WHITE POND WATER QUALITY STUDIES
1988

prepared for

White Pond Advisory Committee
Concord, Massachusetts

by

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1.0 Introduction

This report describes results of water quality studies conducted in White Pond during 1988. A monitoring program was started in 1987, following observations of algal blooms in 1986. Primary objectives of the study are as follows:

(1) to assess existing water quality with respect to algae and related factors;

(2) to describe cause-effect relationships which may control pond conditions; and

(3) to identify measures for restoring/protecting water quality.

A previous report (Walker and Ploetz, 1988) outlined basic scientific concepts pertaining to pond eutrophication (nutrient enrichment) problems, described the setting, morphometry, and hydrology of White Pond and its watershed, compiled historical water quality monitoring data, described results of the 1987 monitoring program, developed a nutrient balance model, and recommended additional diagnostic and protection measures.

This report focuses on monitoring results for 1988 and is organized in the following sections:

2.0 Watershed Topography and Geology
3.0 Hydrology
4.0 Monitoring Program Design
5.0 Temperature and Oxygen Profiles
6.0 Pond Water Quality
7.0 Private Well Sampling
8.0 Shoreline Groundwater Studies
9.0 Pond Protection Measures

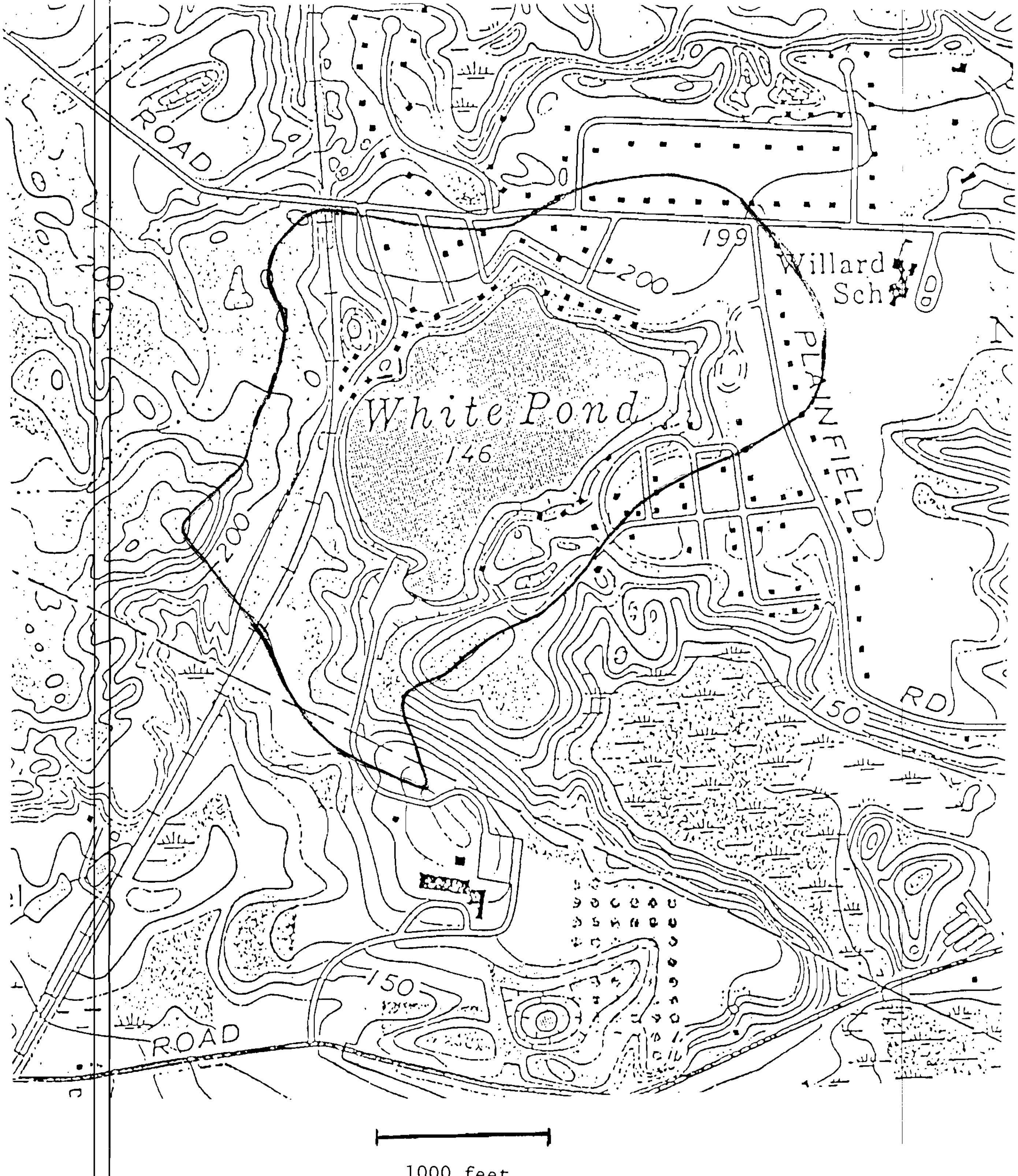
A final section describes conclusions and recommendations based upon study results to date. Appendices A-C contain supplementary data listings and displays. Appendix D is a glossary of technical terms.

2.0 Watershed Topography and Geology

To supplement basic watershed data which was compiled and discussed in the previous report, additional information on watershed topography and geology has been extracted from maps prepared by IEP, Inc. (1979) in a study of Concord's groundwater resources. This information is summarized in the following figures:

Figure 2 - Definition of Terms Used in Watershed Maps
Figure 3 - Cone of Influence for Town Well
Figure 4 - Bedrock Elevation Contours
Figure 5 - Overburden Thickness Contours
Figure 6 - Saturated Thickness Contours
Figure 7 - Geologic Cross-Section

Figure 1
White Pond Watershed



1000 feet

Figure 2
Definition of Terms Used in Watershed Maps

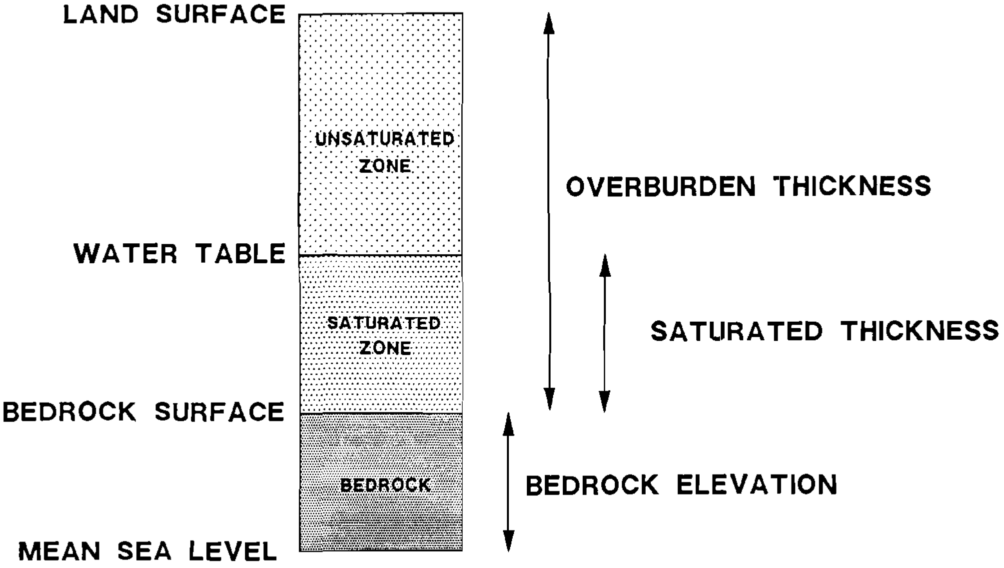


Figure 3
Cone of Influence for Town Well

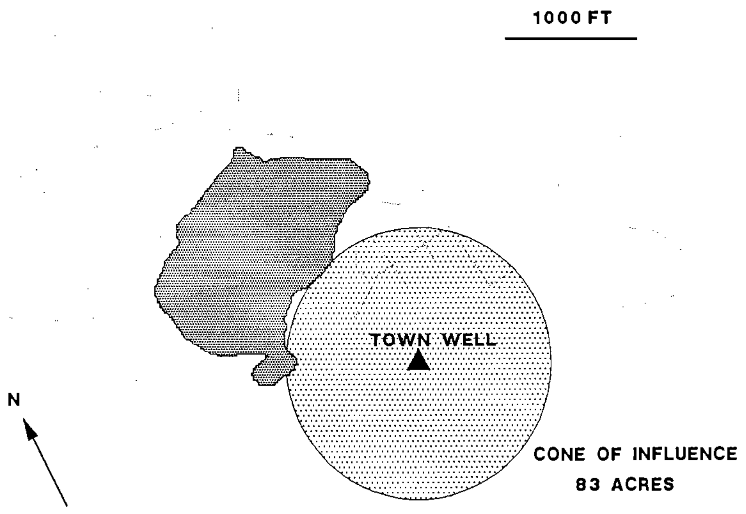


Figure 4
Bedrock Elevation Contours

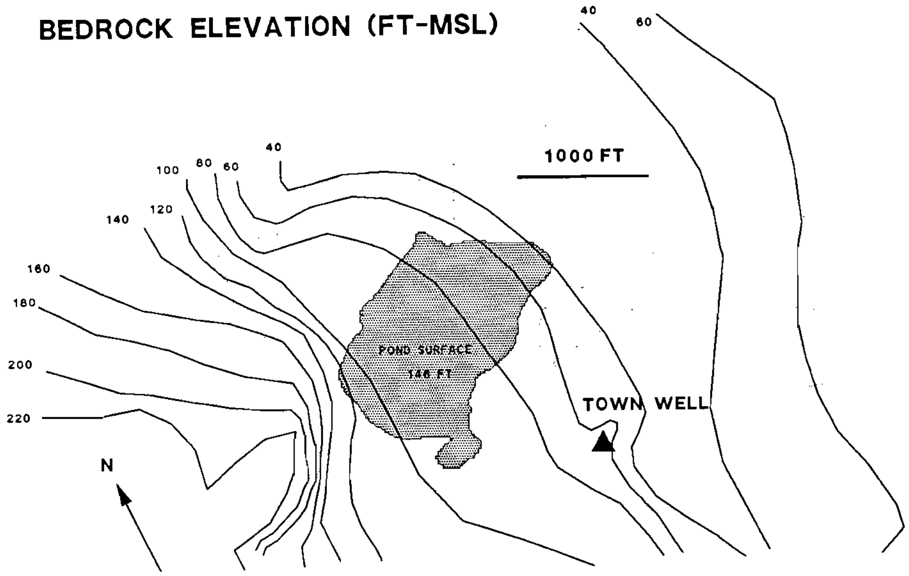


Figure 5
Overburden Thickness Contours

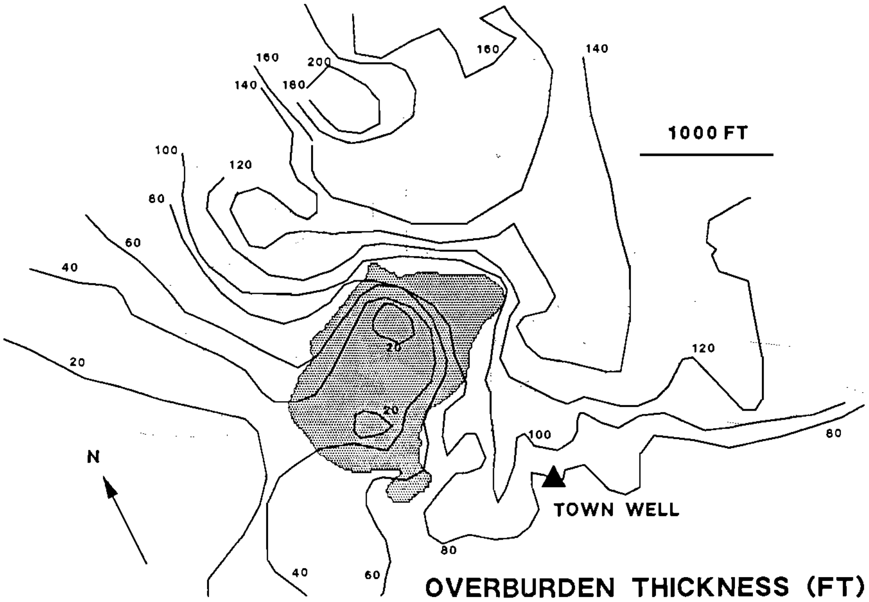
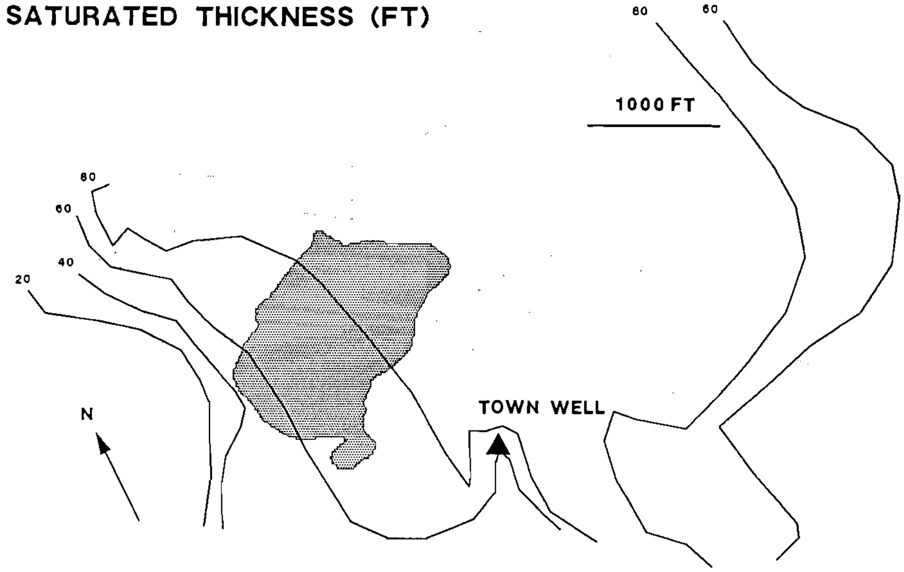
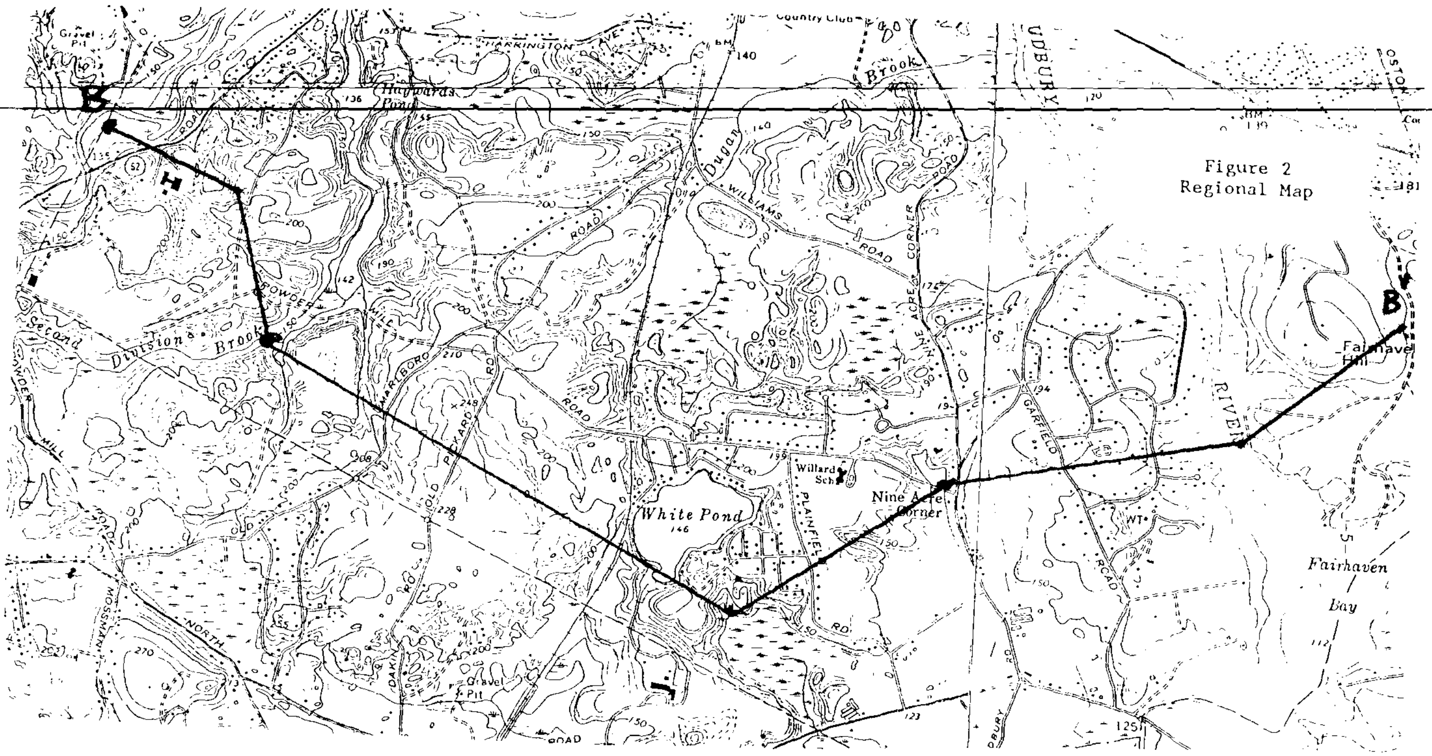
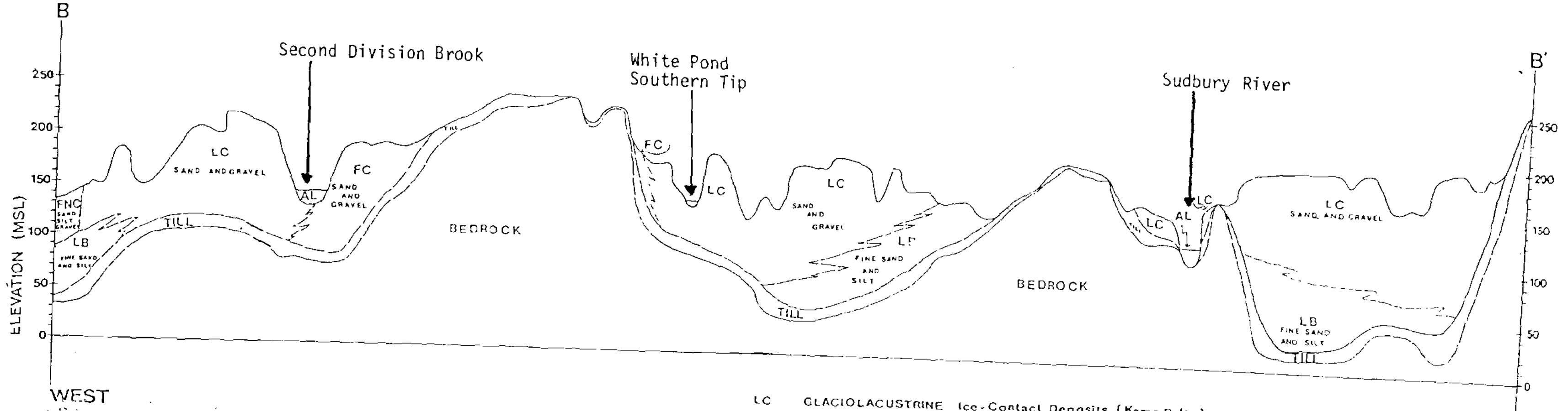


