Sample\,1 - Amount\ in\ Sample\,2)}{0.5\,(Amount\ in\ Sample\,1 + Amount\ in\ Sample\,2)}\, x\,100$$

A total of seven duplicate samples were collected for tributaries and storm drains, and seven for in-lake stations during the sampling period of April-December 2001. RPD values for water quality ranged from 0% to 67%, for in-lake samples and 0% to 100% for tributaries and storm drains (Table 6). In-lake RPD values higher than 20% resulted from small differences in results near the detection limit for dissolved phosphorus (DP). Tributary and storm drain RPD values were much higher. Tributary samples were not “duplicates”; they were a second bottle placed on the same stake or in the same general area in an effort to collect first flush stormwater. Unattended stormwater sampling results in high variability.

Accuracy or percent error is the degree of agreement between the observed value (i.e., measured, estimated, or calculated) and an accepted reference or true value (i.e., the real value). The laboratory employed to analyze samples performs such tests on a regular basis. Percent error was below 10% for most of the accuracy samples (Table 7).

$$PercentError = \frac{(True - Observed)}{(True)}\, x\,100$$

Table 6. QA/QC on Water Quality Data.
QA/QC is expressed as RPD (relative percent difference), a measure of precision.

Tributaries and storm drains

				RPD			
Parameter (units)		n	range of values min - max	min	average	max	std. dev.
pH	SU	5	5.9 -6.8	0.0	0.7	1.7	0.1
Turbidity	NTU	6	2.6 -93	0.0	16.8	56.3	16.5
Spec. Cond	us/cm	5	52 -140	1.5	21.2	81.0	33.7
Alkalinity	mg/L	7	4 -26	0.0	27.6	85.7	2.2
Suspended Solids	mg/L	7	3.7 -252	7.8	33.4	90.9	30.9
Chloride	mg/L	1	10 -11	9.5	9.5	9.5	
Total Phosphorus	mg/L	7	0.012 -0.229	4.4	26.1	59.5	0.0
Dissolved Phosphorus	mg/L	7	0.008 -0.05	0.0	28.3	63.4	0.0
Ammonium-N	mg/L	7	0.01 -0.17	0.0	61.5	133.8	0.0
Nitrate-N	mg/L	7	0.01 -0.81	0.0	19.4	56.3	0.1
TKN	mg/L	7	0.36 -1.989	1.8	8.7	18.2	0.1

In-lake

				RPD			
Parameter (units)		n	range of values min - max	min	average	max	std. dev.
pH	SU	4	7 -8.5	0.0	1.3	4.2	0.1
Turbidity	NTU	4	2.1 -5.2	1.9	10.7	21.3	0.3
Spec. Cond	us/cm	4	91 -111	0.0	1.2	2.2	1.0
Alkalinity	mg/L	4	4 -10	0.0	2.9	11.8	0.5
Total Phosphorus	mg/L	6	0.008 -0.02	0.0	10.6	19.4	0.0
Dissolved Phosphorus	mg/L	6	0.001 -0.004	0.0	22.2	66.7	0.0
Dissolved Iron	mg/L	1	0.01 -0.01	0.0	0.0	0.0	

Table 7. Laboratory Percent Error during the 2001 Lake Pocotopaug Investigation.

Columbia Environmental Laboratory QA/QC

			% Error			Max difference
Parameter (units)		n	min	average	max	True – Obs.
Total Phosphorus	mg/L	12	0	3.5	8.7	0.004
Dissolved Phosphorus	mg/L	8	0	3.5	18.2	0.002
Ammonium-N	mg/L	3	0	6.8	13.1	0.014
Nitrate-N	mg/L	2	3.8	6.8	9.7	0.006
Dissolved Aluminum	mg/L	1	12.5	12.5	12.5	0.05

Completeness is a measure of the amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained under normal conditions (defined as the conditions expected if the sampling plan was implemented as planned). Completeness is calculated as

$$Completeness = \frac{(number\ of\ valid\ measurements)}{(number\ of\ measurements\ planned)} x\,100$$

and was 100% for in-lake samples. Stormwater sampling was variable. A total of 46 samplers were set to capture first flush stormwater. Of the 46, 35 filled and were analyzed, resulting in 76% completeness. Samplers either did not fill enough or were washed away due to heavy flow.

Representativeness expresses the degree to which data accurately and precisely represent a characteristic of a parameter, process, population, or environmental condition within a defined spatial and/or temporal boundary. Following the study design and applying the proper sampling techniques and analytical testing maximized representativeness of the data collected. Where choices of stations to be sampled were made, effort was expended to ensure that those sites sampled were most representative of the conditions the study intended to assess.

4.2 Hydrology

Hydrological data for Lake Pocotopaug included water inputs from tributaries, groundwater, direct precipitation, and runoff from the watershed. The hydrology was linked to water quality data to evaluate pollutant loads. General runoff from the watershed and incoming water from the tributaries were estimated from a combination of actual flow data and yields from mathematical models based on watershed characteristics. Direct precipitation on Lake Pocotopaug was calculated as the average precipitation (1994-2001 = 124.4 cm) times the lake surface area. Precipitation data were obtained from East Hampton/Colchester Water Pollution Control Plant and the Weather Underground web site. Ground water balance was estimated by:

1. using stormwater flow rate from the Environmental Protection Agency Rational Method (Q=CIA, where C=slope (0.05), I=rainfall intensity (1"/hr), and A=surface area (200 ac)),and
2. using a rate of 20 liters/m^2/day multiplied by area assumed to contribute direct groundwater flow (200 ac).

Information for physical characteristics of Lake Pocotopaug and its watershed were gathered from the following:

Topography – United States Geological Survey (USGS) 7.5 minute topographic maps at MAGIC University of Connecticut Geographic Information Center web site

Watershed Delineation – Field investigations, previous reports, and United States Geological Survey (USGS) 7.5 minute topographic maps

Land Use – CT DEP at MAGIC UCONN Geographic Information Center web site

Soils – USDA at MAGIC UCONN Geographic Information Center web site
Lake Bathymetry - Frink and Norvell (1984)
Inlets, outlets, and stormwater pipes locations - field investigations, previous reports, and review of USGS 7.5 minute topographic maps

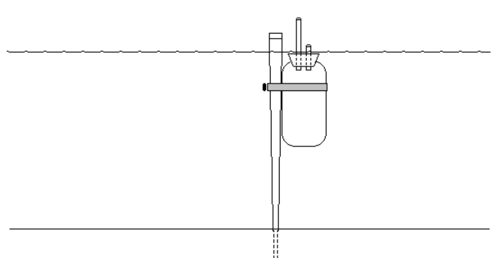
Tributary flows were estimated in the field on most sampling visits to the lake by determining current velocity through a transect across the channel, with measured width and average depth. The width and average depth of the channel allows calculation of a cross-sectional area, and multiplication of this area by the measured velocity yields a flow.

4.3 Water Quality

Water quality was determined for incoming surface (tributaries and storm water drainage pipes) and for in-lake water. Tributary and storm drain water quality samples were divided into two major categories: "dry weather" samples and "wet weather" samples. Dry weather is defined as a period of at least 72 hours (3 days) without any measurable precipitation, and wet weather appropriate for sampling is defined as the first storm event that produces runoff (normally >0.2 inches) after a minimum period of 72 hours with no precipitation. In-lake data were collected only during dry weather whereas tributaries and storm drains were sampled in both dry and wet weather.

Incoming surface water was sampled on four wet weather dates as first flush samples. First-flush samples provide a picture of the major potential impact of stormwater quality on lake water quality. First-flush stormwater was collected using a fixed passive sampling device that sampled on the rising limb of a hydrograph. This device consists of an analytically clean sample bottle fixed to a pole within the stream channel. The bottle is held upright, with the two tubes of unequal length extending out of the top of the bottle (Figure 5). During a dry sample collection survey, wet sample bottles are placed within the stream channel so that one of the bottle tubes is just above the water surface and the second is well above the water surface. In this way, the bottles fill as stage increases immediately after a rain event. As this happens, air is released out of the second tube. Sample bottles were retrieved shortly after the rain event and placed in an ice-filled cooler for transport to a laboratory for analysis.

Figure 5. Illustration of a Passive Surface Water Sampler for Sampling the "First Flush" of Storm-related Flow.



Two bottles per station per sampling event were collected, one for in-situ measurement made by ENSR and one for subsequent laboratory analysis without cross-contamination. All samples were promptly labeled and delivered to an analytical laboratory for analysis (Columbia Environmental Laboratory - CEL located in Columbia, CT or the State of Connecticut Department of Public Health Division of Laboratory Services). The State Laboratory provided only metal analyses; CEL provided limited metal analyses and all other analyses, which ENSR could not perform. Lake and tributary samples were grab samples, representing conditions at the sampling point at the time of collection.

In-situ measurements were made by ENSR during dry weather sampling for both in-lake and tributary stations. Table 8 lists the water quality variables measured by ENSR personnel and the independent laboratory.

Table 8. Water Quality Variables Measured in Lake Pocotopaug.
In-lake water quality variables were determined at three depths (surface, middle and bottom) during periods of stratification, otherwise surface and bottom samples were collected.

Parameter	Tributary/ storm drain	In-Lake	Analysis performed by:
Temperature [1] (ºC)		X	ENSR
Dissolved oxygen [1] (mg/l)		X	ENSR
pH (standard units)	X	X	ENSR/LAB
Alkalinity (mg $CaCO_3$ /L)	X	X	LAB
Specific conductivity (µS/cm)	X	X	ENSR/LAB
Chloride (mg/L)	X		LAB
Hardness (mg/L)	X		LAB
Suspended solids (mg/L)	X		LAB
Turbidity (nephalometric turbidity units)	X	X	ENSR/LAB
Water transparency (Secchi depth, m)		X	ENSR
Chlorophyll *a* [2] (µg/L)		X	ENSR
Phytoplankton[2] (ug/L)		X	ENSR
Total phosphorus (mg/L)	X	X	LAB
Dissolved phosphorus (mg/L)	X	X	LAB
Nitrate nitrogen (mg/L)	X		LAB
Ammonium nitrogen (mg/L)	X		LAB
Total Kjeldahl nitrogen (mg/L)	X		LAB
Aluminum (mg/L)	X (May only)	X (May only)	LAB
Dissolved aluminum (mg/L)		X (May only)	LAB
Arsenic (mg/L)	X (May only)	X (May only)	LAB
Cadmium (mg/L)	X (May only)	X (May only)	LAB
Chromium (mg/L)	X (May only)	X (May only)	LAB
Copper (mg/L)	X (May only)	X (May only)	LAB
Dissolved iron (mg/L)		X (August only)	LAB
Nickel (mg/L)	X (May only)	X (May only)	LAB
Lead (mg/L)	X (May only)	X (May only)	LAB
Zinc (mg/L)	X (May only)	X (May only)	LAB

(1) data collected at 1-m depth intervals to obtain a depth profile.
(2) integrated sample collected (approximately 1-20ft) or from from Secchi disk depth.

Lake Pocotopaug water quality was sampled on ten dates starting in April 2001. Two stations (LP-1 and LP-2, Figure 6) were sampled on each visit. At each site, samples were collected at the surface (0-0.5 m) and near the bottom with the help of a Van Dorn sampler. Samples were collected at the thermocline depth (usually 5-6 m) during periods of stratification. Water quality variables measured on site included pH, conductivity, and turbidity. Additionally, temperature and dissolved oxygen (DO) profiles were determined at 1 m interval depths at each site. SDT was also determined, and a depth-integrated (~ 6 m) water sample was collected at each site for chlorophyll a analysis and phytoplankton identification and quantification. Sampling naming convention was as follows:

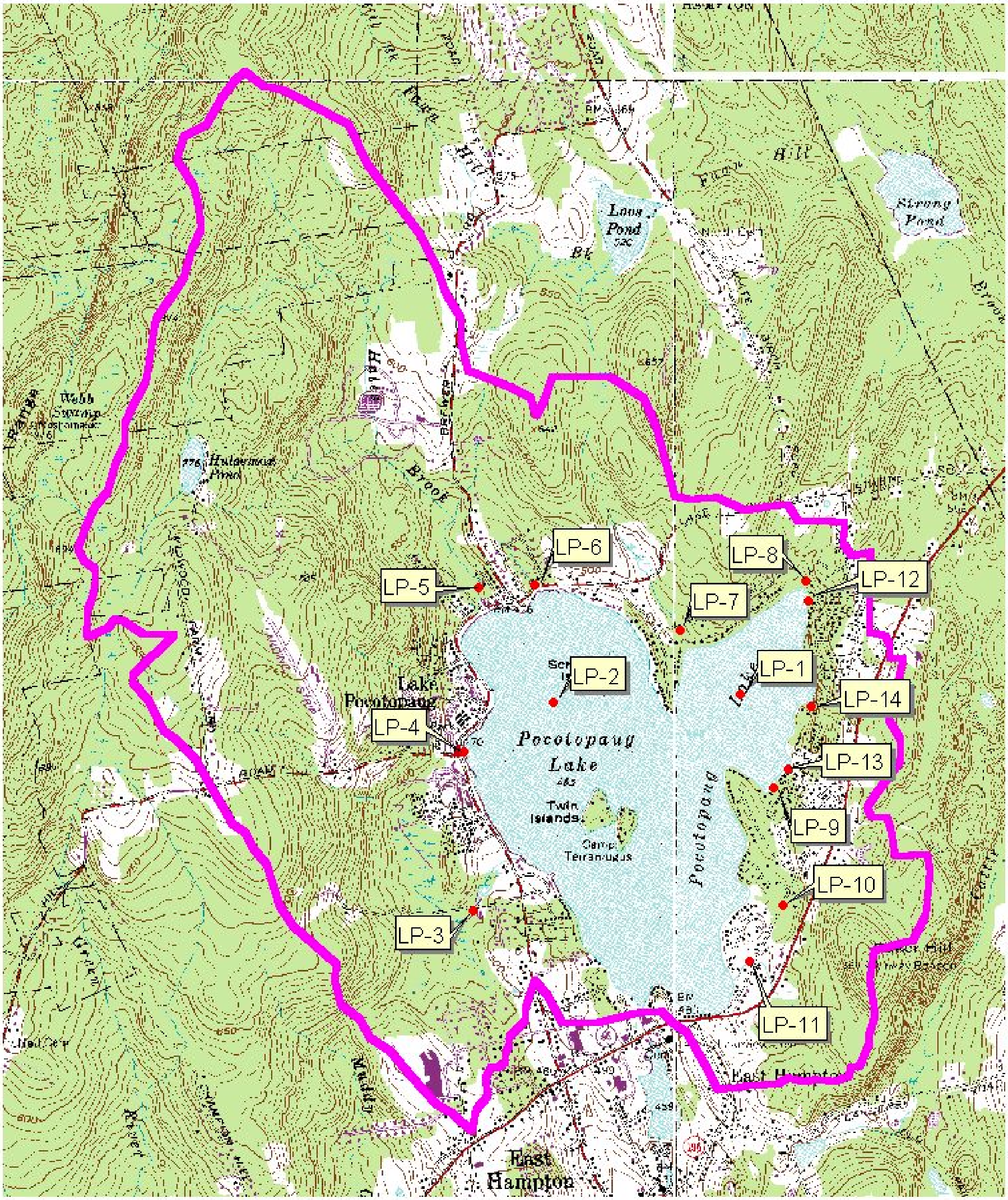
LP-1S or LP-2S – surface water samples
LP-1M or LP-2M – mid-depth (thermocline) water samples
LP-1B or LP-2B – bottom water samples
LP-1I or LP-2I – integrated water samples

Chlorophyll samples were filtered through a 0.45 µm glass fiber filter within 12 hours from collection and frozen until spectrophotometric determination of chlorophyll a content. The surface, mid- and bottom depth water samples were collected and sent to an independent analytical laboratory for determination of total and dissolved phosphorus, and alkalinity. Dissolved and total aluminum was sampled in May. Dissolved aluminum was measured at all three water depths and total aluminum was measured at the surface and bottom. Also in August, dissolved iron was measured at all three depths. Arsenic, cadmium, chromium, copper, nickel, lead, and zinc were measured in May at the surface and bottom.

Tributaries and storm water pipes were sampled during four dry weather and four wet weather visits. The first visit occurred in May 2001, when all potential stations were located, identified, and described. Actual sampling of the stations on subsequent dates was contingent upon existing conditions (i.e., whether the station was active or not) and budgetary constraints. Location of the water quality sampling stations is provided in Figure 6.

A total of 60 samples were collected from tributaries and storm drains, not including QA/QC duplicates. Descriptions of the locations, corresponding VLSG sampling identifier, and drainage areas (VLSG 1992) are provided in Table 9.

Tributary stations were not sampled when flow was too low to cause any appreciable contaminant load to the lake. Water quality variables included temperature, pH, DO, conductivity and turbidity (determined in the field by ENSR personnel), suspended solids, alkalinity, chloride, total and dissolved phosphorus, nitrate nitrogen, ammonium nitrogen, and total Kjeldahl nitrogen, and alkalinity (determined by an independent analytical laboratory). Aluminum, arsenic, cadmium, chromium, nickel, lead, and zinc were analyzed once during dry and once during wet weather.



Lake Pocotopaug
2001 Sampling Locations

East Hampton, Connecticut

Figure 6

ENSR INTERNATIONAL

Table 9. ENSR and VLSG Tributary and Storm Drain Sampling Station Identifier, Description and Drainage Areas.

VLSG Station ID	ENSR Station ID	Location	Area Drained * Total Area (ac)	% Developed	Developed Area (ac)
4	LP-3	Christopher Brook, upstream of Christopher Road	466	36	169
9	LP-4	Storm drain at bottom of Clark Hill	18	100	18
11	LP-5	Hales Brook, at Lake Drive - upstream of Hales Pond	889	12	107
15	LP-6	Candlewood Brook, upstream of Lake Drive	41	39	16
18	LP-7	Bay Road Brook, downstream of Bay Road	156	3	4
21	LP-8	Hazen Brook, end of private drive	20	24	5
	LP-9	Storm drains at lake edge, between cottages at end of Hawthorne and Emerson Road			
23	LP-10	O'Neils Brook, upstream of Old Marlboro Road	53	44	23
26	LP-11	Day's Brook, downstream of Old Marlboro Road	55	15	8
22	LP-12	Storm drain at bottom of MohicanWangonk Trail (north side of beach)	12	100	12
	LP-13	Storm drainage swale, end of Park Street (next to house #5 with ornamental pond)	5*	100	5
	LP-14	Storm drain at S. Wangonk Trail beach	3**	100	3

* Location #28 on WMC (1995)

** Location #25 on WMC (1995); no drainage area listed, assumed 3 acres

4.4 Nutrient Loading

Nutrient loading on Lake Pocotopaug was assessed by two methods: using the actual data (water budget and nutrient concentrations) from this study and using a land-use based export coefficients. This combination yields a range of apparent loads and allows for a reasonable approximation of actual conditions over the longer term. Direct measurement of inputs was applied wherever feasible, within the confines of logistic and budgetary constraints. Actual sample results were used in direct calculations. Literature values were used when actual measurements were not gathered (i.e. waterfowl, groundwater and precipitation). Internal loading was estimated based on a predicted success of the alum treatment. Measurement of internal loading was complicated by the fact that the alum treatment occurred in the same year as this study.

4.5 Biological Characterization

Water samples for biological characterization of planktonic (open-water) biological communities were collected at the same time and stations as for in-lake water quality samples (Figure 6). Planktonic communities include photosynthetic organisms (algae, or phytoplankton) and the invertebrates that feed directly on them (collectively called zooplankton). Both types of organisms influence and reflect other in-lake characteristics such as water quality and fish community features.

Phytoplankton samples were collected by filling a 6-m long, ¾ inch diameter plastic tube with lake water. The tube is immersed vertically, with a terminal weight maintaining the tube vertical position throughout the water column. When the tube is full, the top end is sealed, the bottom end is retrieved and the content is emptied in a container. The water sample collected this way is a composite sample of the water column from the surface to the length of the tube (~ 6 m in this case). Because most of the phytoplankton community lives in the upper water layers of a lake, samples collected this way were representative of the open-water algal community. The collected planktonic algae were preserved by addition of a few milliliters of Lugol's solution.

Taxonomic identification and algal counts (density and biomass) were performed by an ENSR taxonomist, and served as the basis for an expanded ecological discussion of phytoplankton (including community structure, relative abundances, species richness, diversity, and evenness) as related to water quality and other biological components of Lake Pocotopaug. Samples were concentrated and the concentrate was viewed in a counting chamber under phase contrast optics at 400X power. Algae were identified, sized and enumerated, and a computer program converted the raw data to density, either as cells/ml or biomass (µg/L).

Zooplankton were collected by means of a 53-µm mesh, funnel-shaped plankton net lowered through the water column to a depth of ~10 m, and slowly retrieved up to the water surface. The procedure was repeated at least three times for each sample, yielding a concentrated sample of almost 1000 L of lake water. The collected zooplankton were preserved by addition of a few drops of 25% glutaraldehyde solution.

Taxonomic identification and organism counts (density and biomass) were performed by an ENSR taxonomist, and served as the basis for an expanded ecological discussion of zooplankton (including community structure, relative abundance, size distribution, species richness, diversity, and evenness) as related to water quality and other biological components of Lake Pocotopaug. Samples were concentrated and the concentrate was viewed in a counting chamber under brightfield optics at 100X power. Zooplankton were identified, sized and enumerated, and a computer program converted the raw data to density, either as individuals/L or biomass (µg/L).

5.0 HYDROLOGIC INPUTS

The hydrology of the Lake Pocotopaug system is important to pollutant loading and ecological processes that make the lake what it is today. Ultimately, precipitation drives the hydrologic budget, but water may enter the lake as direct precipitation, surface water runoff, direct ground water seepage, or basal surface water flow (surface water derived from ground water that enters streams). Some systems also have discharges in addition to the above natural sources, but no such discharges to Lake Pocotopaug are known. Water leaves the lake as surface overflow, groundwater outseepage, or evaporation. Outputs were not calculated as part of this investigation, but can be found in the Fugro (1993) report.

5.1 Precipitation

Precipitation in the East Hampton area averages about 1.24 m per year. This equates to 49.0 inches per year. Precipitation landing on the watershed of Lake Pocotopaug must become runoff, base flow or groundwater before entering the lake, if it reaches the lake at all. Precipitation landing directly on Lake Pocotopaug amounts to 2.5 million cubic meters per year (2.5×10^6 m^3/yr = 1.24 m falling on 204.7 ha). This equates to a flow rate of just under 3 cubic feet per second (cfs).

5.2 Groundwater

Groundwater flow was not specifically measured in this study. The most direct approach of measuring inseepage and outseepage with seepage meters but was not within the scope of this investigation. As ground water flow was not expected to be a major component of the inflow or outflow, a simple calculation approach was considered appropriate. Bear in mind that ground water pumped from wells is exported from the watershed in sewers, so groundwater will be even less of a source of water (and contaminants) than under natural conditions in this case.

Groundwater flow was calculated by approximating the area of the watershed that contributes groundwater to Lake Pocotopaug directly (approximately 200 acres) and multiplying this area by the typical groundwater flow rate for this area of Connecticut (approximately 20 L/m^2/d). Their product results in an estimated groundwater input of 588,709 m^3/yr. Another method is to use the equation Q=CIA. This equation uses the product of the slope of the area contributing to the lake (0.05), the intensity of rainfall (1"/hr), and the area directly contributing to the lake (200 ac). Using Q=CIA, predicted groundwater flow is 891,127 m^3/yr.

5.3 Surface Water

Surface water flow is often divided into base flow and storm flow, separated by the portion of precipitation landing on the watershed that runs off immediately (st orm flow) or seeps into the ground but is later captured by streams. Field flow measurements were limited in this study, where many measurements would have been necessary to characterize the many small inflows to Lake Pocotopaug. Instead, calculations were applied using land use and expected water export coefficients.

The total annual water load (all inputs) to Lake Pocotopaug can be calculated based on the lake volume (approximately 7,132,000 m^3) and the flushing rate (approximately 1.25 volumes/year). Using these values, Lake Pocotopaug receives approximately 8,915,000 m^3 of water per year. Subtracting precipitation and groundwater inputs yields an estimate of surface water inputs (5.5 – 5.9 million cubic meters per year). Alternatively, a water flow rate per area can be applied to the watershed to get similar results. Using a flow rate of 1.5 cfs/mi^2 (typical runoff for this area of Connecticut) in a 3.7 mi^2 watershed yields a surface water input of approximately 5.6 million cubic meters per year. Using both methods, a range of surface water input is generated (5.5 – 5.9 million cubic meters/year).

Stormwater input can be calculated by multiplying an expected runoff coefficient by annual rainfall and area subject to precipitation. The runoff coefficient used in the WMC report was 0.3 for residential land and seems reasonable for this watershed. Using 0.3, 1.2 meters of precipitation and the watershed area (9,636,008 m^2), stormwater runoff is estimated to be 3.5 million cubic meters per year.

Dry weather, or base flow, was estimated by subtracting stormwater flow from the total surface water input (2.0 – 2.4 million cubic meters). It was also calculated using the average flow rate measured during this investigation (0.3 cfs). The base flow was calculated to be 2.7 million cubic meters, comparable to the value obtained through subtraction above.

6.0 WATER QUALITY

6.1 In-Lake Water Quality

Temperature and DO profiles at the two in-lake stations during April-November 2001 are presented in Figure 7. Other water quality data are summarized in Table 10. Values recorded below the detection limit are reported as ½ the detection limit. 2001 in-lake values for each sampling and a summary of all data (previous reports and 2001 data) are provided in Appendix B.

Thermal stratification occurs when sunlight warms the upper waters but wind mixing is insufficient to mix this warmer water all the way to the bottom of the waterbody. This is a natural process, but has distinct implications for lake ecology, as the lower water layer can be a refuge or a detriment depending on how much oxygen is present. Lake Pocotopaug was beginning to thermally stratify in April 2001 and was almost destratified by September. The thermocline was present at five meters at LP-1 and at six meters at LP-2 in May. The thermocline dropped to 5.5 and 6.5 meters at LP-1 and LP-2, respectively, come July and dropped another 0.5 meters in August. These results indicate that Lake Pocotopaug is a typical dimictic water body (two complete mixing events in spring and fall separated by summer thermal stratification).

Oxygen stratification roughly followed thermal stratification (Figure 7). DO readings below the thermocline were often less than 1.0 mg/L. DO below 1.0 mg/L was recorded above the thermocline at both stations (6 and 7 meters, respectively) in August. Anoxic conditions were also recorded above the thermocline in June 2000 (VLSG 2001). DO readings of less than 6 mg/l, undesirable for many aquatic life forms, were never recorded at depths above 5 m.

Turbidity is a measure of water clarity. Turbid waters are indicative of high levels of suspended particles that may include algal cells, silt, or resuspended sediments and are usually associated with poor water quality. Acceptable standards depend on water body use, but turbidity readings higher than 10 nephalometric turbidity units (NTU) are indicative of potentially undesirable water quality. Most “clean” New England lakes exhibit turbidity ranging from 1 to ~5 NTU. Maximum turbidity in Lake Pocotopaug surface water exceeded the 5 NTU threshold at LP-2 (5.2 NTU recorded in August), but averages were below 5 NTU (2.8 and 2.7 NTU, Table 10).

Turbidity was higher near the sediment-water interface. Settling particles accumulating in the deeper areas of the reservoir were likely responsible, though accidental stirring of fine sediments by the sampling procedure could have contributed to the higher readings.

The pH varied little in time and space during the 2001 sampling (Table 10). pH ranged from 6.1 to 8.5 SU, with the lower values measured near the bottom and the high values near the surface. Mean pH ranged from 6.6 to 7.4 SU.

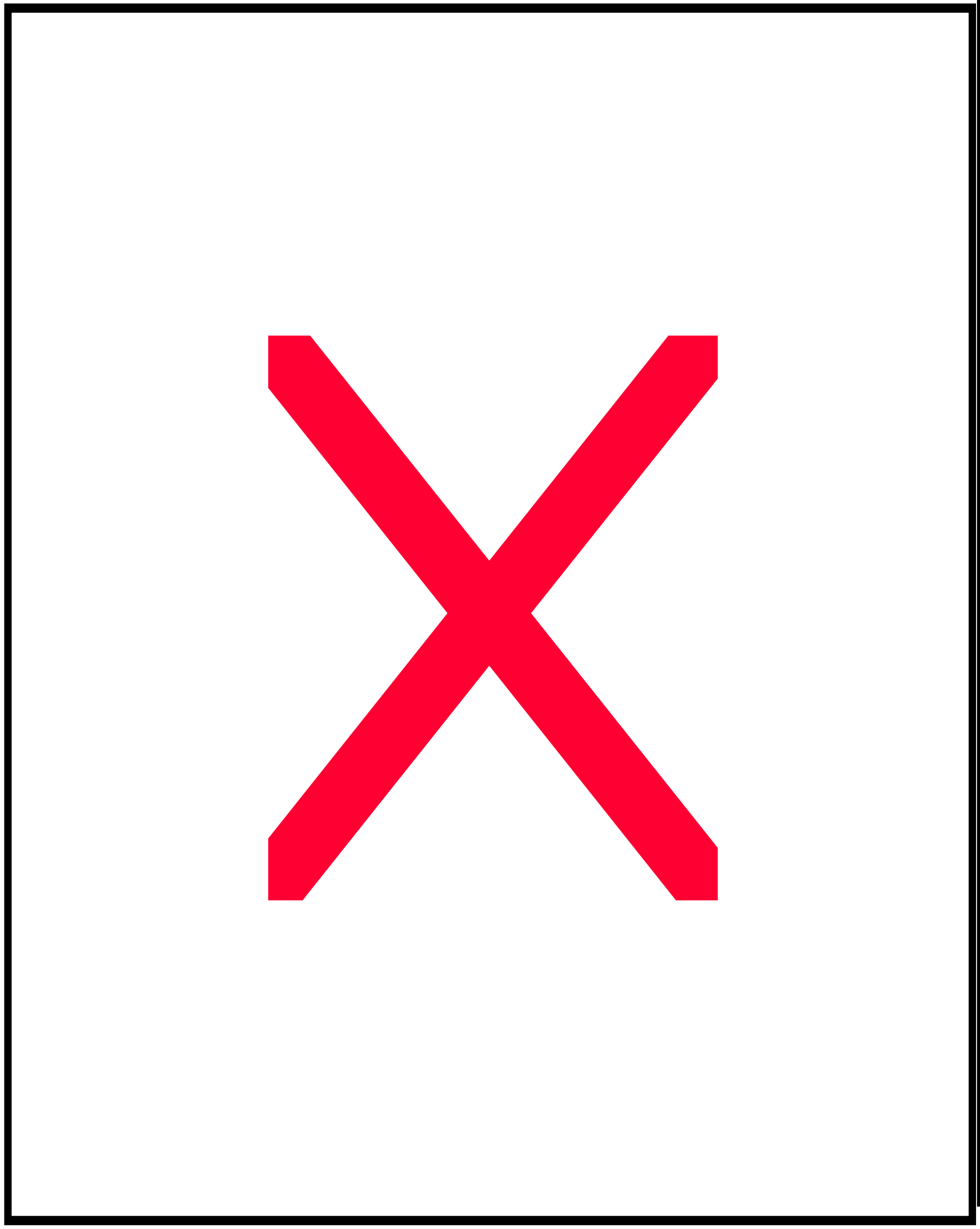
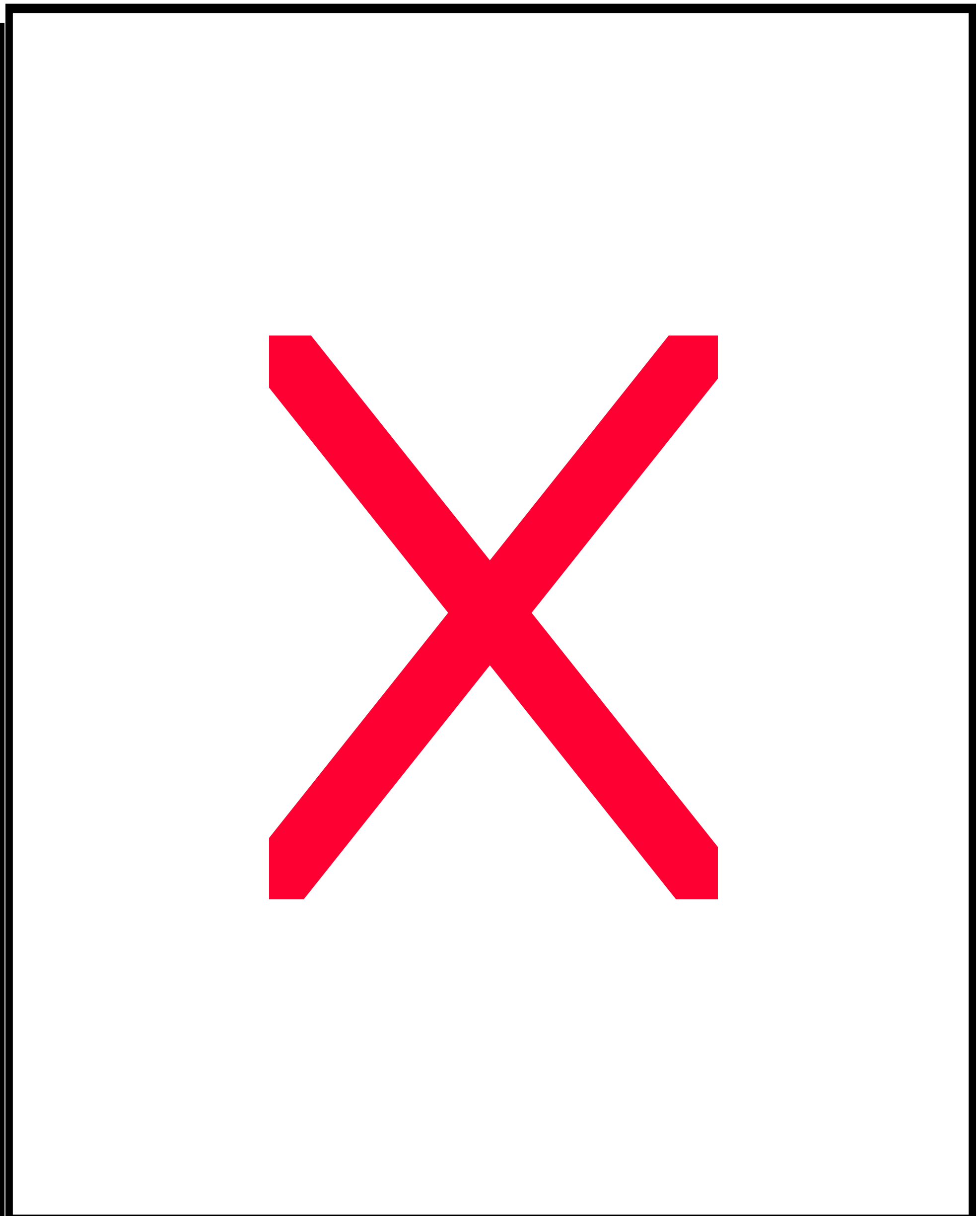



Figure 7. 2001 Temperature and Dissolved Oxygen Profiles.

