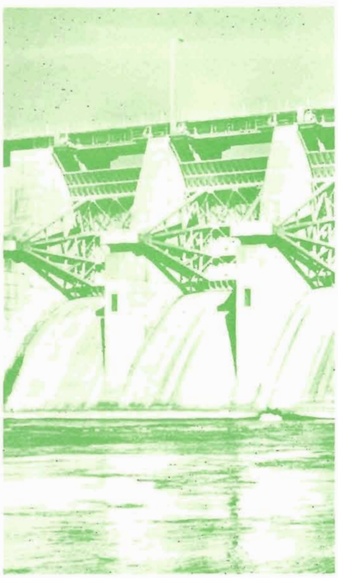
US Army Corps of Engineers

MISCELLANEOUS PAPER EL-88-6

EUTROPHICATION ASSESSMENT AND MANAGEMENT AT TIOGA, HAMMOND, COWANESQUE, WHITNEY POINT, AND EAST SIDNEY LAKES PENNSYLVANIA-NEW YORK



by

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April 1988

Final Report

Prepared for US Army Engineer District, Baltimore
Baltimore, Maryland 21203-1715

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY 2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
4. PERFORMING ORGANIZATION REPORT NUMBER(S) Miscellaneous Paper EL-88-6	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION USAEWES Environmental Laboratory 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) PO Box 631 Vicksburg, MS 39180-0631	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION USAED, Baltimore 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code) Baltimore, MD 21203-1715	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
Eutrophication Assessment and Management at Tioga, Hammond, Cowanesque, Whitney Point, and East Sidney Lakes, Pennsylvania-New York

12. PERSONAL AUTHOR(S)
Kennedy, Robert H.; Ashby, Steven L.; Gaugush, Robert F.; Gunkel, Robert C., Jr.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final report	FROM ____ TO ____	April 1988	118

16. SUPPLEMENTARY NOTATION
Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Eutrophication Nutrients Sampling design
			Loading Reservoirs

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Reservoirs provide hydroelectric power, flood control, navigation, water supply, fish and wildlife habitat, and recreation, and are thus a valued national resource that must be protected from the adverse impacts of human activity. These impacts include increases in algal standing crop due to the influx of excessive amounts of nutrients, reductions in water clarity, and losses of dissolved oxygen in bottom waters.

Water quality studies reported here document the existence of eutrophication-related problems at Cowanesque, Tioga, Hammond, Whitney Point, and East Sidney Lakes, five Corps of Engineers reservoirs located in northern Pennsylvania and south-central New York. Excessive nutrient loads from predominantly agricultural watersheds have led to the development of algal blooms and reductions in water clarity. Recommendations for future studies to better define these conditions and possible causes are provided. Also included are recommendations for statistically sound sampling designs for the accomplishment of these studies.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE (Include Area Code) / 22c. OFFICE SYMBOL

SECURITY CLASSIFICATION OF THIS PAGE

SECURITY CLASSIFICATION OF THIS PAGE

PREFACE

The study described in this report was sponsored by US Army Engineer District, Baltimore (NAB), and was conducted by the US Army Engineer Waterways Experiment Station (WES) under Intra-Army Order No. E8687031, dated 24 June 1987. Mr. Pete Juhle, Chief of the Water Control Management Section, NAB, served as the point of contact.

This report was prepared by Dr. Robert H. Kennedy, Mr. Steven L. Ashby, Dr. Robert F. Gaugush, and Mr. Robert C. Gunkel, Jr., of the Environmental Laboratory (EL), WES. Participating in the conduct of the study were Mr. William Jabour, Mr. William Taylor, Mr. Harry Eakin, Mr. Michael Potter, and Dr. John Hains, EL. The study was conducted under the direct supervision of Dr. Thomas L. Hart, Chief, Aquatic Processes and Effects Group, and under the general supervision of Mr. Donald L. Robey, Chief, Ecosystem Research and Simulation Division, and Dr. John Harrison, Chief, EL.

COL Dwayne G. Lee, CE, was the Commander and Director of WES. Dr. Robert W. Whalin was Technical Director.

This report should be cited as follows:

Kennedy, R. H., Ashby, Steven L., Gaugush, Robert F., and Gunkel, Robert C., Jr. 1988. "Eutrophication Assessment and Management at Tioga, Hammond, Cowanesque, Whitney Point, and East Sidney Lakes, Pennsylvania-New York," Miscellaneous Paper EL-88-6, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

CONTENTS

EUTROPHICATION ASSESSMENT AND MANAGEMENT AT TIOGA, HAMMOND, COWANESQUE, WHITNEY POINT, AND EAST SIDNEY LAKES

PART I: INTRODUCTION

1. Reservoirs provide flood control, hydroelectric power, navigation, water supply, fish and wildlife habitat, and recreation, and are thus a vital water resource of great national value. The manner in which this resource is managed will vary among sites depending upon water quality conditions and requirements, and the operational capabilities and constraints at each project. Thus, an understanding of factors which determine water quality is a necessary prerequisite in the development of water quality management programs.

2. Reservoir water quality is a function of inflow characteristics, physicochemical and biological processes occurring within the lake, and discharge operations. Inflows provide nutrient loads to the reservoir, the magnitude and quality of which are a function of such watershed characteristics as land use, soils, topography, and runoff patterns. Frequently, high-flow events contribute a major portion of the annual nutrient load (Baxter 1977; Carmack et al. 1979; Kennedy et al. 1981). Physicochemical and biological processes contribute to the temporal and spatial distribution and cycling of chemical constituents once they enter the lake. The timing, magnitude, and manner in which discharges occur will often influence the thermal structure and material budgets of the lake.

3. In many cases, spatial gradients and temporal changes in reservoir water quality characteristics have been observed (Thornton et al. 1980; Kennedy et al. 1982). Advective influences on nutrient transport (Gloss et al. 1980) and material recycling from anoxic sediments (Garber and Hartman 1985; Stauffer 1981; Cooke et al. 1977) can often contribute significantly to phytoplankton productivity, resulting in further heterogeneities in water quality. Reservoir operations, such as pool elevation fluctuation and varied withdrawal depths, can also affect water quality conditions in the lake and discharge. The existence of temporal and spatial variability in reservoir water quality suggests the need for well-designed management programs that consider site-specific factors determining water quality.

4. The US Army Engineer District, Baltimore (NAB), currently maintains and operates five projects in northern Pennsylvania and south-central New York. While their primary purpose is flood control, these projects also provide a variety of other water-based benefits. Optimal use of these benefits will require improved understanding of factors influencing water quality and the development of sound management strategies based on this understanding. Objectives addressed in this study were to (a) compile and evaluate existing water quality data for these projects, (b) evaluate sampling strategies and needs, and (c) offer recommendations for future studies directed at the establishment of management strategies.

PART II: SITE DESCRIPTIONS

5. The five projects considered in this study are located in the watershed of the North Branch of the Susquehanna River in south-central New York and north-central Pennsylvania (Figure 1). Whitney Point and East Sidney Lakes, both of which are located in New York, were completed in 1942 and 1950, respectively. Tioga-Hammond and Cowanesque Lakes, completed in 1978 and 1980, respectively, are located in Pennsylvania. Because of highly acid inflows to Tioga Lake and more alkaline inflows to Hammond Lake, the two are linked by a connecting channel to provide for water quality control through dilution and neutralization. While operated primarily for flood control, all five projects provide multiple recreation uses. Physical characteristics of the five projects are presented in Table 1.

6. All five projects are located in the Northern Appalachian Plateau and Uplands Ecoregion (Omernik 1987). This ecoregion is characterized by the presence of northern hardwood forests and Inceptisol soils. Topography, which is similar throughout the study area, ranges from gently rolling hills to deep valleys with moderately steep side slopes. Dairy operations and associated agriculture are the predominant land use in the area with woodlots occupying areas unsuitable for cultivation or pasture. Numerous strip-mining operations exist in the watershed of Tioga Lake. Although many small towns are located in the area, major urban areas are not present in the watersheds.

7. The water quality of impounded waters reflects the influence of land use and runoff patterns in the watershed of each project. Inflows to Tioga Lake are highly acidic due to strip-mining operations in the watershed. East Sidney, Whitney Point, Cowanesque and Hammond Lakes receive high nutrient loads as a result of phosphorus- and nitrogen-enriched runoff from dairy operations and agricultural lands. High nutrient loads stimulate phytoplankton production which often results in nuisance algal blooms during summer stratification. Organic loads, as a result of inflows and increased in-lake production, contribute to oxygen depletion in hypolimnia during stratification. Hypolimnetic oxygen depletion, in turn, contributes to the mobilization of nutrients and metals from sediments; this further exacerbates adverse water quality conditions.

8. Efforts to ameliorate adverse water quality conditions at Tioga and Hammond Lakes were provided for in the original design for these projects.

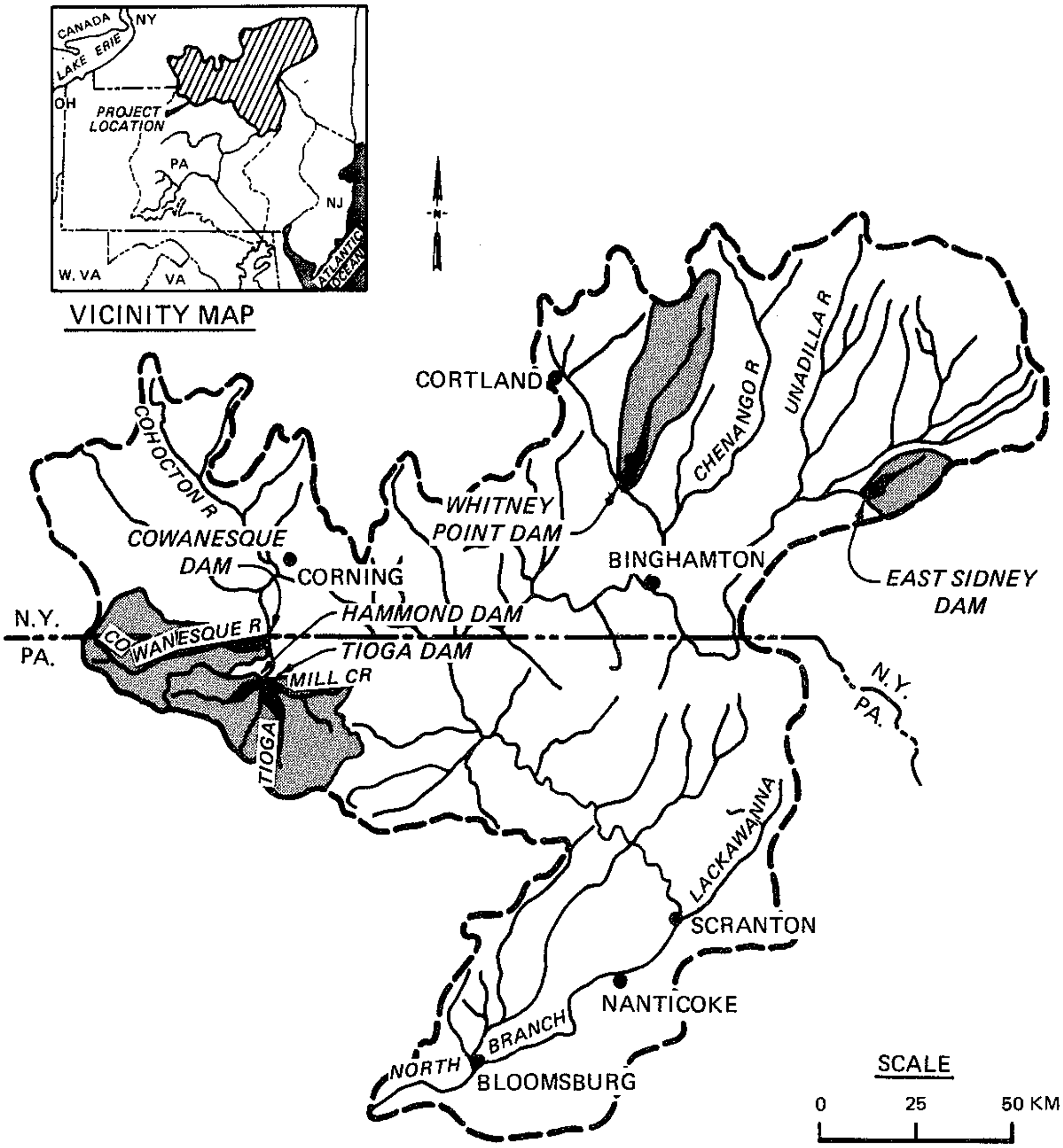

Figure 1. Locations of Tioga, Hammond, Cowanesque, Whitney Point, and East Sidney Lakes

A connecting channel allows the mixing of water from Hammond Lake, which is moderately alkaline, with acidic water from Tioga Lake to produce acceptable conditions in the outflow (US Army Corps of Engineers 1987; Dortch 1976). Additional improvements in water quality is accomplished via selective withdrawal. Currently, only Cowanesque and Tioga Lakes have selective withdrawal

Table 1

Project Physical Characteristics

Characteristic	Value	
	Summer Pool	Winter Pool
East Sidney Lake		
Pool Surface Elevation (meters, NGVD)	350.5	347.5
Drainage Area at Dam (square kilometers)	264	264
Surface Area (hectares)	85.0	40.0
Drainage Area/Surface Area	311	660
Volume (million cubic meters)	4.13	2.10
Maximum Depth (meters)	15.7	12.7
Mean Depth (meters)	4.9	4.0
Pool Length (kilometers)	4.0	0.0
Shoreline Length (kilometers)	9.7	0.0
Shoreline Development Ratio	2.97	0.0
Average Inflow Rate (cubic meters per second)	4.90	4.90
Hydraulic Residence Time (days)	9.8	5.0
Whitney Point Lake		
Pool Surface Elevation (meters, NGVD)	296.5	294.4
Drainage Area at Dam (square kilometers)	660	660
Surface Area (hectares)	485.6	376.4
Drainage Area/Surface Area	136	175.3
Volume (million cubic meters)	15.42	6.17
Maximum Depth (meters)	7.0	4.9
Mean Depth (meters)	3.2	1.6
Average Inflow Rate (cubic meters per second)	13.03	13.03
Hydraulic Residence Time (days)	13.5	5.4

(Continued)

Table 1 (Concluded)

Characteristic	Value at Normal or Recreation Pool
Cowanesque Lake	
Pool Surface Elevation (meters, NGVD)	318.5
Drainage Area at Dam (square kilometers)	772
Surface Area (hectares)	165.9
Drainage Area/Surface Area	465
Volume (million cubic meters)	8.64
Maximum Depth (meters)	10.7
Mean Depth (meters)	5.2
Average Inflow Rate (cubic meters per second)	8.30
Hydraulic Residence Time (days)	12.1
Tioga Lake	
Pool Surface Elevation (meters, NGVD)	329.5
Drainage Area at Dam (square kilometers)	725
Surface Area (hectares)	190.2
Drainage Area/Surface Area	381
Volume (million cubic meters)	11.7
Maximum Depth (meters)	15.2
Mean Depth (meters)	6.2
Average Inflow Rate (cubic meters per second)	9.37
Hydraulic Residence Time (days)	14.5
Hammond Lake	
Pool Surface Elevation (meters, NGVD)	331.0
Drainage Area at Dam (square kilometers)	316
Surface Area (hectares)	275.2
Drainage Area/Surface Area	115
Volume (million cubic meters)	10.92
Maximum Depth (meters)	11.9
Mean Depth (meters)	4.0
Average Inflow Rate (cubic meters per second)	3.12
Hydraulic Residence Time (days)	40.6

capabilities. Release from Whitney Point, East Sidney, and Hammond Dams is via bottom withdrawal.

9. The outlet structure at Cowanesque contains four intake ports for water quality control and two slide gates for normal and low flow conditions. Present construction activities at Cowanesque Dam will allow raising of the pool for water supply and modification of selective withdrawal capabilities (Holland 1982). The multilevel intake tower at Tioga consists of two service gates, one emergency gate, two low-flow gates, and four water quality intake ports. Minimal outflow from Hammond is provided through the Crooked Creek outlet works, while the majority of the outflow is diverted through the connecting channel to Tioga Lake.

PART III: WATER QUALITY DATA ASSESSMENT

Review of Historical Water Quality Data

10. Data collected by NAB personnel during the period 1974-1987 were summarized as a means of assessing historical water quality conditions and trends. Variables for which data were provided included temperature, dissolved oxygen, ammonia nitrogen, nitrate nitrogen, nitrite nitrogen, and total hydrolyzed phosphorus. Also included for selected dates and stations were iron and calcium carbonate concentrations. Data for many variables for Tioga Lake were not available. An inventory of all data is provided in Appendix A.

11. Locations of stations at which these data were collected are presented in Figures 2 through 5. In general, each of the projects were sampled at multiple stations from headwater to dam. Greatest emphasis was placed on sampling at the deepest, most downstream station. Samples were obtained at selected depths as a means of describing vertical patterns. Temperature and

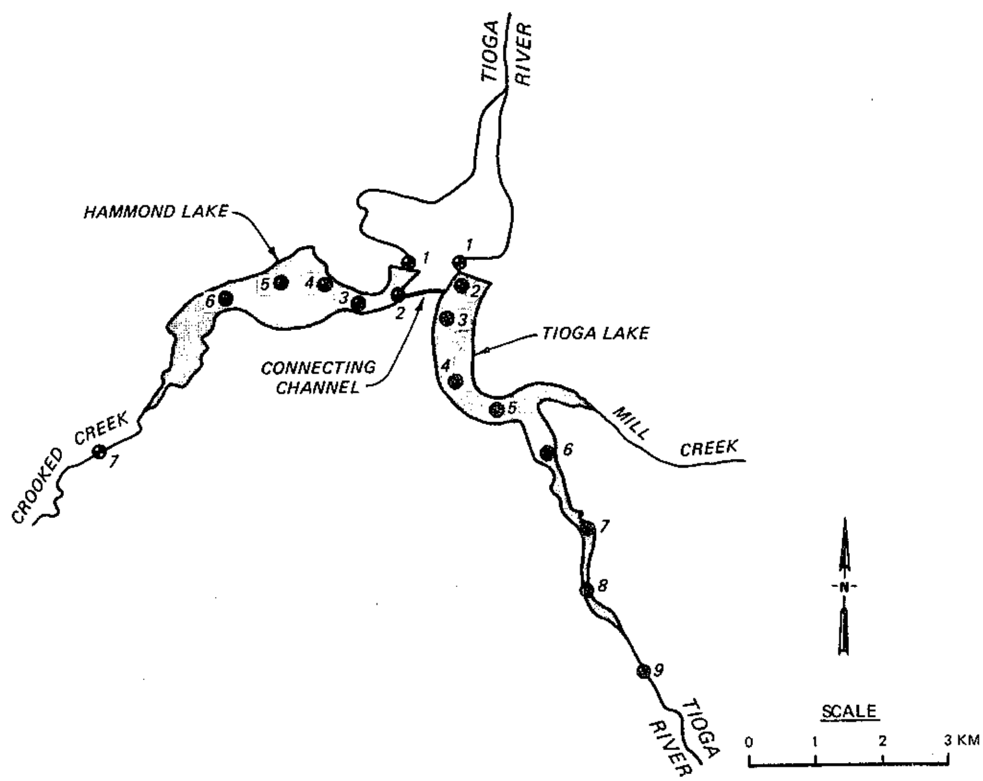

Figure 2. Map indicating the locations of sampling stations in Tioga-Hammond Lakes for which water quality data were available

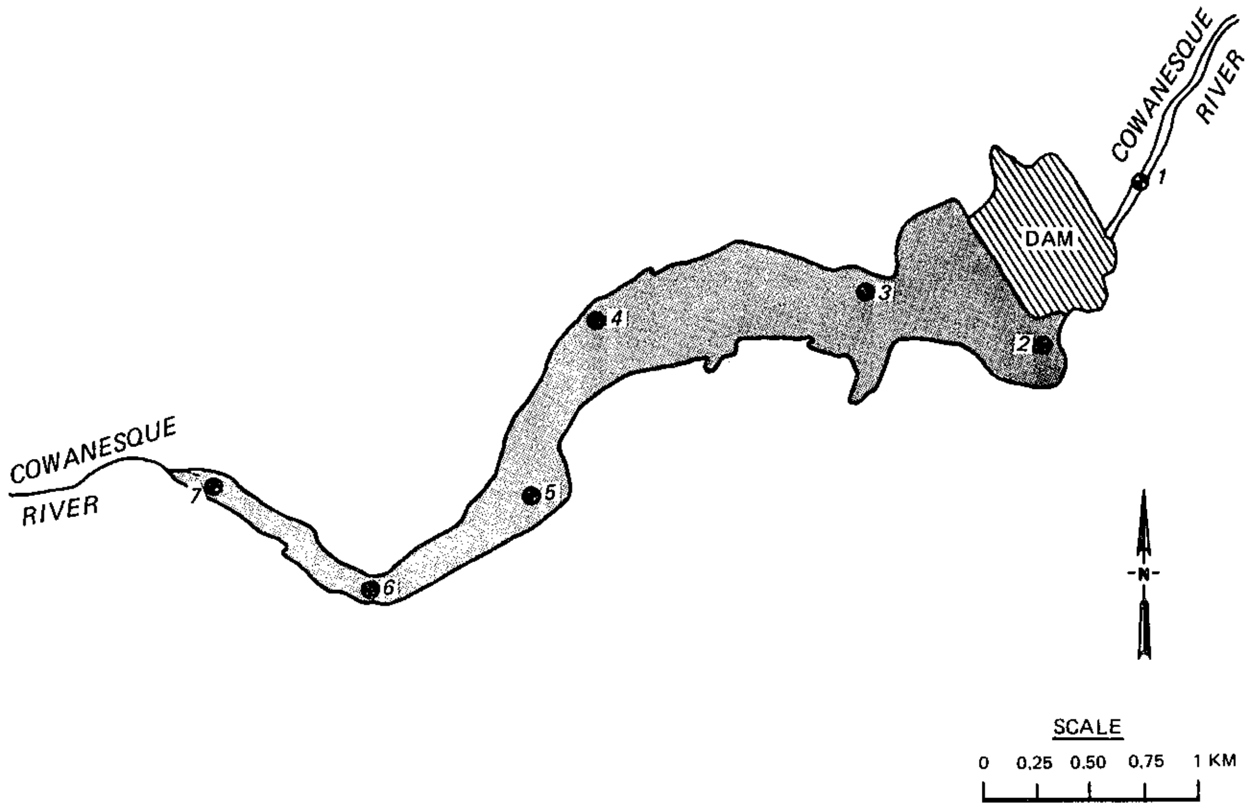

Figure 3. Map indicating the locations of sampling stations in Cowanesque Lake for which water quality data were available

dissolved oxygen data were frequently collected as profiles. Information was often not available for inflows or discharges.

12. Mixed-layer (0-3 m), growing season (May-September) median and area-weighted mean values for total hydrolyzed phosphorus and various forms of soluble inorganic nitrogen are presented for each project in Table 2. Also presented are coefficients of variation (C.V.), which provide a measure of data variability. Area-weighting was based on the spatial distribution of sampling stations and the relative area represented by each. The use of area-weighting allows the calculation of a more realistic mean value when data for multiple stations are available. However, median values provide less biased measures of central tendency when data are skewed.

13. Median total inorganic nitrogen, calculated as the sum of ammonia, nitrate and nitrite, ranged from 359.9 μg N/ℓ for Hammond Lake to 821.5 μg N/ℓ for Cowanesque Lake. The most prevalent nitrogen form was nitrate; as would be expected for surface waters, nitrite represented a minor component of total

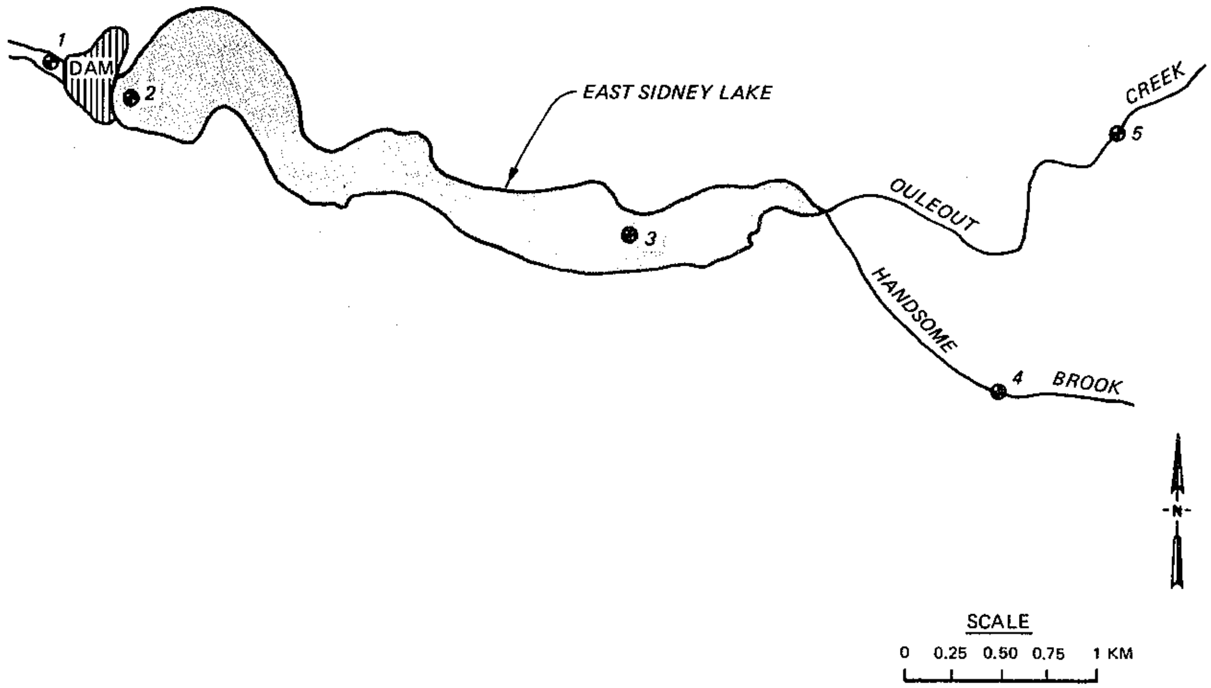

Figure 4. Map indicating the locations of sampling stations in East Sidney Lake for which water quality data were available

inorganic nitrogen. The range of values for total inorganic nitrogen is consistent with values reported for other productive systems. Vollenweider (1968, as reported in Wetzel 1975) indicates that total inorganic nitrogen for epilimnetic waters ranges from 300-650 μg N/ℓ for meso-eutrophic lakes and from 500-1500 μg N/ℓ for eutrophic lakes. The four projects summarized here clearly fall within the meso-eutrophic range with respect to total inorganic nitrogen.

