NORTH CAROLINA LAKE ASSESSMENT REPORT

This report has been approved for release:

Steve W. Tedder, Chief — Date: 5/25/92

Report 92-02

NORTH CAROLINA DEPARTMENT OF ENVIRONMENT, HEALTH, AND NATURAL RESOURCES
Division of Environmental Management
Water Quality Section

PART ONE

Introduction to Lake Assessment in North Carolina

CONTENTS

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TABLES

PREFACE

The North Carolina Lake Assessment Report was written to provide a reference from which individuals can quickly access data on the state's significant lakes. The information was presented in a manner that can be understood and utilized by both government agencies and interested citizens. Efforts were made to include the essential physical, chemical, and biological information needed to assess the water quality characteristics of each lake, as well as supplemental information on lake history, location, and use.

The report is divided into two parts: introductory information and assessments of water quality for individual lakes. Part One provides a description of the Lake Assessment Program in North Carolina, as well as an overview of water quality in the state's lakes. "Methods and Definitions" describes methods used to collect and analyze samples, and defines key terms and water quality parameters. "Ecological Concepts" provides an introduction to lake ecology and the factors that influence lake water quality. This excellent overview was excerpted from the Lake and Reservoir Restoration Guidance Manual (U.S. EPA 1990), and provides background material helpful for interpreting the report. DEM wishes to thank the North American Lake Management Society for granting permission to reprint this material without charge.

Part Two is composed of water quality summaries for individual lakes. These are grouped by river basin and are presented in downstream progression within each basin. The river basins are arranged in alphabetical order. Each group of lake assessments begins with a Basin Summary containing a brief description of the river basin and a summary of the water quality characteristics of the basin. This is followed by a map of the basin showing the locations of the individual lakes.

The individual lake summaries are the focus of this report. To facilitate information retrieval, they share a uniform format of text, tables and graphs which contain geographic, historic, and water quality information. A map of the lake shows the sampling stations, major tributaries feeding the lake, and other pertinent geographic information. Graphs of dissolved oxygen and temperature profiles characterize water depth and stratification patterns at each station. Phytoplankton information is summarized in two bar graphs. One depicts relative contributions of each class of phytoplankton to the station's total biovolume. The other presents total algal concentrations in terms of density, biovolume, and chlorophyll-a. Dominant species, the presence of bloom conditions, and interpretations of trends seen over time and between sampling locations are discussed in the text.

Data presented in the report were collected through the Lake Assessment Program of the North Carolina Division of Environmental Management (DEM). In many cases, local governments, public utilities, and private landowners provided additional information regarding lake history and morphometry. Their assistance is appreciated.

Questions and comments regarding this document or about lake water quality in North Carolina should be addressed to:

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(Attention: Lake Assessment Program)

INTRODUCTION

LAKES IN NORTH CAROLINA

General Information

Lakes and reservoirs are integral features of the North Carolina landscape, supplying water for personal, industrial and municipal users. Lakes provide recreational opportunities and aesthetic enjoyment for the public, and support rich communities of aquatic plants and animals. Public use of the state's lakes is high, and lake-related recreation provides significant revenues. The North Carolina Division of Environmental Management (DEM) is committed to protecting these valuable resources for public use.

A recent inventory identified more than 1,800 lakes (natural lakes or impoundments of 10 acres or more) in North Carolina. The state's only natural lakes, mostly Carolina Bay lakes, all occur in the coastal plain. The remaining lakes range from small impoundments to large, multi-purpose reservoirs. While the majority of these waterbodies are small and privately owned, more than 100 are accessible to the public and greater than 100 acres in surface area.

Classifications and Standards

As with other waters of the state, lakes are classified for their "best usage," and are subject to the state's water quality standards (table 1). Special classifications may supplement basic standards for specific situations (like more stringent temperature and dissolved oxygen standards for trout waters). Several lakes are classified for more than one use, and some also have supplemental classifications. Lake water quality is evaluated relative to selected numerical standards (table 2). A complete listing of current water classifications and standards can be found in Title 15 North Carolina Administrative Code, Chapter 2B, Sections .0100 and .0200.

Of particular importance to lakes is the chlorophyll-a standard. Chlorophyll-a may not exceed 40 µg/l in lakes and reservoirs larger than 10 acres in surface area. Designated trout waters may not have chlorophyll-a levels greater than 15 µg/l. The turbidity standard is also lower in trout waters (10 NTU) than in other lakes (25 NTU).