Figure 6
Saturated Thickness Contours







SURFICIAL GEOLOGIC CROSS-SECTION B-B'
CONCORD, MASSACHUSETTS

LC GLACIOLACUSTRINE Ice-Contact Deposits (Kame Delta)
LB GLACIOLACUSTRINE Lake-Bottom Deposits
FNC GLACIOFLUVIAL Non Ice-Contact Deposits
FC GLACIOFLUVIAL Ice-Contact Deposits.

Figure 7
Geologic Cross-Section

The contours shown on these maps were estimated by IEP geologists, based upon their interpretation of well logs, seismic data, and surface topography. The maps depict general regional patterns; conditions may deviate significantly at specific locations.

This information is presented for reference purposes. It helps to define factors which control the hydrology of the pond and depths of soil available for treating effluent from onsite waste disposal systems. The geologic cross-section (Figure 7) and contour maps indicate that White Pond lies at the western edge of a valley defined by bedrock elevation peaks near Garfield Road to the East and Stone Root Road to the West. Because of its location at the western edge of the valley, bedrock elevations decrease from about 200 to 40 ft-msl moving from west to east across the watershed. Overburden thickness (depth to bedrock) also decreases from 20 to 140 feet moving from west to east.

Because of these gradients in topography and geology, less soil depth is available for treating effluent from onsite disposal systems on the western end of the watershed. Relatively thin layers of unsaturated soils would limit the efficiency and longevity of phosphorus removal in septic plumes. This may have implications for the existing high cottage density in the White Avenue area and for possible future urban development of the former Sperry/Unisys property southwest of the Pond (see Section 9.0).

3.0 Hydrology

The pond's surface elevation was approximately 2-3 feet lower than in 1988, as compared with 1987. Based upon data presented below, this probably resulted from the combination of a relatively hot, dry summer and high rates of pumping from the Town Well. Shoreline areas increased substantially as a result of the lower pond level. No specific water quality impacts were observed, however.

Figure 8 plots monthly precipitation data measured at Worcester Airport between 1984 and 1988. The 12-month moving average precipitation varied between .3 and .8 inches/month below normal during the last 9 months of 1988, compared with a range of 0 to .7 inches/month above normal during the corresponding months in 1987. Below-normal precipitation would promote lower pond levels by supplying less groundwater recharge in the watershed and less rainfall directly on the pond surface.

Figure 9 plots monthly pumping rates for the Town Well, based upon data provided by Concord Water Department. As shown in Figure 3, the well's cone of influence apparently intersects the pond shoreline along the southern and southeastern shore (IEP, 1979). It is likely that groundwater discharge occurs from the pond to the town well during periods of well pumping. As indicated in Figure 9, 124 million gallons were pumped from the well in 1988, compared with a range of 85 to 100 million gallons per year between 1984 and

Figure 8
Precipitation Time Series - Worcester Airport

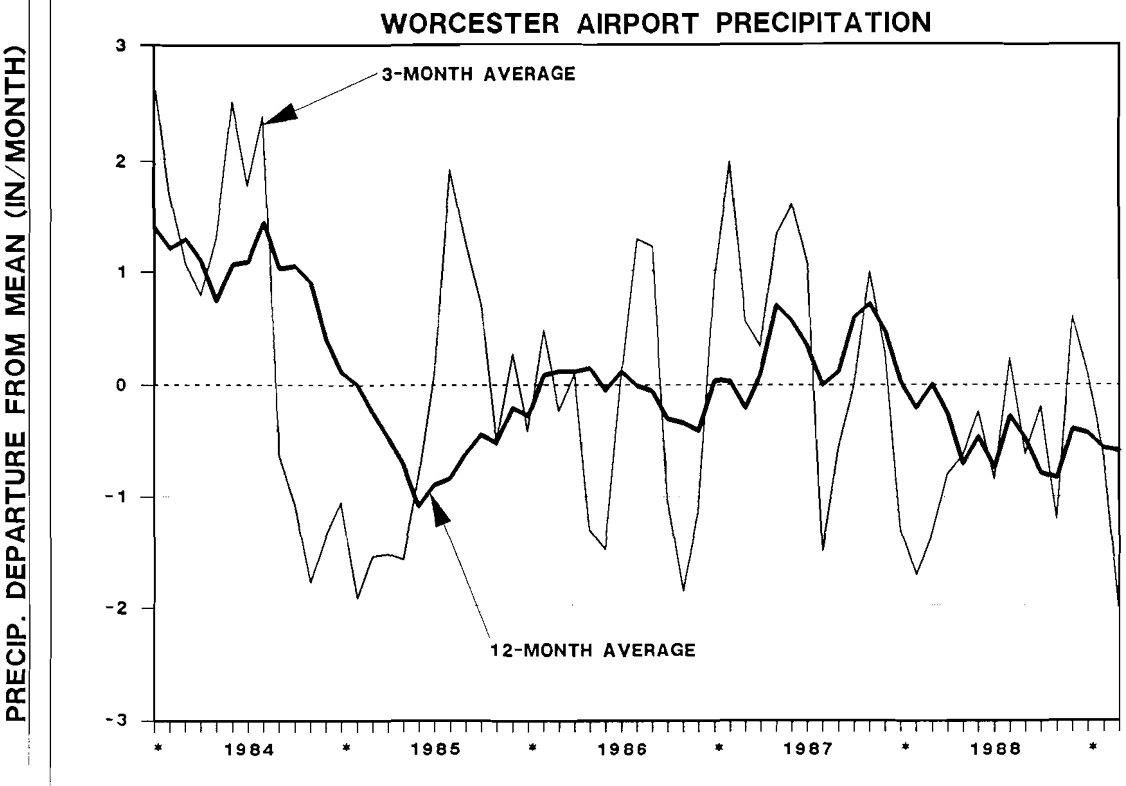


Figure 9
Monthly Pumping Rates - White Pond Well - Town of Concord

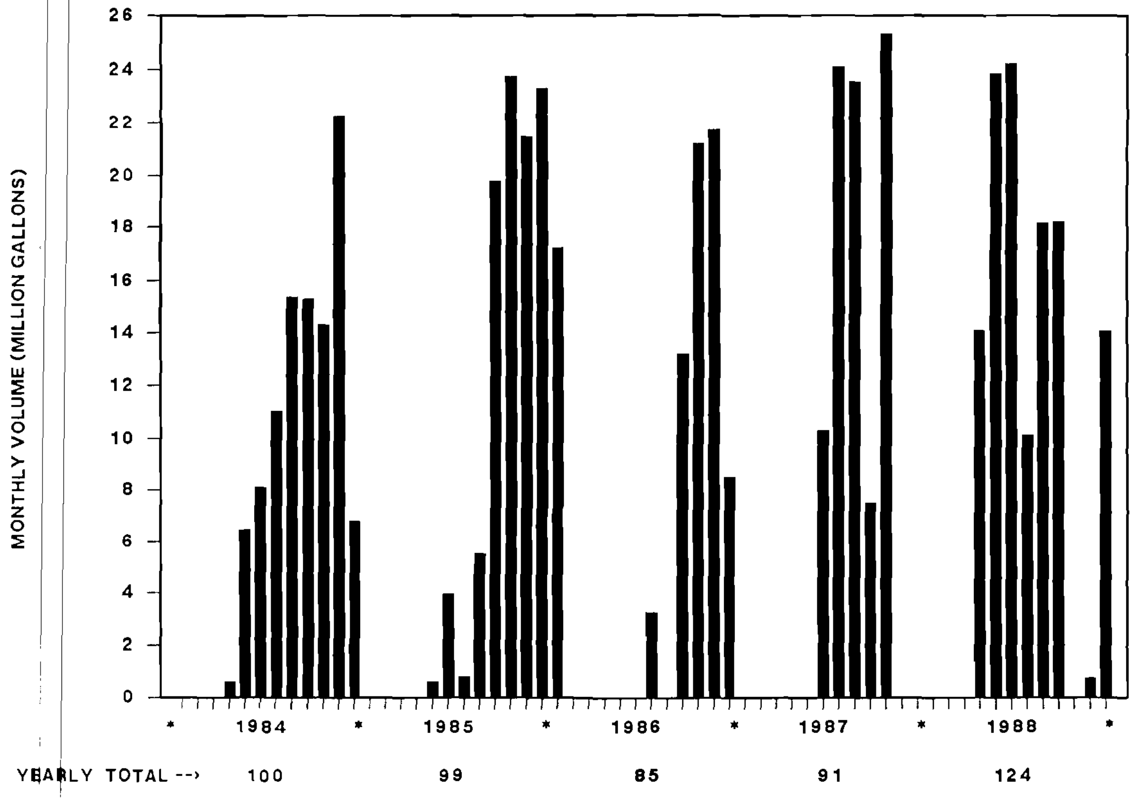
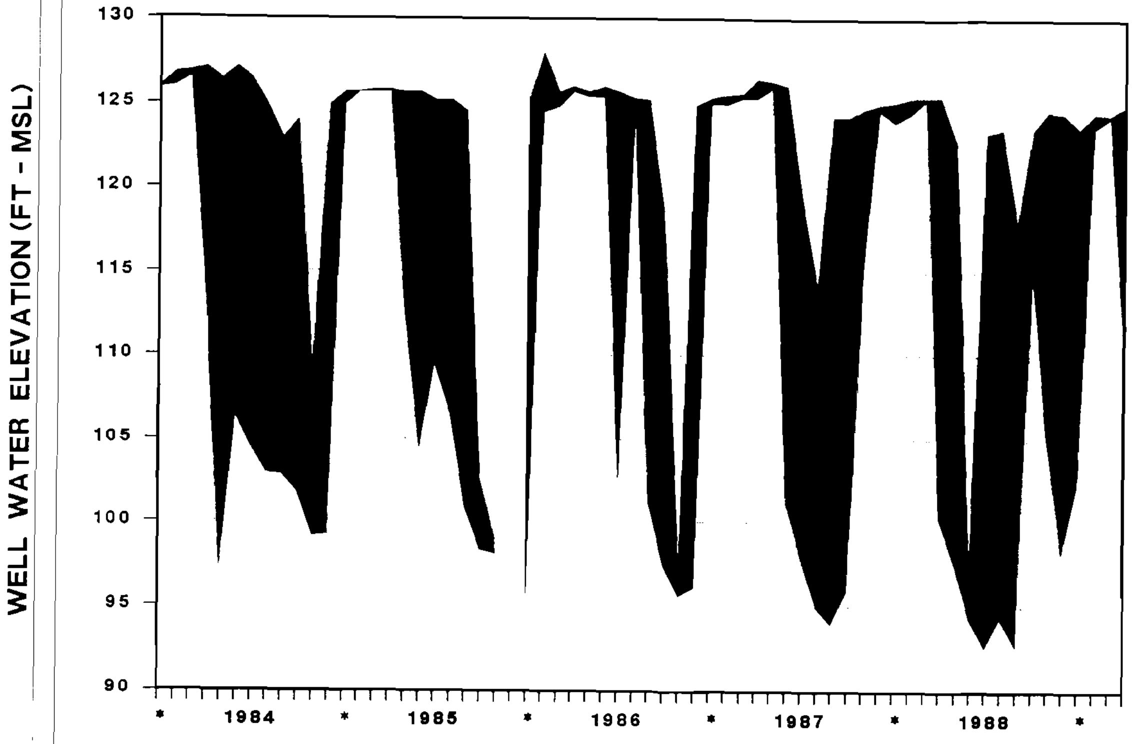


Figure 10
Monthly Water Elevation Range - White Pond Well - Town of Concord



1987. The rate of pumping is also related to climatologic factors, since consumer water demand increases significantly during hot, dry periods. Because many residences in the White Pond area use Town water, some portion of the water pumped from the well is recycled to the local groundwater reservoir; the remainder flows to other regions of the Town or to consumptive uses (e.g., lawn watering).

