Prepared for:
Town of East Hampton, CT

Lake Pocotopaug 2004
MONITORING RESULTS AND MANAGEMENT IMPLICATIONS

Prepared by:

ENSR INTERNATIONAL

11 Phelp's Way
P.O. Box 506
Willington, CT 06279

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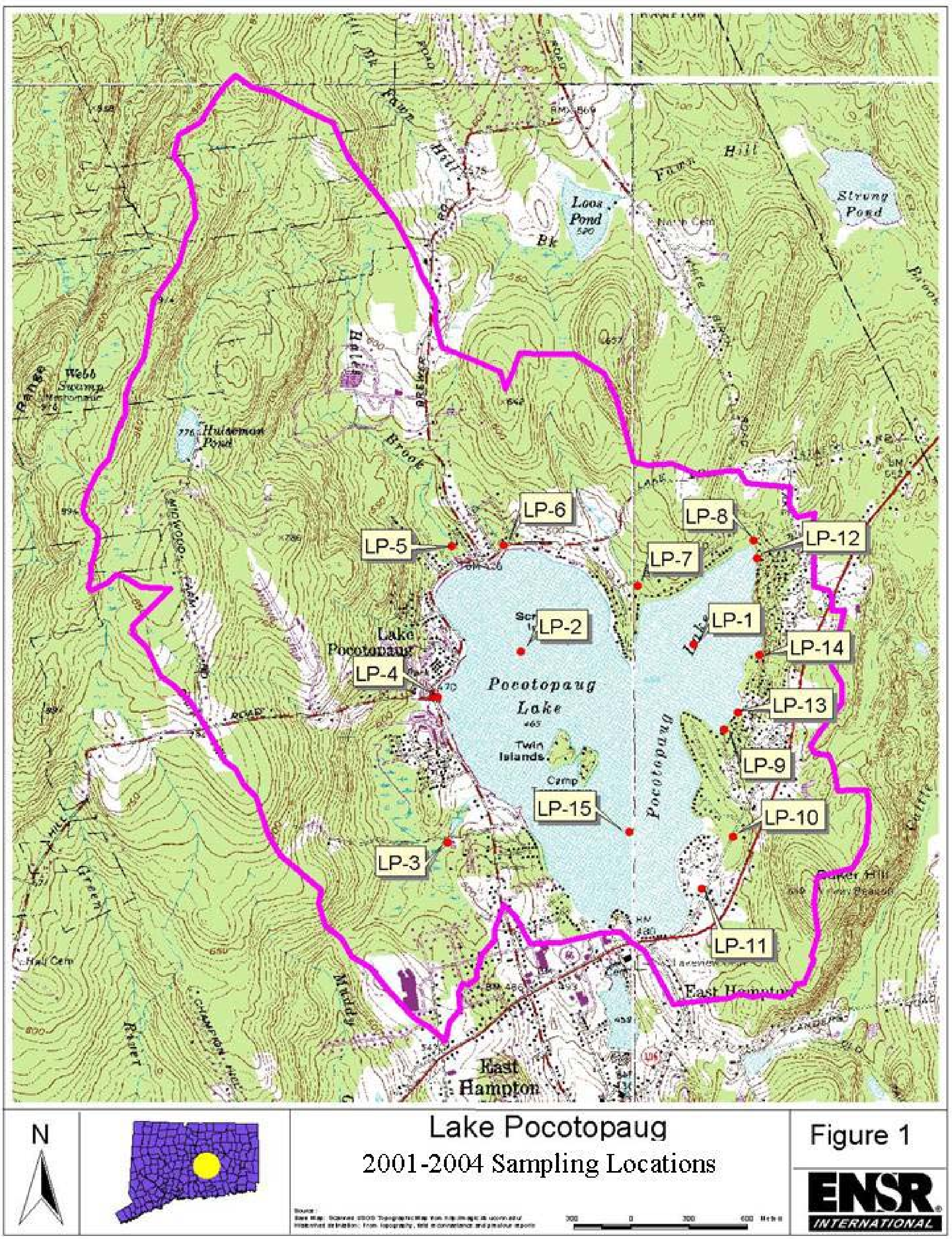
2004 SAMPLING APPROACH

Lake Pocotopaug was sampled at one in-lake station in 2004 (Figure 1), located in the western deep basin (Oakwood Basin; LP-2), on a monthly basis from July until September. Sampling occurred at two depths (surface and bottom) for each sampling period. Samples were analyzed for nutrients (total and dissolved phosphorus, ammonium nitrogen and nitrate nitrogen), conductivity, turbidity, and pH. Secchi disk transparency (SDT) and temperature/dissolved oxygen profiles were recorded during each sampling event. Two algal samples were collected on each date (surface and bottom) and analyzed by an ENSR taxonomist. Additional phytoplankton samples were taken during the summer months starting in June in an effort to detect an onset of an algal bloom. Four zooplankton samples were collected and analyzed by an ENSR taxonomist. Three samples were collected at the LP-2 site, and one was collected off the jetty at Sears Park.

Dry, wet and post-wet weather tributary and storm drain sampling occurred during September 2004, at stations including LP-3, LP-4, LP-5 and LP-11. Not all stations shown in Figure 1 were sampled for budgetary reasons, but the selected stations are considered representative of inputs to the lake. Dry weather was categorized as 72 hours without a precipitation event. Wet weather sampling (first flush) was conducted using passive storm samplers during a precipitation event yielding at least 0.2 inches of rainfall following a period of dry weather. Details regarding the passive samplers are provided in *Lake Pocotopaug Lake and Watershed Restoration Evaluation East Hampton, Connecticut* (ENSR, 2002). The post-wet sampling occurred during the waning hydrograph (period of reduced flow) of the wet weather event sampled. Together, these samples provide insight into the pattern of nutrient loading to the lake.

Figure 1. A map of sampling locations 2001-2004



CHEMICAL AND PHYSICAL RESULTS

In-Lake

Temperature profiles for Lake Pocotopaug in 2004 indicate that the lake was stratified by late July when sampling occurred (Figure 2). Profiles from previous years indicate strong thermal stratification during the months of July and August and sometimes late June. Dissolved oxygen concentrations followed roughly the same pattern as temperature. As in 2003, anoxia was present above the thermocline in August and September.

Lake Pocotopaug 2004 pH and conductivity values were comparable to previous years. The pH in 2004 ranged from 6.5 to 7.7 SU (Table 1), with higher values reported in surface samples. Conductivity was relatively consistent throughout the water column and sampling period with one value greater than 200 umhos/cm occurring at the bottom in July. Values ranged from 87 to 225 umhos/cm with a surface water average of 95 umhos/cm. Values from 1991 to 2003 ranged from 44 to 252 umhos/cm.

Surface water turbidity in 2004 ranged from 1.4 to 8.4 NTU, with an average of 5.6 NTU (Table 1). Surface turbidity values in previous years (1991-2003) ranged from 0.5 – 13.0 NTU. Values at or above 5.0 NTU (threshold for “clean” New England lakes) were reported at the surface during late August and September. Bottom samples were higher on average, ranging from 7.1 to 7.9 NTU. Higher bottom water turbidity is typical with increased suspended solids.

Ammonium and nitrate nitrogen are inorganic forms which are readily available for algal uptake. Levels of ammonium nitrogen greater than 1.0 mg/L are generally considered high while concentrations less than 0.1 mg/L are considered low. Nitrate concentrations were low; 67% of the samples were below the 0.01 mg/L detection limit. Nitrate levels in 2004 were comparable to those observed in previous years. Ammonium nitrogen was low at the surface (<0.1 to 0.05 mg/L) but elevated at the bottom (0.13 to 1.3 mg/L). Average 2004 surface water ammonium concentration was comparable to that measured in previous years.

Average summer surface water phosphorus was the same in 2004 as 2003 (0.024 mg/L). Mean summer surface water total phosphorus concentrations were identical in 2004 and 2003, but significantly higher in 2003 and 2004 than in 2001 and several previous years ($P<0.05$; Figure 3). Over all years, summer bottom total phosphorus concentrations did not vary significantly between years for any given month ($P>0.05$), but did vary significantly between months when considering the complete record ($P<0.05$; Figure 4). Average bottom total phosphorus concentration for the 2004 sampling period was 0.083 mg/L, with a range of 0.034 to 0.141. Surface dissolved phosphorus concentrations in 2004 were generally low, ranging from <0.010 to 0.020 mg/L, with an average of 0.017 mg/L. Dissolved phosphorus concentrations at the bottom were slightly elevated, ranging from 0.023 to 0.094, with an average of 0.048 mg/L (Figure 5). The highest concentration was recorded during late August, consistent with progressive build-up during stratification.

Secchi disk transparancy (SDT) ranged from 2.5 to 9.5 feet. The maximum Secchi depth in 2004 was higher than the maximum in 2002 or 2003. Historically August and September have the lowest Secchi Depth Transparencies (Figure 6).

Figure 2. Lake Pocotopaug Temperature and Dissolved Oxygen Profiles 2004.