Table 1. Freshwater Classifications and Associated Best Uses.

PRIMARY WATER CLASSES:

Class	Best Uses
C	Aquatic life propagation/protection and secondary recreation
B	Primary recreation and class C uses
WS	Water Supply watershed and class C uses

SUPPLEMENTAL CLASSIFICATIONS:

Class	Best Uses
Tr	Trout Waters: modifies standards to protect trout propagation and survival
SW	Swamp Waters: slow-moving waters where normal standards may not be applicable
NSW	Nutrient Sensitive Waters: waters subject to excessive algal or other plant growth where nutrient controls are required
ORW	Outstanding Resource Waters: unique and special surface waters which are unimpacted by pollution and have some special resource values.

NORTH CAROLINA LAKE ASSESSMENT PROGRAM

Background

Assessment of water quality is necessary to determine the health of a lake and its suitability for public use. DEM has monitored lakes in North Carolina for several decades; however, early efforts concentrated on fecal coliform bacteria and other concerns related to human health. A change in direction came through the Federal Clean Lakes Program, which was established by the national Clean Water Act of 1972, and which enabled states and local communities to work together with the federal government for lake protection and restoration.

Table 2. North Carolina standards for freshwater lakes. (excerpted from Title 15 North Carolina Administrative Code, Chapter 2B, Section .0200). Although additional standards also apply to lakes, the following parameters are routinely sampled as part of the Lake Assessment Program.

Parameters	Standards for All Freshwater		More Stringent Standards to Support Additional Uses	
	Aquatic Life	Human Health	Water Supply	Trout
Chloride (mg/l)	230 (AL)		250	
Chlorophyll-a, corrected (µg/l)	40			15
Coliform, fecal (MFTCC/100ml)		200		
Dissolved oxygen (mg/l)	5.0 (SW)(1)			
Hardness, total (mg/l)			100	
Nitrate nitrogen (mg/l)			10	
pH (units)	6.0-9.0 (SW)			
Turbidity (NTU)	25			10
Metals:				
Arsenic (µg/l)	50			
Cadmium (µg/l)	2.0			0.4
Chromium(µg/l)	50			
Copper (µg/l)	7 (AL)			
Lead (µg/l)	25			
Mercury (µg/l)	0.012			
Nickel (µg/l)	88		25	
Selenium (µg/l)	5			
Zinc (µg/l)	50 (AL)			

Note: (AL) Values represent action levels as specified in .0211 (b) (4).

(SW) Designated swamp waters may have a pH as low as 4.3 and dissolved oxygen less than 5.0 mg/l if due to natural conditions.

(1) An instantaneous reading may be as low as 4.0 mg/l but the daily average must be 5.0 mg/l or more.

In 1981, DEM received federal Clean Lakes funding to classify the trophic (or nutrient enrichment) status of North Carolina's publicly owned freshwater lakes, and to prioritize lakes for restoration. Federal grants administered by the U.S. EPA provided financial and technical assistance to the states to meet the following requirements:

- Classify publicly owned freshwater lakes according to trophic conditions;
- Establish procedures and methods to control sources of lake pollution; and
- Establish procedures and methods to restore lake quality where necessary.

A sampling program was established in 1981 to survey the trophic condition of 65 lakes. Thirty-one of these lakes were sampled again in 1982. One benefit of this work was the development of the North Carolina Trophic State Index (NCTSI) that the state has used for all subsequent trophic classifications. The NCTSI is discussed in greater detail in the following section of this report.

Federal funds were not available from 1983 through 1987, but DEM continued to track trophic conditions and to screen lakes for potential water quality problems. Federal grants obtained in 1988 and 1990 enabled the program to grow again, by increasing the number of lakes sampled and expanding monitoring for toxic metals.

The Lake Assessment Program has supplied valuable water quality information for several lakes. Baseline assessments were completed for all significant public lakes by the end of 1990, and are summarized in this report.

In addition to baseline monitoring, more intensive work is needed to assess lakes with demonstrated environmental problems, or to address regulatory questions. For instance, analysis of water quality trends and model development/calibration were two goals for monitoring Falls of the Neuse Reservoir and Jordan Lake. Other lakes have been monitored intensively to evaluate lake restoration attempts. Merchants Millpond, Big Lake, and Lake Wheeler have been monitored because of aquatic weed control measures. Belews, Hyco, and Mayo continue to be monitored because of selenium contamination. High Rock Lake and Lake Wylie were intensively monitored in 1989 and 1990 in response to problems associated with eutrophication.

