New York State Clean Lakes Assessment

According to the best available estimates, New York State has 7,650 ponded bodies of water (lakes, ponds, reservoirs, etc.) covering a surface area of over 790,000 acres (not including Lakes Ontario and Erie, which collectively cover more than 3,000,000 acres within New York's borders alone). For this assessment, New York State considers lakes, ponds and reservoirs included in the current state indexing system as "significant" waters. The reporting system in New York State does not distinguish between what might be defined as private versus public lakes, since all of the waters of the state are considered public (public versus private status is usually conferred upon issues of access, not ownership of the waters themselves). As such, this report will consider all sampled waters to be significant publicly owned and subject to assessment in this document. The assessment has been conducted on a total of 1,931 different significant water bodies representing 516,200 acres of surface area (not including Lake Ontario); about 75 percent of these waters are located in the Adirondack Region of the state. This statewide total represents a larger number than reported in 1996, since more than 45 previously unsampled lakes are included in this report.

The characterization of trophic status has been conducted using total phosphorus, chlorophyll a, and Secchi transparency, along with true color to distinguish waters which are stained or "colored" from organic material and have low transparency. True, or soluble, color of the water is a surrogate of organic material in the water and should be included in the evaluation since phosphorus associated with the organic material is unavailable for uptake by organisms but is contained in the total phosphorus results reported from water quality analysis.

About 54 percent (1047) of the total (1,931) waters in which trophic indicators and color were measured had true color values less than or equal to 30 mg/l platinum color units, comprising a surface area of 428,560 acres. These waters were classified into trophic state using total phosphorus and Secchi transparency. There were 227 waters classified as eutrophic based on total phosphorus, 163 waters classified as eutrophic based on Secchi transparency, and 143 waters classified as eutrophic based on chlorophyll *a*. Chlorophyll *a* was not very useful in this analysis since relatively few waters (only about 30 percent of the 1,931 assessed) had chlorophyll *a* data available.

Only 165 of the 884 waters with true color values greater than 30 mg/l Pt could be classified into trophic state, using available chlorophyll *a* data (color readings have not been obtained for the balance of the assessed waters (80)). Based on this criterion, 9 waters were oligotrophic, 81 waters were mesotrophic and 75 waters were eutrophic.

Acidity status was assessed using midsummer pH of the surface water. Waters are considered impaired if pH is < 5.0, threatened if pH is ≥ 5.0 and ≤ 6.0, and acceptable if pH is > 6.0. A total of 1,978 waters in New York State, including 1,376 waters through the Adirondack Lake Survey Corporation study, were assessed for acidity. There were 363 ponded waters impaired, 316 waters threatened, and 1299 waters had acceptable conditions. The waters impaired by acidity represent less than two percent of the total surface area included in the current assessment.

Significant Waters and the Lakes Inventory

New York State uses an indexing system to identify ponded waters within the state. The pond number, or *P-#*, is the number that has been assigned to a specific ponded water by the NYSDEC in Part 800 of its

Codes, Rules and Regulations.[1] These Rules and regulations pertain to Article 15 of the New York State Environmental Conservation Law.[2] With reference to the *Guidelines for the Preparation of the 1990 State Water Quality Assessment (305(b) Report*,[3] New York State defines "significant" waters as those lakes, ponds and reservoirs that are included in the indexing system at the present time.

Although New York State has over 7,600 ponded waters within its boundaries, not all of these waters are indexed and included in the state inventory at the present time, and the exact number of ponded waters is not known. Surface area is one fundamental limitation that precludes certain waters within the state from being included in the inventory since waters below a certain size will not appear on USGS topographic maps. The Division of Water has regularly updated the *Codes, Rules and Regulations* to reclassify some waters and add many of the ponded waters that are not indexed.

A partial inventory of state waters is included in *Characteristics of New York State Lakes; Gazetteer of Lakes, Ponds and Reservoirs*, 3rd Edition (1987), which lists nearly 3,500 ponded waters that have surface areas greater than 6.4 acres, appear on USGS 7.5 minute topographic maps, are named and indexed. The 6.4 acre, or 0.01 square mile, surface area was the minimum size included in the previous gazetteer by Greeson and Robinson[4] and has remained the minimum ponded water acreage in all recent updates. A summary of different categories of ponded waters within the state with reference to the current inventory process is presented below.

Table 1

Categories of Ponded Waters in New York State

Number of Lakes/Ponds	Lake/Pond Characteristics		
	Size/Surface Area	Included in Inventory	Named Lake/Pond
135	Greater than 500 acres	yes	yes
2,911	6.4 to 500 acres	yes	yes and no
832	less than 6.4 acres	yes	yes and no
3770 (est)	less than 6.4 acres	no	yes and no

The total number of lake waterbodies in the state is currently estimated to be 7,849 representing are total cumulative surface area estimated to be over 790,000 acres (not including Lakes Ontario and Erie).

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[1] State of New York. 1984. Official Compilation of Codes, Rules and Regulations. Title 6, Volumes A-F, New York State Department of State.

[2] State Of New York. 1984. Environmental Conservation Law of New York. Volumes 1-11, New York State Department of State.

[3] United States Environmental Protection Agency. 1997. Guidelines for the Preparation of the State Water Quality Assessment (305(b) Report) and Electronic Updates. Assessment and Watershed Protection Division (4503F), Washington, D.C.

[4] Greeson, P. E. and F. L. Robinson. 1970. Characteristics of New York State Lakes. Part I. Gazetteer of Lakes, Ponds and Reservoirs. Bulletin 68, U. S. Geological Survey and N. Y. S. Department of Environmental Conservation. 124 p.

Lake Assessment Methods

The data that were used to prepare this lake assessment were compiled from several local, State and Federal sources. Samples included in the current assessment were collected between 1982 and 2007. The 1982 cutoff corresponds with a previous lake water quality assessment report submitted to USEPA by New York State (Mikol, 1983), as well as a distinct 25 year interval. The sources of data in the present report are the Adirondack Lake Survey (NYS Department of Environmental Conservation and Empire State Electric Energy Research Corporation, 1984 through 1987), the Eastern Lake Survey (USEPA, 1984) which was Phase IA of the National Surface Water Survey, the Lake Classification and Inventory Project (NYSDEC, 1982 through 1991, and beginning again in 1996 until the present day), the Citizens' Statewide Lake Assessment Program (NYSDEC, 1986 through the present), the Water Quality Surveillance Network (NYSDEC, 1982 to 1986), the Rensselaer County Water Quality Program (1990), the Adirondack Effects Assessment Program (AEAP; Rensselaer Polytechnic Institute, NYSDEC, and other institutions, 1994-present) and various Clean Lakes Projects and special studies. Water quality data for approximately 150 lakes throughout the state were also collected by the USEPA and USFWS through the Environmental Monitoring and Assessment Program (EMAP)-Surface Water and TIME (Temporally Integrated Monitoring of Ecosystems) programs (1991 through 1996), but these data have only been released for individual lakes through 1993; all later data cannot be included in this assessment. Systematic monitoring of the eleven Finger Lakes was commenced in 1996 by the NYSDEC Lake Services Section and Upstate Freshwater Institute, and continues through the present. All of the data were collected and analyzed using USEPA approved quality assurance - quality control protocols. Except for several of the Clean Lakes Projects and the Rensselaer County data, all laboratory analyses were conducted by either NYSDEC or New York State Department of Health laboratories prior to 1998. Beginning in 1998, analyses were performed by either one or more contract laboratories (for sampling conducted for the LCI, Finger Lakes, and AEAP programs, and CSLAP after 2000) or the NYS Department of Health (CSLAP prior to 2002).

All data were obtained from the original sources in computer compatible form and were entered into a database using Microsoft Excel, running on an Dell Pentium computer. Although the full database contains information on a wide variety of water quality measurements, the present draft of this report has been restricted to a summary of parameters related to trophic classification and acidity status, unless otherwise noted.

The data were coded with a single character to identify the source. The codes were *L* (NYSDEC Lake Classification and Inventory), *C* (Citizens' Statewide Lake Assessment Program), *B* (NYSDEC Biota Survey), *W* (NYSDEC Water Quality Surveillance Network), *A* (Adirondack Lake Survey Corporation), *E* (USEPA Eastern Lake Survey), *R* (Rensselaer County), *T (*TIME and USEPA/USFWS EMAP Program), *P* (RPI/NYSDEC/etc. Adirondack Effects Assessment program), *F (*Finger Lakes study), and *S* (Special studies). An *M* (multiple source) indicates that more than one program collected information on the ponded water.

Certain identifying information has been presented for most of the lakes and ponds in the data summary including the name of the water body, the index number (*Pond No,*) which consists of the watershed number and the pond number, the surface area (*Surf. Area*) in hectares (ha), the current water quality classification (*W.Q.Class.*), and the county code (*County*) for the location of the water body.

The water quality data summary was produced using **EXCEL** to calculate average or median values for the various parameters included in the assessment. The data summary represents samples that were collected during midsummer from the upper portion of the water column (sample depth $\leq$ 3m). Data summaries were prepared for the following parameters: Secchi depth (*Secchi*, in meters), trophic state

based upon Secchi (*Secchi T.S.*), chlorophyll *a* (*Chl a*, in µg/l), trophic state based upon Chlorophyll *a* (*Chl a T.S.*), total phosphorus (*TotP*, in mg/l), trophic state based upon total phosphorus (*TotP T.S.*), pH (*pH*, in standard units), pH status (*pH Status*), acid neutering capacity (*ANC*, in µeq/l), true color (*True Color*, in mg Pt units/l), and the source of the data (*Code*). For lakes from which samples were collected over several years or programs, reported averages correspond to the summer mean values from all programs averaged over the number of years sampled. Although median values may be used for some calculations, unless otherwise noted, all calculations for central tendency are based on sample mean.

The USEPA Eastern Lakes Survey (ELS) data collected on 240 ponded waters were not incorporated into the calculation of average values for the data summary since the ELS field sampling was conducted during the fall, not midsummer, of 1984. As a result, significant differences occurred in the values of certain parameters collected from the same ponded water by one source during midsummer and by the ELS during the fall.

Lake Trophic Status

The current assessment has employed the traditional classification of trophic status, i.e., oligotrophy, mesotrophy and eutrophy, as a framework for water quality assessment by using the values and ranges for transparency, total phosphorus and chlorophyll *a* outlined in Table 2.

Table 2

Assessment Criteria for Lake Trophic Status

Parameter	Oligotrophic	Mesotrophic	Eutrophic
Transparency (m)	> 5	2 - 5	< 2
Total Phosphorus (µg/l)	< 10	10 - 20	> 20
Chlorophyll *a* (µg/l)	< 2	2 - 8	> 8

The values and ranges of values generally agree with trophic status criteria that are reported in the literature, although the ranges for chlorophyll *a* are somewhat lower than have been used in historical versions of this report. The present report will highlight any apparent discrepancies or “trends” that are actually the result of the shift in reporting ranges. New York State has not adopted a statistical definition related to the categories hypereutrophic or dystrophic; therefore, these categories are not included here.