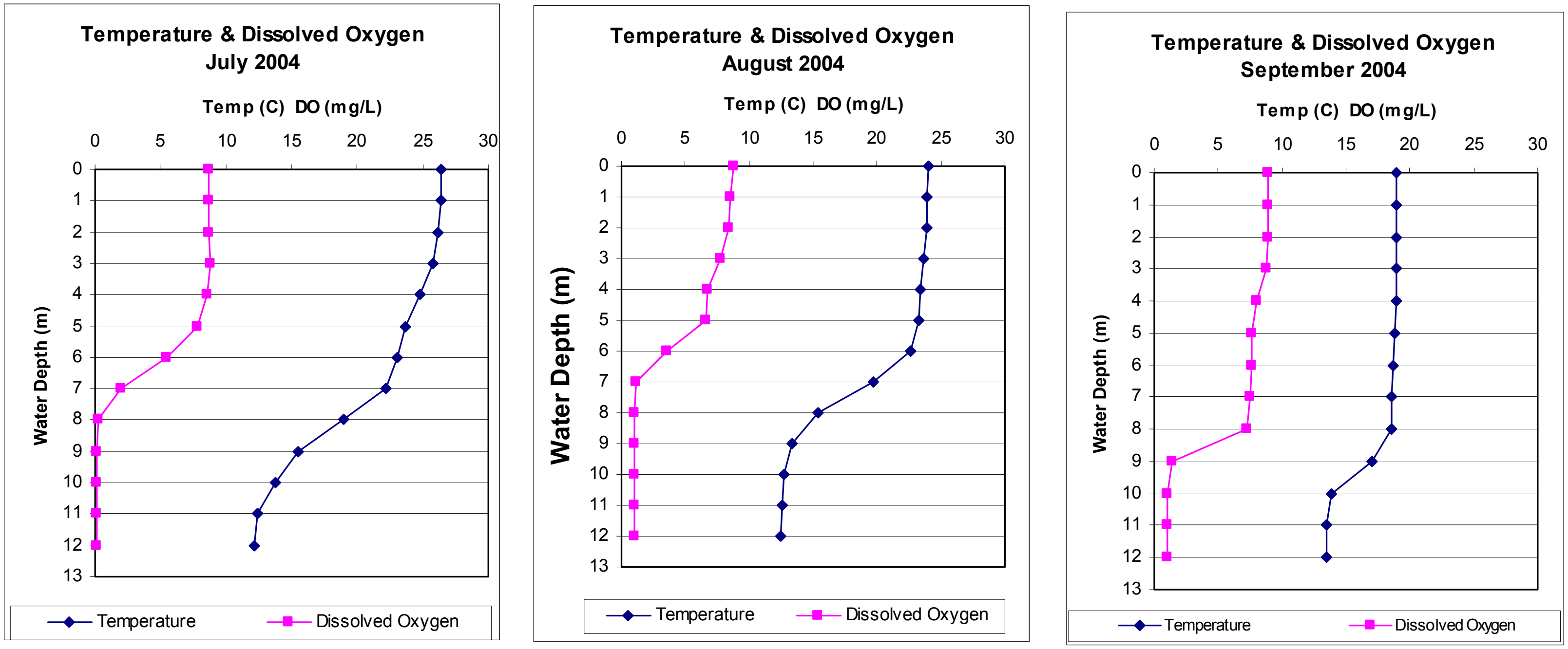


Table 1. Water Quality Sampling Results during 2004.

		7/22/2004	8/26/2004	9/22/2004		Min	Max	Mean
pH (SU)	LP-2S	7.7	7.7	6.8		6.8	7.7	7.4
	LP-2B	6.8	7.1	6.5		6.5	7.1	6.8
Conductivity (umhos/cm)	LP-2S	99	98	87		87	99	95
	LP-2B	225	135	156		135	225	172
Turbidity (NTU)	LP-2S	1.41	6.91	8.35		1.41	8.35	5.56
	LP-2B	7.89	7.51	7.13		7.13	7.89	7.51
Ammonium (mg/L)	LP-2S	0.03	<0.01	0.05		0.03	0.05	0.04
	LP-2B	0.47	1.3	0.13		0.13	1.30	0.63
Nitrate (mg/L)	LP-2S	<0.01	<0.01	0.01		0.01	0.01	0.01
	LP-2B	<0.01	<0.01	0.01		0.01	0.01	0.01
Total Phosphorus (mg/L)	LP-2S	0.02	0.025	0.026		0.020	0.026	0.024
	LP-2B	0.073	0.141	0.034		0.034	0.141	0.083
Dissolved Phosphorus (mg/L)	LP-2S	0.014	<0.010	0.02		0.014	0.020	0.017
	LP-2B	0.028	0.094	0.023		0.023	0.094	0.048
Secchi Disk Transparency (ft)		9.5	2.5	3.1		2.5	9.5	5.0

Figure 3. Surface (Epilimnetic) Water Total Phosphorus at Oakwood Basin (LP-2).

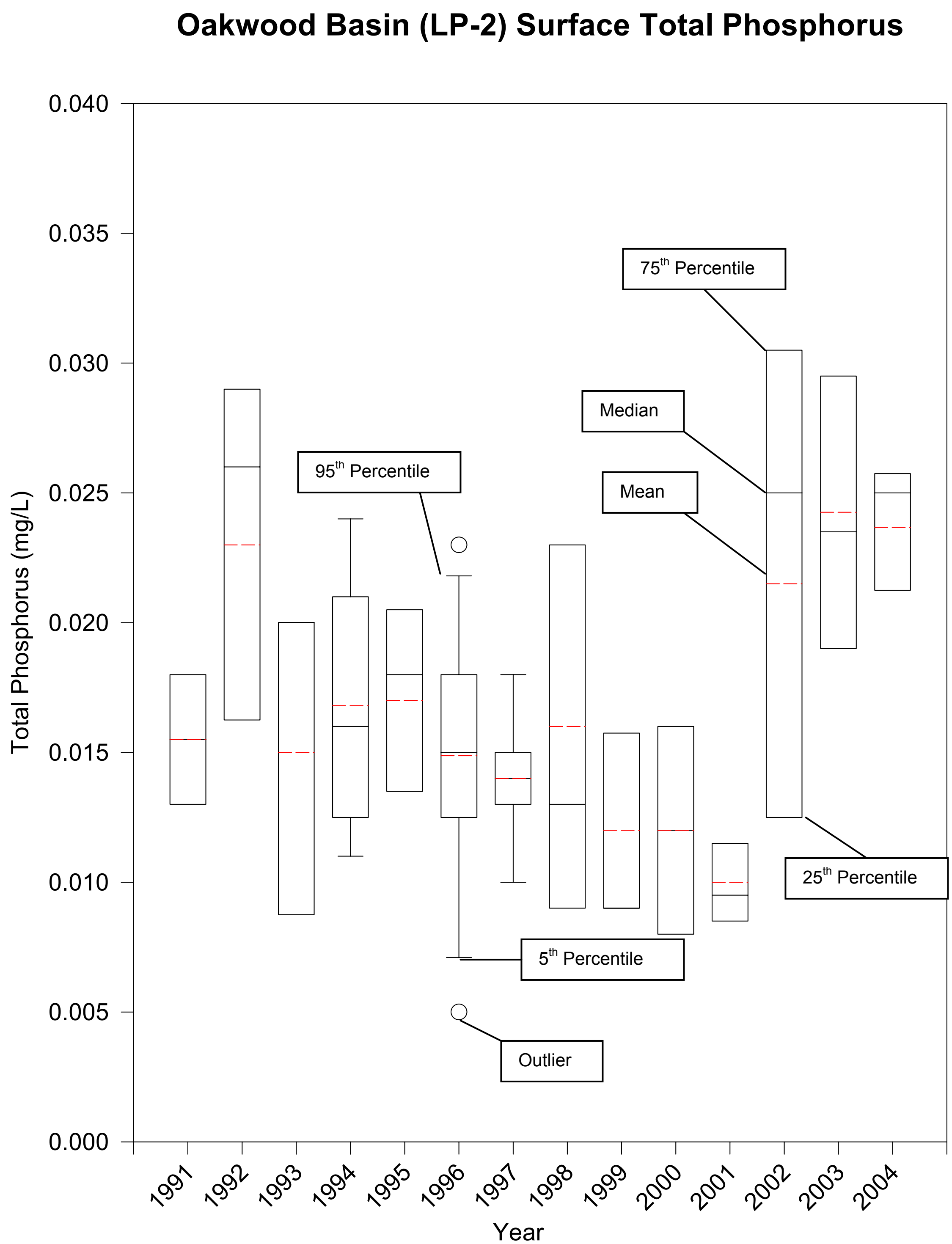


Figure 4. Bottom (Hypolimnetic) Water Total Phosphorus at Oakwood Basin (LP-2).