The initial stages of lakes monitoring in North Carolina focused on trophic state classification and problems associated with eutrophication. However, as work on lakes progressed, new areas of concern began to emerge. These include water supply contamination (by organic pollutants and toxic metals), sedimentation and erosion, bacterial contamination, and nuisance macrophytes. Clearly, assessment of lake trophic state is valuable, but may inadequately measure how well a lake supports its various uses. In the future, more attention will be devoted to determining use support for each lake.

North Carolina Trophic State Index

Trophic classification is a relative description of a lake's biological productivity. The productivity of a lake is determined by a number of chemical and physical characteristics of which the most important are the availability of essential plant nutrients (primarily nitrogen and phosphorus), algal density, and the depth of light penetration. Lakes are classified according to productivity: unproductive lakes are termed "oligotrophic"; moderately productive lakes are termed "mesotrophic"; and productive lakes are termed "eutrophic". Individuals wanting further information on the trophic classification of lakes are urged to read the section entitled "Ecological Concepts". In addition, the 1982 North Carolina Clean Lakes Classification Survey (NRCD 1982) and Wetzel (1975) also review this subject.

The productivity of a lake is also related to water quality. In general, oligotrophic lakes have good water quality. Mesotrophic lakes are moderately productive and show little, if any, signs of water quality degradation. Eutrophic lakes may be so productive that the potential for water quality degradation exists in these water bodies. Many of these lakes already show symptoms of water quality problems such as algal blooms, fish kills, or excessive sedimentation.

Numerical indices are often used to evaluate the trophic status of lakes. An index was developed specifically for North Carolina lakes as part of the state's original Clean Lakes Classification Survey (NRCD 1982). The North Carolina Trophic State Index (NCTSI) is based on total phosphorus (TP in mg/l), total organic nitrogen (TON in mg/l), Secchi depth (SD in inches), and chlorophyll-a (CHL in µg/l). Lakewide means for these parameters are manipulated to produce a NCTSI score for each lake, using the following equations:

$$\text{TON score} = \frac{\text{Log(TON)} + (0.45)}{0.24} \times 0.90$$

$$\text{TP score} = \frac{\text{Log(TP)} + (1.55)}{0.35} \times 0.92$$

$$\text{SD score} = \frac{\text{Log(SD)} - (1.73)}{0.35} \times -0.82$$

$$\text{CHL score} = \frac{\text{Log(CHL)} - (1.00)}{0.43} \times 0.83$$

$$\text{NCTSI} = \text{TON score} + \text{TP score} + \text{SD score} + \text{CHL score}$$

In general, NCTSI scores relate to trophic classifications as follows:

NCTSI	CLASSIFICATION
< -2.0	Oligotrophic
-2.0 to 0.0	Mesotrophic
0.0 to 5.0	Eutrophic
> 5.0	Hypereutrophic

When the NCTSI values border between different classes, best professional judgement is used to assign the most appropriate trophic classification. In some cases, such as in lakes dominated by macrophytes, the index tends to underestimate trophic status, and best professional judgement is again employed to assign a realistic trophic status.

Lakes that have been monitored in North Carolina exhibit a wide range of productivity (table 3). Oligotrophic lakes are characteristically found in the mountains or in undisturbed watersheds. Many eutrophic and mesotrophic lakes are found in the central piedmont. A few are hypereutrophic, usually because point or nonpoint sources of pollution contribute high levels of nutrients. TSI values for a lake normally vary somewhat from year to year, but major differences may signal a change in trophic status and water quality (table 4).

NCTSI scores are less meaningful for evaluating dystrophic lakes. These acidic, "blackwater" lakes are rich in organic matter, mainly in the form of suspended plant colloids and larger plant fragments, but usually have low productivity and few water quality problems. In North Carolina, dystrophic lakes are scattered throughout the coastal plain, often located in marshy areas or overlying peat deposits.

Water Quality Issues

Most water quality problems in North Carolina lakes arise from three sources: eutrophication, macrophytes, and sedimentation. Toxic metal contamination is a concern in a few lakes. In addition, there is growing concern for the safety of drinking water supplies. Some work has been done to survey contamination of drinking waters by pesticides and other organic compounds, but more testing is needed across the state. Lake concerns and management options are discussed below.