Classification of trophic status using traditional criteria has very limited application in certain regions of New York State, however. In the Adirondacks and Catskills, for example, transparency is not a good indicator for all water bodies since many waters are stained or "colored" and have low transparency from humic and fulvic acids. The presence of these compounds in the water indicates the incomplete microbial decomposition of the organic compounds of green plants and does not necessarily relate to productivity. True, or soluble, color of the water is a surrogate of this organic material and should be included in the evaluation of trophic status since phosphorus associated with organic material in the water is unavailable for uptake by organisms but is a portion of the total phosphorus analyzed in water samples.

Information presented in Table 3 from an analysis of trophic status in the Adirondacks[5] illustrates the significance of adding true color to the classification of trophic status. The results are total phosphorus and true color analyses for 1469 Adirondack waters that were sampled by the ALSC between 1984 and 1987.

Just over 50 percent (730) of the Adirondack waters surveyed had high color imparted by organic material, and most of these waters had moderate to high levels of unavailable phosphorus associated with the organic material and part of the total phosphorus fraction. The balance (638) of the waters surveyed are clear, and can be separated into trophic categories, based on phosphorus concentration, as shown in Table 4.

Table 3

True Color as Indicator of Trophic Status in Adirondacks/Catskills

True Color	Total Phosphorus			Total Lakes/Ponds
	<10	**10 - 20**	**> 20**	
≤ 30	314	225	99	638
> 30	76	296	358	730
Total Lakes/Ponds	390 (29%)	521 (38%)	457 (33%)	1,368

As shown in the tables, evaluating the trophic status of Adirondack waters without consideration of true color would lead to 33 percent (457) of the waters being categorized as eutrophic instead of 15 percent (99) of the waters.

Table 4

Lake Trophic Status for "Clear" Waters (True Color > 30)

	Oligotrophic	**Mesotrophic**	**Eutrophic**
Total Phosphorus (µg/l)	< 10	10 - 20	> 20
Total Lakes/Ponds	314 (49%)	225 (35%)	99 (15%)

Since about 75 percent of the water bodies included on the current water quality assessment list for New York State are within the Adirondack Region, true color has been incorporated into the current analysis of trophic status as an indicator of organic material (and associated phosphorus). Adding this information allows clearwater lakes and ponds (true color ≤ 30 mg Pt/l, or simply 30 Ptu) to be distinguished from

[5] Sutherland, J. W., S. A. Kishbaugh, J. A. Bloomfield, W. T. Lavery, and F. E. VanAlstyne. 1990. Water Resources and Water Quality in the Adirondack Park. Issue Paper #5e in Volume II, Technical Reports, Commission on the Adirondacks in the Twenty-first Century. Division of Water, NYSDEC, Albany, N.Y. 141 p.

waters with a visible stained appearance (true color > 30 mg Pt/l). In ponded waters with visible color (true color > 30 mg Pt/l), the Secchi depth was not included in the evaluation of trophic condition. If a value for true color was not available then the soluble organic carbon (SOC) value was used instead. If the SOC was greater than 7.0 mg/l, the Secchi was not used to assess trophic status. Both true color and SOC typically are used to characterize the level of yellow organic (humic and fulvic) acids.

There is one other limitation in the current assessment that must be mentioned. Chlorophyll *a*, although a good indicator of trophic state, was not very useful in the current analysis since relatively few waters (only 30 percent of the 1,931 assessed for trophic indicators) had any chlorophyll *a* data. Most of the water quality data for this assessment were collected by the ALSC during the Adirondack survey, 1984 through 1987, and chlorophyll *a* was not one of the parameters sampled in this program.

The results of the current assessment of trophic status of significant waterbodies are presented in Table 5 and show number of waters and surface area in acres (in brackets) for each category (these area data do not include Lake Ontario).

If it is assumed that an equivalent percentage (in the assessed database) of unassessed lake numbers and lake areas possess color readings less than 30 Ptu, then trophic conditions in weakly colored waters are not known for approximately 3200 lakes comprising an area of 230,000 acres.

A total of 884 waters in the current assessment had true color values greater than 30 mg/l Pt, and total phosphorus and Secchi transparency were not used to evaluate the trophic status. Unfortunately, only 165 of these waters had chlorophyll *a* data and could be classified. The results are presented in Table 6.

Table 5

Lake/Pond Condition for Waters with True Color ≤ 30

(1047 Lakes/Ponds covering 428,562 acres)

Assessment Based on:	Oligotrophic	Mesotrophic	Eutrophic	No Data
Total Phosphorus	428 lakes (122,002 Ac)	380 (240,728)	227 (64,904)	12 (928)
Secchi	166 (107,586)	636 (282,493)	163 (37,240)	82 (1,244)
Chlorophyll	64 (65,474)	201 (261,368)	143 (72,184)	639 (29,536)

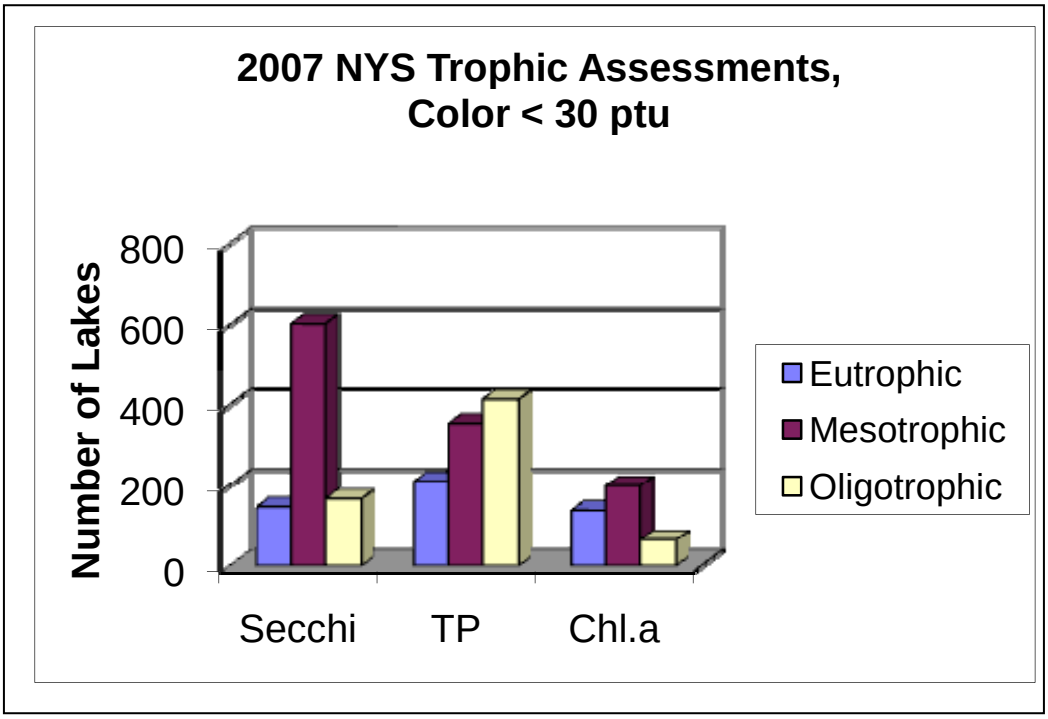
The discrepancy between the totals for some of the assessment indicators in Table 5 is due to the lack of data for some indicators (for example, some lakes were sampled for phosphorus only, or for phosphorus and water clarity only). A total of 228 waters were excluded from the above analyses because true color data were not available. If it is assumed that an equivalent percentage (in the assessed database) of unassessed lake numbers and lake areas possess color readings greater than 30 Ptu, then trophic conditions in highly colored waters are not known for approximately 2700 lakes comprising an area of 25,000 acres. The evaluation of trophic status itemized above is presented graphically in Figure 16.

Table 6

Lake/Pond Condition for Waters with True Color > 30

(884 Lakes/Ponds covering 38,376 acres)

Assessment Based on:	Oligotrophic	Mesotrophic	Eutrophic	No Data
Chlorophyll	9 (3,953)	81 (9,154)	75 (6,632)	719 (18,637)



In summary, a total of 1,930 waters are included in the current water quality assessment, and about 75 percent of these waters are located in the Adirondack Region of the state. About 54 percent (1047) of the total waters assessed had true color values less than 30 mg/l Pt and these waters were classified into trophic state using total phosphorus, Secchi transparency, and chlorophyll *a*. There were 227 waters classified as eutrophic based on total phosphorus, 163 waters classified as eutrophic based on Secchi transparency, and 143 waters classified as eutrophic based on chlorophyll *a*. Only 165 of the 884 waters with true color values greater than 30 mg/l Pt could be classified into trophic state at the present time, using chlorophyll *a* data.

The itemization of trophic status for the ELS waters surveyed in New York State is presented in Table 7. As mentioned previously, these data were kept separate from the remainder of the database since the ELS was conducted during the fall instead of during midsummer. Chlorophyll *a* was not determined by the ELS, and so the assessment of trophic status is based upon total phosphorus, Secchi depth and true color. There were 158 of the 240 ELS waters with true color $\leq$ 30 mg/l Pt and the assessment of trophic state is presented below. Seventy-eight ELS waters had true color values > 30 mg/l Pt and were not assessed for trophic state. True color was missing in 4 ELS waters (surface area = 410.0 acres), and these waters were not included in the current analysis.

Table 7

Lake/Pond Condition for ELS Waters with True Color ≤ 30 Ptu

(158 Lakes/Ponds covering 69,262 acres)

Assessment Based on:	Oligotrophic	Mesotrophic	Eutrophic	No Data
Total Phosphorus	99 lakes (58,522 Ac)	20 (4,392)	13 (981)	26 (5,367)
Secchi	41 (53,950)	91 (11,105)	26 (4,206)	0 (0)

It has been determined that at least half of the 240 waters sampled by the ELS also were sampled by some other program in the current dataset.

Water Quality Standards Applicable to Ponded Waters

New York State classifies all surface waters by *best use*, a designation that takes into account such factors as stream flow, existing water quality, and the past, present and desired uses of the waters and bordering lands. Best use is defined as the use that requires the "cleanest" water and includes drinking waters, swimming, fish (or shellfish) propagation and survival. For example, all surface fresh and salt waters must be safe, at least, for aquatic organisms, all fresh groundwater must be protected for drinking water supply. Although waters are classified to achieve best use, including all uses that require less demanding water quality standards, the best use may not be achievable under current conditions. A summary of New York State Water Quality Classifications is presented in Appendix B of this report. NYSDEC continues to reclassify waters within the state as better information becomes available to aid in this process.

The water quality standards most applicable to New York State lakes are the standards corresponding to pH, and dissolved oxygen, although guidance values and safety requirements on swimming beaches are also applicable to total phosphorus concentrations and water clarity, respectively. While other numeric or narrative water quality standards may be of concern for individual waters within the state, either the existing database does not support broad assessment of the resources of the state for applicable standards (such as bacteria) or the standards are not violated for the vast majority of waterbodies in the state. The state pH standard for all waters Class C or higher is between 6.5 and 8.5. For Class D waters, the pH standard is between 6.5 and 9.5

The state dissolved oxygen standard is as follows: for all but Class D and A-special lakes (none in either category assessed in this report):

> "For cold waters suitable for trout spawning, the DO concentration shall not be less than 7.0 mg/L from other than natural conditions. For trout waters, the minimum daily average shall not be less than 6.0 mg/L, and at no time shall the concentration be less than 5.0 mg/L. For non-trout waters, the minimum daily average shall not be less than 5.0 mg/L, and at no time shall the DO concentration be less than 4.0 mg/L".