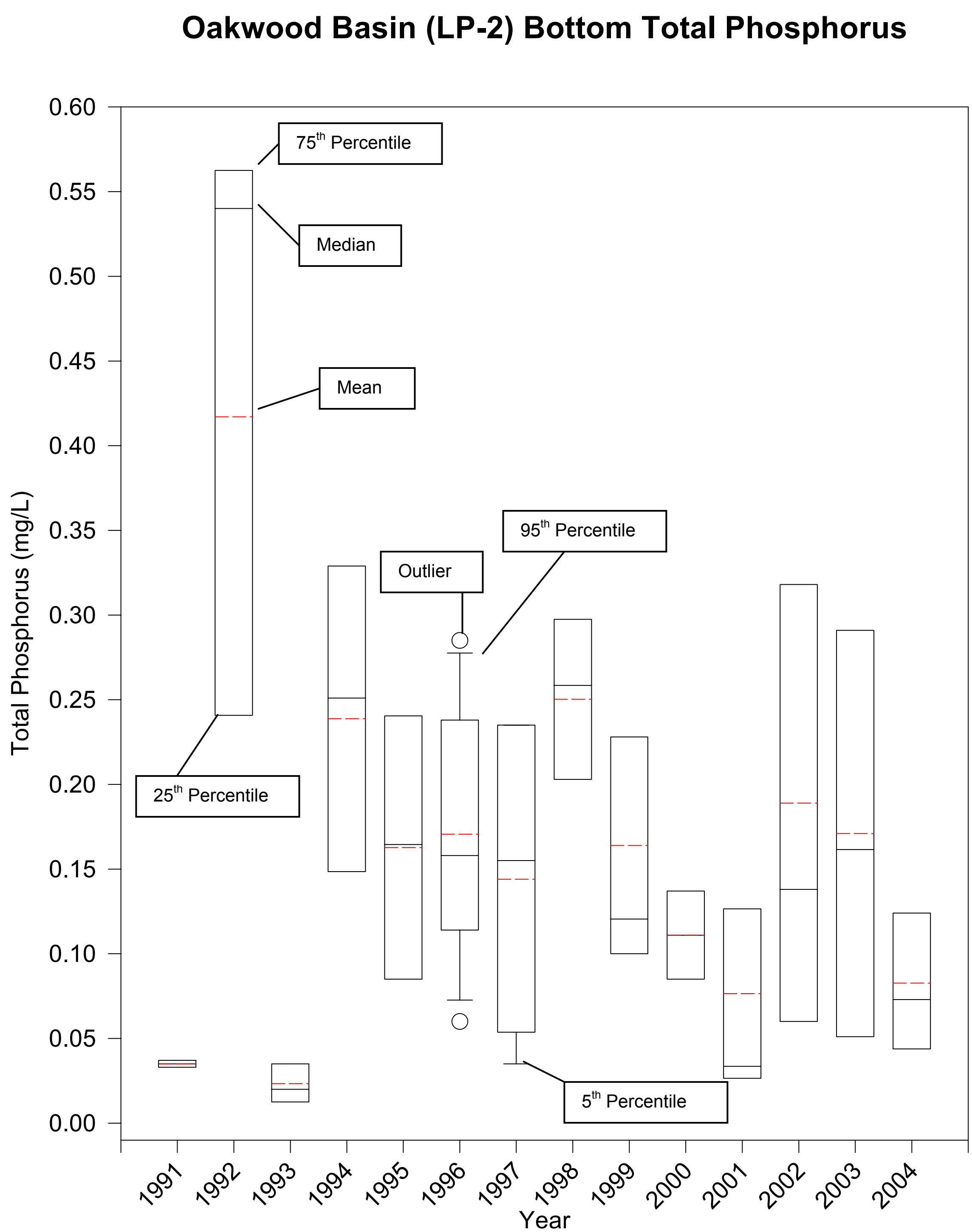


Figure 5. Lake Pocotopaug Dissolved Phosphorus at Oakwood Basin (LP-2) 2001-2004.

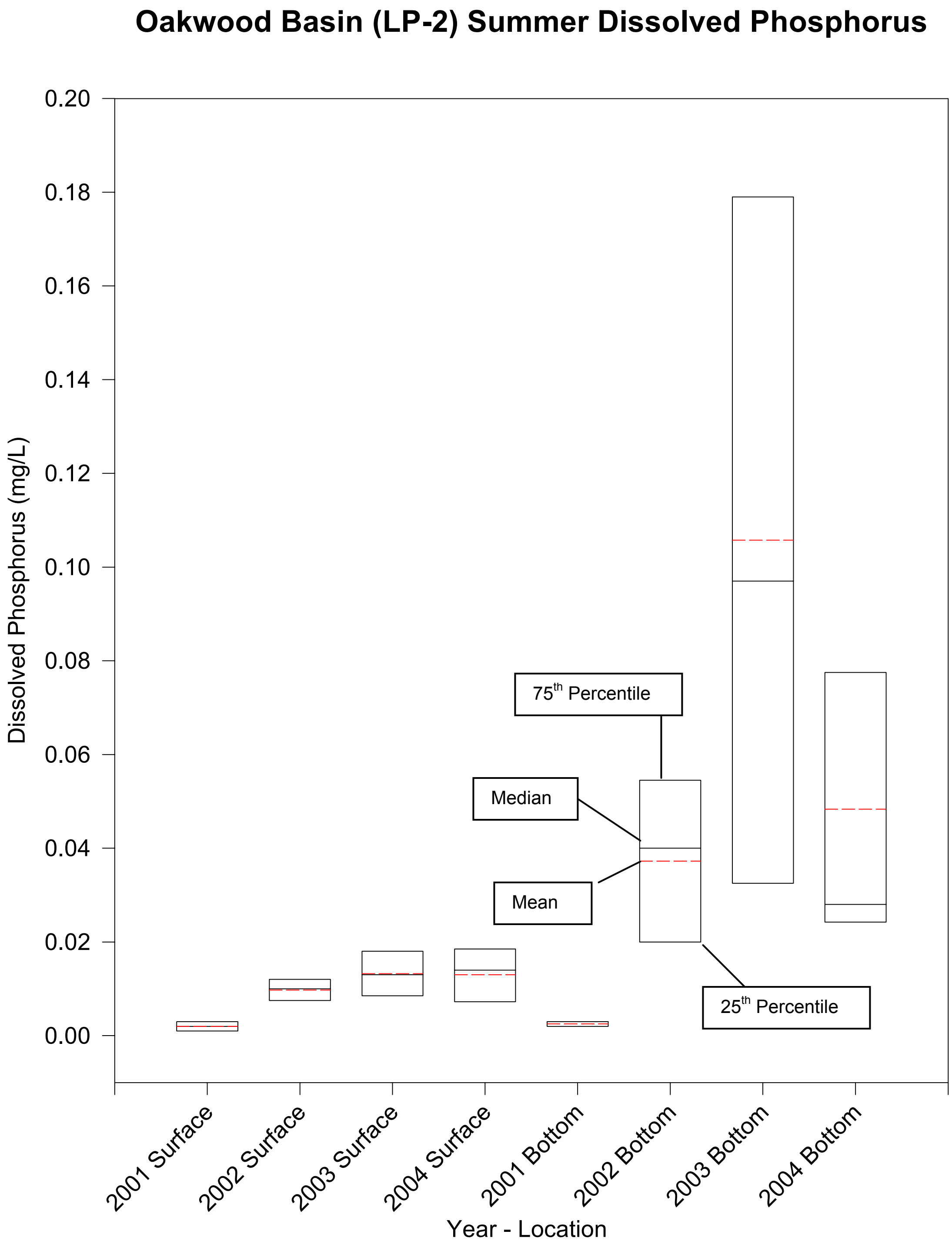
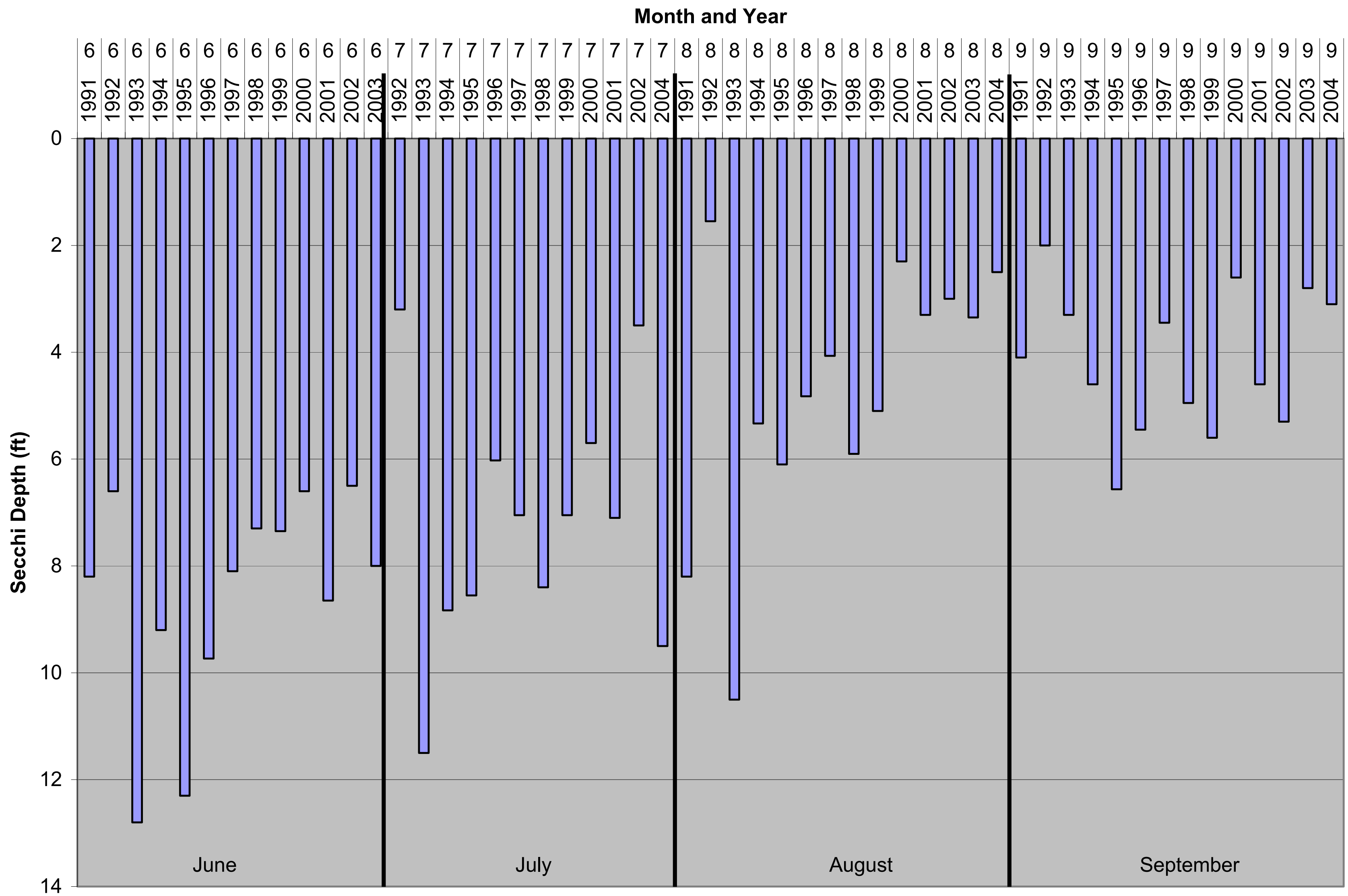


Figure 6. Average Secchi Disk Transparency 1991-2004 at Oakwood Basin (LP-2)



Watershed

Dry weather watershed sampling occurred at three locations (LP-3, LP-5, and LP-11) in August and October 2004. No dry weather data are available for a fourth potential station (LP-4) because this sampling area is dry during non-storm events. Dry weather nitrogen and phosphorus concentrations were low to moderate at sampled locations, with the highest values coming from LP-11 (Table 2). Turbidity was generally low except for the October dry sample for LP-11 which was 18.4 NTU. Conductivity ranged from 46-181 umhos/cm among all sites. Values for pH were the lowest at LP-11 (5.8 and 5.9 SU).