14. Methods used for determination of phosphorus concentrations make interpretation and comparison of data difficult. Acid treatment of samples prior to analysis, as was apparently done, results in the partial conversion of particulate or bound phosphorus to a chemically detectable form. Thus, the concentration estimated (i.e., hydrolyzed phosphorus) is less than total phosphorus yet greater than soluble inorganic phosphorus. Since most indices of lake trophic state are based on total phosphorus, only approximate comparisons can be made. Total phosphorus concentrations in excess of 20 μg P/ℓ in surface waters are generally associated with eutrophic conditions (Wetzel 1975). Data for hydrolyzed phosphorus presented in Table 2 suggest that these lakes

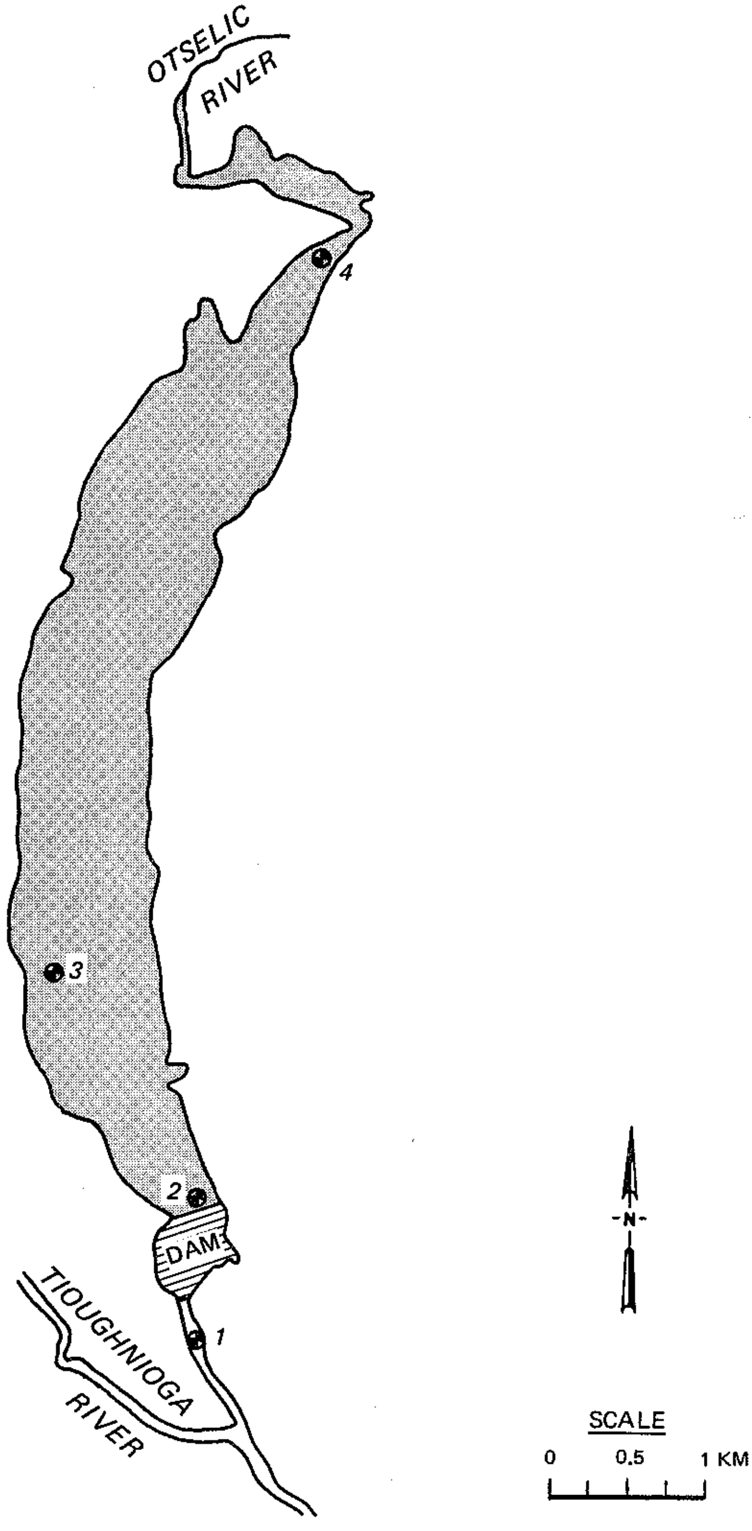

Figure 5. Map indicating the locations of sampling stations in Whitney Point Lake for which water quality data were available

Table 2

Median and Mean Nutrient Concentrations for the Mixed Layer (Depth 0 to 3 m)*

Variable	Median µg/ℓ	Mean µg/ℓ	C.V.	n
	Cowanesque			
Ammonia Nitrogen	218.0	216.4	0.74	21
Nitrite Nitrogen	10.6	9.4	0.50	29
Nitrate Nitrogen	592.9	631.3	0.74	31
Soluble Phosphorus	29.0	47.1	1.06	34
	Hammond			
Ammonia Nitrogen	200.0	268.8	0.91	98
Nitrite Nitrogen	5.7	8.5	1.28	96
Nitrate Nitrogen	154.2	302.8	1.06	97
Soluble Phosphorus	14.6	32.7	1.92	105
	East Sidney			
Ammonia Nitrogen	120.0	240.2	1.01	17
Nitrite Nitrogen	7.0	11.4	1.11	12
Nitrate Nitrogen	400.0	449.1	0.99	15
Soluble Phosphorus	33.0	48.9	1.18	18
	Whitney Point			
Ammonia Nitrogen	160.0	198.1	0.72	13
Nitrite Nitrogen	7.5	19.4	1.46	10
Nitrate Nitrogen	275.0	340.4	0.97	13
Soluble Phosphorus	21.5	34.9	1.18	15

* Based on pooled data for the growing season only (May through September). Values for multiple stations are area-weighted. C.V. is the coefficient of variation and n is the number of individual samples.

can be conservatively considered to be eutrophic due to excessive phosphorus concentrations.

15. Measurements of chlorophyll a concentrations, an indication of algal biomass, were not available. However, discussions with project and NAB personnel indicate the frequent occurrence of excessive, and often severe, algal blooms. Such occurrences would be anticipated based on nutrient concentrations described above.

16. The decomposition of organic material in the hypolimnia of stratified lakes leads to the loss of dissolved oxygen during summer months. This is of particular concern for tailwaters below reservoirs which discharge water

from depths at or below the thermocline. The rate at which dissolved oxygen is lost is often used as a measure of trophic state under the assumption that excessive production of organic material in surface waters leads to increased dissolved oxygen losses in bottom waters. The calculation of this rate (termed the hypolimnetic oxygen depletion rate or HOD) assumes isolation of bottom waters due to density stratification and requires sufficient data to describe changes in dissolved oxygen concentrations from the onset of thermal stratification until the date of minimal concentration. For lakes in which dissolved oxygen concentrations in bottom waters reach a value of zero, the calculation can apply only to the period when dissolved oxygen concentration was non-zero.

17. A review of dissolved oxygen data provided for the five NAB projects identified few sites and occasions when the requirements of the HOD calculation were met. These included 1981 and 1985 for Cowanesque Lake, 1984 for Hammond Lake, and 1977 and 1981 for East Sidney. It should be noted that low thermal stability in the lakes during summer months, as will be discussed more fully below, resulted in complete or partial mixing on several occasions. This violates the assumption of the calculation since such events would introduce oxygen to deeper strata. As an example, data for two sampling periods in 1983 at Whitney Point Lake are presented in Figure 6. In late June a well-established thermocline was located between 4 and 6 meters of depth and near-anoxic conditions were observed below the thermocline. However, by mid-August bottom waters had warmed by approximately 6 degrees C and a less pronounced thermocline was located between the surface and a depth of 3 meters. Also, the concentration of dissolved oxygen, while still well below saturation, was markedly increased. The source of additional oxygen to bottom waters was apparently the mixing of well-oxygenated surface waters to deeper depths.

18. HOD rates for the above mentioned years at Cowanesque, Hammond, and East Sidney Lakes were calculated using the computer program PROFILE (Walker 1987). Values ranged from 0.08 to 0.59 mg/cm^2/month. Accepted ranges for oligotrophic and eutrophic lakes are 0.1 to 1.0 and greater than 1.5 mg/cm^2/month, respectively. Clearly the calculated rates are not consistent with other measures of trophic state for these projects. The fact that withdrawals of water are made from the meta- or hypolimnia and that mixing occurs frequently suggests that HOD rates, unless calculated over short

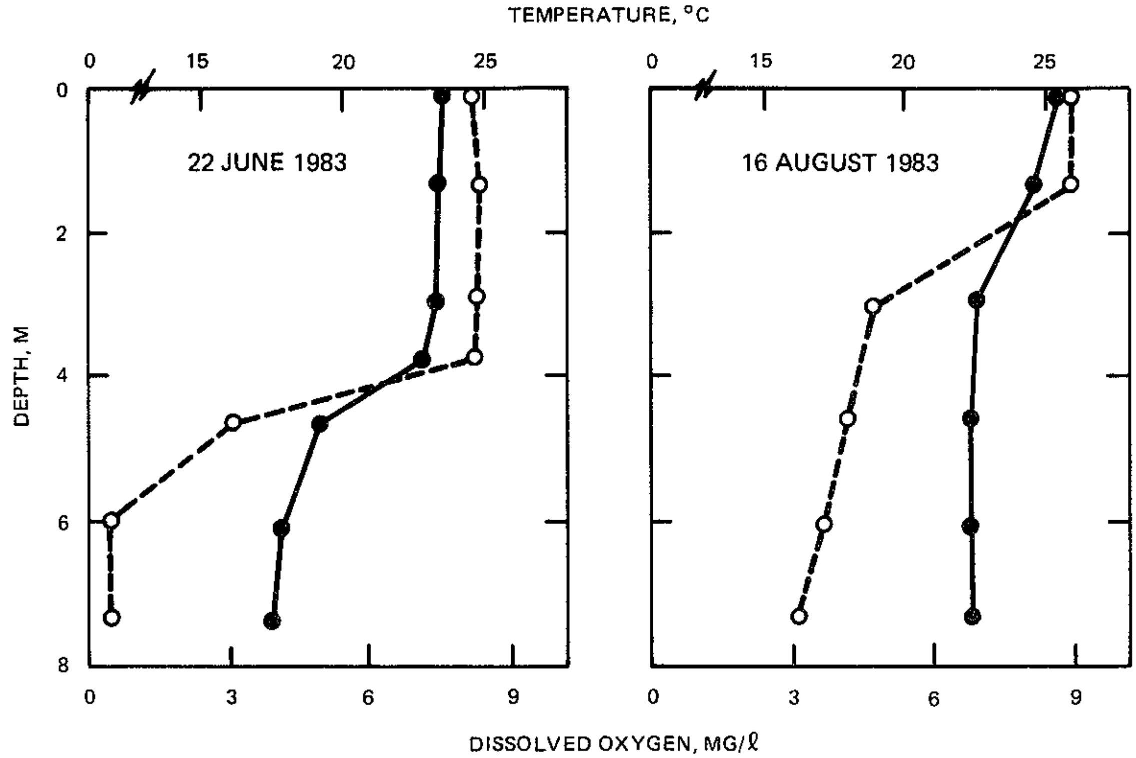

Figure 6. Temperature (solid line) and dissolved oxygen concentration (broken line) profiles for Whitney Point Lake during the summer stratified period in 1983

intervals of time when mixing is minimal, will be of little value in assessing water quality characteristics in these projects.

Thermal Stability

19. Weather-related mixing events have been shown to act as an important mechanism for epilimnetic nutrient loading in lakes during the summer when external loadings can be expected to be minimal. Stauffer and Lee (1973) demonstrated that cold front passage and wind stress resulted in thermocline migration in Lake Mendota. These migrations increased epilimnetic nutrient concentrations and were followed by increased chlorophyll concentrations. Stefan and Hanson (1981) observed significant phosphorus transport from anoxic hypolimnia to epilimnia associated with mixing in five shallow lakes in south-central Minnesota. Phosphorus transport was followed by intense algal blooms in these lakes. Kortmann et al. (1982) reported the occurrence of algal

blooms in response to the thermocline descending below the anaerobic interface in Lake Waramaug.

20. The influence of weather-induced mixing events has not been as well studied in reservoirs as in lakes. A comparison of 309 natural lakes and 107 Corps of Engineer reservoirs included in the 1972-75 USEPA National Eutrophication Survey indicated that reservoirs are generally larger, deeper, morphologically more complex, and have shorter hydraulic residence times than natural lakes (Thornton et al. 1982). These differences coupled with the importance of advective and unidirectional transport in reservoirs (Baxter 1977), and the presence of either selective or bottom withdrawal may alter a reservoir's thermal regime in such a way as to make it more susceptible to mixing events.

21. Thermal stability, which is equivalent to the amount of work required to mix the entire volume of the lake to a uniform temperature (Birge 1915), can be thought of as a measure of a lake's resistance to mixing. Given hypsographic information and temperature profiles, thermal stability (S, $gm\text{-}cm/cm^2$) can be calculated from the integral given by Hutchinson (1957):

$$S = A_o^{-1} \int_o^{z_m} - [(z - z_g) A_z (1 - p_z)] \, dz$$

where

z = depth, m

z_m = maximum depth

z_g = lake's center of gravity

A_o = lake surface area, m

A_z = area enclosed at depth z

p_z = density of water at depth z

The lake's center of gravity (zg) is:

$$zg = V^{-1} \int_o^{z_m} z A_z \, dz$$

where V is the lake volume, in meters.

Lake heat content, the store of heat that the lake could impart to its surroundings on cooling to 0 degrees C, is defined as:

$$H_L = cT_LV$$

where

c = specific heat of water, 10^3 kcal deg^{-1} m^{-3}

T_L = volume-weighted mean lake temperature

H_L = lake heat content, 10^3 kcal

The volume-weighted mean lake temperature is defined as:

$$T_L = V^{-1} \int T_z V_z \, dz$$

where

T_z = temperature at depth z

V_z = stratum volume at depth z

22. Thermal stabilities and heat contents in Cowanesque, East Sidney, Hammond, and Whitney Point calculated from summer (June through August) temperature profiles are presented in Figure 7. Summer stability is highly variable in these impoundments as shown by the coefficients of variation for mean summer stability (Table 3). This variability is not a result of combining values across a number of years since heat contents calculated over the same time period show little variability. The relative constancy of heat content and the highly variable stability suggest these reservoirs are subjected to rather frequent episodes of wind-driven mixing.

23. Two factors act to make these lakes susceptible to mixing during the summer. First, mean summer hypolimnetic temperatures are relatively high (Table 4). High hypolimnetic temperatures reduce density differences between the epilimnion and the hypolimnion which, in turn, reduces resistance to mixing or stability. Figure 6, presented earlier, provides an example of the considerable hypolimnetic warming that occurs in these projects.

24. Secondly, the hypsography of these reservoirs (Figure 8) is an important determinant of their response to wind. The mean summer stability is directly related to the surface-to-volume ratio in these reservoirs. The two least stable lakes, Hammond and Whitney Point, expose a large surface area to

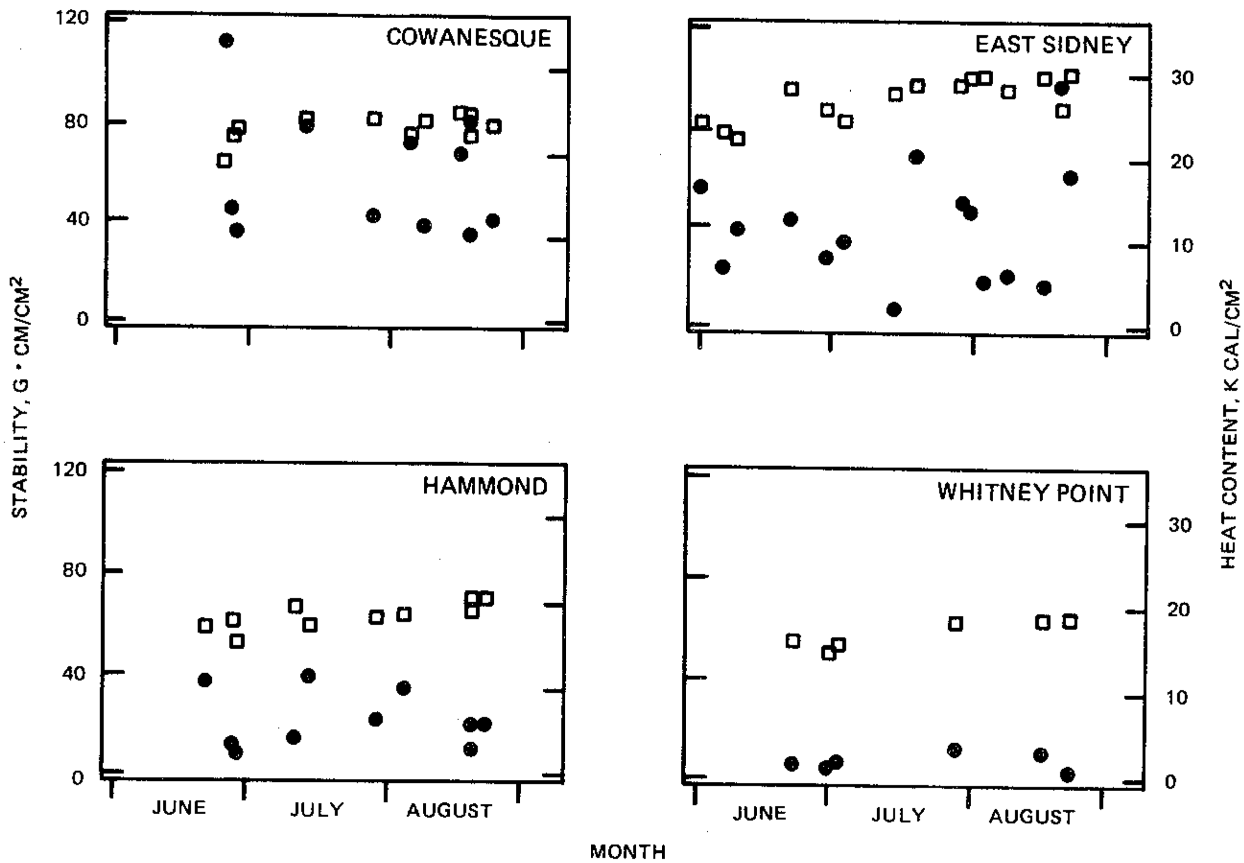

Figure 7. Changes in thermal stability (circles) and heat content (squares) during summer months in Cowanesque, East Sidney, Hammond, and Whitney Point Lakes

Table 3

Summer (June through August) Heat Content and Stability

	Heat Content cal/cm^2		Stability gm-cm/cm^2	
Reservoir	Mean	CV	Mean	CV
Cowanesque	22,426	7.1	57.80	43.5
East Sidney	28,378	7.3	43.90	58.4
Hammond	17,769	8.0	19.81	57.3
Whitney Point	17,410	8.5	8.66	35.8

Table 4

Summer (June through August) Hypolimnetic Temperatures

Reservoir	Depth	Hypolimnetic Temperature Mean	s.d.
Cowanesque	>8	16.80	1.84
East Sidney	>10	18.35	1.78
Hammond	>6	17.91	2.84
Whitney Point	>6	19.70	2.22

the wind. This, coupled with relatively shallow mean depth makes them particularly susceptible to wind mixing.

25. The considerable variability in thermal stability and the relatively high hypolimnetic temperatures suggests that summer mixing events may be a factor in material cycling and the development of algal blooms in these reservoirs. Hypolimnetic temperature in lakes with surface outflow is determined by the water temperature when the lake first stratifies in late spring. After the onset of stratification, hypolimnetic temperatures are relatively constant until fall turnover. In temperate lakes, hypolimnetic temperatures may range from 4 to 10 degrees C depending on how long the lake circulates prior to stratification. Low hypolimnetic temperatures imply a large density gradient between the warm surface waters and the cooler hypolimnion. It is this density gradient that imparts the considerable resistance to wind-driven mixing. In stable lakes, the thermocline acts as an effective barrier to the transport of nutrients from the hypolimnion to the epilimnion. In these systems, wind mixing will only act on the epilimnion and will result in only a slight depression of the thermocline.

26. Reservoirs with low-level or bottom releases may be, by the nature of their operation, less stable and, therefore, more susceptible to mixing events which transport nutrients across the thermocline. Low-level releases from reservoirs cause the loss of cold water from the hypolimnion which results in considerable hypolimnetic warming as cold water is replaced by relatively warm water from above. Higher hypolimnetic temperatures result in a reduced density gradient between surface and bottom and, in turn, lower resistance to mixing. Hypolimnetic heating and mixing act in a positive

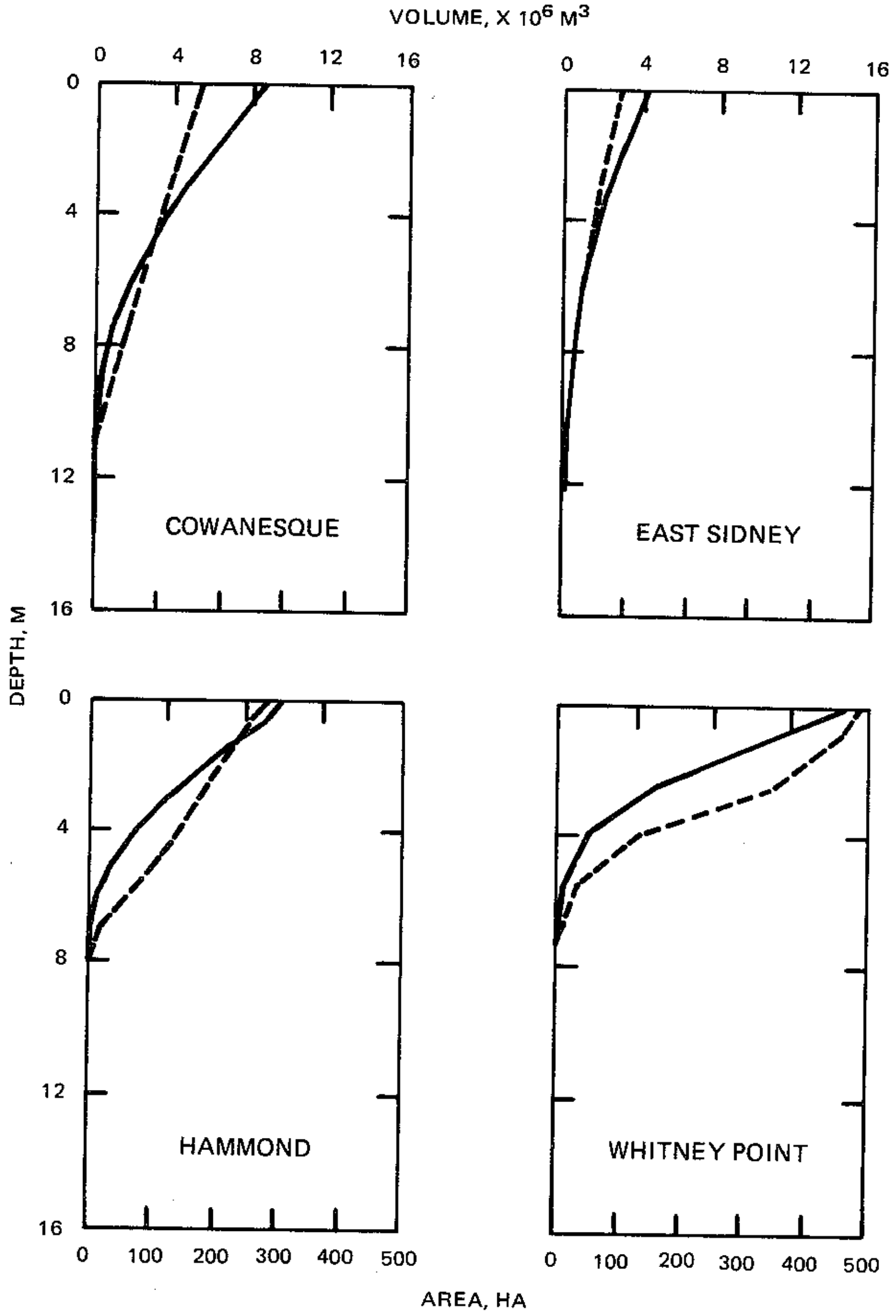

Figure 8. Volume (solid line) and area (broken line) as a function of depth (at normal summer pool elevation) for Cowanesque, East Sidney, Hammond, and Whitney Point Lakes

feedback loop. Hypolimnetic warming lowers the system's resistance to mixing and, when a mixing event occurs, hypolimnetic temperature increases further as epilimnetic water is introduced by mixing. As a result, resistance to mixing is reduced by the mixing event.

27. Eau Galle Lake, a eutrophic reservoir in west central Wisconsin, has been shown to function in the manner described above (Gaugush 1984). This reservoir has a low-level release and hypolimnetic temperatures reach 18 degrees C by August. Summers are marked by a series of mixing events which impact epilimnetic water quality in one of two ways, depending on the magnitude of the mixing event. Large scale mixes result in oxygenation of the entire hypolimnion and reductions in phosphorus, nitrogen, and chlorophyll concentrations. These mixes also result in increases in hypolimnetic temperature. Small scale mixes do not affect the hypolimnion and result in significant loading of nitrogen and phosphorus to the epilimnion. In response to increased nutrient concentrations, algal blooms follow the small-scale events. Mixing events act as a primary controlling factor in the timing and magnitude of algal blooms in Eau Galle Lake. Given the available data, it is not possible to determine the relationship between thermal stability and algal productivity in the NAB reservoirs, but the data suggest that these systems would function in a similar manner.

28. It is possible to examine the effect of hypolimnetic heating on thermal stability by examining the stability that results when lower hypolimnetic temperatures are inserted into the observed data. This analysis was performed for East Sidney and Whitney Point because, in these lakes, it might be possible to lower hypolimnetic temperatures by altering release schedules or by the addition of a skimming weir. Lowering the hypolimnetic temperature in East Sidney from a mean of 18.35 C to a temperature between 10 and 14 C produces a 16- to 28-percent increase in stability. In Whitney Point, lowering the hypolimnetic temperature to between 10 and 14 C produces an increase in stability of 47 to 69 percent (Table 5). While lower hypolimnetic temperatures in Whitney Point produce a much larger change in stability, the actual values of stability are still relatively low. The morphometry of Whitney Point may preclude any real benefit from lowering hypolimnetic temperatures. These changes in stability must be considered as rough estimates because of the arbitrary manner in which lower hypolimnetic temperatures were inserted into the data. Better estimates could be derived from the output of CE-THERM-R1 (see Environmental Laboratory 1986), a numerical simulation model which can predict changes in thermal stratification resulting from changes in structure or operation.

Table 5

Increased Stability in East Sidney and Whitney Point Resulting from Reduced Hypolimnetic Temperatures

Reservoir	Hypolimnetic Temperature	Stability	
		$gm\text{-}cm/cm^2$	% change
East Sidney	10	56.15	27.9
	12	53.88	22.7
	14	51.21	16.4
Whitney Point	10	14.61	68.7
	12	13.72	58.4
	14	12.75	47.2

Nutrient Loading Estimates

29. Insufficient nutrient concentration and stream discharge data were available to directly estimate the loading of nutrients to each of the five lakes. Instead, three indirect methods for estimating nutrient loads were employed; comparison with lakes in the same geographic region having similar watersheds, use of values reported in the literature for similar land uses, and extrapolation of the direct estimate of nutrient loading at a single station for which appropriate data were available.

30. A search of data complied during the National Eutrophication Survey (NES, US Environmental Protection Agency 1975) led to the identification of nine lakes in central New York for which loading estimates were available. Although an attempt was made to locate similar data for lakes or reservoirs in Tioga, Potter, Lycoming, Sullivan, and Bradford Counties in northcentral Pennsylvania, none were found. New York lakes included: Swinging Bridge Reservoir, Swan Lake, and Lake Huntington in Sullivan County; Cannonsville Reservoir in Delaware County; Cross Lake in Onodaga County; Cayuga Lake in Seneca and Cayuga Counties; Goodyear Lake in Otsego County and; Keuka Lake in Yates County. Landuses in the watersheds of these lakes include undisturbed forest, old fields and pasture, row crop farming, dairy and beef farming, and urban and residential utilization.

31. Data for a total of 43 tributary streams, draining subwatersheds varying in area from 0.8 to 7,907.3 km^2, were evaluated to determine patterns

in point and non-point source nutrient export for the watersheds of these nine lakes. While export coefficients for nitrogen and phosphorus varied greatly between subwatersheds (nitrogen export ranged from 246 to 1,351 kg N/km^2/yr while phosphorus export ranged from 4 to 105 kg P/km^2/yr), regression analysis indicated no significant relation between either nitrogen or phosphorus export rate and drainage area. Therefore, data for all streams were pooled in the final analysis. Mean and quartile values for non-point and non-point plus point source nitrogen and phosphorus export coefficients are presented in Table 6.

Table 6

Nitrogen and Phosphorus Export Coefficient Values

Item	Quartile Value 25%	50%	75%	Mean
	Non-Point Source Only			
P-Export (kg/km^2/yr)	9.0	13.0	27.0	23.7
N-Export (kg/km^2/yr)	389	521	710	556.3
	Non-Point Plus Point Source			
P-Export (kg/km^2/yr)	15.2	35.8	52.8	34.8
N-Export (kg/km^2/yr)	562	724	848	712.8

32. Beaulac and Reckhow (1982) compiled nutrient export coefficient data for various land uses. These values vary widely between and among land uses. For example, median phosphorus export ranges from approximately 0.2 kg P/km^2/yr for forested watersheds to approximately 250 kg P/km^2/yr for feedlots and manure storages. Respective values for nitrogen export are approximately 2.5 and 2,900 kg N/km^2/yr. The great variability in these values and the lack of detailed quantitative information on land use patterns suggest that the use of these coefficients is of limited value in estimating loads to the five lakes considered here.