Evaluation of lake DO data can be confounded by the time of sampling (samples generally collected prior

to June or after September may correspond to destratified lake conditions, in which temperature and oxygen concentrations are usually uniform throughout the water column), depth of the lake (shallow lakes and ponds may not thermally stratify, limiting shifts in DO to the microlayer just above the sediment-water interface, a zone difficult to accurately monitor), and samples collected outside the deepest hole in the lake. It may be most appropriate to evaluate oxygen conditions only in waterbodies sufficiently deep (say > 5 meters) to thermally stratify, during the period in which thermal stratification is stable (generally June through September).

The phosphorus guidance value for Class B and higher waters corresponds to 0.020 mg/L. No such value has been designated for any lakes classified as Class C or lower.

The minimum recommended (by the NYS Department of Health Sanitary Code) water clarity for designated swimming beaches is 4 feet (= 1.2 meters). While this recommendation could apply to all Class B and higher waters (and even to many of the Class C waters that are used for contact recreation), the lack of an inventory of waterbodies with "designated" swimming beaches precludes a strict application of this recommendation. However, the water clarity database will be presented for the purposes of broadly assessing water quality conditions as related to potential for swimming impairments.

Table 8 summarizes the extent to which these standards and/or guidance values have been violated. pH, water clarity, and phosphorus criteria are evaluated against mean values for each analyte, while the dissolved oxygen criteria is evaluated against minimum values within the hypolimnion. While most of the sampling programs include pH, water clarity, and phosphorus among the measured parameters, dissolved oxygen data are either not universally collected (for example, in CSLAP or in some isothermal lakes) or have not been electronically stored (in the ALSC and many other monitoring programs from prior to 1990). It should also be noted that, in many monitoring programs such as the ALSC project, oxygen "profiles" are often limited to discrete samples at a small number of points (usually two) within the water column.

The data in Table 8 suggest that violation of water quality standards and/or guidance values or criteria is common among assessed lakes. The violations of the pH standard and phosphorus guidance value have been discussed above. A relatively small number of lakes have experienced systematic violations of the recommended water clarity readings at swimming beaches. It is likely that a larger percentage of sampled lakes have experienced occasionally low water clarity readings; as such, these figures may not accurately reflect the percentage of lakes in which poor water clarity results in at least some aesthetic and bathing impairments. However, these figures also include some moderately colored waters and a small number of very shallow lakes for which water clarity is measurable (i.e. the Secchi disk is not visible while sitting on the lake bottom) but is nonetheless adversely affected by lake depth. In other words, these figures also include some waterbodies for which water clarity may not be an accurate "water quality" indicator. Table 8 also suggests that, at least among the relatively small number of assessed waterbodies, dissolved oxygen standards are commonly violated, and anoxic conditions (functionally defined as DO readings < 1 mg/l to account for inaccuracies in very low level dissolved oxygen measurements and the lack of DO data within the last meter or two of water depth immediately above the sediment-water interface) are routinely experienced. This table shows that **more than 70% of assessed waters that are thermally stratified experience hypoxia in the hypolimnion.** There has been much discussion about the occurrence of "natural" DO depletion in lakes due to morphometry and focusing. Without sediment coring data for the vast majority of these lakes, it is impossible to separate out natural and culturally-induced DO depletion in these lakes. It must also be conceded that Table 8 reflects a database (mostly publicly accessible, moderately sized, moderately high profile LCI lakes, often with some pre-sampling evidence of water quality problems that led to its inclusion in the monitoring program) that may not be fully representative

of the “typical” NYS lake. However, the high percentage of assessed lakes experiencing hypoxic conditions suggests that this phenomenon needs to be far more closely monitored and evaluated. The NYSDEC will devote significant effort in the upcoming 305b cycle to fully assessing the existing (electronic and hard copy) dissolved oxygen database, recognizing the limitations inherent in comprehensively evaluating the paucity of full profile data, as well as a renewed effort to collect additional full water column profiles in all subsequently sampled lakes

Table 8

Statewide Assessment of Lake Water Quality

Water Quality Indicator		Water Quality Criterion	Percent of All Lakes that: (Percent of Assessed Lakes that:)			
			Violate Standard	Meet Standard	Sampled, but Not Assessed**	Sampled, but Not for this Indicator
pH	Lower	6.5 SU	44%	56%	< 1%	< 1%
	Upper	8.5 SU	1%	98%	< 1%	< 1%
Dissolved Oxygen	Trout Waters	5.0-6.0 mg/l	7% (71%)	5% (29%)	83%	6%
	Non-Trout Water	4.0 mg/l	7% (75%)	2% (25%)	82%	10%
	Hypoxia*	4.0 mg/l	7% (71%)	3% (29%)	83%	8%
	Anoxia*	1.0 mg/l	- - - (59%)	- - - (41%)		
Total Phosphorus (Class B and higher)		20 µg/l	30%	68%	< 1%	2%
Water Clarity (Class B and higher)		1.2 m	7%	83%	10%	< 1%

* Analysis limited to thermally stratified lakes sampled from June through September.

** Dissolved Oxygen data for these lakes have either not been converted to electronic formats or were not collected as part of depth profiles, thus limiting their utility. It is anticipated that subsequent editions of the 305(b) Report will include these data.

New York State Lake Programs

Lake water quality monitoring by New York State is currently being conducted by the NYSDEC and includes the following ongoing components: the Citizens' Statewide Lake Assessment Program (CSLAP), the Lake Classification and Inventory (LCI) Survey, the Lake Champlain Monitoring Program and special studies

involving acid rain, lake use impairment, USEPA Clean Lakes projects, special projects as related to local, short-term problem assessment, and other miscellaneous activities. The NYSDEC Inland Lakes and Freshwater Section also works jointly with other institutions in other contemporary or recently completed lake monitoring projects, including the Adirondack Effects Assessment Program (AEAP, with RPI and others), Finger Lakes Monitoring (with UFI), the Environmental Monitoring and Assessment Program (EMAP, with USEPA, USFWS, and others), and stormwater monitoring of tributaries to several NYS lakes, including Lake George and several NYC reservoirs.

The *Citizens' Statewide Lake Assessment Program* was started in 1986 and is a scientific and educational program in which citizen volunteers are trained to collect water quality information. The program is a cooperative effort between the NYSDEC and the Federation of Lake Associations, Inc., a coalition of organizations dedicated to the preservation and restoration of all lakes, ponds and rivers throughout New York State. During 2007, there were about 225 lakes and ponds associated with the program, although only about 90-100 are actively sampled in any particular year. Biweekly sampling begins in mid-June and continues for 15 weeks through early October. Water quality data collected as part of the program include Secchi disk transparency and the following chemical parameters: total phosphorus, nitrate-nitrogen, true color, pH, specific conductance, and chlorophyll *a*. At some lakes, dissolved oxygen, lake level, amount and pH of precipitation, and aquatic plant populations also are assessed. Volunteer monitors also complete user and (since 1992) field perception surveys, the latter of which are cross-referenced against instantaneous water quality data collected to provide a linkage between public opinion and measured eutrophication parameters. These linkages are being utilized to develop phosphorus guidance values serving as the endpoint in the revision of aforementioned phosphorus effluent TOGS.

The *Lake Classification and Inventory Program* [6]was initiated in 1982. Each year, approximately 10-25 water bodies are sampled in a specific geographic region of the State. The waters selected for sampling are considered to be the most significant in that particular region, both in terms of water quality and level of public access. Samples are collected for pH, ANC, specific conductance, temperature, oxygen, chlorophyll *a*, nutrients and plankton at the surface and with depth at the deepest point of the lake, four-seven times per year (with stratified lakes sampled more frequently than shallow lakes). Sampling generally begins during May and ends in October. This project had been suspended after 1992, due to resource (mostly staff time) limitations, but was resumed on a smaller lakeset beginning again in 1996. Since 1998, this program has been geographically linked with the Rotating Intensive Basin Sampling (RIBS) stream monitoring program conducted by the NYSDEC Bureau of Watershed Assessment. LCI sites are chosen within the RIBS monitoring basins (Susquehanna River basin in 2003, Long Island Sound/Atlantic Ocean and Lake Champlain basins in 2004, Genesee and Delaware River basins in 2005, the Mohawk and Niagara Rivers basins in 2006, Upper Hudson River and Seneca/Oneida/Oswego Rivers basins in 2007, and the Lake Champlain, Lower Hudson River, and Atlantic Ocean/Long Island Sound basin in 2008) from among the waterbodies listed on the NYS Priority Waterbodies List for which water quality data are incomplete or absent, or from the largest lakes in the respective basin in which no water quality data exists within the NYSDEC database. Sampling via this program is also conducted in two year intervals, with limited (1-2x) sampling in the first year for lakes without water quality data, and monthly for NYS PWL lakes for which data are incomplete. These are referred to as “mass attack” and “rotating basin” sampling, respectively, after the RIBS stream sampling model (to complete the model, the NYS ambient lakes monitoring program considers the CSLAP and Finger Lakes dataset to be the “fixed site” or “index lake” network sites).

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[6]New York State Department of Environmental Conservation. 1982. New York State Lake Classification and Inventory Annual Report - 1982. Bureau of Water Research, Albany, N.Y.

New York State Lake Restoration Efforts

NYSDEC does not have an organizational unit that is responsible for statewide lake management. However, within the Division of Water, the Inland Lakes and Freshwaters Section (ILFS) comes the closest to fulfilling that responsibility. The ILFS (previously referred to as the Lake Services Section, or LSS) consists of five scientists, three engineers, one technician, and associated support staff (from the NYSDEC regions) who work on various aspects of lake management. The ILFS is responsible for administering the Federal Clean Lakes Program and equivalent State-funded projects. In recent State Fiscal Years, the latter consisted of projects exceeding $1 million, affecting more than 50 lakes. The State-funded projects are not part of a competitive grants program, but rather the State legislature determines annual eligibility for funding. The ILFS staff is then responsible for working with the locality to prepare a Program Narrative, developed with the guidelines contained in the Federal Clean Lakes Rules and Regulations. A second difference between the Federal and State programs is that monitoring, diagnosis, feasibility and implementation can all be conducted simultaneously by the locality. The State program has no requirement for phased design and implementation.

The ILFS staff also assists local governments in the conduct of specific State and Federal Clean Lakes Projects. They also are responsible for carrying out all the lake monitoring for NYSDEC (except for fish sampling). The LSS staff also acts as a liaison to the public for lake-related matters and are involved in the preparation of Lake Management Plans for specific lakes. This responsibility has necessarily been reduced by the limited scope of the Federal Clean Lakes Program in recent years.

In most lake restoration projects, a cooperative agreement between the public and governmental agencies must be reached to ensure success. Working relationships between federal (USDA-SCS, USEPA), state (NYSDEC, NYSDOH), county planning or environmental management councils, health, lake protection and preservation districts, and local offices all contribute to the management of the lake and surrounding watershed.