Two passive stormwater samplers were set at each location (all four sites) during the dry weather sampling event. Nutrient concentrations were elevated during wet weather. Total phosphorus concentrations ranged from 0.016 to 0.683 mg/L. Dissolved phosphorus concentrations ranged from <0.010 to 0.096 mg/L. The highest dissolved phosphorus concentration was recorded at LP-4 (Clark Hill storm drain). Turbidity values ranged from 1.28 to 77.6 NTU among sites. Conductivity values were generally lower under wet conditions than under dry, and pH values were similar between dry and wet conditions. A post-wet sample was collected at the time of pickup if flowing water was present in the tributaries or storm drains. A post-wet sample was not collected at LP-4 in August because there was no flowing water.

Post-wet nitrogen and total phosphorus concentrations were generally higher than dry weather samples but lower than wet-weather. The post-wet samples at LP-11 contained higher concentrations of dissolved phosphorus and nitrate than the wet or dry sample, indicating that phosphorus loading is still substantial at this location at the end of the storm. Post-wet turbidity values were acceptable at all locations. Post-wet conductivity values were comparable to dry weather, except at LP-11 where post-wet conductivity was more similar to wet weather conditions.

Table 2. Lake Pocotopaug 2004 Watershed Sampling Results

	LP-3			LP-3			LP-4	LP-4	
	8/26/2004	8/31/2004	8/31/2004	10/12/2004	10/19/2004	10/19/2004	8/31/2004	10/19/2004	10/19/2004
	Dry	Wet	Post-Wet	Dry	Wet	Post-Wet	Wet	Wet	Post-Wet
Ammonium (mg/L)	0.01	0.03	0.03	0.01	<0.01	<0.01	<0.01	<0.01	0.05
Nitrate (mg/L)	0.39	0.27	0.17	0.33	0.19	0.18	0.55	0.11	0.08
Total Phosphorus (mg/L)	0.022	0.104	0.03	0.022	0.03	0.022	0.634	0.216	0.197
Dissolved Phosphorus (mg/L)	0.022	0.036	0.03	0.016	<0.010	<0.010	0.096	0.104	0.106
Turbidity (NTU)	4.1	8.27	2.36	3.96	8.59	4.04	29.7	11.14	7.68
Specific Conductivity (umhos/cm)	110	64	86	105	92	96	126	17	29
pH (SU	6.3	6.2	6.4	6.6	6.2	6.3	6.7	6.4	6.5

	LP-5			LP-5			LP-11			LP-11		
	8/26/2004	8/31/2004	8/31/2004	10/12/2004	10/19/2004	10/19/2004	8/26/2004	8/31/2004	8/31/2004	10/12/2004	10/19/2004	10/19/2004
	Dry	Wet	Post-Wet	Dry	Wet	Post-Wet	Dry	Wet	Post-Wet	Dry	Wet	Post-Wet
Ammonium (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.08	0.15	0.14	0.04	<0.01	<0.01
Nitrate (mg/L)	0.25	0.3	0.11	0.17	0.08	0.07	0.08	0.24	0.6	0.02	0.15	0.17
Total Phosphorus (mg/L)	0.017	0.036	0.022	0.019	0.016	0.033	0.066	0.683	0.109	0.04	0.197	0.156
Dissolved Phosphorus (mg/L)	<0.010	0.025	0.019	0.016	<0.010	<0.010	0.039	0.038	0.093	0.03	0.06	0.066
Turbidity (NTU)	0.77	1.28	1.18	0.64	1.36	0.97	2.49	64.1	58.2	18.4	77.6	59.6
Specific Conductivity (umhos/cm)	49	48	44	46	48	43	175	129	136	181	139	136
pH (SU	6.8	6.9	6.8	6.7	6.6	6.7	5.8	6.0	6.2	5.9	5.9	6.3

BIOLOGICAL RESULTS

2004 Phytoplankton

Phytoplankton were collected on 10 dates between late June and late September, with the intent of tracking the rise of any blooms, especially of the problem cyanophyte (blue-green alga, or cyanobacterium) *Anabaena aphanizomenoides*. Samples were preserved in gluteraldehyde and viewed under a microscope after at least 3 days of settling and sample concentration to a factor of about 10. Phytoplankton density and biomass were calculated from each of the collected samples as in past years.

In early summer the phytoplankton was a mixed assemblage with multiple groups well represented and generally moderate biomass. During mid- to late summer of 2004 the phytoplankton community was dominated by cyanophtyes (Tables 3-5) at generally moderate biomass. However, as cyanophyte cell size is small, a higher turbidity is imparted per unit of biomass. Also, the characteristic color of the cyanophytes creates a less desirable appearance. The two most abundant cyanophyte species were *Anabaena* and *Lyngba* (Table 3), and these species also dominanted the biomass of the samples (Table 4). It was a relatively slow transition, with moderate levels of the diatom *Tabellaria* encountered in July and August. *A. aphanizomenoides* was detected in the June sample, the first collected in 2004, but did not achieve dominance for over a month. The highest levels of *A. aphanizomenoides* were present on 8/26/2004, followed by 7/22/2004. Between late July and mid-August the density of *A. aphanizomenoides* decreased, but spiked again in late August. Water clarity declined markedly by 8/26, and the water had distinctly greenish color by late August. *Anabaena aphanizomenoides* was detected in some summer bottom samples, but only as a few scattered filaments, so the intended early warning of a possible bloom was never given.

There is some perception that the intensity of blooms is subsiding, and it is possible that the reduction in available surficial sediment phosphorus produced by the alum treatment is causing a gradual improvement of conditions. However, it is also possible that observed conditions in 2004, similar to 2003, are a function of weather, including greater flushing and lower incident light (more cloudy days). Additionally, greater amounts of wind mix the cyanophytes and make them less obvious; during calm periods these algae concentrate in the upper 7 ft of the water column and can form surface scums. Further monitoring of algae is warranted.

2004 Zooplankton

Zooplankton were sampled in Lake Pocotopaug on four dates in 2004. Zooplankton were present but not abundant on each date. Zooplankton abundance peeked in July, and was lowest in August, presumably as fish predation increased (Table 6), but all densities were low relative what could be expected in a southern New England lake. No especially large-bodied forms were detected, although some *Daphnia* were present in all samples, including late summer samples. Cladocerans were only found in the September sample. Overall, body size was low to moderate but a greater number of larger bodied zooplankton were present in 2004 compared to 2003, suggesting that the stocking of walleye may be influencing the zooplankton through predation on panfish. That stocking program has only been going on for three years, while effects are more commonly noted after about five years, when the stocked walleye have achieved a larger density at greater average size. Good growth has been reported for walleye stocked in the first two years of the program, but the population is simply not large enough yet to control small white and yellow perch.

Table 3. 2004 phytoplankton density (cells/mL) for all stations and dates. The problem species is highlighted in yellow.

	LP	LP	LP	LP	LP	LP	LP	LP	LP	LP	LP	LP	LP	LP	LP	LP	LP	LP	LP
	Jetty	#2s	#2b	#2s	#2b	#2s	#2b	#2s	#2b	#2s	#2b	#2s	#2b	#2s	#2b	#2s	#2b	#2s	#2b
TAXON	**6/22**	**7/7**	**7/7**	**7/20**	**7/20**	**7/22**	**7/22**	**7/29**	**7/29**	**8/4**	**8/4**	**8/10**	**8/10**	**8/18**	**8/18**	**8/26**	**8/26**	**9/22**	**9/22**
BACILLARIOPHYTA																			
Centric Diatoms																			
Aulacoseira	168	60	0	72	0	230	0	60	96	68	130	320	120	90	51	88	54	0	400
Cyclotella	14	15	15	9	16	0	18	0	0	0	13	0	0	0	0	0	0	38	0
Melosira	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stephanodiscus	0	0	0	0	0	0	0	0	0	0	13	0	15	0	0	0	0	0	20
Urosolenia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20
Araphid Pennate Diatoms																			
Asterionella	0	60	30	0	176	23	72	40	24	0	13	16	60	30	34	0	18	0	20
Fragilaria/related taxa	112	0	0	171	0	0	0	0	0	0	13	0	30	0	0	0	0	0	0
Synedra	0	60	30	45	176	23	0	80	24	0	0	16	30	90	0	0	0	0	20
Tabellaria	42	240	315	531	192	23	18	500	24	323	39	336	360	585	68	132	180	76	120
Monoraphid Pennate Diatoms																			
Achnanthidium/related taxa	0	0	0	18	16	23	0	20	0	0	0	16	0	0	0	0	0	0	0
Cocconeis	0	0	0	45	0	0	0	0	0	0	0	0	0	15	0	0	0	0	0
Biraphid Pennate Diatoms																			
Amphora	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20
Cymbella/related taxa	0	0	0	9	0	0	0	0	0	17	0	0	0	0	0	0	0	19	20
Eunotia	0	0	0	0	0	0	0	0	0	17	0	0	0	0	0	0	0	0	0
Gomphonema/related taxa	0	0	0	0	0	0	0	20	0	17	0	0	0	0	0	0	0	0	20
Navicula/related taxa	56	0	0	18	16	0	0	0	0	0	26	16	15	0	34	0	18	0	20
Nitzschia	0	0	0	36	160	23	18	20	48	17	13	0	15	15	0	0	36	0	40
CHLOROPHYTA																			
Coccoid/Colonial Chlorophytes																			
Ankistrodesmus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	77	0	57	60
Coelastrum	0	0	0	0	0	0	0	0	0	0	0	128	0	0	0	88	0	0	0
Crucigenia	0	0	120	72	0	184	0	0	0	0	0	384	0	120	0	0	0	0	0
Dictyosphaerium	0	0	0	0	0	0	0	160	0	136	0	384	180	360	306	176	0	456	0
Elakatothrix	0	30	0	0	0	0	0	0	0	17	0	0	0	0	0	0	0	0	0
Micractinium	56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	0	0	0
Oocystis	0	60	60	0	32	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pediastrum	0	0	0	0	0	0	0	0	0	68	0	0	0	0	0	0	0	0	0
Scenedesmus	0	60	60	108	0	92	0	40	0	0	0	0	0	0	0	22	0	0	0
Schroederia	56	0	0	0	16	0	0	20	0	17	0	16	0	0	0	0	0	0	0
Desmids																			
Closterium	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cosmarium	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mougeotia/Debarya	0	0	0	0	0	23	0	0	0	0	0	0	0	0	0	0	0	0	0
Staurastrum	0	0	0	0	0	0	0	0	0	0	13	0	0	15	0	0	0	0	0
Staurodesmus	0	15	0	0	0	0	0	0	0	0	0	16	15	0	0	0	0	0	0
CHRYSOPHYTA																			
Flagellated Classic Chrysophytes																			
Dinobryon	0	525	30	63	32	23	18	40	0	17	0	16	0	0	0	0	0	0	0
Mallomonas	0	30	0	0	0	23	0	0	0	0	13	16	0	0	0	0	0	57	40
CRYPTOPHYTA																			
Cryptomonas	0	0	0	0	0	0	0	0	0	0	0	80	0	0	17	11	0	0	0
CYANOPHYTA																			
Unicellular and Colonial Forms																			
Aphanocapsa	0	0	0	0	0	1840	0	1200	0	1020	0	0	0	0	0	0	0	1140	0
Chroococcus	0	60	0	0	0	0	0	80	0	136	0	0	0	0	0	0	0	0	0
Dactylococcopsis	0	0	0	0	0	0	0	0	0	510	0	0	0	0	0	0	0	0	0
Merismopedia	224	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Microcystis	0	0	0	270	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Filamentous Nitrogen Fixers																			
Anabaena	2100	0	0	2250	320	15180	180	4800	0	12240	0	10080	0	6300	170	14520	720	4560	1200
Aphanizomenon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1650	0	0	0
Filamentous Non-Nitrogen Fixers																			
Lyngbya	2800	0	0	0	0	22770	0	15600	480	5100	0	13440	600	6300	0	20460	3780	6080	3600
Pseudanabaena	0	0	0	0	320	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EUGLENOPHYTA																			
Euglena	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0
Trachelomonas	0	15	30	0	48	0	36	40	24	17	13	16	75	30	17	22	18	57	40
PYRRHOPHYTA																			
Ceratium	0	15	0	9	0	12	0	0	0	0	7	16	0	0	0	0	0	0	0