Table 10. 2001 Lake Pocotopaug In-lake Data Summary.

Station	Statistic	Turb (NTU)	pH (SU)	Alka (mg/L)	Specific Cond. (us/cm)	Total Phos (mg/L)	Diss. Phos (mg/L)	Secchi (ft)	Phyto (ug/L)	Chloro a (ug/L)	Al (mg/L)	Diss. Al (mg/L)	As (mg/L)	Cd (mg/L)	Cr (mg/L)	Cu (mg/L)	Diss.Fe (mg/L)	Ni (mg/L)	Pb (mg/L)	Zn (mg/L)
LP-1S	MEAN	2.8	7.4	6.3	104	0.012	0.002	6.9	3783	---	0.036	0.010	0.000	0.000	0.002	0.003	0.010	0.001	0.003	0.004
	MAX	4.9	8.5	10.0	113	0.019	0.005	9.8	5249	---	0.036	0.010	0.000	0.000	0.002	0.003	0.010	0.001	0.003	0.004
	MIN	1.4	6.6	4.0	93	0.005	0.001	3.5	3047	---	0.036	0.010	0.000	0.000	0.002	0.003	0.010	0.001	0.003	0.004
	n	7	6	6	6	10	9	10	3	---	1	1	1	1	1	1	1	1	1	1
LP-1M	MEAN	2.7	7.0	8.3	108	0.015	0.003	---	---	---	---	0.010	---	---	---	---	0.010	---	---	---
	MAX	4.1	7.3	10.0	111	0.022	0.006	---	---	---	---	0.010	---	---	---	---	0.010	---	---	---
	MIN	1.5	6.5	6.0	106	0.009	0.001	---	---	---	---	0.010	---	---	---	---	0.010	---	---	---
	n	5	4	4	4	8	7	---	---	---	---	1	---	---	---	---	1	---	---	---
LP-1B	MEAN	4.5	6.4	14.3	111	0.039	0.004	---	---	---	0.105	0.010	0.000	0.000	0.000	0.004	0.010	0.001	0.003	0.016
	MAX	9.9	6.5	30.0	141	0.160	0.004	---	---	---	0.105	0.010	0.000	0.000	0.000	0.004	0.010	0.001	0.003	0.016
	MIN	2.1	6.2	4.0	94	0.015	0.003	---	---	---	0.105	0.010	0.000	0.000	0.000	0.004	0.010	0.001	0.003	0.016
	n	7	6	6	6	7	6	---	---	---	1	1	1	1	1	1	1	1	1	1
LP-1	MEAN	---	---	---	---	---	---	---	6653	6.0	---	---	---	---	---	---	---	---	---	---
Inter.	MAX	---	---	---	---	---	---	---	15912	14.8	---	---	---	---	---	---	---	---	---	---
	MIN	---	---	---	---	---	---	---	2921	1.5	---	---	---	---	---	---	---	---	---	---
	n	---	---	---	---	---	---	---	6	6	---	---	---	---	---	---	---	---	---	---
LP-2S	MEAN	2.7	7.3	6.5	102	0.013	0.002	6.3	2745	---	0.049	0.010	0.000	0.000	0.000	0.003	0.010	0.000	0.005	0.004
	MAX	5.2	8.4	10.0	111	0.020	0.005	9.8	3953	---	0.049	0.010	0.000	0.000	0.000	0.003	0.010	0.000	0.005	0.004
	MIN	1.1	6.7	4.0	90	0.008	0.001	3.3	890	---	0.049	0.010	0.000	0.000	0.000	0.003	0.010	0.000	0.005	0.004
	n	7	6	6	6	10	9	10	3	---	1	1	1	1	1	1	1	1	1	1
LP-2M	MEAN	2.8	6.7	8.8	107	0.017	0.003	---	---	---	---	0.010	---	---	---	---	0.010	---	---	---
	MAX	5.1	7.2	12.0	111	0.025	0.006	---	---	---	---	0.010	---	---	---	---	0.010	---	---	---
	MIN	1.6	6.2	6.0	101	0.009	0.001	---	---	---	---	0.010	---	---	---	---	0.010	---	---	---
	n	5	4	4	4	8	7	---	---	---	---	1	---	---	---	---	1	---	---	---

Table 10 continued. 2001 Lake Pocotopaug In-lake Data Summary.

Station	Statistic	Turb (NTU)	pH (SU)	Alka (mg/L)	Specific Cond. (us/cm)	Total Phos (mg/L)	Diss. Phos (mg/L)	Secchi (ft)	Phyto (ug/L)	Chloro a (ug/L)	Al (mg/L)	Diss. Al (mg/L)	As (mg/L)	Cd (mg/L)	Cr (mg/L)	Cu (mg/L)	Diss.Fe (mg/L)	Ni (mg/L)	Pb (mg/L)	Zn (mg/L)
LP-2B	MEAN	13.7	6.6	20.0	122	0.052	0.003	---	---	---	0.794	0.010	0.000	0.000	0.001	0.006	0.010	0.002	0.014	0.027
	MAX	46.0	7.2	40.0	174	0.216	0.008	---	---	---	0.794	0.010	0.000	0.000	0.001	0.006	0.010	0.002	0.014	0.027
	MIN	2.2	6.1	4.0	91	0.015	0.001	---	---	---	0.794	0.010	0.000	0.000	0.001	0.006	0.010	0.002	0.014	0.027
	n	7	6	6	6	7	6	---	---	---	1	1	1	1	1	1	1	1	1	1
LP-2	MEAN	---	---	---	---	---	---	---	6606	5.5	---	---	---	---	---	---	---	---	---	---
Inter.	MAX	---	---	---	---	---	---	---	16584	11.7	---	---	---	---	---	---	---	---	---	---
	MIN	---	---	---	---	---	---	---	2923	1.6	---	---	---	---	---	---	---	---	---	---
	n	---	---	---	---	---	---	---	6	6	---	---	---	---	---	---	---	---	---	---
Total	MEAN	5.1	6.9	11.0	109	0.023	0.003	6.6	5508	5.8	0.246	0.020	0.000	0.000	0.001	0.004	0.010	0.001	0.006	0.013
	MAX	46.0	8.5	40.0	174	0.216	0.008	9.8	16584	14.8	0.794	0.020	0.000	0.000	0.002	0.006	0.010	0.002	0.014	0.027
	MIN	1.1	6.1	4.0	90	0.005	0.001	3.3	890	1.5	0.036	0.020	0.000	0.000	0.000	0.003	0.010	0.000	0.003	0.004
	n	38	32	32	32	50	44	20	18	12	4	4	4	4	4	4	6	4	4	4

.

Alkalinity remained at constant low values (range 4-12 mg/l) at surface and mid-depths in Lake Pocotopaug in 2001 (Table 10). Bottom values were higher but averages did not exceed 20 mg/L. Alkalinity values in 2001 were comparable to previous years. Alkalinity is a measure of the buffering capacity of water, its ability to absorb H^+ ions without major oscillations in pH that may impact the biota. Alkalinity values lower than 2 mg/l indicate no buffering capacity; values between 2 and 20 mg/l suggest limited buffering capacity. High buffering capacity exists for alkalinity values higher than ~50 mg/l. The low alkalinity in Lake Pocotopaug is considered typical range and does not suggest the occurrence of water quality problems at the lake or watershed scale.

Specific conductivity in 2001 ranged from 90 to 174 µS/cm (Table 10). Mean conductivity ranged from 102 to 122 µS/cm. Again, higher values were recorded at the bottom. Conductivity is a measure of the ion concentration in the water, and indirectly of total dissolved solids. The 100 µS/cm is considered the threshold below which a water body is likely to be nutrient-poor, as only a small portion of the dissolved solids are nutrients. Contaminated or fertile lakes, where nutrient-driven phytoplankton blooms are likely to occur, are characterized by higher conductivity readings (often above 300 µS/cm), although it is possible to have high conductivity and low fertility with a lot of non-nutrient solids.

Water transparency is typically measured as SDT. SDT corresponds to the depth at which light intensity is approximately 10% of the surface value (Wetzel 1983), thus approximately delimitating the range of the photic zone (i.e., where photosynthesis can occur). SDT is associated with light scattering by particulate matter in suspension, including algae (Carlson 1977; Wetzel 1983). SDT can be used as a general measure of lake condition, with depths greater than 4 m indicating desirable water quality and depths less than 1 m indicating undesirable water quality (Carlson 1977). Carlson's lower threshold is similar to the Connecticut's Water Quality Standard for mesotrophic lakes (2 – 6 m during the summer).

Water transparency or SDT in Lake Pocotopaug was less than desirable in 2001 (Table 10). Maximum SDT was 3 meters, below the 4 meter desirable threshold. Minimum transparency was recorded at LP-2 in August (1 m). On average, SDT in 2001 was 2.1 and 1.9 meters for LP-1 and LP-2 respectively. LP-2 often has slightly lower transparencies than LP-1. Minimum transparencies ranged from 0.4 to 1.7 meters from 1991-2000. Maximum transparencies from mid-May to mid-September in 1991-2000 ranged from 2.3 to 4.0 meters. The greatest SDTs were typically recorded during mid to the end of June (2001 was no exception). However, maximum transparency was recorded in early July in 1997, 1998 and 2000.

Phosphorus is usually the nutrient limiting freshwater photosynthetic organisms, including algae (Hecky & Kilham 1988). Total phosphorus (TP) includes all forms of phosphorus in the water column, from readily absorbable dissolved orthophosphates to refractory particulate phosphorus. TP is often used as a measure of a lake trophic state (Carlson 1977). Surface TP concentrations below 0.01 mg/l are usually associated with clear water and lack of appreciable phytoplankton biomass (Wetzel 1983). Nuisance algal blooms and other eutrophication-related problems often occur at TP concentrations above the 0.025-0.030 mg/l threshold (Carlson 1977; Mitchell 2000).

Surface TP concentrations during the 2001 ranged from 0.005 mg/L to 0.019 mg/L at LP-1 (average 0.012 mg/L). LP-2 surface TP concentrations ranged from 0.008 to 0.020 mg/L (average 0.013 mg/L). Lake Pocotopaug experiences algal blooms even at these low TP concentrations. Maximum surface phosphorus concentrations for 1991-2000 ranged from 0.018 to 0.036 mg/L. Bottom and mid depth TP concentrations were higher than at the surface. Maximum mid-depth TP concentrations for 2001 ranged from 0.009 – 0.025 mg/L (LP-1 average 0.015 and LP-2 average 0.017 mg/L). Bottom TP concentrations in 2001 ranged from 0.015 – 0.216 mg/L (LP-1 average 0.039 and LP-2 average 0.052). Maximum TP bottom concentrations for 1991-2000 ranged from 0.065 – 0.645 mg/L. Figures 8 and 9 display the range of TP values from 1991-2001.

Statistically, there was a significant difference (P< 0.05) in mean summer TP at LP-1B in 2001 from 1992, 1994, 1997 and 1998. There was a statistical difference (P< 0.05) in mean summer TP at LP-2B in 2001 from 1998. From these data, one might conclude that the alum treatment in 2001 was not effective in reducing the internal load, since 6 or the 9 pre-alum treatment years were not significantly different than 2001 (post-treatment). However, bottom TP sampling can be highly variable if particulate material from sediments is present in the sample. Comparing dissolved phosphorus would be a better measure of the efficacy of the alum treatment. Unfortunately, dissolved phosphorus values for 1991-2000 are not available. Summer surface and mid-depth TP were not significantly different in 2001 from 1991-2000.

Dissolved phosphorus (DP) refers to the soluble portion of TP (inorganic and organic). DP is more readily available to aquatic organisms than particulate phosphorus, and may be a more accurate variable for predicting water quality than TP. However, methodologic consistency over the years has led to most relationships being based on TP. Because of the lack of reference concentration values for DP, the 0.010-0.025 mg/l TP reference values are used here, but DP may be cycled so rapidly as to suggest that the presence of measurable DP is a negative sign. As for TP, DP concentration values below the detection limit were reported as ½ the detection limit.

Surface DP concentrations during the 2001 ranged from below the 0.001 mg/L detection limit to 0.005 mg/L at both stations (averages were both 0.002 mg/L). DP was not measured in 1991-2000. A similar analysis was performed, ortho-phosphophate, but is not directly comparable. Ortho-phosphate is phosphate that is not associated with organic material. However, a measurement of ortho-phosphate does not include polyphosphates, another form of inorganic phosphates, which DP does. Ortho-phosphate was measured in 1991, 1992 and 1995. Surface ortho-phosphate values ranged from below the 0.002 mg/L detection limit to 0.030 mg/L

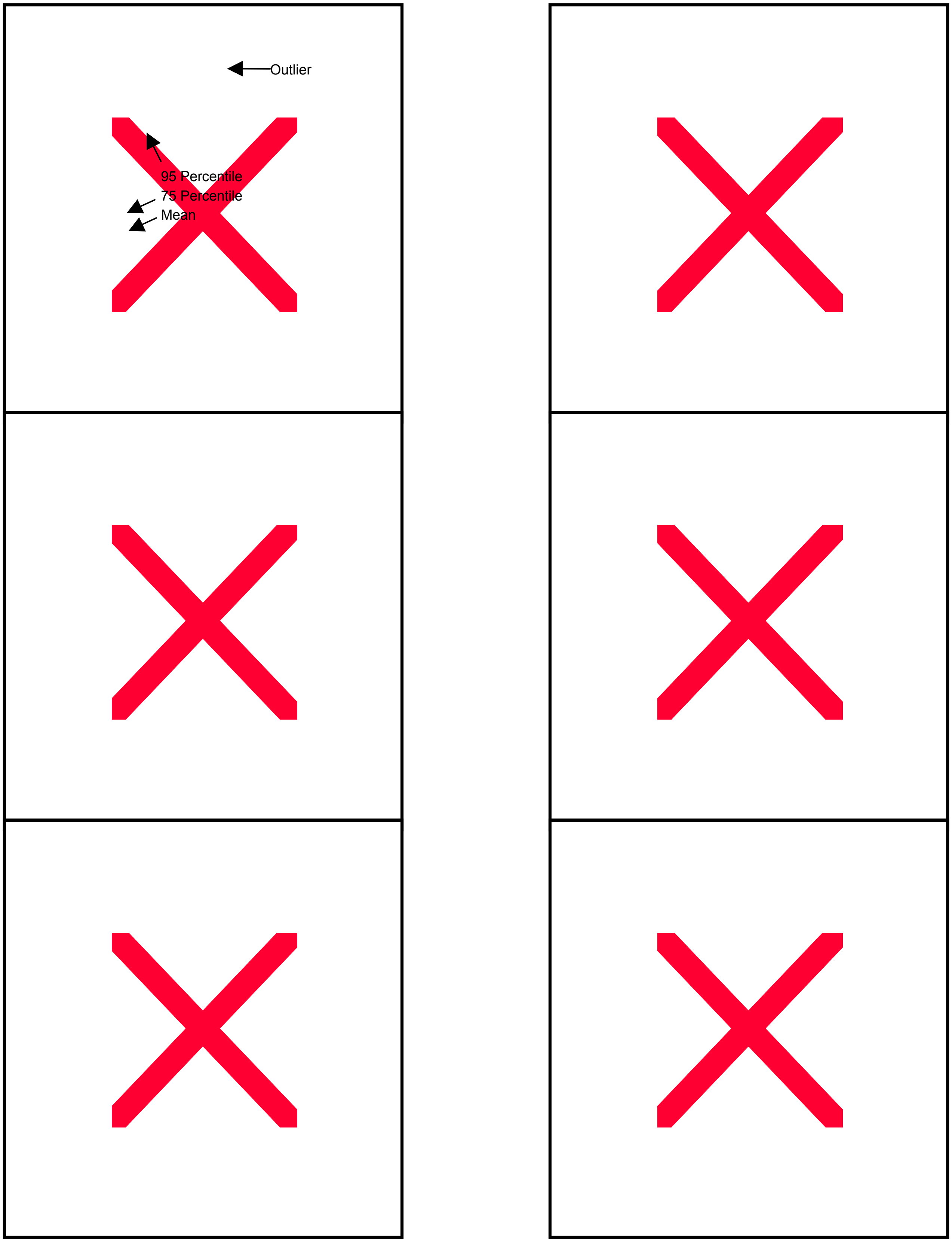


Figure 8. Annual Total Phosphorus from 1991-2001

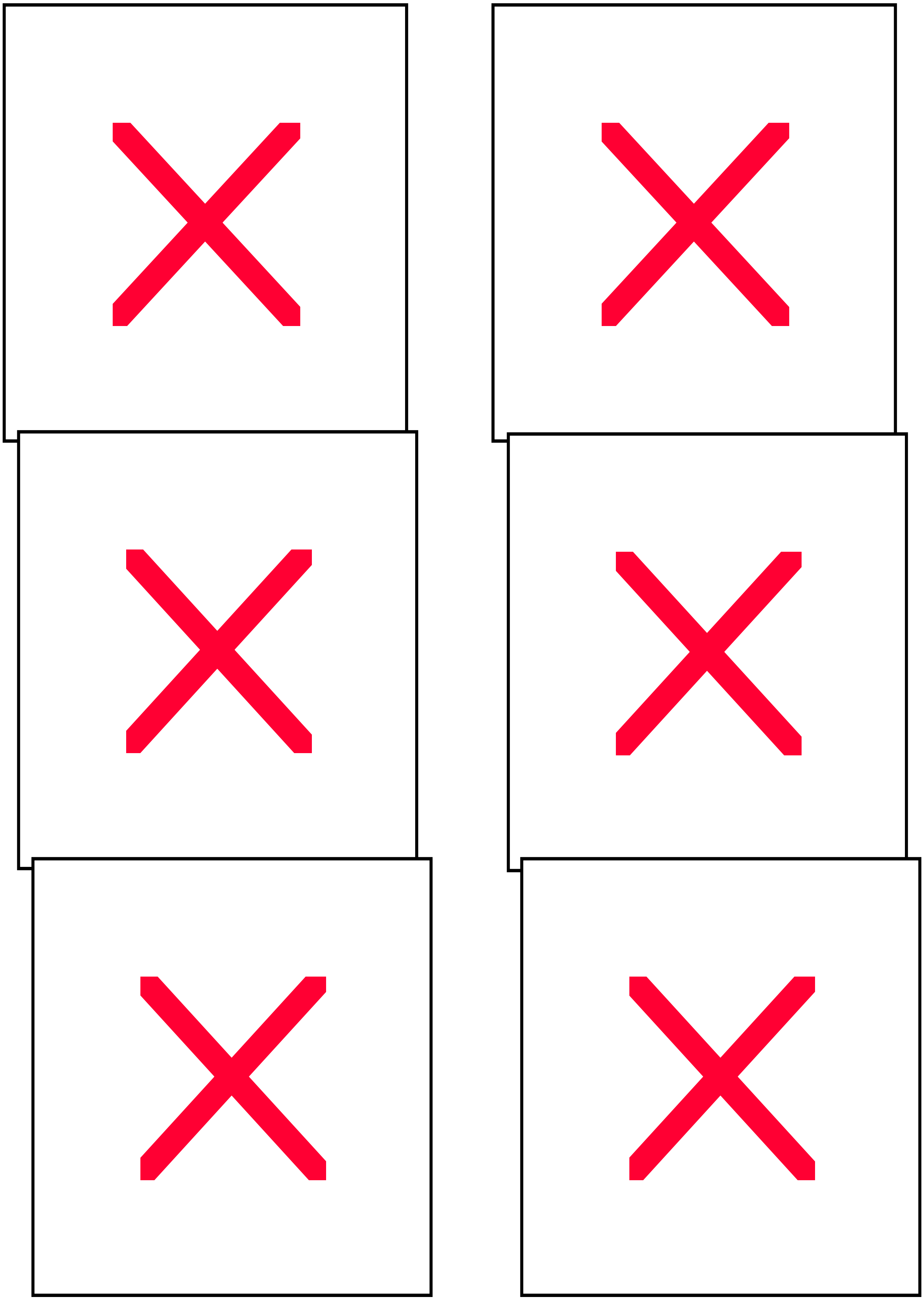


Figure 9. Annual June, July and August Total Phosphorus.

(average LP-1 = 0.003 and LP-2 =0.005 mg/L). 2001 bottom and mid-depth DP concentrations were higher than at the surface. Maximum mid-depth DP concentrations were 0.006 mg/L for both stations averages were identical (0.005 mg/L) as well. Average mid-depth ortho-phosphate for 1991, 1992, and 1995 were 0.016 and 0.030 mg/L for LP-1 and LP-2, respectively. Bottom DP concentrations in 2001 ranged below the 0.001 mg/L detection limit to 0.008 mg/L. Average DP bottom concentrations were 0.004 and 0.003 mg/L for LP-1 and LP-2, respectively. Maximum ortho-phosphate bottom concentrations for 1991, 1992 and 1995 ranged from less than the 0.001 mg/L detection limit to 0.370 mg/L.

Nitrogen is a nutrient that also may be limiting for aquatic organisms such as algae and plants. Nitrogen exists in lakes in many forms. The most important forms of readily absorbable nitrogen are nitrate (NO_3^-) and ammonium (NH_4^+) (Wetzel 1983). Both forms are unlikely to cause water quality problems such as algal blooms at concentrations below 0.3 mg/l, but problems may occur at concentrations above 1 mg/l. Nitrogen was not measured in-lake as part of this investigation. Previous reports suggest that phosphorus is the limiting nutrient in this system and therefore our focus was phosphorus. Nitrogen values reported in previous studies are provided in Appendix B. Maximum values did not exceed the 1.0 mg/L threshold, but did exceed 0.3 mg/L.

Total Kjeldahl nitrogen (TKN) is a measure of ammonium-N and organic nitrogen forms present in the water column. Low (<0.5 mg/l) TKN concentrations are usually indicative of desirable water quality, with problems such as algal blooms unlikely to occur. Concentrations higher than 2 mg/l are indicative of undesirable water quality, with a substantial transition range in between those thresholds. Like nitrate and ammonium nitrogen, TKN was not included in the 2001 investigation. Values of TKN from previous reports can be found on Appendix B. In summary, TKN mean values in Lake Pocotopaug exceeded the "low" threshold at mid and bottom depths. The 2.0 mg/L threshold was exceeded at station LP-m at mid-depth.

While phosphorus usually determines phytoplankton biomass (quantity of suspended algae), the N:P ratio often determines phytoplankton species composition (Wetzel 1983). When N:P is higher than 15:1 (by weight), the water body is typically phosphorus-limited, and green algae (Chlorophyta) are typically favored over blue-greens (Cyanophyta) because of their more efficient phosphorus uptake (Lee 1989). When N:P is lower than 7:1 (by weight), nitrogen limitation occurs, and most blue-greens, which can fix dissolved gaseous nitrogen (N_2), are favored over green algae (Lee 1989). When nutrient levels are high overall, nuisance blue-green blooms are more likely to occur. Intermediate N:P ratios are less conclusive for phytoplankton species composition predictions, but algal species have distinct preferences and the type of algae found is usually a function of nutrient ratios (Tilman 1982).

Using data from previous studies, N:P ratios for Lake Pocotopaug surface waters were 0.5:1 to 188:1, with a median value of 37:1. Mid-depth ratios ranged from 1:1 to 311:1, with a median value of 46:1. Bottom ratios ranged from 1:1 to 182:1, with a median ration of 25:1. Ratios below 7:1 occurred on September 22, 1993 at surface and mid depths and occurred in May, August, and September in 1993 at the bottom.

The trophic state of Lake Pocotopaug, determined as Carlson's (1977) trophic state index (TSI) from July and August SDT, surface TP, and chlorophyll *a* (chl *a*) values was typical of mesotrophic conditions (intermediate nutrient levels) during summer stratification. TSI values higher than 60 are indicative of degraded (eutrophic) conditions, while TSI values below 40 typically apply to oligotrophic lakes (Carlson 1977). Mitchell (2000) proposes a TSI=70 threshold for contact recreation. TSI for all categories were below 60 but above 40.

Using July and August data from 1991-2001, the trophic state of Lake Pocotopaug, as determined from the State of Connecticut Water Quality Standards, is mesotrophic, (intermediate nutrient levels). Table 11 compares Lake Pocotopaug range of means with State Water Quality Standards for mesotrophic conditions.

Table 11. Lake Pocotopaug July and August Range of Annual Means and Water Quality Standards for Mesotrophic Lakes in Connecticut.

	Mesotrophic Standard	Lake Pocotopaug Annual Mean Range (July and August)
TP	10-30 ug/L spring and summer	11-23
TN	200-600 ug/L spring and summer	440
Chl a	2-15 ug/L mid summer	5.5-7.4
SDT	2-6 meters mid summer	0.7-3.5

Dissolved iron provides a measure of the potential of a water body to limit phosphorus internal loading. Ferrous iron (Fe^{++}) is often released from anoxic sediments along with dissolved phosphorus (DP). Ferric iron (Fe^{+++}) is the dominant form of iron in the presence of oxygen, and forms from Fe^{++}. Iron tends to bind with phosphorus during this conversion and, because of low solubility, iron phosphates precipitate to the sediment.

Dissolved iron concentrations just above the water-sediment interface provide a measure of the potential for release of sediment-bound phosphorus and its return to the sediments. Dissolved iron values much higher than 1.0 mg/l are often indicative of substantial redox activity in the sediments, whereby chemical oxidation-reduction reactions can allow certain contaminants to be released from the sediment back into the water column. However, dissolved iron in excess of ten times the DP level is usually sufficient to precipitate out all DP under oxic conditions, so phosphorus released by this mechanism will not necessarily be available for algal uptake and growth.

Dissolved iron concentrations at the water-sediment interface in Lake Pocotopaug was measured in August 2001. Values were low, below the 0.01 mg/L detection limit at both stations and all water depths (Table 10). These low values in the summer suggest a low phosphorus binding capacity in Lake Pocotopaug.

Total and dissolved aluminum were analyzed in 2001 prior to the alum treatment. Total aluminum ranged from 0.036 to 0.794 mg/L. Dissolved aluminum was below the detection limit. Aluminum is not list on the State of Connecticut Water Quality Standard Numerical Criteria, but these values are consider relatively low. In addition, arsenic, cadmium, chromium, copper, nickel, lead, and zinc were analyzed in May 2001. All values were low (Table 10) and suggest no water column metal contamination in Lake Pocotopaug.

6.2 Tributary and Storm Drain Water Quality

2001 water quality data for tributaries and storm drains are presented for both dry and wet weather in Table 12. Data collected in March of 2001 by the CT DHS are included in this summary. Locations of the incoming water stations are given in Figure 6 and Table 9.

Generally, stormwater sampling resulted in higher concentrations with the exception of pH, chloride, hardness, conductivity and nitrate. This may indicate that there are constant sources, which are being diluted during precipitation, and/or precipitation itself (acid rain) is lowering these values.

Table 12. 2001 Dry and Wet Weather Tributary and Storm Drain Data.

		Suspended Solids (mg/L)		Turbidiy (mg/L)		pH (SU)		Alkalinity (mg/L)		Chloride (mg/L)		Hardness (mg/L)		Specific Conductance (us/cm)	
Station		Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
LP-3	Mar	1	16	1.0	10.0	6.5	5.9	10.0	10.0	5	3	10	10		
	May	2	117	1.2		6.5		8.0	12.0	17	20			118	
	Jun	5		0.9		6.7		7.0		16				116	
	Aug	3	9	3.0	5.8	7.2	6.7	18.0	16.0	15				117	104
	Sept		354		110.0		6.5		12.0						79
LP-4	Mar		93		37.0		7.0		10.0		63		32		
	May		260						42.0		31				
	Jun														
	Aug		77		42.0		6.5		11.0						101
	Sept		940		180.0		6.1		10.0						54
LP-5	Mar	4	27	1.4	6.0	6.4	5.9	10.0	21.0	3	1	10	10		
	May	5	81	0.6		6.7		4.0	6.0	5	7			54	
	Jun	5	335	0.9	140.0	6.5		5.0	4.0	5				49	
	Aug	2	2	1.1	1.2	7.2	7.0	8.0	10.0	13				73	73
	Sept	1	54	0.4	73.0	6.7	6.6	9.0	11.0	11				86	67
LP-6	Mar	3	16	0.9	3.5	6.4	6.4	24.0	17.0	10	1	10	10		
	May	7	264	2.4		6.5		8.0	10.0	8	9			45	
	Jun	9	66	1.8	75.0	6.5		4.0	16.0	9				89	
	Aug	6		1.4		6.7		30.0		13				139	
	Sept		36		13.0		6.8		24.0						108
LP-7	Mar	8	11	4.1	3.0	6.2	5.7	10.0	10.0	11	1	10	10		
	May	7	268	5.8		6.5		6.0	6.0	5	10			50	
	Jun	3		1.7		6.1		6.0		8				65	
	Aug														
	Sept		25		16.0		6.3		4.0						58

Table 12 continued. 2001 Dry and Wet Weather Tributary and Storm Drain Data.

		Suspended Solids (mg/L)		Turbidiy (mg/L)		pH (SU)		Alkalinity (mg/L)		Chloride (mg/L)		Hardness (mg/L)		Specific Conductance (us/cm)	
Station		**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**
LP-8	Mar	20	10	6.4	2.3	6.2	5.9	10.0	10.0	13	1	10	10		
	May	12	114	2.2		6.5		6.0	10.0	12	15			43	
	Jun	8	156	1.5	182.0	6.1		3.0	4.0	15				93	
	Aug														
	Sept		80		51.0		6.3		6.0						115
LP-9	Mar														
	May	7	310	0.5		6.4		32.0	8.0	105	24			519	
	Jun		960		770.0				54.0						
	Aug		15		4.9		6.6		42.0						513
	Sept		246		52.0		6.9		28.0						412
LP-10	Mar	1	25	6.0	29.0	6.6	6.5	19.0	25.0	40	15	10	10		
	May	15	1020	11.9		6.3		42.0	26.0	83	26			425	
	Jun	16	498	17.0	690.0	6.3		42.0	22.0	61				347	
	Aug		520		165.0		6.6		24.0						219
	Sept		83		47.0		6.2		8.0						153
LP-11	Mar	3	8	1.9	3.2	6.1	5.8	11.0	18.0	7	1	10	10		
	May	6	35	2.6		6.3		6.0	12.0	14	18			113	
	Jun	4	116	2.7	133.0	6.1		4.0	4.0	11				71	
	Aug														
	Sept		576		210.0		6.7		28.0						165
LP-12	Mar	6	20	3.0	8.0	6.6	6.3	16.0	34.0	180	92	99	57		
	May		526						8.0		9				
	Jun	8		1.5		7.0		7.0		72				357	
	Aug		18		8.1		7.0		12.0						70
	Sept		652		20.0		6.1		9.0						28

Table 12 continued. 2001 Dry and Wet Weather Tributary and Storm Drain Data.