The monthly range of water elevations observed in White Pond well between 1984 and 1988 is plotted in Figure 10. In each month, the maximum elevation was observed following periods of little or no pumping. The water elevation decreased rapidly during pumping until it reached a level which reflected regional groundwater levels, pumping rate, and aquifer hydraulic conductivity. In comparing Figures 9 and 10, it is apparent that water elevations remained high (126 - 127 ft) during winter months when the well was not pumped. Both the minimum and the maximum water elevations were lower in 1988 than in previous years by approximately 2-4 feet. This correlates with the higher rate of pumping, lower precipitation, and lower pond levels observed in 1988. Aquifer pumping associated with the Sperry/Unisys aquifer cleanup operation may have also contributed to the lower well levels observed in recent years.

Figure 11 plots 12-month, moving-average well pumping rates and aquifer recharge between 1984 and 1988. The pumped volume is divided by the area of the well's cone of influence (83 acres, Figure 3) to express it in units of inches per year. Groundwater recharge is estimated by subtracting 21 inches/year (typical value for evapotranspiration in this region) from the 12-month average precipitation. Calculated in this way, the recharge time series does not reflect variations in temperature or solar radiation. Since the pumping rate per unit area exceeds the recharge rate by a factor of 2 to 3, flows must be induced from areas beyond the cone of influence during periods of heavy pumping and aquifer drawdown.

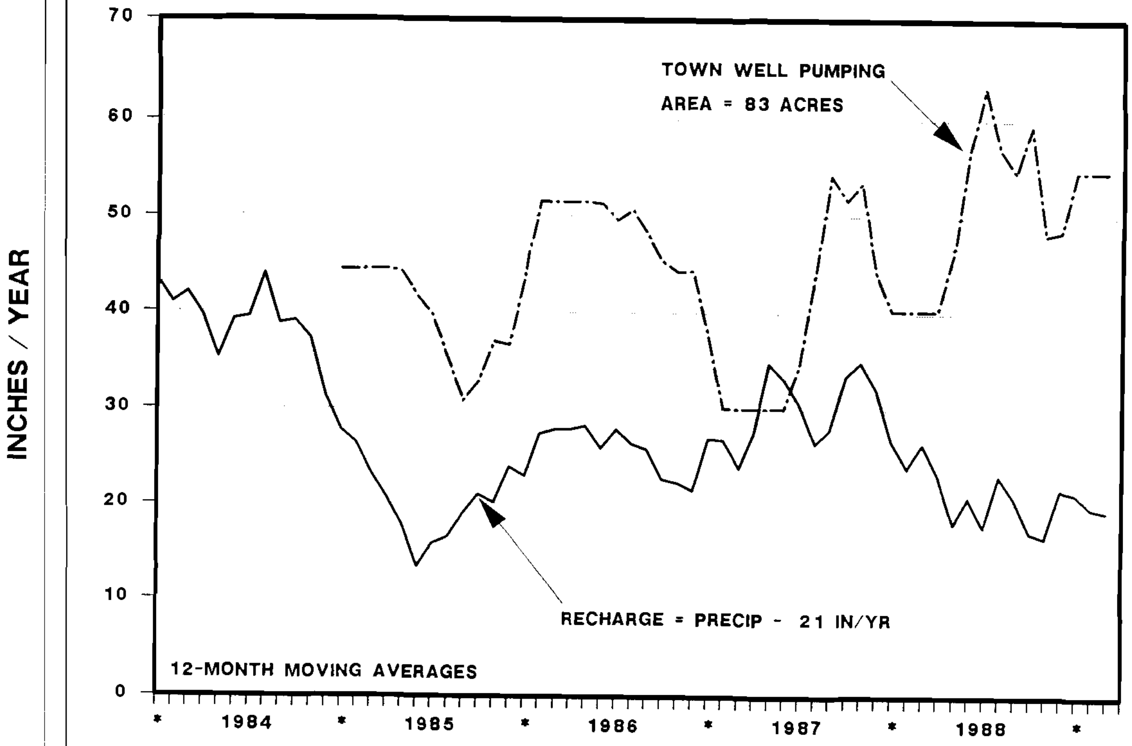
The relatively high pumping rates and low recharge rates are consistent with low pond elevations observed in 1988 and early 1989. Mathematical modeling of the aquifer would provide more detailed information on factors controlling variations in pond and groundwater levels. Routine measurements of pond water elevation at a surveyed gauge would provide an improved data base for developing an understanding of pond hydrology and controlling factors.

4.0 Monitoring Program Design

The pond was sampled at its deepest point on eight occasions between March and October 1988. Variables monitored in 1988 included:

Oxygen and Temperature	(2-4 foot intervals)
Secchi Disk Transparency	(surface)
Total Phosphorus	(3-5 depths)
Nitrogen + Inorg.Chemistry *	(4 depths May, 5 depths August)

Figure 11
Groundwater Recharge and Town Well Pumping Rates
12-Month Moving Averages



Town Well Pumping = 12-Month Total Pumping / Cone Area
Area of Cone of Influence = 83 acres (IEP, Inc.,1979)

Recharge = estimated annual groundwater recharge
= annual precipitation - 21 in/yr evapotranspiration

* Nitrate N, Nitrite N, Ammonia N, Kjeldahl N, Iron, Manganese, Sulfate, Conductivity, Alkalinity, pH

Transparency was measured by lay monitors (Linda Stansfield and/or Gail Jewell) on six additional dates. Monitoring dates and field notes are summarized in Table 1. Temperature, oxygen, transparency, and total phosphorus measurements are listed in Appendix A. Laboratory reports for other chemical analyses are contained in Appendix B.

Oxygen and temperature measurements were conducted in the field using a Yellow Springs Model 57 dissolved oxygen meter calibrated to saturation. Chemical analyses were conducted by commercial laboratories using EPA approved methods. Samples were preserved by refrigeration and, where appropriate, acidification, prior to chemical analysis.

Samples were also collected and filtered for chlorophyll-a (algal pigment) analyses. Weak filter coloration indicated, however, that algal densities were low and much higher sample volumes would be required to obtain sufficient chlorophyll-a for quantitative analysis. Rather than conduct routine chlorophyll-a analyses, it was decided to invest more of the study resources in collecting additional phosphorus and water chemistry samples. No chlorophyll-a measurements are reported for 1988. The 1989 monitoring strategy is to collect, filter, and preserve (freeze) samples for chlorophyll-a, but to run the analyses only when filter coloration suggests a high pigment level or when an algal bloom is observed on the pond. Because of the low color and inorganic turbidity levels in the pond, the Secchi Disk transparency measurement (easily performed in the field) is a good relative indicator of surface chlorophyll-a and algal density.

Based upon visual observations, pond water quality was generally high in 1988. Field notes (Table 1) indicate occasional shoreline foams and algal flakes, as observed in 1987. These observations are symptoms of nutrient enrichment. It is likely that shoreline accumulations of organic matter resulted from dieoff of subsurface algal populations and subsequent concentration by wind-induced currents. A "milky blue" bloom was observed by lay monitors in the cove adjacent to Camp Thoreau on July 6, but no pond-wide blooms were observed. A slight oily film of undefined origin was noted on July 8. At about the same time, a swimmer at the White Pond Association beach complained to the Health Department of becoming coated with an oily substance after diving off the beach raft. Upon investigation the subsequent day, however, no concentrated areas or sources of oil could be identified.

5.0 Temperature and Oxygen Profiles

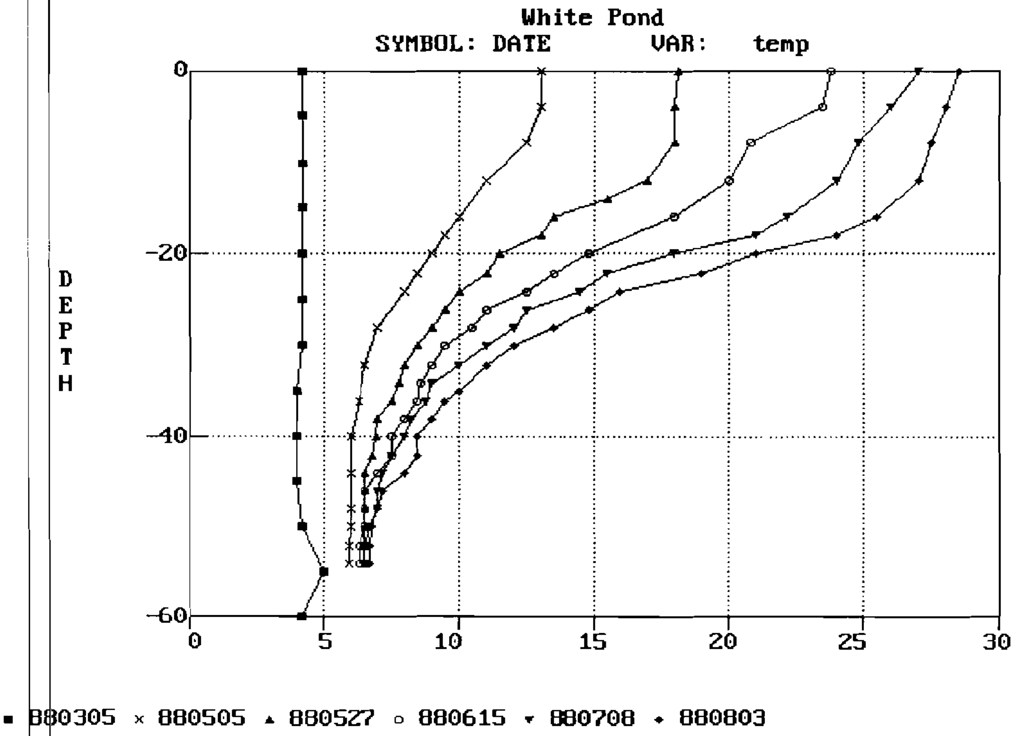
As described in the previous report (Walker and Ploetz, 1988), temperature and oxygen profiles provide information on the vertical mixing and metabolism of organic material in the pond. Profiles

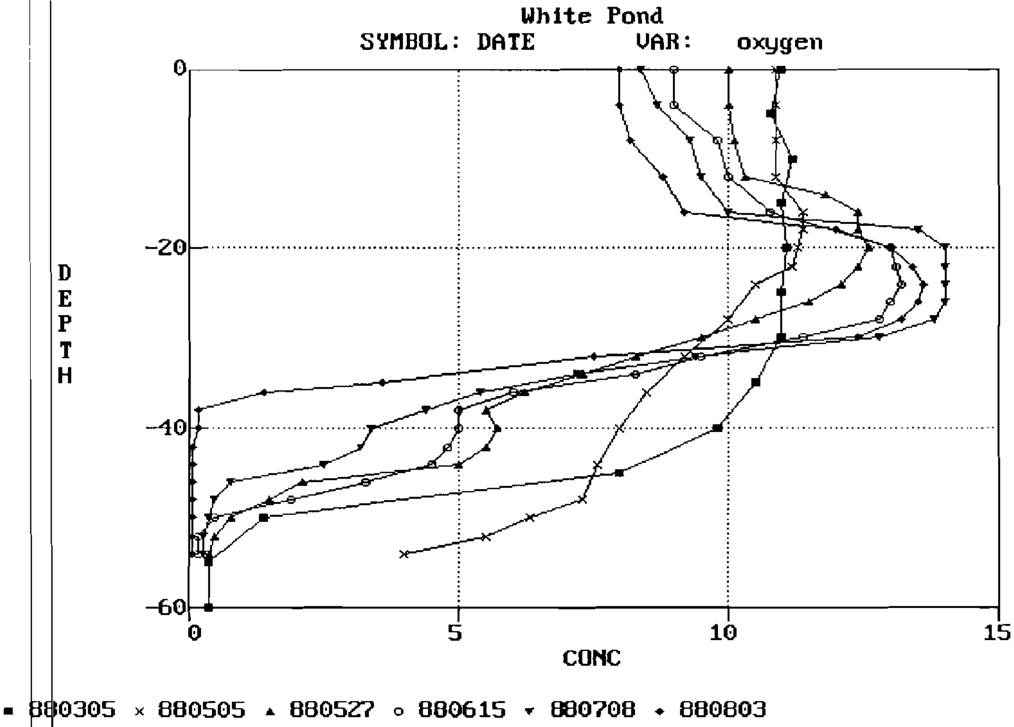
Table 1
White Pond Sampling - 1988

Date	Transparency	Thermocline		Bottom	
	Feet	Depth	Oxygen	Oxygen	Field Notes
March 3	21	52	1.4	0.4	Under Ice; Intense Fishing Activity Recently Stocked
May 5	22	14	11.4	6.3	
May 27	22	16	12.4	0.8	
June 14 *	24				
June 15	24	18	13.0	0.5	
July 6 *	18				"Milky Blue" bloom @ Camp Thoreau Thick Green Algae Along Shoreline
July 8	17	20	14.0	0.4	Flakes Near Assoc. Beach Slight Oily Film on Surface
July 31 *	21				
August 3	20	19	13.6	0.1	Foam Near Assoc. Beach Algal Flakes @ Camp Thoreau
August 10 *	18				Green Algae NE Shoreline
August 20 *	20				No Algae; Weeds along RR tracks
August 30 *	23				Foam NE Shoreline
September 24	27	27	12.6	0.2	H_2S Odor @ 50 ft
October 31	22	43	6.8	0.1	Strong H_2S Odor @ 50 ft

* Lay Monitors

Figure 12
Temperature and Oxygen Profiles
March-August 1988





collected between March and August (warming season) are displayed in Figure 12. All profiles are plotted by date in Appendix C.

The gradual warming of the surface waters between from 4 deg-C in March to 28 deg-C in August is evident in Figure 12. The corresponding increase in bottom temperatures (4 to 7 deg-C) indicates that little heat was transferred to this region. Vertical heat transfer was impeded by the density gradient across the thermocline, which ranged from 18 to 35 feet in summer.

Patterns in dissolved oxygen were similar to those observed in 1987. Oxygen concentrations were near saturation in the surface layer (because of free oxygen exchange with the atmosphere), higher in the thermocline (because of oxygen produced by algal photosynthesis), and approached zero on the bottom (because of oxygen consumed by decaying organic material and bottom muds).

Based upon profiles taken on May 5 and May 27, the rate of oxygen depletion below the thermocline was estimated to be 347 mg/m^2-day, which agrees with the 362 mg/m^2-day value estimated from 1987 monitoring data. This rate is one measure of the amount of organic material being produced and metabolized by the pond. Based upon criteria suggested by Hutchinson (1957), oxygen depletion rates exceeding 550 mg/m^2-day are symptomatic of "eutrophic" or excessively enriched conditions. Based upon the measured oxygen depletion rate, White Pond would be classified as "mesotrophic" or moderately enriched. The actual metabolic rate may be somewhat higher because the calculation does not account for effects of photosynthetic production by algae in and below the thermocline, possible in this case because of the high transparency of the pond (16 to 27 feet).

Oxygen concentrations were near zero at depths exceeding 50 feet on March 3. Despite the cold water temperatures and weak thermal stratification during winter, the rate of oxygen consumption by bottom muds was apparently sufficient to cause depletion of oxygen. The volume and surface area of anaerobic water were much less than those observed during late summer, however. Hydrogen sulfide odors were not detected in the March bottom sample; this indicates that the oxygen depletion was not severe enough to cause microbial reduction of sulfate, a process which could promote release of phosphorus from bottom muds. Unfortunately, phosphorus analyses were not conducted on the March 3 samples because of a laboratory error.

6.0 Pond Water Quality

Total phosphorus and transparency measurements in 1987 and 1988 are plotted in Figure 13. Seasonal comparisons of data from the two years are shown in Figure 14.