Table 4. 2004 phytoplankton biomass (ug/L) for all stations and dates. The problem species is highlighted in yellow.

	LP	LP	LP	LP	LP	LP	LP	LP	LP	LP	LP	LP	LP	LP	LP	LP	LP	LP	LP
	Jetty	#2s	#2b	#2s	#2b	#2s	#2b	#2s	#2b	#2s	#2b	#2s	#2b	#2s	#2b	#2s	#2b	#2s	#2b
TAXON	**6/22**	**7/7**	**7/7**	**7/20**	**7/20**	**7/22**	**7/22**	**7/29**	**7/29**	**8/4**	**8/4**	**8/10**	**8/10**	**8/18**	**8/18**	**8/26**	**8/26**	**9/22**	**9/22**
BACILLARIOPHYTA																			
Centric Diatoms																			
Aulacoseira	50	18	0	22	0	69	0	18	29	20	39	96	36	27	15	26	16	0	120
Cyclotella	1	38	38	1	2	0	2	0	0	0	1	0	0	0	0	0	0	95	0
Melosira	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stephanodiscus	0	0	0	0	0	0	0	0	0	0	1	0	38	0	0	0	0	0	50
Urosolenia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24
Araphid Pennate Diatoms																			
Asterionella	0	12	6	0	35	5	14	8	5	0	3	3	12	6	7	0	4	0	4
Fragilaria/related taxa	34	0	0	51	0	0	0	0	0	0	4	0	9	0	0	0	0	0	0
Synedra	0	48	24	230	141	18	0	64	19	0	0	13	24	72	0	0	0	0	160
Tabellaria	34	192	252	425	154	18	14	400	19	258	31	269	288	468	54	106	144	61	96
Monoraphid Pennate Diatoms																			
Achnanthidium/related taxa	0	0	0	2	2	2	0	2	0	0	0	2	0	0	0	0	0	0	0
Cocconeis	0	0	0	18	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0
Biraphid Pennate Diatoms																			
Amphora	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28
Cymbella/related taxa	0	0	0	9	0	0	0	0	0	17	0	0	0	0	0	0	0	19	20
Eunotia	0	0	0	0	0	0	0	0	0	17	0	0	0	0	0	0	0	0	0
Gomphonema/related taxa	0	0	0	0	0	0	0	20	0	17	0	0	0	0	0	0	0	0	20
Navicula/related taxa	28	0	0	50	8	0	0	0	0	0	13	8	8	0	17	0	9	0	10
Nitzschia	0	0	0	29	128	18	14	16	38	14	10	0	12	12	0	0	77	0	32
CHLOROPHYTA																			
Coccoid/Colonial Chlorophytes																			
Ankistrodesmus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	6	6
Coelastrum	0	0	0	0	0	0	0	0	0	0	0	26	0	0	0	18	0	0	0
Crucigenia	0	0	12	7	0	18	0	0	0	0	0	38	0	12	0	0	0	0	0
Dictyosphaerium	0	0	0	0	0	0	0	16	0	14	0	38	18	36	31	18	0	46	0
Elakatothrix	0	3	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Micractinium	168	0	0	0	0	0	0	0	0	0	0	0	0	0	0	66	0	0	0
Oocystis	0	24	24	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pediastrum	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0	0	0
Scenedesmus	0	6	6	11	0	9	0	4	0	0	0	0	0	0	0	2	0	0	0
Schroederia	140	0	0	0	40	0	0	50	0	43	0	40	0	0	0	0	0	0	0
Desmids																			
Closterium	0	0	1500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cosmarium	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mougeotia/Debarya	0	0	0	0	0	23	0	0	0	0	0	0	0	0	0	0	0	0	0
Staurastrum	0	0	0	0	0	0	0	0	0	0	10	0	0	12	0	0	0	0	0
Staurodesmus	0	9	0	0	0	0	0	0	0	0	0	10	9	0	0	0	0	0	0
CHRYSOPHYTA																			
Flagellated Classic Chrysophytes																			
Dinobryon	0	1575	90	189	96	69	54	120	0	51	0	48	0	0	0	0	0	0	0
Mallomonas	0	15	0	0	0	12	0	0	0	0	7	8	0	0	0	0	0	29	20
CRYPTOPHYTA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cryptomonas	0	0	0	0	0	0	0	0	0	0	0	16	0	0	3	2	0	0	0
CYANOPHYTA																			
Unicellular and Colonial Forms																			
Aphanocapsa	0	0	0	0	0	18	0	12	0	10	0	0	0	0	0	0	0	11	0
Chroococcus	0	24	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
Dactylococcopsis	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0
Merismopedia	45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Microcystis	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Filamentous Nitrogen Fixers																			
Anabaena	420	0	0	450	64	3036	36	960	0	2448	0	2016	0	1260	34	2904	144	912	240
Aphanizomenon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	215	0	0	0
Filamentous Non-Nitrogen Fixers																			
Lyngbya	56	0	0	0	0	455	0	312	10	102	0	269	12	126	0	409	76	122	72
Pseudanabaena	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EUGLENOPHYTA																			
Euglena	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0
Trachelomonas	0	15	30	0	48	0	36	40	24	17	13	16	140	95	17	22	18	139	40
PYRRHOPHYTA																			
Ceratium	0	261	0	157	0	200	0	0	0	0	113	278	0	0	0	0	0	0	0

Table 5. Density and biomass summary statistics for all 2004 phytoplankton stations and dates.