Nutrient enrichment of North Carolina's lakes is a primary concern. Many of the lakes which have been monitored are eutrophic, and a few are hypereutrophic. When algal blooms, weed infestations, and fish kills occur, these waters may not fully support their designated uses. One should note that eutrophication, or the gradual progression toward increased lake nutrient status and productivity, is a natural process. However, human activity in a watershed can accelerate this process. Especially in the piedmont region of North Carolina, nutrient inputs from point source discharges and from nonpoint sources have contributed to "cultural" eutrophication of lakes.

Macrophytes are another source of lake problems. The greatest threat is from hydrilla,

Table 3. Ranking of lakes by NCTSI. The most recent North Carolina Trophic State Index (NCTSI) value for each lake is shown, followed by the descriptive trophic classification (D=Dystrophic, H=Hypereutrophic, E=Eutrophic, M=Mesotrophic, O=Oligotrophic). Lakes are ordered from highest to lowest NCTSI.

LAKE NAME	NCTSI		LAKE NAME	NCTSI	
Pungo Lake	8.7	D	Kannapolis Lake	1.2	E
Wendell Lake	7.7	H	Maxton Pond	1.2	E
White Millpond	6.8	H	Lake Corriher	1.1	E
Lake Lee	6.1	H	Lake Higgins	1.1	E
Johns Pond	5.4	H	Lake Townsend	1.1	E
Lake Crabtree	5.4	H	Roberdel Lake	1.1	D
Waterville Lake	5.0	H	Maiden Lake	0.8	E
Greenfield Lake	4.9	H	Cane Creek Reservoir	0.7	E
Lake Fisher	4.7	E	Kerr Reservoir	0.7	E
Upper Moccasin Lake	4.6	E	Swan Creek Lake	0.7	D
B. Everett Jordan Reservoir	4.5	E	Corporation Lake	0.6	E
Toisnot Reservoir	4.0	E	Pages Lake	0.5	E
Ross Lake	3.9	E	Kernersville Reservoir	0.4	E
Lake Emory	3.8	E	Catfish Lake	0.2	D
Wiggins Mill Reservoir	3.8	E	Lake Orange	0.0	E
Falls of the Neuse Reservoir	3.7	E	Burlington Reservoir	0.0	M
Merchants Millpond	3.7	E	Lookout Shoals Lake	0.0	M
Alligator Lake	3.6	D	Badin Lake	-0.2	M
Lake Concord	3.6	E	Lake Raleigh	-0.2	M
High Rock Lake	3.3	E	Lake Roxboro	-0.2	M
Lake Monroe	3.3	E	Harris Lake	-0.3	M
Lake Twitty	3.2	E	Oak Hollow Lake	-0.3	M
Wadesboro City Pond	2.9	E	Lake Hickory	-0.4	M
Back Creek Lake	2.8	E	Lake Benson	-0.5	M
Blewett Falls Lake	2.8	E	Lake Tillery	-0.6	M
University Lake	2.8	E	Falls Lake	-0.7	M
Buckhorn Reservoir	2.7	E	Roanoke Rapids Lake	-0.7	M
Lake Junaluska	2.7	E	Little River Reservoir	-0.8	M
Pittsboro Lake	2.7	E	Cliffs of the Neuse Lake	-0.9	M
Tar River Reservoir	2.6	E	Lake Tabor	-0.9	M
Lake Devin	2.5	E	Lake Wright	-0.9	M
Quaker Creek Lake	2.5	E	Lake Gaston	-1.1	M
Bass Lake	2.4	E	Lake Reese	-1.1	M
Lake Brandt	2.3	E	Lake Rhodhiss	-1.1	M
Lake Tom-a-Lex	2.2	E	Richland Lake	-1.1	M
Lake Michie	2.1	E	Long Lake	-1.4	D
Lower Moccasin Lake	2.1	E	Bessemer City Lake	-1.7	M
Tuckertown Reservoir	2.0	E	Reidsville Lake	-1.7	M
Salem Lake	1.9	E	Winston Lake	-1.7	M
Lake Burlington	1.7	E	Hamlet City Lake	-1.8	M
Hope Mills Lake	1.5	E	Mountain Island Lake	-1.8	M
Lake Mattamuskeet	1.5	E	W. Kerr Scott Reservoir	-1.9	M
Lake Wylie	1.5	E	Lake Butner	-2.0	M
Little River Dam	1.5	E	Salters Lake	-2.0	D
Roxboro Lake	1.4	E	Lake Norman	-2.1	M
Great Lake	1.3	D	Hanging Rock Lake	-2.1	O
Lake Ben Johnson	1.3	E	Lake Hunt	-2.1	O
Lake Sequoyah	1.3	E	Boiling Springs Lake	-2.3	D
Lake Wheeler	1.3	E	Lake Lure	-2.3	O
Big Lake	1.2	E	Old Town Reservoir	-2.3	O
High Point Lake	1.2	E	Lake Adger	-2.7	O