		Suspended Solids (mg/L)		Turbidiy (mg/L)		pH (SU)		Alkalinity (mg/L)		Chloride (mg/L)		Hardness (mg/L)		Specific Conductance (us/cm)	
Station		**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**
LP-13	Mar														
	May		2825						12.0		19				
	Jun	10		0.9		6.8		18.0		47				256	
	Aug		252		6.3		5.9		8.0						52
	Sept														
LP-14	Mar														
	May														
	Jun														
	Aug		120		18.0		6.0		5.0						47
	Sept		796		16.0		6.1		5.0						22
28	Mar	3	13	2.3	5.9	6.3	6.3	42.0	63.0	150	64	100	47		
	May														
	Jun														
	Aug														
	Sept														

Table 12 continued. 2001 Dry and Wet Weather Tributary and Storm Drain Data.

		Ammonium-N (mg/L)		Nitrate-N (mg/L)		TKN (mg/L)		Total Phosphorus (mg/L)		Dissolved Phosphorus (mg/L)	
Station		Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
LP-3	Mar	0.050	0.050	0.50	0.30	0.10	0.10	0.010	0.030	0.005	0.005
	May	0.042	0.010	0.34	0.11	0.22	2.29	0.008	0.196	0.004	0.007
	Jun	0.023		0.15		0.45		0.010		0.004	
	Aug	0.050	0.102	0.13	0.13	0.30	0.38	0.021	0.027	0.014	0.012
	Sept		0.010		0.26		1.16		0.108		0.012
LP-4	Mar		0.050		2.00		0.20		0.100		0.070
	May										
	Jun										
	Aug		0.093		0.33		1.38		0.210		0.104
	Sept		0.098		0.01		0.83		0.196		0.022
LP-5	Mar	0.050	0.050	0.20	0.10	0.10	0.10	0.005	0.300	0.005	0.070
	May	0.005	0.023	0.15	0.05	0.12	0.89	0.008	0.084	0.003	0.006
	Jun	0.025	0.005	0.07	0.01	0.20	0.88	0.009	0.098	0.004	0.006
	Aug	0.010	0.013	0.22	0.29	0.21	0.25	0.008	0.011	0.001	0.001
	Sept	0.014	0.045	0.26	0.24	0.18	0.36	0.003	0.019	0.002	0.011
LP-6	Mar	0.050	0.050	0.30	0.30	0.10	0.20	0.450	0.100	0.005	0.080
	May	0.030	0.023	0.05	0.07	0.25	4.80	0.021	0.590	0.009	0.013
	Jun	0.010	0.010	0.08	0.23	0.36	0.88	0.021	0.255	0.005	0.019
	Aug	0.013		0.07		0.20		0.017		0.005	
	Sept		0.045		0.24		0.54		0.053		0.050
LP-7	Mar	0.050	0.050	0.10	0.05	0.10	0.10	0.080	0.300	0.020	0.060
	May	0.060	0.010	0.03	0.01	0.44	3.05	0.036	0.335	0.010	0.027
	Jun	0.033		0.01		0.39		0.015		0.006	
	Aug										
	Sept		0.170		0.23		0.59		0.047		0.020

Table 12 continued. 2001 Dry and Wet Weather Tributary and Storm Drain Data.

		Ammonium-N (mg/L)		Nitrate-N (mg/L)		TKN (mg/L)		Total Phosphorus (mg/L)		Dissolved Phosphorus (mg/L)	
Station		Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
LP-8	Mar	0.050	0.050	0.50	0.50	0.10	0.10	0.030	0.200	0.020	0.070
	May	0.015	0.010	0.01	0.16	0.21	1.77	0.026	0.137	0.002	0.007
	Jun	0.010	0.011	0.01	0.10	0.28	1.77	0.012	0.203	0.001	0.012
	Aug										
	Sept		0.026		0.63		0.84		0.112		0.027
LP-9	Mar										
	May	0.021	0.113	2.75	0.01	0.18	5.08	0.234	0.770	0.185	0.135
	Jun		0.034		0.26		4.76		1.245		0.028
	Aug		0.039		1.29		0.38		0.063		0.011
	Sept		0.026		0.76		0.22		0.034		0.030
LP-10	Mar	0.050	0.050	0.30	0.05	0.10	0.40	0.260	0.070	0.005	0.005
	May	0.206	0.034	0.29	0.20	0.44	7.80	0.026	1.210	0.007	0.014
	Jun	0.117	0.025	0.15	0.33	0.70	2.96	0.058	1.070	0.016	0.029
	Aug		0.143		0.96		3.66		0.706		0.024
	Sept		0.091		0.61		0.85		0.075		0.070
LP-11	Mar	0.050	0.050	0.05	1.30	0.10	0.50	0.010	0.040	0.005	0.030
	May	0.063	0.091	0.01	0.09	0.56	1.35	0.012	0.084	0.008	0.017
	Jun	0.049	0.011	0.01	0.01	0.79	1.70	0.022	0.196	0.008	0.015
	Aug										
	Sept		0.032		0.40		0.90		0.206		0.040
LP-12	Mar	0.050	0.050	2.10	1.90	0.10	0.40	0.060	0.080	0.030	0.050
	May		0.113		0.01		9.08		0.925		0.031
	Jun	0.049		1.27		0.32		0.013		0.001	
	Aug		0.132		0.51		1.30		0.162		0.095
	Sept		0.072		0.01		0.87		0.079		0.060

Table 12 continued. 2001 Dry and Wet Weather Tributary and Storm Drain Data.

		Ammonium-N (mg/L)		Nitrate-N (mg/L)		TKN (mg/L)		Total Phosphorus (mg/L)		Dissolved Phosphorus (mg/L)	
Station		Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
LP-13	Mar										
	May		0.113		0.01		22.95		3.010		0.012
	Jun	0.035		0.33		0.38		0.007		0.006	
	Aug		0.032		0.12		1.74		0.124		0.014
	Sept										
LP-14	Mar										
	May										
	Jun										
	Aug		0.110		0.40		1.73		0.198		0.041
	Sept		0.032		0.01		0.60		0.120		0.082
28	Mar	0.050	0.050	3.20	0.40	0.10	0.60	0.020	0.090	0.005	0.030
	May										
	Jun										
	Aug										
	Sept										

Table 12 continued. 2001 Dry and Wet Weather Tributary and Storm Drain Data.

		Al (mg/L)		As (mg/L)		Cd (mg/L)		Cr (mg/L)		Cu (mg/L)		Ni (mg/L)		Pb (mg/L)		Zn (mg/L)	
Station		**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**
LP-3	Mar																
	May	0.056	0.854	0.000	0.003	0.000	0.000	0.000	0.001	0.002	0.005	0.000	0.002	0.001	0.007	0.010	0.019
	Jun																
	Aug																
	Sept																
LP-4	Mar																
	May																
	Jun																
	Aug																
	Sept																
LP-5	Mar																
	May	0.055	0.856	0.000	0.001	0.000	0.000	0.000	0.001	0.002	0.004	0.001	0.003	0.001	0.004	0.004	0.014
	Jun																
	Aug																
	Sept																
LP-6	Mar																
	May	0.131	2.220	0.000	0.001	0.000	0.001	0.000	0.002	0.002	0.008	0.001	0.004	0.001	0.014	0.007	0.052
	Jun																
	Aug																
	Sept																
LP-7	Mar																
	May	0.224	3.030	0.000	0.001	0.000	0.001	0.000	0.004	0.002	0.007	0.001	0.004	0.002	0.015	0.010	0.065
	Jun																
	Aug																
	Sept																

Table 12 continued. 2001 Dry and Wet Weather Tributary and Storm Drain Data.

		Al (mg/L)		As (mg/L)		Cd (mg/L)		Cr (mg/L)		Cu (mg/L)		Ni (mg/L)		Pb (mg/L)		Zn (mg/L)	
Station		Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
LP-8	Mar																
	May	0.120	0.960	0.000	0.000	0.000	0.000	0.001	0.001	0.004	0.005	0.000	0.002	0.002	0.005	0.014	0.061
	Jun																
	Aug																
	Sept																
LP-9	Mar																
	May	0.119	5.580	0.000	0.002	0.000	0.001	0.000	0.011	0.004	0.028	0.001	0.010	0.001	0.016	0.027	0.131
	Jun																
	Aug																
	Sept																
LP-10	Mar																
	May	0.110	15.70	0.000	0.005	0.000	0.003	0.000	0.018	0.003	0.043	0.002	0.021	0.001	0.066	0.010	0.143
	Jun																
	Aug																
	Sept																
LP-11	Mar																
	May	0.151	0.488	0.000	0.001	0.000	0.000	0.000	0.001	0.003	0.006	0.002	0.003	0.002	0.005	0.009	0.020
	Jun																
	Aug																
	Sept																
LP-12	Mar																
	May		4.100		0.001		0.000		0.007		0.042		0.011		0.009		0.265
	Jun																
	Aug																
	Sept																

Table 12 continued. 2001 Dry and Wet Weather Tributary and Storm Drain Data.

		Al (mg/L)		As (mg/L)		Cd (mg/L)		Cr (mg/L)		Cu (mg/L)		Ni (mg/L)		Pb (mg/L)		Zn (mg/L)	
Station		**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**
LP-13	Mar																
	May		7.860		0.002		0.001		0.011		0.033		0.020		0.036		0.094
	Jun																
	Aug																
	Sept																
LP-14	Mar																
	May																
	Jun																
	Aug																
	Sept																
28	Mar																
	May																
	Jun																
	Aug																
	Sept																

Suspended solids and turbidity concentrations were substantially higher in wet weather, indicating that sediment loading to Lake Pocotopaug is significant. WMC documented high sediment load and provided a detailed list of procedures with costs to reduce this load in their 1995 report (Appendix C).

pH was moderately to slightly acidic in all tributaries and storm drains. pH ranged from 5.7 to 7.2 SU during dry and wet weather combined. Average, across all stations, was slightly lower during wet weather, likely due to acid precipitation. Alkalinity was slightly higher in wet weather (average 14 vs 16 mg/L in dry and wet conditions, respectively).

Chloride, hardness and conductivity were slightly lower in wet weather; average chloride values were 32 to 20 mg/L (dry and wet, respectively), average hardness were 30 to 21 mg/L (dry and wet, respectively), and average conductivity were 154 and 128 mg/L (dry and wet, respectively). These lower values during wet conditions suggest a constant load from the watershed that is being diluted during precipitation.

Nutrients, for the most part, were higher during wet weather than during dry conditions on average in 2001. Ammonium and TKN concentrations were generally higher during precipitation events. However, nitrate was lower on average. TKN was the only nitrogen variable that was substantially different in dry verses wet weather in 2001 (average 0.27 and 2.0 mg/L during dry and wet weather respectively). Total and dissolved phosphorus values were significantly higher ($P< 0.005$) during wet weather. Wet weather TP concentrations ranged from 0.01 to 3.01 mg/L; DP wet weather concentrations ranged from 0.001 to 0.135 mg/L. Average dry weather TP and DP concentrations were 0.050 and 0.013 mg/L. Average wet weather TP and TP concentrations were 0.317 and 0.035 mg/L, respectively.

Dry weather metal concentrations were generally low. Concentrations increased for the most part during wet weather. Aluminum concentrations ranged from 0.06 to 15.7 mg/L. Cadmium, copper, lead and zinc exceed the State of Connecticut Water Quality Standards for Acute Toxicity to Freshwater Aquatic Life during wet weather conditions. Arsenic, chromium and nickel were below the state standards.

6.3 In-Lake Biology

6.3.1 Phytoplankton

The phytoplankton of Lake Pocotopaug were sampled and analyzed monthly from April through December 2001, with samples collected from two stations. From April through September samples were collected as a composite of the epilimnetic waters (roughly the upper 20 ft), while two discrete samples were collected near the surface and at the Secchi depth in October through December. Samples were preserved in Lugol's solution, concentrated by settling, and viewed in a Palmer Maloney counting chamber at 400x under phase optics. Phytoplankton were identified to genus and enumerated as cells/ml (Table 13). Conversion to biomass was based on cell size, cell shape, and a specific gravity of 1.0 (Table 14).

The phytoplankton of Lake Pocotopaug in 2001 were fairly typical of high mesotrophic to low eutrophic lakes in New England (Tables 13 and 14, Figures 10 and 11). The phosphorus inactivation treatment performed in 2001 may have affected composition and density somewhat, but the general phytoplankton features of 2001 do not appear radically altered from earlier years. Furthermore, the pattern was quite similar among the two stations. Overall algal biomass was moderate (>1000 but <10,000 ug/L) except in the August samples, and was usually between 3000 and 7000 ug/L. This quantity of algae will impart color and turbidity to the lake, but not at a level that makes it unappealing for contact recreation. Since algae form the base of the aquatic food web and Lake Pocotopaug has a desirable fishery that depends on energy derived indirectly from algae, algal density on most dates would be considered acceptable and appropriate to all lake uses. It is only the August bloom, at about 16,000 ug/L, that presents a major concern.

Spring phytoplankton assemblages were dominated by Bacillariophyta (diatoms) and Chrysophyta (golden algae), both cold water forms that produce a brownish color in the water but are not harmful to people. In fact, these algae are an excellent food source for zooplankton, which in turn are consumed by small fish. The diatom-golden assemblage continues through June, but is replaced by blue-greens in July. Blue-green algae are actually photosynthetically active bacteria, and are more properly called Cyanobacteria, but they are commonly included with algae in plankton analyses. Blue-greens occur in a wide range of conditions, but are the group most often responsible for dense blooms, foul odors, and sometimes illness (e.g., rashes, gastroenteritis). They often become nuisances in warm, nutrient-rich waters. Although dominant in July through September, blue-greens did not produce excessive biomass until late August, and declined by mid-September. The primary blue-green genera were *Anabaena* and *Lyngbya*, with several species of the former detected.

In October the assemblage was mixed, with diatoms and cryptomonads (small flagellates) at moderate densities, lower densities of golden algae and blue-greens, and traces of green algae and euglenoids. There was no appreciable difference among stations or water depths. Golden and green algae were more abundant in November, and overall biomass declined somewhat. Golden algae were most abundant in the December samples, with a similar biomass to that observed in November at LP-1 and a higher biomass at LP-2. The pattern of water clarity may differ from algal biomass with shifts in algal composition. The transition to dominance by golden algae over the fall could be expected to result in higher water clarity, even without a major change in biomass, as particle size and pigment composition greatly affects water clarity.

Table 13. 2001 Phytoplankton Density.

	PHYTOPLANKTON DENSITY (CELLS/ML)											
	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2
TAXON	4/26/01	4/26/01	5/17/01	5/17/01	6/13/01	6/13/01	7/23/01	7/23/01	8/23/01	8/23/01	9/20/01	9/20/01
BACILLARIOPHYTA												
Achnanthes	0	0	0	0	0	0	0	34	0	0	0	0
Amphora	0	0	0	0	0	0	0	0	41	0	0	0
Asterionella	4200	1653	680	342	0	63	44	68	0	0	0	0
Cyclotella	504	348	136	90	0	42	0	34	0	0	0	0
Cymbella	0	87	17	0	21	21	0	0	0	0	0	0
Eunotia	0	0	0	0	0	0	0	0	0	0	0	0
Fragilaria	0	0	0	0	0	0	0	0	0	0	0	0
Gomphonema	84	0	0	0	0	0	0	0	0	0	0	0
Melosira	1260	957	102	234	588	294	352	68	82	371	1080	580
Navicula	84	87	34	18	21	21	44	34	0	0	0	29
Nitzschia	0	87	17	18	0	21	44	34	0	0	0	0
Pinnularia	0	0	0	0	0	0	0	0	0	0	0	0
Rhizosolenia	0	0	0	0	0	0	44	0	0	0	0	0
Stauroneis	0	0	0	0	0	0	0	0	0	0	0	0
Stephanodiscus	168	174	289	252	21	21	0	0	0	0	0	0
Surirella	0	0	0	0	0	0	0	0	0	0	0	0
Synedra	84	348	17	0	0	0	0	0	41	53	54	29
Tabellaria	0	87	221	414	294	336	308	34	164	318	216	116
CHLOROPHYTA												
Ankistrodesmus	0	0	0	0	0	0	0	0	0	0	0	0
Botryococcus	0	0	0	0	168	0	0	0	0	0	0	0
Carteria	0	0	0	0	0	0	0	34	0	0	0	0
Closteriopsis	0	0	34	18	21	21	44	34	0	0	0	0
Cosmarium	84	0	17	18	0	0	44	0	0	0	0	0
Crucigenia	0	0	0	0	0	0	0	0	0	0	0	0
Dictyosphaerium	0	0	0	0	336	168	0	0	0	0	0	0

Table 13 continued. 2001 Phytoplankton Density.

PHYTOPLANKTON DENSITY (CELLS/ML)												
	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2
TAXON	4/26/01	4/26/01	5/17/01	5/17/01	6/13/01	6/13/01	7/23/01	7/23/01	8/23/01	8/23/01	9/20/01	9/20/01
CHLOROPHYTA												
Elakatothrix	0	0	0	0	210	189	0	0	0	0	27	29
Golenkinia	0	0	0	0	0	0	0	0	0	0	27	0
Kirchneriella	0	0	0	0	42	0	0	0	0	0	0	0
Micractinium	0	0	0	0	0	0	0	0	82	0	0	0
Oocystis	0	0	136	0	42	0	0	0	0	0	108	0
Pediastrum	0	0	0	0	0	0	0	0	0	0	162	0
Quadrigula	0	0	0	0	0	0	0	0	0	0	0	0
Scenedesmus	336	0	68	36	84	84	0	0	0	0	0	174
Schroederia	0	0	0	0	21	21	0	0	41	0	0	0
Sphaerocystis	0	0	0	72	42	0	0	0	328	212	0	232
Staurastrum	0	0	0	0	0	0	0	0	41	53	0	0
Staurodesmus	0	87	34	36	21	42	0	0	41	53	0	0
CHRYSOPHYTA												
Centritractus	0	0	0	0	21	42	0	0	0	0	0	0
Dinobryon	1008	1131	102	108	987	714	308	204	0	0	0	0
Mallomonas	84	87	0	0	0	0	0	0	0	0	0	29
Ochromonas	0	0	0	0	147	84	308	170	0	0	0	0
Synura	0	0	0	0	0	0	0	0	0	0	0	0
Flagellated coccoid golden	0	0	0	0	0	0	0	0	0	0	0	0
CRYPTOPHYTA												
Cryptomonas	0	0	289	108	63	63	176	136	82	53	54	29
CYANOPHYTA												
Anabaena spp.	0	0	476	144	2016	6720	14520	9520	7380	2120	810	1740
Anabaena aphanizomenoides	0	0	0	0	210	0	6600	12240	61500	89040	9720	11600
Aphanizomenon	0	0	0	0	0	0	0	0	0	0	0	0

Table 13 continued. 2001 Phytoplankton Density.

	PHYTOPLANKTON DENSITY (CELLS/ML)											
	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2
TAXON	4/26/01	4/26/01	5/17/01	5/17/01	6/13/01	6/13/01	7/23/01	7/23/01	8/23/01	8/23/01	9/20/01	9/20/01
CYANOPHYTA												
Aphanocapsa	0	0	0	0	0	0	0	0	0	0	0	4060
Chroococcus	0	0	0	144	0	84	0	0	0	0	0	0
Dactylococcopsis	0	0	0	0	0	0	44	34	0	0	0	0
Lyngbya limnetica	0	0	0	0	0	0	29040	52360	280440	196100	18360	20010
Microcystis	0	0	0	0	0	0	0	0	0	0	0	0
Oscillatoria	0	0	0	0	0	0	0	0	0	0	0	0
EUGLENOPHYTA												
Trachelomonas	0	0	0	0	21	0	0	0	41	53	27	29
PYRRHOPHYTA												
Ceratium	0	0	17	18	11	11	22	34	0	0	0	0
Peridinium	0	0	0	0	0	0	0	0	0	0	0	29
RHODOPHYTA												

Table 13 continued. 2001 Phytoplankton Density.

PHYTOPLANKTON DENSITY (CELLS/ML)												
	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2
TAXON	4/26/01	4/26/01	5/17/01	5/17/01	6/13/01	6/13/01	7/23/01	7/23/01	8/23/01	8/23/01	9/20/01	9/20/01
SUMMARY STATISTICS												
DENSITY (#/ML)												
BACILLARIOPHYTA	6384	3828	1513	1368	945	819	836	306	328	742	1350	754
CHLOROPHYTA	420	87	289	180	987	525	88	68	533	318	324	435
CHRYSOPHYTA	1092	1218	102	108	1155	840	616	374	0	0	0	29
CRYPTOPHYTA	0	0	289	108	63	63	176	136	82	53	54	29
CYANOPHYTA	0	0	476	288	2226	6804	50204	74154	349320	287260	28890	37410
EUGLENOPHYTA	0	0	0	0	21	0	0	0	41	53	27	29
PYRRHOPHYTA	0	0	17	18	11	11	22	34	0	0	0	29
RHODOPHYTA	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL PHYTOPLANKTON	7896	5133	2686	2070	5408	9062	51942	75072	350304	288426	30645	38715
TAXONOMIC RICHNESS												
BACILLARIOPHYTA	7	9	9	7	5	8	6	7	4	3	3	4
CHLOROPHYTA	2	1	5	5	10	6	2	2	5	3	4	3
CHRYSOPHYTA	2	2	1	1	3	3	2	2	0	0	0	1
CRYPTOPHYTA	0	0	1	1	1	1	1	1	1	1	1	1
CYANOPHYTA	0	0	1	2	2	2	4	4	3	3	3	4
EUGLENOPHYTA	0	0	0	0	1	0	0	0	1	1	1	1
PYRRHOPHYTA	0	0	1	1	1	1	1	1	0	0	0	1
RHODOPHYTA	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL PHYTOPLANKTON	11	12	18	17	23	21	16	17	14	11	12	15
S-W DIVERSITY INDEX	0.66	0.83	1.00	1.04	0.92	0.51	0.49	0.39	0.26	0.30	0.44	0.54
EVENNESS INDEX	0.64	0.77	0.80	0.85	0.68	0.39	0.41	0.32	0.22	0.29	0.41	0.46

Table 13 continued. 2001 Phytoplankton Density.

	PHYTOPLANKTON DENSITY (CELLS/ML)											
	LP-1 (0.2m)	LP-1 (1.5m)	LP-2 (0.2m)	LP-2 (1.5m)	LP-1 (0.2m)	LP-1 (2.8m)	LP-2 (0.2m)	LP-2 (2.6m)	LP-1 (0.2m)	LP-1 (2.6m)	LP-2 (0.2m)	LP-2 (2.3m)
TAXON	**10/31/01**	**10/31/01**	**10/31/01**	**10/31/01**	**11/27/01**	**11/27/01**	**11/27/01**	**11/27/01**	**12/28/01**	**12/28/01**	**12/28/01**	**12/28/01**
BACILLARIOPHYTA												
Achnanthes	0	0	0	0	0	0	0	0	0	0	0	0
Amphora	0	29	0	0	0	0	0	0	0	0	0	0
Asterionella	0	174	48	32	30	150	135	54	0	352	0	63
Cyclotella	0	58	24	0	90	75	27	0	0	0	0	0
Cymbella	26	0	0	0	0	0	0	0	0	0	0	0
Eunotia	0	0	0	0	0	38	0	0	0	0	0	0
Fragilaria	26	58	24	16	0	0	27	0	0	0	0	0
Gomphonema	0	29	0	0	0	0	0	0	0	0	0	0
Melosira	468	290	144	160	0	0	0	54	132	0	0	0
Navicula	26	29	24	16	30	0	0	27	0	0	0	0
Nitzschia	26	29	24	16	0	0	0	81	88	0	0	0
Pinnularia	0	29	0	0	0	0	0	27	0	0	0	0
Rhizosolenia	0	0	0	0	0	0	0	0	0	0	0	0
Stauroneis	13	0	0	0	0	0	0	0	0	0	0	0
Stephanodiscus	78	0	24	0	0	0	0	0	0	0	51	63
Surirella	0	0	5	0	0	0	0	0	9	0	0	0
Synedra	0	29	0	16	30	0	0	27	0	88	102	63
Tabellaria	1014	377	1272	928	180	150	108	81	88	352	561	378
CHLOROPHYTA												
Ankistrodesmus	0	0	0	32	0	0	0	0	0	0	0	0
Botryococcus	0	0	0	0	0	0	0	0	0	0	0	0
Carteria	0	0	0	0	0	0	0	0	0	0	0	0
Closteriopsis	0	0	0	0	30	0	0	0	0	0	0	0
Cosmarium	0	29	0	0	0	0	0	0	0	0	0	0
Crucigenia	0	58	0	0	0	0	0	0	0	0	0	0
Dictyosphaerium	0	0	0	0	0	0	0	0	0	0	0	252

Table 13 continued. 2001 Phytoplankton Density.

	PHYTOPLANKTON DENSITY (CELLS/ML)											
	LP-1 (0.2m)	LP-1 (1.5m)	LP-2 (0.2m)	LP-2 (1.5m)	LP-1 (0.2m)	LP-1 (2.8m)	LP-2 (0.2m)	LP-2 (2.6m)	LP-1 (0.2m)	LP-1 (2.6m)	LP-2 (0.2m)	LP-2 (2.3m)
TAXON	**10/31/01**	**10/31/01**	**10/31/01**	**10/31/01**	**11/27/01**	**11/27/01**	**11/27/01**	**11/27/01**	**12/28/01**	**12/28/01**	**12/28/01**	**12/28/01**
CHLOROPHYTA												
Elakatothrix	52	29	24	32	60	150	0	108	88	88	102	0
Golenkinia	0	0	0	0	0	0	0	0	0	0	0	0
Kirchneriella	0	0	0	0	0	0	0	0	0	0	0	0
Micractinium	0	0	0	0	0	0	0	0	0	0	0	0
Oocystis	104	116	0	0	0	0	0	0	0	0	0	0
Pediastrum	0	0	0	0	0	0	0	0	0	0	0	0
Quadrigula	208	116	96	224	0	0	0	0	0	0	0	0
Scenedesmus	0	0	48	0	0	0	54	0	0	0	0	0
Schroederia	0	0	0	0	30	150	27	27	0	88	0	63
Sphaerocystis	208	232	192	0	5760	3900	432	5184	1056	704	408	756
Staurastrum	0	29	0	0	0	0	0	27	0	0	0	0
Staurodesmus	0	0	24	0	0	0	0	27	0	0	0	0
CHRYSOPHYTA												
Centritractus	0	0	0	0	0	0	0	0	0	0	0	63
Dinobryon	52	116	48	16	60	75	27	27	220	264	51	63
Mallomonas	130	116	96	192	0	0	54	27	1408	1760	1275	2331
Ochromonas	208	319	264	208	150	2025	1809	2484	2376	2200	3978	1953
Synura	0	0	0	0	30	0	27	27	44	44	0	0
Flagellated coccoid golden	0	0	0	0	630	0	81	54	132	132	255	126
CRYPTOPHYTA												
Cryptomonas	1092	1885	888	1088	90	675	189	378	572	440	867	882
CYANOPHYTA												
Anabaena spp.	0	0	240	0	0	0	0	0	0	0	0	0
Anabaena aphanizomenoides	1300	870	960	608	0	0	0	0	0	0	0	0

Table 13 continued. 2001 Phytoplankton Density.

PHYTOPLANKTON DENSITY (CELLS/ML)												
	LP-1 (0.2m)	LP-1 (1.5m)	LP-2 (0.2m)	LP-2 (1.5m)	LP-1 (0.2m)	LP-1 (2.8m)	LP-2 (0.2m)	LP-2 (2.6m)	LP-1 (0.2m)	LP-1 (2.6m)	LP-2 (0.2m)	LP-2 (2.3m)
TAXON	**10/31/01**	**10/31/01**	**10/31/01**	**10/31/01**	**11/27/01**	**11/27/01**	**11/27/01**	**11/27/01**	**12/28/01**	**12/28/01**	**12/28/01**	**12/28/01**
CYANOPHYTA												
Aphanizomenon	1040	0	600	160	0	0	0	0	0	0	0	0
Aphanocapsa	0	0	960	0	0	0	0	0	0	0	0	0
Chroococcus	0	0	0	0	0	0	0	0	0	0	0	0
Dactylococcopsis	26	0	0	0	0	0	0	0	0	0	0	0
Lyngbya limnetica	2600	0	0	0	0	1500	1080	540	880	0	0	0
Microcystis	1300	0	720	1280	0	0	0	0	0	0	0	0
Oscillatoria	520	1160	960	640	0	0	0	0	0	0	1020	0
EUGLENOPHYTA												
Trachelomonas	52	29	72	16	60	0	27	0	0	44	0	0
PYRRHOPHYTA												
Ceratium	0	0	0	0	0	0	0	0	0	0	0	0
Peridinium	0	0	0	0	0	0	0	0	0	0	0	0
RHODOPHYTA												

Table 13 continued. 2001 Phytoplankton Density.