	LP	LP	LP	LP	LP	LP	LP	LP	LP	LP	LP	LP	LP	LP	LP	LP	LP	LP	LP
	Jetty	#2s	#2b	#2s	#2b	#2s	#2b	#2s	#2b	#2s	#2b	#2s	#2b	#2s	#2b	#2s	#2b	#2s	#2b
	6/22	7/7	7/7	7/20	7/20	7/22	7/22	7/29	7/29	8/4	8/4	8/10	8/10	8/18	8/18	8/26	8/26	9/22	9/22
DENSITY (CELLS/ML) SUMMARY																			
BACILLARIOPHYTA	**392**	**435**	**390**	**963**	**752**	**345**	**126**	**740**	**216**	**459**	**260**	**720**	**645**	**825**	**187**	**220**	**306**	**133**	**720**
Centric Diatoms	182	75	15	90	16	230	18	60	96	68	156	320	135	90	51	88	54	38	440
Araphid Pennate Diatoms	154	360	375	747	544	69	90	620	72	323	65	368	480	705	102	132	198	76	160
Monoraphid Pennate Diatoms	0	0	0	63	16	23	0	20	0	0	0	16	0	15	0	0	0	0	0
Biraphid Pennate Diatoms	56	0	0	63	176	23	18	40	48	68	39	16	30	15	34	0	54	19	120
CHLOROPHYTA	**112**	**165**	**255**	**189**	**48**	**299**	**0**	**220**	**0**	**238**	**13**	**928**	**195**	**495**	**306**	**385**	**0**	**513**	**60**
Coccoid/Colonial Chlorophytes	112	150	240	180	48	276	0	220	0	238	0	912	180	480	306	385	0	513	60
Desmids	0	15	15	9	0	23	0	0	0	0	13	16	15	15	0	0	0	0	0
CHRYSOPHYTA	**0**	**555**	**30**	**63**	**32**	**46**	**18**	**40**	**0**	**17**	**13**	**32**	**0**	**0**	**0**	**0**	**0**	**57**	**40**
Flagellated Classic Chrysophytes	0	555	30	63	32	46	18	40	0	17	13	32	0	0	0	0	0	57	40
CRYPTOPHYTA	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**80**	**0**	**0**	**17**	**11**	**0**	**0**	**0**
CYANOPHYTA	**5124**	**60**	**0**	**2520**	**640**	**39790**	**180**	**21680**	**480**	**19006**	**0**	**23520**	**600**	**12600**	**170**	**36630**	**4500**	**11780**	**4800**
Unicellular and Colonial Forms	224	60	0	270	0	1840	0	1280	0	1666	0	0	0	0	0	0	0	1140	0
Filamentous Nitrogen Fixers	2100	0	0	2250	320	15180	180	4800	0	12240	0	10080	0	6300	170	16170	720	4560	1200
Filamentous Non-Nitrogen Fixers	2800	0	0	0	320	22770	0	15600	480	5100	0	13440	600	6300	0	20460	3780	6080	3600
EUGLENOPHYTA	**0**	**15**	**30**	**0**	**48**	**0**	**36**	**40**	**24**	**17**	**26**	**16**	**75**	**30**	**17**	**22**	**18**	**57**	**40**
PYRRHOPHYTA	**0**	**15**	**0**	**9**	**0**	**12**	**0**	**0**	**0**	**0**	**7**	**16**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
TOTAL	**5628**	**1245**	**705**	**3744**	**1520**	**40492**	**360**	**22720**	**720**	**19737**	**319**	**25312**	**1515**	**13950**	**697**	**37268**	**4824**	**12540**	**5660**
CELL DIVERSITY	**0.53**	**0.85**	**0.77**	**0.66**	**0.92**	**0.41**	**0.65**	**0.43**	**0.51**	**0.49**	**0.90**	**0.45**	**0.77**	**0.48**	**0.69**	**0.41**	**0.32**	**0.52**	**0.52**
CELL EVENNESS	0.53	0.74	0.77	0.52	0.83	0.35	0.77	0.36	0.60	0.39	0.81	0.36	0.72	0.44	0.77	0.38	0.36	0.52	0.43
BIOMASS (UG/ML) SUMMARY																			
BACILLARIOPHYTA	**147**	**308**	**320**	**839**	**469**	**131**	**45**	**528**	**110**	**343**	**103**	**390**	**426**	**591**	**94**	**132**	**250**	**175**	**564**
Centric Diatoms	52	56	38	25	2	69	2	18	29	20	42	96	74	27	15	26	16	95	194
Araphid Pennate Diatoms	67	252	282	707	330	41	29	472	43	258	38	285	333	546	61	106	148	61	260
Monoraphid Pennate Diatoms	0	0	0	20	2	2	0	2	0	0	0	2	0	6	0	0	0	0	0
Biraphid Pennate Diatoms	28	0	0	87	136	18	14	36	38	65	23	8	20	12	17	0	86	19	110
CHLOROPHYTA	**308**	**42**	**1542**	**25**	**53**	**51**	**0**	**70**	**0**	**71**	**10**	**152**	**27**	**60**	**31**	**111**	**0**	**51**	**6**
Coccoid/Colonial Chlorophytes	308	33	42	18	53	28	0	70	0	71	0	142	18	48	31	111	0	51	6
Desmids	0	9	1500	7	0	23	0	0	0	0	10	10	9	12	0	0	0	0	0
CHRYSOPHYTA	**0**	**1590**	**90**	**189**	**96**	**81**	**54**	**120**	**0**	**51**	**7**	**56**	**0**	**0**	**0**	**0**	**0**	**29**	**20**
Flagellated Classic Chrysophytes	0	1590	90	189	96	81	54	120	0	51	7	56	0	0	0	0	0	29	20
CRYPTOPHYTA	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**16**	**0**	**0**	**3**	**2**	**0**	**0**	**0**
CYANOPHYTA	**521**	**24**	**0**	**453**	**74**	**3510**	**36**	**1285**	**10**	**2567**	**0**	**2285**	**12**	**1386**	**34**	**3528**	**220**	**1045**	**312**
Unicellular and Colonial Forms	45	24	0	3	0	18	0	13	0	17	0	0	0	0	0	0	0	11	0
Filamentous Nitrogen Fixers	420	0	0	450	64	3036	36	960	0	2448	0	2016	0	1260	34	3119	144	912	240
Filamentous Non-Nitrogen Fixers	56	0	0	0	10	455	0	312	10	102	0	269	12	126	0	409	76	122	72
EUGLENOPHYTA	**0**	**15**	**30**	**0**	**48**	**0**	**36**	**40**	**24**	**17**	**20**	**16**	**140**	**95**	**17**	**22**	**18**	**139**	**40**
PYRRHOPHYTA	**0**	**261**	**0**	**157**	**0**	**200**	**0**	**0**	**0**	**0**	**113**	**278**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
TOTAL	**976**	**2240**	**1982**	**1662**	**739**	**3972**	**171**	**2043**	**144**	**3049**	**252**	**3194**	**605**	**2132**	**179**	**3795**	**488**	**1438**	**942**
BIOMASS DIVERSITY	**0.76**	**0.49**	**0.40**	**0.86**	**0.91**	**0.41**	**0.74**	**0.71**	**0.78**	**0.38**	**0.79**	**0.62**	**0.73**	**0.57**	**0.80**	**0.40**	**0.71**	**0.58**	**1.00**
BIOMASS EVENNESS	0.76	0.43	0.40	0.68	0.82	0.35	0.87	0.59	0.93	0.31	0.71	0.49	0.68	0.53	0.88	0.37	0.79	0.58	0.83

Table 6. Lake Pocotopaug 2004 zooplankton summary.

TAXON	ZOOPLANKTON DENSITY (#/L) LP Jetty 6/22	LP #2 7/22	LP #2 8/26	LP #2 9/22		ZOOPLANKTON BIOMASS (UG/L) LP Jetty 6/22	LP #2 7/22	LP #2 8/26	LP #2 9/22
PROTOZOA									
Ciliophora	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
Sarcodina	2.6	0.0	0.0	0.0		0.1	0.0	0.0	0.0
ROTIFERA									
Conochilus	0.0	3.6	0.1	0.0		0.0	0.1	0.0	0.0
Kellicottia	0.0	0.0	0.4	1.4		0.0	0.0	0.0	0.1
Keratella	0.3	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Polyarthra	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0
Trichocerca	0.3	0.0	0.0	0.0		0.0	0.0	0.0	0.0
COPEPODA									
Copepoda-Cyclopoida									
Cyclops	0.0	0.0	0.2	0.4		0.0	0.0	0.5	1.0
Mesocyclops	0.0	2.8	0.2	0.8		0.0	3.5	0.3	1.0
Copepoda-Calanoida									
Diaptomus	0.0	1.9	0.1	0.1		0.0	0.9	0.0	0.0
Copepoda-Harpacticoida	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
Other Copepoda-Copepodites	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Other Copepoda-Nauplii	0.0	1.1	0.2	0.3		0.0	2.9	0.6	0.8
CLADOCERA									
Alona	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Bosmina	1.6	0.0	0.1	0.5		1.6	0.0	0.1	0.5
Ceriodaphnia	0.5	0.0	0.0	0.0		1.2	0.0	0.0	0.0
Chydorus	0.3	0.0	0.2	1.0		0.3	0.0	0.2	1.0
Daphnia ambigua	0.0	0.6	0.1	0.3		0.0	1.0	0.1	0.5
Diaphanosoma	0.0	1.8	0.7	1.0		0.0	1.8	0.7	1.0
Leptodora	0.0	0.0	0.0	0.1		0.0	0.0	0.0	8.3
OTHER ZOOPLANKTON									
Ostracoda	0.2	0.0	0.3	0.7		1.6	0.0	2.8	7.0
SUMMARY STATISTICS									
DENSITY (#/L)									
PROTOZOA	2.6	0.0	0.0	0.0		0.1	0.0	0.0	0.0
ROTIFERA	0.6	3.7	0.5	1.4		0.0	0.2	0.0	0.1
COPEPODA	0.0	5.8	0.7	1.6		0.0	7.2	1.4	2.8
CLADOCERA	2.4	2.4	1.1	2.9		3.1	2.7	1.1	11.2
OTHER ZOOPLANKTON	0.2	0.0	0.3	0.7		1.6	0.0	2.8	7.0
TOTAL ZOOPLANKTON	5.8	11.9	2.5	6.6		4.8	10.1	5.3	21.1
TAXONOMIC RICHNESS									
PROTOZOA	1	0	0	0					
ROTIFERA	2	2	2	1					
COPEPODA	0	3	4	4					
CLADOCERA	3	2	4	5					
OTHER ZOOPLANKTON	1	0	1	1					
TOTAL ZOOPLANKTON	7	7	11	11					
S-W DIVERSITY INDEX	0.65	0.74	0.94	0.94					
EVENNESS INDEX	0.77	0.87	0.90	0.90					
MEAN LENGTH (mm): ALL FORMS	0.19	0.44	0.49	0.46					
MEAN LENGTH: CRUSTACEANS	0.34	0.59	0.60	0.57					

DISCUSSION AND RECOMMENDATIONS

ENSR now has four years of monitoring completed at Lake Pocotopaug. Along with the volunteer and town based monitoring program conducted since 1991 and an additional investigation by Fugro East in the early 1990s, the data base is sufficient to draw some general conclusions regarding conditions in the lake and the causes of those conditions. We can offer the following observations:

1. Watershed inputs are weather dependent; inputs are lower during dry years (2001-2002) and higher during wet years (2003-2004).
2. Concentrations of phosphorus tend to increase with increasing inflow, indicative of non-point sources such as lawn fertilizer and atmospheric pollutants deposited on impervious surfaces. Both flows and concentrations increase during precipitation, making the wet weather loading the major component of inputs to the lake.
3. Concentrations of ammonium and nitrate show no consistent or strong pattern with regard to weather. While overall loading is higher during wet weather by virtue of higher flows, the concentrations are more stable. This is indicative of inputs related to ground water, either from past septic system inputs or ongoing lawn fertilization. Precipitation increases the flow from these sources to the lake, but cannot cause wash-out as with surface runoff or dilution as with intense point sources like septic systems.
4. Available nitrogen levels tend to be low; while phosphorus will limit overall algal production during summer, the types of algae may be more related to nitrogen availability. Nitrogen-fixing cyanophytes, such as *Anabaena*, will be favored.
5. Water clarity tends to decline over time during most summers. There is no longer term trend for clarity in June, July or September, but there may be a gradual decrease in clarity in August over the period of record. Certainly clarity has been worse in August of 2000-2004 than in August of 1993-1999.
6. All assessed tributaries are potentially significant contributors of nutrients to the lake. What these tributaries have in common is intense development near the lake. Much of the watershed more remote from the lake is not heavily developed and would not be expected to contribute phosphorus concentrations such as those observed in 2003 and 2004 in storm water samples, but data from remote portions of the watershed are lacking.
7. Internal loading of phosphorus was strongly curtailed by the 2001 alum treatment, but has increased back to pre-treatment levels since (although the 2004 values were among the lowest observed). This is consistent with treatment longevity at 3-5 times the detention time of the lake (which is about 6 months) when watershed inputs are substantial. Reduced phosphorus levels would be expected as a result of treatment for 1.5 to 2.5 years, which is what was observed.
8. There is some indication that walleye stocking is having enough of an impact on perch to start changing the zooplankton community size structure, but not yet enough influence to increase zooplankton biomass and grazing pressure. It would be helpful to know how the walleye are growing and what percentage of the population is now being caught and kept by anglers.

In light of the watershed and in-lake water quality monitoring results from 2004, it does appear that more attention should be paid to watershed inputs. The levels of phosphorus in first flush storm water is quite high, although most of this is in particulate form and not readily available to support algae growth. However, those particulate inputs can decay and release the associated phosphorus, and the rise in bottom phosphorus levels since the alum treatment in 2001 is a concern. Additionally, the dissolved phosphorus in first flush storm water is high enough to be a concern, particularly in the Clark Hill storm discharge and Day Creek, although it may also be high at other inlets or at other times not assessed in this program. Although the nutrient levels from the storm water samples are lower than in 2003, the nutrient load to the lake during the summer of 2004 was still elevated. Precipitation during the summer of 2004 was elevated enough to minimize nutrient build-up during dry weather. Instead, moderate levels of nutrients were being carried into the lake more frequently, resulting in overall loads similar to those of 2003.

It does appear from the storm water data that there is at least a modified first flush effect in this watershed. Peak phosphorus concentrations did not persist for more than a few hours, and while the associated volume of storm water was not measured, it represents only a fraction of the total inflow. Values later in storms were not negligible, but there is indication in the data that the bulk of the phosphorus load is associated with the first flush from multiple small drainage areas around the lake. While more distant areas may indeed contribute, the available data suggest that the primary sources of phosphorus and probably nitrogen are fairly close to the lake, arriving in the earliest runoff. This matches well with the pattern of land use in the watershed, and suggests that more effort needs to go into addressing these nearby sources. Considerably more progress must be made in the management of first flush storm water to protect the lake; we estimate that the phosphorus load needs to be reduced by about 50% to achieve desirable conditions.

Watershed management is not a rapid process, however, and interim measures are needed to enhance lake condition until enough watershed management can be accomplished to make the desired difference. Options include an additional alum treatment, increasing oxygen levels in the bottom waters, mixing of surface waters, and use of algaecides. We can offer the following perspective on each option:

1. An additional alum treatment may further inactivate P in the sediment such that extraction by algal resting cells is not possible, but this is highly speculative. An additional treatment could reduce in-lake phosphorus levels somewhat, but will not prevent watershed inputs and would only be expected to have an effect for about two years. There is no way to do this on a smaller scale than was performed in 2000 and have any meaningful effect. This option would be very costly and the public perception of an additional alum treatment appears negative.
2. Increased oxygen in the bottom waters would enhance fish habitat, provide a zooplankton refuge, reduce internal phosphorus loading, and may eliminate a likely trigger for the rise of the problem algae. There is no substantial downside to such an approach, but it is also expensive and there is no guarantee it will provide reduced phosphorus in a wet year when watershed inputs could be dominant. This must be done in all areas with deep (>15 ft) water, although it is possible that a test could be run with some validity in Markham Bay.
3. Mixing surface waters would not change phosphorus loading, but could change nutrient forms and dynamics, altering conditions such that cyanophytes were not favored. Physical mixing is also considered disruptive to buoyant cyanophytes, including the problem species in this lake. The mixing could involve whole lake mixing, in which case the benefits of option #2 could also be realized, or it could just involve the upper water layer, which is what SolarBee has proposed. Mixing should be induced over the whole surface of the lake, but it is possible that a valid test could be run in Markham Bay. The SolarBee approach appears worth testing, and with a rental agreement, the cost is not prohibitive.
4. Algaecides have been discussed previously and permitted at least twice, but have not been applied to this lake. Past discussions have focused on copper, which has potential negative side effects and is not effective on all algal species, but has some potential to disrupt the life

cycle of the problem alga and is inexpensive. Based on the monitoring to date, it does not appear that a deep water treatment with copper to kill algae before they rise to the upper water layer is feasible; we have not been able to detect any mass migration upward, and 2003-2004 results suggest that the population either accrues very slowly or expands rapidly after a seed population has reached the surface. A whole lake, surficial copper treatment would therefore be necessary, and probably would have to be repeated once in each of three years to significantly reduce the supply of resting stages for the algae that are in the bottom sediment. This approach has been effective in several other New England cases, but is not especially attractive to many people concerned about copper toxicity.

5. An alternative algaecide, GreenClean, which is peroxide based, is now available in Connecticut and is more effective against cyanophytes than other more desirable algae. It is much more expensive than copper, but no toxicity to non-target organisms has been demonstrated. This algaecide may be more palatable to people concerned about copper use.

Of the above options, #2 (mixing) and #5 (peroxide based algaecide) are most attractive at this time. Of the mixing options, the whole lake mixing is more appealing in terms of potential benefits, but if not done well, it could have negative impacts (i.e., moving low oxygen waters to the surface if mixing is insufficient on a sustained basis). The surficial mixing approach espoused by SolarBee has minimal potential to cause any negative effects. However, neither the peroxide based algaecide nor the SolarBee mixing system has a track record that we can use to reliably evaluate likely effectiveness and non-target impacts in Lake Pocotopaug. Additional information is presented in the Appendix as a starting point for discussion.

Sampling of water quality and phytoplankton in the lake should proceed in 2005, to expand the long-term data base and aid further evaluation of management needs and progress. It should be sufficient to monitor algae and water quality in the lake once in each of June, July and August, although more frequent measurement of algae (weekly to every other week) is desirable if affordable. It would also be helpful to repeat the tributary monitoring, with expansion on each system to an upstream point above which human influence is limited, to determine if it really is the nearshore development that is responsible for observed loading.

If either a SolarBee mixing system is installed or an algaecide treatment is performed, it will be important to monitor water quality and algae in any test area on a more frequent basis. For the algaecide, phytoplankton types and abundance should be monitored over several locations in the lake (Oakwood, Markham, and south of the big island), and dissolved nutrient levels should be checked shortly after treatment. The DEP has also expressed an interest in monitoring benthic invertebrates before and after any such treatment, and zooplankton should also be monitored. With installation of a circulation unit in Markham Bay, it will be important to compare the phytoplankton and nutrient levels in the treated area compared to Oakwood Basin to determine the effect of the circulation unit. Measurement of temperature and oxygen profiles at several points in Markham Bay and a reference point in the Oakwood area should also be assessed on about a weekly basis.

The value of a longer term water quality data base is not to be underestimated, especially in a lake with the features of Lake Pocotopaug. We now have over a decade of seemingly reliable measurements, at least in the lake, and four years of at least partial input monitoring. The effect of alum treatment has been documented and the role of weather in nutrient loading has been elucidated. As watershed management proceeds, continued assessment of conditions will be important to tracking progress and adjusting the program for maximum effectiveness. Both the management actions and the related monitoring carry substantial costs, so a long-term financial commitment to lake and watershed management is necessary.

ENSR would be happy to prepare proposals for any management action and the associated monitoring, and will meet with town officials to discuss the options at your convenience. The town is in receipt of a proposal from SolarBee for a mixing system, and ENSR would support a test in the Markham Bay area, which appears to require two units. Representatives from Green Clean are present in Connecticut and could also provide the town with a proposal.

APPENDIX:

SUPPORTING INFORMATION RELATING TO CERTAIN MANAGEMENT OPTIONS

TREATMENT WITH PEROXIDE

How it Works

Oxidation is a commonly used treatment process in water and waste water management, with a wide variety of oxidants applied. In the natural environment, many of these chemicals proved too harsh for regular use, but more benign compounds featuring peroxides that target algae have been developed. Peroxides attack the cell walls of algae, essentially dissolving them through strong oxidation reactions, and will destroy some cell contents, including chlorophyll. Susceptible algal cells are impacted within seconds to minutes of contact. Reactions with non-algal cells tend to be less severe, minimizing damage to non-target organisms such as fish. Various formulations are available, based on the chemistry of the carrier molecules to which the peroxides are attached. PAK27 is the chemical tradename of the active ingredient most commonly encountered now (sodium carbonate peroxyhydrate), while Green Clean is the tradename for the peroxide-based algaecide now registered for use in most states. Liquid and granular formulations are available, with granular application more common in lake environments (liquids are more commonly used in swimming pools). Doses range from 3-10 pounds per acre-foot for algal growth prevention to 10-50 pounds per acre-foot for microscopic planktonic bloom disruption to 50-150 pounds per acre-foot for algal mat control. Effectiveness is minimally affected by pH, but where algal growths are dense, a second application may be needed to gain control. Use with bacterial additives has been recommended by some suppliers, but scientific evaluations of results are lacking.