33. The locations and data for recent US Geological Survey discharge gaging and water quality sampling stations on tributary streams draining the five reservoir watersheds were obtained from Water Resources Data Reports for New York and Pennsylvania. These reports are published annually for each

state. While paired observations of various nutrient concentrations and instantaneous flow were available for four stations, records of average daily flows were not, thus precluding any detailed evaluation of flux or annual mass discharge rates at these stations. However, daily flow rates were available for a gage at Mansfield, Pa., which is located upstream of the water quality sampling gage at Lambs Creek on the Tioga River. For periods of data overlap, comparisons of flows between the two gages allowed the routing of flows from Mansfield to Lambs Creek using regression analysis. The resulting slope (1.34) was applied to average daily flows observed at the Mansfield gage during the period 1976-84 to create a flow record at the Lambs Creek site. These data were then pooled to calculate average daily flow for each month. The resulting flows approximate average discharge during an "average" year.

34. Utilizing these data and the computer program FLUX (Walker 1987), flux rates at Lambs Creek on the Tioga River were estimated. This was accomplished by establishing a relation between nutrient concentration and instantaneous flow, and then using that relation and the daily flow record to generate an annual estimate of total mass flux. This analysis was performed for total phosphorus, total Kjeldahl nitrogen, and nitrate nitrogen; the latter two were summed to yield an estimate of total nitrogen flux. These values were converted to export coefficients by dividing annual mass flux, expressed in kg/yr, by the area of the Tioga River watershed above Lambs Creek ($482\ km^2$). The resulting values for total phosphorus and total nitrogen were $48.05\ kg\ P/km^2/yr$ and $481.3\ kg\ N/km^2/yr$, respectively.

35. Nutrient loading rates, expressed on a total mass (kg/yr) and an areal basis ($gm/m^2/yr$), were computed for each of the five projects using export coefficient information obtained from NES-sampled streams and from the Lambs Creek gage on the Tioga River. In each case, mass load was computed as the product of project watershed area and export coefficient. Areal load was computed by dividing mass load by the average annual pool surface area. Values for mass and areal phosphorus and nitrogen loading rates are presented in Table 7. While the manner in which they were computed precludes rigorous statistical comparison, the similarity in values computed by each method suggests that export coefficients obtained from the NES-sampled watersheds can be used to estimate loads. However, it must be assumed that data obtained for the Lambs Creek gage is representative of the region and that watersheds sampled by the NES are similar to those of the five projects considered here.

Table 7

Comparison of Mass and Areal Phosphorus Loads Based on Two Methods of Estimation

Load	Estimation Method* 1	3
	Whitney Point	
Phosphorus:		
Mass (kg/yr)	23,628	31,713
Areal (gm/m^2/yr)	5.5	7.4
Nitrogen:		
Mass (kg/yr)	477,840	317,658
Areal (gm/m^2/yr)	110.9	73.7
	East Sidney	
Phosphorus:		
Mass (kg/yr)	9,451	12,685
Areal (gm/m^2/yr)	15.1	20.3
Nitrogen:		
Mass (kg/yr)	191,136	127,063
Areal (gm/m^2/yr)	305.8	203.3
	Hammond	
Phosphorus:		
Mass (kg/yr)	13,481	15,184
Areal (gm/m^2/yr)	4.9	5.5
Nitrogen:		
Mass (kg/yr)	228,784	152,091
Areal (gm/m^2/yr)	83.1	55.3
	Tioga	
Phosphorus:		
Mass (kg/yr)	25,955	34,836
Areal (gm/m^2/yr)	13.6	18.3
Nitrogen:		
Mass (kg/yr)	524,900	348,943
Areal (gm/m^2/yr)	276.0	183.5

(Continued)

* Estimation Method 1 provides values based on median export coefficients for 43 streams sampled by the NES. Estimation Method 3 computes loads based on data obtained for the gage located at Lambs Creek on the Tioga River.

Table 7 (Concluded)

Load	Estimation Method 1	Estimation Method 3
	Cowanesque	
Phosphorus:		
Mass (kg/yr)	27,638	37,095
Areal ($gm/m^2/yr$)	16.7	22.4
Nitrogen:		
Mass (kg/yr)	558,928	371,564
Areal ($gm/m^2/yr$)	336.9	224.0

36. As a preliminary evaluation of the influence of nutrient loading on trophic state (as measured by average in-pool nutrient concentration) and the potential benefits to be gained through nutrient loading reductions, phosphorus and water loading rates were plotted (Figure 9). Phosphorus loading was expressed as an areal rate ($gm/m^2/yr$), while water load was calculated as mean depth divided by water residence time yielding units of meters per year. The loci of observations for each of the five lakes approximates the expected in-pool phosphorus concentration given the observed phosphorus loading rate and the modifying influence of flushing rate. Reductions in expected in-pool phosphorus concentrations would be realized following either reductions in phosphorus loading rate or increases in water loading rate.

37. Data plotted in Figure 9 clearly indicate that, under current conditions, all five of the NAB projects would be expected to exhibit excessive phosphorus concentrations. The elevation of points above a line demarking a "dangerous limit" to loading provide a frame of reference for the degree of this excess. Loads above the dangerous limit would result in in-pool phosphorus concentrations exceeding 20 μg P/ℓ, a value considered to promote excessive algal growth (see Reckhow and Chapra 1983).

38. Efforts to employ the computer program BATHTUB (Walker 1987) to evaluate lake responses to varied nutrient loading rates, as proposed in the Scope of Work, were not attempted since data limitations would have precluded meaningful results. The program does, however, offer opportunities to evaluate alternative management approaches should appropriate data be collected in the future.

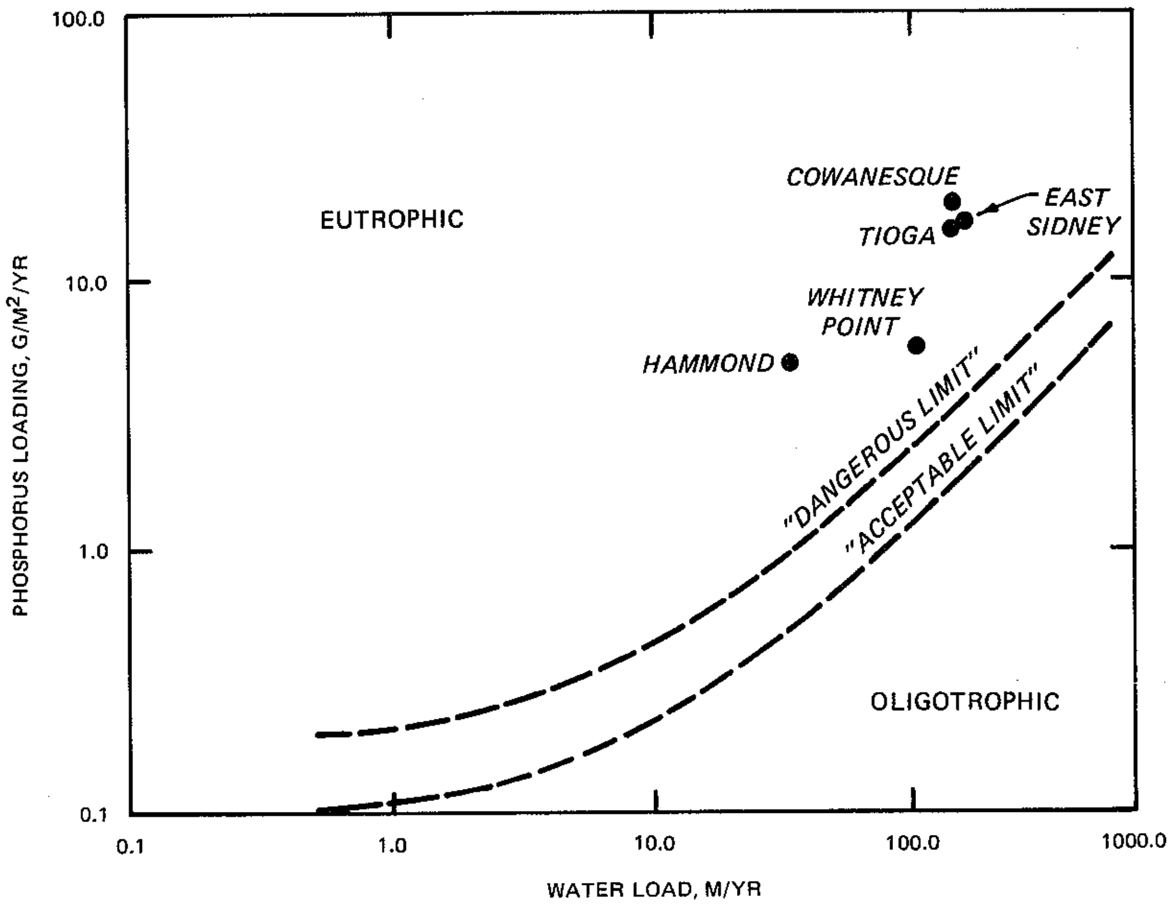

Figure 9. Areal phosphorus and annual water loading relationships for Cowanesque, Tioga, Hammond, East Sidney, and Whitney Point Lakes. See text for explanation

Intensive Water Quality Sampling

39. Intensive water quality sampling was conducted at each of the five projects during late August 1987, to quantify spatial heterogenieties within each lake and to characterize general water quality conditions. Initially, four to seven stations at each lake were selected to define longitudinal and lateral variabilities in water quality. However, due to unseasonably cool temperatures and wind-induced mixing, the lakes were almost completely mixed at the time of sampling and assessment of spatial heterogeneities was not possible. Consequently, the number of stations and depths sampled in each lake was reduced and the major sampling objective was modified to allow an overall assessment of general limnological conditions at each lake.

40. Sampling stations at each lake are depicted in Figure 10 through 13. In-situ measurements were conducted at 1-m intervals at each station for temperature, dissolved oxygen, specific conductance and pH using a Hydrolab Surveyor II System (Hydrolab Corp., Austin, TX). Samples for chemical analyses were collected at the surface, one meter from the bottom and at intermediate depths as necessary (based on in-situ measurements) to adequately describe chemical profiles at each station. Chemical analysis included alkalinity, turbidity, total iron, total manganese, total phosphorus and total nitrogen. Alkalinity analyses (titration to pH 5.1) and turbidity analyses using a laboratory turbidimeter (Model 2100A, Hach Chemical Co., Loveland, CO) were conducted in the field within eight hours of sample collection. Total iron and

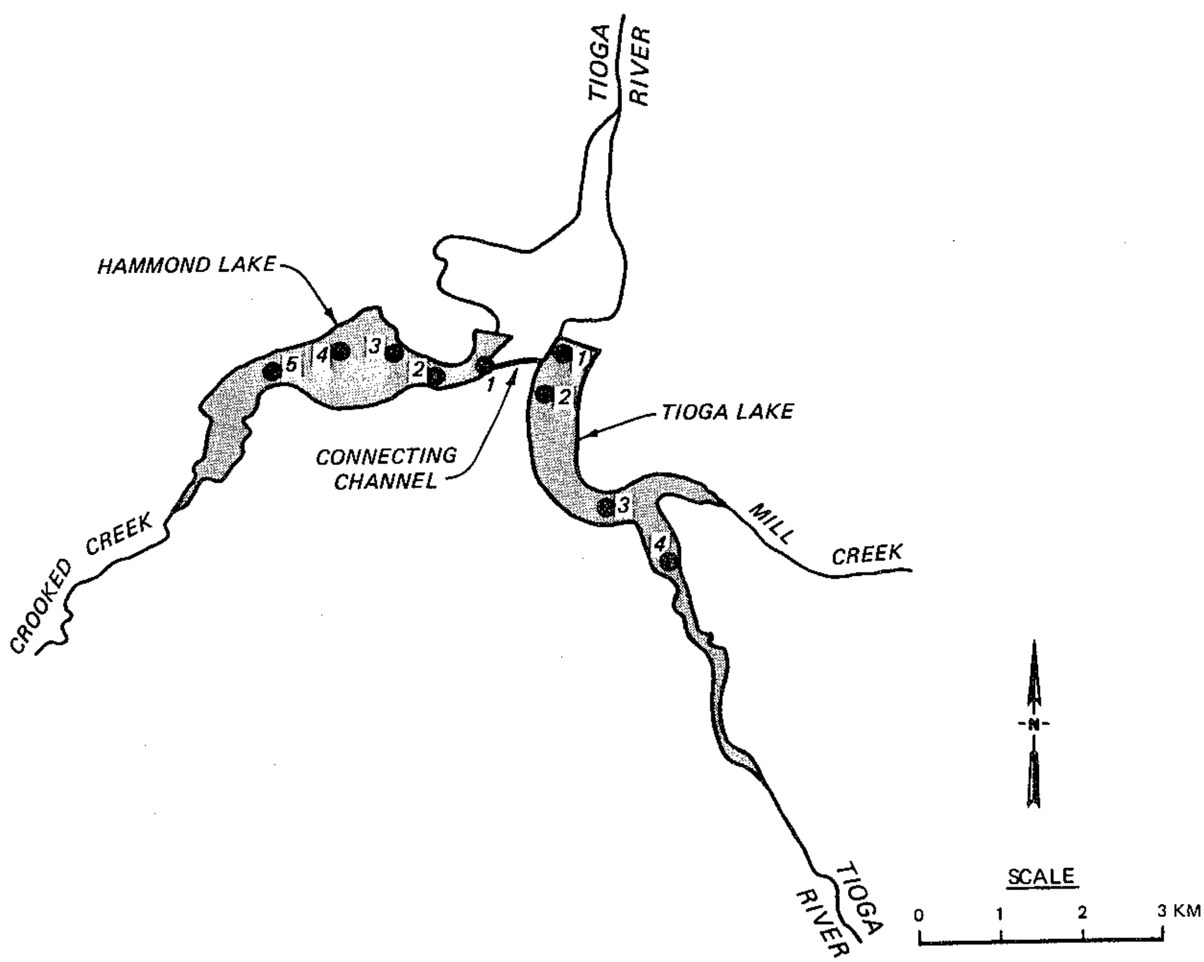

Figure 10. Locations of stations in Tioga-Hammond Lakes sampled during August 1987

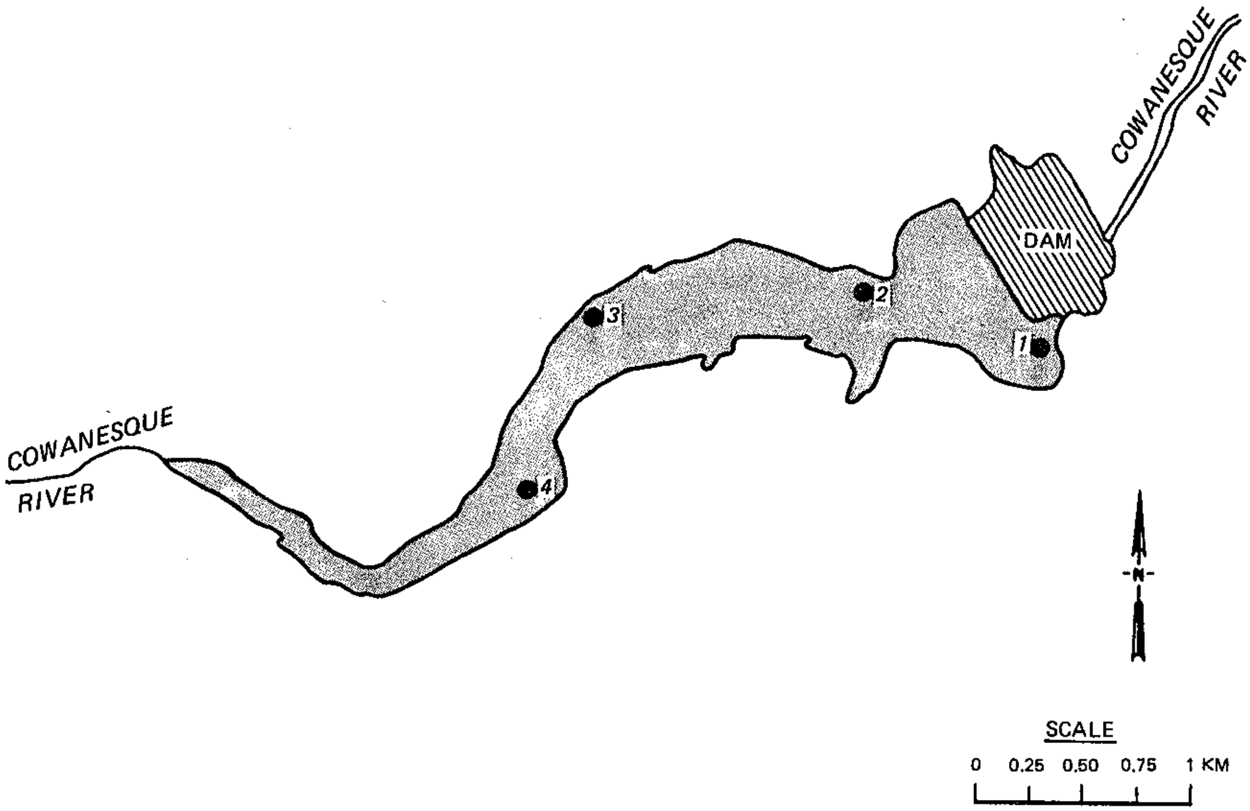

Figure 11. Locations of stations in Cowanesque Lake sampled during August 1987

manganese samples were digested with a hydrochloric/nitric acid reflux procedure and analyzed with an atomic adsorption spectrophotometer (Model 4000, Bodenseewerk Perkin-Elmer and Company, Uberlingen, West Germany) employing an air/acetylene carrier. Determination of total phosphorus employed a persulfate oxidation digestion of the sample followed by automated colorimetric (880 nm) analysis using the ascorbic acid reduction method (American Public Health Association 1980). Automated colorimetric determinations were conducted with a Technicon AAII System (Technicon Industrial Systems, Tarrytown, NY). Due to contamination during digestion, total nitrogen analyses were not conducted.

41. Samples for chlorophyll analysis and phytoplankton enumeration were collected at each station with an integrating sampler at a depth equal to twice the Secchi depth. Samples for chlorophyll analysis were filtered within four hours of collection and the filters were frozen until analysis. Chlorophyll determinations were conducted using a dimethylformamide extraction procedure (Hains 1985) and spectrophotometric determination. Samples for

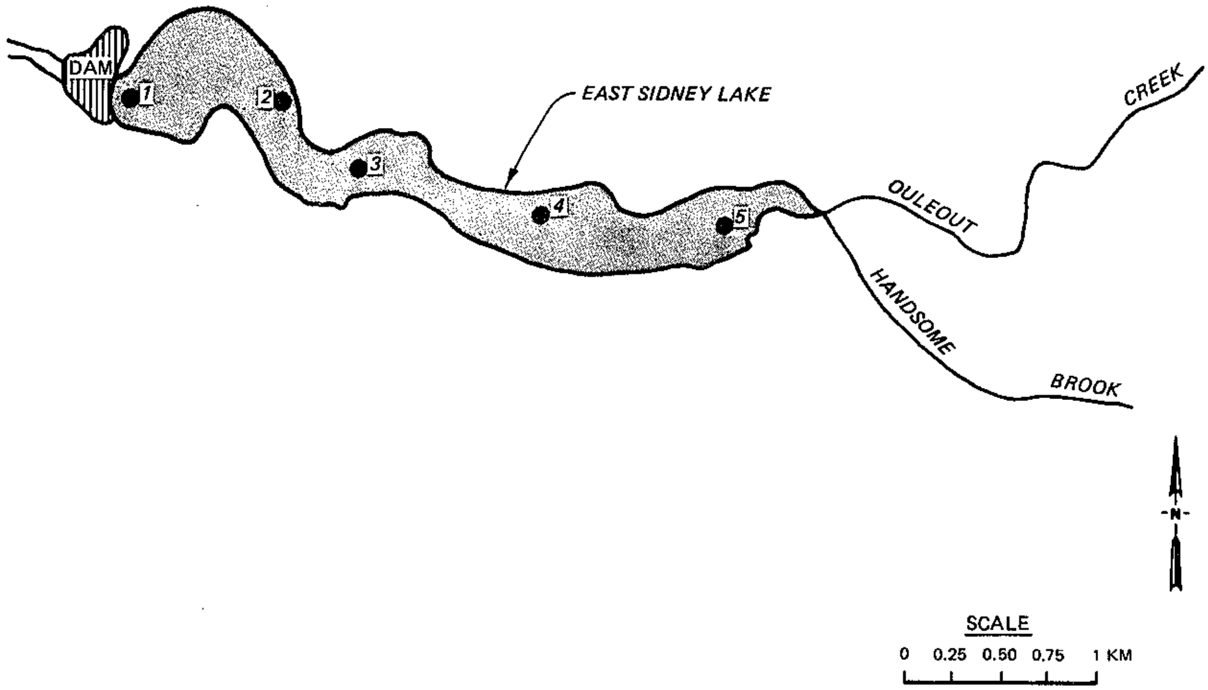

Figure 12. Locations of stations in East Sidney Lake sampled during August 1987

phytoplankton enumeration were preserved with Lugol's solution (1:100 by volume).

42. Temperature and dissolved oxygen profiles at the deepest station in Tioga Lake typify well-mixed conditions present throughout much of each lake (Figure 14). However, complete destratification had not occurred immediately upstream of the dam at Cowanesque and East Sidney Lakes (Figure 15). Vertical gradients in chemical profiles were observed primarily at stations where destratification had not occurred. Most pronounced were increased concentrations of total iron, manganese and phosphorus in anoxic bottom waters in Cowanesque Lake. A complete listing of in-situ and chemical data is provided in Appendix B.

43. Mean concentrations of chemical constituents for the upper strata (depth <6 m) of each lake are reported in Table 8. Mean concentrations of total manganese, alkalinity and chlorophyll a were the most varied among the lakes. Total manganese mean concentrations ranged from 0.08 mg/ℓ in East Sidney to 1.46 mg/ℓ in Tioga. Alkalinity (as $CaCO_3$/ℓ) ranged from 20.5 mg/ℓ

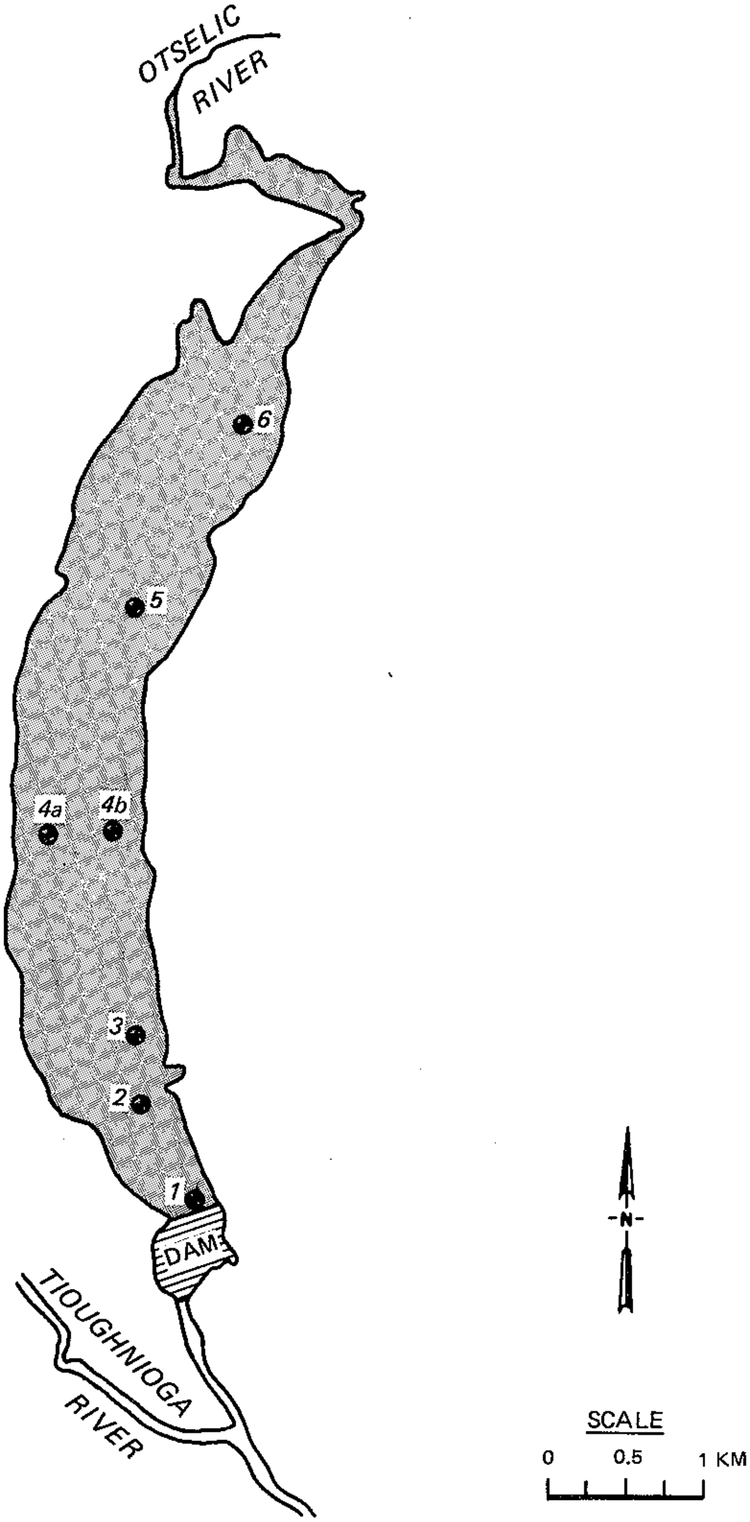

Figure 13. Locations of stations in Whitney Point Lake sampled during August 1987

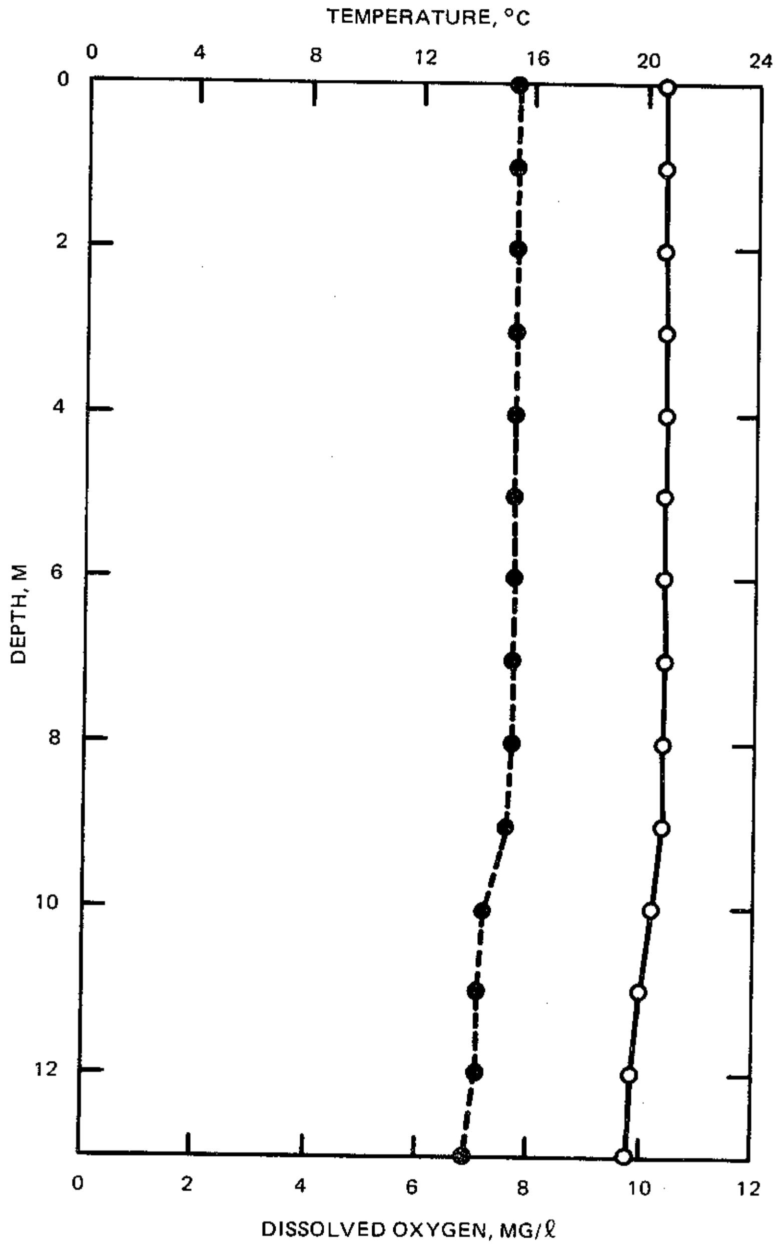

Figure 14. Temperature (solid line) and dissolved oxygen concentration (broken line) profiles at the deep-water station in Tioga Lake in August 1987

in Tioga to 70.0 mg/ℓ in Cowanesque. Chlorophyll a mean concentrations ranged from 3.7 μg/ℓ in Tioga to 44.0 μg/ℓ in Hammond. Mean total phosphorus values varied little between lakes (0.03 to 0.09 mg/ℓ) with lowest concentrations observed in Tioga.