PHYTOPLANKTON DENSITY (CELLS/ML)												
	LP-1 (0.2m)	LP-1 (1.5m)	LP-2 (0.2m)	LP-2 (1.5m)	LP-1 (0.2m)	LP-1 (2.8m)	LP-2 (0.2m)	LP-2 (2.6m)	LP-1 (0.2m)	LP-1 (2.6m)	LP-2 (0.2m)	LP-2 (2.3m)
TAXON	10/31/01	10/31/01	10/31/01	10/31/01	11/27/01	11/27/01	11/27/01	11/27/01	12/28/01	12/28/01	12/28/01	12/28/01
SUMMARY STATISTICS												
DENSITY (#/ML)												
BACILLARIOPHYTA	1677	1131	1589	1184	360	413	297	351	317	792	714	567
CHLOROPHYTA	572	609	384	288	5880	4200	513	5373	1144	880	510	1071
CHRYSOPHYTA	390	551	408	416	870	2100	1998	2619	4180	4400	5559	4536
CRYPTOPHYTA	1092	1885	888	1088	90	675	189	378	572	440	867	882
CYANOPHYTA	6786	2030	4440	2688	0	1500	1080	540	880	0	1020	0
EUGLENOPHYTA	52	29	72	16	60	0	27	0	0	44	0	0
PYRRHOPHYTA	0	0	0	0	0	0	0	0	0	0	0	0
RHODOPHYTA	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL PHYTOPLANKTON	10569	6235	7781	5680	7260	8888	4104	9261	7093	6556	8670	7056
TAXONOMIC RICHNESS												
BACILLARIOPHYTA	8	11	9	7	5	4	4	7	4	3	3	4
CHLOROPHYTA	4	7	5	3	4	3	3	5	2	3	2	3
CHRYSOPHYTA	3	3	3	3	4	2	5	5	5	5	4	5
CRYPTOPHYTA	1	1	1	1	1	1	1	1	1	1	1	1
CYANOPHYTA	6	2	6	4	0	1	1	1	1	0	1	0
EUGLENOPHYTA	1	1	1	1	1	0	1	0	0	1	0	0
PYRRHOPHYTA	0	0	0	0	0	0	0	0	0	0	0	0
RHODOPHYTA	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL PHYTOPLANKTON	23	25	25	19	15	11	15	19	13	13	11	13
S-W DIVERSITY INDEX	1.03	1.00	1.09	0.95	0.40	0.68	0.73	0.59	0.82	0.83	0.74	0.79
EVENNESS INDEX	0.75	0.72	0.78	0.74	0.34	0.66	0.62	0.46	0.74	0.74	0.71	0.71

Table 14. 2001 Phytoplankton Biomass

	PHYTOPLANKTON BIOMASS (UG/L)											
	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2
TAXON	4/26/01	4/26/01	5/17/01	5/17/01	6/13/01	6/13/01	7/23/01	7/23/01	8/23/01	8/23/01	9/20/01	9/20/01
BACILLARIOPHYTA												
Achnanthes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.4	0.0	0.0	0.0	0.0
Amphora	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	57.4	0.0	0.0	0.0
Asterionella	840.0	330.6	136.0	68.4	0.0	12.6	8.8	13.6	0.0	0.0	0.0	0.0
Cyclotella	655.2	452.4	176.8	95.4	0.0	4.2	0.0	3.4	0.0	0.0	0.0	0.0
Cymbella	0.0	87.0	17.0	0.0	21.0	21.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunotia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fragilaria	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gomphonema	84.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Melosira	378.0	287.1	30.6	70.2	176.4	88.2	105.6	20.4	24.6	111.3	324.0	174.0
Navicula	42.0	43.5	17.0	9.0	10.5	10.5	22.0	17.0	0.0	0.0	0.0	14.5
Nitzschia	0.0	69.6	13.6	14.4	0.0	16.8	35.2	27.2	0.0	0.0	0.0	0.0
Pinnularia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rhizosolenia	0.0	0.0	0.0	0.0	0.0	0.0	52.8	0.0	0.0	0.0	0.0	0.0
Stauroneis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stephanodiscus	1176.0	1218.0	2023.0	1764.0	147.0	147.0	0.0	0.0	0.0	0.0	0.0	0.0
Surirella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Synedra	67.2	278.4	13.6	0.0	0.0	0.0	0.0	0.0	32.8	42.4	432.0	23.2
Tabellaria	0.0	69.6	176.8	331.2	235.2	268.8	246.4	27.2	131.2	254.4	172.8	92.8
CHLOROPHYTA												
Ankistrodesmus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Botryococcus	0.0	0.0	0.0	0.0	33.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carteria	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.6	0.0	0.0	0.0	0.0
Closteriopsis	0.0	0.0	17.0	9.0	10.5	10.5	22.0	17.0	0.0	0.0	0.0	0.0
Cosmarium	67.2	0.0	13.6	14.4	0.0	0.0	35.2	0.0	0.0	0.0	0.0	0.0
Crucigenia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dictyosphaerium	0.0	0.0	0.0	0.0	33.6	16.8	0.0	0.0	0.0	0.0	0.0	0.0
Elakatothrix	0.0	0.0	0.0	0.0	21.0	18.9	0.0	0.0	0.0	0.0	5.4	5.8

Table 14 continued. 2001 Phytoplankton Biomass

PHYTOPLANKTON BIOMASS (UG/L)												
	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2
TAXON	4/26/01	4/26/01	5/17/01	5/17/01	6/13/01	6/13/01	7/23/01	7/23/01	8/23/01	8/23/01	9/20/01	9/20/01
CHLOROPHYTA												
Golenkinia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.4	0.0
Kirchneriella	0.0	0.0	0.0	0.0	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Micractinium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	246.0	0.0	0.0	0.0
Oocystis	0.0	0.0	54.4	0.0	16.8	0.0	0.0	0.0	0.0	0.0	43.2	0.0
Pediastrum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.4	0.0
Quadrigula	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scenedesmus	33.6	0.0	6.8	3.6	8.4	8.4	0.0	0.0	0.0	0.0	0.0	17.4
Schroederia	0.0	0.0	0.0	0.0	52.5	52.5	0.0	0.0	102.5	0.0	0.0	0.0
Sphaerocystis	0.0	0.0	0.0	14.4	8.4	0.0	0.0	0.0	65.6	42.4	0.0	46.4
Staurastrum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.8	42.4	0.0	0.0
Staurodesmus	0.0	52.2	20.4	21.6	12.6	25.2	0.0	0.0	24.6	31.8	0.0	0.0
CHRYSOPHYTA												
Centritractus	0.0	0.0	0.0	0.0	12.6	25.2	0.0	0.0	0.0	0.0	0.0	0.0
Dinobryon	3024.0	3393.0	306.0	324.0	2961.0	2142.0	924.0	612.0	0.0	0.0	0.0	0.0
Mallomonas	42.0	43.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	116.0
Ochromonas	0.0	0.0	0.0	0.0	7.4	4.2	15.4	8.5	0.0	0.0	0.0	0.0
Synura	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Flagellated coccoid golden	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CRYPTOPHYTA												
Cryptomonas	0.0	0.0	462.4	172.8	42.0	71.4	158.4	122.4	73.8	84.8	86.4	46.4
CYANOPHYTA												
Anabaena spp.	0.0	0.0	95.2	28.8	403.2	1344.0	2904.0	1904.0	1476.0	424.0	162.0	348.0
Anabaena aphanizomenoides	0.0	0.0	0.0	0.0	27.3	0.0	858.0	1591.2	7995.0	11575.2	1263.6	1508.0
Aphanizomenon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aphanocapsa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40.6

Table 14 continued. 2001 Phytoplankton Biomass

PHYTOPLANKTON BIOMASS (UG/L)												
	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2
TAXON	4/26/01	4/26/01	5/17/01	5/17/01	6/13/01	6/13/01	7/23/01	7/23/01	8/23/01	8/23/01	9/20/01	9/20/01
Chroococcus	0.0	0.0	0.0	57.6	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0
Dactylococcopsis	0.0	0.0	0.0	0.0	0.0	0.0	1.3	1.0	0.0	0.0	0.0	0.0
CYANOPHYTA												
Lyngbya limnetica	0.0	0.0	0.0	0.0	0.0	0.0	580.8	1047.2	5608.8	3922.0	367.2	400.2
Microcystis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oscillatoria	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EUGLENOPHYTA												
Trachelomonas	0.0	0.0	0.0	0.0	21.0	0.0	0.0	0.0	41.0	53.0	27.0	29.0
PYRRHOPHYTA												
Ceratium	0.0	0.0	295.8	313.2	182.7	182.7	382.8	591.6	0.0	0.0	0.0	0.0
Peridinium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	60.9
RHODOPHYTA												
SUMMARY STATISTICS												
BIOMASS (UG/L)												
BACILLARIOPHYTA	3242.4	2836.2	2604.4	2352.6	590.1	569.1	470.8	112.2	246.0	408.1	928.8	304.5
CHLOROPHYTA	100.8	52.2	112.2	63.0	201.6	132.3	57.2	30.6	471.5	116.6	86.4	69.6
CHRYSOPHYTA	3066.0	3436.5	306.0	324.0	2981.0	2171.4	939.4	620.5	0.0	0.0	0.0	116.0
CRYPTOPHYTA	0.0	0.0	462.4	172.8	42.0	71.4	158.4	122.4	73.8	84.8	86.4	46.4
CYANOPHYTA	0.0	0.0	95.2	86.4	430.5	1344.8	4344.1	4543.4	15079.8	15921.2	1792.8	2296.8
EUGLENOPHYTA	0.0	0.0	0.0	0.0	21.0	0.0	0.0	0.0	41.0	53.0	27.0	29.0
PYRRHOPHYTA	0.0	0.0	295.8	313.2	182.7	182.7	382.8	591.6	0.0	0.0	0.0	60.9
RHODOPHYTA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL PHYTOPLANKTON	6409.2	6324.9	3876.0	3312.0	4448.9	4471.7	6352.7	6020.7	15912.1	16583.7	2921.4	2923.2

Figure 10. 2001 Phytoplankton Biomass for LP-1

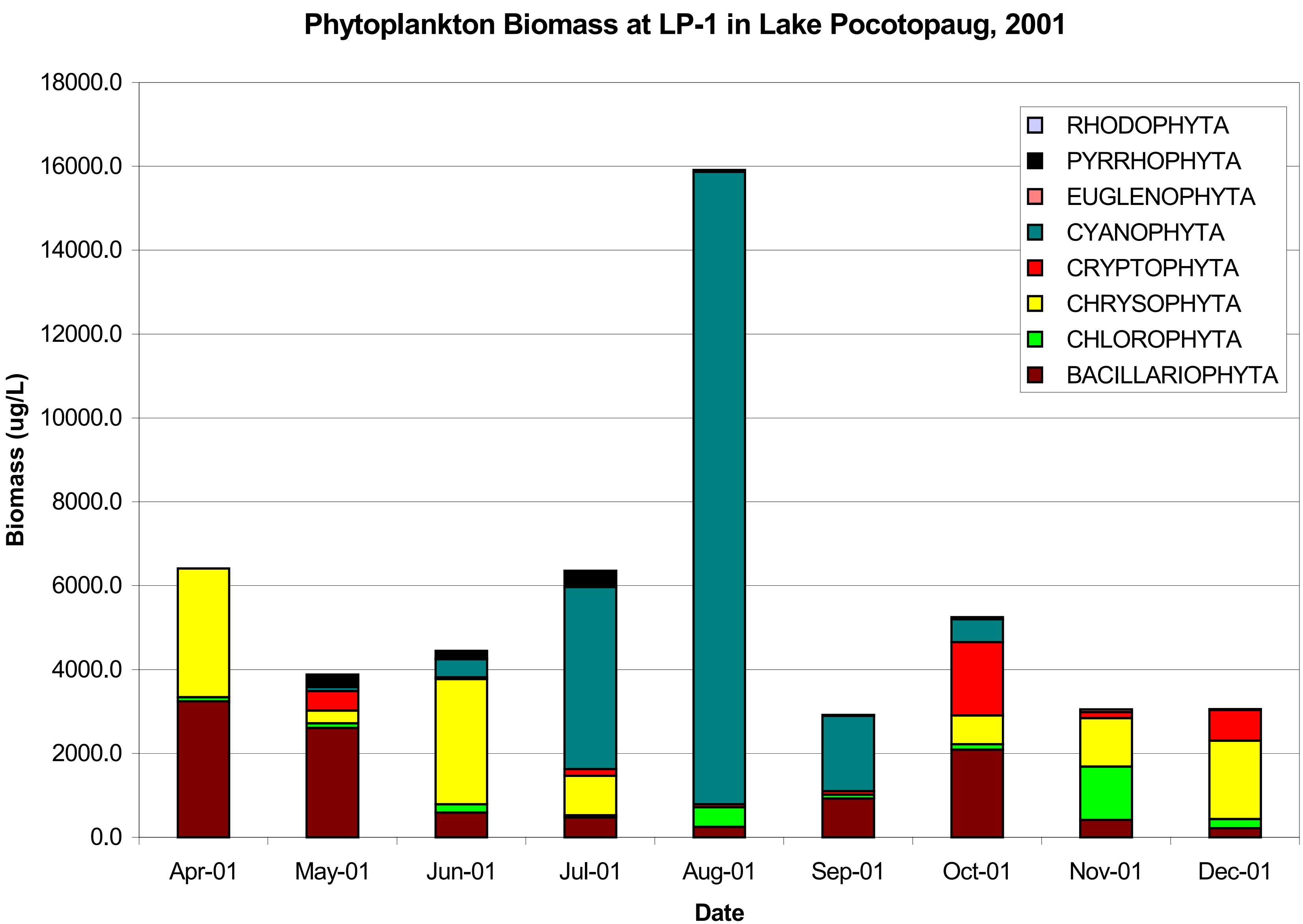
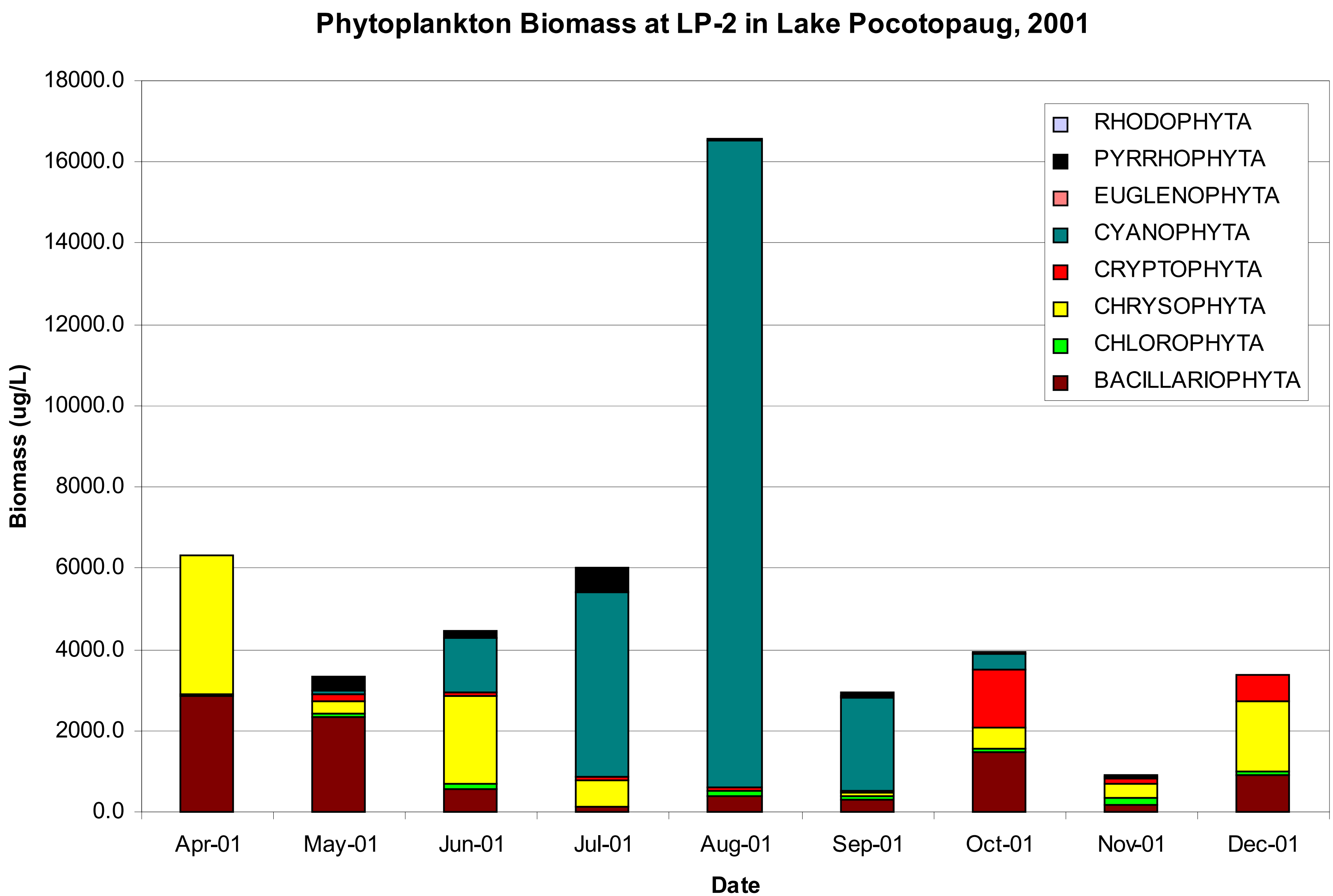


Figure 11. 2001 Phytoplankton Biomass for LP-2



The late summer bloom of blue-greens is consistent with conditions in past years. Water clarity was higher for longer in the summer than in most recent years, but the eventual decline to levels undesirable for contact recreation suggests that the successful inactivation of phosphorus in deeper sediments of the lake is not the whole answer to controlling algae in Lake Pocotopaug.

Hypolimnetic phosphorus levels were indeed very low in 2001, and epilimnetic phosphorus concentrations rarely >10 ug/L, but the bloom still occurred. This is an unusual phenomenon in southern New England lakes and warrants further investigation.

It has been hypothesized that a bloom of toxic golden algae in the fall of 1999 was responsible for the fish kill of late 1999 and early 2000. It is assumed that an increase in clarity corresponded to a die off of those algae, with release of the toxin into the water. Although plausible, this scenario does not appear to be consistent with observed 2001 conditions. No haptophytes were found in the Pocotopaug samples collected in the fall and early winter of 2001. Even if those specific types of golden algae known to be potentially toxic are present in Lake Pocotopaug, the densities observed in 2001 appear too low to elicit a toxic response by fish. Fish did again school up at the mouths of tributaries to the lake, and there was a noticeable increase in clarity in December, but the increase in clarity corresponds to a shift to greater dominance by non-haptophyte golden algae. It is possible that algae bloomed and died off between the November and December sampling dates, but this is highly speculative.

6.3.2 Chlorophyll a

Chlorophyll a samples were collected utilizing the same methods as phytoplakton. However, chlorophyll a samples were taken from April to September only.

Chlorophyll is the green pigment in plants, with chlorophyll *a* common to all plants and often used as a surrogate for biomass or primary production potential in aquatic environments. Values <1 µg/l are hardly detectable to human eyes, while values >10 µg/l usually impart some color to the water. Values >20 µg/l are often associated with undesirable conditions, with levels >100 µg/l often described as appearing like a “paint spill” or “pea soup”. Chlorophyll breaks down into other pigments that can be measured, with phaeophytin usually taken as an indicator of dying algae. Even a healthy algae community will have some phaeophytin, but it should be a minor component of the total chlorophyll concentration.

Total chlorophyll *a* concentration in Lake Pocotopaug ranged from 1.5 to 14.8 µg/l with an average of 6.0 and 5.5 µg/l for LP-1 and LP-2, respectively (Table 10). Most of this pigment was active, healthy chlorophyll. As seen in the past, nuisance levels of phytoplankton exist at chlorophyll levels below the 20 ug/L threshold in Lake Pocotopaug. Values at peak phytoplankton biomass were between 6 and 11 ug/L. Therefore Wetzel’s (1983) cutoff value of 4 µg/l for overfertilized (eutrophic) systems is a more appropriate target for mean chlorophyll levels in Lake Pocotopaug than the 10 ug/L threshold. This represents enough of a food base to support a thriving fishery but not enough to present any aesthetic or safety issues for swimmers and boaters.

6.3.3 Zooplankton

The zooplankton of Lake Pocotopaug were sampled at two stations monthly from April to September. A net with 53 um mesh size was towed through 30 m of water, yielding a concentrate from 942 liters of water. Concentrates were examined in a Sedgewick Rafter counting chamber at 40x to 100x with brightfield optics. Zooplankters were identified, measured and enumerated (Table 15). Results were converted to biomass based on genus-specific length-weight regressions (Table 16).

Types of zooplankton in Lake Pocotopaug were typical of southern New England lakes, with protozoans, rotifers, copepods and cladocerans all present, as well as the phantom midge *Chaoborus* (found in two samples). Copepods and cladocerans were the most abundant zooplankters, but overall abundance was quite low in most samples. A biomass of >100 ug/L is generally considered necessary to provide adequate fish food and filter enough lake water on a daily basis to exercise some control over algal abundance. Only the May sample from station 1 exhibited a biomass >100 ug/L, and over half the biomass values were <30 ug/L.

While several large bodied cladocerans (especially *Daphnia pulex* and *D. retrocurva*) were observed in May samples, these were generally absent later in the year and the largest zooplankters were often copepods. The overall mean length of zooplankters was low (<0.4 mm) in half the samples and moderate (>0.4 but <0.7 mm) in the other half. Mean size for just the crustacean zooplankters (copepods and cladocerans) was moderate at 0.41 to 0.76 mm. Small to moderate mean length and low biomass indicate both sub-optimal grazing control over algae and limited food availability for small fish. Food quality can affect zooplankton size distribution and abundance, but there is no indication of poor quality (mainly diatoms and golden algae) in spring, and predation by abundant panfish is suspected as the primary force shaping the zooplankton community.

Table 15. 2001 Zooplankton Density

	ZOOPLANKTON DENSITY (#/L)											
	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2
TAXON	**04/26/01**	**04/26/01**	**05/17/01**	**05/17/01**	**06/13/01**	**06/13/01**	**07/23/01**	**07/23/01**	**08/23/01**	**08/23/01**	**09/20/01**	**09/20/01**
PROTOZOA												
Ciliophora	0.0	0.0	23.5	11.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mastigophora	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sarcodina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ROTIFERA												
Asplanchna	0.0	0.3	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Conochilus	0.0	0.0	15.7	10.4	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Filinia	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kellicottia	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2
Keratella	2.7	6.1	6.9	2.9	1.3	0.3	2.5	0.8	0.3	0.2	0.1	0.9
Polyarthra	0.0	0.3	0.0	0.4	0.5	0.2	0.0	0.0	0.0	0.0	0.0	0.1
Trichocerca	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1
COPEPODA												
Copepoda-Cyclopoida												
Cyclops	1.4	1.9	11.3	4.0	0.5	3.4	0.0	0.0	0.0	0.0	0.8	0.3
Mesocyclops	0.0	0.0	0.0	0.9	0.2	0.2	2.5	3.8	0.5	0.5	0.7	0.7
Copepoda-Calanoida												
Diaptomus	0.9	0.8	1.0	0.7	0.5	0.2	6.3	6.1	1.3	1.9	0.4	0.5
Copepoda-Harpacticoida	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other Copepoda-Adults	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other Copepoda-Copepodites	0.0	0.0	1.5	0.9	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Other Copepoda-Nauplii	0.1	0.2	5.9	0.7	0.5	0.6	2.9	3.5	0.7	0.5	0.7	0.4
CLADOCERA												
Alona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bosmina	0.9	1.0	5.4	0.7	0.0	0.0	0.4	0.3	0.0	0.0	0.0	0.0
Ceriodaphnia	0.0	0.0	0.0	0.4	0.2	0.2	0.4	0.0	2.3	1.0	0.0	0.0
Chydorus	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.2	7.5	25.2	7.9	8.8

Table 15 continued. 2001 Zooplankton Density

	ZOOPLANKTON DENSITY (#/L)											
	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2
TAXON	04/26/01	04/26/01	05/17/01	05/17/01	06/13/01	06/13/01	07/23/01	07/23/01	08/23/01	08/23/01	09/20/01	09/20/01
CLADOCERA												
Daphnia ambigua	0.1	0.2	2.0	1.8	0.0	0.1	1.7	0.5	3.1	7.7	0.0	0.0
Daphnia pulex	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Daphnia retrocurva	0.0	0.0	11.8	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diaphanosoma	0.0	0.0	1.0	0.7	0.3	0.0	11.4	8.3	3.9	11.3	1.1	0.5
Leptodora	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2
OTHER ZOOPLANKTON												
Chaoboridae	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0
SUMMARY STATISTICS												
DENSITY (#/L)												
PROTOZOA	0.0	0.0	23.5	11.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ROTIFERA	2.7	11.0	22.5	14.0	1.8	0.5	2.5	0.8	0.5	0.2	0.4	1.2
COPEPODA	2.5	2.9	19.6	7.2	1.6	4.6	11.6	13.4	2.5	2.9	2.5	1.8
CLADOCERA	1.3	1.3	20.1	7.0	0.5	0.2	13.9	9.3	16.9	45.1	9.1	9.5
OTHER ZOOPLANKTON	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0
TOTAL ZOOPLANKTON	6.5	15.2	85.8	39.4	3.8	5.4	27.9	23.5	20.0	48.2	12.1	12.5
TAXONOMIC RICHNESS												
PROTOZOA	0	0	1	1	0	0	0	0	0	0	0	0
ROTIFERA	1	5	2	5	2	2	1	1	3	1	3	4
COPEPODA	3	3	4	5	4	5	3	3	3	3	4	4
CLADOCERA	3	3	4	7	2	2	4	4	4	4	3	3
OTHER ZOOPLANKTON	0	0	0	0	0	1	0	0	1	0	0	0
TOTAL ZOOPLANKTON	7	11	11	18	8	10	8	8	11	8	10	11
S-W DIVERSITY INDEX	0.67	0.74	0.88	0.93	0.82	0.61	0.72	0.69	0.77	0.56	0.57	0.53
EVENNESS INDEX	0.79	0.71	0.84	0.74	0.90	0.61	0.79	0.76	0.74	0.62	0.57	0.51

Table 16. 2001 Zooplankton Biomass

	ZOOPLANKTON BIOMASS (UG/L)											
	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2
TAXON	**04/26/01**	**04/26/01**	**05/17/01**	**05/17/01**	**06/13/01**	**06/13/01**	**07/23/01**	**07/23/01**	**08/23/01**	**08/23/01**	**09/20/01**	**09/20/01**
PROTOZOA												
Ciliophora	0.0	0.0	0.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mastigophora	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sarcodina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ROTIFERA												
Asplanchna	0.0	0.5	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Conochilus	0.0	0.0	0.6	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Filinia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kellicottia	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Keratella	0.2	0.5	0.6	0.3	0.1	0.0	0.2	0.1	0.0	0.0	0.0	0.1
Polyarthra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trichocerca	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
COPEPODA												
Copepoda-Cyclopoida												
Cyclops	3.5	4.7	27.5	9.7	1.2	8.2	0.0	0.0	0.0	0.0	1.9	0.7
Mesocyclops	0.0	0.0	0.0	1.1	0.2	0.3	3.1	4.8	0.7	0.6	0.8	0.8
Copepoda-Calanoida												
Diaptomus	0.4	0.4	0.5	0.3	0.2	0.1	3.0	2.9	0.6	0.9	0.2	0.2
Copepoda-Harpacticoida	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other Copepoda-Adults	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other Copepoda-Copepodites	0.0	0.0	0.4	0.3	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Other Copepoda-Nauplii	0.3	0.4	15.6	1.9	1.3	1.5	7.6	9.3	1.7	1.3	1.7	1.0
CLADOCERA												
Alona	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bosmina	0.9	0.9	8.2	1.4	0.0	0.0	0.4	0.3	0.0	0.0	0.0	0.0
Ceriodaphnia	0.0	0.0	0.0	1.7	0.4	0.4	1.0	0.0	6.1	2.5	0.0	0.0
Chydorus	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.2	7.4	24.7	7.8	8.7

Table 16 continued. 2001 Zooplankton Biomass

ZOOPLANKTON BIOMASS (UG/L)												
	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2	LP-1	LP-2
TAXON	04/26/01	04/26/01	05/17/01	05/17/01	06/13/01	06/13/01	07/23/01	07/23/01	08/23/01	08/23/01	09/20/01	09/20/01
CLADOCERA												
Daphnia ambigua	0.2	0.3	7.3	4.4	0.0	0.1	2.8	0.8	5.1	12.4	0.0	0.0
Daphnia pulex	0.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Daphnia retrocurva	0.0	0.0	84.8	20.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diaphanosoma	0.0	0.0	2.9	2.1	0.3	0.0	11.2	8.2	3.8	11.1	1.1	0.5
Leptodora	0.0	0.0	0.0	14.9	0.0	0.0	0.0	0.0	0.0	0.0	9.1	15.8
OTHER ZOOPLANKTON												
Chaoboridae	0.0	0.0	0.0	0.0	0.0	40.0	0.0	0.0	65.0	0.0	0.0	0.0
SUMMARY STATISTICS												
BIOMASS (UG/L)												
PROTOZOA	0.0	0.0	0.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ROTIFERA	0.2	1.2	1.2	1.1	0.2	0.0	0.2	0.1	0.0	0.0	0.0	0.1
COPEPODA	4.3	5.5	44.0	13.3	2.9	10.1	13.6	17.0	3.0	2.8	4.7	2.8
CLADOCERA	1.4	1.4	103.2	50.3	0.7	0.5	15.3	9.4	22.3	50.7	18.0	24.9
OTHER ZOOPLANKTON	0.0	0.0	0.0	0.0	0.0	40.0	0.0	0.0	65.0	0.0	0.0	0.0
TOTAL ZOOPLANKTON	5.9	8.1	148.9	64.9	3.8	50.7	29.2	26.5	90.4	53.5	22.6	27.7
MEAN LENGTH: ALL FORMS	0.37	0.24	0.36	0.33	0.37	0.61	0.61	0.61	0.51	0.49	0.41	0.38
MEAN LENGTH: CRUSTACEANS	0.56	0.57	0.70	0.76	0.59	0.63	0.66	0.63	0.51	0.49	0.43	0.41

7.0 RELATIONSHIPS AND TRENDS

7.1 Precipitation

There is no significant relationship between four of the five in-lake water quality variables analyzed and precipitation. The sum of precipitation values 7 and 30 days prior to sampling were plotted against turbidity, TP, DP, SDT, and chlorophyll a from 1991-2001. There was no significant correlation between any of these variables and 7 and 30 days of accumulated precipitation. However, when only summer values were regressed, a significant correlation was reported for chlorophyll a and 30 days of precipitation ($P < 0.05$). Approximately 97% of the variation in chlorophyll a were accounted for by precipitation (Figure 12).

Precipitation patterns by year and water quality variable concentration graphs are provided in Appendix B.

7.2 Secchi Disk Transparency, Total Phosphorus and Chlorophyll a

Mathematical relationships between SDT, TP and chl a have been developed over time. Data from Lake Pocotopaug was plotted against relationships established by:

- Carlson (1977) - using a data set from all of North America,
- Frink and Norvell (1984) - using Connecticut lake data for SDT vs chl a, and chl a vs TP, and
- Ad Hoc Lake Advisory Committee – using Lake Pocotopaug Data for SDT vs TP

Using all surface water in-lake data (1991 – 2001), SDT was plotted against TP. This produced substantial scatter (Figure 13) and does not appear to follow the trend outlined by either Carlson or the AHLAC. Plotting only July and August data did not reduce scatter but data were closer to the AHLAC curve. Data were further reduced to include only 2001 SDT and TP (Figure 14). Although some data fell along the VLSG curve, the majority of it was skewed to the left (lower TP concentration vs SDT). Surface and mid-depth phosphorus values were then average, assuming that mid-depth TP was available for phytoplankton uptake, shifting the values toward the right (Figure 15). Interestingly, SDT was the lowest in August (concurrent with the highest phytoplankton density), yet TP values were low (approximately 10 ug/L); down and to the left of the AHLAC curve. In summary, Lake Pocotopaug exhibits lower SDT than predicted based on TP concentrations. Either SDT is limited by non-algal turbidity and/or phytoplankton are present in moderate to high densities even with limited phosphorus availability.

Figure 12. Average Surface July and August Chlorophyll a vs. 30 Days of Precipitation.