Restoration Techniques

The techniques used for lake restoration can be categorized as in-lake treatments and watershed management programs. Watershed management involves the implementation of methods to reduce nutrients and/or sediments from entering the lake. This requires the identification of the problem(s), assessment of the magnitude of the problem(s), and the development of management practices/controls to mitigate the controllable problem(s). Most restoration projects consist of a combination of in-lake and watershed management techniques in order to achieve long-term benefits.

In-lake restoration techniques are typically applied after nutrient reduction or diversion plans have been accomplished. The purpose of employing in-lake restoration techniques is to remove the sediments and/or nutrients to reduce algal blooms, reduce the nuisance growth of aquatic plants and eliminate oxygen depletions in the deeper waters. The method selected will be determined in large part by what is causing the water quality impairment. In some instances, the use of multiple restoration methods may be required.

The following is a discussion of in-lake restoration techniques that have been conducted in New York State through USEPA Clean Lakes Phase II projects or other lake management efforts. The list is ranked by the frequency of use as a restoration technique, although it is likely that locally-funded and sponsored projects

utilize some techniques such as drawdown and mechanical weed harvesting more frequently. Several techniques which have not been utilized within the State Clean Lakes process, but to some extent via "private" projects, include lake aeration/circulation, dilution/flushing, and biological controls, such as sterile grass carp. These techniques will be discussed at the end of this section. The use of aquatic herbicides and algaecides has not been associated with any Clean Lakes projects, although these lake management strategies have been commonly utilized by lake communities and managers.

Physical or Mechanical Techniques

Dredging has been used more frequently in New York than any other type of in-lake physical restoration technique, with the possible exception of drawdown. Used in conjunction with diversion or measures to reduce siltation upstream, dredging removes the sediments that may continue to be a significant source of nutrients to the overlying water column. This technique is also useful to control aquatic plant growth by the reduction in light penetration to the deeper waters.

There are two types of dredging for lake restoration projects, hydraulic and dry excavation. The method selected will depend upon the degree of treatment required, lake morphology, whether the lake can be drained properly and cost. The use of dry excavation has been utilized on eight Phase II projects in New York State, while hydraulic dredging has been used on two other Phase II restoration or demonstration projects since 1976. Smaller scale dredging activities have been conducted on many more small NYS lakes.

The disposal of the spoils from the dredging operation, the disruption of the littoral zone and benthic fauna and flora, destruction of wetland habitat (including the submergent vegetation), increased turbidity to the surrounding waters and possible impairment of use during the dredging operation all have increased the difficulty of obtaining the necessary environmental permits that are required to initiate new projects. Restrictions on the location of new spoils area and new, more restrictive weight limits for dump trucks also have contributed substantially to an increase in the costs of these projects.

The benefits derived from a dredging project generally are considered to last longer than the benefits derived from other lake restoration techniques, thus ameliorating the cost differences.

Small-scale dredging projects, particularly drawdown excavation, are much more common than in-lake or hydraulic dredging projects in New York State, although navigational dredging (to deepen a waterway to open or enhance navigation) and dredging to clean up contaminants is more common in river systems and some portions of lakes. These projects including dredging on the Great Lakes and Cumberland Bay in Lake Champlain, and Collins Lake. Excavation dredging was performed at Belmont Lake in Long Island for the control of fanwort in the early 1970s, and a number of lakes in the past (Central Park Lake, Hyde Park Lake and Van Cortlandt Park Lake in New York City, Steinmetz Lake in Schenectady, Delaware Park Lake in Buffalo, Washington Park Lake, Tivoli Lake, Buckingham Lake, and Hampton Manor Lake in the Albany area, Scudders Pond in Long Island, etc.). Navigational dredging was conducted in Glen Lake in 2006. There have also been proposed dredging projects (Lake Montauk, Lake George, Cuba Lake, Tannery Pond, Quaker/Red House Lake, etc.) in recent years for navigation or water quality improvement rather than for weed control. The removal of sediment as a medium to enhance weed growth (and water deepening) may result in reduction in nuisance weed growth. Projects associated with the federal Clean Lakes program are described below.

Phosphorus precipitation/inactivation is also used in conjunction with nutrient diversion or reduction. The degree of treatment, i.e. the amount of chemical applied, determines which method is being utilized. Phosphorus precipitation is employed when the lake sediments are not a significant source of nutrients. Phosphorus inactivation is used in all other applications.

The object of phosphorus precipitation is to add enough chemical to bind with the soluble phosphorus in the water column, forming a chemical floc which then settles to the bottom. Phosphorus inactivation not only strips the phosphorus in the water column, but enough additional chemicals are applied to form a barrier on top of the sediments that inhibits the release of phosphorus back into the water. The expected benefits from phosphorus inactivation may last several years.

Alum is the chemical most often used for phosphorus precipitation/inactivation. The addition of alum will lower the pH of the water, through a series of chemical reactions. If the pH is lowered below 4.5, the aluminum can be solublized and create a toxicity problem to fish and invertebrates. The dosage rates of alum has to be carefully determined and monitored during the application to maintain the pH above 4.5.

In New York, Saratoga Lake and Irondequoit Bay have been treated with alum in an experimental manner to determine its effectiveness in phosphorus inactivation. The Irondequoit Bay, treated during the summer of 1987, has increased water clarity, reduced levels of chlorophyll *a* and lowered phosphorus levels within the hypolimnetic waters. The long-term effect on the recycling of nutrients from the sediments will be determined by further monitoring. There was no appreciable improvement in the water quality in Saratoga Lake as a result of the alum application. This was due to the small treatment area and low application rates. An experimental low-level alum treatment is presently (2001 onward) being conducted (and closely monitored) in Kinderhook Lake. This technique will be utilized more often in the future, possibly to replace dredging in certain cases due to costs and environmental considerations. It may be especially well suited in small lakes or ponds to control algal blooms, provided these lakes have significant internal nutrient loading.

Lake-Level Drawdown has been used to control the growth of aquatic vegetation in near shore areas where lake levels can be controlled. Since drawdown effects only plants growing near shore, it is often utilized in conjunction with other in-lake restoration techniques. The control of vegetation is achieved through the freezing action on the exposed sediments during the winter months. Not all vegetation responds to the freezing action in the same manner. While some species may be affected negatively, others may not be affected at all, or may actually increase in abundance.

Drawdown during the winter months also allows ice scouring to disrupt the roots of plants. The exposed soils are compacted and much of the fine grained organic materials are removed to deeper waters. Another advantage of this technique is that it requires little or no expense.

In addition to possible shift in aquatic plant species, drawdown can result in increased turbidity and/or algae blooms. The turbidity increase is usually the result of a lack of vegetation along the shoreline which acted as a buffer to the wave energy. Lowering of the lake during the winter months may also result in a fish kill if an insufficient amount of water volume remains. Lake levels

need to be restored to near normal by spring to provide adequate fish spawning areas. Finally, lake residents are often concerned that the lake will not reach its normal lake level by summer. There is no guarantee that adequate runoff will fill the lake by the time people want to use it.

Drawdown has been commonly utilized at many New York State lakes, most often for benefits not associated (or directly geared toward) aquatic plant control. The NYS lakes for which drawdown was used as a weed control method include Galway Lake (Saratoga County), Saratoga Lake, and Greenwood Lake (on the New Jersey/New York border), and some of the lakes in the Fulton Chain of Lakes (interior Adirondacks) for controlling Eurasian watermilfoil, Forest Lake in the southern Adirondacks to control Elodea and pondweed, and Minerva Lake (southern Adirondacks) for the control of native plants. Most of these have been fairly successful, although immediately after drawdown a different mix of invasive plants have often colonized and dominated the aquatic plant community before the lakes reached equilibrium after a few years. For example, the dominant plants in Robinson Pond (Columbia County) shifted from Eurasian watermilfoil to bushy pondweed after the lake was regularly drawn down (for maintaining fisheries habitat downstream rather than for weed control), although this shift reversed several years later..

Mechanical Aquatic Plant Harvesting is restricted to applications where macrophyte growth impairs the use of the lake. The aquatic harvesters cut and remove vegetation below the surface of the water and transport the biomass to a conveyer for disposal away from the lake. Although the plants will grow back, some species requiring several harvests during a growing season, this technique removes the vegetation and associated nutrients from the lake. There also is evidence that the long-term harvesting, especially late in the season, causes some disruption to the growth cycle of some species of plants.

Although harvesting is only a temporary solution to vegetation problems and generally is not fundable as a sole restoration technique through the Clean Lakes Program, it has been used on the Saratoga Lake project in conjunction with other lake restoration techniques and watershed management programs. In fact, this technique is the most commonly used short-term method of vegetation control by lakes in this State, whether done “formally” with full-sized mechanical harvesters, informally with cutting bars and hand removal of floating plants, or individual cutting with plants removed from downwind shorelines.

Mechanical harvesters have been seen on lakes large and small throughout the state for many years, although in recent years the use of herbicides has largely superseded harvesting as the most common means for “whole lake” control of nuisance plants. While the use of harvesters in New York State dates back at least to the 1950s, the most significant regional activities originated with the advent of the Aquatic Vegetation Control Program in the Finger Lakes region in the late 1980s. In this program, state (member item) funds were provided to several counties in the Finger Lakes Region to conduct a variety of lake management activities. In some counties, this included the purchase of mechanical weed harvesters or harvesting services for several Finger Lakes, embayments to Lake Ontario, and some smaller waterbodies in these counties. The harvesting program at Chautauqua Lake has been used to evaluate nutrient removal from harvesting operations. Large lakes outside of the Finger Lakes region that have been harvested

include Lake Champlain and Oneida Lake (for water chestnut) and Greenwood Lake (for Eurasian watermilfoil). A statewide inventory of lakes that utilize mechanical harvesters has not been compiled, in large part due to the lack of regulatory oversight (and therefore a paper trail of permits) in most parts of the state..

Another type of mechanical harvesting, suction harvesting, utilizes divers, hoses, and a pump to create suction to remove aquatic plants. This technique is relatively new, but may provide longer term control of vegetation by removing the roots as well as the plants. The process of having diver(s) remove aquatic plants by suction hoses is more selective at removing only the nuisance species, thus leaving the native plants to recolonize the disturbed area. The removed plants and roots are discharged to a collection basket where they are then properly disposed of.

Suction harvesting is a slow and expensive operation when compared to mechanical harvesters, but is ideally suited as a secondary treatment when combined with rotovating or dredging and for new infestations of exotic plants. This technique has been used in several lakes in New York, including Lake George, East Caroga Lake and Saratoga Lake. Results from these studies indicate suction harvesting to be an effective means for controlling weed populations when applied under the appropriate circumstances.

Rotovating (also called rototilling) is a relatively new form of mechanical control for aquatic vegetation that uses a rototilling machine to cut and dislocate aquatic plants and roots from the sediment, and then removes the cut plants from the lake. **Hydroraking** is essentially the same technique that uses a mechanical rake, and collects and removes some of the cut material.

A rototilling machine is usually mounted on a barge. The machine has a large rotating head with several protruding tines that churn up the sediments, dislodging the roots and plants. The rotating head can be easily positioned with a hydraulic boom winch and winch cable (as hydroraking). The plants are either brought up on the rotator and disposed of on shore, or the floating vegetation is raked up for proper disposal.