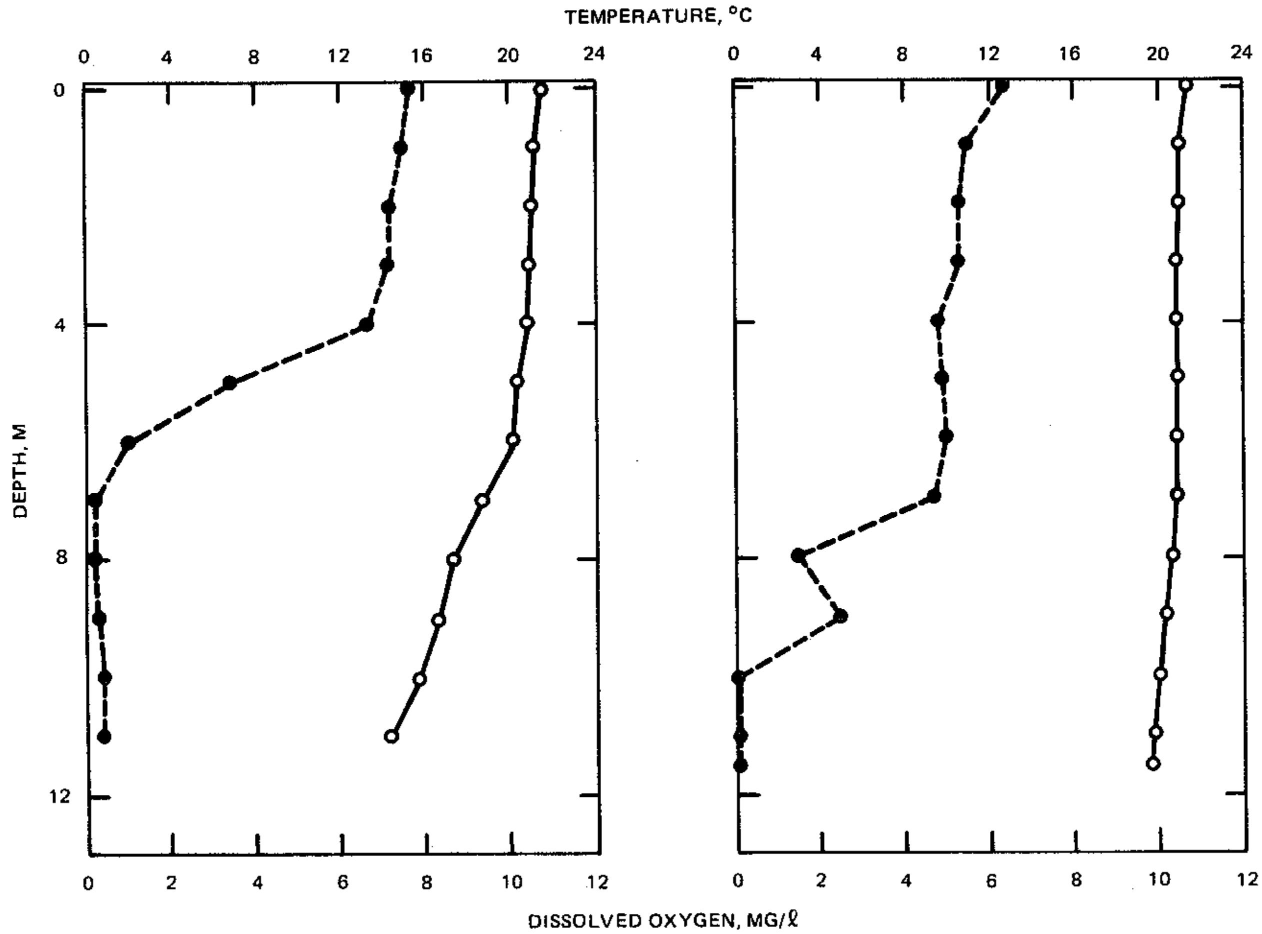

Figure 15. Temperature (solid line) and dissolved oxygen concentration (broken line) profiles for deep-water stations in Cowanesque (left) and East Sidney (right) Lakes in August 1987

Table 8

Mixed-Layer (Depth 0 to 6 m), Mean Concentrations of Selected Water Quality Variables. Based on Data Collected August 1987

Lake*	TMN			TFE			CHLA		
	Mean	C.V.	N	Mean	C.V.	N	Mean	C.V.	N
CW	0.31	0.349	5	0.31	0.627	5	16.7	0.076	4
ES	0.08	0.244	12	0.34	0.293	12	17.7	0.234	5
HM	0.23	0.291	8	0.38	0.582	8	44.0	0.431	5
TI	1.46	0.122	6	0.25	0.568	6	3.7	0.323	4
WP	0.10	0.149	16	0.62	0.354	16	18.2	0.234	7

* Names for Cowanesque (CW), East Sidney (ES), Hammond (HD), Tioga (TI), and Whitney Point (WP) Lakes are abbreviated.

44. Phytoplankton present in each lake at the time of sampling and their relative abundance are listed in Appendix C. However, a summary of abundant species is presented for each lake in Table 9. In general, blue-green species dominated the phytoplankton population in each lake, with *Coelosphaerium*, *Aphanizomenon* and *Anabaena* being the most abundant genera. Two diatom genera, *Melosira* and *Cyclotella*, were the next most abundant, followed by the green alga *Coelastrum reticulatum*.

Table 9

Abundant Algal Species

Algal Species	Lake*				
	CW	ES	WP	TI	HM
Cyanophyta					
Coelosphaerium Naegelianum		+	+		+
Aphanizomenon flos-aquae	+		+	+	
Anabaena (3 species)	+		+		+
Chrysophyta					
Melosira (2 species)			+		
Rhizosolenia eriensis?			+		
Cyclotella			+	+	
Attheya				+	
Chlorophyta					
Coelastrum reticulatum	+	+		+	
Euglenophyta					
Trachelomonas (3 species)	+		+		

* Abbreviated forms are: Cowanesque (CW), East Sidney (ES), Hammond (HD), Tioga (TI), and Whitney Point (WP).

PART IV: SUMMARY

45. Four of the five NAB projects considered here clearly exhibit water quality conditions characteristic of eutrophic lakes. A possible exception is Tioga Lake, owing to the modifying influences of acidic inflows from the Tioga River. Although not quantifiable from existing information, the nature and extent of nutrient-yielding land uses are such that nutrients are transported from watershed to lake in quantities in excess of the assimilative capacities of each of the lakes. Casual observation during the intensive water quality survey in August 1987 identified numerous farming operations in these watersheds, many of which are adjacent to tributary streams. Conversations with project personnel and local inhabitants identified farming practices, such as the spreading of animal wastes on frozen fields, which would further intensify nutrient export to downstream lakes.

46. While data are sparse, nutrient concentrations in Hammond, Cowanesque, Whitney Point, and East Sidney Lakes are excessive and algal biomass is seasonally high. Nutrient conditions in Tioga Lake, which are less well defined, are apparently relatively less severe. Blue-green algae, which are intolerant to extremely low pH values, are also less prevalent or abundant in Tioga Lake. A possible explanation for this condition is the potential for coprecipitation of nutrients, particularly phosphorus, with metals following increases in pH as river waters enter the relatively less acidic surface waters of the lake.

47. Additional water quality problems include reduced clarity in surface waters and anoxic or near-anoxic conditions in bottom waters. While much of the reduction in water clarity is presumably due to algal biomass, nonalgal sources of turbidity may play an important role. As described in Part III, thermal stability in these projects is low due to their shallow morphometry and hypolimnetic withdrawal. Reductions in stability increase the frequency and extent of mixing, which in turn promotes resuspension of bottom sediments. Other processes may also influence the concentrations of inorganic suspended material. These include scour by inflowing tributaries, particularly during high flow events, shoreline erosion, and bioperturbation. A possible example of the latter process was identified during the August intensive survey at Hammond Lake. The shallow, upper basin of the lake, which receives tributary inflows and is somewhat isolated from the remainder of the

lake by a narrow constriction, is reported by project personnel to be inhabited by numerous large, bottom-feeding fish. On several occasions, turbid conditions here have occurred coincident with increased activity of these fish.

48. Dissolved oxygen conditions in bottom waters are characteristic of those for other stratified, eutrophic lakes. However, the periodic occurrence of partial or complete mixing during the stratified period leads to increases in dissolved oxygen, thus reducing the severity of conditions which might otherwise exist. This, of course, is also accompanied by the redistribution of materials (i.e., nutrients, metals, etc.) stored in hypolimnia, which can exert a negative influence on the quality of surface waters. A determination of the rates at which oxygen is depleted from hypolimnia following stratification was confounded by mixing, suggesting the need for the collection of dissolved oxygen data over shorter intervals of time than were employed during previous studies.

PART V: RECOMMENDATIONS

General Recommendations

49. The development of effective management approaches must be founded on a sound understanding of environmental conditions and interactions as they relate to user needs and attainable goals. In this regard, data reviewed here were, in many instances, insufficient. These shortcomings could be overcome by future studies designed to: (a) more completely describe watershed/lake interactions, (b) obtain sufficient water quality information to better describe limnological conditions during the stratified period, and (c) identify realistic management goals.

50. The export of growth-stimulating nutrients, particularly phosphorus and nitrogen, from watershed to lake is a direct cause of eutrophication-related problems in lakes and reservoirs. For this reason, relatively precise estimates of material loadings are required. These estimates must allow quantification of mass inputs as well as their temporal distribution.

51. While export from undisturbed watersheds may vary widely, anthropogenic influences clearly elevate loadings to receiving lakes and reservoirs. Some land uses, such as construction, increase the rates at which materials are lost due to erosion, while others introduce nutrients not otherwise present (e.g., additions of fertilizers for crop production, etc.). Many of these sources can be identified through an inventory of watershed land uses. Since they are not available for the five watersheds considered here, effort should be made to obtain such inventories. These inventories allow for improved monitoring of nutrient inputs, but more importantly, they provide a basis for the formulation of watershed management plans. While the implementation of these plans is clearly not within the mission or regulatory authority of the Corps of Engineers, cooperative efforts with concerned state and local authorities are facilitated by the careful delineation of land use patterns.

52. Several approaches, involving varying levels of effort, can be taken to obtain land use inventories. At a minimum, the records of various state, county, and/or local agencies may be used to compile a relatively complete list of land uses. Unfortunately, discussions with NAB personnel indicate that little information may be obtained for these watersheds using this approach. Alternatively, land use types and areas associated with each type

may be estimated through on-site inspection, landowner interviews, and the use of detailed maps for the area. This approach is manpower intensive and the quality of data obtained would vary with the degree of effort expended.

53. A third approach, which involves a relatively new technology, has been developed by the Tennessee Valley Authority (TVA). Analyses of images obtained by low-level aerial photography allow the development of layered maps depicting erosion potential, major off-channel drainages and their confluence with streams, and land uses. Also included in the analysis are calculations of areas associated with each land use and runoff category. These data are extremely useful in the estimation of potential nutrient discharges and in the development of monitoring programs.

54. A knowledge of land uses, while providing essential information upon which to base watershed management plans, provide only indirect estimates of nutrient loads to receiving water bodies. Accurate estimates of loading must be based on direct measurement of inflows. Two types of data are needed: paired observations of instantaneous flow and mass concentrations, and daily observations of flow. With such data, relations between flow and concentration (obtained from the paired observations covering representative periods of time and flow) can be used in conjunction with continuous flow records to estimate mass loadings over annual or seasonal time periods. These calculations are facilitated by the computer program FLUX (Walker 1987).

55. Critical in the calculation of these loads is the collection of data at representative sites and over appropriate time frames. Placement of the sampling station must be such that significant inflows to the tributary do not occur between the sampling site and the lake. Sites should also be chosen which allow easy access and which have appropriate physical characteristics for accurate stream gaging.

56. The temporal distribution of sampling effort will, because of seasonal changes in flow, have a potentially great influence on the variability or error associated with the data. Since such increases reduce certainty in data, care must be taken in designing sampling programs. As discussed in detail in Appendix D, sampling of tributary streams is recommended during both high and low flow seasons of the year, with greatest emphasis placed on high flows. Also included in Appendix D are suggested variables for which data should be obtained. Collection of appropriate information spanning

appropriate times will allow the calculation of statistically-sound estimates of loading rates for materials influencing lake water quality.

57. As will be discussed below, much can learned of lake nutrient dynamics and trophic state through the use of mass balance calculations. To perform these calculations, data describing inputs, outputs, and changes in mass content of the lake are required. Thus, monitoring flows and concentrations for the discharge is also recommended. Recommended approaches for discharge sampling are also presented in Appendix D. In general, sampling guidelines discussed for tributaries apply equally to discharges. As with tributary data analyses, the program FLUX provides a convenient method for data reduction and summarization.

58. It is recommended that a better understanding of conditions and important limnological processes be sought. While historical water quality data provide general information for each project, additional data are required. Acquisition of more detailed water quality data will allow (a) mass balance calculations, (b) description of water quality conditions, (c) delineation of the impacts of such limnological processes as wind-induced mixing, and (d) evaluation of management alternatives.

59. As mentioned above for tributaries and discharges, mass balance calculations are useful in determining rates at which nutrients are delivered to lakes. Mass balance values also provide information concerning sedimentary losses and potential sources of nutrients within lakes. Differences between mass inflow and discharge, and change in mass content of a lake indicate the degree to which materials are retained due to sedimentation. In general, lakes with high particulate inputs and/or long water retention times tend to retain materials to a greater degree than do lakes with low particulate inputs or short water retention times.

60. On a season basis, mass balances may be used to approximate the importance of internal loading. In summer months, when nutrient inputs are generally low and anoxia exists in hypolimnia, nutrients released from bottom sediments often become important sources for phytoplankton growth, particularly if mixing events occur. If internal loading is occurring, changes in the content of nutrients in the lake will exceed those otherwise anticipated based on mass input and discharge.

61. It is recommended that sampling be continued at each project as a means for further defining water quality conditions. Appendix D presents a

detailed discussion of statistical analyses performed using data from previous efforts. Appendix D also provides suggested designs for future sampling efforts. In general, these designs will allow collection of information suitable for characterizing water quality conditions in three vertical strata in the deepest portion of the each lake. Considering the size and morphometry of these projects, and the importance of mixing, assessment of "average" conditions can be appropriately made using these data. The program PROFILE (Walker 1987) provides a convenient method for reviewing, plotting, and summarizing pool water quality data. PROFILE also allows the calculation of dissolved oxygen depletion rates, should sufficient data be available.

62. Three levels of modeling effort should be considered as supplemental means for interpreting water quality data and evaluating management alternatives. The program BATHTUB (Walker 1987), which assumes the lake or portions thereof to respond to inputs and discharges in a manner similar to a constantly-stirred tank reactor, provides a simple approach to describing trophic state. BATHTUB, which has the advantage of low data requirements, also provides the capability to compute water and nutrient balances, and rank eutrophication responses. Management alternatives involving changes in nutrient availability or loading, and/or flushing rate are easily evaluated by running the program under differing input conditions. A potential drawback is the fact that the models employed in BATHTUB sum responses over seasonal or annual averaging periods. The models also do not deal explicitly with water quality processes, and thus, do not provide detailed evaluation of some ameliorative approaches (e.g., changes to the structure or withdrawal schedule).

63. The model CE-QUAL-R1 (Environmental Laboratory 1986), which is a one-dimensional reservoir water quality model, deals explicitly with several water quality processes. CE-THERM-R1, the thermal portion of CE-QUAL-R1, may be used independently to simulate potential changes in lake thermal structure following either structural or operational modifications. Since thermal stability may have a strong influence on the water quality of these five projects, changes in structure and/or operation at one or more of the projects could be evaluated as a means of reducing internal loading. For instance, reductions in the relative amount of cold water discharged could increase thermal stability, thus potentially reducing internal loading associated with periodic wind-generated mixing. As discussed before, East Sidney and

Cowanesque Lakes, because of their morphometry, would potentially benefit from such changes. CE-THERM-R1 could be employed using relatively little additional data.

64. For a more detailed analysis of water quality processes, CE-QUAL-R1 could be used. However, while this model simulates several interacting water quality processes, data requirements are more extensive than either BATHTUB or CE-THERM-R1. This would require increases in sampling effort.

65. The development of management plans involves identification of needs or problems and the formulation of alternative approaches to satisfy these needs. It is recommended that initial efforts center on the identification of needs. While an evaluation of water quality, as recommended above, will allow quantification of current conditions, this information must be placed in the context of user needs and expectations. Principal user groups should be identified and polled to determine use patterns and perceived problems. Such an effort would also identify user conflicts.

66. In many cases, user-identified problems are perceived and, thus, difficult to identify based solely on "hard" data (e.g., water quality data gained through sampling). For instance, highly productive (i.e., eutrophic) lakes are perceived by fishermen differently than they are by swimmers or boaters. Therefore, any survey of user needs or problems must be broad-based. Thus, local fishing clubs, day-use bathers, boat owners, and others whose use of the project is impacted by water quality should be given equal opportunity to express their needs. In some cases, user conflicts can be reduced through careful reallocation of existing resources, while in other cases judgements must be made by the managing agency. While such judgments may reduce or preclude one or more benefits, the analysis of user survey information provides a realistic and defensible approach.

Specific Recommendations

67. The development of sound management approaches for the five NAB projects discussed in this report requires the collection of additional information concerning current water quality conditions and use patterns, and the identification of water quality issues. Considering the number of projects involved and the quantity of information required, it is recommended that these tasks be conducted in phases or stages. It is anticipated that such an

approach would be more cost-effective and would provide opportunity for methodological refinement.

68. It is recommended that the initial phase or stage involve efforts at Whitney Point and East Sidney Lakes only. Ongoing construction activities at Cowanesque Dam, and the complex operational plan at Tioga and Hammond Lakes, would confound initial efforts if they were to be conducted at these projects. Additionally, Whitney Point and East Sidney Lakes have the advantage of small size, well-defined user access, and less complex watershed land-use patterns. It is anticipated that information gained and methods developed as a result of efforts at these two projects could be adapted to studies at the remaining three projects, should such studies be conducted.

69. Four specific tasks are recommended:

- a. Describe land use patterns.
- b. Determine nutrient loading rates.
- c. Evaluate water quality relationships.
- d. Identify user patterns.

The completion of these four tasks would provide information currently not available or incomplete, and would provide the informational base for the identification of issues and the formulation of management objectives. These tasks are discussed in more detail in the following paragraphs.

70. As mentioned in the previous section, an understanding of land use patterns, because of their impact on material loads to reservoirs, provide valuable information on water quality management. However, obtaining such information places great demand on manpower and funding. Therefore, it is recommended that the TVA aerial photographic methodology be applied to the East Sidney Lake watershed. Should the results obtained and the experienced gained in this smaller watershed indicate that the method is technically sound and cost-effective, efforts could be extended to the Whitney Point Lake watershed.

71. Nutrient loads to East Sidney and Whitney Point Lakes should be determined for an annual cycle employing the methods and sample design described in Appendix D (see Table D-10). The choice of Level 1 (15 stratified samples) or Level 2 (30 stratified samples) will depend on availability of funds. This task would involve the establishment of routine monitoring stations at the inflow to each lake and the acquisition of daily flow data by gaging or through water balance calculation based on operational records.

72. While data for a limited number of water quality variables provide some historical information, the collection of additional pool water quality data, following the sampling guidelines presented in Appendix D, is recommended for both lakes. As presented in Table D-7, emphasis should be placed on water quality events during the summer growing season. Here again, the choice of level of effort will be dictated, in part, by the availability of funds. Resultant data could be analyzed and summarized using the program PROFILE (Walker 1987). It is further recommended that these data be used to establish mass balances for the growing season and to evaluate water quality interactions. Both of these latter tasks could accomplished through the use of the program BATHTUB (Walker 1987). BATHTUB would also provide a means for estimating potential water quality changes following a variety of non-structural mitigative measures.

73. The final recommended task would involve a census of user benefits, user needs, and perceived problems. This could be accomplished most easily through the use of specifically designed questionnaires, user interviews, and/or meetings with other interested agencies and user groups. This effort should be designed in such a way as to allow clear definition of water quality issues.

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APPENDIX A: HISTORICAL WATER QUALITY DATA

1. The following tables present summaries of water quality data collected by US Army Engineer District, Baltimore, for Cowanesque, Tioga-Hammond, East Sidney, and Whitney Point Lakes. Stations numbers refer to station identifiers presented on the original data forms. Dates are in year-month-day format. Sample frequency tables present the number of samples per station and date. Summary values are averaged across dates and stations. A summary value of -9 indicates a missing value. Stations weights (WTS) refer to the relative area represented by each station and were used in the calculation of weighted mean values. Sample frequency information and summary values were prepared using the PROFILE program.

Table A-1

Summary of Ammonium-Nitrogen Sample Number and Concentration (μg N/ℓ) data for Whitney Point Lake. Values Reported Are for the Entire Water Column

Sample Frequencies:

Station Date	2	3	Total
75 515	0	0	0
77 617	0	0	0
77 719	0	1	1
771018	0	0	0
78 822	3	0	3
80 7 1	2	2	4
83 622	3	0	3
83 816	3	0	3
84 9 5	2	0	2
85 629	0	1	1
85 814	1	0	1
86 728	3	0	3
Totals	17	4	21

Summary Values:

Station Date	2 WTS>0.500	3 0.500	Mean
75 515	-9.0	-9.0	-9.0
77 617	-9.0	-9.0	-9.0
77 719	-9.0	120.0	120.0
771018	-9.0	-9.0	-9.0
78 822	50.0	-9.0	50.0
80 7 1	375.0	375.0	375.0
83 622	80.0	-9.0	80.0
83 816	500.0	-9.0	500.0
84 9 5	205.0	-9.0	205.0
85 629	-9.0	160.0	160.0
85 814	70.0	-9.0	70.0
86 728	570.0	-9.0	570.0
Medians	205.0	160.0	160.0
Means	264.3	218.3	236.7
CV	0.821	0.628	0.828
CV (Mean)	0.310	0.363	0.276

Table A-2

Summary of Nitrite-Nitrogen Sample Number and Concentration (μg N/ℓ) Data for Whitney Point Lake. Values Reported Are for the Entire Water Column

Sample Frequencies:

Station Date	2	3	Total
75 515	0	0	0
77 617	0	0	0
77 719	0	1	1
771018	0	1	1
78 822	0	0	0
80 7 1	1	1	2
83 622	3	0	3
83 816	3	0	3
83 9 5	2	0	2
85 629	0	1	1
85 814	1	0	1
86 728	0	0	0
Totals	10	4	14

Summary Values:

Station Date	2 WTS>0.500	3 0.500	Mean
75 515	-9.0	-9.0	-9.0
77 617	-9.0	-9.0	-9.0
77 719	-9.0	27.0	27.0
771018	-9.0	25.0	25.0
78 822	0.0	-9.0	0.0
80 7 1	0.0	0.0	0.0
83 622	90.0	-9.0	90.0
83 816	8.0	-9.0	8.0
84 9 5	5.5	-9.0	5.5
85 629	-9.0	6.0	6.0
85 814	15.0	-9.0	15.0
86 728	-9.0	-9.0	-9.0
Medians	6.8	15.5	8.0
Means	19.8	14.5	19.6
CV	1.765	0.933	1.436
CV (Mean)	0.721	0.466	0.479

Table A-3

Summary of Nitrate-Nitrogen Sample Number and Concentration (μg N/ℓ) Data for Whitney Point Lake. Values Reported Are for the Entire Water Column

Sample Frequencies:

Station Date	2	3	Total
75 515	0	0	0
77 617	0	1	1
77 719	0	1	1
771018	0	0	0
78 822	0	0	0
80 7 1	2	2	4
83 622	3	0	3
83 816	3	0	3
84 9 5	2	0	2
85 629	0	1	1
85 814	1	0	1
86 728	3	0	3
Totals	14	5	19

Summary Values:

Station Date	2 WTS>0.500	3 0.500	Mean
75 515	-9.0	-9.0	-9.0
77 617	-9.0	4.0	4.0
77 719	-9.0	500.0	500.0
771018	-9.0	-9.0	-9.0
78 822	0.0	-9.0	0.0
80 7 1	0.0	10.0	5.0
83 622	900.0	-9.0	900.0
83 816	800.0	-9.0	800.0
84 9 5	600.0	-9.0	600.0
85 629	-9.0	300.0	300.0
85 814	100.0	-9.0	100.0
86 728	200.0	-9.0	200.0
Medians	200.0	155.0	250.0
Means	371.4	203.5	340.9
CV	1.039	1.185	0.996
CV (Means)	0.393	0.593	0.315

Table A-4

Summary of Hydrolyzed Phosphorus Sample Number and Concentration (μg P/ℓ) Data for Whitney Point Lake. Values Reported Are for the Entire Water Column

Sample Frequencies:

Station Date	2	3	Total
75 515	0	1	1
77 617	0	1	1
77 719	0	1	1
771018	0	1	1
78 822	3	0	3
80 7 1	2	0	2
83 622	3	0	3
83 816	3	0	3
84 9 5	2	0	2
85 629	0	1	1
85 814	1	0	1
86 728	3	0	3
Totals	17	5	22

Summary Values:

Station Date	2 WTS>0.500	3 0.500	Mean
75 515	-9.0	0.0	0.0
77 617	-9.0	46.0	46.0
77 719	-9.0	33.0	33.0
771018	-9.0	49.0	49.0
78 822	39.0	-9.0	39.0
80 7 1	0.0	-9.0	0.0
83 622	10.0	-9.0	10.0
83 816	16.0	-9.0	16.0
84 9 5	16.5	-9.0	16.5
85 629	-9.0	23.0	23.0
85 814	16.0	-9.0	16.0
86 728	23.0	-9.0	23.0
Medians	16.0	33.0	19.8
Means	17.2	30.2	22.6
CV	0.695	0.657	0.721
CV (Mean)	0.263	0.294	0.208

Table A-5

Summary of Ammonium-Nitrogen Sample Number and Concentration (μg N/ℓ) Data for Whitney Point Lake. Values Reported Are for the Mixed Layer (0-3 m)

Sample Frequencies:

Station Date	2	3	Total
75 515	0	0	0
77 617	0	0	0
77 719	0	1	1
771018	0	0	0
78 822	1	0	1
80 7 1	2	1	3
83 622	1	0	1
83 816	2	0	2
84 9 5	1	0	1
85 629	0	1	1
85 814	1	0	1
86 728	2	0	2
Totals	10	3	13

Summary Values:

Station Date	2 WTS>0.500	3 0.500	Mean
75 515	-9.0	-9.0	-9.0
77 617	-9.0	-9.0	-9.0
77 719	-9.0	120.0	120.0
771018	-9.0	-9.0	-9.0
78 822	50.0	-9.0	50.0
80 7 1	375.0	300.0	337.5
83 622	80.0	-9.0	80.0
83 816	445.0	-9.0	445.0
84 9 5	180.0	-9.0	180.0
85 629	-9.0	160.0	160.0
85 814	70.0	-9.0	70.0
86 728	340.0	-9.0	340.0
Medians	180.0	160.0	160.0
Means	220.0	193.3	198.1
CV	0.746	0.489	0.716
CV (Mean)	0.282	0.282	0.239

Table A-6

Summary of Nitrite-Nitrogen Sample Number and Concentration ($\mu g\ N/\ell$) Data for Whitney Point Lake. Values Reported Are for the Mixed Layer (0-3 m)

Sample Frequencies:

Station Date	2	3	Total
75 515	0	0	0
77 617	0	0	0
77 719	0	1	1
771018	0	1	1
78 822	0	0	0
80 7 1	1	1	2
83 622	1	0	1
83 816	2	0	2
84 9 5	1	0	1
85 629	0	1	1
85 814	1	0	1
86 728	0	0	0
Totals	6	4	10

Summary Values:

Station Date	2 WTS>0.500	3 0.500	Mean
75 515	-9.0	-9.0	-9.0
77 617	-9.0	-9.0	-9.0
77 719	-9.0	27.0	27.0
771018	-9.0	25.0	25.0
78 822	0.0	-9.0	0.0
80 7 1	0.0	0.0	0.0
83 622	90.0	-9.0	90.0
83 816	7.5	-9.0	7.5
84 9 5	4.0	-9.0	4.5
85 629	-9.0	6.0	6.0
85 814	15.0	-9.0	15.0
86 728	-9.0	-9.0	-9.0
Medians	5.8	15.5	7.5
Means	19.4	14.5	19.4
CV	1.804	0.933	1.459
CV (Mean)	0.737	0.466	0.486

Table A-7

Summary of Nitrate-Nitrogen Sample Number and Concentration (μg N/ℓ) Data for Whitney Point Lake. Values Reported Are for the Mixed Layer (0-3 m)

Sample Frequencies:

Station Date	2	3	Total
75 515	0	0	0
77 617	0	1	1
77 719	0	1	1
771018	0	0	0
78 822	0	0	0
80 7 1	2	1	3
83 622	1	0	1
83 816	2	0	2
84 9 5	1	0	1
85 629	0	1	1
85 814	1	0	1
86 728	2	0	2
Totals	9	4	13

Summary Values:

Station Date	2 WTS>0.500	3 0.500	Mean
75 515	-9.0	-9.0	-9.0
77 617	-9.0	4.0	4.0
77 719	-9.0	500.0	500.0
771018	-9.0	-9.0	-9.0
78 822	0.0	-9.0	0.0
80 7 1	0.0	0.0	0.0
83 622	900.0	-9.0	900.0
83 816	750.0	-9.0	750.0
84 9 5	600.0	-9.0	600.0
85 629	-9.0	300.0	300.0
85 814	100.0	-9.0	100.0
86 728	250.0	-9.0	250.0
Medians	250.0	152.0	275.0
Means	371.4	201.0	340.4
CV	1.007	1.213	0.973
CV (Mean)	0.381	0.607	0.308

Table A-8

Summary of Hydrolyzed Phosphorus Sample Number and Concentration (μg P/ℓ) Data for Whitney Point Lake. Values reported Are for the Mixed Layer (0-3 m)

Sample Frequencies:

Station Date	2	3	Total
75 515	0	1	1
77 617	0	1	1
77 719	0	1	1
771018	0	1	1
78 822	1	0	1
80 7 1	2	0	2
83 622	1	0	1
83 816	2	0	2
84 9 5	1	0	1
85 629	0	1	1
85 814	1	0	1
86 728	2	0	2
Totals	10	5	15

Summary Values:

Station Date	2 WTS>0.500	3 0.500	Mean
75 515	-9.0	0.0	0.0
77 617	-9.0	46.0	46.0
77 719	-9.0	33.0	33.0
771018	-9.0	49.0	49.0
78 822	59.0	-9.0	59.0
80 7 1	0.0	-9.0	0.0
83 622	7.0	-9.0	7.0
83 816	15.5	-9.0	15.5
84 9 5	20.0	-9.0	20.0
85 629	-9.0	23.0	23.0
85 814	16.0	-9.0	16.0
86 728	150.0	-9.0	150.0
Medians	16.0	33.0	21.5
Means	38.2	30.2	34.9
CV	1.381	0.657	1.175
CV (Means)	0.522	0.294	0.339

Table A-9

Summary of Ammonium-Nitrogen Sample Number and Concentration (µg N/ℓ) Data for East Sidney Lake. Values Reported Are for the Entire Water Column

Sample Frequencies:

Station Date	2	3	Total
75 8 8	0	0	0
76 713	0	0	0
76 917	2	0	2
77 719	5	0	5
78 822	3	2	5
79 731	4	0	4
81 820	3	1	4
82 6 9	3	0	3
82 8 3	3	0	3
83 621	3	0	3
83 816	3	2	5
84 9 5	1	0	1
85 629	1	0	1
85 813	1	0	1
86 729	3	0	3
Totals	35	5	40

Summary Values:

Station Date	2 WTS>0.500	3 0.500	Mean
75 8 8	0.0	-9.0	0.0
76 713	-9.0	-9.0	-9.0
76 917	340.0	-9.0	340.0
77 719	170.0	-9.0	170.0
78 822	280.0	225.0	252.5
79 731	1,050.0	-9.0	1,050.0
81 820	500.0	600.0	550.0
82 6 9	160.0	-9.0	160.0
82 8 3	340.0	-9.0	340.0
83 621	300.0	-9.0	300.0
83 816	640.0	425.0	532.5
84 9 5	750.0	-9.0	750.0
85 629	110.0	-9.0	110.0
85 813	80.0	-9.0	80.0
86 729	390.0	-9.0	390.0
Medians	320.0	425.0	320.0
Means	365.0	416.7	358.9
CV	0.791	0.450	0.795
CV (Mean)	0.211	0.260	0.212

Table A-10

Summary of Nitrite-Nitrogen Sample Number and Concentration ($\mu g\ N/\ell$) Data for East Sidney Lake. Values Reported Are for the Entire Water Column

Sample Frequencies:

Station Date	2	3	Total
75 8 8	0	0	0
76 713	2	0	2
76 917	0	0	0
77 719	5	0	5
78 822	0	0	0
79 731	4	1	5
81 820	0	0	0
82 6 9	0	0	0
82 8 3	3	0	3
83 621	3	0	3
83 816	3	2	5
84 9 5	1	0	1
85 629	1	0	1
85 813	1	0	1
86 729	0	0	0
Totals	23	3	26

Summary Values:

Station Date	2 WTS>0.500	3 0.500	Mean
75 8 8	0.0	-9.0	0.0
76 713	12.0	-9.0	12.0
76 917	-9.0	-9.0	-9.0
77 719	10.0	-9.0	10.0
78 822	-9.0	-9.0	-9.0
79 731	27.5	28.0	27.8
81 820	-9.0	-9.0	-9.0
82 6 9	-9.0	-9.0	-9.0
82 8 3	7.0	-9.0	7.0
83 621	40.0	-9.0	40.0
83 816	10.0	3.5	6.8
84 9 5	1.0	-9.0	1.0
85 629	7.0	-9.0	7.0
85 813	8.0	-9.0	8.0
86 729	-9.0	-9.0	-9.0
Medians	9.0	15.8	7.5
Means	12.3	15.8	11.9
CV	1.004	1.100	1.042
CV (Mean)	0.318	0.778	0.329

Table A-11

Summary of Nitrate-Nitrogen Sample Number and Concentration ($\mu g\ N/\ell$) Data for East Sidney Lake. Values Reported Are for the Entire Water Column

Sample Frequencies:

Station Date	2	3	Total
75 8 8	0	0	0
76 713	2	0	2
76 917	2	0	2
77 719	3	0	3
78 822	0	0	0
79 731	4	1	5
81 820	3	1	4
82 6 9	3	0	3
83 8 3	3	0	3
83 621	3	0	3
83 816	2	2	4
84 9 5	1	0	1
85 629	1	0	1
85 813	1	0	1
86 729	3	0	3
Totals	31	4	35

Summary Values:

Station Date	2 WTS>0.500	3 0.500	Mean
75 8 8	0.0	-9.0	0.0
76 713	50.0	-9.0	50.0
76 917	300.0	-9.0	300.0
77 719	600.0	-9.0	600.0
78 822	-9.0	-9.0	-9.0
79 731	1,450.0	1,100.0	1,275.0
81 820	30.0	0.0	15.0
82 6 9	1,200.0	-9.0	1,200.0
82 8 3	700.0	-9.0	700.0
83 621	700.0	-9.0	700.0
83 816	750.0	500.0	625.0
84 9 5	200.0	-9.0	200.0
85 629	600.0	-9.0	600.0
85 813	0.0	-9.0	0.0
86 729	500.0	-9.0	500.0
Medians	550.0	500.0	550.0
Means	505.7	533.3	483.2
CV	0.886	1.033	0.865
CV (Mean)	0.237	0.596	0.231

Table A-12

Summary of Hydrolyzed Phosphorus Sample Number and Concentration (μg P/ℓ) Data for East Sidney Lake. Values Reported Are for the Entire Water Column

Sample Frequencies:

Station Date	2	3	Total
75 8 8	1	0	1
76 713	2	0	2
76 917	2	0	2
77 719	5	0	5
78 822	3	2	5
79 731	4	1	5
81 820	3	1	4
82 6 9	3	0	3
82 8 3	3	0	3
83 621	3	0	3
83 816	3	2	5
84 9 5	1	0	1
85 629	1	0	1
85 813	1	0	1
86 729	3	0	3
Totals	38	6	44

Summary Values:

Station Date	2 WTS>0.500	3 0.500	Mean
75 8 8	228.0	-9.0	228.0
76 713	0.0	-9.0	0.0
76 917	42.5	-9.0	42.5
77 719	16.0	-9.0	16.0
78 822	114.0	73.5	93.8
79 731	128.5	228.0	178.3
81 820	36.0	42.0	39.0
82 6 9	33.0	-9.0	33.0
82 8 3	16.0	-9.0	16.0
83 621	10.0	-9.0	10.0
83 816	13.0	7.5	10.3
84 9 5	26.0	-9.0	26.0
85 629	176.0	-9.0	176.0
85 813	42.0	-9.0	42.0
86 729	41.0	-9.0	41.0
Medians	36.0	57.8	39.0
Means	61.5	87.8	63.5
CV	1.108	1.109	1.133
CV (Mean)	0.286	0.554	0.293

Table A-13

Summary of Ammonium-Nitrogen Sample Number and Concentration (μg N/ℓ) Data for East Sidney Lake. Values Reported Are for the Mixed Layer (0-3 m)

Sample Frequencies:

Station Date	2	3	Total
76 917	1	0	1
77 719	1	0	1
78 822	1	1	2
79 731	2	0	2
81 820	1	0	1
82 6 9	1	0	1
82 8 3	1	0	1
83 621	1	0	1
83 816	1	2	3
84 9 5	1	0	1
85 629	1	0	1
85 813	1	0	1
86 729	1	0	1
Totals	14	3	17

Summary Values:

Station Date	2 WTS>0.500	3 0.500	Mean
76 917	310.0	-9.0	310.0
77 719	170.0	-9.0	170.0
78 822	0.0	50.0	25.0
79 731	650.0	-9.0	650.0
81 820	400.0	-9.0	400.0
82 6 9	120.0	-9.0	120.0
82 8 3	0.0	-9.0	0.0
83 621	70.0	-9.0	70.0
83 816	350.0	425.0	387.5
84 9 5	750.0	-9.0	750.0
85 629	110.0	-9.0	110.0
85 813	80.0	-9.0	80.0
86 729	50.0	-9.0	50.0
Medians	120.0	237.5	120.0
Means	235.4	237.5	240.2
CV	1.035	1.116	1.013
CV (Mean)	0.287	0.789	0.281

Table A-14

Summary of Nitrite-Nitrogen Sample Number and Concentration (μg N/ℓ) Data for East Sidney Lake. Values Reported Are for the Mixed Layer (0-3 m)

Sample Frequencies:

Station Date	2	3	Total
76 917	0	0	0
77 719	1	0	1
78 822	0	0	0
79 731	2	1	3
81 820	0	0	0
82 6 9	0	0	0
82 8 3	1	0	1
83 621	1	0	1
83 816	1	2	3
84 9 5	1	0	1
85 629	1	0	1
85 813	1	0	1
86 729	0	0	0
Totals	9	3	12

Summary Values:

Station Date	2 WTS>0.500	3 0.500	Mean
76 917	0.0	-9.0	0.0
77 719	10.0	-9.0	10.0
78 822	-9.0	-9.0	-9.0
79 731	28.5	28.0	28.3
81 820	-9.0	-9.0	-9.0
82 6 9	-9.0	-9.0	-9.0
82 8 3	5.0	-9.0	5.0
83 621	37.0	-9.0	37.0
83 816	9.0	3.5	6.3
84 9 5	1.0	-9.0	1.0
85 629	7.0	-9.0	7.0
85 813	8.0	-9.0	8.0
86 729	-9.0	-9.0	-9.0
Medians	8.0	15.8	7.0
Means	11.7	15.8	11.4
CV	1.073	1.100	1.110
CV (Mean)	0.358	0.778	0.370

Table A-15

Summary of Nitrate-Nitrogen Sample Number and Concentration (μg N/ℓ) Data for East Sidney Lake. Values Reported Are for the Mixed Layer (0-3 m)

Sample Frequencies:

Station Date	2	3	Total
76 917	1	0	1
77 719	0	0	0
78 822	0	0	0
79 731	2	1	3
81 820	1	0	1
82 6 9	1	0	1
82 8 3	1	0	1
83 621	1	0	1
83 816	1	2	3
84 9 5	1	0	1
85 629	1	0	1
85 813	1	0	1
86 729	1	0	1
Totals	12	3	15

Summary Values:

Station Date	2 WTS>0.500	3 0.500	Mean
76 917	0.0	-9.0	0.0
77 719	-9.0	-9.0	-9.0
78 822	-9.0	-9.0	-9.0
79 731	1,100.0	1,100.0	1,100.0
81 820	20.0	-9.0	20.0
82 6 9	70.0	-9.0	70.0
82 8 3	700.0	-9.0	700.0
83 621	600.0	-9.0	600.0
83 816	300.0	500.0	400.0
84 9 5	200.0	-9.0	200.0
85 629	600.0	-9.0	600.0
85 813	0.0	-9.0	0.0
86 729	1,250.0	-9.0	1,250.0
Medians	300.0	800.0	400.0
Means	440.0	800.0	449.1
CV	1.013	0.530	0.988
CV (Mean)	0.306	0.375	0.298

Table A-16

Summary of Hydrolyzed Phosphorus Sample Number and Concentration (μg P/ℓ) Data for East Sidney Lake. Values Reported Are for the Mixed Layer (0-3 m)

Sample Frequencies:

Station Date	2	3	Total
76 917	1	0	1
77 719	1	0	1
78 822	1	1	2
79 731	2	1	3
81 820	1	0	1
82 6 9	1	0	1
82 8 3	1	0	1
83 621	1	0	1
83 816	1	2	3
84 9 5	1	0	1
85 629	1	0	1
85 813	1	0	1
86 729	1	0	1
Totals	14	4	18

Summary Values:

Station Date	2 WTS>0.500	3 0.500	Mean
76 917	46.0	-9.0	46.0
77 719	7.0	-9.0	7.0
78 822	33.0	59.0	46.0
79 731	122.0	228.0	175.0
81 820	16.0	-9.0	16.0
82 6 9	33.0	-9.0	33.0
82 8 3	16.0	-9.0	16.0
83 621	10.0	-9.0	10.0
83 816	13.0	7.5	10.3
84 9 5	26.0	-9.0	26.0
85 629	176.0	-9.0	176.0
85 813	42.0	-9.0	42.0
86 729	33.0	-9.0	33.0
Medians	33.0	59.0	33.0
Means	44.1	98.2	48.9
CV	1.120	1.175	1.181
CV (Mean)	0.311	0.678	0.327

Table A-17

Summary of Ammonium-Nitrogen Sample Number and Concentration ($\mu g\ N/\ell$) Data for Cowanesque Lake. Values Reported Are for the Entire Water Column

Sample Frequencies:

Station Date	2	3	4	5	6	Total
81 5 5	0	1	0	0	1	2
81 519	0	0	0	0	0	0
81 523	0	0	0	0	0	0
81 727	0	0	0	0	0	0
81 817	3	0	0	3	0	6
82 712	0	0	0	0	0	0
82 8 4	3	0	0	3	0	6
83 624	3	0	0	3	0	6
83 817	2	0	2	0	0	4
84 822	3	0	2	0	0	5
84 9 5	3	0	0	0	0	3
85 626	3	0	0	2	0	5
85 814	2	0	0	1	0	3
86 627	5	3	0	0	0	8
Totals	27	4	4	12	1	48

Summary Values:

Station Date	2 WTS>0.400	3 0.300	4 0.100	5 0.100	6 0.100	Mean
81 5 5	-9.0	240.0	-9.0	-9.0	180.0	225.0
81 519	0.0	-9.0	-9.0	-9.0	-9.0	0.0
81 523	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0
81 727	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0
81 817	690.0	-9.0	-9.0	580.0	-9.0	668.0
82 7 2	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0
82 8 4	880.0	-9.0	-9.0	270.0	-9.0	758.0
83 624	260.0	-9.0	-9.0	360.0	-9.0	280.0
83 817	770.0	-9.0	340.0	-9.0	-9.0	684.0
84 822	300.0	-9.0	305.0	-9.0	-9.0	301.0
84 9 5	620.0	-9.0	-9.0	-9.0	-9.0	620.0
85 626	420.0	-9.0	-9.0	285.0	-9.0	393.0
85 814	105.0	-9.0	-9.0	110.0	-9.0	106.0
86 627	400.0	700.0	-9.0	-9.0	-9.0	528.6
Medians	410.0	470.0	322.5	285.0	180.0	393.0
Means	444.5	470.0	322.5	321.0	180.0	414.9
CV	0.652	0.692	0.077	0.533	-9.000	0.612
CV (Mean	0.206	0.489	0.054	0.238	-9.000	0.184

Table A-18

Summary of Nitrite-Nitrogen Sample Number and Concentration (μg N/ℓ) Data for Cowanesque Lake. Values Reported Are for the Entire Water Column

Sample Frequencies:

Station Date	2	3	4	5	6	Total
81 5 5	0	0	0	0	0	0
81 519	3	1	1	3	0	8
81 523	3	0	0	3	0	6
81 727	3	0	0	0	0	3
81 817	0	0	0	0	0	0
82 712	3	3	3	3	2	14
82 8 4	3	0	0	3	0	6
83 624	3	0	0	3	0	6
83 817	3	0	3	0	0	6
84 822	3	0	2	0	0	5
84 9 5	3	0	0	0	0	3
95 626	3	0	0	2	0	5
85 814	3	0	0	1	0	4
86 627	0	0	0	0	0	0
Totals	33	4	9	18	2	66

Summary Values:

Station Date	2 WTS>0.400	3 0.300	4 0.100	5 0.100	6 0.100	Mean
81 5 5	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0
81 519	9.0	10.0	8.0	6.0	-9.0	8.9
81 523	13.0	-9.0	-9.0	14.0	-9.0	13.2
81 727	5.0	-9.0	-9.0	-9.0	-9.0	5.0
81 817	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0
82 712	16.0	27.0	35.0	23.0	21.0	22.4
82 8 4	4.0	-9.0	-9.0	12.0	-9.0	5.6
83 624	12.0	-9.0	-9.0	15.0	-9.0	12.6
83 817	13.0	-9.0	10.0	-9.0	-9.0	12.4
84 822	10.0	-9.0	11.5	-9.0	-9.0	10.3
84 9 5	3.0	-9.0	-9.0	-9.0	-9.0	3.0
85 626	6.0	-9.0	-9.0	4.0	-9.0	5.6
85 814	0.0	-9.0	-9.0	4.0	-9.0	0.8
06 627	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0
Medians	9.0	18.5	10.8	12.0	21.0	8.9
Means	8.3	18.5	16.1	11.1	21.0	9.1
CV	0.607	0.650	0.785	0.627	0.000	0.667
CV (Mean)	0.183	0.459	0.393	0.237	0.000	0.201

Table A-19

Summary of Nitrate-Nitrogen Sample Number and Concentration ($\mu g\ N/\ell$) Data for Cowanesque Lake. Values Reported Are for the Entire Water Column

Sample Frequencies:

Station Date	2	3	4	5	6	Total
81 5 5	0	0	0	0	0	0
81 519	3	1	1	3	0	8
81 523	3	0	0	3	0	6
81 727	2	0	0	0	0	2
81 817	3	0	0	3	0	6
82 712	3	3	3	3	2	14
82 8 4	2	0	0	1	0	3
83 624	3	0	0	3	0	6
83 817	3	0	3	0	0	6
84 822	3	0	2	0	0	5
84 9 5	3	0	0	0	0	3
85 626	3	0	0	2	0	5
85 814	3	0	0	1	0	4
86 627	5	3	0	0	0	8
Totals	39	7	9	19	2	76

Summary Values:

Station Date	2 WTS>0.400	3 0.300	4 0.100	5 0.100	6 0.100	Mean
81 5 5	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0
81 519	1,200.0	1,900.0	1,300.0	1,500.0	-9.0	1,477.8
81 523	330.0	-9.0	-9.0	300.0	-9.0	324.0
81 727	55.0	-9.0	-9.0	-9.0	-9.0	55.0
81 817	600.0	-9.0	-9.0	500.0	-9.0	580.0
82 712	400.0	1,200.0	1,400.0	1,100.0	1,400.0	910.0
82 8 4	0.0	-9.0	-9.0	0.0	-9.0	0.0
83 624	1,000.0	-9.0	-9.0	1,000.0	-9.0	1,000.0
83 817	1,500.0	-9.0	1,000.0	-9.0	-9.0	1,400.0
84 822	600.0	-9.0	400.0	-9.0	-9.0	560.0
84 9 5	400.0	-9.0	-9.0	-9.0	-9.0	400.0
85 626	8.0	-9.0	-9.0	13.0	-9.0	9.0
85 814	300.0	-9.0	-9.0	300.0	-9.0	300.0
86 627	600.0	900.0	-9.0	-9.0	-9.0	728.6
Medians	400.0	1,200.0	1,150.0	400.0	1,400.0	560.0
Means	537.9	1,333.3	1,025.0	589.1	1,400.0	595.7
CV	0.854	0.385	0.439	0.933	0.000	0.825
CV (Mean)	0.237	0.222	0.220	0.330	0.000	0.229

Table A-20

Summary of Hydrolyzed Phosphorus Sample Number and Concentration ($\mu g\ P/\ell$) Data for Cowanesque Lake. Values Reported Are for the Entire Water Column

Sample Frequencies:

Station Date	2	3	4	5	6	Total
81 5 5	0	1	0	0	1	2
81 519	3	1	1	3	0	8
81 523	3	0	0	3	0	6
81 727	0	0	0	0	0	0
81 817	3	0	0	3	0	6
82 712	3	3	3	3	2	14
82 8 4	3	0	0	3	0	6
83 624	3	0	0	3	0	6
83 817	3	0	3	0	0	6
84 822	3	0	2	0	0	5
84 9 5	3	0	0	0	0	3
85 626	3	0	0	2	0	5
85 814	3	0	0	1	0	4
86 627	5	3	0	0	0	8
Totals	38	8	9	21	3	79

Summary Values:

Station Date	2 WTS>0.400	3 0.300	4 0.100	5 0.100	6 0.100	Mean
81 5 5	-9.0	26.0	-9.0	-9.0	26.0	26.0
81 519	29.0	29.0	29.0	29.0	-9.0	29.0
81 523	26.0	-9.0	-9.0	41.0	-9.0	29.0
81 727	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0
81 817	29.0	-9.0	-9.0	91.0	-9.0	41.4
82 712	65.0	57.0	49.0	46.0	40.5	56.6
82 8 4	65.0	-9.0	-9.0	42.0	-9.0	60.4
83 624	13.0	-9.0	-9.0	16.0	-9.0	13.6
83 817	59.0	-9.0	33.0	-9.0	-9.0	53.8
84 822	46.0	-9.0	55.5	-9.0	-9.0	47.9
84 9 5	33.0	-9.0	-9.0	-9.0	-9.0	33.0
85 626	16.0	-9.0	-9.0	6.5	-9.0	14.1
85 814	85.0	-9.0	-9.0	652.0	-9.0	198.4
86 627	16.0	29.0	-9.0	-9.0	-9.0	21.6
Medians	31.0	29.0	41.0	41.5	33.3	33.0
Means	40.2	35.3	41.6	115.4	33.3	48.1
CV	0.583	0.413	0.304	1.891	0.308	0.994
CV (Mean)	0.168	0.207	0.152	0.668	0.218	0.276

Table A-21

Summary of Ammonium-Nitrogen Sample Number and Concentration ($\mu g\ N/\ell$) Data for Cowanesque Lake. Values Reported Are for the Entire Water Column

Sample Frequencies:

Station Date	2	3	4	5	6	Total
81 5 5	0	1	0	0	1	2
81 519	0	0	0	0	0	0
81 523	0	0	0	0	0	0
81 727	0	0	0	0	0	0
81 817	1	0	0	1	0	2
82 712	0	0	0	0	0	0
82 8 4	1	0	0	2	0	3
83 624	1	0	0	1	0	2
83 817	1	0	1	0	0	2
84 822	1	0	1	0	0	2
84 9 5	1	0	0	0	0	1
85 626	1	0	0	1	0	2
85 814	1	0	0	1	0	2
86 627	2	1	0	0	0	3
Totals	10	2	2	6	1	21

Summary Values:

Station Date	2 WTS>0.400	3 0.300	4 0.100	5 0.100	6 0.100	Mean
81 5 5	-9.0	240.0	-9.0	-9.0	180.0	225.0
81 519	0.0	-9.0	-9.0	-9.0	-9.0	0.0
81 523	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0
91 727	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0
81 817	690.0	-9.0	-9.0	130.0	-9.0	578.0
82 712	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0
82 8 4	80.0	-9.0	-9.0	190.0	-9.0	102.0
83 624	20.0	-9.0	-9.0	90.0	-9.0	34.0
83 817	240.0	-9.0	600.0	-9.0	-9.0	312.0
84 822	300.0	-9.0	250.0	-9.0	-9.0	290.0
84 9 5	200.0	-9.0	-9.0	-9.0	-9.0	200.0
95 626	210.0	-9.0	-9.0	250.0	-9.0	218.0
85 814	120.0	-9.0	-9.0	110.0	-9.0	118.0
86 627	260.0	360.0	-9.0	-9.0	-9.0	302.9
Medians	205.0	300.0	425.0	130.0	180.0	218.0
Means	212.0	300.0	425.0	154.0	180.0	216.4
CV	0.926	0.283	0.582	0.425	-9.000	0.740
CV (Means)	0.293	0.200	0.412	0.190	-9.000	0.223

Table A-22

Summary of Nitrite-Nitrogen Sample Number and Concentration ($\mu g\ N/\ell$) Data for Cowanesque Lake. Values Reported Are for the Mixed Layer (0-3 m)

Sample Frequencies:

Station Date	2	3	4	5	6	Total
81 5 5	0	0	0	0	0	0
81 519	1	1	1	1	0	4
81 523	1	0	0	1	0	2
81 727	2	0	0	0	0	2
81 817	0	0	0	0	0	0
82 712	1	1	1	2	2	7
82 8 4	1	0	0	2	0	3
83 624	1	0	0	1	0	2
83 817	1	0	1	0	0	2
84 822	1	0	1	0	0	2
84 9 5	1	0	0	0	0	1
85 626	1	0	0	1	0	2
85 814	1	0	0	1	0	2
86 627	0	0	0	0	0	0
Totals	12	2	4	9	2	29

Summary Values:

Station Date	2 WTS>0.400	3 0.300	4 0.100	5 0.100	6 0.100	Mean
81 5 5	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0
81 519	9.0	10.0	8.0	6.0	-9.0	8.9
81 523	13.0	-9.0	-9.0	14.0	-9.0	13.2
81 727	7.5	-9.0	-9.0	-9.0	-9.0	7.5
81 817	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0
81 712	10.0	10.0	11.0	17.0	21.0	11.9
82 8 4	17.0	-9.0	-9.0	12.5	-9.0	16.1
83 624	12.0	-9.0	-9.0	12.0	-9.0	12.0
83 817	13.0	-9.0	14.0	-9.0	-9.0	13.2
84 822	10.0	-9.0	13.0	-9.0	-9.0	10.6
84 9 5	3.0	-9.0	-9.0	-9.0	-9.0	3.0
85 626	6.0	-9.0	-9.0	6.0	-9.0	6.0
85 814	0.0	-9.0	-9.0	4.0	-9.0	0.8
86 627	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0
Medians	10.0	10.0	12.0	12.0	21.0	10.6
Means	9.1	10.0	11.5	10.2	21.0	9.4
CV	0.531	0.000	0.230	0.478	0.000	0.498
CV (Mean)	0.160	0.000	0.115	0.181	0.000	0.150

Table A-23

Summary of Nitrate-Nitrogen Sample Number and Concentration (μg N/ℓ) Data for Cowanesque Lake. Values Reported Are for the Mixed Layer (0-3 m)

Sample Frequencies:

Station Date	2	3	4	5	6	Total
81 5 5	0	0	0	0	0	0
81 519	1	1	1	1	0	4
81 523	1	0	0	1	0	2
81 727	2	0	0	0	0	2
81 817	1	0	0	1	0	2
82 712	1	1	1	2	2	7
82 8 4	0	0	0	0	0	0
83 624	1	0	0	1	0	2
83 817	1	0	1	0	0	2
84 822	1	0	1	0	0	2
84 9 5	1	0	0	0	0	1
85 626	1	0	0	1	0	2
85 814	1	0	0	1	0	2
86 627	2	1	0	0	0	3
Totals	14	3	4	8	2	31

Summary Values:

Station Date	2 WTS>0.400	3 0.300	4 0.100	5 0.100	6 0.100	Mean
81 5 5	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0
81 519	1,000.0	1,900.0	1,300.0	1,500.0	-9.0	1,388.9
81 523	210.0	-9.0	-9.0	210.0	-9.0	210.0
81 727	55.0	-9.0	-9.0	-9.0	-9.0	55.0
81 817	600.0	-9.0	-9.0	600.0	-9.0	600.0
82 712	600.0	600.0	700.0	950.0	1,400.0	725.0
82 8 4	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0
83 624	1,000.0	-9.0	-9.0	1,100.0	-9.0	1,020.0
83 817	1,500.0	-9.0	1,000.0	-9.0	-9.0	1,400.0
84 822	800.0	-9.0	700.0	-9.0	-9.0	780.0
84 9 5	500.0	-9.0	-9.0	-9.0	-9.0	500.0
85 626	8.0	-9.0	-9.0	24.0	-9.0	11.2
85 814	300.0	-9.0	-9.0	300.0	-9.0	300.0
86 627	650.0	500.0	-9.0	-9.0	-9.0	585.7
Medians	600.0	600.0	850.0	600.0	1,400.0	592.9
Means	601.9	1,000.0	925.0	669.1	1,400.0	631.3
CV	0.721	0.781	0.311	0.801	0.000	0.735
CV (Mean)	0.208	0.451	0.155	0.303	0.000	0.212

Table A-24

Summary of Hydrolyzed Phosphorus Sample Number and Concentration (µg P/ℓ) Data for Cowanesque Lake. Values Reported Are for the Mixed Layer (0-3 m)

Sample Frequencies:

Station Date	2	3	4	5	6	Total
81 5 5	0	1	0	0	1	2
81 519	1	1	1	1	0	4
81 523	1	0	0	1	0	2
81 727	0	0	0	0	0	0
81 817	1	0	0	1	0	2
82 712	1	1	1	2	2	7
82 8 4	1	0	0	2	0	3
83 624	1	0	0	1	0	2
83 817	1	0	1	0	0	2
84 822	1	0	1	0	0	2
84 9 5	1	0	0	0	0	1
85 626	1	0	0	1	0	2
85 814	1	0	0	1	0	2
86 627	2	1	0	0	0	3
Totals	13	4	4	10	3	34

Summary Values:

Station Date	2 WTS>0.400	3 0.300	4 0.100	5 0.100	6 0.100	Mean
81 5 5	-9.0	26.0	-9.0	-9.0	26.0	26.0
81 519	29.0	29.0	29.0	29.0	-9.0	29.0
81 523	13.0	-9.0	-9.0	41.0	-9.0	18.6
81 727	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0
81 817	29.0	-9.0	-9.0	91.0	-9.0	41.4
82 712	65.0	24.0	23.0	39.5	40.5	43.5
82 8 4	163.0	-9.0	-9.0	60.5	-9.0	142.5
83 624	13.0	-9.0	-9.0	10.0	-9.0	12.4
83 817	42.0	-9.0	33.0	-9.0	-9.0	40.2
84 822	46.0	-9.0	46.0	-9.0	-9.0	46.0
84 9 5	23.0	-9.0	-9.0	-9.0	-9.0	23.0
85 626	0.0	-9.0	-9.0	0.0	-9.0	0.0
85 814	46.0	-9.0	-9.0	652.0	-9.0	167.2
86 627	18.0	29.0	-9.0	-9.0	-9.0	22.7
Medians	29.0	27.5	31.0	40.3	33.3	29.0
Means	40.6	27.0	32.8	115.4	33.3	47.1
CV	1.048	0.091	0.297	1.895	0.308	1.058
CV (Mean)	0.303	0.045	0.149	0.670	0.218	0.293

Table A-25

Summary of Ammonia-Nitrogen Sample Number and Concentration (μg N/ℓ) Data for Hammond Lake. Values Reported Are for the Entire Water Column

Station Date	Sample Frequencies: 2	3	4	5	6	Total
80 7 1	0	2	0	0	0	2
81 5 4	1	0	0	1	1	3
81 521	0	0	0	1	0	1
81 524	0	0	0	0	0	0
81 729	0	0	0	0	0	0
81 819	1	4	3	0	0	8
8111 4	1	0	0	0	2	3
82 112	0	1	0	0	0	1
82 714	0	0	0	0	0	0
82 8 4	3	3	0	2	0	8
83 524	3	0	0	0	0	3
83 624	0	5	0	0	0	5
83 818	0	1	0	0	2	3
84 620	3	0	0	0	1	4
84 821	2	0	2	0	2	6
84 9 6	0	3	0	0	0	3
85 627	4	4	4	3	3	18
85 711	4	4	4	3	3	18
85 819	4	4	4	3	3	18
85 9 4	4	4	4	3	3	18
85 918	4	4	4	4	3	19
8510 2	4	4	4	4	4	20
851030	4	4	4	4	3	19
86 627	2	3	2	0	0	7
Totals	44	50	35	28	30	187

(Continued)

Table A-25 (Concluded)

Station Date	Summary Values: 2 WTS>0.250	3 0.350	4 0.200	5 0.100	6 0.100	Mean
80 7 1	-9.0	700.0	-9.0	-9.0	-9.0	700.0
81 5 4	220.0	-9.0	-9.0	250.0	330.0	251.1
81 521	-9.0	-9.0	-9.0	6.0	-9.0	6.0
81 524	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0
81 729	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0
81 819	410.0	1,450.0	330.0	-9.0	-9.0	845.0
8111 4	450.0	-9.0	-9.0	-9.0	380.0	430.0
82 112	-9.0	400.0	-9.0	-9.0	-9.0	400.0
82 714	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0
82 8 4	970.0	2,000.0	-9.0	255.0	-9.0	1,382.9
83 524	200.0	-9.0	-9.0	-9.0	-9.0	200.0
83 624	-9.0	790.0	-9.0	-9.0	-9.0	790.0
83 818	-9.0	300.0	-9.0	-9.0	475.0	338.9
84 620	80.0	-9.0	-9.0	-9.0	80.0	80.0
84 821	645.0	-9.0	570.0	-9.0	275.0	550.5
84 9 6	-9.0	60.0	-9.0	-9.0	-9.0	60.0
85 627	200.0	200.0	450.0	400.0	200.0	270.0
85 711	300.0	300.0	300.0	200.0	200.0	280.0
85 819	200.0	300.0	200.0	200.0	200.0	235.0
85 9 4	1,400.0	1,350.0	1,550.0	1,400.0	1,700.0	1,442.5
85 918	116.5	99.5	132.0	139.0	121.0	116.3
8510 2	110.0	70.0	70.0	200.0	70.0	93.0
851030	430.0	465.0	500.0	525.0	500.0	472.8
86 627	880.0	270.0	275.0	-9.0	-9.0	461.9
Medians	300.0	300.0	315.0	225.0	237.5	338.9
Means	440.8	583.6	437.7	357.5	377.6	447.9
CV	0.862	0.994	0.964	1.097	1.165	0.886
CV (Mean)	0.223	0.257	0.305	0.347	0.336	0.193

Table A-26

Summary of Nitrite-Nitrogen Sample Number and Concentration (μg N/ℓ) Data for Hammond Lake. Values Reported Are for the Entire Water Column

Station Date	Summary Frequencies: 2	3	4	5	6	Total
80 7 1	0	2	0	0	0	2
81 5 4	0	0	0	0	0	0
81 521	3	0	0	2	0	5
81 524	3	0	0	2	0	5
81 729	0	1	0	0	0	1
81 819	0	0	0	0	0	0
8111 4	1	0	0	0	2	3
82 112	0	1	0	0	0	1
82 714	3	3	2	0	2	10
82 8 4	3	3	0	2	0	8
83 524	3	0	0	0	0	3
83 624	0	5	0	0	0	5
83 818	0	0	0	0	0	0
84 620	3	0	0	0	1	4
84 821	2	0	2	0	2	6
84 9 6	0	3	0	0	0	3
85 627	4	3	4	3	3	17
85 711	4	4	4	3	3	18
85 819	4	4	4	3	3	18
85 9 4	4	4	4	3	3	18
85 918	4	4	4	4	3	19
8510 2	4	4	4	4	4	20
851030	4	4	4	4	3	19
86 627	0	0	0	0	0	0
Totals	49	45	32	30	29	185

(Continued)

Table A-26 (Concluded)

Station Date	Summary Values: 2 WTS>0.250	3 0.350	4 0.200	5 0.100	6 0.100	Mean
80 7 1	-9.0	10.0	-9.0	-9.0	-9.0	10.0
81 5 4	0.0	-9.0	-9.0	-9.0	-9.0	0.0
81 521	8.0	-9.0	-9.0	37.5	-9.0	16.4
81 524	7.0	-9.0	-9.0	7.5	-9.0	7.1
81 729	-9.0	1.0	-9.0	-9.0	-9.0	1.0
81 819	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0
8111 4	6.0	-9.0	-9.0	-9.0	6.5	6.1
82 112	-9.0	9.0	-9.0	-9.0	-9.0	9.0
82 714	6.0	13.0	8.0	-9.0	14.0	10.1
82 8 4	3.0	1.0	-9.0	5.0	-9.0	2.3
83 524	8.0	-9.0	-9.0	-9.0	-9.0	8.0
83 624	-9.0	3.0	-9.0	-9.0	-9.0	3.0
83 818	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0
84 620	7.0	-9.0	-9.0	-9.0	5.0	6.4
84 821	7.0	-9.0	4.5	-9.0	2.5	5.3
84 9 6	-9.0	270.0	-9.0	-9.0	-9.0	270.0
85 627	6.5	7.0	6.0	5.0	4.0	6.2
85 711	4.5	2.0	1.0	2.0	2.0	2.4
85 819	2.0	2.0	2.0	2.0	3.0	2.1
85 9 4	3.5	4.0	3.0	3.0	4.0	3.6
85 918	4.0	4.0	4.5	4.5	3.0	4.1
8510 2	24.0	25.0	25.0	20.0	20.0	23.8
851030	6.0	6.0	6.0	6.0	6.0	6.0
86 627	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0
Median	6.0	5.0	4.5	5.0	4.0	6.1
Means	6.4	25.5	6.7	9.3	6.4	19.2
CV	0.812	2.771	1.081	1.211	0.881	3.009
CV (Mean)	0.203	0.741	0.360	0.383	0.266	0.657

Table A-27

Summary of Nitrate-Nitrogen Sample Number and Concentration (μg N/ℓ) Data for Hammond Lake. Values Reported Are for the Entire Water Column

Station Date	Summary Frequencies: 2	3	4	5	6	Total
80 7 1	0	2	0	0	0	2
81 5 4	0	0	0	0	0	0
81 521	3	0	0	1	0	4
85 524	3	0	0	2	0	5
81 729	0	1	0	0	0	1
81 819	1	4	3	0	0	8
8111 4	1	0	0	0	2	3
82 112	0	1	0	0	0	1
82 714	3	2	2	0	2	9
82 8 4	3	3	0	2	0	8
83 524	3	0	0	0	0	3
83 624	0	5	0	0	0	5
83 818	0	2	0	0	2	4
84 620	3	0	0	0	1	4
84 821	2	0	2	0	2	6
84 9 6	0	3	0	0	0	3
85 627	0	1	0	0	1	2
85 711	4	4	4	3	3	18
85 819	4	4	4	3	3	18
85 9 4	4	4	4	3	3	18
85 918	4	4	4	4	3	19
8510 2	4	4	4	4	4	20
851030	4	4	4	4	3	19
86 627	2	3	2	0	0	7
Totals	48	51	33	26	29	187

(Continued)

Table A-27 (Concluded)

Station Date	Summary Values: 2 WTS>0.250	3 0.350	4 0.200	5 0.100	6 0.100	Mean
80 7 1	-9.0	0.0	-9.0	-9.0	-9.0	0.0
81 5 4	0.0	-9.0	-9.0	-9.0	-9.0	0.0
81 521	90.0	-9.0	-9.0	70.0	-9.0	84.3
81 524	55.0	-9.0	-9.0	35.0	-9.0	49.3
81 729	-9.0	38.0	-9.0	-9.0	-9.0	38.0
81 819	0.0	0.0	400.0	-9.0	-9.0	100.0
8111 4	700.0	-9.0	-9.0	-9.0	500.0	642.9
82 112	-9.0	800.0	-9.0	-9.0	-9.0	800.0
82 714	800.0	600.0	700.0	-9.0	700.0	688.9
82 8 4	900.0	500.0	-9.0	650.0	-9.0	664.3
83 524	600.0	-9.0	-9.0	-9.0	-9.0	600.0
83 624	-9.0	800.0	-9.0	-9.0	-9.0	800.0
83 818	-9.0	300.0	-9.0	-9.0	800.0	411.1
84 620	800.0	-9.0	-9.0	-9.0	800.0	800.0
84 821	250.0	-9.0	0.0	-9.0	0.0	113.6
84 9 6	-9.0	17.0	-9.0	-9.0	-9.0	17.0
85 627	-9.0	3.0	-9.0	-9.0	3.0	3.0
85 711	1.5	2.0	1.5	1.0	2.0	1.7
85 819	2.0	3.0	3.5	2.0	2.0	2.7
85 9 4	0.0	-1.0	1.0	2.0	2.0	0.3
95 918	11.5	12.0	18.0	9.5	7.0	12.3
8510 2	110.0	55.0	140.0	80.0	70.0	89.8
351030	248.5	214.5	231.0	180.0	163.0	217.7
86 627	250.0	300.0	500.0	-9.0	-9.0	334.4
Medians	110.0	38.0	79.0	35.0	38.5	94.9
Means	283.4	214.3	199.5	114.4	254.1	269.6
CV	1.178	1.350	1.267	1.828	1.341	1.156
CV (Mean)	0.286	0.327	0.401	0.609	0.387	0.236

Table A-28

Summary of Hydrolyzed Phosphorus Sample Number and Concentration (μg P/ℓ) Data for Hammond Lake. Values Reported Are for the Entire Water Column

Station Date	Summary Frequencies: 2	3	4	5	6	Total
80 7 1	0	0	0	0	0	0
81 5 4	1	0	0	1	1	3
81 521	3	0	0	2	0	5
81 524	3	0	0	2	0	5
81 729	0	1	0	0	0	1
81 819	1	4	3	0	0	8
8111 4	1	0	0	0	2	3
82 112	0	1	0	0	0	1
82 714	2	0	1	0	1	4
82 8 4	3	3	0	2	0	8
83 524	3	0	0	0	0	3
83 624	0	5	0	0	0	5
83 818	0	2	0	0	2	4
84 620	3	0	0	0	1	4
84 821	2	0	2	0	2	6
84 9 6	0	1	0	0	0	1
85 627	4	4	4	3	3	18
85 711	4	4	4	3	3	18
85 819	4	4	4	3	3	18
85 9 4	4	4	4	3	3	18
85 918	4	4	4	4	3	19
8510 2	4	4	4	4	4	20
851030	4	4	4	4	3	19
86 627	2	3	2	0	0	7
Totals	52	48	36	31	31	198

(Continued)

Table A-28 (Concluded)

Station Date	2 WTS>0.250	3 0.350	4 0.200	5 0.100	6 0.100	Mean
	Summary Values:					
80 7 1	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0
81 5 4	23.0	-9.0	-9.0	26.0	13.0	21.4
81 521	10.0	-9.0	-9.0	23.0	-9.0	13.7
81 524	65.0	-9.0	-9.0	33.0	-9.0	55.9
81 729	-9.0	307.0	-9.0	-9.0	-9.0	307.0
81 819	140.0	161.0	42.0	-9.0	-9.0	124.7
8111 4	20.0	-9.0	-9.0	-9.0	37.5	25.0
82 112	-9.0	33.0	-9.0	-9.0	-9.0	33.0
82 714	13.0	-9.0	3.0	-9.0	26.0	11.7
82 8 4	39.0	196.0	-9.0	18.0	-9.0	114.5
83 524	52.0	-9.0	-9.0	-9.0	-9.0	52.0
83 624	-9.0	49.0	-9.0	-9.0	-9.0	49.0
83 818	-9.0	165.0	-9.0	-9.0	15.5	131.8
84 620	42.0	-9.0	-9.0	-9.0	52.0	44.9
84 821	49.0	-9.0	65.0	-9.0	32.5	51.8
84 9 6	-9.0	13.0	-9.0	-9.0	-9.0	13.0
85 627	3.0	3.0	8.5	7.0	10.0	5.2
85 711	7.0	6.0	9.0	3.0	3.0	6.3
85 819	3.0	3.0	3.0	3.0	3.0	3.0
85 9 4	3.0	3.0	3.0	3.0	3.0	3.0
85 918	3.0	3.0	3.0	3.0	3.0	3.0
8510 2	3.0	3.0	3.0	3.0	3.0	3.0
851030	2.0	2.0	2.0	2.0	2.0	2.0
86 627	13.0	13.0	16.5	-9.0	-9.0	13.9
Medians	13.0	13.0	3.0	3.0	10.0	21.4
Means	27.2	64.0	14.4	11.3	15.7	47.3
CV	1.271	1.496	1.426	1.018	0.046	1.457
CV (Mean)	0.300	0.386	0.430	0.307	0.290	0.304

Table A-29

Summary of Ammonium-Nitrogen Sample Number and Concentration (μg N/ℓ) Data for Hammond Lake. Values Reported Are for the Mixed Layer (0-3 m)

Station Date	Summary Frequencies: 2	3	4	5	6	Total
80 7 1	0	1	0	0	0	1
81 5 4	1	0	0	1	1	3
81 521	0	0	0	0	0	0
81 524	0	0	0	0	0	0
81 729	0	0	0	0	0	0
81 819	0	2	1	0	0	3
8111 4	0	0	0	0	1	1
82 112	0	1	0	0	0	1
82 714	0	0	0	0	0	0
82 8 4	1	1	0	1	0	3
83 524	1	0	0	0	0	1
83 624	0	2	0	0	0	2
83 818	0	0	0	0	1	1
84 620	2	0	0	0	1	3
84 821	1	0	1	0	1	3
84 9 6	0	1	0	0	0	1
85 627	2	2	2	2	2	10
85 711	2	2	2	2	2	10
85 819	2	2	2	2	2	10
85 9 4	2	2	2	2	2	10
85 918	2	2	2	2	2	10
8510 2	2	2	2	2	3	11
851030	2	2	2	2	2	10
86 627	1	2	1	0	0	4
Totals	21	24	17	16	20	98

(Continued)

Table A-29 (Concluded)

Station Date	Summary Values: 2 WTS>0.250	3 0.350	4 0.200	5 0.100	6 0.100	Mean
80 7 1	-9.0	600.0	-9.0	-9.0	-9.0	600.0
81 5 4	220.0	-9.0	-9.0	250.0	330.0	251.1
81 521	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0
81 524	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0
81 729	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0
81 819	-9.0	0.0	310.0	-9.0	-9.0	112.7
8111 4	-9.0	-9.0	-9.0	-9.0	380.0	380.0
82 112	-9.0	400.0	-9.0	-9.0	-9.0	400.0
92 714	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0
82 8 4	10.0	130.0	-9.0	110.0	-9.0	84.3
83 524	200.0	-9.0	-9.0	-9.0	-9.0	200.0
83 624	-9.0	65.0	-9.0	-9.0	-9.0	65.0
83 818	-9.0	-9.0	-9.0	-9.0	250.0	250.0
84 620	65.0	-9.0	-9.0	-9.0	80.0	69.3
84 821	190.0	-9.0	200.0	-9.0	200.0	195.5
84 9 6	-9.0	200.0	-9.0	-9.0	-9.0	200.0
85 627	200.0	103.0	200.0	300.0	200.0	176.1
85 711	200.0	200.0	200.0	200.0	200.0	200.0
85 819	200.0	200.0	200.0	200.0	200.0	200.0
85 9 4	1,200.0	850.0	1,200.0	1,200.0	1,550.0	1,112.5
85 918	116.5	89.5	109.5	139.0	121.0	108.3
8510 2	70.0	70.0	37.0	120.0	70.0	68.4
851030	430.0	465.0	465.0	550.0	465.0	464.8
86 627	260.0	245.0	200.0	-9.0	-9.0	238.4
Medians	200.0	200.0	200.0	200.0	200.0	200.0
Means	258.6	258.4	312.1	341.0	337.2	268.8
CV	1.166	0.929	1.063	1.023	1.185	0.907
CV (Mean)	0.323	0.248	0.336	0.341	0.342	0.203

Table A-30

Summary of Nitrite-Nitrogen Sample Number and Concentration (μg N/ℓ) Data for Hammond Lake. Values Reported Are for the Mixed Layer (0-3 m)

Station Date	Summary Frequencies: 2	3	4	5	6	Total
80 7 1	0	1	0	0	0	1
81 5 4	0	0	0	0	0	0
81 521	1	0	0	1	0	2
81 524	1	0	0	1	0	2
81 729	0	1	0	0	0	1
81 819	0	0	0	0	0	0
8111 4	0	0	0	0	1	1
82 112	0	1	0	0	0	1
82 714	1	1	2	0	1	5
82 8 4	1	1	0	1	0	3
83 524	1	0	0	0	0	1
83 624	0	2	0	0	0	2
83 818	0	0	0	0	0	0
84 620	2	0	0	0	1	3
84 821	1	0	1	0	1	3
84 9 6	0	1	0	0	0	1
85 627	2	1	2	2	2	9
85 711	2	2	2	2	2	10
85 819	2	2	2	2	2	10
85 9 4	2	2	2	2	2	10
85 918	2	2	2	2	2	10
8510 2	2	2	2	2	3	11
851030	2	2	2	2	2	10
86 627	0	0	0	0	0	0
Totals	22	21	17	17	19	96

(Continued)

Table A-30 (Concluded)

	Summary Values:					
Station Date	2 WTS>0.250	3 0.350	4 0.200	5 0.100	6 0.100	Mean
80 7 1	-9.0	10.0	-9.0	-9.0	-9.0	10.0
81 5 4	0.0	-9.0	-9.0	-9.0	-9.0	0.0
81 521	8.0	-9.0	-9.0	5.0	-9.0	7.1
81 524	7.0	-9.0	-9.0	8.0	-9.0	7.3
81 729	-9.0	1.0	-9.0	-9.0	-9.0	1.0
81 819	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0
8111 4	-9.0	-9.0	-9.0	-9.0	7.0	7.0
82 112	-9.0	9.0	-9.0	-9.0	-9.0	9.0
82 714	6.0	6.0	8.0	-9.0	10.0	6.9
82 8 4	3.0	6.0	-9.0	5.0	-9.0	4.8
83 524	50.0	-9.0	-9.0	-9.0	-9.0	50.0
83 624	-9.0	2.5	-9.0	-9.0	-9.0	2.5
83 818	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0
84 620	6.0	-9.0	-9.0	-9.0	5.0	5.7
84 812	3.0	-9.0	4.0	-9.0	2.0	3.2
84 9 6	-9.0	17.0	-9.0	-9.0	-9.0	17.0
85 627	5.5	7.0	4.5	5.0	3.5	5.6
85 711	5.5	1.5	1.0	2.0	2.0	2.5
85 819	1.5	1.5	2.0	2.0	2.5	1.8
85 9 4	3.0	3.5	3.0	3.0	3.5	3.2
85 918	4.0	3.5	4.5	11.0	3.5	4.6
8510 2	23.0	20.0	30.0	20.0	20.0	22.8
851030	7.5	6.0	6.0	6.0	6.0	6.4
86 627	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0
Medians	5.5	6.0	4.5	5.0	3.5	5.7
Means	8.9	6.8	7.0	6.7	5.9	8.5
CV	1.413	0.847	1.267	0.809	0.891	1.280
CV (Mean)	0.365	0.226	0.422	0.256	0.269	0.279

Table A-31

Summary of Nitrate-Nitrogen Sample Number and Concentration ($\mu g\ N/\ell$) Data for Hammond Lake. Values Reported Are for the Mixed Layer (0-3 m)

Station Date	Summary Frequencies: 2	3	4	5	6	Total
80 7 1	0	1	0	0	0	1
81 5 4	0	0	0	0	0	0
81 521	1	0	0	1	0	2
81 524	1	0	0	1	0	2
81 729	0	1	0	0	0	1
81 819	0	2	1	0	0	3
8111 4	0	0	0	0	1	1
82 112	0	1	0	0	0	1
82 714	1	1	2	0	1	5
82 8 4	1	1	0	1	0	3
83 524	1	0	0	0	0	1
83 624	0	2	0	0	0	2
83 818	0	0	0	0	1	1
84 620	2	0	0	0	1	3
84 821	1	0	1	0	1	3
84 9 6	0	1	0	0	0	1
85 627	0	1	0	0	1	2
85 711	2	2	2	2	2	10
85 819	2	2	2	2	2	10
85 9 4	2	2	2	2	2	10
85 918	2	2	2	2	2	10
8510 2	2	2	2	2	3	11
851020	2	2	2	2	2	10
86 627	1	2	1	0	0	4
Totals	21	25	17	15	19	97

(Continued)

Table A-31 (Concluded)