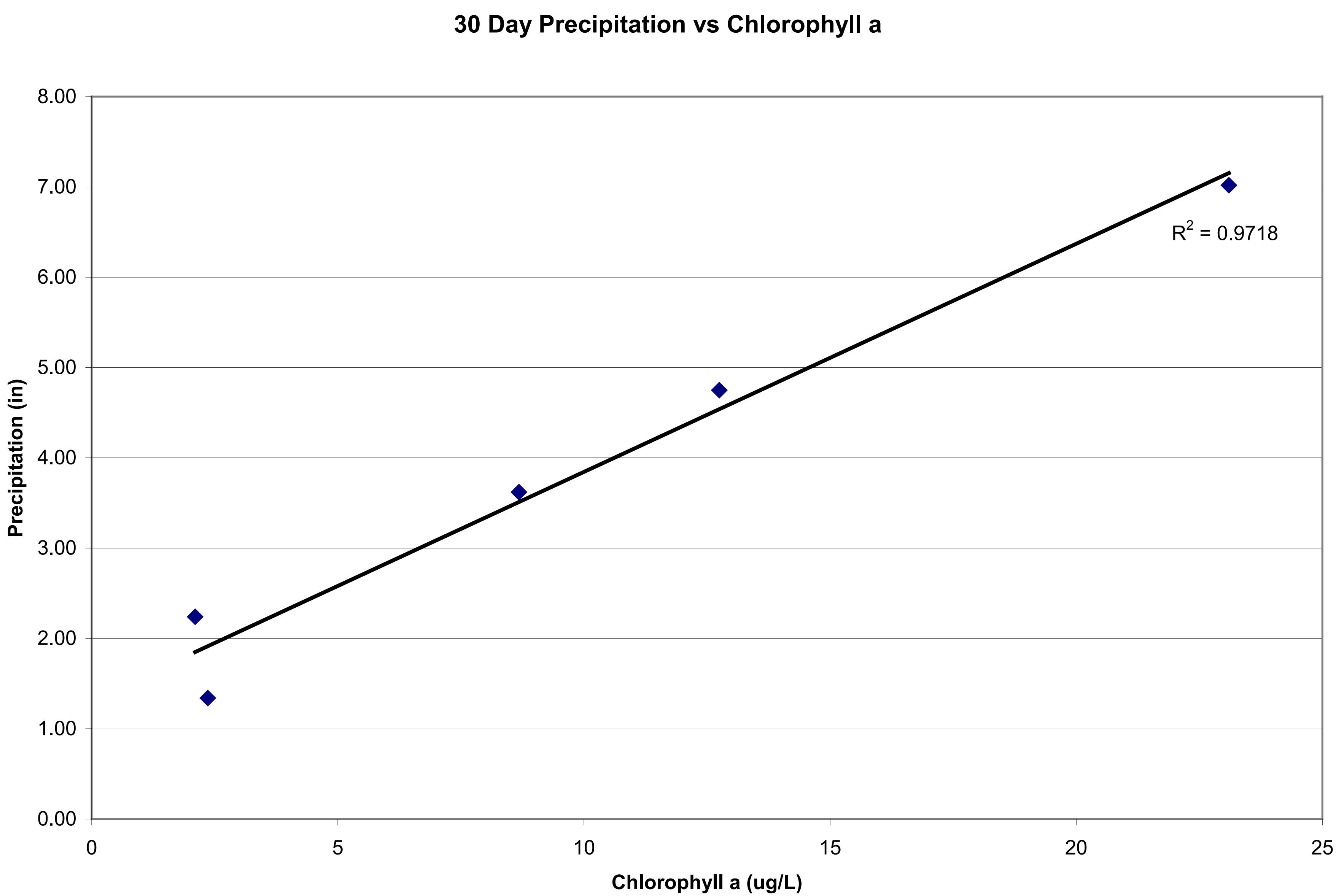


Figure 13. 1991-2001 Surface Water Phosphorus vs. Secchi Disk Transparency

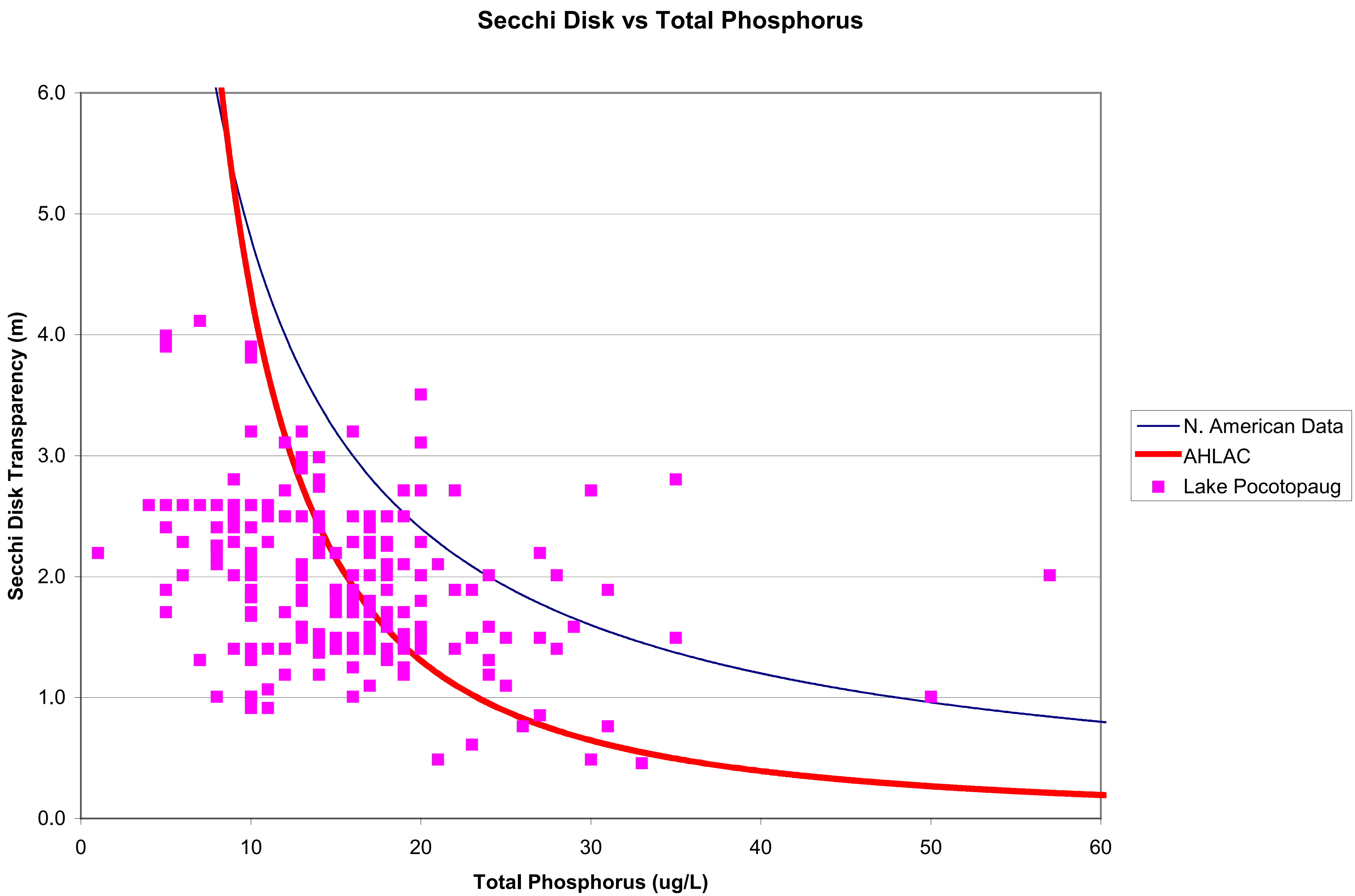


Figure 14. 2001 Surface Water Phosphorus vs. Secchi Disk Transparency

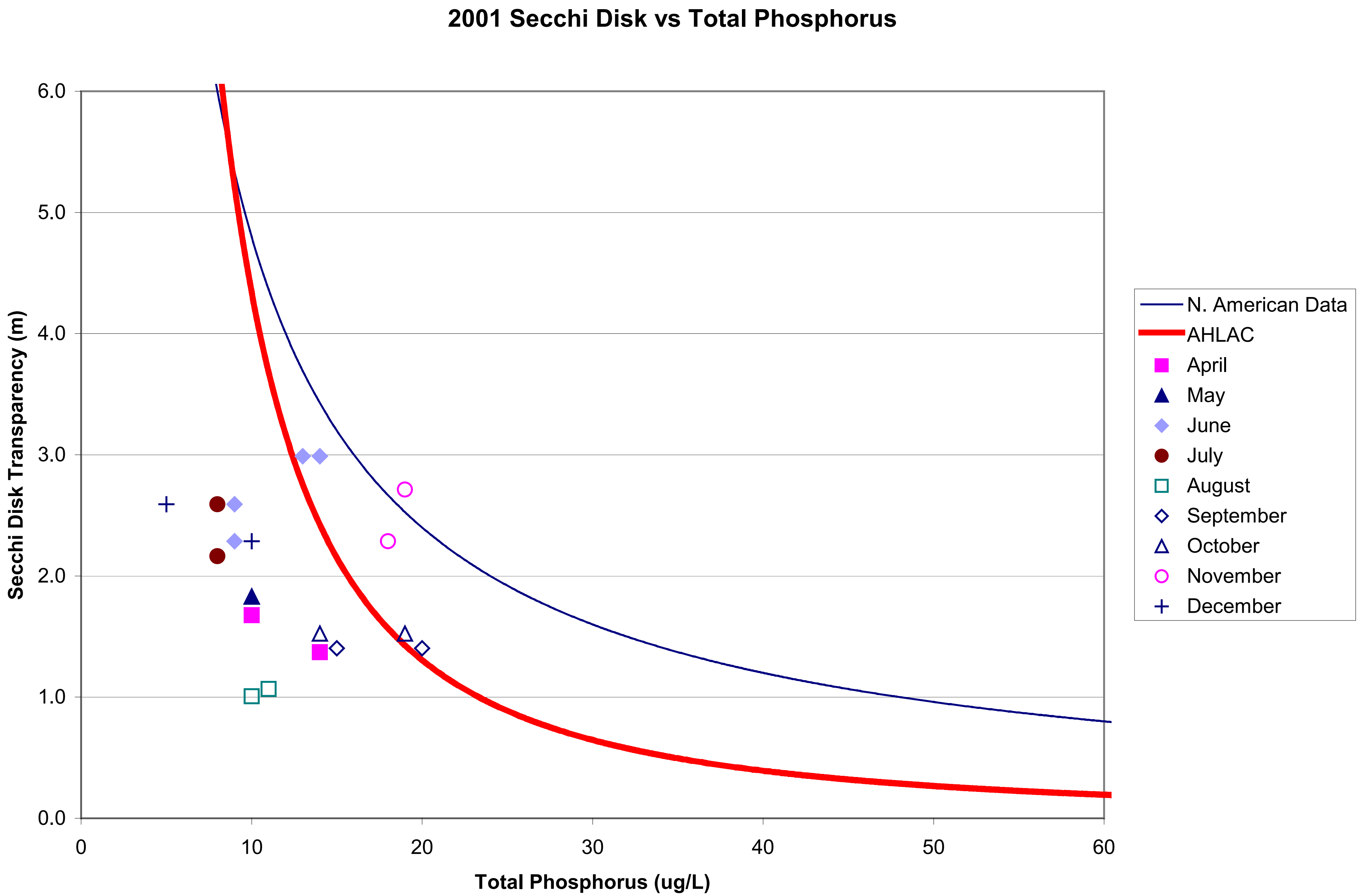
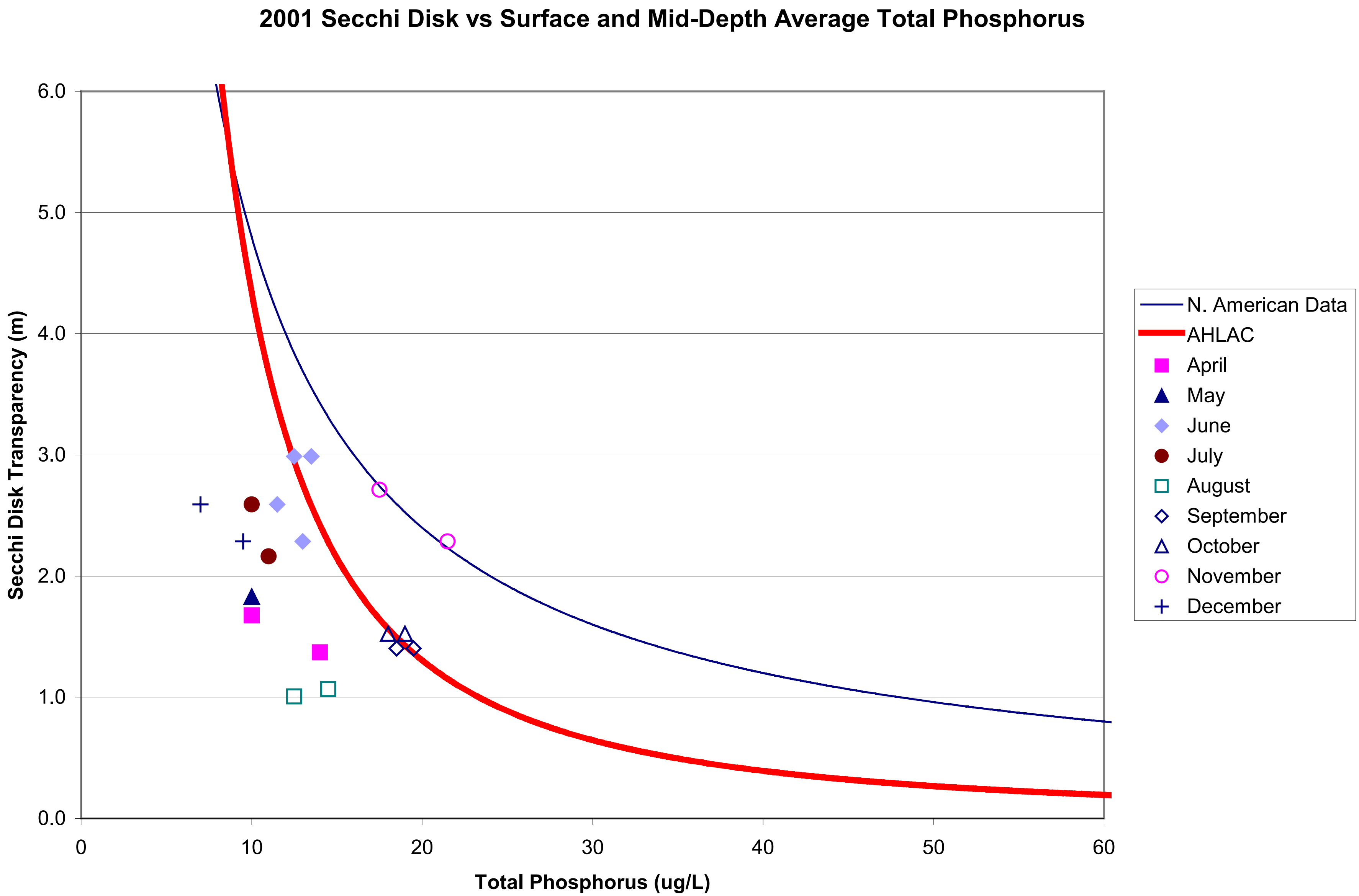


Figure 15. 2001 Surface and Mid-depth Phosphorus vs. Secchi Disk Transparency



The same analysis was performed with SDT and chlorophyll a values from 1991-2001, but using Carlsons and Frink and Norvell data (Figure 16). Scatter was worse; data did not fit either curve. Reducing the data set to July and August values did not increase the correlation (Figure 17). Data by year was plotted. 2001 appeared to follow the trend, but values were again shifted down and to the left (Figure 18); indicating that Pocotopaug is exhibiting lower SDT based on chlorophyll a values. One could conclude that SDT is based more on non-algal turbidity.

Total phosphorus and chlorophyll a values were plotted and compared to Carlson's and Frink and Norvell's data. Again, all 1991-2001 and July/August data produced much scatter (Figures 19 and 20). 1991, 1993 and 2001 data were plotted separately (these are the only three years with chlorophyll a data). 2001 data provided the closest fit, although the slope was steeper than Carlson or Frink and Norvell (Figure 21). The steeper upward trend indicates that there is more chlorophyll a than predicted by phosphorus concentrations. Algal density is higher than expected; algae are thriving in a lower phosphorus environment. However, more chlorophyll a data are needed to verify this trend.

When comparing Lake Pocotopaug 2001 (TP between 10 and 20 ug/L) data to empirical models presented in literature, we find that average chlorophyll a in Lake Pocotopaug should be between 2.1 and 9.9 ug/L (Table 17). In 2001, Lake Pocotopaug average chlorophyll was 5.8 ug/L, within the predicted average of the four empirical model calculations (3.1 – 7.6 ug/L). However, considering that average TP concentrations in 2001 were closer to the 10 ug/L (12 and 13 ug/L), 2001 chlorophyll values are high compared to the empirical model predictions. Similarly, maximum chlorophyll values in Lake Pocotopaug were 11.7 and 14.8 ug/L at LP-1 and LP-2 respectively, within the 11.2 – 26.1 ug/L average maxima range. Indicating that Lake Pocotopaug resembles most lakes at their worst condition (maxima are closer to measured Lake Pocotopaug values than averages). Average 2001 SDT was 2.01 m, below the predicted average for both 10 and 20 ug/L. Maximum 2001 SDT was 2.99 m, below predicted maxima.

Using the average and maximum predicted chlorophyll, SDT was predicted using Carlson (1977) and Frink and Norvell (1984) calculations. Carlson's average and maximum SDT ranged from 1.93 – 3.57 m and 0.84 – 1.49 m, respectively. Frink and Norvell average and maximum SDT ranged from 2.98 – 4.78 and 1.18 – 2.30 m, respectively. This indicates that if Lake Pocotopaug behaved more like other lakes (reduce chlorophyll concentrations per unit TP), average SDT should be slightly lower than 3.57 and 4.78 m, with a worse case scenario of slightly less than 1.49 – 2.30 m. Thus, increasing current average SDT by 1.5 m or greater, provided that SDT in Lake Pocotopaug is chl a driven.

Figure 16. 1991-2001 Chlorophyll a vs. Secchi Disk Transparency

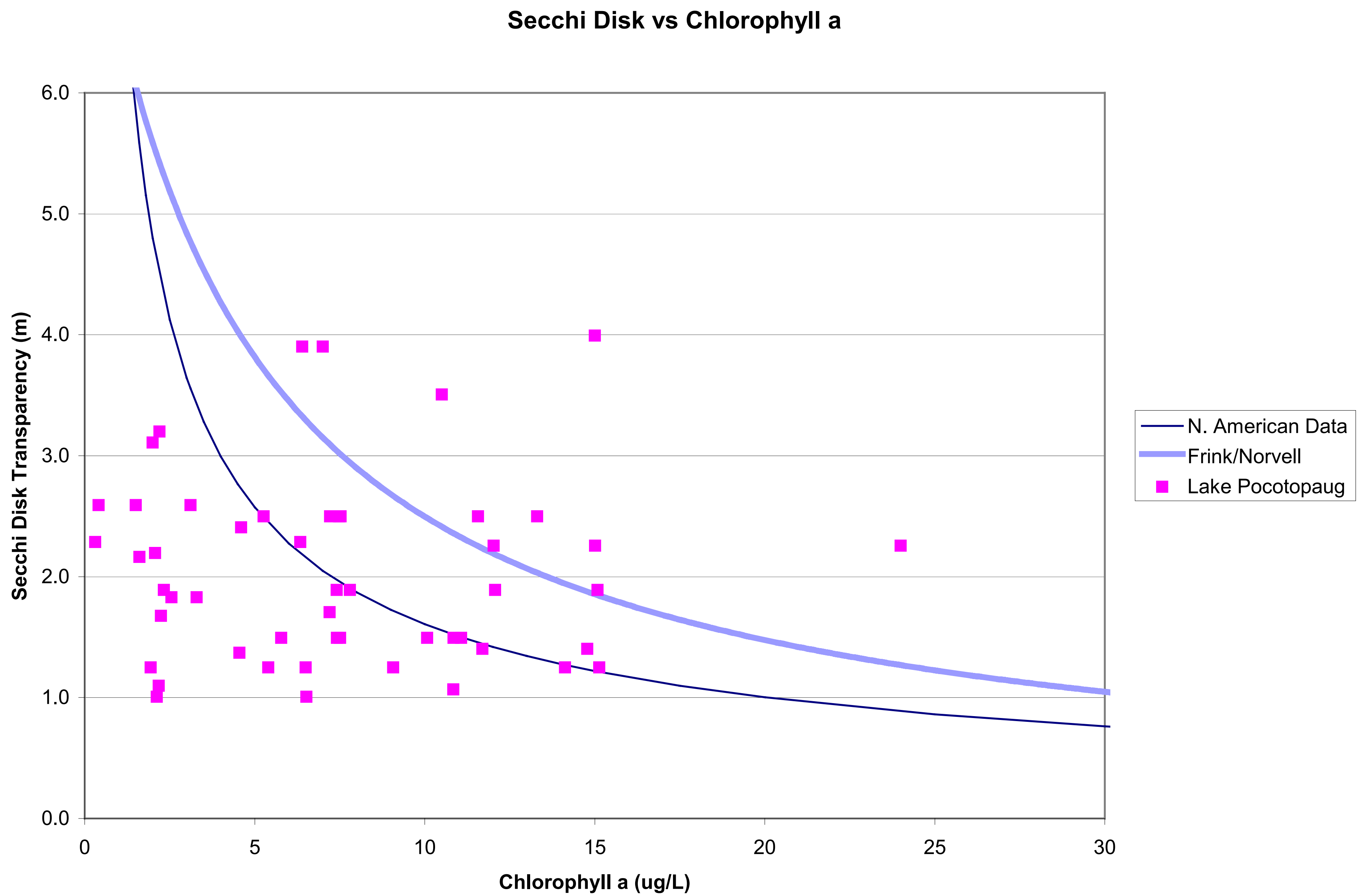


Figure 17. 1991-2001 July and August Chlorophyll a vs. Secchi Disk Transparency

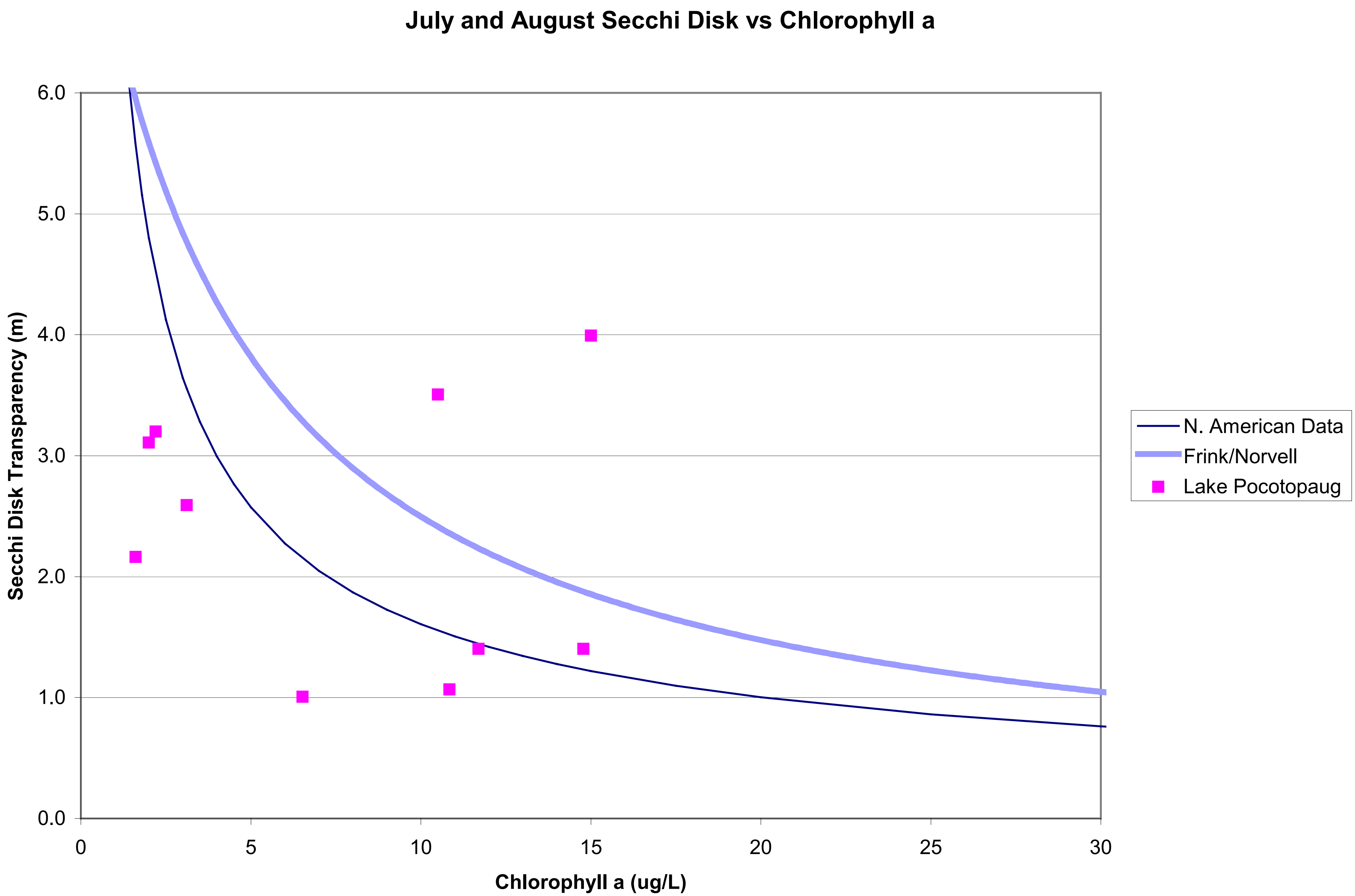


Figure 18. 2001 Chlorophyll a vs. Secchi Disk Transparency

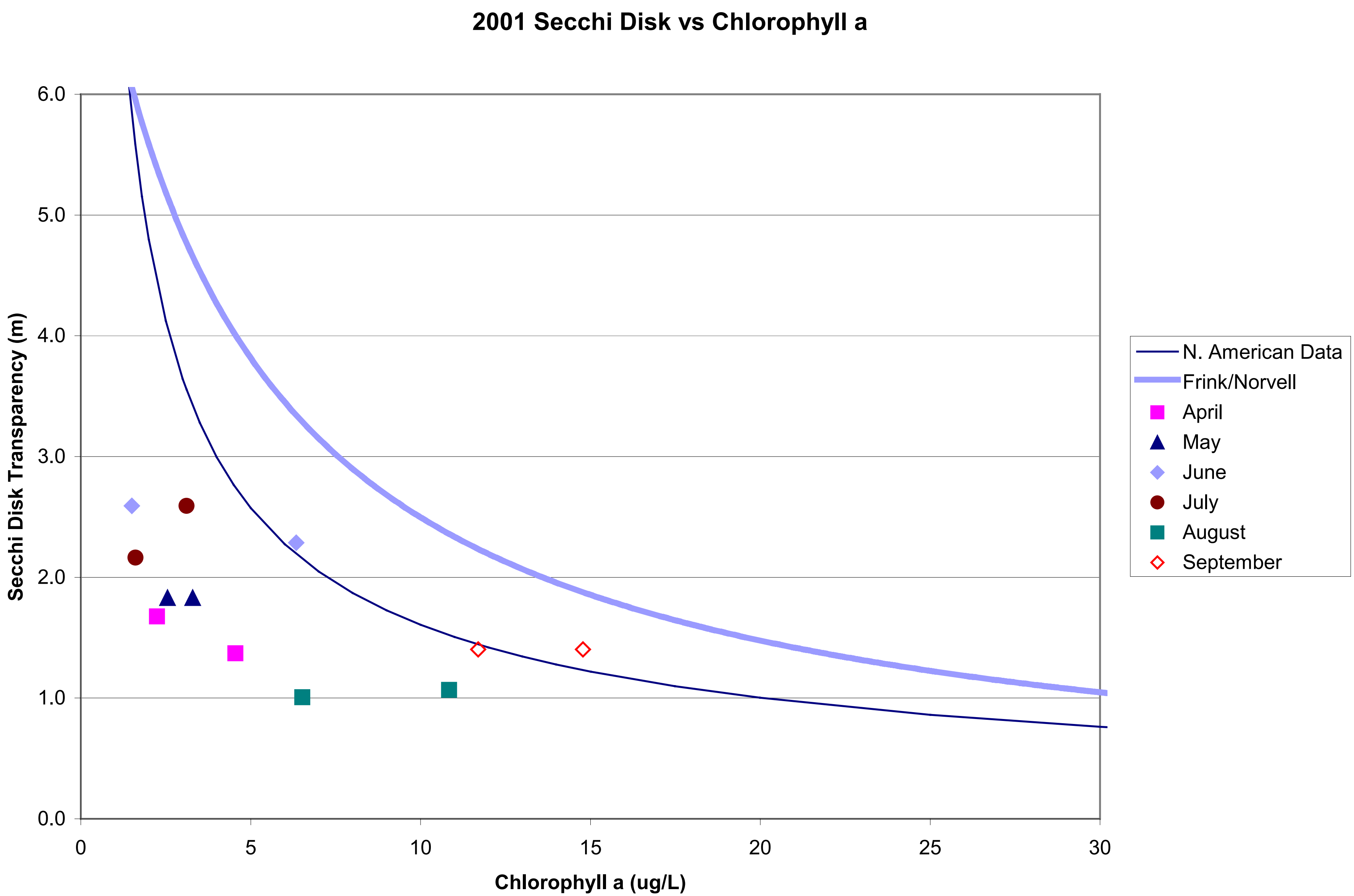


Figure 19. 1991-2001 Surface Total Phosphorus vs. Chlorophyll a.

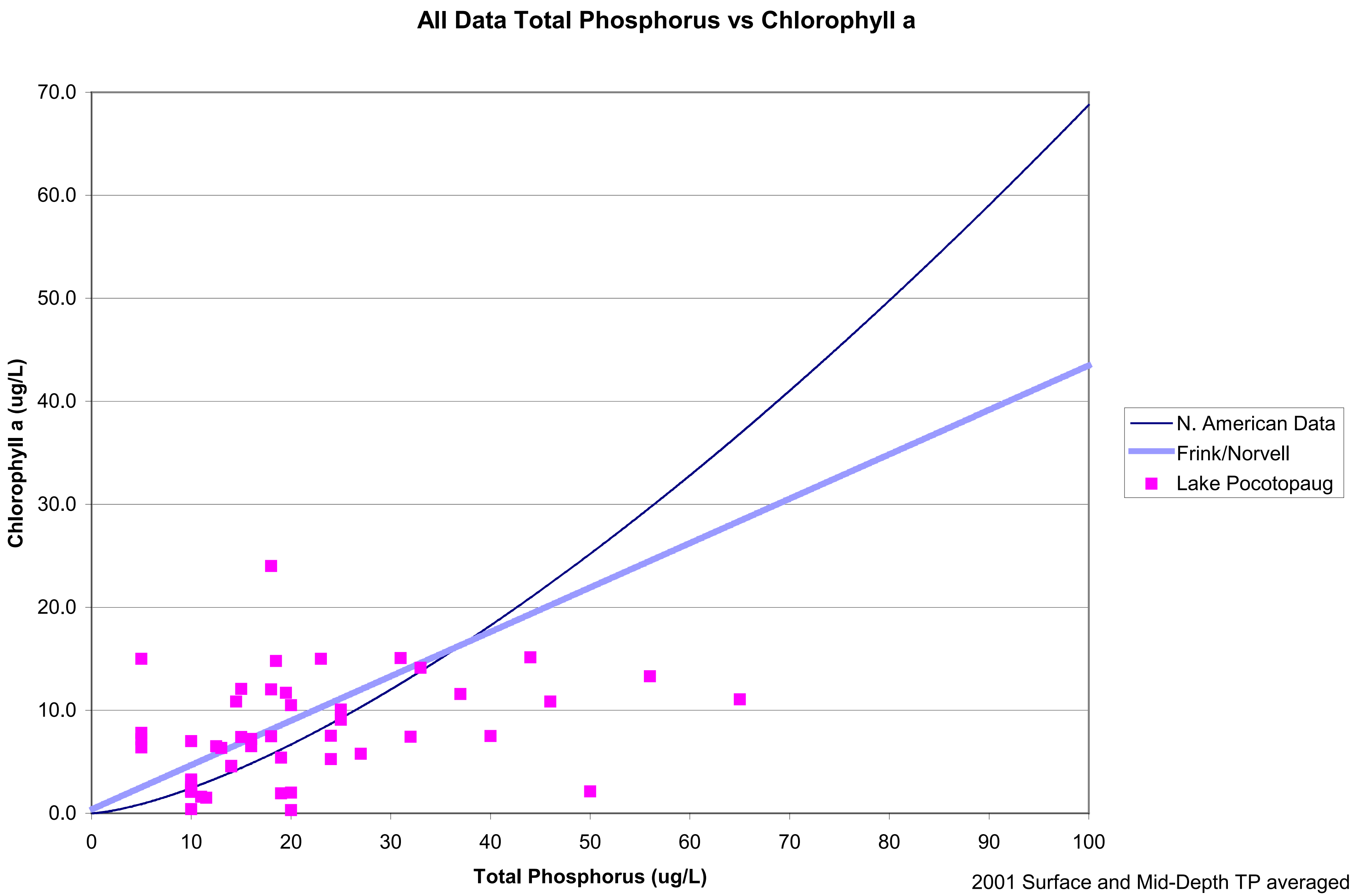
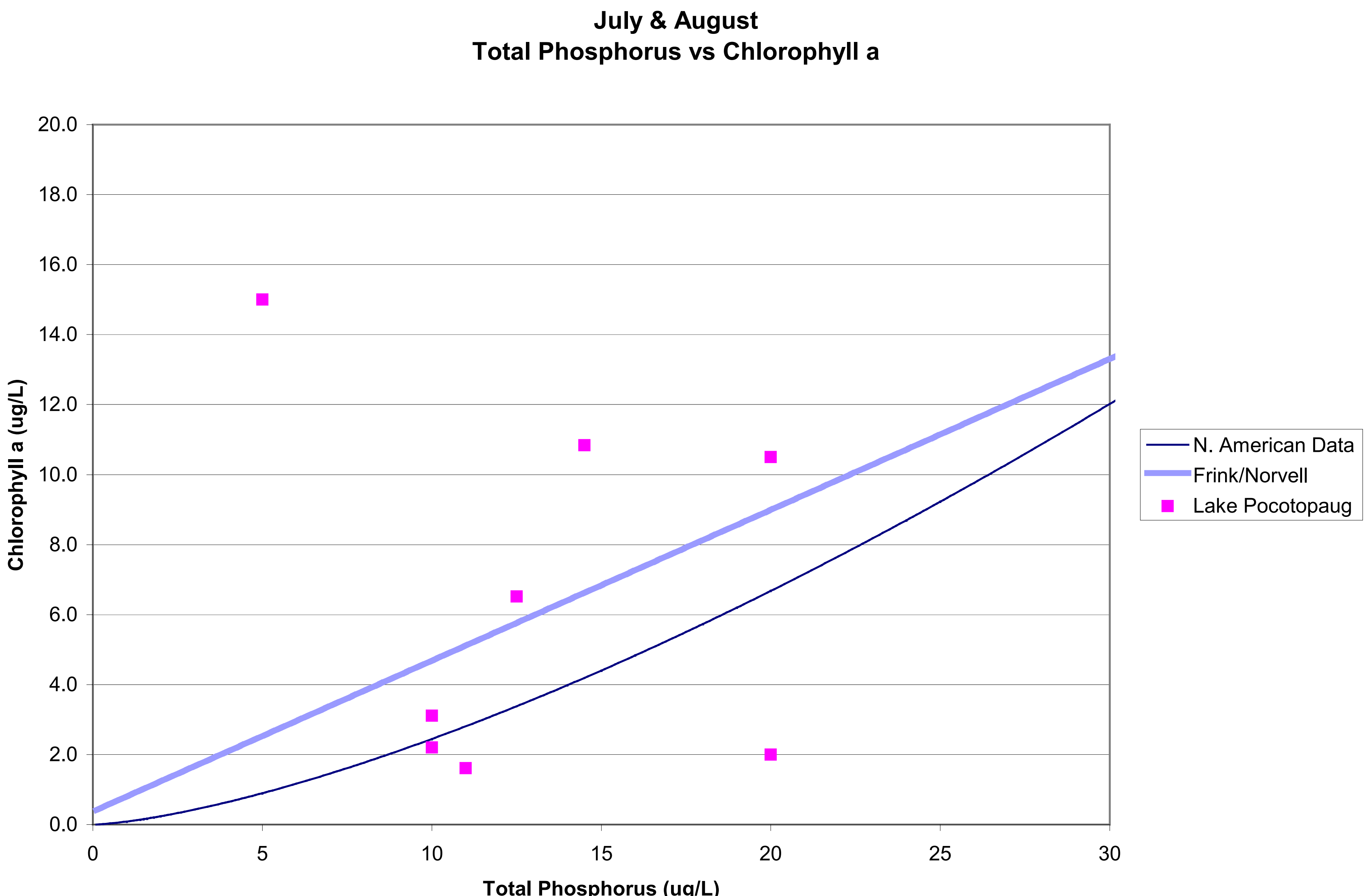


Figure 20. 1991-2001 July and August Surface Total Phosphorus vs. Chlorophyll a.