There is only a short history of the use of rotovating and hydroraking in New York State, and specific examples have not been documented for any New York State lakes, although rotovating is being used at an increasing frequency in small plots in much larger lakes, particularly in the Finger Lakes region and in western NYS. It is believed that much small scale rotovating- outside individual properties- occurs under the regulatory radar screen, brought to the attention of regulatory agencies only through the vigilance of concerned neighbors

Aeration/Artificial Circulation have been used in other state Clean Lake projects to alleviate depleted oxygen in the hypolimnion with limited success. These two techniques have not been used on any Clean Lake projects in New York, although they have been utilized in privately-funded work. Aeration introduces oxygen to the hypolimnion without disrupting the temperature gradients, while artificial circulation mixes the entire water column. This latter treatment is not recommended in lakes where cold water fish species are present.

The use of imported water to replace existing lake water is referred to as dilution or flushing techniques. The objective is to exchange the high nutrient waters with water that is low in nutrients. The use of groundwater or nearby streams with low nutrient concentrations are sources for flushing. The lack of sufficient water of desirable quality and the cost of operation

and maintenance limit the use of this technique.

Shading involves the use of chemical dyes to inhibit light penetration to the lake bottom, ultimately controlling the growth of nuisance aquatic vegetation in areas greater than two to four feet deep. These non- toxic vegetable dyes work by reducing light penetration in the water ("shading"), and by the absorption of wavelengths within the photosynthetically active region of light. Absorbing these wavelengths prevents the plants from photosynthesizing and growing.

The dyes treat the entire waterbody and are usually not used on large lakes due to cost limitations. Dyes are most effective in small waterbodies with little or no flow where the appropriate concentration can be maintained. The duration for treatment for either large or small lakes is a function of water retention time. Dyes will be significantly and quickly diluted or washed downstream in lakes with inflow and outflow.

There is little historical information on the use of shading agents in New York State lakes, although they have been commonly used on ponds, particularly golf course and ornamental ponds, for many years. Perhaps the only large-lake experiments involving lake dyes was in Adirondack Lake in the late 1980s.

Chemical Techniques

Aquatic Herbicides and Algicides have been utilized for the control of nuisance aquatic plants; *herbicides* have been used to reduce populations of excessive rooted aquatic macrophytes, while *algicides* have been used to control nuisance algae growth (including macroalga such as *Chara*). Herbicides are available in liquid or granular form, utilizing a variety of formulations and active agents. Some herbicides elicit toxic reactions to the plant leaves and/or root structure, while other herbicides disrupt the photosynthetic or metabolic processes in plants. Algicides control algae by toxicity. While algae control has required primarily whole-lake treatments, herbicidal control of nuisance weeds has occurred as both spot and whole-lake treatments. Treatment duration, effectiveness, and selectivity are largely functions of the choice of herbicide, extent and type of plant coverage, bottom sediment structure, hydrologic characteristics of the lake, and other factors.

The primary aquatic herbicides registered for use in New York State are 2,4-D, Endothall (and other like formulations), Diquat, Rodeo, and Sonar. While herbicide treatments have historically focused on a variety of nuisance native and exotic submergent and emergent plants, much attention in recent years has been focused on exotic submergent species, primarily *Myriophyllum spicatum* (Eurasian water milfoil). Sonar, a fluridone-based compound utilized in other states for control of *M. spicatum* (and other nuisance macrophytes), was permitted for use in New York state in 1995, and has been utilized increasingly for the control of *M. spicatum* in NYS lakes (at least 40 lakes larger than 25 acres), although not in any lakes utilizing Clean Lakes funding. However, 2,4-D and other herbicides have a long history of use for controlling Eurasian water milfoil throughout the state. Algicides are primarily formulations of copper-based compounds. Both herbicides and algicides are regulated through an extensive licensing and permitting process by the NYSDEC.

Most of the New York State lakes treated with aquatic herbicides have not been closely studied either before or after treatment. The most closely monitored lakes include Waneta Lake in Schuyler County and Snyders Lake in Rensselaer County, both infected by Eurasian watermilfoil. Permits have been issued for aquatic herbicides in nearly every part of New York State. In fact, upwards of 500 permits are issued annually, not including purchase permits for small farm ponds. However, in some regions of the state, such as the Adirondacks, no aquatic herbicide permits have been issued. The myriad of reasons include overlapping regulatory authority (the DEC and the Adirondack Park Agency), strong sentiments about the use of herbicides, the presence of and concern for protecting rare and endangered species, and the lack of historical precedent in the use of many aquatic plant control strategies (due in part to the historical lack of problems with invasive plants). A paucity of permits is also the case for lakes in other regions of the state used for potable water intake or encompassing wetland areas, since the permitting rigor is often more significant in these waterbodies. On the other hand, many lakes in the downstate region have been treated with aquatic herbicides.

Copper sulfate has been used for many decades on many New York State lakes- some on an annual basis- and each year is used on more than 300 lakes and ponds throughout the state (mostly small ponds less than 3 acres in size). Most of these small pond treatments have not been well documented, although the NYSDEC has conducted a study of relatively small lakes with persistent copper sulfate treatments.

Biological Techniques

Herbivorous fish control of nuisance aquatic plants have been used for several years on small NYS ponds and lakes, and in the last few years on larger lakes with control structures, though there have been no treatments through the Clean Lakes Program. The use of sterile hybrid grass carp (*Ctenopharyngodon idella* x *Hypophthalmichthys nobilis*) was approved in New York on June 1, 1990, for waterbodies less than five acres, having no inlet or outlet and which lie wholly within the boundaries of the individuals requesting a permit. Up to 15 certified triploid grass carp per acre will be allowed where submergent vegetation and/or duckweed (*Lemnaceae*) occupy over 30% of the water's surface area and significantly impair the intended use of the waterbody. A more rigid permitting process is utilized for applications in larger lakes.

There have been literally thousands of permits issued by the DEC for the use of grass carp since 1991; the vast majority of these are for very small (< 1 acre “farm”) ponds with no inlet or outlet and a single landowner. The majority of the stockings appear to be in Finger Lakes region and western New York (nearly 1000 every year), and in the downstate region (nearly 500 per year). The effectiveness of these stockings has not been documented. The grass carp stocking and aquatic plant response of Walton Lake in Orange County, one of the original (experimental) stockings in the state, has been documented by the DEC Division of Fish and Wildlife. Information about other stockings is largely anecdotal

Biomanipulation is another restoration alternative that has not been widely used but may prove useful in some situations. The objective of this technique is to control the growth of algae by increasing the populations of zooplankton which graze on the algae. This is accomplished by reducing or eliminating small fish which feed on the zooplankton by increasing predation or restocking.

Although biomanipulation has been commonly used in New York State as a fisheries management tool, it has not been regularly utilized or documented as a lake management activity to restore or enhance water quality conditions. For example, rotenone has been used within the Adirondacks to restore native brook trout (by removing other fish that outcompete the brook trout), but this undertaking was not intended to improve water quality. Biomanipulation has largely been limited to either accidental introductions of exotic species (such as zebra mussels or Eurasian watermilfoil) or unintended results from the introductions of fish such as alewives in Conesus Lake. A small scale biomanipulation project has been conducted at Lake Neatahwanta

Herbivorous insects have been increasingly used in NYS lakes to control the growth of nuisance levels of *Myriophyllum spicatum*. Although several different herbivorous insects have been implicated in natural crashes of Eurasian watermilfoil through North America, only two have been reared and stocked in NYS lakes. *Euhrychiopsis lecontei*, the milfoil weevil, is native to many NYS lakes and is stocked commercially by a private company in Ohio. Adult weevils live submersed and lay eggs on milfoil meristems. The larvae eat the meristem and bore down through the stem, consuming the cortex, and then metamorphose lower on the stem. The consumption of meristem and stem mining by larvae are the two main effects of weevils on the plant and this damage can suppress plant growth, reduce root biomass and carbohydrate stores and cause the plant to sink from the water column (information from Ray Newman, University of Minnesota, Department of Fisheries and Wildlife). The milfoil weevil has been stocked in six NYS lakes since 1998. At present there do not appear to be any NYS stocked weevil populations that have become self-sustaining or have been demonstrated to adequately reduce Eurasian watermilfoil populations, although these lake stockings continue to be watched. There is some evidence that native populations of *Euhrychiopsis lecontei* have caused a crash in Eurasian watermilfoil in Findley Lake.

The milfoil moth, *Acentria ephemerella*, has been cited as the cause of a substantial crash of Eurasian watermilfoil in the northern end of Cayuga Lake. Although not native to NYS lakes, it has effectively become naturalized in many lakes since the late 1920s, and is now found in most surveyed NYS lakes. The moth caterpillars use their silken thread to bind milfoil's feathery leaves into individual nests (larval retreats), effectively halting growth of the plant stems. The moth has been introduced experimentally on a small scale into Dryden Lake and on a larger scale into Lincoln Pond. Commercial or other non-experimental stocking activities have not yet been conducted.

Although recent surveys have indicated that both the milfoil weevil and moth are found in most surveyed New York State lakes, the history of herbivorous insect stockings in New York State lakes dates back only to the late 1990s. Aquatic weevils have been stocked in small plots in several small New York State lakes, including Lake Moraine in Madison County, Sepasco Lake in Dutchess County, Findley Lake in Chautauqua County, and Millsite Lake in Jefferson County, as well as an experimental stocking in Saratoga Lake. Each of these projects has exhibited some very limited successes, but in no cases have migration out of the treatment plots, or long-term reductions of milfoil beds, been observed. This has been closely monitored for several years, although longer-term successes have also not been observed.

Current and Completed Clean Lakes Projects

Over the past 20 years the Department of Environmental Conservation, under the Federal Clean Lakes Program (Section 314 of the Federal Clean Water Act), has conducted 26 lake management and restoration projects on *public* lakes. The various projects cover almost every aspect of lake management from vegetation harvesting to the control of agricultural runoff. Since 1983, NYSDEC, through its Inland Lakes and Freshwater Section, also has supervised nearly 80 additional projects, financed solely with State funds, amounting to almost $15 million dollars. These projects, conducted in areas that comprise over 75 percent of the State's population, have improved the use of lakes and ponds as water supplies, and for swimming, fishing, and water-based recreational activities.

The Clean Lakes program is broken down into two components, Phase I and Phase II cooperative agreements. Phase I projects are the diagnostic/feasibility studies to determine a lake's quality, evaluate possible solutions to existing pollution problems and recommend a feasible program to restore or preserve the quality of the lake. A Phase II project is undertaken to implement the recommended methods for controlling pollution entering the lake, and to restore the lake. Applications to the U.S. Environmental Protection Agency (USEPA) for a Clean Lakes project must be made by the NYSDEC. The proposal to conduct a Phase I or Phase II project can be submitted to the NYSDEC by any government entity for a public water body.

Federal cost-sharing for Phase I projects are 70 percent of the total budget, with a maximum Federal grant of $100,000. Phase II grants are 50/50 cost sharing, with no maximum limit. The match to the Federal grant can be composed of state and/or local monies which are not being matched to any other Federal program.