Phosphorus limits the growth of algae and production of organic material in the pond (Walker and Ploetz, 1988). The total phosphorus concentration in the surface layer during summer is a

Figure 13
Transparency and Total Phosphorus
Time Series by Depth Interval

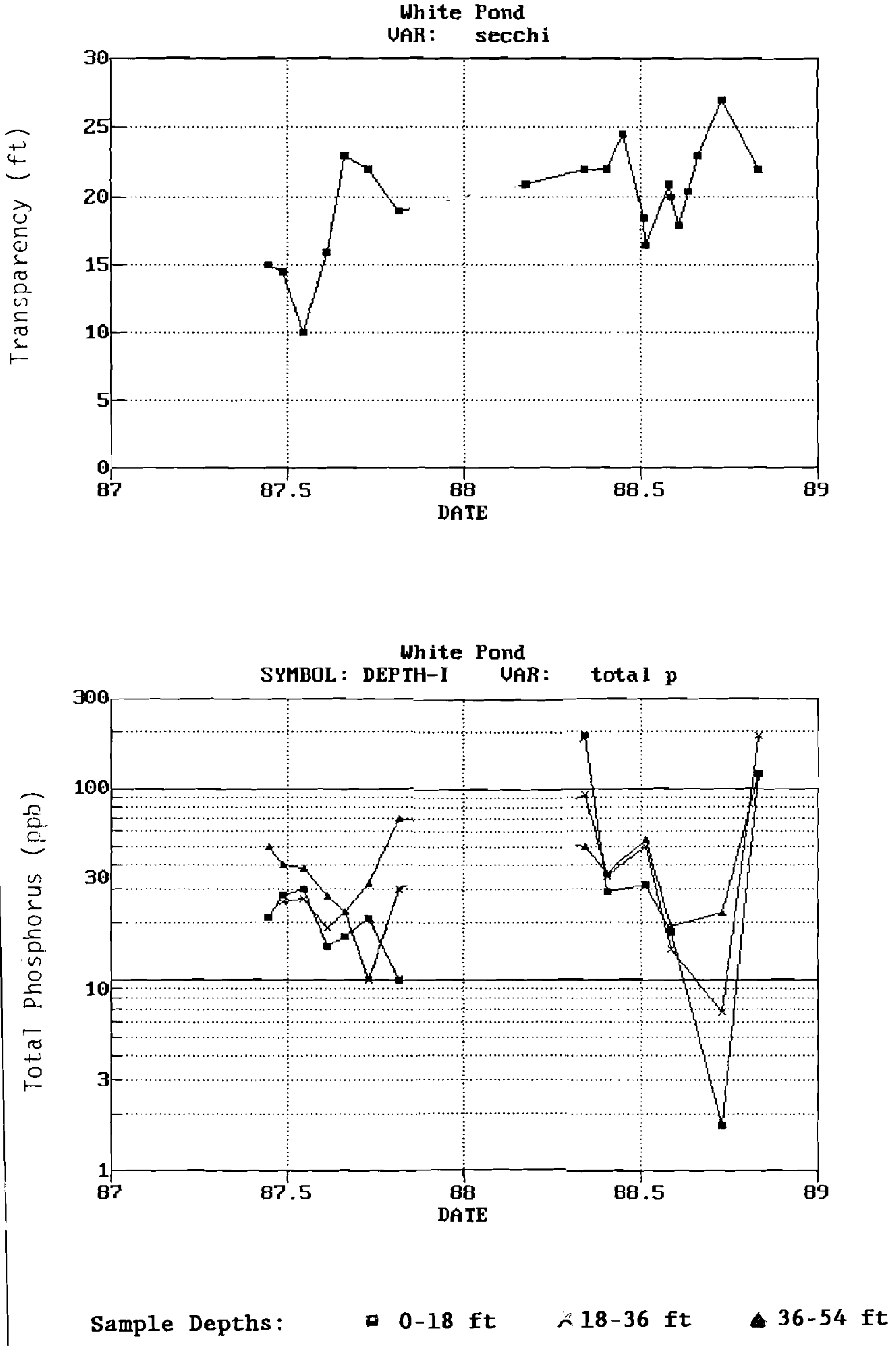
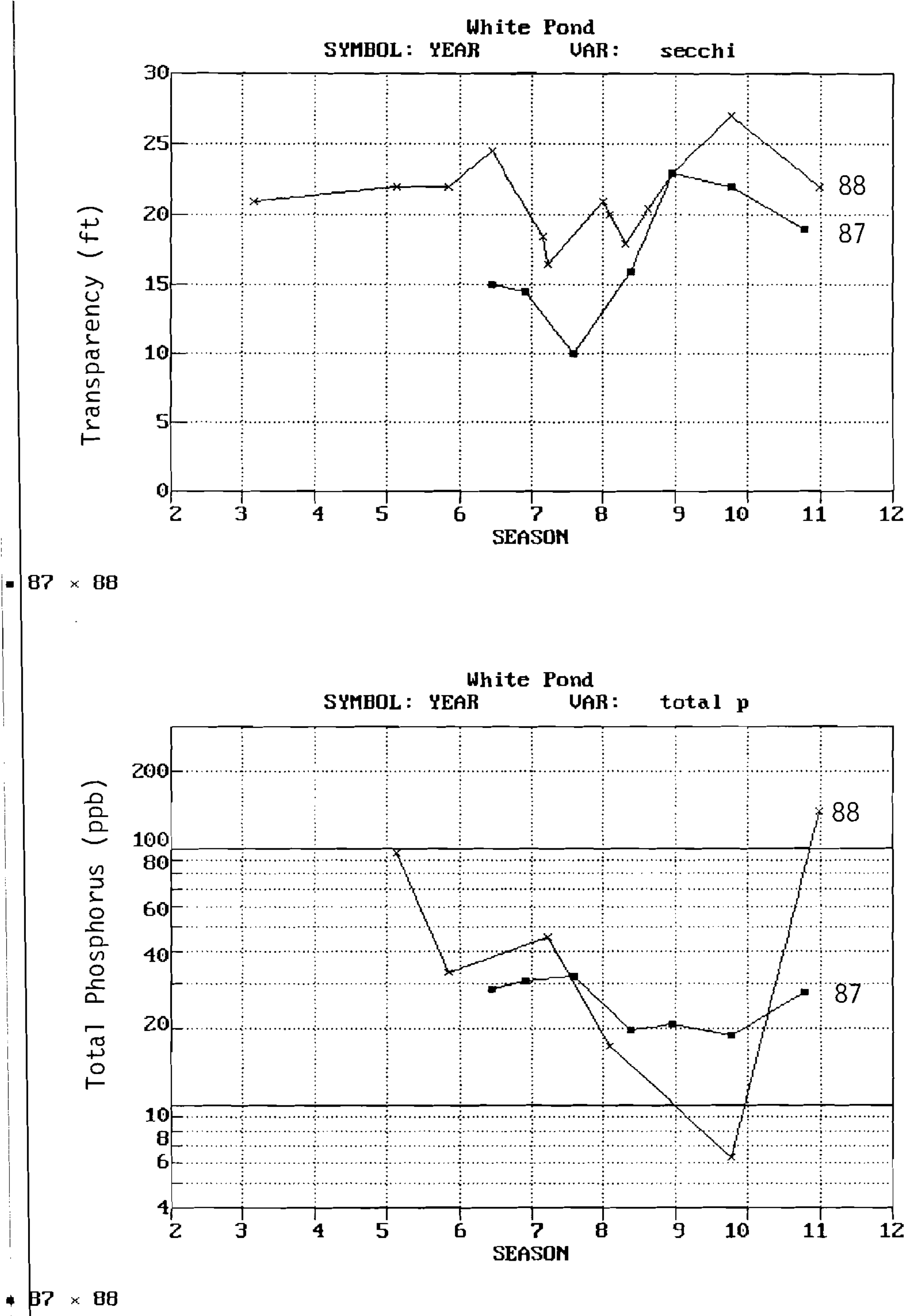


Figure 14
Transparency and Total Phosphorus
Seasonal Variations - 1987 vs. 1988



Total Phosphorus Concentrations Averaged over 0-35 Feet

Season = Month

measure of the pond's trophic state and of the potential for nuisance algal blooms. Median total phosphorus concentrations were 22 ppb in 1987 and 20 ppb in 1988. As shown in Figure 13, the variability in the phosphorus measurements was much greater in 1988. Higher concentrations measured in spring and fall of 1988 may reflect runoff from the watershed or lake turnover periods. Because of the variability, the difference between the 1987 and 1988 median values is not statistically significant.

Mid and late summer phosphorus data from both years indicate that White Pond is in a mesotrophic, or moderately enriched condition (total phosphorus between 10 and 25 ppb). Measurements in spring, early summer, and fall are indicative of a eutrophic, or excessively enriched condition (total phosphorus greater than 25 ppb). Episodes of isolated algal blooms, shoreline organic accumulations, and surface films (Table 1) are signs of biological response to nutrient enrichment. Further increases in phosphorus levels would be expected to result in more frequent and more severe episodes. As discussed in Section 9.0, preventing further increases in phosphorus loading to the pond is a fundamental approach to protecting water quality.

Transparency is measured by lowering a Secchi Disk (black and white disk 20 centimeters in diameter) into the water until it disappears. Given the low levels of color and inorganic turbidity in the pond, transparency measurements would be inversely related to the amount of algae and other suspended organic material in the surface layer of the pond. Summer median transparencies were 16 feet in 1987 and 21 feet in 1988. As shown in Figure 14, seasonal variations were similar in the two years, with minimum values measured in July of each year (10 ft in 1987, 16 ft in 1988).

Based upon median transparency measurements, White Pond would be classified as "oligotrophic" or nutrient-poor (transparency exceeding 4 meters of 13.1 feet). Minimum transparencies are in the mesotrophic range (2-4 meters or 6.6-13.1 ft). White Pond has an unusually high transparency, given the range of phosphorus concentrations. There are two primary reasons for this:

(1) The Pond is fed primarily by groundwater, as opposed to surface streams which would contribute silt, inorganic particles, and color. For this reason, White Pond has a higher transparency at a given nutrient level than lakes or ponds fed by surface streams.

(2) Based upon vertical oxygen profiles in 1987 and 1988 (Figure 12), much of the algal growth in the pond occurs in the thermocline instead of the epilimnion or surface layer. Algal populations located below the Secchi depth would not influence the transparency measurement.

Although transparency is a good measure of aesthetic quality, phosphorus concentrations and dissolved oxygen profiles are better indicators of trophic state in White Pond for the above reasons.

High concentrations of iron (.48-1.51 ppm), manganese (.10-.14 ppm), and ammonia (.35-.43 ppm) were detected in the hypolimnion (40 and 50 ft samples) in August 1988. These substances are released from the pond bottom sediments under anaerobic conditions. Hydrogen sulfide odors in bottom samples collected on September 24 and October 31, as observed in 1987, indicated that sulfate reduction and iron sulfide precipitation had occurred. These changes in bottom chemistry are often accompanied by release of phosphorus from bottom sediments in eutrophic lakes and ponds. Phosphorus concentrations in the bottom waters were similar to those observed in the surface waters, however.

Measurements of surface pH and alkalinity in 1987 and 1988 are summarized in Table 2. According to the system employed by the Massachusetts Acid Rain Monitoring Project (Ruby et al., 1988), White Pond would be classified in the "Endangered" category based upon two out of the four samples and the average results. Based upon statewide sampling in October 1984 and April 1985, 32-42% of the lakes in Massachusetts would be placed in the "Endangered" category or worse.

The lowest alkalinity (2.0 ppm) and pH (5.4) levels were measured in August 1988. These values were particularly unusual because they were lower than those measured in May (3.7 ppm and 6.3, respectively), whereas alkalinity and pH typically increase in lakes and ponds during summer. Unlike the August 1987 profile, when a pH of 8.8 was detected in the thermocline (probably due to photosynthetic activity), pH levels were below 6 throughout the water column in August 1988. It is possible that the August 1988 measurements were in error. Resampling of pH and alkalinity profiles is planned for August 1989.

7.0 Private Well Sampling

To provide basic data on background nutrient levels in regional groundwater, 18 samples were collected from private water-supply wells in the White Pond watershed in September of 1988. Sample locations and results are listed in Table 3. Locations are mapped in Figure 15. Samples were analyzed for total phosphorus and nitrate nitrogen.

Total phosphorus is of concern because it limits the growth of algae in the pond. While phosphorus is normally removed to a high degree in leach fields and unsaturated soils, elevated phosphorus concentrations in the groundwater (and pond) might result from a variety of factors, including:

(1) improper design or maintenance of onsite disposal systems;

Table 2
Surface Alkalinity and pH Measurements

Date	pH	Alkalinity (ppm)	Alkalinity Category
August 12, 1987	7.0	4.4	Endangered
May 5, 1988	6.3	3.7	Endangered
August 3, 1988	5.4	2.0	Critical
October 31, 1988	6.8	7.0	Highly Sensitive

Alkalinity Classification System
Mass. Acid Rain Monitoring Program
Ruby et al. (1988)

ARM Alkalinity Category	Alkalinity Range (ppm)	Percent of Mass. Lakes Oct 1984 %	April 1985 %
Acidified	< 0	4.7	5.7
Critical	0-2	10.2	16.7
Endangered	2-5	13.6	19.6
Highly Sensitive	5-10	17.1	21.2
Sensitive	10-20	24.5	19.5
Not Sensitive	>20	29.9	17.2
Number of Samples		2493	2472

Table 3
White Pond Private Well Samples - September 1988

	Parcel	Name	Address	Dist. Pond Ft	Well Depth Ft	Water Level Ft	Total P ppb	Nitrate-N ppb
1	3286	Strontd	10 Shore				0.1	655
2	3304	Harrison	38 Shore	5	15		0.6	10
3	3305	H Abraham	42 Shore	70	35		25.8	10
4		Ricker	68 Shore	50			2.4	10
5	3334	McBreen	88 Shore				2.8	3077
6	3414	Le Blanc	96 Shore				0.1	10
7		Rosen	27 Hemlock	(town well)			144.7*	10
8	3215	Barns	455 Powder Mill	140	217	50	12.1	10
9	3252	Simms	55 Seymour	20	15		9.8	10
10	3222	Erwin	121 Seymour	90	500		6.6	10
11	3204	Nyholm	12 White	150-200	175		0.1	10
12	3209	Gallagher	17 White	50	15		1.2	810
13	3202	Gravel	39 White	30	31	12	5.5	3470
14	3201	Sprott	43 White				7.8	368
15	3200	McDonald	47 White	30			0.1	10
16	3199	McCleod	55 White	60	25		8.8	581
17	3198	Stansfield	57 White	30	20		0.1	457
18	3194	Melnechuk	75 White	30	10-12		4.2	219

* high reading influenced by zinc metaphosphate added routinely by Concord Water Dept to water pumped from well for control of iron/manganese problems