2001 Surface and Mid-Depth TP averaged

Figure 21. 2001 Surface Total Phosphorus vs. Chlorophyll a.

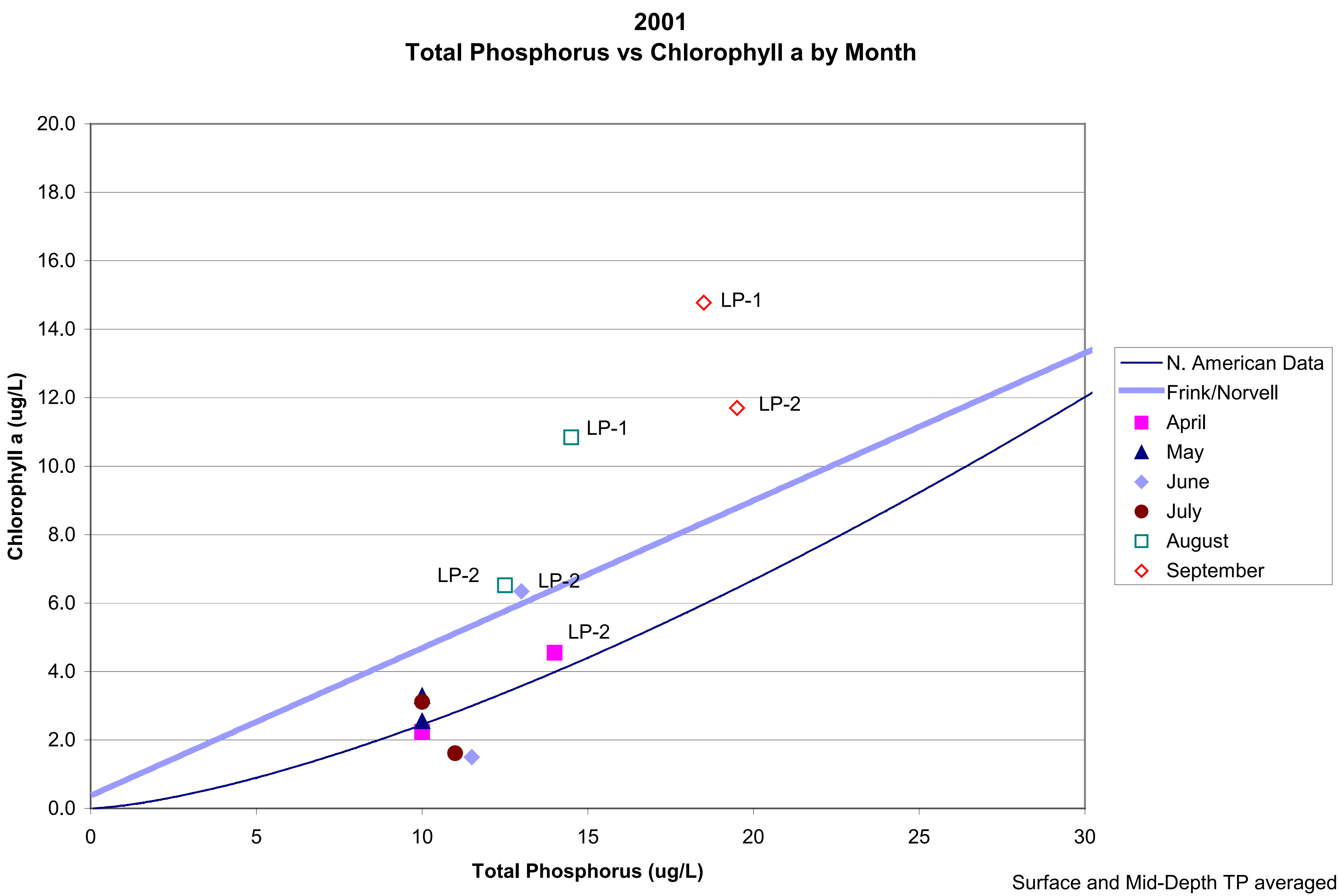


Table 17. Empirical Model Calculations using Lake Pocotopaug TP Range.

MODEL	Value Using 10 ug/L	Value Using 20 ug/L	Value Using 5 ug/L
Mean Chlorophyll (ug/L)			
Dillon and Rigler 1974	2.1	5.6	0.8
Jones and Bachmann 1976	2.3	6.4	0.9
Oglesby and Schaffner 1978	2.8	8.6	0.0
Modified Vollenweider 1982	5.1	9.9	2.6
Average	3.1	7.6	1.1
"Maximum" Chlorophyll (ug/L)			
Modified Vollenweider (TP) 1982	14.4	29.7	6.9
Vollenweider (CHL) 1982	8.6	22.5	2.7
Modified Jones, Rast and Lee 1979	10.7	26.2	3.8
Average	11.2	26.1	4.5
Secchi Transparency (M)			
Oglesby and Schaffner 1978 **(Avg)**	3.9	2.3	6.7
Modified Vollenweider 1982 **(Max)**	5.1	4.2	6.2
	SDT (m)	**SDT (m)**	**SDT (m)**
Carlson (1977) with avg chl	3.57	1.93	7.44
Frink and Norvell (1984) with avg chl	4.78	2.98	6.55
Carlson (1977) with max chl	1.49	0.84	2.77
Frink and Norvell (1984) with max chl	2.30	1.18	4.04

8.0 PHOSPHORUS LOADING

The loading of phosphorus to Lake Pocotopaug is critical to its ecological function and general appearance. To clearly define inputs, a very large amount of sampling is needed over an extended time period. As it is seldom possible to perform this level of sampling, most studies combine a lower sampling frequency with modeling efforts to estimate the range of likely loading. This study has involved several in-lake samplings and tributary samplings covering both wet and dry conditions. The phosphorus loading analysis presented here uses phosphorus literature values and concentrations recorded during 2001. Total phosphorus concentrations are multiplied by the volume of each input to obtain an estimate of the total phosphorus load to Lake Pocotopaug.

8.1 Loading Sources

A total of 30 dry weather and 45 wet weather samples were collected the 2001 investigation. Sites included both tributaries and stormwater inputs. Not all stations were sampled on all dates, as flow was minimal in some cases and extensive flows washed away some of the passive stormwater samplers.

Direct precipitation loading was calculated from a range of values of precipitation TP concentration of 10-20 ug/L, based on studies of other southern New England lakes by ENSR staff. The volume of water entering Lake Pocotopaug through precipitation was multiplied by the TP values. A value slightly lower than the average (simply as a function of convenient rounding) was used as the "best estimate" for phosphorus loading from precipitation (Table 18). Groundwater loading was estimated in a similar way (10-20 ug/L multiplied by volume of water entering Lake Pocotopaug), based on values obtained for other lakes by ENSR staff. An average was used as the "best estimate" for phosphorus loading from groundwater. Given the few septic systems in this largely sewered watershed, it can be reasonably expected that loading of phosphorus from groundwater will be small.

Wet weather loading was calculated using median and mean TP values recorded during 2001 (0.124 and 0.317 mg/L). The volume of water entering the lake during wet weather was multiplied by median and mean TP concentrations to obtain a wet weather loading range of 434 – 1110 kg/yr. The best estimate was calculated using the percent DP in the TP samples, since it is likely that much of the phosphorus entering the lake is bound and unavailable, and much of it settles to the bottom (Table 18). Dry weather phosphorus loading was calculated using the same methodology. Median and mean dry weather phosphorus values were 0.019 and 0.050 mg/L. Again, the best estimate was calculated using the percent DP in the TP samples (Table 18).

Table 18. Total Phosphorus Loading Estimates

Source	Volume/Year	2001 TP (ug/L)	TP Load Calculated (kg/yr)	Best Estimate (kg/yr)	% of Total
Direct Precipitation[1]	$2.5 \times 10^6\ m^3$	10 - 20	25 - 50	35	13 – 7
Ground Water[2]	$0.5 - 0.9 \times 10^6\ m^3$	10 - 20	5 - 18	12	4 – 2
Surface Water[3]	$5.5 - 5.9 \times 10^6\ m^3$				
Wet Weather[4]	$3.5 \times 10^6\ m^3$	124 - 317	434 - 1110	126 – 322	
Dry Weather[5]	$2.0 - 2.4 \times 10^6\ m^3$	19 - 50	38 - 120	15 – 48	
				Total 141 - 370	50 – 73
[Load Coeff][6]			[232 - 480]		
[Mass Balance][7]			[280 - 720]		
Waterfowl (100 - 200 bird years)		0.2 kg/bird/yr	20 - 40	30	11 – 6
Internal Loading	2/3 lake area x 0.5 $mg/m^2/d$ x 90 d		62	62	22 – 12
				Total 280 - 509	
With 60% surface water phosphorus reduction				195 - 287	
% remaining				70 - 56	
	Predicted in-lake TP concentration			7 – 11 ug/L	

[1] Average Precipitation 1994-2001(1.2m) * Lake Surface Area (511.7 ac); Assumed precipitation concentration 10 - 20 ug/L

[2] Assuming an area of 200 ac of direct groundwater drainage. Low range from 200 ac * 20 L/m^2/day. High range (Q=CIA); where C = 0.05, I = 221 m/yr, A = 80645 m^2; Assumed TP in GW at 10 - 20 ug/L

[3] Assuming 1.5 cfs/mi^2 * watershed area (3.7 mi^2); through subtracting precipitation and groundwater from input volume ($8.9 \times 10^6\ m^3$)

[4] Assuming runoff coefficient of 0.3; used wet weather median and average TP concentrations; used percent Dissolved Phosphorus to Total Phosphorus to calculate "Best Estimate" (40% of TP was DP)

[5] Difference between surface water and wet weather; used dry weather median and average TP concentrations; used percent Dissolved Phosphorus to Total Phosphorus to calculate "Best Estimate" (29% of TP was DP)

[6] Calculated from land export coefficient (0.3 - 0.5) used in DF and Ad Hoc Advisory studies and watershed land use (AHLAC and CT DEP)

[7] Mass balance using whole lake and epilimnion volumes

Surface water TP loading can also be calculated by using a load coefficient. This technique was used by the AHLAC and the range of values was tighter than the range calculated using actual data (as described in the previous paragraph). A load coefficient of 0.3 – 0.5, depending on land use was used, in previous investigations, predicting a TP load of 232 – 480 kg/yr.

Additionally, a mass balance equation (using both whole lake and eplimnion areas and a 75% retention rate) was to estimate the TP load. Mass balance results provide a TP range of 280 – 720 kg/yr.

Waterfowl contributions were based an estimated 100-200 bird/years multiplied by a phosphorus concentration of 0.2 kg/bird/yr (Brezonik, 1973; Manny et al., 1994). Waterfowl are estimated to provide 6 to 11 percent of the total phosphorus load to Lake Pocotopaug. Fugro (1993) estimated that waterfowl contribute 43 kg/yr (about 4% of the budget estimated by Fugro).

Internal loading was calculated based on the expected remaining sediment release following alum treatment. The 2002 in-lake data clearly indicate that internal loading and the rate of contribution were greatly reduced by the alum treatment. Therefore, an adjusted rate of 0.5 $mg/m^2/day$ (typical of oxic sediments in other lakes studied by ENSR staff) was applied to the untreated lake area for a period of 90 days (summer), resulting in an annual load of 62 kg/yr, or 12 – 22 % of the current TP budget.

8.4 Tributary and Storm Drain Loading

A method for determining the phosphorus load from the watershed used in the "Land Use and Phosphorus Input to Lake Pocotopaug" by the AHLAC in 1995 was repeated using median 2001 stormwater data and is presented in Table 19.

Additionally, the relative phosphorus load was calculated using median stormwater concentrations in 2001 (Table 20). Table 20 is sorted by percent relative load contribution. Hales, Bay, O'Neils, and Christopher Brooks contribute the bulk of the TP entering Lake Pocotopaug. However, excessive phosphorus loading is prevalent throughout the watershed.

Table 19. Wet Weather Loading Summary for 2001 Data.

			Area Drained *								
Ad Hoc Station	ENSR Station	Location	Total Area (ac)	% Developed	Developed Area (ac)	Median 2001 TP Conc. (mg/L)	Annual TP load[1] (lbs/yr)	Ad Hoc Study (lbs/yr)	Median 2001 DP Conc. (mg/L)	Annual DP load[1] (lbs/yr)
4	LP-3	Christopher Brook, upstream of Christopher Rd	466	36	169	0.069	171	109	0.010	24
9	LP-4	Storm drain at bottom of Clark Hill	18	100	18	0.196	19	12	0.070	7
11	LP-5	Hales Brook, at Lake Drive-upstream of Hales Pond	889	12	107	0.084	396	196	0.006	28
15	LP-6	Candlewood Brook, upstream of Lake Drive	41	39	16	0.178	39	30	0.035	8
18	LP-7	Bay Road Brook, downstream of Bay Road	156	3	4	0.300	248	41	0.027	22
21	LP-8	Hazen Brook, end of private drive	20	24	5	0.169	18	4	0.020	2
	LP-9[2]	Storm drains at lake edge, between cottages at end of Hawthorne and Emerson Road	5	100	5	0.417	11		0.029	1
23	LP-10	O'Neils Brook, upstream of Old Marlboro Road	53	44	23	0.706	199	22	0.024	7
26	LP-11	Day's Brook, downstream of Old Marlboro Road	55	15	8	0.140	41	46	0.024	7
22	LP-12	Storm drain at bottom of MohicanWangonk Trail (north side of beach)	12	100	12	0.121	8	8	0.055	4
	LP-13[3]	Storm drainage swale, end of Park Street (next to house #5 with ornamental pond)	5	100	5	1.567	42		0.013	0
	LP-14[4]	Storm drain at S. Wangonk Trail beach	3	100	3	0.159	3		0.062	1
						Total lbs/yr	1193	468	Total lbs/yr	110
						Total kg/yr	541	212	Total kg/yr	50

* areas obtained from Ad Hoc Lake Advisory Committee (1995) or WMC (1995) when indicated

[1] Median wet weather (first flush) concentration x area x runoff (0.495 x 1.20 m/yr)

[2] Assumed 5 acres

[3] area 28 on WMC report

[4] area 25 on WMC report - no area listed assumed 3 ac

Table 20. Relative Wet Weather Total Phosphorus Loading

ENSR Station	Location	Total Area (ac)	Fraction of Total Area (ac)	Water Volume (m^3)	2001 Median TP Conc (mg/L)	Relative Load* (kg/yr)	Percent Total
LP-5	Hales Brook, at Lake Drive-upstream of Hales Pond	889	0.37	1306804	0.084	109.8	33.2
LP-7	Bay Road Brook, downstream of Bay Road	156	0.07	229315	0.300	68.8	20.8
LP-10	O'Neils Brook, upstream of Old Marlboro Road	53	0.02	77908	0.706	55.0	16.6
LP-3	Christopher Brook, upstream of Christopher Road	466	0.20	685006	0.069	47.3	14.3
LP-13	Storm drainage swale, end of Park Street (next to house #5 with ornamental pond)	5	0.00	7350	1.567	11.5	3.5
LP-11	Day's Brook, downstream of Old Marlboro Road	55	0.02	80848	0.140	11.3	3.4
LP-6	Candlewood Brook, upstream of Lake Drive	41	0.02	60269	0.178	10.7	3.2
LP-4	Storm drain at bottom of Clark Hill	18	0.01	26459	0.196	5.2	1.6
LP-8	Hazen Brook, end of private drive	20	0.01	29399	0.169	5.0	1.5
LP-9	Storm drains at lake edge, between cottages at end of Hawthorne and Emerson Road	5	0.00	7350	0.417	3.1	0.9
LP-12	Storm drain at bottom of MohicanWangonk Trail (north side of beach)	12	0.01	17640	0.121	2.1	0.6
LP-14	Storm drain at S. Wangonk Trail beach	3	0.00	4410	0.159	0.7	0.2
					Total	330	100

*Loads based on estimated stormwater flows * median first flush concentration

8.5 Loading Summary

Taking all methods described above into consideration, the range of likely loads to Lake Pocotopaug is somewhere between 280 and 859 kg/yr, and will vary depending on weather patterns. The watershed is the primary source of phosphorus, providing between 50 and 73% of the total load. Ground water and precipitation provided 9 – 17% of the total phosphorus load collectively. Waterfowl provides approximately 6 –11% and internal loading provides 12 – 22% of the TP load. The internal loading estimate is less than the load previously report but this reduction not 100% attributable to the alum treatment. Initial internal loading was approximated at 373 kg/yr, slightly lower than the 499 kg/yr estimated by Fugro (1993).

Loading by sampling station produced values comparable to loading calculations presented in Section 8.1. Relative TP load was estimated at 330 kg/yr, slightly above the high range of the wet weather calculations. Relative loads were calculated based on first flush samples and are likely to be the worst case scenario. In addition, best estimates allowed for the settling of particulate matter. Overall, all calculations of the TP load to Lake Pocotopaug presented here are reasonable. Although the major tributaries comprise the bulk of the stormwater TP load, excessive stormwater phosphorus concentrations are present throughout the watershed.

With the best possible treatment of surface water inputs, a reduction of 60%, TP values in-lake are predicted to be about 7 to 11 ug/L. This may not be enough to control algal growths to the extent desired, as blooms have formed when surface concentrations were as low as 10 to 11 ug/L. However, the frequency and severity of blooms may decline, and combined with other techniques (e.g., biomanipulation) this may be adequate to satisfy users of the lake.

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9.0 DIAGNOSTIC SUMMARY

Lake Pocotopaug was enhanced back in the 1700's by the construction of a dam. Industry and tourism became a major part of East Hampton's economy. Increased transportation efficiency soon lead to development around the lake shore with year-round homes. The lake is now approximately 511.7 acres with mean and maximum depths of 3.4 and 11.6 meters, respectively. Total water volume is estimate to be 7.1 million cubic meters. It is a heart shaped waterbody with the shallowest area to the south and deeper hole in the upper lobes. Lake Pocotopaug has islands and exposed bedrock that make navigation around the lake difficult for inexperienced boaters.

The watershed of Lake Pocotopaug is approximately 2,381 acres. Much of this land is forested (65 – 77%). The low watershed:lake area ratio (<5:1) suggests limited water flow to this large water body and high potential for successful water quality management. However, much of the shoreline is developed. Developed land near Lake Pocotopaug has a disproportionately large potential for water quality impact, and appropriate land management practices are necessary to protect the lake. Future development is limited by topographic features and environmental regulations, but is great enough to pose a threat to current water quality.

Hydrologically, Lake Pocotopaug receives enough water annually to replace the full volume just over one time. That means that water entering the lake has an average residence time of just under a year. The inflow of the surface waters provides roughly 65% of total inflow. Precipitation and groundwater provide 35%. Flows are very uneven over the course of a year, however, and fall-winter drawdown, spring refill, and summer water level maintenance complicates the hydrologic budget.

Water quality in Lake Pocotopaug and its tributaries is generally acceptable for designated uses. Oxygen is low below the thermocline and anoxia occasionally occurs just above the thermocline. Internal recycling is evident, but the recent alum treatment is expected to reduce that load from 47% (Fugro 1995) to 12 – 22% of the total phosphorus load. Although chemically safe, Lake Pocotopaug is sometimes aesthetically unappealing, which may deter contact recreation.

Nutrient levels are generally low, and are typically below the level below at which algal blooms are generally found. However, Lake Pocotopaug is unusual in this regard. Algal blooms are present even under this relatively low phosphorus condition. Reducing the surface water phosphorus concentration by 60%, about the maximum it is reasonable to expect, is predicted to result in phosphorus concentrations between 7 – 11 ug/L (as opposed to the current 10-22 ug/L), a level at which blooms may still occur in Lake Pocotopaug.

Differences can be observed between developed and undeveloped areas of the watershed when examining both dry weather and storm water quality, suggesting that protection of lake water quality should focus on inputs from developed areas. Unstable soils and lack of function from the existing storm water attenuation devices yield substantial solid and nutrient loading. There is no “smoking gun” in the watershed. Excessive nutrient concentrations are found in all tributaries and storm drains, although runoff from developed areas tends to provide the highest values. However, spring runoff seems to be more detrimental than summer runoff and the major tributaries are suspect due to the higher portion of the load they contribute.

Excessive external and possibly internal solid loading, and algal growth reduce in-lake water clarity. Disturbance of sediments in the shallow basin could influence whole lake water clarity, could provide nutrients to support algal growth, and should be investigated as a potential source.

Using the predictive curves and mathematical empirical models, Lake Pocotopaug should currently experience reduced phytoplankton density if it behaved more like other lakes. In other words, current phosphorus concentrations should be low enough to control algal growth, based on empirical relationships established from data for many lakes. However, Lake Pocotopaug produces more algae per unit of phosphorus than most other lakes, placing it on the fringe of known relationships between phosphorus and chlorophyll and chlorophyll and water clarity. Finding and managing the differences between Lake Pocotopaug and other lakes could be important to reducing excessive growths of algae.

Phytoplankton and zooplankton communities in Lake Pocotopaug are less than ideal, and may represent important differences from other lakes. Phytoplankton densities are typically moderate to high and zooplankton densities are relatively low. As a result, water clarity is sometimes undesirable for recreational uses. Since phytoplankton are thriving at low phosphorus concentrations, reducing TP alone (within reasonable constraints) may not achieve desired results; a top down control method supplementing phosphorus reduction may be necessary. Altering the fish community to have more predators and less planktivorous panfish could increase zooplankton grazing on phytoplankton. The recent stocking of walleye could produce a desirable secondary affect, if the population is large enough and is not decimated by fishing too quickly.

There was no information gathered from this study that provides a conclusive explanation of past fish kills and recent schooling behavior; more detailed fish investigation was beyond the scope of this project. Panfish may be looking for alternative food sources in the tributaries due to low in-lake zooplankton density. Sediment-water quality interactions during the time of decreasing lake temperature may play a role. Sporadic inputs from certain tributaries could be stressing fish in some locations. Pockets of supercooled water could be a stressor. Contact with over 30 fishery professionals from a range of states did not reveal any clear explanation, however, and the data on hand are insufficient to explain observations.

Although some may argue that by appearance Lake Pocotopaug is eutrophic, it is classified as mesotrophic by the State of Connecticut, largely due to the low nutrient levels. Unfortunately, lowering nutrient levels may not be a realistic solution to Lake Pocotopaug's low water clarity, given practical limits on such reductions. Certainly the maintenance of low phosphorus is a prerequisite for increasing water clarity, but it may not be the whole answer.

10.0 MANAGEMENT NEEDS AND OBJECTIVES

Although once used for industrial purposes, current use of Lake Pocotopaug is heavily weighted towards recreational activities, and providing continued high quality swimming, boating and fishing experiences is the primary goal of management for this system. Achieving this goal depends upon managing the watershed and the lake for reduced sediment and nutrient loading, less algae, and healthy fish populations.

The surrounding watershed is heavily forested. However, this land is primarily privately owned and protecting this land from development may be a difficult task. Development, realistically, is inevitable, although current environmental regulations will restrict it to some degree and will dictate some water quality safeguards. Ensuring proper storm water Best Management Practices (BMPs) during and after any development is essential. Unfortunately for the lake, development around the lakeshore is already dense. Reducing impacts from this area in addition to protection of what is now undeveloped land should be the focus for management of Lake Pocotopaug and it's watershed.

Concerns expressed early in this study included low water clarity and excessive algal densities. Poor water clarity has been documented since the early 1970's. It does not appear to be solely influenced by algal density, as storm-induced solids inputs and resuspended sediment from within the lake are significant sources of turbidity (and reduced clarity), but algal blooms in late summer do severely reduce water clarity without appreciable non-algal particulate abundance. Reduced suspended solids and reduced algal density are therefore the primary objectives of management for Lake Pocotopaug. These objectives will be addressed in the subsequent sections.

11.0 POTENTIAL MANAGEMENT OPTIONS

11.1 Reducing Non-Algal Turbidity

Control of non-algal turbidity requires understanding the sources and having the economic resources available. In the case of Lake Pocotopaug, the source of non-algal turbidity is unclear. Sediment loading is extensive and well documented. However, there is no significant relationship between precipitation and in-lake turbidity. This is not to say that stormwater runoff does not contribute to in-lake turbidity or more importantly, to sedimentation (the infilling of the lake). What it does suggest is that an additional source may be present. Lake sediment in the southern portion of the lake may be entrained in the water column through wind action, distributing fine sediment throughout the lake and reducing water clarity. More data are needed to prove or disprove this theory, but observations suggest that this may be a substantial factor in lowered water clarity much of the year.

If mixing is a source for decreased water clarity, management can be difficult. Changing wind patterns or mixing resistance is highly impractical. Dredging of the shallow areas to reducing mixing potential or the use of benthic barriers may help in this regard, but these measures are expensive on a large scale and do not seem appropriate for Lake Pocotopaug at this time. Alum treatment of the southern area, avoided previously because it is not deep enough to have strong anoxia and associated phosphorus release, may both help congeal the sediments to limit resuspension and inactivate any phosphorus that does get entrained in the water column. This approach has seldom been tried, however, and is somewhat experimental.

Sediment inputs should be controllable. The “Storm Water Renovation and Management Plan for Lake Pocotopaug” prepared by WMC in 1995 outlines many techniques for sediment input reduction. The plan is provided in Appendix C for further reference. This section will not discuss each drainage basin and the techniques to employ, as the WMC report was fairly thorough, but it will give several options to consider for sediment reduction.

Areas of concern are beaches (public or private), catch basins throughout the watershed and major tributaries (Christopher, Hales, Bay and O’Neill Brooks). Beaches might be provided with a vegetated buffer strip, although this is unpopular with beach goers. Alternatively, using the coarsest possible sand for beaches will help, and covering the beach with filter fabric or setting up silt fence may be viable in the off-season. The most critical time is in the spring when there is a high potential for runoff and beach attendance is minimal, but it may be necessary to take action in late autumn to ensure spring protection.

Beaches are only a small part of the problem, however, and management of other watershed lands will be essential to reducing solids inputs. Most alternatives for reducing sedimentation go hand in hand with phosphorus reducing techniques (a method of controlling algae). In an effort to avoid repeating sections, reduction of sediment and phosphorus will be discussed together in the next section.

11.2 Reducing Total Phosphorus and Sediment Loading from the Watershed

Objectives are strongly linked to watershed management, and specifically to management of developed areas. Development of a watershed creates impervious surface that changes the hydrology of the area and tends to increase loading of pollutants to waterways. Pollutants falling from the sky as atmospheric deposition are not incorporated into soils as in forests or meadows, but rather are transported into the aquatic environment. Additional pollutants from human activities in developed areas include solids from exposed soils, nutrients from fertilizers and waste disposal, bacteria from waste disposal, urban wildlife and pets, hydrocarbons from automotive and other machine use, and metals from a variety of sources. These are also carried into the aquatic environment and can cause water quality degradation and use impairment. Similar consequences result from agricultural development, but with more solids and nutrients and less metals and hydrocarbons. Some degree of additional pollutant loading is almost inevitable with development, but there are methods for minimizing inputs and impacts.

In the Lake Pocotopaug watershed there are both residential lands and agricultural lands, although the residential land is more abundant and is close to the lake and more likely to impact water quality in the lake. Nutrient loading analysis based on recent data suggest that current loads are excessive, that loads from developed areas are higher than for undeveloped areas, and that protection of water quality can be gained by addressing pollutant sources and transport in developed areas. Techniques for reducing pollutant loads and associated impacts are discussed below.

11.2.1 Source Controls

Agricultural Best Management Practices

Agricultural Best Management Practices (BMPs) incorporate techniques in forestry, animal science, and crop science to minimize adverse impacts to water resources. This management approach actually relies upon a combination of techniques in source reduction and transport mitigation. Such practices include manure management, fertilizer management, use of cover crops, and use of buffer zones. The use of agricultural BMP’s is highly recommended in the Lake Pocotopaug watershed. However, with the small amount of land in agriculture, this is not likely to provide a major change in the water quality of Lake Pocotopaug. Rather, this is a protective measure to be encouraged, especially where livestock are involved, as their nutrient input per unit area involved can be very large. Many of the techniques discussed as BMPs for residential areas are also applicable to agricultural lands.

Bank and Slope Stabilization

Erosion control is an important component of an overall management plan designed to decrease pollutant loading to aquatic ecosystems. This is especially important in areas of new development or re-development, where soils are both exposed and susceptible to erosion. Stabilization of stream banks and road shoulders in the vicinity of crossings is another important area for application, particularly when dirt roads are involved. Other critical areas include storm water drainage ditches and small tributaries in developed areas. This is a recommended management technique in the lake Pocotopaug watershed, and the towns and the CT DEP should maintain lists of susceptible areas and check them periodically.

Source Controls for Residential Land

Source controls are methods used to reduce the amount of pollutants generated in the watershed, or to prevent their release to the environment. Eliminating some sources is impractical, but minimizing unnecessary pollutant use and keeping the pollutant from contacting storm water or ground water may be feasible. Helpful texts include Hansen et al. (1988), Humstone Squires (1990) and Maine COLA (1991). The focus is on limiting the amount of any pollutant that is available to be transported in runoff. In most cases this involves behavioral changes by homeowners.

Behavioral modifications involve changing the actions of watershed residents and lake users to improve water quality. Such changes may include conversion to non-phosphate detergents, elimination of garbage grinders, proper inspection and maintenance of septic systems, limits on lawn fertilization, and eliminating illegal dumping in roadways and watercourses. Behavioral modifications can be brought about in two principal ways, through public education and/or the implementation of local bylaws and bans. Education is a critical first step and should precede any attempt at regulation.

Public education can be accomplished by mailing an informative brochure on watershed management to all residents in the watershed, through the use of video programs on local access television, by placing informative signs in high access areas, or by holding public meetings for watershed residents. Public education relies heavily upon cooperation from residents and other lake users, and is not likely to result in major improvements in water quality by itself. However, some level of improvement has been noted in other studies and the education process sets the stage for community involvement and cooperation. Public education is a recommended management technique for Lake Pocotopaug, and should focus on landscape management.

Information on relevant ordinances has been provided separately to East Hampton officials, but the most obvious need is control of lawn fertilization. Education is preferable to regulation, but the latter may be necessary, in which case education should precede regulation.

Land Use Conversion

Land use conversion involves purchasing properties that contribute excessive amounts of pollutants and converting these properties to less deleterious land uses. For example, the CT DEP or a town may decide to purchase an agricultural property and convert the land to open space, thus reducing pollutant generation from this parcel of land. This is a very expensive proposition and is not practical on a large scale in most cases, but may be practical for targeting specific properties that could generate excessive amounts of pollutants that eventually discharge into Lake Pocotopaug. Since a large portion of the watershed is currently undeveloped forest land, an opportunity may exist to preserve some of this land. This technique, if economically feasible, is an option for minimizing pollutant loading from the Lake Pocotopaug watershed.

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Zoning and Land Use Planning

This is a very important component in controlling watershed inputs to aquatic resources. A strong relationship exists between land use type and pollutant generation, with developed lands (including agriculture) typically generating greater pollutant loads than non-developed lands. Preserving undeveloped land in the Lake Pocotopaug watershed is highly recommended, with particular emphasis on preserving areas of land that form buffer zones along the lake and its tributaries; undeveloped land near the lake is minimal, but land along tributaries is worth evaluating. The zoning laws of East Hampton in the watershed should be reviewed with maintenance of buffer strips in mind. A summary of land use and zoning issues and recommendations are provided in the "Stormwater Renovation and Management Plan for the Lake Pocotopaug Watershed" prepared by WMC in 1995 (Appendix C).

Much of the watershed is privately controlled with most of the undeveloped land suitable for development. There may be increasing development pressure over the next decade, and planning now to minimize impacts of possible future development is strongly recommended. Development need not be prevented in this case, but should conform to all applicable regulations. Consideration at the town level of appropriate development features around Lake Pocotopaug and throughout its watershed is warranted.

Waste Water Management

A properly functioning on-site waste disposal system (e.g., septic system) can be an effective means of reducing pollutant loading to an aquatic ecosystem. Of particular concern are those systems where septic effluent is breaking-out above ground and is transported to the lake or a tributary during storm events. We have no evidence of failing septic systems in this watershed, and sanitary sewers service much of the watershed.