Prior to 1980, USEPA funded Demonstration projects that were similar, in scope, to the present Phase II projects. New York completed seven of these demonstration projects before the regulation was adopted that established the present Clean Lakes program. Since that time, the State has completed ten Phase I studies, four Phase II projects, and currently has five Phase II programs that are active.

During 1994, the Department submitted six new Phase I applications and one Phase II grant application to USEPA. USEPA Region 2 recommended that one of the Phase I applications be funded while no Phase II studies or other Phase I grant applications be awarded. USEPA Region 2 also recommended funding the state lake water quality assessment grant, used to fund some of the aforementioned monitoring activities. Since funding for Section 314 projects has been eliminated, no additional Phase I or Phase II applications have been submitted to the USEPA since 1994, and some activities funded under the Water Quality Assessment Grant have been transferred to the Nutrient Assessment program.

The following is a summary of the completed and ongoing Clean Lakes projects.

I. Demonstration Projects.

A. *Washington Park Lake* and *Buckingham Lake*, City of Albany ($46,500 Federal, $46,500 Local). Project completed in 1978. Lakes were dredged of accumulated bottom sediments to restore water depth.

B. *Hampton Manor Lake*, Town of East Greenbush ($50,000 Federal, $50,000 Local). Project completed in 1979. Project consisted of hydraulic dredging to increase water depth.

C. *Steinmetz Lake*, City of Schenectady ($36,680 Federal, $36,680 Local). Project completed in

1979. Restoration consisted of dredging of bottom sediments to increase water depth and to reduce aquatic plant growth.

D. *Tivoli Lake*, City of Albany ($202,645 Federal, $202,645 Local). Project completed in 1981. Restoration included dredging contaminated sediment, diversion of stormwater runoff around the lake, rehabilitation of the earthen dam and establishment of wetland wildlife areas. The Lake was restocked with Largemouth bass, and presently is the only "natural" city park in upstate.

E. *Central Park Pond*, City of New York ($498,000 Federal, $498,000 Local). Project completed in 1981. Project consisted of dredging of accumulated sediment, rehabilitation of inlet and outlet structures and improvement of shoreline rip-rap. The purpose of the project was to increase water depth, as the pond is in a high use area of Central Park, Manhattan.

F. *Scudder's Pond*, Village of Sea Cliff and Glen Cove ($50,000 Federal, $50,000 Local). Project completed in 1982. Restoration included dredging of accumulated sediment, and construction of sediment traps to treat surface runoff. The pond is part of an environmental recreation area and is used for fishing.

G. *Ann Lee Pond*, Albany County ($98,246 Federal, $98,246 Local). Project completed in 1982. Restoration measures consisted of hydraulic dredging to increase water depth, and repair of the outlet dam. The pond is now used for fishing and is the focus of a wildlife area.

II. Completed Phase I projects

A. Lake Champlain, NYSDEC ($234,860 Federal, $100,654 State). Project period from 6/26/89 to 12/30/93. A cooperative Phase I diagnostic/feasibility study with the State of Vermont, completed as merger with Lake Champlain Management Plan.

B. Otsego Lake, SUNY Oneonta ($100,000 Federal, $50,000 Local). Project period from 7/22/91 to 6/30/97. A diagnostic/feasibility study examining nutrient inputs from the watershed and develop management plan to maintain current water quality.

C. *Upper Saranac Lake*, NYSDEC and the Upper Saranac Lake Association ($100,000 Federal, $136,000 State). Project period from 10/1/94 to 9/30/96. A diagnostic/feasibility study examining nutrient inputs and development of a management plan for the lake and its watershed.

D. *Chautauqua Lake*, Chautauqua County Planning Dept. ($100,000 Federal, $50,000 Local). Project period from 7/22/91 to 4/30/97. A diagnostic/feasibility study examining nutrient inputs and develop management plan to reduce eutrophication in lake.

III. Completed Phase II Projects (Phase I project completed prior to implementation).

A. *Hyde Park Lake*, Niagara County ($894,667 Federal, $894,667 Local). Project completed in 1984. Restoration included dredging of accumulated sediment, excavating the inlet and outlet tributaries and providing for a source of clean make up water for dilution. The lake is in the only park in the City of Niagara Falls, and is used for boating, fishing and aesthetic enjoyment.

B. *Delaware Park Lake*, City of Buffalo ($3,741,500 Federal, $2,000,000 State, $1,741,500 Local). Project completed in 1985. Restoration included diversion of the incoming stream around the Lake, rerouting of storm sewers, and dredging to remove accumulated sediment. The Lake is in a major city park and is used for fishing, boating and aesthetic enjoyment.

C. *Lake Ronkonkoma*, Suffolk County ($335,572 Federal, $335,572 Local). Project completed in 1986. Project consisted of public land acquisition, and the development of a management

plan for the lake and its watershed. Two experimental biofilters for treating stormwater were constructed and evaluated as part of the project.

D. *Iroquois Lake*, City of Schenectady ($290,747 Federal, $240,000 State, $50,747 Local). Project completed 1987. Restoration consisted of dredging for deepening and vegetation control, stormwater diversion and sealing of the bottom with clean fill. The Lake was restocked with fish and is used for boating, fishing, and aesthetic enjoyment.

E. *Irondequoit Bay*, Monroe County ($329,743 Federal, $165,000 State, $164,743 Local). Project period 6/1/85 to 12/21/89. Project consisted of alum addition for the control of phosphorus release from deep anoxic sediments. Monroe County also has developed a management plan for reducing urban and agricultural runoff impacts from the Lake's watershed.

F. *Belmont Lake*, NYSOPR&HP, Suffolk County ($290,000 Federal, $290,000 State). Project period 9/1/83 to 12/21/89. Restoration consists of removal of accumulated bottom sediment for control of the exotic plant fanwort (*Cabomba caroliniana*). The Lake is used extensively for boating, fishing, and aesthetic enjoyment.

G. *Saratoga Lake*, NYSDEC, Saratoga County ($339,241 Federal, $180,000 State, $159,241 Local). Project period 6/1/84 to 5/31/89. Project consists of water level control, agricultural runoff controls, aquatic vegetation harvesting, alum addition for nutrient inactivation, and formation of a lake management district. The Lake is an excellent warm water fishery with a severe infestation of Eurasian watermilfoil (*Myriophyllum spicatum*).

H. *Van Cortlandt Park Lake*, City of New York ($88,759 Federal, $88,759 Local). Project period 6/1/86 to 5/31/92. Restoration was to consist of dredging to increase water depth, stormwater diversion and the use of existing wetlands to filter stormwater runoff. No work done due to City unable to come up with match for project.

I. *Collins Lake*, Village of Scotia ($221,821 Federal, $110,000 State, $111,821 Local). Project period 4/1/85 to 3/31/95. Project to include hydraulic dredging to increase water depth by 1 meter to reduce growth of the exotic plant Curlyleaf pondweed (*Potamogeton crispus*). The Lake is used extensively for swimming, boating and fishing.

J. *Greenwood Lake*, Greenwood Lake Watershed Management District, Inc. ($369,000 Federal, $240,000 State, $129,600 Local). Project period 6/26/89 to 9/30/95. Project to control aquatic vegetation and reduce nutrient loadings to the lake. Methods include drawdown, mechanical harvesting, stormwater management, development of a septic management district, fisheries survey, and a basin-wide sensitive lands management plan.

K. *Lake George*, NYSDEC ($367,390 Federal, $367,390 State/Local). Project period from 6/26/89 to 5/31/93. Project includes aquatic plant management, critical land acquisition, and monitoring. An increase in federal funds for this project is currently being requested.

IV. Special Grants

A. Water Quality Assessment Grant, NYSDEC ($50,000 Federal, $21,429 State). Project period from 9/1/94 to 8/31/96. A grant to assist DEC in the administration of its Lake Water Quality Assessment Program.

B. Onondaga Lake Management Conference, NYSDEC ($1,750,000 Federal, $750,000 State). Project period from 6/26/89 to 9/30/94. A compilation/review of studies to determine additional monitoring necessary and what strategies would succeed in the restoration of Onondaga Lake.

C. Lake Champlain Management Conference, NYSDEC ($2,000,000 Federal, $857,143 State). Project period from to 9/30/94. To convene a management conference to study and address the water quality concern in Lake Champlain. The project is conducted with the State of

Vermont.

D. TMDL-Mini Grant for In-Lake Sedimentation Study ($15,000 Federal). Project Period 10/1/93 to 9/30/94. A grant to conduct sedimentation chemistry and rate studies on several lakes of various trophic conditions

E. Nutrient Assessment Grants (two grants, total $125,000 Federal, $53,573 State). Project Period 7/1/98 to 9/30/00. A grant to assist DEC administration of its Nutrient Assessment Program.

F. Nutrient Criteria Development Grant ($30,000 Federal (EPA Regions I, II, and V), awarded to the NYS Federation of Lake Associations). Project Period 10/1/01-6/30/03. A grant to evaluate the use of lake perception data in developing nutrient criteria

Acidification of Lakes

The assessment of lakes and ponds for acidity in New York State is based upon a system to categorize waters as being in acceptable, threatened or impaired ("affected") condition as determined by midsummer acidity levels (Pfeiffer and Festa, 1980). The system relates the environmental requirements for survival of endemic fish populations and current acidification status. The categories of pH are

Impaired condition	pH < 5.0 standard units
Threatened condition	pH $\geq$ 5.0 and $\leq$ 6.0 standard units
Acceptable condition	pH > 6.0 standard units

In previous 305(b) reports, the presence of a viable fish population also was used to determine acidity status. Although not a direct measure of trophic state, this classification provides important information about the concurrent use impairment due to the severity of the acidification problem.

A total of 1,850 lakes and ponds representing 503,400 acres have been assessed for acidity in New York State (not including Lake Ontario). Most of the information for the current evaluation came from the Adirondack Lakes Survey Corporation field investigations of 1,469 ponded waters between 1984 and 1987. The ELS waters were not sampled during midsummer and are not included in the current assessment. The 1,376 waters included in the current assessment from the ALSC report represent about 50 percent of the total number of water bodies in the Adirondack Region.

The results of the current assessment for acidity status based upon midsummer air-equilibrated pH values are outlined on Table 9 (with the ALSC data summarized in parentheses).

The 365 ponded waters impaired by acidity represents about 20 percent of the total number of lakes, but less than 2% of the total surface area included in the current acidity status assessment.

The specific sources of acidity in the acid deposition that affects Adirondack lakes and ponds are the millions of tons of sulfur dioxide and oxides of nitrogen that are emitted annually into the atmosphere. Deposition of sulfate and nitric acid takes place in both "wet" (precipitation) and "dry" (direct deposition to the ground surface) forms.