Station Date	2 WTS>0.250	3 0.350	Summary Values: 4 0.200	5 0.100	6 0.100	Mean
80 7 1	-9.0	0.0	-9.0	-9.0	-9.0	0.0
81 5 4	0.0	-9.0	-9.0	-9.0	-9.0	0.0
81 521	90.0	-9.0	-9.0	70.0	-9.0	84.3
81 524	20.0	-9.0	-9.0	40.0	-9.0	25.7
81 729	-9.0	38.0	-9.0	-9.0	-9.0	38.0
81 819	-9.0	100.0	400.0	-9.0	-9.0	209.1
8111 4	-9.0	-9.0	-9.0	-9.0	500.0	500.0
82 112	-9.0	800.0	-9.0	-9.0	-9.0	800.0
82 814	600.0	700.0	700.0	-9.0	900.0	694.4
82 8 4	700.0	400.0	-9.0	500.0	-9.0	521.4
83 524	800.0	-9.0	-9.0	-9.0	-9.0	800.0
83 624	-9.0	750.0	-9.0	-9.0	-9.0	750.0
83 818	-9.0	-9.0	-9.0	-9.0	600.0	600.0
84 620	850.0	-9.0	-9.0	-9.0	800.0	835.7
84 821	200.0	-9.0	0.0	-9.0	0.0	90.9
84 9 6	-9.0	700.0	-9.0	-9.0	-9.0	700.0
85 627	-9.0	3.0	-9.0	-9.0	3.0	3.0
85 711	1.5	61.0	5.0	1.0	2.0	23.0
85 819	2.0	5.5	3.5	2.0	2.0	3.5
85 9 4	1.0	-1.0	1.5	2.0	0.5	0.5
85 918	14.5	12.5	25.5	7.0	4.5	14.3
8510 2	100.0	55.0	185.0	100.0	80.0	99.3
851030	255.5	188.5	218.5	227.0	154.0	211.6
86 627	100.0	300.0	400.0	-9.0	-9.0	262.5
Medians	100.0	80.5	105.3	40.0	42.3	154.2
Means	249.0	257.0	193.9	105.4	253.8	302.8
CV	1.278	1.201	1.236	1.566	1.363	1.062
CV (Mean)	0.330	0.300	0.391	0.522	0.394	0.217

Table A-32

Summary of Hydrolyzed Phosphorus Sample Number and Concentration (μg P/ℓ) Data for Hammond Lake. Values Reported Are for the Mixed Layer (0-3 m)

Station Date	Summary Frequencies: 2	3	4	5	6	Total
80 7 1	0	0	0	0	0	0
81 5 4	1	0	0	1	1	3
81 521	1	0	0	1	0	2
81 524	1	0	0	1	0	2
81 729	0	1	0	0	0	1
81 819	0	2	1	0	0	3
8111 4	0	0	0	0	1	1
82 112	0	1	0	0	0	1
82 714	1	0	1	0	1	3
82 8 4	1	1	0	1	0	3
83 524	1	0	0	0	0	1
83 624	0	2	0	0	0	2
83 818	0	0	0	0	1	1
84 620	2	0	0	0	1	3
84 821	1	0	1	0	1	3
84 9 6	0	1	0	0	0	1
85 627	2	2	2	2	2	10
85 711	2	2	2	2	2	10
85 819	2	2	2	2	2	10
85 9 4	2	2	2	2	2	10
85 918	2	2	2	2	2	10
8510 2	2	2	2	2	3	11
851030	2	2	2	2	2	10
86 627	1	2	1	0	0	4
Totals	24	24	18	18	21	105

(Continued)

Table A-32 (Concluded)

Station Date	Summary Values: 2 WTS>0.250	3 0.350	4 0.200	5 0.100	6 0.100	Mean
80 7 1	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0
81 5 4	23.0	-9.0	-9.0	26.0	13.0	21.4
81 521	10.0	-9.0	-9.0	26.0	-9.0	14.6
81 524	68.0	-9.0	-9.0	33.0	-9.0	58.0
81 729	-9.0	307.0	-9.0	-9.0	-9.0	307.0
81 819	-9.0	83.0	42.0	-9.0	-9.0	68.1
8111 4	-9.0	-9.0	-9.0	-9.0	46.0	46.0
82 112	-9.0	33.0	-9.0	-9.0	-9.0	33.0
82 714	13.0	-9.0	3.0	-9.0	26.0	11.7
82 8 4	0.0	33.0	-9.0	23.0	-9.0	19.8
83 524	7.0	-9.0	-9.0	-9.0	-9.0	7.0
83 624	-9.0	18.0	-9.0	-9.0	-9.0	18.0
83 818	-9.0	-9.0	-9.0	-9.0	7.0	7.0
84 620	42.5	-9.0	-9.0	-9.0	52.0	45.2
84 821	33.0	-9.0	65.0	-9.0	26.0	43.4
84 9 6	-9.0	13.0	-9.0	-9.0	-9.0	13.0
85 627	3.0	5.0	7.0	8.5	8.5	5.6
85 711	7.0	6.0	4.0	3.0	3.0	5.3
85 819	3.0	3.0	3.0	3.0	3.0	3.0
85 9 4	3.0	3.0	3.0	3.0	3.0	3.0
85 918	3.0	3.0	3.0	3.0	3.0	3.0
8510 2	3.0	3.0	3.0	3.0	3.0	3.0
851030	2.0	2.0	2.0	2.0	2.0	2.0
86 627	16.0	16.5	10.0	-9.0	-9.0	14.7
Medians	7.0	9.5	3.0	3.0	7.0	14.6
Means	14.8	37.8	13.2	12.1	15.0	32.7
CV	1.263	2.132	1.572	0.999	1.147	1.920
CV (Mean)	0.316	0.570	0.474	0.301	0.318	0.400

APPENDIX B: INTENSIVE WATER QUALITY DATA

1. A listing of variable definitions is provided below:

Variable	Label
STATION	Station identification
TIME	Sample time
COLDEPTH	Depth of water column, m
SECCHI	Secchi disk depth, m
DEPTH	Depth of sample, m
DO	Dissolved oxygen, mg/ℓ
TEMP	Temperature, °C
SPCOND	Specific conductance, μmhos/cm
PH	pH, standard pH units
TURB	Turbidity, NTU
TALK	Total alkalinity, mg/ℓ
TP	Total phosphorus, mg/ℓ
TMN	Total manganese, mg/ℓ
TFE	Total iron, mg/ℓ
IDEPTH	Depth of integrated sample, m
CHLA	Chlorophyll a, μg/ℓ
CHLB	Chlorophyll b, μg/ℓ
CHLC	Chlorophyll c, μg/ℓ
PHAEO	Phaeophytin, μg/ℓ

COWANESQUE (AUGUST 26, 1987)

STATION	TIME	COLDEPTH	SECCHI	DEPTH	DO	TEMP	SPCOND	PH	TURB	TALK	TP	TMN	TFE	IDEPTH	CHLA	CHLB	CHLC	PHAEO
1	1105	11.5	1.3	0.0	7.7	21.6	223	7.8	8.0	70	0.054	0.20	0.21	.	.	.	.	.
				1.0	7.5	21.2	223	7.8	.	.	.	.	.	.	.	.	.	.
				2.0	7.2	21.1	223	7.7	.	.	.	.	.	.	.	.	.	.
				3.0	7.2	21.0	223	7.6	.	.	.	.	.	.	.	.	.	.
				4.0	6.7	20.9	223	7.6	.	.	.	.	.	.	.	.	.	.
				5.0	3.4	20.4	227	7.1	.	.	.	.	.	.	.	.	.	.
				6.0	1.0	20.2	225	7.0	7.0	71	0.067	0.48	0.45	.	.	.	.	.
				7.0	0.2	18.7	221	6.9	.	.	.	.	.	.	.	.	.	.
				8.0	0.2	17.3	225	6.9	.	.	.	.	.	.	.	.	.	.
				9.0	0.3	16.6	230	6.9	.	.	.	.	.	.	.	.	.	.
				10.0	0.4	15.7	243	6.9	.	.	.	.	.	.	.	.	.	.
				11.0	0.4	14.3	265	6.9	.	106	0.815	4.78	7.09	.	.	.	.	.
				.	.	.	.	.	.	.	.	.	.	2.6	15.38	2.61	2.01	0.00
2	1145	9.0	1.5	0.0	7.8	21.6	325	7.7	7.0	69	0.060	0.25	0.14	.	.	.	.	.
				1.0	7.6	21.2	224	7.7	.	.	.	.	.	.	.	.	.	.
				2.0	7.3	21.0	223	7.7	.	.	.	.	.	.	.	.	.	.
				3.0	7.2	21.0	223	7.7	.	.	.	.	.	.	.	.	.	.
				4.0	7.2	21.0	224	7.6	.	.	.	.	.	.	.	.	.	.
				5.0	4.5	20.7	225	7.3	.	.	.	.	.	.	.	.	.	.
				6.0	2.4	20.4	229	7.2	.	.	.	.	.	.	.	.	.	.
				7.0	0.2	19.3	229	6.9	12.0	75	0.138	1.06	0.91	.	.	.	.	.
				8.0	0.2	18.7	225	6.8	.	.	.	.	.	.	.	.	.	.
				9.0	0.2	17.9	225	6.8	12.0	87	0.238	2.54	2.08	.	.	.	.	.
				.	.	.	.	.	.	.	.	.	.	3.0	16.54	2.29	0.37	2.62
3	1205	7.0	1.3	0.0	7.3	21.4	225	7.5	7.0	68	0.044	0.28	0.17	.	.	.	.	.
				1.0	7.1	21.1	224	7.5	.	.	.	.	.	.	.	.	.	.
				2.0	6.4	20.8	225	7.5	.	.	.	.	.	.	.	.	.	.
				3.0	5.6	20.7	226	7.4	.	.	.	.	.	.	.	.	.	.
				4.0	5.5	20.6	226	7.3	.	.	.	.	.	.	.	.	.	.
				5.0	5.3	20.6	227	7.3	.	.	.	.	.	.	.	.	.	.
				6.0	5.2	20.4	229	7.2	.	.	.	.	.	.	.	.	.	.
				7.0	1.6	19.5	240	7.0	14.0	72	0.074	0.47	0.95	.	.	.	.	.
				.	.	.	.	.	.	.	.	.	.	2.6	16.45	3.06	0.86	1.71
4	1020	4.2	0.8	0.0	6.8	20.0	228	7.3	.	72	0.054	0.36	0.58	.	.	.	.	.
				1.0	6.3	19.9	228	7.4	.	.	.	.	.	.	.	.	.	.
				2.0	6.2	19.7	232	7.4	.	.	.	.	.	.	.	.	.	.
				3.0	5.8	19.3	241	7.3	.	.	.	.	.	.	.	.	.	.
				4.0	5.4	19.2	251	7.2	.	.	.	.	.	.	.	.	.	.
				.	.	.	.	.	.	.	.	.	.	1.6	18.42	3.46	1.15	2.35

EAST SIDNEY (AUGUST 25, 1987)

STATION	TIME	COLDEPTH	SECCHI	DEPTH	DO	TEMP	SPCOND	PH	TURB	TALK	TP	TMN	TFE	IDEPTH	CHLA	CHLB	CHLC	PHAEO
1	1100	11.5	1.4	0.0	6.4	21.4	95	6.9	10.0	27	0.055	0.10	0.21	.	.	.	.	.
				1.0	5.5	21.0	95	6.8	.	.	.	.	.	.	.	.	.	.
				2.0	5.3	21.0	95	6.9	.	.	.	.	.	.	.	.	.	.
				3.0	5.3	20.9	95	6.8	.	.	.	.	.	.	.	.	.	.
				4.0	4.8	20.9	95	6.8	.	.	.	.	.	.	.	.	.	.
				5.0	4.9	20.9	95	6.8	.	.	.	.	.	.	.	.	.	.
				6.0	5.0	20.9	95	6.8	9.4	27	0.044	0.13	0.29	.	.	.	.	.
				7.0	4.7	20.9	96	6.8	.	.	.	.	.	.	.	.	.	.
				8.0	1.5	20.7	99	6.6	.	.	.	.	.	.	.	.	.	.
				9.0	2.5	20.4	100	6.6	.	.	.	.	.	.	.	.	.	.
				10.0	0.1	20.1	104	6.7	.	.	.	.	.	.	.	.	.	.
				11.0	0.1	19.8	120	6.7	15.0	30	0.076	0.64	1.24	.	.	.	.	.
				11.5	0.1	19.7	125	6.7	.	.	.	.	.	.	.	.	.	.
				.	.	.	.	.	.	.	.	.	.	3.0	13.98	3.01	3.76	3.05
2	1130	9.0	1.5	0.0	6.1	21.3	95	6.9	9.0	28	0.057	0.09	0.26	.	.	.	.	.
				1.0	6.0	21.0	94	6.9	.	.	.	.	.	.	.	.	.	.
				2.0	6.0	20.9	94	6.9	.	.	.	.	.	.	.	.	.	.
				3.0	5.9	20.9	94	6.9	.	.	.	.	.	.	.	.	.	.
				4.0	6.0	20.9	94	6.9	8.5	.	0.055	0.06	0.41	.	.	.	.	.
				5.0	5.8	20.9	94	6.8	.	.	.	.	.	.	.	.	.	.
				6.0	5.8	20.9	95	6.8	.	.	.	.	.	.	.	.	.	.
				7.0	5.8	20.9	94	6.8	.	.	.	.	.	.	.	.	.	.
				8.0	5.4	20.8	95	6.7	11.0	.	0.068	0.11	0.31	.	.	.	.	.
				9.0	1.5	20.5	99	6.6	.	.	.	.	.	.	.	.	.	.
				.	.	.	.	.	.	.	.	.	.	2.8	13.32	2.90	3.30	1.02
3	1145	7.0	1.4	0.0	6.1	21.3	95	6.9	12.0	27	0.057	0.10	0.21	.	.	.	.	.
				1.0	6.1	21.3	95	6.9	.	.	.	.	.	.	.	.	.	.
				2.0	6.3	21.2	95	6.9	.	.	.	.	.	.	.	.	.	.
				3.0	6.8	21.0	95	7.0	.	.	.	.	.	.	.	.	.	.
				4.0	6.9	21.0	95	7.0	12.0	.	0.072	0.07	0.32	.	.	.	.	.
				5.0	6.8	21.0	95	7.0	.	.	.	.	.	.	.	.	.	.
				6.0	6.6	21.0	95	7.0	9.5	.	0.059	0.07	0.29	.	.	.	.	.
				7.0	6.2	20.9	95	7.0	.	.	.	.	.	.	.	.	.	.
				.	.	.	.	.	.	.	.	.	.	2.8	18.00	3.13	2.75	2.51
4	1230	6.7	1.0	0.0	7.4	21.1	95	7.1	9.4	27	0.064	0.08	0.29	.	.	.	.	.
				1.0	7.4	20.9	95	7.1	.	.	.	.	.	.	.	.	.	.
				2.0	7.4	20.7	95	7.1	.	.	.	.	.	.	.	.	.	.
				3.0	7.4	20.6	95	7.1	.	.	.	.	.	.	.	.	.	.
				4.0	7.4	20.6	94	7.1	11.0	.	0.080	0.07	0.40	.	.	.	.	.
				5.0	7.4	20.5	95	7.0	.	.	.	.	.	.	.	.	.	.
				6.0	7.4	20.2	95	7.0	4.6	.	0.078	0.07	0.48	.	.	.	.	.
				6.7	7.2	20.2	95	7.0	.	.	.	.	.	.	.	.	.	.
				.	.	.	.	.	.	.	.	.	.	2.0	20.27	4.76	5.97	3.90

EAST SIDNEY (AUGUST 25, 1987)

STATION	TIME	COLDEPTH	SECCHI	DEPTH	DO	TEMP	SPCOND	PH	TURB	TALK	TP	TMN	TFE	IDEPTH	CHLA	CHLB	CHLC	PHAEO
5	1215	3.3	0.7	0.0	9.2	20.7	95	7.9	15.0	28	0.115	0.07	0.45	.	.	.	.	.
				1.0	9.2	20.6	95	7.8	.	.	.	.	.	.	.	.	.	.
				2.0	9.0	20.2	95	7.6	.	.	.	.	.	.	.	.	.	.
				3.0	8.1	18.3	98	7.3	17.0	.	0.110	0.07	0.49	.	.	.	.	.
				3.3	8.1	18.3	98	7.3	.	.	.	.	.	.	.	.	.	.
				.	.	.	.	.	.	.	.	.	.	1.4	23.09	5.53	7.38	2.40

HAMMOND (AUGUST 26, 1987)

STATION	TIME	COLDEPTH	SECCHI	DEPTH	DO	TEMP	SPCOND	PH	TURB	TALK	TP	TMN	TFE	IDEPTH	CHLA	CHLB	CHLC	PHAEO
1	1440	7.5	0.5	0.0	11.0	22.3	144	8.9	26.0	56	0.121	0.24	0.21	.	.	.	.	.
				1.0	8.5	21.9	143	8.6	.	.	.	.	.	.	.	.	.	.
				2.0	7.3	21.7	145	8.4	.	.	.	.	.	.	.	.	.	.
				3.0	7.2	21.6	145	8.2	.	.	.	.	.	.	.	.	.	.
				4.0	6.8	21.5	146	8.1	11.0	52	0.067	0.24	0.32	.	.	.	.	.
				5.0	6.5	21.2	147	7.8	.	.	.	.	.	.	.	.	.	.
				6.0	6.5	21.0	148	7.6	.	.	.	.	.	.	.	.	.	.
				7.0	6.3	21.0	148	7.6	15.0	53	0.114	0.33	0.74	.	.	.	.	.
				.	.	.	.	.	.	.	.	.	.	1.0	64.83	10.80	7.36	0.00
2	1510	7.5	0.4	0.0	9.8	21.6	144	8.7	20.0	52	0.096	0.24	0.27	.	.	.	.	.
				1.0	9.1	21.5	145	8.6	.	.	.	.	.	.	.	.	.	.
				2.0	8.2	21.1	146	8.4	.	.	.	.	.	.	.	.	.	.
				3.0	8.2	21.0	146	8.2	.	.	.	.	.	.	.	.	.	.
				4.0	7.9	20.7	147	8.1	12.0	52	0.072	0.26	0.42	.	.	.	.	.
				5.0	7.7	20.6	146	7.9	.	.	.	.	.	.	.	.	.	.
				6.0	7.8	20.6	147	7.5	.	.	.	.	.	.	.	.	.	.
				7.0	7.2	20.5	147	7.7	26.0	54	0.149	0.52	2.77	.	.	.	.	.
				.	.	.	.	.	.	.	.	.	.	0.8	64.06	9.58	6.81	4.38
3	1520	5.2	0.8	0.0	10.6	21.5	145	8.5	14.0	52	0.087	0.07	0.13	.	.	.	.	.
				1.0	10.2	21.4	145	8.6	.	.	.	.	.	.	.	.	.	.
				2.0	8.3	20.8	147	8.2	.	.	.	.	.	.	.	.	.	.
				3.0	7.8	20.5	147	8.0	.	.	.	.	.	.	.	.	.	.
				4.0	7.7	20.4	147	7.8	.	.	.	.	.	.	.	.	.	.
				5.0	7.7	19.6	148	7.7	.	.	.	.	.	.	.	.	.	.
				.	.	.	.	.	.	.	.	.	.	1.6	35.43	5.38	4.55	3.90
4	1530	4.5	0.8	0.0	10.0	21.5	146	8.5	12.0	53	0.085	0.29	0.38	.	.	.	.	.
				1.0	9.7	21.4	147	8.5	.	.	.	.	.	.	.	.	.	.
				2.0	8.7	19.9	147	8.2	.	.	.	.	.	.	.	.	.	.
				3.0	7.6	19.1	150	7.6	.	.	.	.	.	.	.	.	.	.
				4.0	7.6	18.7	154	7.5	19.0	51	0.091	0.26	0.86	.	.	.	.	.
				.	.	.	.	.	.	.	.	.	.	1.6	27.34	5.64	5.18	3.15
5	1545	2.2	0.7	0.0	10.2	21.0	144	8.6	16.0	53	0.105	0.24	0.47	.	.	.	.	.
				1.0	10.0	20.0	147	8.4	.	.	.	.	.	.	.	.	.	.
				2.0	7.8	18.4	176	7.5	.	.	.	.	.	.	.	.	.	.
				.	.	.	.	.	.	.	.	.	.	1.4	28.24	5.53	7.70	2.83

TIOGA (AUGUST 27, 1987)

STATION	TIME	COLDEPTH	SECCHI	DEPTH	DO	TEMP	SPCOND	PH	TURB	TALK	TP	TMN	TFE	IDEPTH	CHLA	CHLB	CHLC	PHAEO
1	0950	13.7	1.3	0.0	7.7	20.6	203	7.0	7.0	23	0.022	1.30	0.14	.	.	.	.	.
				1.0	7.7	20.6	203	7.0	.	.	.	.	.	.	.	.	.	.
				2.0	7.7	20.6	203	7.0	.	.	.	.	.	.	.	.	.	.
				3.0	7.7	20.6	203	7.0	.	.	.	.	.	.	.	.	.	.
				4.0	7.7	20.6	203	7.0	.	.	.	.	.	.	.	.	.	.
				5.0	7.7	20.6	203	7.0	.	.	.	.	.	.	.	.	.	.
				6.0	7.7	20.6	203	6.9	.	.	.	.	.	.	.	.	.	.
				7.0	7.7	20.6	203	6.9	.	.	.	.	.	.	.	.	.	.
				8.0	7.7	20.6	203	6.8	.	.	.	.	.	.	.	.	.	.
				9.0	7.6	20.6	204	6.8	.	.	.	.	.	.	.	.	.	.
				10.0	7.2	20.3	220	6.7	.	.	.	.	.	.	.	.	.	.
				11.0	7.1	19.9	244	6.5	12.0	13	0.028	2.54	0.44	.	.	.	.	.
				12.0	7.1	19.6	269	6.4	.	.	.	.	.	.	.	.	.	.
				13.0	6.9	19.5	293	6.4	18.0	10	0.052	3.48	0.98	.	.	.	.	.
				.	.	.	.	.	.	.	.	.	.	2.6	4.73	1.69	2.03	1.87
2	1010	12.2	1.4	0.0	7.5	20.6	204	6.9	5.0	22	0.043	1.33	0.17	.	.	.	.	.
				1.0	7.5	20.6	204	6.9	.	.	.	.	.	.	.	.	.	.
				2.0	7.5	20.6	204	6.8	.	.	.	.	.	.	.	.	.	.
				3.0	7.6	20.5	204	6.8	.	.	.	.	.	.	.	.	.	.
				4.0	7.6	20.6	204	6.8	.	.	.	.	.	.	.	.	.	.
				5.0	7.5	20.6	205	6.8	.	.	.	.	.	.	.	.	.	.
				6.0	7.5	20.6	206	6.7	.	.	.	.	.	.	.	.	.	.
				7.0	7.5	20.5	207	6.6	.	.	.	.	.	.	.	.	.	.
				8.0	7.5	20.5	207	6.5	.	.	.	.	.	.	.	.	.	.
				9.0	7.5	20.5	208	6.4	.	.	.	.	.	.	.	.	.	.
				10.0	7.4	20.3	229	6.3	.	.	.	.	.	.	.	.	.	.
				11.0	7.2	19.8	269	6.0	8.0	17	0.036	2.18	0.43	.	.	.	.	.
				12.0	7.1	19.5	321	5.7	8.0	10	0.034	3.42	0.55	.	.	.	.	.
				.	.	.	.	.	.	.	.	.	.	2.8	4.82	1.58	1.37	1.39
3	1030	.	1.3	0.0	7.9	20.5	206	6.8	5.0	22	0.034	1.36	0.13	.	.	.	.	.
				1.0	7.9	20.5	206	6.8	.	.	.	.	.	.	.	.	.	.
				2.0	8.0	20.5	206	6.7	.	.	.	.	.	.	.	.	.	.
				3.0	8.0	20.5	206	6.6	.	.	.	.	.	.	.	.	.	.
				4.0	8.0	20.5	207	6.6	.	.	.	.	.	.	.	.	.	.
				5.0	8.0	20.5	207	6.5	.	.	.	.	.	.	.	.	.	.
				6.0	8.0	20.5	206	6.4	.	.	.	.	.	.	.	.	.	.
				7.0	8.0	20.3	212	6.1	.	.	.	.	.	.	.	.	.	.
				8.0	7.8	19.2	335	5.6	6.0	20	0.088	1.67	0.37	.	.	.	.	.
				.	.	.	.	.	.	.	.	.	.	2.6	2.68	1.32	1.78	1.71

TIOGA (AUGUST 27, 1987)

STATION	TIME	COLDEPTH	SECCHI	DEPTH	DO	TEMP	SPCOND	PH	TURB	TALK	TP	TMN	TFE	IDEPTH	CHLA	CHLB	CHLC	PHAEO
4	1045	6.2	1.4	0.0	8.3	20.4	213	6.5	5.0	19	0.035	1.47	0.21	.	.	.	.	.
				1.0	8.3	20.4	212	6.4	.	.	.	.	.	.	.	.	.	.
				2.0	8.3	20.4	212	6.3	.	.	.	.	.	.	.	.	.	.
				3.0	8.3	20.4	212	6.2	.	.	.	.	.	.	.	.	.	.
				4.0	8.3	20.4	216	6.1	.	.	.	.	.	.	.	.	.	.
				5.0	8.4	20.2	231	5.8	7.0	19	0.037	1.53	0.36	.	.	.	.	.
				6.0	9.0	19.2	415	4.5	8.0	18	0.037	1.78	0.48	.	.	.	.	.
				.	.	.	.	.	.	.	.	.	.	2.8	2.70	1.25	0.80	1.71

WHITNEY POINT (AUGUST 24, 1987)

STATION	TIME	COLDEPTH	SECCHI	DEPTH	DO	TEMP	SPCOND	PH	TURB	TALK	TP	TMN	TFE	IDEPTH	CHLA	CHLB	CHLC	PHAEO
1	1520	5.0	0.8	0.0	8.4	21.9	146	8.0	12.0	.	0.111	0.09	0.44	.	.	.	.	.
				1.0	8.4	21.9	146	8.0	.	.	.	.	.	.	.	.	.	.
				2.0	8.1	21.9	146	7.9	.	.	.	.	.	.	.	.	.	.
				3.0	8.0	21.9	146	8.0	12.0	52	0.090	0.09	0.48	.	.	.	.	.
				4.0	8.0	21.9	145	8.0	.	.	.	.	.	.	.	.	.	.
				5.0	7.9	21.9	146	7.9	12.0	50	0.104	0.10	0.56	.	.	.	.	.
				5.5	7.7	21.9	145	7.9	.	.	.	.	.	.	.	.	.	.
				.	.	.	.	.	.	.	.	.	.	1.6	9.30	2.79	4.31	3.37
2	1455	7.1	0.7	0.0	8.1	21.9	145	8.0	12.0	50	0.085	0.09	0.47	.	.	.	.	.
				1.0	8.0	21.9	146	8.0	.	.	.	.	.	.	.	.	.	.
				2.0	8.0	21.9	145	8.0	.	.	.	.	.	.	.	.	.	.
				3.0	7.8	21.8	146	7.9	12.0	49	0.085	0.10	0.51	.	.	.	.	.
				4.0	7.7	21.7	146	7.9	.	.	.	.	.	.	.	.	.	.
				5.0	7.6	21.7	146	7.8	.	.	.	.	.	.	.	.	.	.
				6.0	7.5	21.7	145	7.8	.	.	.	.	.	.	.	.	.	.
				7.0	7.2	21.7	145	7.7	13.0	49	0.148	0.10	0.59	.	.	.	.	.
				.	.	.	.	.	.	.	.	.	.	1.4	19.28	3.62	5.53	2.94
3	1410	5.6	0.7	0.0	7.8	21.8	146	7.8	13.0	49	0.059	0.10	0.62	.	.	.	.	.
				1.0	7.6	21.8	145	7.7	.	.	.	.	.	.	.	.	.	.
				2.0	7.3	21.7	145	7.7	.	.	.	.	.	.	.	.	.	.
				3.0	7.2	21.7	146	7.7	13.0	.	0.068	0.10	0.64	.	.	.	.	.
				4.0	7.1	21.6	146	7.6	.	.	.	.	.	.	.	.	.	.
				5.0	6.8	21.6	146	7.6	14.0	.	0.073	0.10	0.65	.	.	.	.	.
				5.6	6.8	21.6	146	7.6	.	.	.	.	.	.	.	.	.	.
				.	.	.	.	.	.	.	.	.	.	1.4	20.91	3.14	3.68	3.74
4A	1335	6.9	0.8	0.0	8.0	21.8	145	7.9	12.0	.	0.070	0.09	0.56	.	.	.	.	.
				1.0	7.8	21.8	145	7.9	.	.	.	.	.	.	.	.	.	.
				2.0	7.6	21.7	145	7.8	.	.	.	.	.	.	.	.	.	.
				3.0	7.4	21.7	145	7.8	10.0	49	0.063	0.11	0.60	.	.	.	.	.
				4.0	7.0	21.6	145	7.7	.	.	.	.	.	.	.	.	.	.
				5.0	6.9	21.6	145	7.7	.	.	.	.	.	.	.	.	.	.
				6.0	6.8	21.6	145	7.6	10.0	.	0.077	0.15	1.36	.	.	.	.	.
				6.9	6.3	21.5	145	7.5	.	.	.	.	.	.	.	.	.	.
				.	.	.	.	.	.	.	.	.	.	1.6	18.43	3.31	3.32	5.08
4B	1355	3.8	0.7	0.0	7.8	21.6	145	7.7	13.0	50	0.069	0.10	0.65	.	.	.	.	.
				1.0	7.5	21.6	145	7.7	.	.	.	.	.	.	.	.	.	.
				2.0	7.5	21.5	145	7.7	.	.	.	.	.	.	.	.	.	.
				3.0	7.3	21.5	146	7.7	13.0	.	0.073	0.10	0.68	.	.	.	.	.
				3.8	7.1	21.5	145	7.6	.	.	.	.	.	.	.	.	.	.
				.	.	.	.	.	.	.	.	.	.	1.4	17.35	3.02	2.29	4.12

WHITNEY POINT (AUGUST 24, 1987)

STATION	TIME	COLDEPTH	SECCHI	DEPTH	DO	TEMP	SPCOND	PH	TURB	TALK	TP	TMN	TFE	IDEPTH	CHLA	CHLB	CHLC	PHAEO
5	1305	3.9	0.9	0.0	7.8	21.6	145	7.8	11.0	.	0.066	0.09	0.45	.	.	.	.	.
				1.0	7.7	21.7	145	7.8	.	.	.	.	.	.	.	.	.	.
				2.0	7.6	21.6	145	7.8	.	.	.	.	.	.	.	.	.	.
				3.0	7.5	21.6	145	7.8	11.0	49	0.076	0.10	0.48	.	.	.	.	.
				3.9	6.8	21.5	145	7.7	.	.	.	.	.	.	.	.	.	.
				.	.	.	.	.	.	.	.	.	.	1.8	19.59	2.99	1.68	4.22
6	1244	1.8	0.6	0.0	7.9	21.3	146	7.4	15.0	50	0.095	0.12	0.79	.	.	.	.	.
				1.0	7.8	21.3	147	7.5	.	.	.	.	.	.	.	.	.	.
				1.8	8.0	21.2	147	7.6	.	.	.	.	.	.	.	.	.	.
				.	.	.	.	.	.	.	.	.	.	1.2	22.49	3.01	2.61	2.73

APPENDIX C: INVENTORY OF PHYTOPLANKTON

1. The following tables list phytoplankton species present in samples collected in the surface waters of Cowanesque, Tioga-Hammond, East Sidney, and Whitney Point Lakes in August 1987. Determinations of species abundance are relative and comparisons between lakes are not possible.