Maintenance and inspection of on-site waste disposal systems is a recommended management technique for the Lake Pocotopaug watershed. Education is the first step in alerting residents to this need. Consideration of a bylaw that requires proof of septic system inspection and maintenance on an every other year basis is worthwhile, but probably not necessary at this time. Some effort should be made to educate septic system users of the limitations of those systems, and how users can minimize strain on system capabilities. Key factors include proper sizing of systems to meet user demands, and where the system is already in place, altering user demand to meet system limits. For example, the use of garbage grinders places a heavy load on septic systems that should be avoided.

Stormwater Diversion

Re-routing a discharge away from a target water-body is one of the most effective ways to change the quality of incoming water. It suffers from the philosophical drawback of passing the problem downstream without dealing with the source of the pollution, and is not feasible in many areas where downstream uses must be protected. There are many direct entry storm drains discharging to Lake Pocotopaug, and rerouting these discharges would not be an easy task. Although a useful technique, major sources of phosphorus could not be re-routed without significant effort and cost, and would have undesirable downstream effects. Dealing with the problem at the source is preferable.

11.2.2 Transport Mitigation

Transport mitigation involves trapping pollutants after they leave the source area but before they enter the resource under management. The choice of transport mitigation method is largely a function of the features of the sources and land areas in question, but multiple methods may apply in any instance. Cost is another primary determinant of pollutant trapping strategy. Entire texts have been devoted to the application and success of these best management practices (BMPs), and much has been learned over the last two decades (Galli 1990, Scheuler et al. 1992, Kadlec and Knight 1996, Claytor and Scheuler 1996).

Buffer Strips

Buffer strips (or vegetated filter strips or grassed buffers) are areas of grass or other dense vegetation that separate a waterway from an intensive land use (Figure 22). These vegetated strips allow overland flow to pass through vegetation that filters out some percentage of the particulates and decreases the velocity of the storm water. Particulate settling and infiltration of water often occurs as the storm water passes through the vegetation. Buffer strips need to be at least 25 ft wide before any appreciable benefit is derived, and superior removal requires a width >100 ft. This can create land use conflicts, but creative planting and use of buffer strips can be a low cost, low impact means to minimize inputs to the aquatic environment.

This management technique is highly recommended for the Lake Pocotopaug watershed, although limits on retrofitting buffer strips to developed lands are recognized. Limiting future development in defined buffer areas could be an inexpensive means of maximizing pollutant

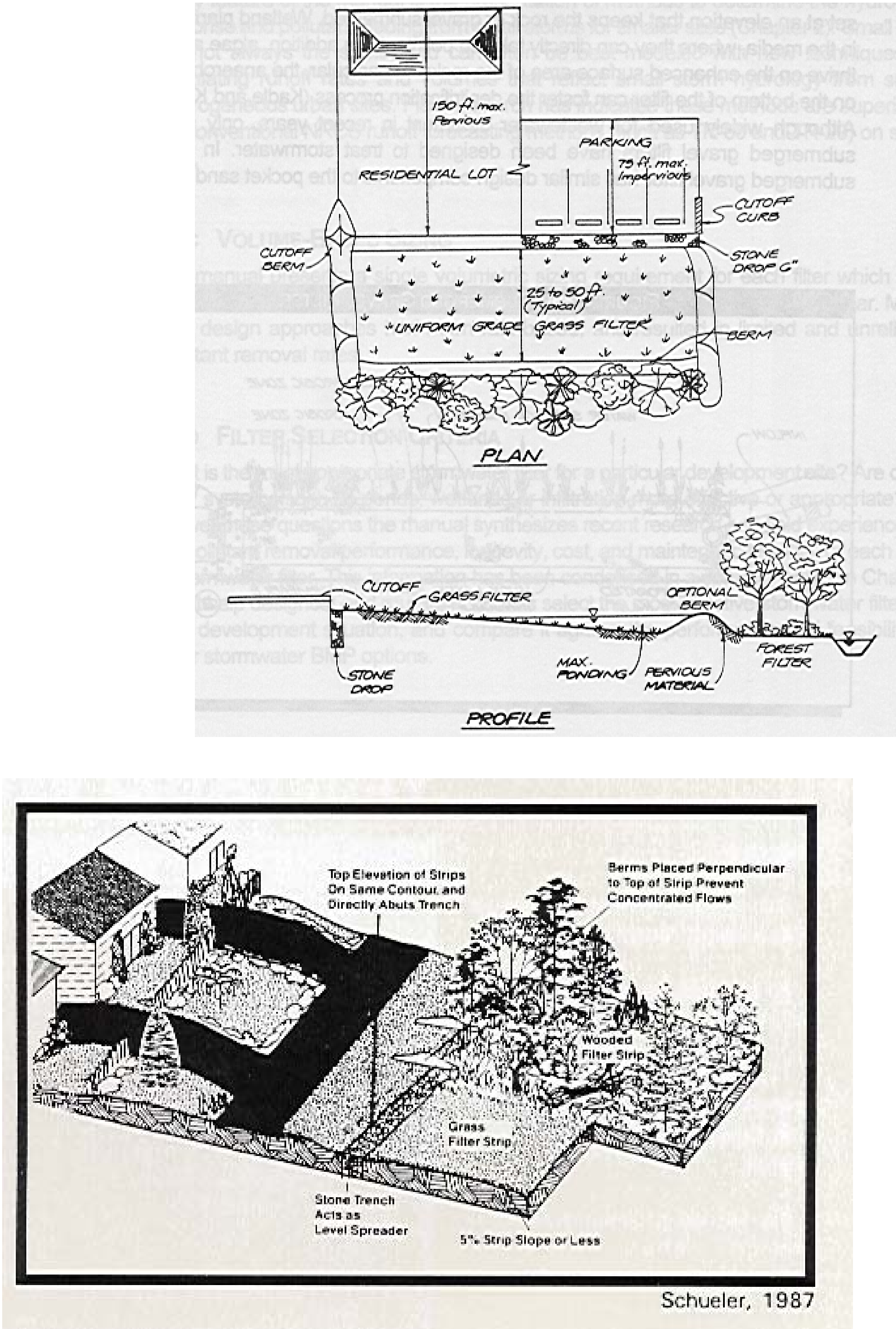


Figure 22. Buffer Strips for Pollutant Transport Mitigation.

trapping in this case. Requiring buffer strips for all new developments is not unreasonable and is workable in many cases. Establishing buffer strips for existing residential land is more difficult, and would best be accomplished through a combination of education and incentive (funding) programs.

Catch Basins with Sumps and Hoods

Deep sump catch basins equipped with hooded outlets can be installed as part of a storm water conveyance system (Figure 23). Deep sumps provide capacity for sediment accumulation and hooded outlets prevent discharge of floatables (including non-aqueous phase hydrocarbons). Catch basins are usually installed as pre-treatment for other BMPs and are not generally considered adequate storm water treatment as a sole system. Volume and outlet configuration are key features that maximize particle capture, but it is rare that more than the coarsest fraction of the sediment/pollutant load is removed by these devices.

This is a recommended management technique for the Lake Pocotopaug watershed, but is not expected to be sufficient by itself to make an appreciable difference. Rather, this will be an important pre-treatment mechanism for infiltration strategies or detention schemes associated with future development. It may, however, be important along the roads nearest the lake, where failure to trap coarse particles results in small deltas in the lake and the need for expensive maintenance dredging.

Oil/Grit Chambers

A number of oil/grit chamber designs are currently on the market. These self-contained units include an initial settling chamber for sediment removal, typically have hooded internal passages to trap oil and other floatables, and often incorporate some form of outlet pool to control exit velocity (Figure 24). Several rely on a vortex design to enhance sediment removal (e.g., Vortechnics, Storm Defender). Such systems are most applicable as pre-treatment for other BMPs, but can trap 80% of the solids load and are generally well suited as retrofits for relatively small areas in developed watersheds. Installing these devices as off-line systems may enhance pollutant removal, but their more common use as on-line pre-treatment devices can be very beneficial. This is a recommended management technique for the Lake Pocotopaug watershed, especially in combination with infiltration or wetland treatment technologies.

Street Sweeping/Catch Basin Cleaning

Removal of pollutants before they are washed into Lake Pocotopaug could be accomplished by frequent street sweeping and catch basin cleaning. Both techniques provide only limited benefits by themselves, but could be effective tools in combination with other BMPs. Truly effective street sweeping is accomplished with vacuum equipment, which costs in excess of $100,000/vehicular unit. Maintenance costs can also be substantial, and this approach has less value where dirt roads are plentiful. Frequent street sweeping is appropriate for parts of the Lake Pocotopaug watershed, but it is probably sufficient to do a good job of such sweeping in

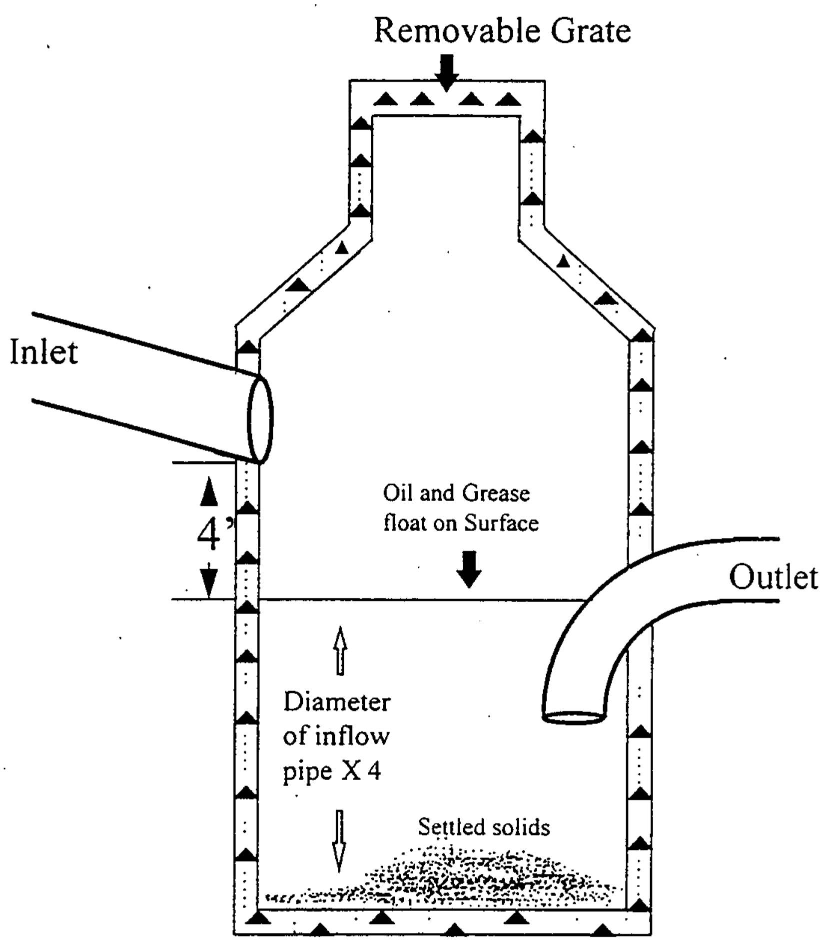
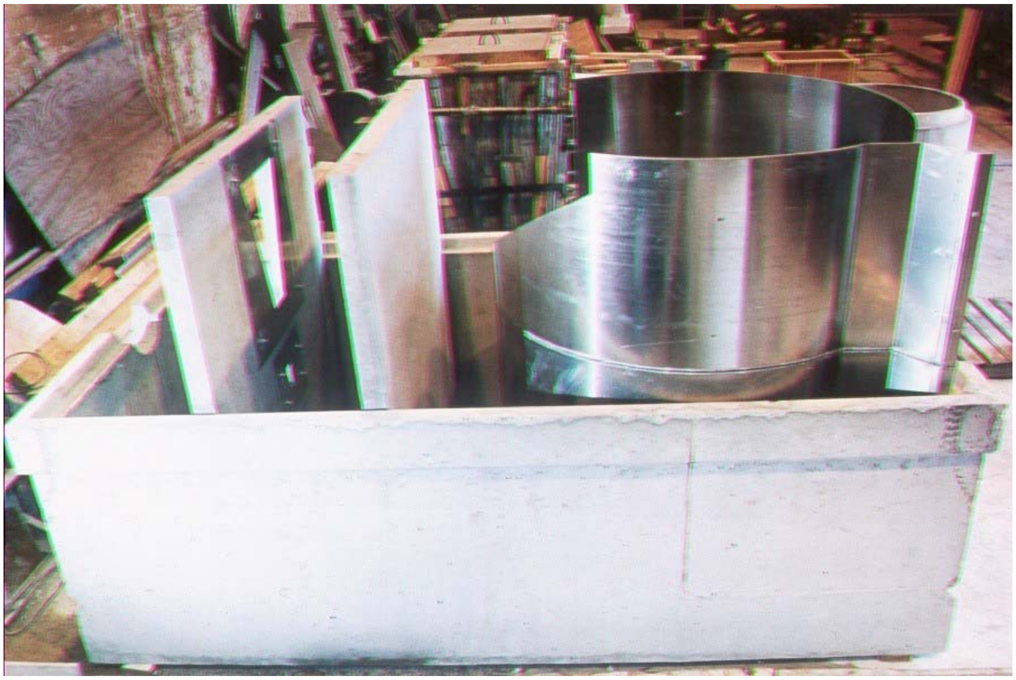
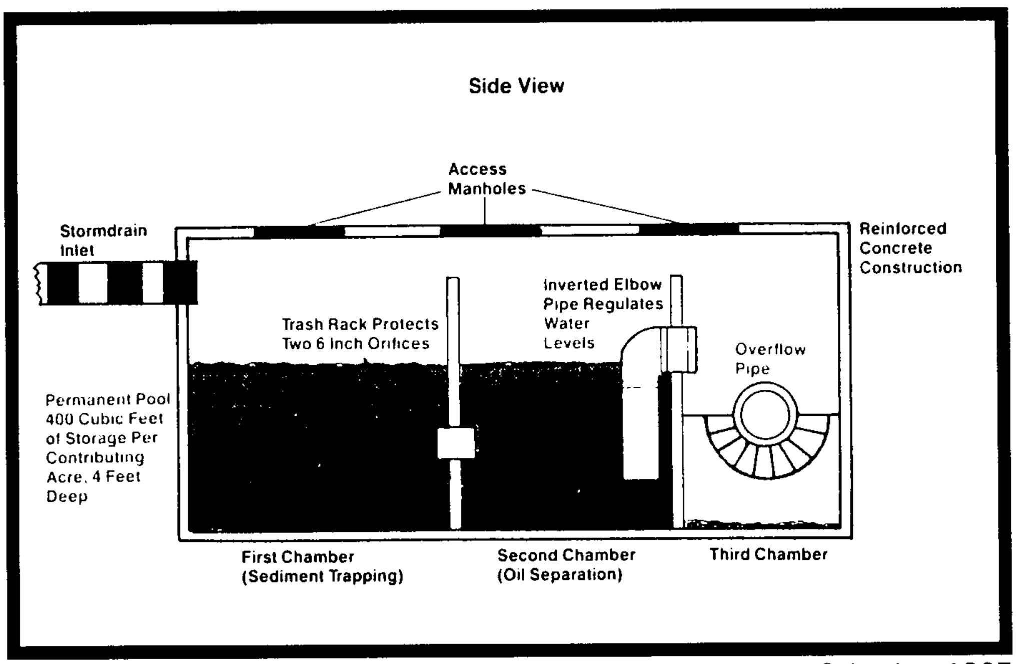


Figure 23. Catch Basin with Sump and Hood.





Schueler, 1987

Figure 24. Oil and Grit Traps.

early spring to capture what appears to be a highly significant load to the lake from paved surfaces.

Catch basin cleaning should be a semi-annual activity in any developed area, but rarely is; restoration of catch basin capacity is essential to the proper function of storm-water drainage systems, and costs about $50-$70 per catch basin per year when basins are cleaned on a bulk basis. Catch basin cleaning is important in the Lake Pocotopaug watershed, as part of normal road maintenance and storm water drainage system management.

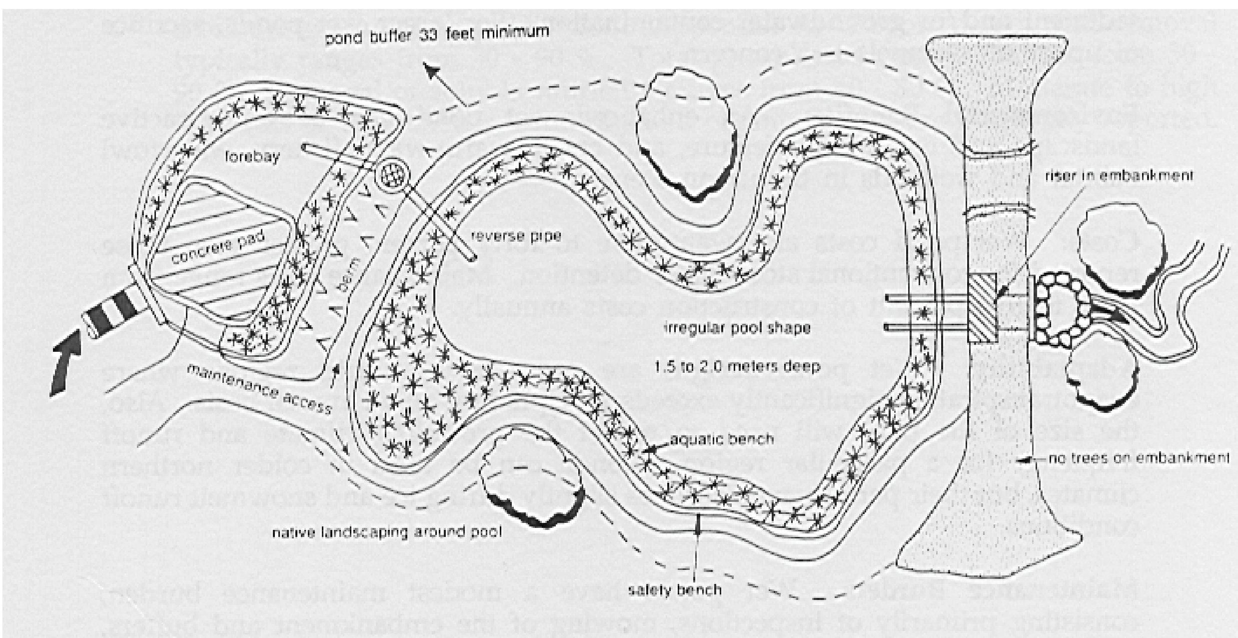
Detention

Detention ponds are essentially basins that are designed to hold a portion of storm water runoff for at least 12-24 hours (Figure 25). Pollutant removal is accomplished mainly through settling and biological uptake. Wet detention ponds are more effective than dry detention ponds as the latter have a greater risk of sediment re-suspension and generally do not provide adequate soluble pollutant removal. Although effective, the land requirement is typically large; the area should be at least 2% of the drainage area it serves, and preferably as much as 7% of that area. This approach should be considered in conjunction with treatment wetland construction for new development projects. Application to developed basins will be more difficult, given current land use and land value, but opportunities may exist in selected basins. Additionally, current structures such as the Hales Brook pond could be expanded, or at least deepened, to increase the holding capacity and retention time.

Infiltration Systems

Infiltration systems may include trenches, basins or dry wells, and involve the passage of water into the soil or an artificial medium (Figure 26). Particles are filtered by the soil matrix and many soluble compounds are adsorbed to soil particles. Such systems require sufficient storage capacity to permit the gradual infiltration of runoff into suitable soils. Pre-treatment of the runoff allows larger particles to be removed, thereby aiding in the prevention of infiltration system failure due to clogging and sediment accumulation.

Site constraints such as shallow depth to groundwater table or bedrock and poorly drained soils often limit the effective use of infiltration. In sites with suitable conditions, off-line infiltration systems are generally preferred. The key to successful infiltration is providing adequate pre-infiltration settling time or other treatment to remove particles that could clog the interface at which infiltration occurs. Soils within the watershed appear suitable for infiltration chambers, provided bedrock and water table are not a hindrance. Lake Pocotopaug would benefit greatly by letting natural filtration attenuate the current solid and phosphorus load from the watershed. Removal of nearly all pollutants of concern (dissolved nitrogen is the only contaminant not removed by soil) could be accomplished by such action.



Source: Schueler, 1991.

Figure 25. Detention Systems.

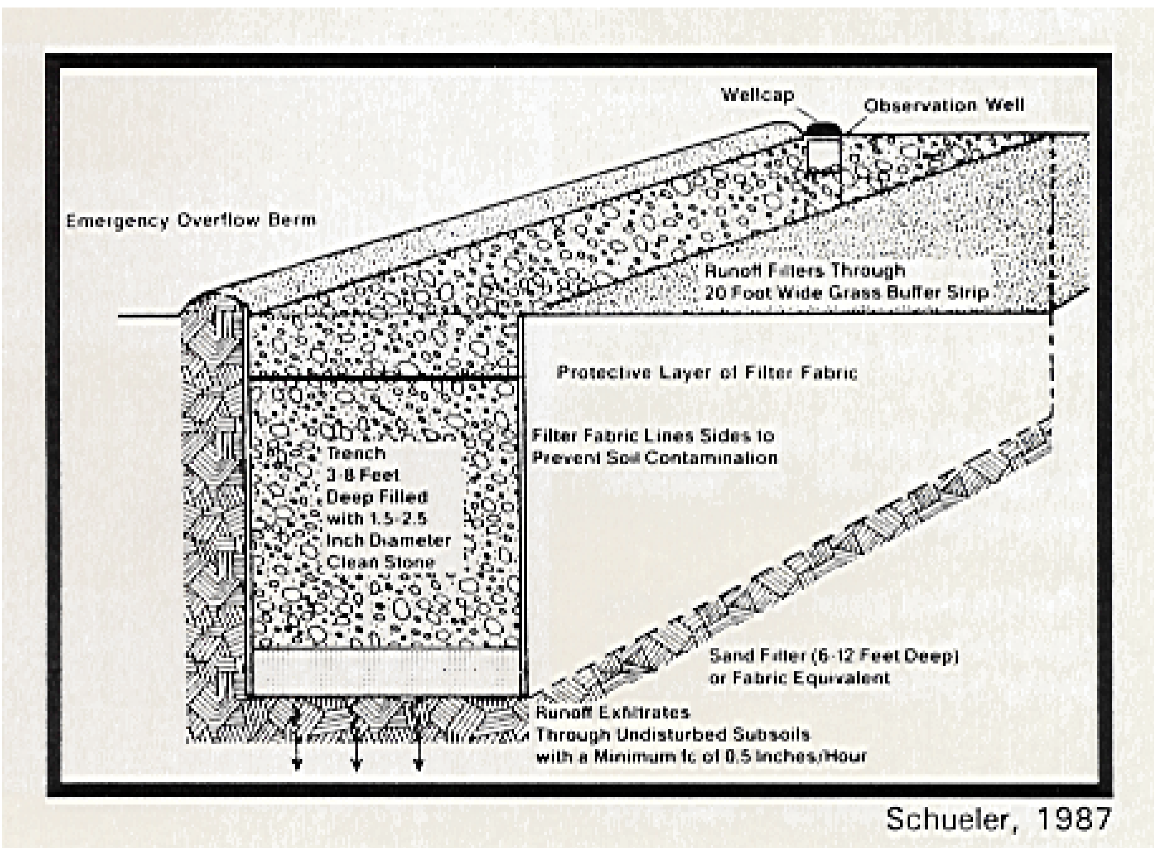


Figure 26. Infiltration Systems.

Created Wetlands

Created wetlands are shallow pools that create conditions suitable for the growth of marsh or wetland plants (Figure 27). These systems maximize pollutant removal through vegetative filtration, nutrient uptake, soil binding, bacterial decomposition, and enhanced settling. Much of the effectiveness of the treatment is related to microbial action; the plants are more the substrate than the active pollutant removers. An effective treatment system may combine created wetlands with detention ponds. Created wetlands are suitable for on-line or off-line treatment (assuming maintenance of adequate hydrology with off-line systems to support the wetland). This technique is recommended in association with any new development.

There is little space proximal to the lake for the construction of new wetlands. Natural wetlands already fulfill this function in many areas, but the capacity of those natural wetlands should not be strained by new development. Rather, the establishment of treatment wetlands to handle runoff from developing areas should be used to minimize impacts on the natural wetlands wherever possible. Establishment of treatment wetlands in existing developed areas is desirable, but may not be practical under space limitations. Enhancing existing systems such as the pond near Christopher Road and along Hales Brook through the plantings of native wetland species could increase pollutant-trapping capabilities in these drainage areas.

Advanced Drainage Swales

Ditches have long been used to convey storm water, but with careful planning and construction these swales can become combination detention, infiltration and treatment systems (Figure 28). Grassed swales are preferable to exposed soil ditches, and if the ground water table is high a wetland flora may be sustainable. Small permeable barriers (rock-filled baskets, or gabions) can be used to slow velocity and encourage both settling and infiltration. Deeper portions, usually near road crossings or other access points, will trap coarse particles and can be cleaned out like catch basin sumps or small detention basins. Such swales must be maintained, but can provide both adequate drainage and treatment of runoff. These may also function as a conduit for ground water break-out that forms baseflow in many streams, providing some measure of treatment before entry to a stream or lake.

Drainage swales already exist in some areas around Lake Pocotopaug, but are more rudimentary than suggested here as a management system. Retrofitting these swales is possible, however, and should be considered for developed areas. The greatest concern involves traffic safety in areas with steeper slope or winding roads, given potentially icy winter conditions. Proper safety precautions, such as guardrails, may add substantially to cost and have limited swale use in some areas of the northeastern US, but this can be a cost-effective technique.

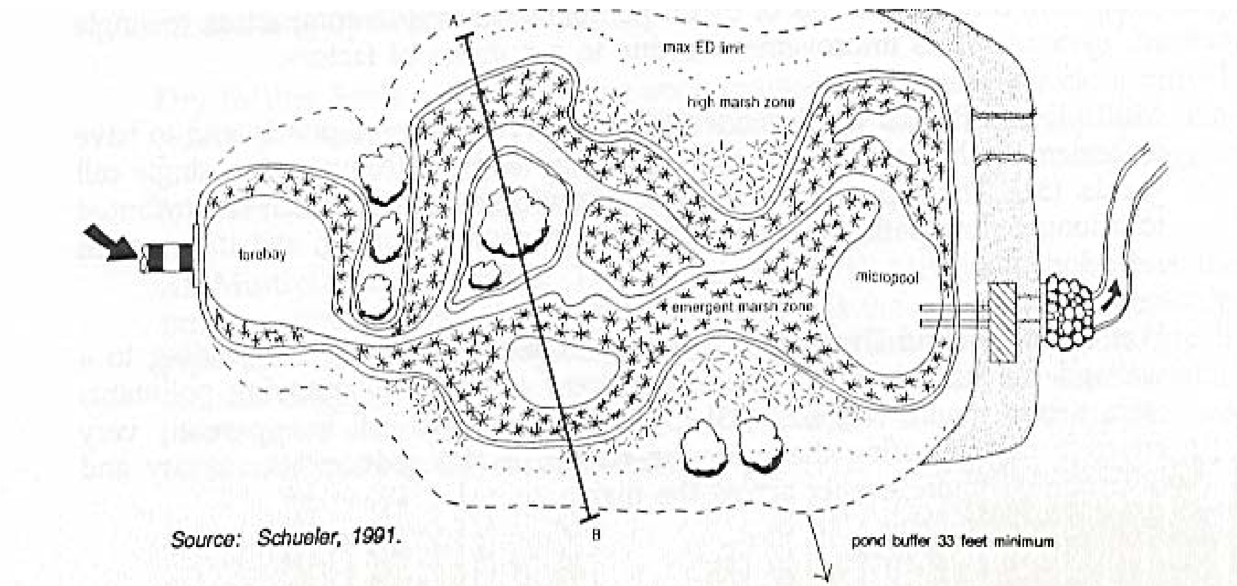
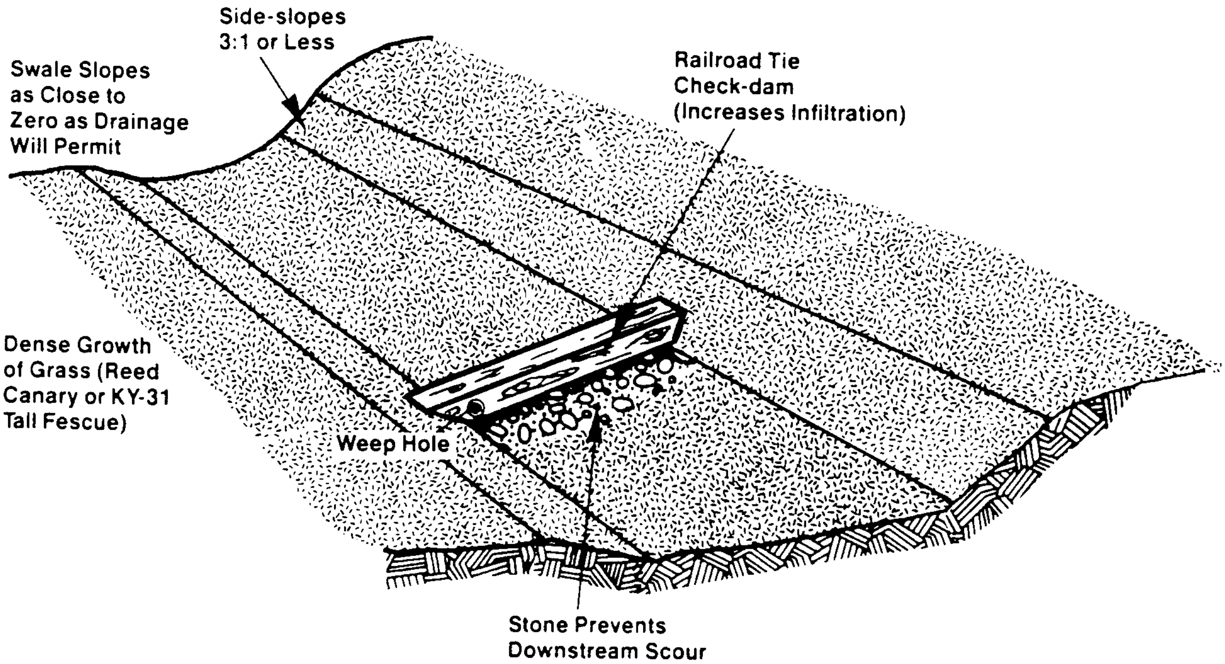


Figure 27. Constructed Treatment Wetlands.



Scheuler et al. 1992

Figure 28. Water Quality Improvement Swales.

Chemical Treatment

In-stream chemical treatment involves the dosing of stream flows with alum or other coagulants to bind phosphorus and coagulate sediments to promote settling. During this process, phosphorus permanently complexes with aluminum or another binding agent, rendering it unavailable for biological uptake by algae. Clarification of drinking water uses alum extensively, and removal of phosphorus from wastewater in tertiary treatment systems often involves alum. This in-stream treatment technology has been successfully applied in other regions, especially Florida. The primary application of this technology has been for phosphorus removal where other BMPs were not viable. Phosphorus removal rates ranging from 50-95% have been reported. Removal rates ranging from 50-99% have also been documented for other pollutants such as suspended solids, nitrogen, color, and bacteria. The alum treatment performed in the lake itself was intended to inactivate past inputs from the watershed; application in the watershed would constitute pre-entry inactivation.

Although effective, this technique is not recommended for Lake Pocotopaug due to high operational and maintenance costs. A dosing station would be needed for each discharge point, with at least four major locations possible. It may be possible to selectively treat the most problematic discharges, but this would not be considered until other means of controlling loads have been explored, attempted, and dismissed.

11.3 Prevent algal blooms from occurring and maximize water clarity

Algal blooms are an issue at Lake Pocotopaug. Low nutrient availability typically controls algal growth, but not to the desired extent in this system. Blooms have occurred when total phosphorus concentrations were as low as 10 ug/L, a level considered safe in most systems. This problem may be due to the types of algae present (a high volume to mass ratio blue-green is dominant in blooms), additional nutrient sources not being measured by water column monitoring (sediment uptake) or lack of substantial zooplankton grazing. When considering graphs of the relationship between water clarity and chlorophyll or phosphorus, Lake Pocotopaug falls along the outside edge of the range of observed values. That is, while the observed relationships are within the range observed elsewhere, this lake is experiencing about as high a level of production per unit of available phosphorus as allowed anywhere and as low a water clarity per unit of chlorophyll as might be expected. This means that management must aim to do better than average – there is nothing average about Lake Pocotopaug!