Table 9

Assessment of Lake Acidification

	Impaired	Threatened	Acceptable
Air-Equilibrated pH	**< 5.0**	**5.0 - 6.0**	**> 6.0**
Number of Lakes/Ponds	**365 (326)**	**289 (257)**	**1184 (793)**
Percent of Total Assessed	**20% (24%)**	**16% (19%)**	**64% (58%)**
Total Number of Lake Acres	**7,210 (4,155)**	**16,374 (8,030)**	**436,311 (36,255)**

Ohio, Pennsylvania and West Virginia, immediately southwest of New York State, are major contributors of sulfur dioxide. In previous years these three states together contribute 21 percent of the sulfur deposition at the Whiteface receptor, 23 percent at the western Adirondack receptor, and 36 percent at the Catskill receptor. These three states, together with New York State, Ontario and Quebec at one time accounted for most of the sulfur dioxide emissions west of, and within, 1000 km of the Adirondacks, 68 percent of the deposition at Whiteface, 67 percent of the deposition in the western Adirondacks, and 68 percent of the deposition at the Catskill receptor. The remaining 30 percent of the deposition at these three receptors was contributed by several widely separated regions. New York State's contribution to total sulfur deposition at all receptors in New York State ranged from 14 percent to 31 percent.

The predominant contributors to oxides of nitrogen emissions are motor vehicles located in heavily urbanized areas. The largest non-New York contributors to the New York receptors are located immediately to the southwest of the State and include the western Pennsylvania, eastern Ohio, and West Virginia areas. This region contributes about 14 percent of the total emissions sources. The Canadian contribution to nitrate deposition at some receptors is considerably higher than that found for sulfate deposition, which reflects the influence of large Canadian metropolitan areas such as Montreal and Toronto. New York State's contributions to emissions in the general area at one time ranged from 2.6 percent at Muskoka, which is west of New York State, to 32 percent at Brookhaven on the eastern end of Long Island.

Based on ionic contributions and other evidence, acidification of waters in the Adirondacks has occurred primarily from the atmospheric deposition of sulfate. Higher concentrations of nitrate occur during events such as snowmelt and influence short-term changes in pH and ANC.

The NYSDEC began neutralizing certain acidic waters in 1959 as a management tool used to help restore or protect valuable fisheries. The neutralizing material used is agricultural limestone. The NYSDEC liming program has in recent years included 32 waters, all of which are located within the Adirondack Park. As another alternative to mitigate the harmful effects of high acidity, the Lake Acidification Mitigation Project (LAMP) conducted research on watershed liming to determine the effects of liming the entire ecosystem on the water chemistry, terrestrial vegetation and soil biota.

Mitigation Measures for High Phosphorus

More than 40 small lakes have been identified as impaired due to excessive nutrients, warranting their inclusion on the New York State Section 303(d) list. Most of these systems suffer from a lack of nutrient loading data, but most are also found within a single jurisdiction with relatively small watersheds. As such, nutrient loading to these systems could be modeled with relatively simple desk-top modeling programs, leading to the development of total maximum daily load (TMDL) calculations required for 303(d) listed waterbodies. The NYSDEC Division of Water, working with EPA and their consultants, identified candidate waterbodies for inclusion in a small lakes TMDL modeling project, and several representative lake watersheds for calibrating these models. The lack of event-based monitoring data for many of these systems resulted in the choice of a steady-state watershed and lake response model to characterize contemporary nutrient loading and lake conditions, and to predict lake response to changes in nutrient inputs.

The ArcView Generalized Watershed Loading Function (AVGWLF) model was used in combination with BATHTUB to develop three TMDLs for small lakes impaired by phosphorus. The approach employed by an EPA contractor consisted of using AVGWLF to determine mean annual phosphorus loading to the lake, and then using BATHTUB to define the extent to which this load must be reduced to meet the water quality target. This approach required no additional data collection thereby expediting the modeling efforts. These TMDLs did not involve any Waste Load Allocations.

The EPA contractor is also using the AVGWLF model to review watershed loads in several other impaired lakes. Most of these lakes have larger, more complicated watersheds and the TMDLs will need to set Waste Load Allocations for wastewater treatment discharges or Municipal Separate Storm Sewer Systems. This relatively simple, desktop, model-based approach will be adopted to address TMDL development for 40-50 small lake systems throughout New York State.

Mitigation Measures for High Acidity

1. *Acid Rain Lakes Total Maximum Daily Load (TMDL)*

About 400 waters are included on the New York State Section 303(d) list because of impairment to aquatic life support attributed to acid rain. The majority of these lakes were added to the list in 1998 and were based on chemistry and biologic data from the mid-1980s or prior. The focus of the Acid Rain Lakes restoration strategy/TMDL is limited to those affected lake waters that fall within New York State Adirondack Forest Preserve lands. The reason for limiting the universe of waters to be covered is due to the applicable water quality standards for these waters. The applicable pH standard for most waters outside the Forest Preserve lands is “not less than 6.5.” While this is a scientifically derived standard based on the support of aquatic life, it might not be a realistic standard for all waters of the Adirondacks, where natural limitations such as limited acid neutralizing capacity (ANC), soil characteristics, geology and hydrology and other considerations suggest some of these

waters may have never attained a pH of 6.5. Even so, acid rain may still restrict aquatic life support in these waters.

The ultimate goal for all waters would be that they achieve all water quality standards for classified waters and support a full and diverse aquatic community. However, State water quality standards such as the pH standard of 6.5 have not been applied to waters within the Forest Preserve because of the alternative protection provided in Article 14 of the New York State Constitution. If State standards were applied, a TMDL would have to demonstrate that prescribed loading reductions could meet this standard. The lack of specific, numeric water quality standards for Forest Preserve Waters allows for some flexibility in developing interim TMDL endpoints.

The nature of the loading sources responsible for this impairment to New York State waters also complicates the loading reduction strategy called for in this restoration plan. Because significant sources lie outside New York State borders any effective loading reduction strategy must include national (regional) reduction efforts. Beyond any initial reductions, additional reductions are likely to be needed to attain water quality standards and restore uses of at least some of these waters. However the complexity of the ransport, deposition, in-water effects and appropriate natural limitations – factors that vary somewhat across the range of 143 target waters – suggest that an incremental/phased approach is appropriate.
.
While retaining a minimum pH of 6.5 as the ultimate goal for these waters, this phased TMDL uses a hierarchy of interim aquatic life support thresholds. As the emission of acid rain precursors are reduced regionally, monitoring data will be used to assess pH recovery and aquatic life support, and to refine simulation models to see what additional reductions would be necessary to achieve further recovery and a higher level of aquatic life support. This iterative adaptive management cycle is an appropriate strategy to deal with the complexities of restoring these acid rain waters.

2. Northeast Regional Mercury (TMDL)

Seven states— New York, Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont—collaborated with the New England Interstate Water Pollution Control Commission (NEIWPCC) to produce the plan for reducing mercury in the waters of New York State and New England to eliminate fish consumption advisories caused by mercury from air deposition. In the Northeast, elevated levels of mercury in certain fish species, such as large and smallmouth bass and walleye, are of great concern. In New York, more than 80 water bodies have advisories for fish consumption based on elevated levels of mercury. While most of the waters are in the Adirondacks and Catskills, others such as parts of the Hudson and Susquehanna Rivers and Lake Champlain are also affected.

This Northeast regional TMDL will help address the link between mercury emissions and mercury pollution in water and highlights the need for implementation of a comprehensive, nationwide mercury reduction strategy that would improve the natural

resources not only in New York, but in all states. The participating states believe that mercury deposition deserves to be a national priority, and requires federal programs to address it. The TMDL acknowledges the success of the Northeast states in eliminating many in-state sources of mercury contamination. Nearly a decade of work has resulted in regional reductions of greater than 70 percent in mercury emissions and discharges, including reductions in emissions from incinerators. As New York State continues to look for new ways to reduce in-state sources of mercury, the TMDL recognizes that the majority of mercury in state waters comes from out-of-state sources. The draft TMDL stipulates the amount by which mercury arriving in the region from out-of-state sources must be reduced if waters are to be removed from the impaired list and the fish consumption advisories rescinded.

The TMDL indicates that by reducing overall mercury deposition to the region by between 86 percent and 98 percent, fish-tissue mercury will decline to levels where fish advisories will no longer be required.

Assessment of Lake Water Quality Trends

The Inland Lakes and Freshwater Section has attempted to provide some preliminary assessments of long term water quality trends of the lakes in New York State. Such an assessment is ultimately limited by the relatively small number of lakes that have been sampled for a sufficient period of time (5-10) years to provide long-term trend analysis and dampen the interannual variability due to changing weather conditions, slight differences in sampling schedules, and other sampling artefacts. Moreover, questions about the representativeness of the ambient monitoring programs datasets (as a cross section of all NYS lakes, or even lakes within a particular region, size range, or water quality classification) further limits the extrapolation of trend analyses within these datasets to assessments of trends within NYS lakes, however the latter may be defined. The EMAP Program was intended to support the collection of long-term baseline data to identify water quality trends. However, since this section of the report is dealing with water quality data collected primarily since 1982, the paucity of long-term data for the majority of state lakes precludes an adequate trend analysis.

Trend analyses can be attempted in a number of ways. Perhaps the simplest would be to evaluate changes in water quality indicators (trophic status, acidification status, etc.) over defined intervals, such as changes in these indicators by decade of sampling. The historical NYS dataset lends itself to this type of analysis, since many lakes were sampled on only a limited basis in relatively short-term water quality monitoring programs within each of the last four decades- the DEC and Eastern Lakes surveys of the 1970s, the ALSC, LCI and CSLAP programs in the 1980s, and the LCI, CSLAP, and Finger Lakes monitoring programs of the 1990s and 2000s.

Another method is traditional long-term data analyses on continuous datasets, such as those collected via CSLAP. At one time, the Citizens Statewide Lake Assessment Program monitored individual lakes for at least five year intervals. At the end of that time, individual lake associations were provided the option of monitoring the lake at their own expense (using the same sampling procedures, equipment, and laboratory for analyses) or be dropped from the program to include other lakes on the waiting list. Since a five year monitoring program does not generally provide the long-term data to provide a water quality

trend, and due to funding restrictions within the program, participating lake associations assumed a portion (appx 5-15%) of the program costs beginning in 2002, and thus were provided opportunities to continue monitoring without five year sampling restrictions. It is anticipated that this may dramatically increase the number of lakes with continuous datasets and provide more years of water quality data for more rigorous trend analysis. At present, 138 CSLAP lakes have been sampled, at present, for at least five years under this program, with 38 lakes sampled for at least 10 years, and 9 lakes sampled for at least 15 years, although they may not have had contiguous records. In recent years, rudimentary statistical analyses have been conducted on individual CSLAP lakes. These analyses can be grouped to provide a summarized simple analys1s of water quality trends in these lakes (and by extension a subset of NYS lakes) since the mid-1980s.

There are more than 230 lakes that have been sampled in two or more of the decades of the 1970s, 1980s, 1990s and 2000s (inclusive of 2006) by one or more of the above described monitoring programs and/or ambient water quality monitoring conducted by the NYSDEC during the 1970s but not summarized in this report. However, since many of these programs collected information on a subset of NYS lakes that may not be representative of the entirety of water resources in the state, such as the mostly acidified lakes sampled in the ALSC project, the larger public access lakes sampled in the LCI, and the mostly larger populated lakes sampled through CSLAP, comparing results from one program to the next (and therefore from one "decade" to the next) may not provide great insights about the recent historical condition of NYS lakes.