Table C-1

Whitney Point Lake Phytoplankton

** Aphanizomenon flos-aquae	Schroederia setigera
** Anabaena (2 spp.)	Dictyosphaerium ehrenbergii
Raphidiopsis curvata	Euastrum
Rhodomonas minuta	Cocconeis (frustuli)
Cryptomonas (2 spp.)	Oocystis
** Melosira (2 spp.)	Coelosphaerium kutzingianum
Nitzschia	Lyngbya limnetica
Gymnodinium	Coelastrum microporum
Microcystis aeruginosa	Trachelomonas (2 spp.)
Aphanocapsa	* Coelosphaerium naegelianum
* Rhizosolenia eriensis ?	Ceratium hirundinella
* Cyclotella	Pediastrum simplex v. duodenarium
Chrysochromulina parva	Staurastrum
Chroococcus	Oscillatoria
Ankistrodesmus	Nephrocytium limneticum ?
Synedra	Carteria or Platymonas

* Abundant species.
** Highly abundant species.
? Species identification not positive.

Table C-2

Hammond Lake Phytoplankton

** Anabaena spiroides v. crassa	Platymonas or Carteria
Aphanocapsa	Melosira granulata
Cryptomonas	Oscillatoria
Coelosphaerium naegelianum	Anabaena sp.
Melosira sp.	Cosmarium
Pediastrum duplex v. reticulatum	Ceratium hirundinella
Rhodomonas minuta	Schroederia setigera
* Trachelomonas (3 spp.)	Mallomonas
Stephanodiscus	Pandorina morum
Trachelomonas volvocina ?	Nephrocytium limneticum ?
Chroococcus	

* Abundant species.
** Highly abundant species.
? Species identification not positive.

Table C-3

Tioga Lake Phytoplankton

* Attheya	Sphaerocystis or Gloeocystis
Melosira granulata	Anabaena
Fragilaria crotonensis	** Aphanizomenon ?
Cymbella	Pediastrum duplex v. clathratum
Synedra	Coelosphaerium naegelianum
Cryptomonas	Closterium
* Coelastrum reticulatum	Pediastrum simplex v. duodenarium
Rhodomonas minuta	Dinobryon
* Cyclotella stelligera ?	

* Abundant species.
** Highly abundant species.
? Species identification not positive.

Table C-4

East Sidney Lake Phytoplankton

Pediastrum duplex v. reticulatum	** Coelosphaerium naegelianum
Trachelomonas (2 spp.)	Chroococcus
Cryptomonas	Melosira
Anabaena (coiled)	Coelastrum microporum
Anabaena (straight)	Cosmarium
* Coelastrum reticulatum	Oocystis
Aphanizomenon ?	Schroederia setigera

* Abundant species.
** Highly abundant species.
? Species identification not positive.

Table C-5

Cowanesque Lake Phytoplankton

Pediastrum simplex v. duodenarium	Schroederia setigera
* Coelastrum reticulatum	** Anabaena (straight)
Anabaena spiroides v. crassa	Cyclotella
** Aphanizomenon	Coelastrum microporum
* Trachelomonas	Oocystis
Cryptomonas	Coelosphaerium naegelianum
Carteria or Platymonas	Ankistrodesmus
Rhodomonas minuta	Ceratium
Crucigenia truncata ?	Scenedesmus

* Abundant species.
** Highly abundant species.
? Species identification not positive.

APPENDIX D: SAMPLING DESIGN

Introduction

1. Five distinct steps are involved in sampling program design, implementation, and data analysis:

   a. Problem identification.

   b. Statement of the objective.

   c. Formulation of the sampling design.

   d. Implementation of the sampling design.

   e. Data analysis.

Preceding sections of this report dealt with the first two of these steps. The remainder of this section will address the third step.

2. The statement of objectives serves to define the target population, while sampling design defines the sample population. The target population can be defined as the set of all possible observations, whereas the sample population is a limited subset of the target population. The definition of the target population serves to restrict the area of concern. In the case of pool sampling, for instance, the stated objective may restrict the target population to all possible observations throughout the growing season rather than the entire year. Defining the sampling population would impose further restriction by detailing when and where observations are to be made. The objectives also define the parameter list or what is to be measured.

3. Sampling and statistical data analysis make it possible, under certain assumptions, to infer the characteristics of the whole (i.e., the target population) from the characteristics of a limited number of its parts (i.e., the sample population). Two assumptions are implicit in sampling design and the eventual analysis of the data derived from the sampling program. First, values of the target population are assumed to be normally distributed. This assumption is required because most statistical methods have been developed to treat normally distributed populations. This assumption is not overly restrictive because most statistical tests are robust with respect to minor deviations from normality. Also, for those cases where deviations are significant, appropriate analytical methods (called distribution-free or nonparametric methods) exist and can be applied. Second, the values of the sample population are assumed to be independent. Independence of the values of a

sample can be assured if every possible observation of the target population has an equal chance of being selected for the sample. The lack of independence will usually result in estimates that are seriously biased.

4. The major objective of sampling design is to provide a means for obtaining an accurate and precise estimate of the target population. The development of a sampling design allows the investigator to consider the uncertainty and costs associated with various designs. There are essentially only two elements to the design of a sampling program. First, determination of sample size and, second, allocation of observations in space (i.e., where to sample) and time (i.e., when to sample).

5. Sample size can be determined, given: (a) the desired precision of the estimates, (b) the acceptable probability of error, and (c) some basic information about the target population in question. Precision refers to the reliability of the estimate and the variability between repeated measures of the same quantity. The desired precision states the level of uncertainty that the investigator is willing to accept. Consider the situation where the sample size for total phosphorus was chosen to provide an estimate of the mean with a desired precision of plus or minus 10 percent. Suppose a sample mean of 15 μg/ℓ was obtained. This would imply that the actual target population mean would lie somewhere between 13.5 and 16.5 μg/ℓ (i.e., 15 ± 1.5 μg/ℓ). It is important to realize that the precision of the estimates describes the uncertainty associated with the estimates. Less precise estimates result in greater uncertainty about the condition of the target population and thus, provide less valuable information to the investigator.

6. Sample size is also dependent on the level of probable error that is defined to be acceptable. In sampling there is always a chance that the actual target population mean will not lie in the interval described by the sample mean and the precision. This probability of error decreases with increasing sample size. In statistics, a 0.05 level of probable error (i.e., 1 chance in 20) is most often used, but in water quality sampling higher levels of probable error may be considered acceptable.

7. Finally, sample size is dependent on the behavior of the target population. It should be obvious that a highly variable population (i.e., large variance) will require more samples to specify the mean within the desired precision than a population with little variability. Estimates of the mean and variance of the target population can be derived from existing data,

data derived from pilot studies, or from educated guesses. In any case, sample size (for a simple random sample) can be calculated from the following equation:

$$n = \frac{t^2 s^2}{(ry)^2}$$

where

t^2 = Student's t-statistic, a function of error probability

s^2 = estimate of the target population's variance

r = desired precision, expressed as a decimal fraction

y = estimate of the target population's mean

8. Given the required sample size, the next step in developing a sampling design involves the allocation of the observations that comprise the sample population. There are essentially three methods for allocating observations in space and time: (a) simple random sampling, (b) stratified random sampling, and (c) systematic sampling. Simple random sampling is a procedure for selecting n observations out of the N possible observations of the target population. While being the simplest sampling program to design, simple random sampling is often difficult to implement because of its completely randomized design and, as a result, is rarely used in water quality sampling. Stratified random sampling consists of dividing the target population into distinct sub-populations referred to as strata. If a random sample is taken from each stratum, then a stratified random design results.

9. Stratified random sampling has two important advantages over simple random sampling. First, it can be advantageous to have data on separate subsets of the target population. For example, stratifying with respect to season would provide estimates of water quality during characteristic periods of the year as well as an estimate of the annual average condition.

10. Second, stratification will often produce an increase in the precision of the estimate of the entire population. The concept behind stratification involves dividing a heterogeneous population into more homogeneous sub-populations. If the measurements within a stratum vary little from one observation to another, a precise estimate can be obtained with relatively few

samples. The total sample size for a stratified design will often be less than would be required by a simple random design.

11. Allocation of observations to the strata can be made by one of three approaches: (a) equal, (b) proportional, or (c) optimal. Equal allocation simply divides the total sample size by the number of strata and assigns the resultant number of observations to each of the strata. Proportional allocation is a weighted allocation scheme wherein the number of observations allocated to a given stratum is proportional to its size or duration in time. For example, assume a reservoir sampling program is to be temporally stratified with the strata defined as spring turnover, summer stratified period, fall turnover, and winter. A proportional allocation scheme would dedicate fewer observations to the spring turnover and fall turnover strata because of their limited duration. Optimal allocation considers both stratum size and variability. Larger and more variable strata are allocated more observations than smaller and less variable strata. Stratified designs are extremely efficient and effective but are not used as often as systematic designs.

12. Systematic sampling designs are the most commonly used but can possess serious drawbacks. Systematic sampling consists of taking samples at specified intervals in time or space and are frequently used because of their ease of implementation. The major limitation to systematic designs is that they may produce data that lack independence. Samples that are taken at equal intervals in space or time are often correlated. The correlation implies that successive values of the same parameter are dependent on previous values and, therefore, the sample as a whole lacks independence. Systematic designs are useful and the best approach when the objective is to document spatial or temporal trends, but systematic designs are a liability when a determination of the average or general condition is required.

13. A more detailed introduction to the concerns of reservoir water quality sampling design and statistical data analysis can be found in Gaugush (1986, 1987).

Statement of the Objectives

14. There are two objectives in the proposed reservoir sampling program:

a. Characterize reservoir-average water quality during the growing season.

b. Determine the mass influx and discharge of phosphorus and nitrogen.

The following paragraphs described possible designs for sampling pools and tributaries, and are based on analyses of historical data.

Pool Water Quality Sampling Design

Analysis of variance

15. In order to identify sources of variability in Cowanesque, East Sidney, Hammond, and Whitney Point, historical data for each reservoir were subjected to a three-factor analysis of variance. Data for Tioga were insufficient for the analysis. Data were analyzed to determine how much of the variance in sampled water quality variables was explained or accounted for by the existing sampling design. The three factors used in the analysis were station, month, and depth. The analysis of variance (Tables D-1 through D-4) indicates that all three factors make a significant contribution to the variance explained by the sampling design. For most of the variables, month and depth effects accounted for the majority of the variance explained, while station effects accounted for a smaller fraction of the variance. This finding is not unexpected given the size and flushing rates of these reservoirs. These reservoirs are relatively small and have residence times of 40 days or less. Both of these factors would act to reduce the significance of longitudinal gradients in water quality and, as a result, station differences would be minor in comparison with depth and time differences. The relatively low stability of these reservoirs also contributes to the minor influence of station effects. Lower stability implies periodic mixing events which would act to reduce spatial differences.

Determination of sample size

16. In order to calculate sample sizes for Cowanesque, East Sidney, Hammond, and Whitney Point, a method for calculating sample size somewhat different than that presented above was used. The method described earlier provides a sample size for a single variable. Rather than calculating sample size on a variable by variable basis, a method for providing a single sample size for all variables was required. Previously, sample size was given as:

Table D-1

Three-Factor Analysis of Variance of Historical Water Quality Data for Cowanesque Lake

Variable	p	Total	Station	Month	Depth
CaCO3	0.0001	68	7	61	--
DO	0.0001	66	8	11	47
NH3	0.0001	64	18	--	46
NO2	0.0204	27	15	12	--
NO3	0.0457	25	14	11	--
pH	0.0069	16	5	5	6
PO4	0.0994	16	--	16	--
TP	0.0989	16	--	16	--
SO4	0.0041	97	19	14	64
SPCOND	0.0001	63	6	57	--
TEMP	0.0001	87	3	63	21

Table D-2

Three-Factor Analysis for Variance of Historical Water Quality Data for East Sidney Lake

Variable	p	Total	Station	Month	Depth
CaCO3	0.1338	--	--	--	--
DO	0.0001	64	3	16	45
NH3	0.6116	--	--	--	--
NO2	0.0583	48	--	48	--
NO3	0.3187	--	--	--	--
pH	0.0002	32	6	26	--
PO4	0.5796	--	--	--	--
TP	0.5793	--	--	--	--
SPCOND	0.0542	17	--	17	--
TEMP	0.0001	78	10	29	39

Table D-3

Three-Factor Analysis for Variance of Historical Water Quality Data for Hammond Lake

Variable	p	Total	Station	Month	Depth
ACID	0.0052	13	--	13	--
CaCO3	0.0001	58	6	47	5
DO	0.0001	71	3	30	38
NH3	0.0001	25	--	9	16
NO2	0.3142	--	--	--	--
NO3	0.0001	24	4	20	--
pH	0.0001	21	--	12	9
PO4	0.0001	30	6	16	8
TP	0.0001	30	6	16	8
Secchi	0.0001	82	4	73	5
SO4	0.0609	10	--	10	--
SPCOND	0.0001	33	6	25	2
TEMP	0.0001	71	--	66	5
TFE	0.0001	34	--	--	34

Table D-4

Three-Factor Analysis of Variance of Historical Water Quality Data for Whitney Point Lake

Variable	p	Total	Station	Month	Depth
CaCO3	0.0090	32	--	32	--
DO	0.0001	55	12	10	33
NH3	0.0001	75	13	--	62
NO2	0.1509	--	--	--	--
NO3	0.3248	--	--	--	--
pH	0.0001	51	--	51	--
PO4	0.5459	--	--	--	--
TP	0.5463	--	--	--	--
SO4	0.1302	--	--	--	--
SPCOND	0.0634	8	8	--	--
TEMP	0.0001	72	--	61	11

$$n = \frac{t^2 s^2}{(r\bar{y})^2}$$

This equation can be arranged to

$$n = \frac{t}{r}^2 \frac{s}{\bar{y}}^2$$

which can also be expressed as

$$n = \frac{t}{r}^2 CV^2$$

Expressing sample size as a function of the coefficient of variation (CV) allows for the calculation of sample size for a number of variables by using their average CV. The CV's for a number of water quality variables in Cowanesque, East Sidney, Hammond, and Whitney Point are given by Table D-5. Also, Table D-5 provides the minimum, average, and maximum CV for each of the reservoirs. Using these values, sample sizes for a number of combinations of desired precision and probability of error can be derived (Table D-6).

17. Sample size ranges from a minimum of three to a maximum of well over a thousand samples. In general, small sample sizes result in lower precision and higher probability of error, whereas large sample sizes provide greater precision and reduced probability of error. Clearly, many of the given sample sizes are too large to be feasible within the constraints of time, manpower, and funding, but Table D-6 provides the means to make decisions about sample size with full knowledge of the consequences (in terms of uncertainty) of those decisions.

Sample allocation

18. There are three dimensions of concern in the development of a design for pool water quality sampling: (a) temporal, (b) vertical, and (c) longitudinal (along an axis parallel to the major hydrological flow). The analysis of variance demonstrated that although the majority of the explained variance was accounted for by month and depth effects, station effects were significant. The historical data suggest that the most effective sampling design would deal with all three dimensions.

Table D-5

Coefficients of Variation

Variable	Cowanesque	East Sidney	Hammond	Whitney Point
Acid	--	--	92	--
CaCO3	20	33	16	26
DO	41	37	32	38
NH3	60	152	107	51
NO2	72	61	403	115
NO3	70	84	138	138
pH	10	12	12	6
PO4	134	130	216	159
TP	134	130	218	159
Secchi	--	--	28	--
SO4	55	--	42	30
SPCOND	16	45	22	42
TEMP	8	7	17	12
TFE	--	80	106	32
Minimum	8	7	12	6
Average	56	70	104	67
Maximum	134	152	403	159

Table D-6

Decision Matrix for Sample Sizes Based on Minimum, Average, and Maximum Coefficients of Variation

	Precision:		0.10			0.20	
Reservoir	Error:	0.05	0.10	0.20	0.05	0.10	0.20
Cowanesque	Min	4	3	3	3	3	3
	Avg	123	87	53	33	23	14
	Max	689	487	296	174	123	75
East Sidney	Min	4	3	3	3	3	3
	Avg	190	134	82	50	35	21
	Max	885	626	381	223	158	96
Hammond	Min	8	6	4	3	3	3
	Avg	416	294	179	106	75	46
	Max	6,206	4,389	2,668	1,554	1,099	668
Whitney Point	Min	3	3	3	3	3	3
	Avg	174	123	75	46	32	20
	Max	969	685	416	244	173	105

19. Given the objective of characterizing growing season conditions, a stratified design would represent the best approach. The year could be divided into four strata: (a) spring turnover, (b) summer stratification, (c) fall turnover, and (d) winter. Sampling would ignore both fall and winter and concentrate most of its effort on spring turnover and the growing season or summer stratified period. The design should also be stratified with respect to depth. Thermal stratification can be used to define the epilimnion, metalimnion, and hypolimnion as the depth strata. The result of temporal and depth stratification and suggested sample sizes are presented in Table D-7.

Table D-7

Temporal and Vertical Allocation of Pool Water Quality Samples at Two Levels of Effort

Temporal Stratification	Vertical Stratification		
Spring Turnover	Surface	Mid-depth	Bottom
	1	1	1
Summer	Epilimnion	Metalimnion	Hypolimnion
Level 1 (monthly)	5	5	5
Level 2 (biweekly)	10	10	10
Fall Turnover		Not Sampled	
Winter		Not Sampled	

20. Consideration of two temporal strata should be sufficient to meet the objective of characterizing growing season conditions. A single sampling effort during spring turnover would serve to characterize that period of the year. Conditions at turnover are important because they tend to set the stage for conditions during the stratified period. Two levels of effort are presented for growing season sampling. Sampling at monthly intervals would provide an adequate description of average conditions. Increasing the sample size in order to take biweekly samples would allow a description of temporal dynamics in the pool and provide more precise estimates of the reservoir-average conditions.

21. Two different schemes for spatial or longitudinal stratification can also be considered. The minimum design would sample one near-dam station

as representative of the entire reservoir whereas a a more rigorous design would deal with three stations (upper, middle, and near-dam). The combination of longitudinal, temporal, and vertical sampling and the resultant sample sizes are presented in Table D-8.

Table D-8

Total Sample Sizes for Pool Water Quality Sampling

Pool Stations	Temporal and Vertical Allocation	
	Level 1	Level 2
Level 1		
Near-dam	18	33
Level 2		
Upper Middle Near-dam	54	99

22. The sampling design proposed as Level 1 represents the bare minimum to adequately characterize reservoir-average water quality during the growing season. This design (1 near-dam station sampled 6 times at 3 depths) should provide estimates having a precision of ±20 percent about the mean with a 20 percent (1 in 5 chance) probability of error. Any reduction in sampling effort below this minimal design would result in data with uncertainties so large as to be nearly meaningless. Increasing the temporal and vertical sampling to Level 2 (1 near-dam station sampled 11 times and 3 depths) would result in data with the same precision but the probability of error would be reduced to 10 percent (1 in 10 chance). Due to the minimal contribution of station effects to the amount of variance explained, any increase in sample size would be most effective if applied to increasing sampling frequency rather than increasing the number of stations.

23. In-situ sampling (measurement of temperature, dissolved oxygen, pH, and specific conductance) should be carried out in a manner somewhat different than described above. Rather than sampling three depth strata, in-situ sampling should be conducted to provide vertical profiles at 1-m intervals. Profile sampling should be carried out for two reasons. First, temperature and dissolved oxygen profiles should be used to define the depth strata to be sampled. Profiles can be plotted in the field and the epilimnion,

metalimnion, and hypolimnion can be easily delineated for the remainder of the water quality sampling. Second, profile sampling will provide a much better estimation of the vertical pattern of these variables.

Parameter list

24. A suggested parameter list at two levels of effort is presented in Table D-9. Level 1 represents the minimal set of variables required to meet the stated objective. Level 2 adds variables that will improve the design by providing a more detailed description of water quality conditions.

Table D-9

Parameter Lists for Pool Water Quality Sampling

Level 1	Level 2
In-Situ Variables	Add:
Temperature	Ortho Phosphorus
Dissolved Oxygen	Nitrate-Nitrite Nitrogen
pH	Ammonia Nitrogen
Specific Conductance	Dissolved Iron
Secchi Depth	Dissolved Manganese
Alkalinity	
Total Phosphorus	
Total Nitrogen	
Chlorophyll *a*	
Total Iron	
Total Manganese	

Tributary/Discharge Sampling Design

25. Based on the analysis of a Corps-wide reservoir database, Walker (1987) made a number of suggestions concerning tributary/discharge monitoring programs directed at estimating nutrient loads or fluxes. The basic approach of either tributary or discharge sampling is to continuously monitor flow (to provide mean daily flows) and to periodically sample for concentration. A purely systematic sampling design is not recommended for tributary/discharge monitoring because of the relationship between load and flow. A stratified sampling design with two strata, high flow and low or base flow, is much more suitable for the estimation of loadings. The design should be weighted toward the high flow stratum because it will usually account for the majority of the load.

26. The monthly contribution to the annual water load from the Tioga River (Figure D-1) can be used as an example of how flow stratification can be used to improve annual loading estimates. Over 50 percent of the annual water load from the Tioga River enters the reservoir during a three month period (February through April). If nutrient concentration increases with flow, as is frequently the case, nutrient loading during this period may represent an even larger fraction of the total nutrient load. Studies conducted on other CE reservoirs indicate that the high flow period may contribute from 75 to 90 percent of the total annual nutrient load. A purely systematic design would tend to over-sample the low or base flow period of the year and under-sample the high flow, high loading period. In the case of the Tioga River, a systematic design would only allocate 25 percent of the effort to sampling the period of high flow. By using a stratified design and allocating more samples to the high flow stratum a more accurate and precise estimate of the annual load can be made.

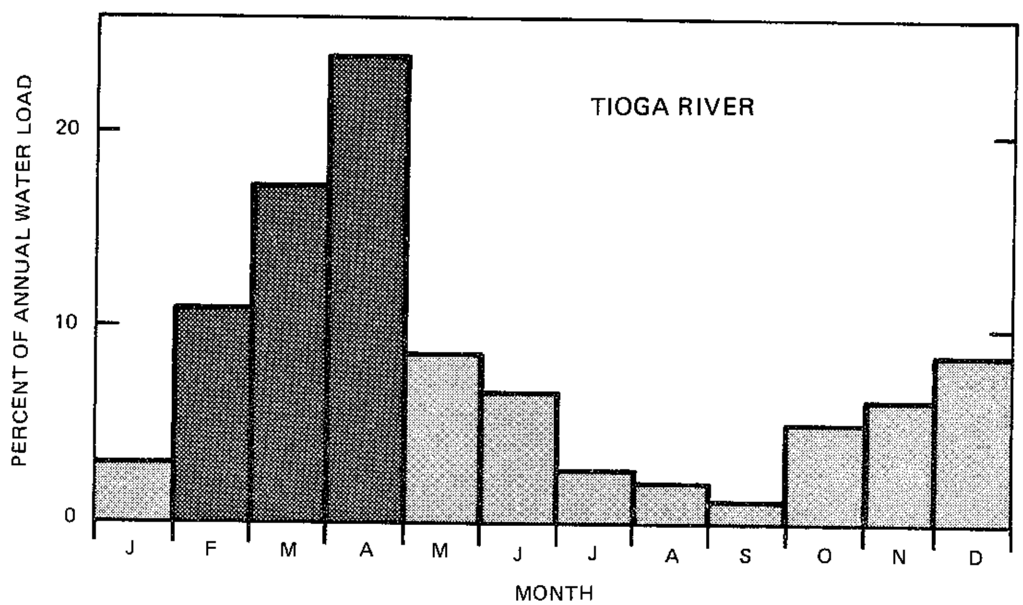

Figure D1. Temporal distribution of water load for the Tioga River based on data for stream gage located at Mansfield, Pa. Average total monthly water loads are expressed as a percentage of average annual total. Dark shading indicates monthly percentage greater than 10 percent

Sample size and allocation

27. Tributary/discharge sampling can be effectively carried out using a stratified systematic design (Table D-10). The design is stratified with respect to flow and sampling is systematic within each stratum. Slightly less

than 50 percent of the total sampling effort is applied to the high flow stratum (approximately February through April), but sampling is twice as frequent. Level 2 sampling is highly recommended because weekly sampling during the high flow stratum should capture a majority of the high flow events. A biweekly sampling interval, as in the Level 1 high flow stratum, may miss a number of these events and, as a result, seriously underestimate loads.

Parameter list

28. Parameter lists for two levels of effort for tributary/discharge sampling are presented in Table D-11. Level 1 sampling considers only total nutrient concentrations and would allow for the calculation of gross mass balances. Increasing effort to Level 2 allows for the consideration of loads and losses of the biologically available forms of nitrogen and phosphorus. Level 2 sampling would provide a better estimation of the relationship between nutrient loading and in-pool responses.

Table D-10

Temporal Allocation of Tributary/Discharge Water Quality Samples at Two Levels of Effort

Temporal Strata	Level 1	Level 2
High Flow (approx. Feb-Apr)	6 (biweekly)	12 (weekly)
Low Flow (approx. May-Jan)	9 (monthly)	18 (biweekly)
Sample Size	15	30

Table D-11

Parameter Lists for Tributary/Discharge Sampling

Level 1	Level 2
Instantaneous Flow	Add:
Total Phosphorus	Soluble Reactive Phosphorus
Total Nitrogen	Nitrate-Nitrite Nitrogen
	Total Dissolved Phosphorus

References

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