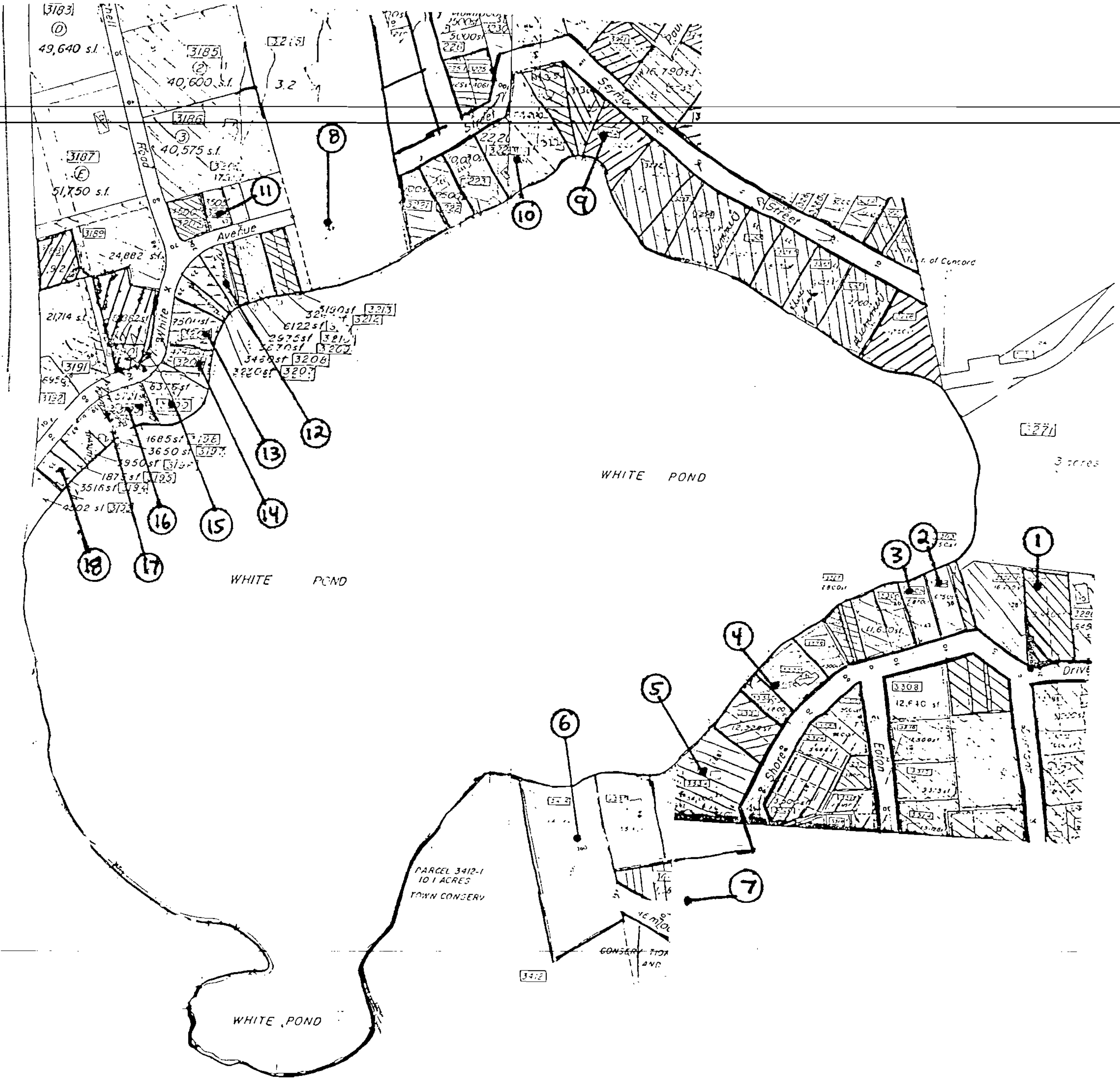


Figure 15
Well Sample Locations

(2) close proximity to pond shoreline;

(3) excessive density of septic systems in the watershed;

(4) sandy, excessively well-drained soils with limited phosphorus adsorption capacity;

(5) shallow and/or flooded soils with limited adsorption capacity;

(6) loss of soil adsorption capacity due waste discharge over long periods of time.

Direct evaluation of these factors throughout the watershed would be a difficult task. Sampling of water supply wells provides a relatively simple means of quantifying background levels of total phosphorus in regional groundwater. The locations of the wells do not permit determination of the extent to which effluents from specific onsite sewage systems are impacting the lake, however.

Nitrate nitrogen measurements were also conducted because nitrate serves as a tracer for domestic effluent. Most of the nitrogen discharged to the soil is rapidly converted to nitrate, which, unlike phosphorus, is not removed as the effluent travels through the soil profile. Samples taken from private wells with elevated nitrate concentrations may indicate that wells are influenced by effluent, although other sources (excessive lawn fertilization) may also contribute to high nitrate levels.

Results of the well sampling program indicate that background levels of total phosphorus in regional groundwater are very low. In 15 out of 18 samples, phosphorus concentration was below 10 ppb and well below the median total phosphorus concentration measured in the pond (20 ppb). It is unlikely that widespread contamination of regional groundwaters with high phosphorus concentrations has occurred, although isolated areas of high concentration may exist. Deep, iron-rich soils promote phosphorus absorption from domestic effluents throughout most of the watershed.

The highest phosphorus concentration (145 ppb, Site 7) was taken from a residence served by the Town well. According to the Town Water Department, zinc metaphosphate is routinely added at all supply wells to prevent iron and manganese precipitation. High iron levels were measured at the town well in September 1988. The high phosphorus concentration measured at Site 7 was probably due to the chemical addition. Direct sampling of the Town well before the point of chemical addition will be conducted in 1989 to investigate further.

Elevated nitrate nitrogen concentrations were detected at Site 5 (3,077 ppb) and Site 13 (3,470 ppb). Results indicate that these wells may be influenced by domestic effluent. Nitrate concentrations were well below the federal drinking water standard

(10,000 ppb), however. Direct sampling of these wells for coliform bacteria would provide an improved basis for evaluating the suitability of specific well waters for drinking purposes. Phosphorus concentrations were very low at these sites (3 and 6 ppb, respectively). This reflects the limited mobility of phosphorus (vs. nitrogen) in the soil.

8.0 Shoreline Groundwater Studies

Although results of the private well sampling program indicate that phosphorus concentrations in regional groundwaters are relatively low, locations of the wells are not ideal for detecting effluent plumes reaching the pond. The well samples do not necessarily reflect the quality of the groundwater being discharged to the pond from the watershed. Other important unknowns include the direction and magnitude of groundwater inflows and outflows. A variety of relatively simple devices have been developed for investigating pond/groundwater interactions, including shoreline wells, manometers, sediment pore samplers, and seepage meters (Mitchell et al., 1988).

To demonstrate a technique for measuring groundwater flow directions and quality, a mini-well was installed on the northwest shoreline (55-57 White Road) by Pine & Swallow, Associates of Groton on August 13, 1988. The well consisted of a 1/2-inch steel pipe, driven 3 feet into the ground approximately 2-5 feet from the water's edge. An onsite sewage disposal system (seepage pit) was located approximately 10-15 feet inland from the sampling well at approximately the same elevation. This system was on a twice-yearly pumpout schedule and had last been pumped on May 25, 1988. Because of the high density of cottages in this area, several other disposal systems were located within ~200 feet of the test well. Results of water quality and elevation measurements taken from the well on three dates are summarized in Table 4.

Table 4
Shoreline Groundwater Measurements

55-57 White Road, 1-3 Feet Depth

Date	Total P ppb	Ortho P ppb	Nitrate N ppb	Head ** inches
8/13/88	5		10	
9/24/88	404		10	.25
9/24/88	24*		72*	
10/31/88	1800	380	40	.50

* sample filtered (.45 microns)
** water elevation inside well - pond water elevation

Water elevations were measured in the test well on two dates (September 24 and October 31) using a manometer (Mitchell et al., 1988). The manometer accurately measures the difference in elevation between water inside the well (indicative of the local groundwater table) and the pond surface. The well water surface was higher than the pond surface on both dates (by .25 inches on September 24 and by .5 inches on October 31). This indicates that the direction of groundwater movement in the vicinity of the well was towards the pond on these dates. The pond water level was approximately 6 inches lower on October 31 as compared with September 24. Although much more intensive shoreline sampling is needed to define flow patterns through the pond, these preliminary measurements are consistent with the theory that the direction of flow through the pond is from the Northwest to the Southeast, in the general direction of the Town Well.

Water quality samples were collected from the well using a battery-powered peristaltic pump on August 13 and using a manual vacuum pump on the September 24 and October 31. The flush out sediment and debris, the well volume was displaced several times before collecting samples for chemical analyses. After initial flushing, the August sample was relatively clear, whereas a black precipitate formed in both the September and October samples. The precipitate probably consisted of insoluble iron and/or manganese compounds which formed when the samples were aerated.

Nitrate nitrogen levels were relatively low (10-72 ppb) in all samples. Total phosphorus concentrations were 5 ppb on August 13, 404 ppb on September 24, and 1800 ppb on October 31. These measurements and the well location suggest that adjacent groundwater was influenced by onsite waste disposal system(s) on the last two sampling dates. High nitrate levels would not be expected because most of the nitrogen in domestic waste and septic effluents is in organic or ammonia form, which is converted to nitrate as the effluent passes through aerobic soil.

Dissolved phosphorus (filtered sample on September 24) was relatively low (24 ppb vs. 404 ppb total P). Most of the phosphorus in the well and groundwater is likely to be in dissolved form. Based upon sample appearance, insoluble iron phosphates may have precipitated when the sample was collected and aerated. This would explain the fact that most of the phosphorus in the September 24 sample was in particulate form.

To some extent, precipitation of insoluble iron phosphates may occur as anaerobic effluent plumes seep into the pond surface waters and are oxygenated. This mechanism may reduce the availability of plume phosphorus loadings to support algal blooms. Iron phosphate precipitates would redissolve, however, if they were to reach anaerobic zones of the pond. The high concentration of ortho phosphorus (soluble form most readily available to algae) in the October 31 sample (380 ppb) indicates that iron phosphate precipitation was not sufficient to remove all of the soluble phosphorus from that sample.

The primary purpose of the above measurements was to develop and demonstrate techniques for measuring groundwater flow directions, measuring groundwater quality, and investigating effects of onsite waste disposal systems. Mini-wells appear to be very useful, although other techniques (seepage meters, pore samplers, septic snoopers) may also be applicable. A more detailed test well program has been proposed for 1989 to obtain a more complete spatial and temporal picture of groundwater flow directions and quality.

9.0 Pond Protection Measures

Our previous report (Walker and Ploetz, 1988) discussed the importance of controlling phosphorus sources as a means of protecting water quality in White Pond. Based upon mathematical modeling of the pond/watershed system, estimated sources of phosphorus are as follows:

Source	lbs/year	% of Total
Runoff from Undeveloped Areas	5.2	10.8%
Runoff from Developed Areas	26.4	55.4%
Onsite Sewage Disposal Systems	8.4	17.5%
Precip./Dustfall on Pond Surface	7.7	16.2%
Total	47.6	100.0%

These approximate estimates provide a frame of reference which can be refined with continued pond monitoring and detailed investigation of specific sources. Because it is linked, through modeling, to the measured pond phosphorus concentration, the total load (48 lbs/yr) is estimated more accurately than the individual source terms and has a margin of error of approximately 50%. The total load is the equivalent of runoff from approximately 27 impervious acres, 43 cubic yards of eroded top soil, domestic waste from 22 people, or animal waste from 1.2 cows, 137 chickens, or 533 seagulls.

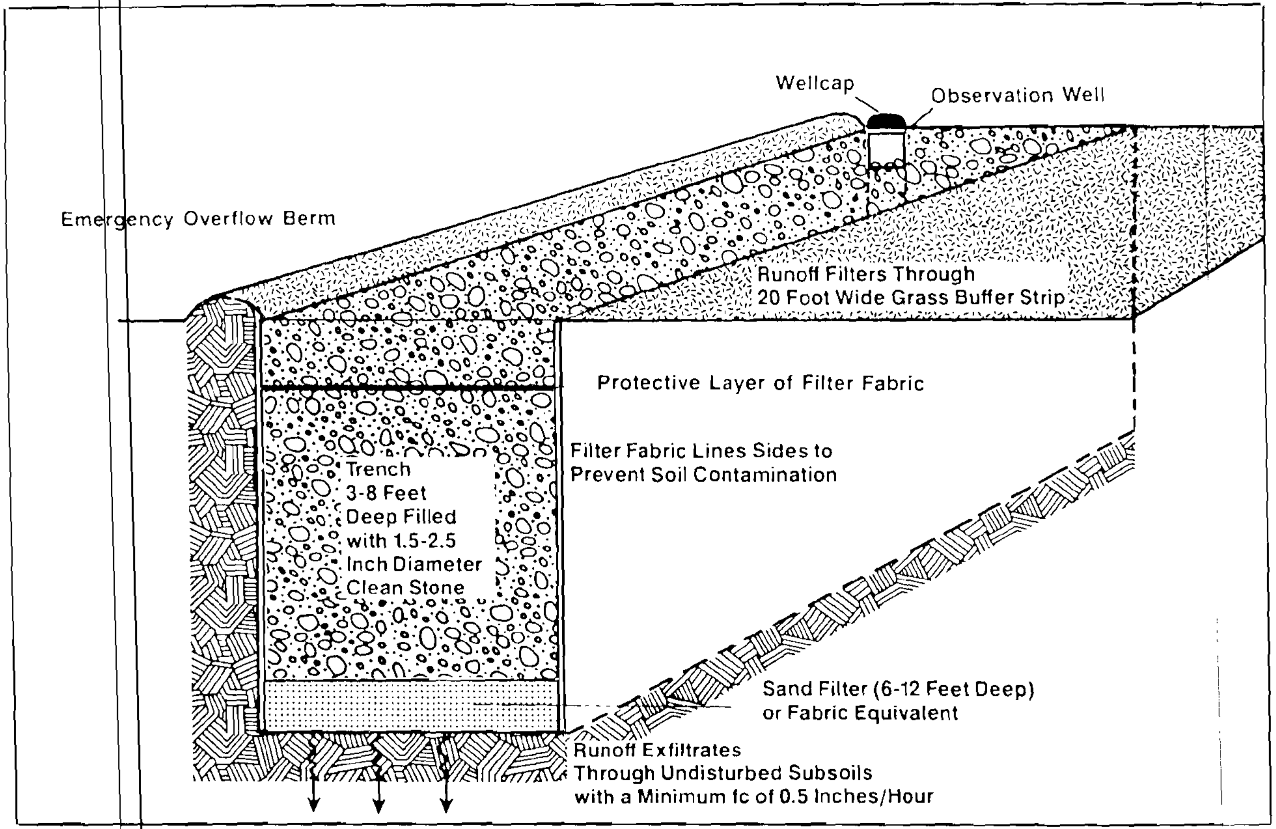
One important control strategy is to reduce the quantity of surface runoff discharged to the pond. Surface runoff washes accumulated debris from impervious surfaces (vegetation, dustfall, pet litter, etc.). It is also in contact with the upper soil horizons, which generally have much higher phosphorus contents as compared with deeper horizons. Surface runoff may also contribute to soil erosion, particularly from steep shoreline areas. Filtration, precipitation, and adsorption processes remove most of the phosphorus from water which infiltrates the soil column before entering the pond. For these reasons, phosphorus concentrations in surface runoff are typically more than 100-fold higher than concentrations in subsurface drainage.

The infiltration trench is one device which can be used to control surface runoff. Figure 16 illustrates a typical design, although several other configurations have been conceived (Schueler, 1987). Typically, such devices are sized so that the storage volume (void volume of trench) equals the volume of runoff from a 1-inch storm over the contributing watershed (roughly = impervious area x 1 inch). Sandy soils in the watershed should provide ample

Figure 16
Typical Design for Infiltration Trench (Schueler, 1987)

Infiltration trenches are an adaptable BMP that effectively remove both soluble and particulate pollutants. As with other infiltration systems, trenches are not intended to trap coarse sediments. Grass buffers (for surface trenches) or special inlets (for underground trenches) must be installed to capture sediment before it enters the trench. Depending on the degree of storage/exfiltration achieved, trenches can provide groundwater recharge, low flow augmentation and localized streambank erosion control. Individual trenches are primarily an on-site control, and are seldom practical or economical on sites larger than 5 or 10 acres. Trenches are only feasible when soils are permeable and the water table and bedrock are situated well below the bottom of the trench. Aside from regular inspections and more rigorous sediment and erosion control, trenches have limited routine maintenance requirements. However, trenches will prematurely clog if sediment is not kept out before, during and after construction of a site. If a trench does become severely clogged, partial or complete replacement of the structure may be required.