Among the lakes sampled in two or more decades since the early 1970s, the trophic condition of these lakes are described in Table 10. Trophic status in each decade was evaluated by evaluating the median value for the trophic indicators for the entire decade.

Review of the data in Table 10 shows that comparisons from one decade to the next are extremely difficult since only a small subset of lakes were sampled in the 1970s, 1980s, 1990s, and 2000s. However, with the larger pool of lakes sampled from the 1970s to the 2000s, from the 1980s to the 2000s, and from the 1990s to 2000s, a tentative assessment of changing trophic status can be presented. This assessment is shown in Table 11.

It appears that there is a trend toward decreasing productivity (trophy), particularly when evaluating total phosphorus concentrations, in the subset of commonly sampled lakes, although it is clear that the majority of these lakes did not change in trophic status over the twenty years of data collection. The discrepancy between chlorophyll *a* and the other indicators reflects both the relative lack of chlorophyll *a* data from the 1980s (it was not collected through the ALSC project) and perhaps the greater consistency in the data collected in the 1990s (in which mean values may be unduly influenced by extremely high early and late summer readings, although this was somewhat accounted for by evaluating median values for these indicators). The large "drop" in trophy from the 1980s to the 1990s as assessed by total phosphorus concentrations may be due in part to questionable (overestimated) total phosphorus data from the ALSC (1980s) study. However, in comparing data from common lakes sampled in the LCI (1980s to 2000s) and CSLAP and AEAP programs (1980s to 2000s), where laboratory methodologies are consistent, 20-30% showed a decrease in trophic status (lower productivity) as determined by total phosphorus concentrations, while only 5-10% showed an increase. This may continue to represent decreases in nutrient concentrations in response to the phosphorus detergent ban instituted in the 1970s.

Table 10

Trophic Condition of Lakes from the 1970s through 2007

Trophic Status Based on:	Oligotrophic	Mesotrophic	Eutrophic	Total Lakes/Ponds
1970s Lake Assessment *				
Total Phosphorus	14	9	19	42
Secchi	9	20	12	41
Chlorophyll	5	16	14	35
1980s Lake Assessment **				
Total Phosphorus	56	71	51	177
Secchi	29	108	40	178
Chlorophyll	12	51	30	93
1990s Lake Assessment ***				
Total Phosphorus	100	78	53	231
Secchi	39	130	61	230
Chlorophyll	48	122	61	231
2000s Lake Assessment****				
Total Phosphorus	43	43	26	112
Secchi	18	71	30	119
Chlorophyll	20	57	32	109

* Lakes sampled in the 1970s by the NYSDEC, and also sampled in the 1980s (by the CSLAP, LCI or ALSC programs) and/or in the 1990s (by CSLAP, the LCI, EMAP and/or the AEAP programs).

** Lakes sampled in the 1980s (by the CSLAP, LCI or ALSC programs) and in the 1970s by the NYSDEC, in the 1990s (by CSLAP, the LCI, EMAP and/or the AEAP programs) and/or in 2000 or 2001 via CSLAP or the LCI.

*** Lakes sampled in the in the 1990s (by CSLAP, the LCI, EMAP and/or the AEAP programs), and in 1970s by the NYSDEC, the 1980s (by the CSLAP, LCI or ALSC programs) and/or in 2000 or 2001 via CSLAP or the LCI.

**** Lakes sampled in 2000 -06 via CSLAP or the LCI and in the 1970s by the NYSDEC, in the 1980s (by the CSLAP, LCI or ALSC programs) and/or in the 1990s (by CSLAP, the LCI, EMAP and/or the AEAP programs).

Table 11

Trophic Condition of Lakes: 1970s to 2000s

Change in Trophic Status Based on:	Increasing Productivity	Decreasing Productivity	No Change in Productivity / Trophic Status
1970s to 1990s Lake Assessment			
Total Phosphorus	5	12	24
Secchi	7	11	21
Chlorophyll	4	3	27
1970s to 2000s Lake Assessment			
Total Phosphorus	2	8	11
Secchi	4	5	14
Chlorophyll	2	3	14
1980s to 1990s Lake Assessment			
Total Phosphorus	11	41	110
Secchi	17	15	131
Chlorophyll	14	8	65
1980s to 2000s Lake Assessment			
Total Phosphorus	5	15	45
Secchi	11	4	56
Chlorophyll	10	13	27
1990s to 2000s Lake Assessment			
Total Phosphorus	7	9	90
Secchi	13	13	79
Chlorophyll	8	15	83

However, the decrease in trophy over this period, as evaluated by the total phosphorus (and to a lesser extent chlorophyll) data, does not appear to be borne out by changes (responses) in water clarity over this period. Most of the longer-term data sets indicate variable responses in water clarity, with trophic

status decreasing (higher clarity) when evaluating the 1970s to 1990s datasets, but increasing (lower clarity) when evaluating the 1980s/90s to 2000s dataset. A closer evaluation of these datasets indicates that most of the decreases in water clarity do not appear to be statistically significant, but are large enough to move the median values for these lakes across the boundaries separating trophic categories (such as a drop in median water clarity from 5.1 meters to 4.9 meters).

Long-term trends can also be evaluated by looking at the summary findings of individual lakes from a consistent data set, such as CSLAP, and attempt to extrapolate consistent findings to the rest of the lakes. Given the non-Gaussian distribution of many of the water quality parameters evaluated in this report, non-parametric tools may be the most effective means for assessing the presence of a water quality trend. However, these tools do not indicate the magnitude of the trend. As such, a combination of parametric and non-parametric tools may need to be employed to evaluate trends.

The Kendall tau ranking coefficient has been utilized by several researches and state water quality agencies to evaluate water quality trends via non-parametric analyses. Kendall tau ranking orders paired observations by one of the variables (say arranging water clarity readings by date). Starting with the left-hand (say earliest date) pair, the number of times that the variable not ordered (in this case clarity readings) is exceeded by the same variable in subsequent pairs is computed as P, and the number of times in which the unordered variable is not exceeded is computed as Q. This computation is completed for each ordered pair, with N= total number of pairs, and the sum of the differences $S = \Sigma P\text{-}Q$. The Kendall tau rank correlation coefficient τ is computed as:

$$\tau = 2S/(N*(N-1))$$

Values for τ range from –1 (complete negative correlation) to +1 (complete positive correlation). As above, strong correlations (or simply "significance") may be associated with values for τ greater than 0.5 (or less than –0.5), and moderate correlations may be associated with values for τ between 0.3 and 0.5 (or between –0.3 and –0.5), but the "significance" of this correlation must be further computed. Standard charts for computing the probabilities for testing the significance of S are provided in most statistics text books, and for values of N greater than 10, a standard normal deviate D can be computed by calculating the quotient

$$D= S\sqrt{18} /\sqrt{[(N(N-1)(2N+5)]}$$

and attributing the following significance:
D > 3.29 = 0.05% significance
2.58 < D < 3.29 = 0.5% significance
1.96 < D < 2.58 = 2.5% significance
D < 1.96 = > 2.5% significance

For the purpose of this exercise, 2.5% significance or less is necessary to assign validity (or, using the vernacular above, "significance") to the trend determined by the Kendall tau correlation. It should be noted again that this evaluation does not determine the magnitude of the trend, but only if a trend is likely to exist.

Parametric trends can be defined by standard best-fit linear regression lines, with the significance of these data customarily defined by the magnitude of the best fit regression coefficient ® or R^2). This can be

conducted using raw or individual data points, or seasonal summaries (using some indicator of central tendency, such as mean or median). Since the former can be adversely influenced by seasonal variability and/or imprecision in the length and breadth of the sampling season during any given year, seasonal summaries may provide more realistic measures for long-term trend analyses. However, since the summaries may not adequately reflect variability within any given sampling season, it may be appropriate to compare deviations from seasonal means or medians with the "modeled" change in the mean/median resulting from the regression analyses.

When similar parametric and non-parametric tools are utilized to evaluate long-term trends in NYS lakes, a few assumptions must be adopted:

- Using the non-parametric tools, trend "significance" (defined as no more than appx. 3% "likelihood" that a trend is calculated when none exists) can only be achieved with at least four years of averaged water quality data. When looking at all summer data points (as opposed to data averaging), a minimum of forty data points is required to achieve some confidence in data significance. This corresponds to at least five years of CSLAP data. The "lesson" in these assumptions is that data trends assigned to data sets collected over fewer than five years assume only marginal significance.

- As noted above, summer data only are utilized (as in the previous analyses) to minimize seasonal effects and different sampling schedules around the fringes (primarily May and September) of the sampling season. This reduces the number of data points used to compile averages or whole data sets, but is considered necessary to best evaluate the CSLAP datasets.

As of 2006, there were 157 CSLAP lakes that have been sampled for at least five years. Table 12 summarizes the "trend" indicated from the parametric and non-parametric analyses – the latter consists of both methods indicated in note 1) above, while the former consists of the best-fit analysis of summer (June 15 through September 15) averages for each of the eutrophication indicators (with trends attributable to instances in which deviations in annual means exceed the deviations found in the calculation of any single annual mean). As alluded to earlier, Table 12 includes only those lakes with more than four years of water quality data. When this method is applied to sampling parameters that are more characteristic of succession than cultural eutrophication, such as conductivity, a much higher percentage of significant change occurs (more than 20% of CSLAP lakes sampled for at least five years have exhibited a significant increase in conductivity), suggesting this methodology may be adequate to reveal significant changes. The decrease in chlorophyll *a* readings in the absence of decreasing nutrient concentrations suggests some localized management of algae, such as the use of algacides. However, some of the discrepancy between lower phosphorus and algae levels may reflect the shift in CSLAP laboratories after 2002- algae levels have been lower in many CSLAP lakes since the shift in laboratories.

These data suggest that while most NYS lakes have not demonstrated a significant change, those lakes that have experienced some change show a trend toward less productive conditions. The lesser significance associated with the chlorophyll *a* readings is probably the result of higher sample-to-sample variability associated with this analysis. There does not appear to be any obvious shared characteristics among these lakes. Some are highly productive, others are quite unproductive, some have been actively managed, some have been sampled for only a few years or are small shallow lakes or are located in the western part of the state, while others are just the opposite. As noted above, there does not appear to be any clear pattern between weather and water quality changes. However, all of these lakes may be the long-term beneficiaries of the ban on phosphorus in detergents in the early 1970's, which with other local

circumstances (perhaps locally more "favorable" weather, local management, etc.) has resulted in less productive conditions.

Table 18

Trends in Lake Water Quality

Water Quality Indicator	**Number (%) of CSLAP Lakes**	**Acres of Lakes**
Total Phosphorus		
Increasing	14 (9%)	17,200
Stable or Fluctuating	96 (56%)	44,900
Decreasing	17 (11%)	50,900
Trend Unknown	35 (24%)	30,500
Secchi Disk:		
Increasing	13 (8%)	55,300
Stable or Fluctuating	107 (61%)	61,800
Decreasing	13 (8%)	4,400
Trend Unknown	34% (22%)	21,700
Chlorophyll *a*:		
Increasing	7 (4%)	700
Stable or Fluctuating	90 (57%)	112,500
Decreasing	28 (18%)	11,300
Trend Unknown	32 (20%)	18,800