Benefits

- Rapid kill of susceptible algae; appears selectively more effective for blue-greens
- Oxidative reactions may inactivate some cell contents unwanted in the water (especially taste and odor compounds)
- Oxygen is added to the water as a by-product

Detriments

- Releases contents of most killed algal cells back into the water column; this may include nutrients and toxins
- Less effective on some algae, particularly thick-walled green algae and algae with copious surrounding mucilage
- Tends to cause floating clumps of dying algae through gas bubble formation during reaction; may facilitate collection if a system is in place, but will be unsightly for a time in recreational situations
- Limited experience with newest formulations, although extensive field testing has been conducted

Information for Proper Application

- Algal monitoring to determine proper timing of treatment
- Water quality data to evaluate dose needs and likely effectiveness
- Monitoring program to assess impacts and effectiveness

Factors Favoring the Use of this Technique

- Algal monitoring allows early response before bloom formation

- Periodic algal blooms impair recreation of water supply use, but are not a frequent occurrence
- Blue-greens are dominant in the plankton
- A surface skimmer is in place to collect floating algal clumps

Performance Guidelines

- Monitor algae at a frequency appropriate to detection of bloom formation before blooms become dense; know which types of algae are dominant
- Peroxides should be applied by licensed applicators with few exceptions
- Preferably apply peroxide while algal growth is in its exponential phase
- Apply peroxide product in accordance with label instructions and restrictions; justify dose, location and timing of treatment
- Monitor water quality before and after treatment, with emphasis on oxygen and nutrient levels
- Where blue-greens or other algae with potential for toxicity are treated, monitor for toxin level in the water before and after treatment
- If repeated treatment is necessary in a single growing season, pursue nutrient controls on algal growth

Possible Permits

- WPA permit through local Conservation Commission/DEP
- Review by NHESP (further action if protected species are present)
- License to Apply Chemicals from DEP

Impacts Specific to the Wetlands Protection Act

- Protection of public and private water supply – Benefit (used to control algae)
- Protection of groundwater supply – Neutral (no significant interaction)
- Storm damage prevention – Neutral (no significant interaction).
- Prevention of pollution – Generally neutral (no significant interaction)
- Protection of land containing shellfish – Generally neutral (no significant interaction), but reduced algae might reduce food resources for shellfish, and direct toxicity is possible under unusual circumstances.
- Protection of fisheries – Possible benefit (habitat enhancement) and possible detriment (food source alteration, direct toxicity).
- Protection of wildlife habitat – Possible benefit (habitat enhancement) and possible detriment (food source alteration, toxicity).

Cost Considerations

A 50 pound bag sells for $135 to $175 and treats 1/3 to 17 acre-feet, depending upon the dose. Treatment of a hypothetical 100 acre area with a depth of 5 ft could therefore cost $4000 to $263,000 for the chemical alone. In reality, smaller areas are typically treated at costs usually ranging from $5000 to $50,000, including application labor and associated monitoring, with an emphasis on bloom prevention. The cost per acre is difficult to precisely determine, but is expected to be on the order of $500 to $1000/ac. This is considerably higher than copper, relegating peroxide to use in smaller lakes partial lake treatments, or more sensitive situations where copper is inappropriate.

INSTALLATION OF SOLAR BEE TECHNOLOGY

What is a SolarBee?

The SolarBee is a floating solar-powered water circulator. The large model is 16 feet in diameter and constructed of stainless steel. Depending on model, the SolarBee draws up to 3,000 gallons per minute directly through the unit and 10,000 gallons per minute total flow from below the machine (inductive flow) and spreads it gently across the top of the reservoir for continuous surface renewal (information available at www.solarbee.com). Note that the target mixing layer is the upper water layer in the lake; although it might be operated to destratify a lake, SolarBee equipment is intended to enhance only surficial mixing.

How It Works

The SolarBee is designed to minimize turbulence and establish a gentle horizontal near-laminar flow which moves radially outward from the SolarBee at the top of the reservoir, and radially inward at the bottom of the reservoir. This near-laminar flow was difficult to achieve because getting water to move long distances in an open reservoir is similar to "pushing a rope"; if too much force is applied, most of the energy produces undirected turbulence, with no long-distance flow patterns. Laminar flow is described as "frictionless" and each water molecule will continue to travel onward until some force disturbs its flow. Normal wave action and wind ripples do not stop the laminar flow, and small particles entrained in the surface flow outward from the SolarBee can be observed to travel both upwind and downwind from the machine until they reach the far edges of the reservoir. With turbulent flow created by typical aerators and mixers, short circuiting occurs where the water goes outward just a short distance and then turns around and comes back to the inlet of the aerator. According to the SolarBee staff, virtually no other surface aerators or mixers are effective beyond 0.75 surface acres, whereas the SolarBees are effective for up to 50 acres, depending on model size.

When the near-laminar radial flow projects outward from the SolarBee at the reservoir surface, the water streamlines are "diverging" from each other, like hands on a clock, and water from deeper in the mixed zone is pulled up to the surface to fill the voids that would otherwise be created between the streamlines. This upward flow everywhere in the reservoir is aided by the "converging" streamlines down at the end of the intake hose. The streamlines there become compacted as water tries to flow toward the machine radially from all directions, so some water moves upward to fill the voids at the top of the reservoir. Thus the horizontal laminar flow away from the SolarBee at the top of the reservoir, together with the horizontal laminar flow toward the SolarBee at the level in the intake, causes a vertical circulation upward between the shallow and the deep horizontal flow layers. This vertical mixing occurs throughout the entire mixed zone, at a higher rate near the SolarBee and a lower rate near the edges of the reservoir. This pattern is distinctly different from, and adds to, the effect of any wind mixing of the reservoir. Wind mixing is mostly in parallel force lines and does not have any consistent vertical element, so it does not affect micro-environments like a SolarBee does. In many SolarBee applications the reservoirs are in windy or very-windy environments (regular winds over 50 miles per hour), yet the SolarBee measurably altered lake conditions beyond the effects of wind.

The Benefits

When deployed for blue-green algae control, the SolarBee limits conversion of phosphorus and nitrogen into inedible blue-green algae blooms that can cause a variety of objectionable conditions. Instead, the SolarBee mixing favors "good" planktonic organisms which are then eaten by zooplankton which in turn are eaten by fish. Since the nutrients are being pushed through the food chain, controlling the levels of phosphorus and nitrogen becomes less important, and the lake becomes highly productive without excessive algal build up while at the same time water clarity and odor improve, dissolved oxygen (DO) may increase, pH and chlorophyll a decline, and zooplankton and fish benefit. Increased fish spawning rates have been observed, relative to before SolarBees were installed. Another benefit appears to be a slow reduction of invasive weed species. Another benefit may be mosquito control (www.solarbee.com). The mechanisms of these responses are not all completely understood, but the results can be explained by limnological principles, and are indeed possible.

The benefits are summarized as follows:

- Large area and volume of influence for a relatively small unit – induced circulation is greater than the circulation provided by direct flow through the unit, allowing relatively few units to handle a larger area.
- Improving DO and pH levels – aerates water and allows pH equilibration through atmospheric interaction, altering conditions for aquatic biota in a generally favorable way.
- Prevent generation and release of hydrogen sulfide and soluble iron, manganese, and phosphorus from sediments in shallow water – appears to be able to oxygenate porewater in sediments of shallow water, minimizing releases of reduced compounds generally considered as undesirable.
- Preventing seasonal fish kills – guarantees an adequate oxygen refuge, although the bottom waters in deeper areas may still be anoxic.
- Minimizing cyanobacteria (blue-green algae) blooms – appears to be a combined function of buoyancy disruption, altered pH and available carbon form, and possibly other factors that tend to disrupt cyanobacterial growth and favor other, more desirable algal forms that thrive in mixed lakes.
- Reducing nuisance aquatic weed growth – appears to be related to oxygenation of porewater and alteration of nutrient forms, particularly nitrogen, but the mechanism is not well understood at this point. As nuisance plant conditions are absent in Lake Pocotopaug, this is not a major factor in this case.

ENSR Recommendation for Lake Pocotopaug

ENSR would support a trial installation of the SolarBee technology in Markham Bay. Two SB10000v12 units would be necessary for complete coverage of Markham Bay. SolarBee reports success of these units on their website and supplies references and case studies. However, despite reported previous successes, specific lake dynamics may impact the success of SolarBee on Lake Pocotopaug, and no guarantee is suggested by ENSR. To determine the effectiveness of the SolarBee units, comparative water quality and plankton monitoring is recommended within Markham Bay and at a reference site in the Oakham area. Comparisons of phytoplankton type and quantity, zooplankton type and quantity, dissolved oxygen, pH, turbidity, secchi disk transparency, and nutrients (total phosphorus, dissolved phosphorus, ammonium and nitrate) would facilitate determination of SolarBee effectiveness.

Payment Options and Costs

The town of East Hampton has three options for acquiring the SolarBee technology. Circulators can be purchased, rented or rented with intent to buy. The SB10000v12 is the recommended unit for Lake Pocotopaug. Based on the SolarBee proposal prepared in late 2004, the cost for this unit is approximately $37,560, but does not include tax, delivery, installation, water testing or training. An additional cost of $10,139 is applied to cover delivery, installation, water testing and training. The rental rate for one SB10000v12 unit is approximately $1000 per month, and must be rented for at least 12 months. Rental units may be purchased within 12 months of the date of installation, and a portion of prior rental payments can be applied to the purchase price of the unit. Consequently, the total cost for a trial of this technology would be about $35,000 for one year, with an option to apply some of this cost to later purchase, while the purchase and trial costs would be about $86,000.