The most preferable approach to eliminating algal blooms involves reducing the in-lake phosphorus concentrations even further, but there are practical limits to this approach. All methods described previously will reduce incoming phosphorus concentrations, but at best we might reasonably expect a 60% reduction in the in-lake concentration of phosphorus could be realized. This should reduce the probability of blooms, but in-lake concentrations will still be high enough at times to fuel algal blooms in this lake. Acting to reduce loading is recommended, but it may not be sufficient by itself to achieve the desired results.

Means by which algal blooms might be controlled through in-lake actions and the primary advantages and disadvantages are listed in Table 21. Most have some applicability to Lake Pocotopaug, but with what has been learned to date, many can be eliminated as front line methods going forward from here. Further in-lake phosphorus inactivation should not be ruled out, but it does not seem appropriate to pursue this approach further until other sources of phosphorus loading have been addressed. Use of algaecides is generally not a good idea except in emergencies, as direct and indirect side effects can be substantial. Some techniques, such as large-scale dredging, drawdown or hypolimnetic withdrawal are minimally applicable to this case. A review of options in Table 21 suggests that the most advantageous in-lake method (after the phosphorus inactivation approach implemented in 2001) is biological control through enhanced grazing by zooplankton on algae.

Biological, or top-down control, is a form of biomanipulation in which biological components of an aquatic system are altered to create a cascading effect within the food web that results in some desirable change. In this and many other cases that change would be increase water clarity. Reducing predation on zooplankton by panfish, currently very abundant in Lake Pocotopaug, should increase zooplankton size and density. Larger and more abundant zooplankton will be a more effective phytoplankton grazing influence, thereby reducing algal density. This relationship has been demonstrated in the lab, in small ponds, and in some fairly large lakes, with each increase in size of resource accompanied by a longer time period to achieve the desired biological structure and enhanced water clarity.

Biological interactions are quite complicated, however, and not nearly as consistent as chemical or physical control methods. The normal approach to enhancing grazing by zooplankton involves either directly removing panfish or stocking predator fish to consume more panfish. The latter approach is generally considered preferable, but adds a step and further complicates the chain of events. If the stocked predator fish reproduce, their young may eat zooplankton for some time before switching to the target panfish assemblage, so zooplankton predation intensity tends to vary considerably over time. Some algae resist grazing fairly well, allowing blooms to form in the presence of abundant zooplankton. However, empirical research has shown that the degree of zooplankton grazing is a major factor in where a lake is positioned within the range of possible chlorophyll and water clarity values for a given phosphorus concentration.

The stocking of walleye in Lake Pocotopaug may have the desired affect. Walleye were stocked in several lakes throughout Connecticut in an effort to increase fishing diversity, but one of the prerequisites for successful walleye introduction is an abundant population of small perch. Lake Pocotopaug certain provides that condition, and if enough walleye were stocked in Lake Pocotopaug, panfish densities should decrease, zooplankton body size and abundance should increase, and phytoplankton densities should decrease. A fisheries study is warranted to determine if enough fish were stocked to have this secondary effect on Lake Pocotopaug.

TABLE 21. MANAGEMENT OPTIONS FOR CONTROL OF ALGAE

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
Physical Controls			
1) Hypolimnetic aeration or oxygenation	♦ Addition of air or oxygen at varying depth provides oxic conditions ♦ May maintain or break stratification ♦ Can also withdraw water, oxygenate, then replace	♦ Oxic conditions promote binding/sedimentation of phosphorus ♦ Counteraction of anoxia improves habitat for fish/invertebrates Build-up of dissolved iron, manganese, ammonia and phosphorus reduced	♦ May disrupt thermal layers important to fish community ♦ May promote supersaturation with gases harmful to fish
2) Circulation and destratification	♦ Use of water or air to keep water in motion ♦ Intended to prevent or break stratification ♦ Generally driven by mechanical or pneumatic force	♦ Reduces surface build-up of algal scums ♦ Promotes uniform appearance ♦ Counteraction of anoxia improves habitat for fish/invertebrates ♦ Can eliminate localized problems without obvious impact on whole lake	♦ May spread localized impacts ♦ May increase oxygen demand at greater depths ♦ May promote downstream impacts
3) Dilution and flushing	♦ Addition of water of better quality can dilute nutrients ♦ Addition of water of similar or poorer quality flushes system to minimize algal build-up ♦ May have continuous or periodic additions	♦ Dilution reduces nutrient concentrations without altering load ♦ Flushing minimizes detention; response to pollutants may be reduced	♦ Diverts water from other uses ♦ Flushing may wash desirable zooplankton from lake ♦ Use of poorer quality water increases loads ♦ Possible downstream impacts

TABLE 21 continued. MANAGEMENT OPTIONS FOR CONTROL OF ALGAE

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
Physical Controls			
4) Drawdown	♦ Lowering of water over autumn period allows oxidation, desiccation and compaction of sediments ♦ Duration of exposure and degree of dewatering of exposed areas are important ♦ Algae are affected mainly by reduction in available nutrients.	♦ May reduce available nutrients or nutrient ratios, affecting algal biomass and composition ♦ Opportunity for shoreline clean-up/structure repair ♦ Flood control utility ♦ May provide rooted plant control as well	♦ Possible impacts on contiguous emergent wetlands ♦ Possible effects on overwintering reptiles or amphibians ♦ Possible impairment of well production ♦ Reduction in potential water supply and fire fighting capacity ♦ Alteration of downstream flows ♦ Possible overwinter water level variation ♦ May result in greater nutrient availability if flushing inadequate
5) Dredging	♦ Sediment is physically removed by wet or dry excavation, with deposition in a containment area for dewatering ♦ Dredging can be applied on a limited basis, but is most often a major restructuring of a severely impacted system ♦ Nutrient reserves are removed and algal growth can be limited by nutrient availability	♦ Can control algae if internal recycling is main nutrient source ♦ Increases water depth ♦ Can reduce pollutant reserves ♦ Can reduce sediment oxygen demand ♦ Can improve spawning habitat for many fish species ♦ Allows complete renovation of aquatic ecosystem	♦ Temporarily removes benthic invertebrates ♦ May create turbidity ♦ May eliminate fish community (complete dry dredging only) ♦ Possible impacts from containment area discharge ♦ Possible impacts from dredged material disposal ♦ Interference with recreation or other uses during dredging

TABLE 21 continued. MANAGEMENT OPTIONS FOR CONTROL OF ALGAE

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
Physical Controls			
5.a) "Dry" excavation	♦ Lake drained or lowered to maximum extent practical ♦ Target material dried to maximum extent possible ♦ Conventional excavation equipment used to remove sediments	♦ Tends to facilitate a very thorough effort ♦ May allow drying of sediments prior to removal ♦ Allows use of less specialized equipment	♦ Eliminates most aquatic biota unless a portion left undrained ♦ Eliminates lake use during dredging
5.b) "Wet" excavation	♦ Lake level may be lowered, but sediments not substantially exposed ♦ Draglines, bucket dredges, or long-reach backhoes used to remove sediment	♦ Requires least preparation time or effort, tends to be least cost dredging approach ♦ May allow use of easily acquired equipment ♦ May preserve aquatic biota	♦ Usually creates extreme turbidity ♦ Tends to result in sediment deposition in surrounding area ♦ Normally requires intermediate containment area to dry sediments prior to hauling ♦ May cause severe disruption of ecological function ♦ Usually eliminates most lake uses during dredging
5.c) Hydraulic removal	♦ Lake level not reduced ♦ Suction or cutterhead dredges create slurry which is hydraulically pumped to containment area ♦ Slurry is dewatered; sediment retained, water discharged	♦ Creates minimal turbidity and impact on biota ♦ Can allow some lake uses during dredging ♦ Allows removal with limited access or shoreline disturbance	♦ Often leaves some sediment behind ♦ Cannot handle coarse or debris-laden materials ♦ Requires sophisticated and more expensive containment area ♦ Requires overflow discharge from containment area

TABLE 21 continued. MANAGEMENT OPTIONS FOR CONTROL OF ALGAE

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
Physical Controls			
6) Light-limiting dyes and surface covers	♦ Creates light limitation	♦ Creates light limit on algal growth without high turbidity or great depth ♦ May achieve some control of rooted plants as well	♦ May cause thermal stratification in shallow ponds ♦ May facilitate anoxia at sediment interface with water
6.a) Dyes	♦ Water-soluble dye is mixed with lake water, thereby limiting light penetration and inhibiting algal growth ♦ Dyes remain in solution until washed out of system.	♦ Produces appealing color ♦ Creates illusion of greater depth	♦ May not control surface bloom-forming species ♦ May not control growth of shallow water algal mats
6.b) Surface covers	♦ Opaque sheet material applied to water surface	♦ Minimizes atmospheric and wildlife pollutant inputs	♦ Minimizes atmospheric gas exchange ♦ Limits recreational use
7) Mechanical removal	♦ Filtering of pumped water for water supply purposes ♦ Collection of floating scums or mats with booms, nets, or other devices ♦ Continuous or multiple applications per year usually needed	♦ Algae and associated nutrients can be removed from system ♦ Surface collection can apply on an “as needed” basis ♦ May remove floating debris ♦ Collected algae dry to minimal volume	♦ Filtration requires high backwash and sludge handling capability for use with high algal densities ♦ Labor intensive unless a mechanized system applied, in which case it is capital intensive ♦ Many algal forms not amenable to collection by net or boom ♦ Possible impacts on non-targeted aquatic life

TABLE 21 continued. MANAGEMENT OPTIONS FOR CONTROL OF ALGAE

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
Physical Controls			
8) Selective withdrawal	♦ Discharge of bottom water which may contain (or be susceptible to) low oxygen and higher nutrient levels ♦ Intake of water from low algae layer to maximize supply quality ♦ May be pumped or utilize passive head differential	♦ Removes targeted water from lake efficiently ♦ Complements other techniques such as drawdown or aeration ♦ May prevent anoxia and phosphorus build up in bottom water ♦ May remove initial phase of algal blooms which start in deep water ♦ May create coldwater conditions downstream	♦ Possible downstream impacts of poor water quality ♦ May eliminate colder thermal layer important to certain fish ♦ May promote mixing of some remaining poor quality bottom water with surface waters ♦ May cause unintended drawdown if inflows do not match withdrawal
Chemical controls			
9) Algaecides	♦ Liquid or pelletized algaecides applied to target area ♦ Algae killed by direct toxicity or metabolic interference ♦ Typically requires application at least once/yr, often more frequently	♦ Rapid elimination of algae from water column, normally with increased water clarity ♦ May result in net movement of nutrients to bottom of lake	♦ Possible toxicity to non-target areas or species of plants/animals ♦ Restrictions on water use for varying time after treatment ♦ Increased oxygen demand and possible toxicity from decaying algae ♦ Possible recycling of nutrients, allowing other growths

TABLE 21 continued. MANAGEMENT OPTIONS FOR CONTROL OF ALGAE

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
Chemical controls			
9.a) Forms of copper	♦ Contact algaecide ♦ Cellular toxicant, suggested disruption of photosynthesis, nitrogen metabolism, and membrane transport ♦ Applied as wide variety of liquid or granular formulations, often in conjunction with chelators, polymers, surfactants or herbicides	♦ Effective and rapid control of many algae species ♦ Approved for use in most water supplies	♦ Toxic to aquatic fauna as a function of concentration, formulation, temperature, pH, and ambient water chemistry ♦ Ineffective at colder temperatures ♦ Copper ion persistent; accumulates in sediments or moves downstream ♦ Certain green and bluegreen nuisance species are resistant to copper ♦ Lysing of cells releases cellular contents (including nutrients and toxins) into water column
9.b) Forms of endothall (7-oxabicyclo [2.2.1] heptane-2,3-dicarboxylic acid)	♦ Contact algaecide ♦ Membrane-active chemical which inhibits protein synthesis ♦ Causes structural deterioration ♦ Applied as liquid or granules, usually as hydrothol formulation for algae control	♦ Moderate control of thick algal mats, used where copper is ineffective ♦ Limited toxicity to fish at recommended dosages ♦ Rapid action	♦ Non-selective in treated area ♦ Toxic to aquatic fauna (varying degrees by formulation) ♦ Time delays on use for water supply, agriculture and recreation ♦ Safety hazards for applicators

TABLE 21 continued. MANAGEMENT OPTIONS FOR CONTROL OF ALGAE

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
Chemical controls			
9.c) Forms of diquat (6,7-dihydropyrido [1,2-2',1'-c] pyrazinediium dibromide)	♦ Contact algaecide ♦ Absorbed directly by cells ♦ Strong oxidant; disrupts most cellular functions ♦ Applied as a liquid, sometimes in conjunction with copper	♦ Moderate control of thick algal mats, used where copper alone is ineffective ♦ Limited toxicity to fish at recommended dosages ♦ Rapid action	♦ Non-selective in treated area ♦ Toxic to zooplankton at recommended dosage ♦ Inactivated by suspended particles; ineffective in muddy waters ♦ Time delays on use for water supply, agriculture and recreation
10) Phosphorus inactivation	♦ Typically salts of aluminum, iron or calcium are added to the lake, as liquid or powder ♦ Phosphorus in the treated water column is complexed and settled to the bottom of the lake ♦ Phosphorus in upper sediment layer is complexed, reducing release from sediment ♦ Permanence of binding varies by binder in relation to redox potential and pH ♦ Potential for use on inlet streams as well	♦ Can provide rapid, major decrease in phosphorus concentration in water column ♦ Can minimize release of phosphorus from sediment ♦ May remove other nutrients and contaminants as well as phosphorus ♦ Flexible with regard to depth of application and speed of improvement	♦ Possible toxicity to fish and invertebrates, especially by aluminum at low pH ♦ Possible release of phosphorus under anoxia or extreme pH ♦ May cause fluctuations in water chemistry, especially pH, during treatment ♦ Possible resuspension of floc in shallow areas with extreme turbulence ♦ Adds to bottom sediment, but typically an insignificant amount

TABLE 21 continued. MANAGEMENT OPTIONS FOR CONTROL OF ALGAE

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
Chemical controls			
11) Sediment oxidation	♦ Addition of oxidants, binders and pH adjustors oxidizes sediment ♦ Binding of phosphorus is enhanced ♦ Denitrification is stimulated	♦ Can reduce phosphorus supply to algae ♦ Can alter N:P ratios in water column ♦ May decrease sediment oxygen demand	♦ Possible impacts on benthic biota ♦ Longevity of effects not well known ♦ Possible source of nitrogen for blue-green algae
12) Settling agents	♦ Closely aligned with phosphorus inactivation, but can be used to reduce algae directly too ♦ Lime, alum or polymers applied, usually as a liquid or slurry ♦ Creates a floc with algae and other suspended particles ♦ Floc settles to bottom of lake ♦ Re-application typically necessary at least once/yr	♦ Removes algae and increases water clarity without lysing most cells ♦ Reduces nutrient recycling if floc sufficient ♦ Removes non-algal particles as well as algae ♦ May reduce dissolved phosphorus levels at the same time	♦ Possible impacts on aquatic fauna ♦ Possible fluctuations in water chemistry during treatment ♦ Resuspension of floc possible in shallow, well-mixed waters ♦ Promotes increased sediment accumulation
13) Selective nutrient addition	♦ Ratio of nutrients changed by additions of selected nutrients ♦ Addition of non-limiting nutrients can change composition of algal community ♦ Processes such as settling and grazing can then reduce algal biomass (productivity can actually increase, but standing crop can decline)	♦ Can reduce algal levels where control of limiting nutrient not feasible ♦ Can promote non-nuisance forms of algae ♦ Can improve productivity of system without increased standing crop of algae	♦ May result in greater algal abundance through uncertain biological response ♦ May require frequent application to maintain desired ratios ♦ Possible downstream effects

TABLE 21 continued. MANAGEMENT OPTIONS FOR CONTROL OF ALGAE

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
Chemical controls			
14) Management for nutrient input reduction	♦ Includes wide range of watershed and lake edge activities intended to eliminate nutrient sources or reduce delivery to lake ♦ Can involve use of wetland treatment cells or detention areas created from part of lake ♦ Essential component of algal control strategy where internal recycling is not the dominant nutrient source, and desired even where internal recycling is important	♦ Acts against the original source of algal nutrition ♦ Decreased effective loading of nutrients to lake ♦ Creates sustainable limitation on algal growth ♦ May control delivery of other unwanted pollutants to lake ♦ Generally most cost effective over long term ♦ Facilitates ecosystem management approach which considers more than just algal control	♦ May involve considerable lag time before improvement observed ♦ May not be sufficient to achieve goals without some form of in-lake management ♦ Reduction of overall system fertility may impact fisheries ♦ May cause shift in nutrient ratios which favor less desirable species ♦ May cost more in the short term, as source management is generally more involved than one or a few treatments of symptoms of eutrophication
Biological Controls			
15) Enhanced grazing	♦ Manipulation of biological components of system to achieve grazing control over algae ♦ Typically involves alteration of fish community to promote growth of large herbivorous zooplankton, or stocking with phytophagous fish	♦ May increase water clarity by changes in algal biomass or cell size distribution without reduction of nutrient levels ♦ Can convert unwanted biomass into desirable form (fish) ♦ Harnesses natural processes to produce desired conditions	♦ May involve introduction of exotic species ♦ Effects may not be controllable or lasting ♦ May foster shifts in algal composition to even less desirable forms

TABLE 21 continued. MANAGEMENT OPTIONS FOR CONTROL OF ALGAE

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
Biological Controls			
15.a) Herbivorous fish	♦ Stocking of fish which eat algae	♦ Converts algae directly into potentially harvestable fish ♦ Grazing pressure can be adjusted through stocking rate	♦ Typically requires introduction of non-native species ♦ Difficult to control over long term ♦ Smaller algal forms may be benefited and bloom
15.b) Herbivorous zooplankton	♦ Reduction in planktivorous fish to promote grazing pressure by zooplankton ♦ May involve stocking piscivores or removing planktivores ♦ May also involve stocking zooplankton or establishing refugia	♦ Converts algae indirectly into harvestable fish ♦ Zooplankton community response to increasing algae can be rapid ♦ May be accomplished without introduction of non-native species ♦ Generally compatible with most fishery management goals	♦ Highly variable response expected; temporal and spatial variability may be problematic ♦ Requires careful monitoring and management action on 1-5 yr basis ♦ May involve non-native species introduction(s) ♦ Larger or toxic algal forms may be benefited and bloom
16) Bottom-feeding fish removal	♦ Removes fish which browse among bottom deposits, releasing nutrients to the water column by physical agitation and excretion	♦ Reduces turbidity and nutrient additions from this source ♦ May restructure fish community in more desirable manner	♦ Targeted fish species are difficult to eradicate or control ♦ Reduction in fish populations valued by some lake users (human and non-human)

TABLE 21 continued. MANAGEMENT OPTIONS FOR CONTROL OF ALGAE

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
Biological Controls			
17) Fungal/bacterial/viral pathogens	♦ Addition of inoculum to initiate attack on algal cells	♦ May create lakewide "epidemic" and reduction of algal biomass ♦ May provide sustained control for several years ♦ Can be highly specific to algal group or genera	♦ Largely experimental approach at this time ♦ Considerable uncertainty of results ♦ May promote resistant forms with high nuisance potential ♦ May cause high oxygen demand or release of toxins by lysed algal cells ♦ Effects on non-target organisms uncertain
18) Competition and allelopathy	♦ Plants may tie up sufficient nutrients to limit algal growth ♦ Plants may create a light limitation on algal growth ♦ Chemical inhibition of algae may occur through substances released by other organisms	♦ Harnesses power of natural biological interactions ♦ May provide responsive and prolonged control	♦ Some algal forms appear resistant ♦ Use of plants may lead to problems with vascular plants ♦ Use of plant material may cause depression of oxygen levels

TABLE 21 continued. MANAGEMENT OPTIONS FOR CONTROL OF ALGAE

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
Biological Controls			
18.a) Plantings for nutrient control	♦ Plant growths of sufficient density may limit algal access to nutrients ♦ Plants can exude allelopathic substances which inhibit algal growth	♦ Productivity and associated habitat value can remain high without algal blooms ♦ Portable plant "pods", floating islands, or other structures can be managed to limit interference with recreation and provide habitat ♦ Wetland cells in or adjacent to the lake can minimize nutrient inputs	♦ Vascular plants may achieve nuisance densities ♦ There will be a water depth limitation on rooted plants but not algae ♦ Vascular plant senescence may release nutrients and cause algal blooms ♦ The switch from algae to vascular plant domination of a lake may cause unexpected or undesirable changes in lake ecology, especially energy flow
18.b) Plantings for light control	♦ Plant species with floating leaves can shade out many algal growths at elevated densities	♦ Vascular plants can be more easily harvested than most algae ♦ Many floating species provide valuable waterfowl food	♦ At the necessary density, the floating plants will be a recreational nuisance ♦ Low surface mixing and atmospheric contact will promote anoxia near the sediment

TABLE 21 continued. MANAGEMENT OPTIONS FOR CONTROL OF ALGAE

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
Biological Controls			
18.c) Addition of barley straw	♦ Input of barely straw can set off a series of chemical reactions which limit algal growth ♦ Release of allelopathic chemicals can kill algae ♦ Release of humic substances can bind phosphorus	♦ Materials and application are relatively inexpensive ♦ Decline in algal abundance is more gradual than with algaecides, limiting oxygen demand and the release of cell contents	♦ Success appears linked to uncertain and potentially uncontrollable water chemistry factors ♦ Depression of oxygen levels may result ♦ Water chemistry may be altered in other ways unsuitable for non-target organisms ♦ Some forms of algae may be resistant and could benefit from the treatment

ecology. Realistically, it may take 3-5 years for an observable effect to become manifest, but this is an approach that virtually all groups can support.

Treating additional areas of the lake with alum could be considered if further testing suggests that such treatment would be beneficial. The 2001 water quality data indicate that hypolimnetic release of dissolved phosphorus was very low, but only about 177 out of 512 acres have been treated. The remaining acreage is not hypolimnetic, but may still be contributing significantly to the phosphorus load. Inactivation may be warranted if that contribution is documented to be sufficiently large.

12.0 ADDITIONAL DATA NEEDS

Management of Lake Pocotopaug and its watershed can proceed based on what we have learned to date, but certain aspects of this system deserve further study to allow the most effective management to be implemented and to answer questions that remain from work done to date. The following additional data collection tasks are recommended:

12.1 In-Lake Monitoring

Despite the apparent need for more watershed work, continued in-lake monitoring is needed as well to assess continued success of the alum treatment in curtailing internal recycling and to evaluate both nutrient and algal dynamics in Lake Pocotopaug. One spring sampling (April), two summer samplings (June-September), and one fall sampling (October/November) for nutrients (total and dissolved phosphorus, ammonium, nitrate and total kjeldahl nitrogen) and T/DO profile, pH and SDT are suggested. Nutrients would be sampled near the surface and bottom on each date in two locations, including the current station 2 and a new station in the south portion or the lake, where wind mixing and sediment resuspension are potentially problematic. A depth-integrated algal sample would also be collected on each date from each station (surface to 2XSDT depth), and a zooplankton sample should also be collected from each in-lake station.

12.2 Watershed Input Monitoring

More data are needed to better quantify loading from tributaries and storm drains, especially as relates to any true first flush phenomenon and spring vs. summer inputs. We suggest targeting up to 12 locations during two storms, with sampling to include pre-storm (dry weather) conditions, the first flush, and a post-peak (waning hydrograph) period. Water quality variables should include total and dissolved phosphorus, ammonium, nitrate and total kjeldahl nitrogen. Flow data should be acquired if possible for each sampling as well, to allow a temporal breakdown of loading during each storm. This sampling will allow an assessment of the importance of early storm inputs vs. later storm and non-storm inputs, and discern any major differences among discharges to the lake (only limited differences are currently apparent). Sampling one storm in the spring and one in the summer will help confirm the apparent higher loading during spring. Combined with the past data, this should allow a more definitive determination of watershed inputs, upon which more cost-effective management plans can be based.

12.3 Additional Algal Monitoring

In addition to the seasonal in-lake sampling noted above, algae should be sampled from two locations in the lake at surface and mid-depth and assessed for composition and relative abundance during November and December on a biweekly basis. The presence of any potentially toxic forms must be noted.

12.4 Additional Investigative Sampling

In addition to the water quality sampling program above, up to 20 samples should be allocated for suspected contaminants as warranted by the above investigations. This investigative sampling allowance will enable investigation of any suspicious inputs or events relating to the lake.

12.5 Algal Assays

The occurrence of blooms in Lake Pocotopaug at relatively low phosphorus levels is unusual, and the ability of ambient phytoplankton (especially the assemblage dominated by *Anabaena aphanizomenoides*) to grow at successively lowered nutrient levels should be investigated. Lab assays using lake water, diluted lake water, and distilled water can be run to determine the growth potential of Lake Pocotopaug algae. These algae may still be getting some nutrition from the sediments as stored reserves in the resting stages before they germinate each year, or may just be very effective at using low ambient levels of phosphorus. This effort should be able to determine the proper target for phosphorus in Lake Pocotopaug to prevent these blooms, and whether additional nutrient inactivation (in other parts of the lake) is necessary.

12.6 Fish Assays

The apparent stress on fish each winter can be investigated by lab assays using lake water and test fish under controlled laboratory conditions. Assays should be run using water from the lake or tributaries to determine if observed effects in the lake can be duplicated in the lab. Assays should occur in December and possibly January, at the time of known past stress. Assays should include water from near the bottom of the lake and any suspicious input source.

13.0 RECOMMENDED MANAGEMENT PROGRAM

Watershed management is the crux of controlling incoming sediment and nutrients. This should include both source controls and transport mitigation techniques, with the objective of reducing inputs to the maximum degree possible. In-lake techniques may be necessary to abate past inputs, as with the 2001 alum treatment. Additional in-lake measures may aid achievement of the desired conditions, including additional alum treatment (if warranted by further investigation) and adjusting the fish community to foster larger and more zooplankton to more effectively graze available algae.

13.1 Source Controls

With regard to source controls, education followed by local ordinances is recommended to curtail practices that result in unnecessary solids and nutrient releases. Paramount among these is lawn fertilization, demonstrated in many studies to be the most major contributor of phosphorus from residential areas. We have a cultural problem in our society today, in that people have attached status and appeal to a very green monoculture of grass around their dwellings. This is a difficult cultural issue to address, and education about the benefits and beauty of a more natural landscape is needed before we are likely to see a cultural shift in landscaping preferences.

Yet even without a major shift in thinking we can make progress, as a mature lawn requires almost no phosphorus additions in the form of fertilizer. The use of no phosphate or at least low phosphate fertilizer is highly desirable, and avoidance of fertilizer use on lawns where a soil test indicates no need represents a savings for both the homeowner and the lake. Additionally, application of fertilizer should be avoided prior to predicted major storms. Minimizing the area of lawn fertilized can also be helpful, leaving a peripheral buffer zone through which fertilizer must pass with runoff before it can leave the property.

The recommended approach is first to educate town residents (not just those on the lake or in its watershed, although this is the target of this study) to their role in protecting water quality and the town's precious water resources, like Lake Pocotopaug. Brochures that can be placed conspicuously in public places and in homes are useful, as are public service advertisements and programs on the local cable access network. The education effort would be followed by a town ordinance controlling fertilizer use, the key provision of which would be a required soil test to demonstrate the need for fertilizer before any application is made. Enforcement can be difficult, and it is suggested that this ordinance be approached slowly and with as much public input as possible. The education phase can be instrumental in getting residents to understand and accept the desired restriction.

A review of other residential practices should be conducted to determine which of these might also be targets for education and regulation. Although much of the watershed is sewered, septic system maintenance is important for those with such systems, and what is good for the environment is generally good for the homeowner in that case (a properly functioning system limits impact and also reduces long-term cost). It is not clear how much yard waste disposal and vehicle washing might affect the lake in this case, but an assessment is worthwhile.

An intensive educational program for the town would be expected to cost on the order of $25,000 over perhaps two years. The cost of ordinance development and enforcement would be internalized and is not easily estimated, but is not negligible.

13.2 Transport Mitigation

With regard to mitigation of the transport of pollutants to the lake, the installation of deeper and larger catch basins as roads are re-worked, maintenance of these and existing coarse sediment and debris traps, expansion of existing detention systems, creation of new detention systems, use of wetland features where practical, and establishment of infiltration chambers wherever possible are all appropriate actions. Easy and relatively inexpensive practices include the installation of silt fences around beach locations during periods of high runoff and increasing the frequency of street sweeping and catch basin cleaning, with emphasis on early spring cleaning.

Deciding exactly which combination of structural techniques is to be applied in each case is a site-specific matter. Making such determination goes beyond the scope of this project, but the report filed by WMC in 1995 is an excellent start in this regard. While more emphasis on water quality management and less focus on flood control would have been better for lake management, the review of drainage systems and suggestions for improvement are largely on target. Be cautious of enlarging culverts, however; associated flood control benefits are being traded against more rapid delivery of sediment and nutrients to the lake. It would be better to look for ways to detain the water in the watershed, providing both flood control and water quality benefits.

Wherever possible, infiltration should be the preferred management alternative for solids and nutrient control. This will entail some form of detention, both for initial solids settling (to avoid clogging) and to provide holding capacity where soil permeability is not extremely high. Off-line systems are suggested as most desirable, with the first half inch of runoff as an appropriate design capacity. That means that for a 10 acre area, the system would have to process 18,150 cubic feet (136,125 gallons) of runoff, possibly in as little as an hour. These systems can be underground, avoiding the use of valuable or scenic surface area, but this does increase the price.

The infiltration approach is especially recommended for areas to the east of the lake, where substantial developed land is at a much higher elevation than the lake and soils appear suitable for this approach. Areas farther from the lake to the north and west are also viable candidates, although these areas have limited development at this time. Costs are difficult to estimate at this point, but as a rough guide, an expense of $3000 to $5000 per acre served is offered. If the entire developed area of the watershed was treated in this manner, the cost could be as high as $2.7 million, but a much smaller area is more likely to be addressed by infiltration technologies.

Low areas and places with soils of lower permeability, such as the immediate area around the lake and substantial additional lands just west and north of the lake, will not be appropriate candidates for infiltration. Where possible, detention and some form of wetland treatment would be most desirable for these areas. This may be possible in conjunction with existing structures in some areas, but will be limited in already developed areas close to the lake with high ground water table. There simply is not enough room to work and existing storm water drainage systems route water away from roads and property for public safety purposes.

Where space is adequate, the detention and wetland treatment area should be about 5% of the area served. In other words, a 10-acre area will require a 0.5-acre detention/wetland area to be truly effective. Smaller areas will still provide some benefit, and could be enhanced with superior design (e.g., filter berm outlets, baffled flow), but the larger the area the better. Excluding any land costs, preparation of a detention area will cost about $100,000 per acre, each of which can handle the runoff from about 20 acres. If all developed land in the watershed was managed through detention, the cost would be about $2.7 million, identical to the estimated infiltration cost.

For those areas where surface and subsurface conditions simply do not allow use of infiltration or detention systems as described above, consideration should be given to small-scale engineered solutions. Leaching or deep catch basins (along roads), swales (perpendicular to runoff flow on developed properties), and "artificial infiltration systems" (StormTreat, StormDefender, etc. that handle smaller volumes of runoff in an engineered container sunk into the ground) should be considered. Again, selection of techniques may be highly site-specific. The cost per unit area served will tend to be higher than that for infiltration or detention systems, although there is room for cost saving creativity and many such systems may be designed to handle less than the ideal amount of runoff.

13.3 In-Lake Actions

Further alum treatment may be warranted if other areas of the lake as yet untreated turn out to be significant sources of phosphorus. Such action would not be taken, however, until additional study was completed. Treatment of another 100 to 150 acres of the lake would be expected to cost on the order of $100,000 to $200,000.

Fish community adjustment is currently underway, although the stocking of walleye was not done explicitly to reduce planktivorous panfish and increase zooplankton populations and grazing capacity. Approximately 15,000 walleye were stocked in November 2001. It is not known if this is an appropriate density to control panfish, and it may take a few years before stocked walleye have any measurable impact, but further monitoring of zooplankton should be sufficient to detect relevant changes in zooplankton community structure. Additional stocking may be warranted, but it seems best to monitor for at least a year before taking further action, unless consultation with CT DEP Inland Fisheries staff indicates otherwise. Cost of stocking will be proportional to the number and size of fish stocked. The cost of fingerlings is low and generally affordable (<$0.50 per fish), but major impacts on biotic structure will take longer than if larger fish (as much as $3/fish) were stocked).

The recommended additional data collection tasks (Section 12) are expected to collectively cost $50,000, including additional water quality monitoring in the lake and watershed, algal and fish monitoring and assays, and associated analysis and reporting.

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Appendix A:
Analysis of Phosphorus Inactivation

Appendix B:
Supplemental Tables and Figures

Appendix C:
WMC 1995 Stormwater Renovation and Management Plan

(not all inclusive – some appendices and figures omitted)

Appendix D:
Educational Materials