Figure 5.1: Schematic of an Infiltration Trench



infiltration capacity. One limitation is that the bottom of the trench should be at least 1 foot above the groundwater table. This would make it difficult to locate these devices near the pond elevation. To remove course suspended solids which would otherwise plug the filter media, a grass swale or sediment trap should be located immediately upstream of the trench. Areas of the watershed where infiltration trenches or other runoff control devices would be appropriate include the Seymour Street drainage system, state boat ramp, and White Pond Association parking lot. Following large storm events, runoff from the parking lot has been observed to flow down the steps, across the beach, and into the pond.

Shoreline erosion control is another important pond protection measure. The local pond association (Friends of White Pond) has submitted plans to the Town Natural Resources Commission for structural measures to control bank erosion from the Town Conservation Land. This project would have significant benefits in terms of protecting pond water quality and enhancing aesthetic values. Erosion at the base of the state boat ramp has proceeded to the point where the ramp is almost unusable. Diversion of runoff from the upper ramp (into an infiltration trench, for example) is needed to control this problem. Other, smaller areas of bank erosion around the shoreline could be controlled via structural or nonstructural measures.

Based upon population equivalents, the potential impact of onsite sewage disposal systems on the pond's phosphorus loading is large. The annual average population in shoreline cottages and residences is approximately 76. Untreated sewage from a population of this size would be expected to contain 167 lbs/year of total phosphorus, as compared with the estimated 48 lbs/year total loading to the pond. An average phosphorus removal efficiency in onsite treatment system of 95% has been assumed in developing the pond's phosphorus budget. A single shoreline residence with 4 inhabitants and a failing onsite treatment system (0% phosphorus removal) would increase the annual phosphorus loading by 8.8 lbs/year or 18.5%. This clearly indicates a need for more intensive studies to characterize pond/groundwater interactions and to evaluate impacts of onsite disposal systems.

Meanwhile, the following measures are suggested to minimize the impacts of onsite disposal systems:

(1) informing shoreline residents of their potential impacts on the pond;

(2) minimizing water use (may increase residence time and treatment efficiency of onsite system);

(3) using non-phosphate detergents;

(4) frequent pumping of septic tanks/seepage pits (at least once per year, more often for "problem" systems).

Depending upon results of diagnostic studies and other factors, longterm solutions to this problem may involve modification or replacement of specific systems. State funding for such work may be feasible under the Massachusetts Clean Lakes Program. Based upon private well sampling results (see Section 7.0), it is unlikely that a watershed-scale sewering project would be required because widespread, regional contamination of groundwaters with phosphorus has not occurred.

Another important longterm measure for protecting pond water quality is proper land use management. Considering the pond's low flushing rate and sensitivity to nutrient loading, any future urban development in the watershed should be done with extreme caution. A recent proposal for construction of 34 housing units on the Concord portion of the Sperry/Unisys land southwest of the pond (Concord Journal, July 20, 1989) is of concern in this regard. Potential water quality impacts would be related to (1) runoff and erosion from construction sites; (2) runoff from impervious surfaces and grassed areas after construction is completed; and (3) seepage from onsite sewage disposal systems.

Based upon studies of low-density residential developments in Maine (Dennis,1986), runoff from a "typical", stabilized urban lot contributes an average of .55 lbs/year of total phosphorus. If runoff from an additional 34 lots were allowed to reach the pond uncontrolled, the pond's phosphorus loading would increase by 18.7 lbs/year or 39%. White Pond does not have the capacity to assimilate such an increase without experiencing major, observable water quality impacts. Control measures, such as runoff diversion or infiltration, should be employed to avoid any increases in surface runoff to the pond, both during and after construction of new housing developments.

Impacts of seepage from new onsite disposal systems are of greater concern. Assuming an average of 4 persons per unit, the addition of 34 units would increase phosphorus loading to groundwater by about 300 lbs/year. Even if a removal efficiency of 95% in the soil system is assumed, phosphorus loading to the pond would increase by 15 lbs/year or 32%. This removal efficiency is highly optimistic, considering geologic data (Section 2.0) which indicate that the thickness of soils in this portion of the watershed is limited by the steep rise in bedrock elevation moving west of the pond.

Design of onsite disposal systems according to state health codes would not necessarily avoid significant water quality impacts related to phosphorus loading, particularly as the systems age and soil phosphorus adsorption capacity is utilized. Collection and disposal of sewage outside of the White Pond watershed may be required to avoid significant adverse water quality impacts. Before development of the Sperry/Unisys property (Concord or Sudbury portions), studies should be performed to determine soil depths and phosphorus adsorption capacities, groundwater elevations and flows, and appropriate measures for avoiding pond impacts.

10.0 Conclusions and Recommendations

(1) White Pond water quality in 1988 was similar to that observed in 1987 with respect to nutrients and related factors. Based upon summer phosphorus concentrations and oxygen depletion rates, the pond would be classified as mesotrophic, or moderately enriched. Important signs of nutrient enrichment include phosphorus concentrations in the eutrophic range during spring and fall, shoreline organic accumulations (flakes, foams), occasional algal bloom episodes, and depletion of bottom dissolved oxygen during summer and winter.

(2) Based upon geologic data presented in a townwide groundwater resources study (IEP, 1979), bedrock elevation increases and soil thickness decreases moving from east to west in the White Pond watershed. These gradients have important implications for evaluating the potential water quality impacts of onsite sewage disposal systems in various regions of the watershed. In particular, the effectiveness and longevity of phosphorus removal may be significantly lower in areas west of the pond because of relatively shallow soils.

(3) Lower water levels in the pond during 1988 were associated with below-average precipitation and above-average pumping rates from the town well located southeast of the pond. Water elevation records from the town well also indicate that groundwater elevations were lower by 2-4 feet in 1988, as compared with 1984-1987. Specific water quality impacts of the low pond levels were not observed, however.

(4) Vertical dissolved oxygen profiles in 1987 and 1988 showed high concentrations in the thermocline (attributed to algal photosynthesis in that region) and depletion below the thermocline (attributed to respiration and decay of organic material in bottom sediments).

(5) Bottom dissolved oxygen was depleted between May 27 and October 31 (last sampling date). Elevated iron, manganese, ammonia, and sulfide levels were observed in the bottom waters in late summer and fall. These are symptomatic of conditions which can trigger recycling of phosphorus from bottom sediments and significantly increase the frequency and severity of algal blooms, especially during turnover periods in the spring and fall. High phosphorus concentrations were not observed in the bottom waters, however.

(6) Despite the weak thermal stratification and low rates of biological activity during winter, dissolved oxygen was also depleted below 50 feet on March 3, 1988. Decay of organic materials in bottom sediments was apparently responsible.

(7) Phosphorus concentrations were in the mesotrophic range (10-25 ppb) during mid summer and in the eutrophic range (> 25 ppb) in spring, early summer, and fall. The summer median phosphorus concentration (20 ppb) was not significantly different from that observed in 1987 (22 ppb).

(8) Transparency was relatively high (median = 21 ft, minimum = 16 ft, maximum = 27 ft) and averaged about 5 ft higher than observed in 1987. Transparency was lowest during July of each year. Surface transparency is a weak indicator of total algal growth in the pond because a significant portion of the growth probably occurs in the thermocline (18-35 feet), based upon increases in dissolved oxygen observed in that region.

(9) Based upon alkalinity levels, White Pond would be classified as "Endangered" with respect to potential acid rain impacts (Ruby et al., 1988). This classification is not unusual for Massachusetts lakes and ponds, particularly for groundwater ponds with sandy watershed soils. While an important longterm concern, acidity is not an immediate threat to aquatic life in the pond.

(10) Sampling of private water supply wells indicates that background phosphorus concentrations in regional groundwaters are very low (less than 10 ppb in 15 out of 18 samples). Widespread regional contamination due to onsite sewage disposal systems has not occurred. Isolated areas of phosphorus concentration may exist in unsampled areas, however, particularly in groundwaters immediately adjacent to the pond. Elevated nitrate concentrations detected at a few wells may reflect influences of onsite disposal systems, but nitrate concentrations were well below the federal drinking water standard.

(11) Preliminary groundwater studies along the White Avenue shoreline indicated that groundwater flow direction was towards pond and contained high phosphorus concentrations in two out of three sampling dates (5, 404, 1800 ppb). It is likely that the high values reflect impacts of onsite disposal systems. Shoreline mini-wells are useful for measuring groundwater flow directions and groundwater quality.

(12) Because of its low flushing rate, White Pond has a limited capacity to assimilate nutrient loadings from the watershed without experiencing significant deterioration in water quality, which, in turn, would have important impacts on aesthetic values, recreational uses, and fisheries. To protect pond water quality, management efforts should be directed at minimizing total phosphorus loadings. Surface runoff and onsite waste disposal systems are two major sources to be targeted now and in the future.

(13) The proposed construction of 34 new housing units on the Sperry/Unisys property (Concord portion) southwest of White Pond is of concern because of potential impacts related to (a) runoff and erosion from construction sites; (b) runoff from impervious surfaces and grassed areas after construction is completed; and (c) seepage from onsite sewage disposal systems. The potential phosphorus loadings from a development of this size are large in relation to the pond's existing phosphorus budget and could therefore have major water quality impacts. For example, the phosphorus contained in domestic wastes from 34 housing units would amount to more than 6 times the estimated total phosphorus loading to the pond under existing conditions. Geologic data indicate that soils in this portion of the watershed are relatively shallow and therefore provide less adsorption capacity for domestic effluents, as compared with other areas of the watershed. Before development of the Sperry/Unisys property (Concord or Sudbury portions), studies should be performed to define environmental conditions and to design appropriate measures for avoiding pond water quality impacts.

(14) Additional diagnostic work is needed to guide management efforts, particularly in defining pond/groundwater interactions, quantifying impacts of onsite waste disposal systems, and designing appropriate control strategies. The current pond monitoring program should be continued and supplemented by lay monitoring of transparency on a weekly basis from May through September.

(15) An application to the State Clean Lakes Program (CLP) has been filed with the Division of Water Pollution Control. If the application is successful, state funds will be available to support more detailed diagnostic work and design/implementation of control measures.

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APPENDIX A - White Pond Profile Data - 1988

DEPTH = sample depth (feet)
TEMP = temperature (deg-C)
OXYGEN = dissolved oxygen (ppm) YSI Probe
SECCHI = Secchi disk transparency (feet)
TOTAL P = total phosphorus (ppb)

DATE	DEPTH	TEMP	OXYGEN	SECCHI	TOTAL P	NOTES
880305	.0	4.2	11.0	21.0		
880305	5.0	4.2	10.8			
880305	10.0	4.2	11.2			
880305	15.0	4.2	11.0			
880305	20.0	4.2	11.1			
880305	25.0	4.2	11.0			
880305	30.0	4.2	11.0			
880305	35.0	4.0	10.5			
880305	40.0	4.0	9.8			
880305	45.0	4.0	8.0			
880305	50.0	4.2	1.4			
880305	55.0	5.0	.4			
880305	60.0	4.2	.4			
880505	.0	13.0	10.9	22.0		
880505	4.0	13.0	10.9			
880505	8.0	12.5	10.9			
880505	10.0				190.0	
880505	12.0	11.0	10.9			
880505	16.0	10.0	11.4			
880505	18.0	9.5	11.4			
880505	20.0	9.0	11.3			
880505	20.0				80.0	
880505	22.0	8.5	11.2			
880505	24.0	8.0	10.5			
880505	28.0	7.0	10.0			
880505	30.0				110.0	
880505	32.0	6.5	9.2			
880505	36.0	6.3	8.5			
880505	40.0	6.0	8.0			
880505	44.0	6.0	7.6			
880505	48.0	6.0	7.3			
880505	50.0	6.0	6.3			
880505	50.0				50.0	
880505	52.0	5.9	5.5			
880505	54.0	5.9	4.0			
880527	.0	18.1	10.0	22.0		
880527	4.0	18.0	10.0			
880527	8.0	18.0	10.1			
880527	10.0				29.0	UFI
880527	12.0	17.0	10.3			
880527	14.0	15.5	11.8			
880527	16.0	13.5	12.4			
880527	18.0	13.0	12.4			
880527	20.0	11.5	12.6			

APPENDIX A - White Pond Profile Data - 1988

DATE	DEPTH	TEMP	OXYGEN	SECCHI	TOTAL P	NOTES
880527	22.0	11.0	12.4			
880527	24.0	10.0	12.1			
880527	26.0	9.5	11.5			
880527	28.0	9.0	10.5			
880527	30.0	8.5	9.5			
880527	30.0				35.0	UFI
880527	32.0	8.0	8.3			
880527	34.0	7.8	7.3			
880527	36.0	7.5	6.2			
880527	38.0	7.0	5.5			
880527	40.0	6.9	5.7			
880527	42.0	6.8	5.5			
880527	44.0	6.5	5.0			
880527	46.0	6.5	2.1			
880527	48.0	6.5	1.5			
880527	50.0				36.0	UFI
880527	50.0	6.5	.8			
880527	52.0	6.5	.5			
880527	54.0	6.5	.4			
880614	.0			24.5		Lay Monitors
880615	.0	23.8	9.0	24.0		
880615	4.0	23.5	9.0			
880615	8.0	20.8	9.8			
880615	12.0	20.0	10.0			
880615	16.0	18.0	10.8			
880615	20.0	14.8	13.0			
880615	22.0	13.5	13.1			
880615	24.0	12.5	13.2			
880615	26.0	11.0	13.0			
880615	28.0	10.5	12.8			
880615	30.0	9.5	11.4			
880615	32.0	9.0	9.5			
880615	34.0	8.6	8.3			
880615	36.0	8.5	6.0			
880615	38.0	8.0	5.0			
880615	40.0	7.5	5.0			
880615	42.0	7.5	4.8			
880615	44.0	7.0	4.5			
880615	46.0	6.5	3.3			
880615	48.0	6.5	1.9			
880615	50.0	6.5	.5			
880615	52.0	6.3	.2			
880615	54.0	6.3	.2			
880706	.0			18.5		Lay Monitors
880708	.0	27.0	8.4	16.5		
880708	4.0	26.0	8.7			
880708	8.0	24.8	9.3			
880708	10.0				31.5	UFI

APPENDIX A - White Pond Profile Data - 1988

DATE	DEPTH	TEMP	OXYGEN	SECCHI	TOTAL P	NOTES
880708	12.0	24.0	9.5			
880708	16.0	22.2	10.0			
880708	18.0	21.0	13.5			
880708	20.0	18.0	14.0			
880708	22.0	15.5	14.0			
880708	24.0	14.5	14.0			
880708	24.0				54.0	UFI
880708	26.0	12.5	14.0			
880708	28.0	12.0	13.8			
880708	30.0				46.5	UFI
880708	30.0	11.0	12.8			
880708	32.0	10.0	9.4			
880708	34.0	9.0	7.2			
880708	36.0	8.8	5.4			
880708	38.0	8.3	4.4			
880708	40.0	8.0	3.4			
880708	42.0	7.5	3.2			
880708	44.0	7.2	2.5			
880708	46.0	7.0	.8			
880708	48.0	7.0	.5			
880708	50.0	6.7	.4			
880708	50.0				54.6	UFI
880708	52.0	6.5	.3			
880708	54.0	6.5	.3			
880731	.0			21.0		Lay Monitors
880803	.0	28.5	8.0	20.0		
880803	.0				20.0	
880803	4.0	28.0	8.0			
880803	8.0	27.5	8.2			
880803	10.0				27.5	UFI
880803	10.0				10.0	
880803	12.0	27.0	8.8			
880803	16.0	25.5	9.2			
880803	18.0	24.0	12.0			
880803	20.0	21.0	13.0			
880803	22.0	19.0	13.4			
880803	22.0				10.0	
880803	22.0				22.2	UFI
880803	24.0	16.0	13.6			
880803	26.0	14.8	13.5			
880803	28.0	13.5	13.2			
880803	30.0				20.0	UFI
880803	30.0	12.0	12.4			
880803	30.0				10.0	
880803	32.0	11.0	7.5			
880803	35.0	10.0	3.6			
880803	36.0	9.5	1.4			
880803	38.0	9.0	.2			
880803	40.0				18.5	UFI
880803	40.0	8.5	.2			

APPENDIX A - White Pond Profile Data - 1988

DATE	DEPTH	TEMP	OXYGEN	SECCHI	TOTAL P	NOTES
880803	40.0				20.0	
880803	42.0	8.5	.1			
880803	44.0	8.0	.1			
880803	46.0	7.2	.1			
880803	48.0	7.0	.1			
880803	50.0				18.0	UFI
880803	50.0				20.0	
880803	50.0	6.8	.1			
880803	52.0	6.7	.1			
880803	54.0	6.7	.1			
880810	.0			18.0		Lay Monitors
880820	.0			20.5		Lay Monitors
880830	.0			23.0		Lay Monitors
880924	.0	20.5	9.3	27.0	1.2	UFI
880924	4.0	20.3	9.3			
880924	8.0	20.3	9.2			
880924	12.0	20.2	9.2			
880924	15.0				2.5	UFI
880924	16.0	20.2	9.1			
880924	20.0	20.2	9.1			
880924	24.0	20.1	9.1			
880924	26.0	20.0	9.1			
880924	28.0	17.1	12.6			
880924	30.0	15.5	12.0		6.8	UFI
880924	32.0	14.0	8.4			
880924	34.0	13.0	6.8			
880924	36.0	11.2	3.6			
880924	38.0	10.1	.4			
880924	40.0	9.5	.3		40.0	UFI
880924	42.0	9.5	.3			
880924	44.0	9.5	.2			
880924	46.0	9.7	.2			
880924	48.0	9.7	.2			
880924	50.0	9.7	.2		12.5	UFI, H_2S Odor
880924	52.0	9.7	.2			
880924	54.0	9.7	.2			
881031	.0	11.5	9.1	22.0		
881031	4.0	11.5	9.1			
881031	8.0	11.5	9.1			
881031	10.0				120.0	
881031	12.0	11.2	8.9			
881031	16.0	11.2	8.9			
881031	20.0	11.2	8.9			
881031	24.0	11.2	8.9			
881031	28.0	11.2	8.9			
881031	30.0				190.0	
881031	32.0	11.2	8.9			

APPENDIX A - White Pond Profile Data - 1988

DATE	DEPTH	TEMP	OXYGEN	SECCHI	TOTAL P	NOTES
881031	36.0	11.2	8.9			
881031	40.0	11.0	8.0			
881031	42.0	10.8	6.9			
881031	44.0	8.0	.2			
881031	46.0	7.4	.2			
881031	48.0	7.0	.1			
881031	50.0	6.9	.1		120.0	Strong H_2S Odor
881031	52.0	6.9	.1			
881031	54.0	6.9	.1			

NOTES:

Lay Monitors = L. Stansfield / G. Jewell Secchi Depth
UFI = Total P Analyses by Upstate Freshwater Institute, Syracuse, NY (Other Total P Analyses by Arnold Greene Labs, Natick, MA)

APPENDIX B

Laboratory Reports

B-2

CONAM INSPECTION

Arnold Greene Testing Laboratories

East Natick Industrial Park
6 Huron Drive • Natick, MA 01760
(617) 235-7330, 653-5950
Telex 948459 GREENELAB NTIK

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Research • Development

Branch Laboratories:
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(413) 734-6548

Auburn, Mass. 01501
(617) 832-5500

CONAM INSPECTION A UNIT OF QUALCORP
California, Texas, Illinois, Pennsylvania, Ohio

TO: WILLIAM WALKER
1127 LOWELL ROAD
CONCORD, MA 01742

DATE: 6/28/88
JOB NO. 9199-1
LAB NO. 7960
JUNT.W03-P1
ORDER NO. NONE

MATERIAL: WATER
BOOK NO. 350-25-6B
SPECIFICATIONS:

SAMPLE ID: 8 WATER SAMPLES
ID: WHITE POND

DATE REC'D: 5/5/1988

Sample Depth →			0'	0'
	~~#1~~	~~#2~~	#3	#4
	~~---~~	~~---~~	---	---
pH	~~1.2~~	~~1.3~~	5.9	6.4

Sample Depth →	10'	30'	50'	20'
	#5	#6	#7	#8
	---	---	---	---
pH	6.3	6.1	5.7	6.2
Total Phosphate (mg/l) as P	0.19	0.11	0.05	0.08
Alkalinity (mg/l)	3.7	5.55	4.63	13.0
Specific Conductance (umhos/cm)	43.2	43.6	45.5	43.8
Nitrate (mg/l)	<0.08	<0.08	<0.08	<0.08
Nitrite (mg/l)	<0.08	<0.08	<0.08	<0.08
Total Kjeldahl Nitrogen (mg/l)	0.27	0.31	0.41	0.26

IN WITNESS WHEREOF, I HAVE HEREUNTO SET MY HAND THIS
28TH DAY OF JUNE 1988
ARNOLD GREENE TESTING LABORATORIES
DIVISION OF CONAM INSPECTION

Donald B. Cowan

Donald B. Cowan, Manager

CONAM INSPECTION

Arnold Greene Testing Laboratories

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(413) 734-6548

Auburn, MA 01501-3204
(508) 832-5500

a unit of CONAM INSPECTION, INC.
California, Texas, Illinois, Pennsylvania, Ohio

To: DR. WILLIAM J. WALKER
1127 LOWELL ROAD
CONCORD, MA 01742

Date 8/23/89
Job No. 12560-1
Lab No. 8505
AUQ.W03-P4
Order No. NONE

Material: WATER
Book No. 374-17-MH
Specifications: NONE

Sample ID: 6 Water Samples @ WHITE POND Date received: 8/3/89

Sample Depth →	0'	10'	22	30'	40'	50'
Total Alkalinity (mg/l)	1.95	1.95	3.90	4.88	6.05	4.88
Ammonia (mg/l) as N	<0.10	<0.10	<0.10	<0.10	0.35	0.43
Nitrate (mg/l) as N	0.08	0.09	0.05	0.04	0.03	0.05
Nitrite (mg/l)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Sulfate (mg/l)	10.2	10.0	10.0	10.2	9.0	11.0
Phosphate, Total (mg/l) as P	0.02	<0.01	0.01	0.01	0.02	0.02
Total Kieldahl-Nitrogen (mg/l) as N	0.32	0.32	0.31	0.77	0.79	0.37
Specific Conductance (umhos/cm)	47	46	47	46	51	52
pH	5.4	5.4	5.6	5.5	5.6	5.3
Total Metals (mg/l):						
Iron	<0.02	<0.02	<0.02	<0.02	0.48	1.51
Manganese	<0.02	<0.02	<0.02	0.02	0.10	0.14

IN WITNESS WHEREOF, I HAVE HEREUNTO SET MY HAND THIS
23RD DAY OF AUGUST 1989
ARNOLD GREENE TESTING LABORATORIES
DIVISION OF CONAM INSPECTION

Donald B. Cowan, Manager

B-4

Arnold Greene Testing Laboratories

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CONAM INSPECTION A UNIT OF QUALCORP
California, Texas, Illinois, Pennsylvania, Ohio

To: WILLIAM W. WALKER
1127 LOWELL ROAD
CONCORD MA 01742

Date: 11/ 3/88

Job Number: 15994-1

Lab Number: A88103103

Order No.: WHITE POND

Date received: 10/31/88

Material: LAKE WATE

Book Number: 390-43GB

SPECIFICATIONS:

Sample ID: 4 samples of LAKE WATER

Page: 1

Analysis Comments: RESULTS IN MG/L. UNLESS OTHERWISE NOTED.

Lake Depth →	10' 1	30' 2	50' 3	↓ Shoreline Well #1 4
Alkalinity	7	9	22	--
pH	6.8	6.3	6.2	--
Nitrate Nitrogen	--	--	--	0.04
Nitrite Nitrogen	--	--	--	<0.02
Ortho Phosphate as P	--	--	--	0.38
Total Phosphate as P	0.12	0.19	0.12	1.80

IN WITNESS WHEREOF, I HAVE HEREUNTO SET MY HAND THIS
3RD DAY OF NOVEMBER 1988
ARNOLD GREENE TESTING LABORATORIES
DIVISION OF CONAM INSPECTION

Donald Cowan
Donald B. Cowan, Manager

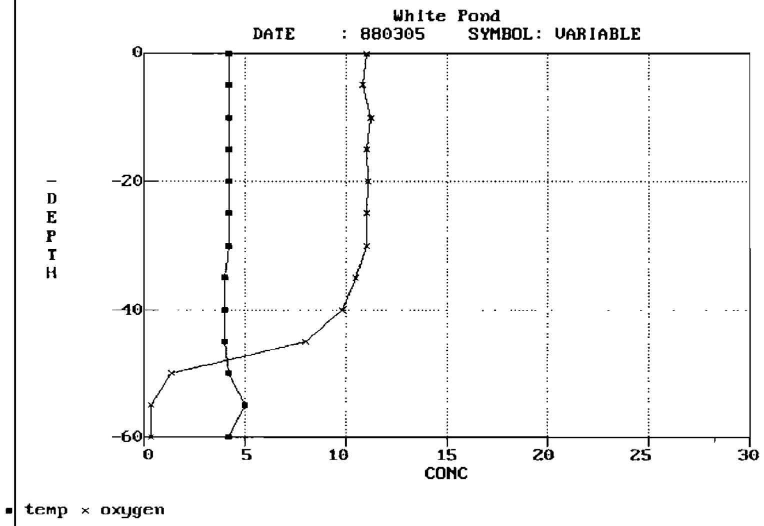
APPENDIX C

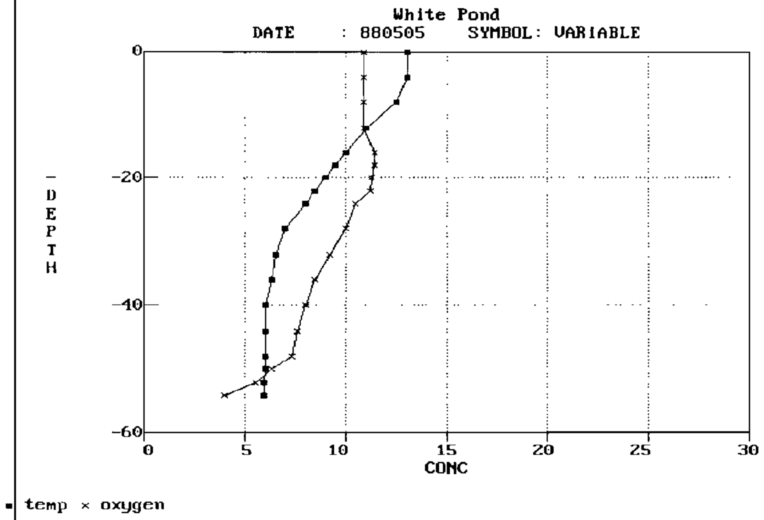
Dissolved Oxygen and Temperature Profiles

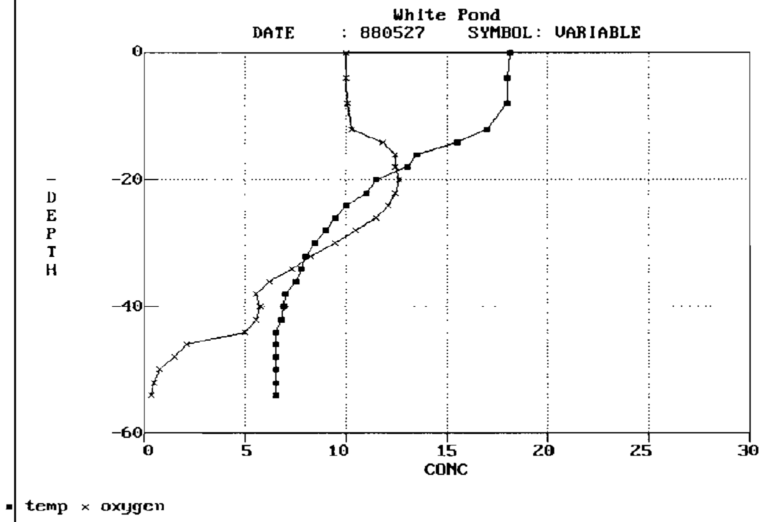
X-Axis = Temperature (deg-C) or Oxygen (ppm)

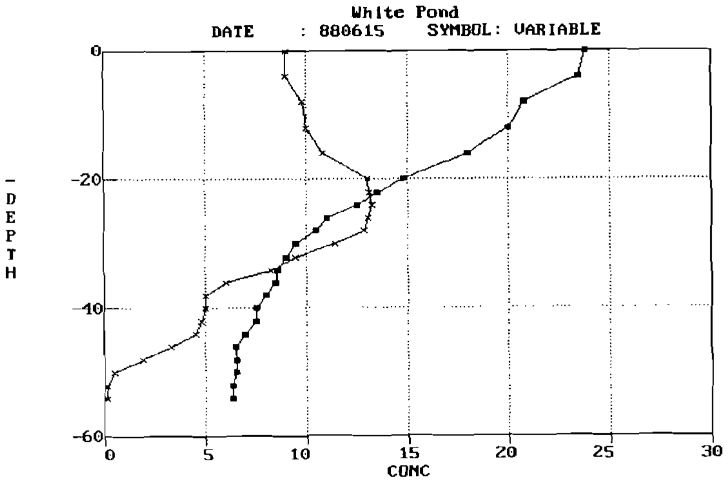
Y-Axis = Depth (feet)

Dates: 3/5/88, 5/5/88, 5/27/88
6/15/88, 7/8/88, 8/3/88
9/24/88, 10/31/88

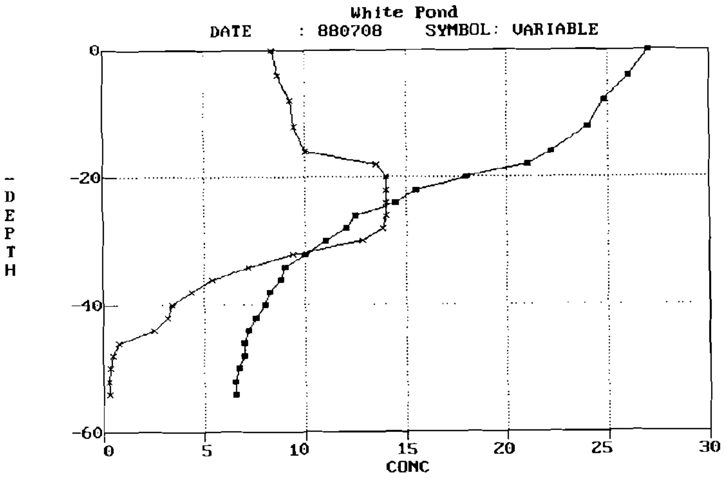

White Pond
DATE : 880305 SYMBOL: VARIABLE
- DEPTH
0
-20
-40
-60
0
5
10
15
20
25
30
CONC
■ temp × oxygen


White Pond
DATE : 880505 SYMBOL: VARIABLE
- DEPTH
0
-20
-40
-60
0
5
10
15
20
25
30
CONC
■ temp × oxygen

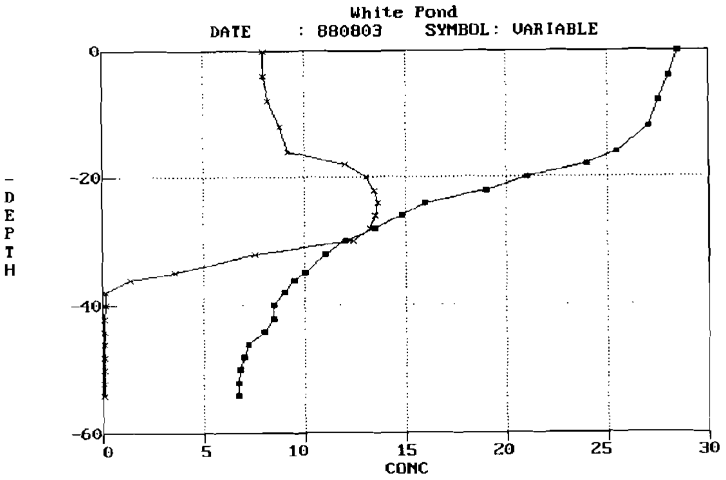

White Pond
DATE : 880527 SYMBOL: VARIABLE
- DEPTH
0
-20
-40
-60
0
5
10
15
20
25
30
CONC
■ temp × oxygen



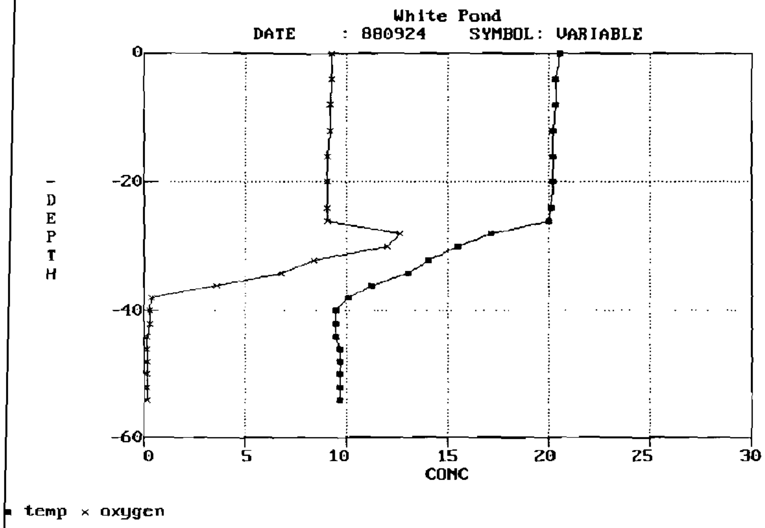
■ temp × oxygen

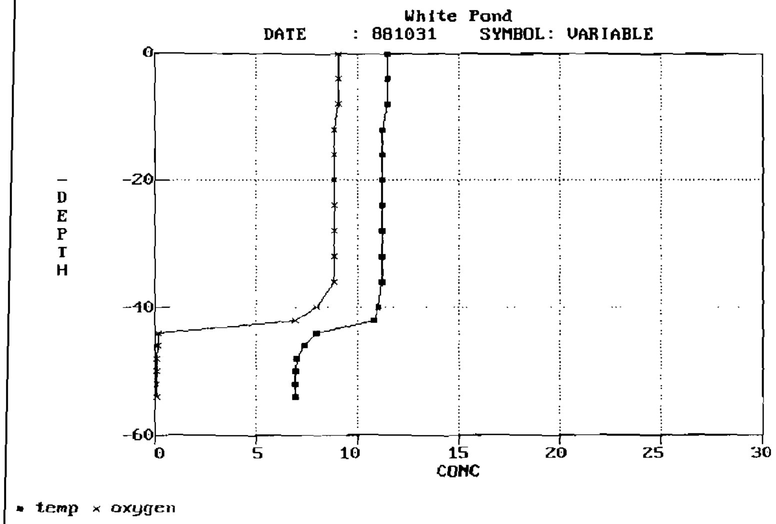


■ temp × oxygen



■ temp × oxygen


White Pond
DATE : 880924 SYMBOL: VARIABLE
- DEPTH
0
-20
-40
-60
0
5
10
15
20
25
30
CONC
■ temp × oxygen


White Pond
DATE : 881031 SYMBOL: VARIABLE
- DEPTH
0
-20
-40
-60
0
5
10
15
20
25
30
CONC
■ temp × oxygen

GLOSSARY

North American Lake Management Society
THE LAKE AND RESERVOIR RESTORATION GUIDANCE MANUAL
U.S. Environmental Protection Agency
Criteria and Standards Division
Nonpoint Sources Branch, Washington
EPA 440/5-88-002
February 1988

Adsorption: The adhesion of one substance to the surface of another; clays, for example, can adsorb phosphorus and organic molecules.

Aerobic: Describes life or processes which require the presence of molecular oxygen.

Algae: Small aquatic plants which occur as single cells, colonies, or filaments.

Allochthonous: Materials (e.g., organic matter and sediment) which enter a lake from atmosphere or drainage basin; see autochthonous.

Anaerobic: Describes processes that occur in the absence of molecular oxygen.

Anoxia: A condition of no oxygen in the water. Often occurs near the bottom of fertile stratified lakes in the summer and under ice in late winter.

Autochthonous: Materials produced within a lake; e.g. autochthonous organic matter from plankton versus allochthonous organic matter from terrestrial vegetation.

Bathymetric map: A map showing the bottom contours and depth of a lake. Can be used to calculate lake volume.

Benthos: Macroscopic (seen without aid of a microscope) organisms living in and on the bottom sediments of lakes and streams. Originally, the term meant the lake bottom, but it is now applied almost uniformly to the animals associated with the substrate.

Biomass: The weight of biological matter. Standing crop is the amount of biomass (e.g., fish or algae) in a body of water at a given time. Often measured in terms of grams per square meter of surface.

Biochemical oxygen demand (BOD): The rate of oxygen consumption by organisms during the decomposition (= respiration) of organic matter, expressed as grams oxygen per cubic meter of water per hour.

Biota: All plant and animal species occurring in a specified area.

Chemical oxygen demand (COD): Nonbiological uptake of molecular oxygen by organic and inorganic compounds in water.

Chlorophyll: A green pigment in algae and other green plants that is essential for the conversion of sunlight, carbon dioxide, and water to sugar. Sugar is then converted to starch, proteins, fats, and other organic molecules.

Chlorophyll-a: A type of chlorophyll present in all types of algae, sometimes in direct proportion to the biomass of algae.

Cluster development: Placement of housing and other buildings of a development in groups to provide larger areas of open space.

Consumers: Animals that cannot produce their own food through photosynthesis and must consume plants or animals for energy (see producers).

Decomposition: The transformation of organic molecules (e.g., sugar) to inorganic molecules (e.g., carbon dioxide and water) through biological and nonbiological processes.

Delphi: A technique that solicits potential solutions to a problem situation from a group of experts and then asks the experts to rank the full list of alternatives.

Density flows: A flow of water of one density (determined by temperature or salinity) over or under water of another density (e.g., flow of cold river water under warm reservoir surface water).

Detritus: Nonliving dissolved and particulate organic material from the metabolic activities and deaths of terrestrial and aquatic organisms.

Drainage lakes: Lakes having a defined surface inlet and outlet.

Drainage basin: Land area from which water flows into a stream or lake (see watershed).

Ecology: Scientific study of relationships between organisms, and their environment. Also, defined as the study of the structure and function of nature.

Ecosystem: A system of interrelated organisms and their physical-chemical environment. In this manual, the ecosystem is usually defined to include the lake and its watershed.

Environment: Collectively, the surrounding conditions, influences, and living and inert matter which affect a particular organism or biological community.

Effluent: Liquid wastes from sewage treatment, septic systems, or industrial sources that are released to a surface water.

Epilimnion: Uppermost, warmest, well-mixed layer of a lake during summertime thermal stratification. The epilimnion extends from the surface to the thermocline.

Erosion: Breakdown and movement of land surface, which is often intensified by human disturbances.

Eutrophic: From Greek for "well-nourished," describes a lake of high photosynthetic activity and low transparency.

Eutrophication: The process of physical, chemical, and biological changes associated with nutrient, organic matter, and silt enrichment and sedimentation of a lake or reservoir. If the process is accelerated by man-made influences, it is termed cultural eutrophication.

Fall overturn: The autumn mixing, top to bottom, of lake water caused by cooling and wind-derived energy.

Fecal coliform test: Most common test for the presence of fecal material from warm-blooded animals. Fecal coliforms are measured because of convenience. They are not necessarily harmful, but indicate the potential presence of other disease-causing organisms.

Flood plain: Land adjacent to lakes or rivers which is covered as water levels rise and overflow the normal water channels.

Flushing rate: The rate at which water enters and leaves a lake relative to lake volume, usually expressed as time needed to replace the lake volume with inflowing water.

Flux: The rate at which a measurable amount of a material flows past a designated point in a given amount of time.

Forage fish: Fish that are prey for game fish, including a variety of panfish and minnows.

Food web: pattern of production and consumption of organic matter in an ecosystem. Green plants are an ultimate source of energy for all food chains.

Ground water: Water found beneath the soil surface and saturating the stratum at which it is located; often connected to lakes.

Hard water: Water with relatively high levels of dissolved minerals such as calcium, iron, and magnesium.

Hydrologic cycle: The circular flow or cycling of water from the atmosphere to the earth (precipitation) and back to the atmosphere (evaporation and plant transpiration). Runoff, surface water, groundwater, and water infiltrated in soils are all part of the hydrologic cycle.

Hydrographic map: A map showing the location of areas or objects within a lake.

Hypolimnion: Lower, cooler layer of a lake during summertime thermal stratification.

Influent: A tributary stream.

Internal nutrient cycling: Transformation of nutrients such as nitrogen or phosphorus from biological to inorganic forms through decomposition, occurring within the lake itself.

Isothermal: The same temperature throughout; fall overturn.

Lake district: A special purpose unit of government with authority to manage a lake(s), and with financial powers to raise funds through mill levy, user charge, special assessment, bonding, and borrowing. May or may not have police power to inspect septic systems, regulate surface water use, or zone land.

Lentic: Relating to standing water (versus lotic, running water).

Limnology: Scientific study of fresh water, especially the history, geology, biology, physics, and chemistry of lakes. Also termed freshwater ecology.

Littoral zone: That portion of a water body extending from the shoreline lakeward to the greatest depth occupied by rooted plants.

Macroinvertebrates: Aquatic insects, worms, clams, snails, and other animals visible without aid of a microscope which may be associated with or live on substrates such as sediments and macrophytes. They supply a major portion of fish diets, and consume detritus and algae.

Macrophytes: Rooted and floating aquatic plants, commonly referred to as waterweeds. These plants may flower and bear seed. Some forms, such as duckweed and Coontail (*Ceratophyllum*) are free-floating forms without roots in the sediment.

Mandatory property owners association: Organization of property owners in a subdivision or development with membership and annual fee required by covenants on the property deed. Association will often enforce deed restrictions on members' property and may have common facilities such as bath house, clubhouse, golf course, etc.

Marginal zone: Area where land and water meet at the perimeter of a lake. Includes plant species, insects, and animals that thrive in this narrow, specialized ecological system.

Metalimnion: Layer of rapid temperature and density change in a thermally stratified lake. Resistance to mixing is high in the region.

Morphometry: Relating to a lake's physical structure (e.g. depth, shoreline length).

Nekton: Large aquatic and marine organisms whose mobility is not determined by water movement – for example fish and amphibians.

Nominal group process: A process of soliciting concerns/issues/ideas from members of a group and ranking the resulting list to ascertain group priorities. Designed to neutralize dominant personalities.

Nutrient: An element or chemical essential to life, including carbon, oxygen, nitrogen, phosphorus, and others.

Nutrient budget: Quantitative assessment of nutrients (e.g. nitrogen or phosphorus) moving into, being retained in and moving out of an ecosystem; commonly constructed for phosphorus due to its tendency to control lake trophic state.

Nutrient cycling: The flow of nutrients from one component of an ecosystem to another, as when macrophytes die and release nutrients that become available to algae (organic to inorganic phase and return).

Oligotrophic: "Poorly nourished," from the Greek. Describes a lake of low plant productivity and high transparency.

Ordinary high water mark: Physical demarcation line, indicating the highest point that water level reaches and maintains for some time. Line is visible on rocks, or shoreline, and by the location of certain types of vegetation.

Organic matter: Molecules manufactured by plants and animals and containing linked carbon atoms and elements such as hydrogen, oxygen, nitrogen, sulfur, and phosphorus.

Ooze: Lake bottom accumulation of inorganic sediments and the partially-decomposed remains of algae, weeds, fish, and aquatic insects. Sometimes called muck; see sediment.

Pelagic zone: This is the open area of a lake, from the edge of the littoral zone to the center of the lake.

Pathogen: A microorganism capable of producing disease. They are of great concern to human health relative to drinking water and swimming beaches.

pH: A measure of the concentration of hydrogen ions of a substance, which ranges from very acid (pH = 1) to very alkaline (pH = 14). pH 7 is neutral and most lake waters range between 6 and 9. pH values less than 6 are considered acidic and most life forms can not survive at pH of 4.0 or lower.

Photic zone: The lighted region of a lake where photosynthesis takes place. Extends down to a depth where plant growth and respiration are balanced by the amount of light available.

Phytoplankton: Microscopic algae and microbes that float freely in open water of lakes and oceans.

Plankton: Planktonic algae float freely in the open water. Filamentous algae form long threads and are often seen as mats on the surface in shallow areas of the lake.

Primary productivity: The rate at which algae and macrophytes fix or convert light, water, and carbon dioxide to sugar in plant cells. Commonly measured as milligrams of carbon per square meter per hour.

Producers: Green plants that manufacture their own food through photosynthesis.

Profundal zone: Mass of lake water and sediment occurring on the lake bottom below the depth of light penetration.

Residence time: Commonly called the hydraulic residence time—the amount of time required to completely replace the lake's current volume of water with an equal volume of "new" water.

Respiration: Process by which organic matter is oxidized by organisms, including plants, animals, and bacteria. The process releases energy, carbon dioxide, and water.

Secchi depth: A measure of transparency of water obtained by lowering a black and white, or all white, disk (Secchi disk, 20 cm in diameter) into water until it is no longer visible. Measured in units of meters or feet.

Seepage lakes: Lakes having either an inlet or outlet (but not both), and generally obtaining their water from groundwater and rain or snow.

Sediment: Bottom material in a lake that has been deposited after the formation of a lake basin. It originates from remains of aquatic organisms, chemical precipitation of dissolved minerals, and erosion of surrounding lands (see ooze).

Soil retention capacity: The ability of a given soil type to adsorb substances such as phosphorus, thus retarding their movement to the water.

Stratification: Layering of water caused by differences in water density. Thermal stratification is typical of most deep lakes during summer. Chemical stratification can also occur.

Swimmers itch: A rash caused by the skin penetration of the immature stage (cercaria) of a flatworm (not easily controlled due to complex life cycle). A shower or alcohol rubdown should minimize penetration.

Thermal stratification: Lake stratification caused by temperature-created differences in water density.

Thermocline: A horizontal plane across a lake at the depth of the most rapid vertical change in temperature and density in a stratified lake. See metalimnion.

Topographic map: A map showing the elevation of the landscape at contours of 2, 5, 10, or 20 feet. Can be used to delineate the watershed.

Trophic state: The degree of eutrophication of a lake. Transparency, chlorophyll-a levels, phosphorus concentrations, amount of macrophytes, and quantity of dissolved oxygen in the hypolimnion can be used to assess state.

Voluntary lake property owners association: Organization of property owners in an area around a lake that members join at their option.

Water table: The upper surface of ground water; below this point, the soil is saturated with water.

Water column: Water in the lake between the interface with the atmosphere at the surface and the interface with the sediment layer at the bottom. Idea derives from vertical series of measurements (oxygen, temperature, phosphorus) used to characterize lakewater.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

Zooplankton: Microscopic animals which float freely in lake water, graze on detritus particles, bacteria, and algae, and may be consumed by fish.

CONCENTRATION UNITS

ppb = parts per billion = ug/l = micrograms per liter

ppm = parts per million = mg/l = milligrams per liter