Table 3. Ranking of lakes by NCTSI, continued. D=Dystrophic, H=Hypereutrophic, E=Eutrophic, M=Mesotrophic, O=Oligotrophic.

LAKE NAME	NCTSI		LAKE NAME	NCTSI	
Lake Johnson	-2.8	M	McCrary Lake	-4.0	O
Lake Waccamaw	-2.8	O	Lake Tahoma	-4.1	O
Mayo Lake	-2.8	O	Wolf Creek Reservoir	-4.1	O
Ellis Lake	-2.9	D	Beetree Reservoir	-4.2	O
Lake Summit	-2.9	O	Hiwassee Lake	-4.2	O
Lake Julian	-3.0	O	White Lake	-4.4	O
Singletary Lake	-3.0	D	Chatuge Lake	-4.6	O
Water Lake	-3.0	O	Burnett Reservoir	-4.9	O
Bay Tree Lake	-3.1	D	Thorpe Reservoir	-4.9	O
Kings Mountain Reservoir	-3.3	O	Belews Lake	-5.0	O
Lake Phelps	-3.3	O	Apalachia Lake	-5.3	O
Mott Lake	-3.4	O	Jones Lake	-5.3	D
Santeetlah Lake	-3.4	O	Cedar Cliff Lake	-6.0	O
Hyco Lake	-3.5	O	Busbee Reservoir	-6.3	O
Bear Creek Reservoir	-3.6	O	Allen Creek Reservoir	-6.6	O
Lake James	-3.6	O	Nantahala Lake	-6.6	O
Fontana Lake	-4.0	O	Calderwood Lake	-7.3	O
Lake Bunch	-4.0	O	Lake Cheoah	-7.4	O

Table 4. Historical NCTSI Values, 1981-1990.

LAKE	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Allen Creek Reservoir										-6.6
Alligator Lake									3.6	
Apalachia Lake	-6.2						-5.3			
B. Everett Jordan Reservoir		4.5	4.4	3.3	3.8	5.7	3.9	4.4	4.0	4.5
Back Creek Lake									2.8	
Badin Lake	0.5	1.6	0.3	1.2	0.4	0.7	0.7			-0.2
Bass Lake							3.1	2.4		
Bay Tree Lake	4.5				-1.4				-3.1	
Bear Creek Reservoir								-3.6		
Beetree Reservoir										-4.2
Belews Lake	-4.4	-2.8	-4.8	-4.4	-4.8	-5.3	-5.0	-5.4		-5.0
Bessemer City Lake										-1.7
Big Lake	0.3						1.2			
Blewett Falls Lake	3.5	5.7	-0.5	1.2	2.4	2.8				
Boiling Springs Lake										-2.3
Buckhorn Reservoir								2.7		
Burlington Reservoir	0.3						0.0	0.0		
Burnett Reservoir										-4.9
Busbee Reservoir										-6.3
Calderwood Lake								-7.3		
Cane Creek Reservoir										0.7
Catfish Lake	-1.3							0.2		
Cedar Cliff Lake								-6.0		
Chatuge Lake	-3.1						-4.6			
Cheoah Lake								-7.4		
Cliffs of the Neuse Lake	-1.8							-0.9		
Corporation Lake								0.6		
Ellis Lake								-2.9		
Falls Lake	0.0		-1.7	0.7	-0.9	-0.5			-0.7	
Falls of the Neuse Reservoir			6.5	5.0	5.4	5.2	4.7	4.0	2.7	3.7
Fontana Lake	-3.7	-5.1					-4.0			
Great Lake	2.5						1.3			
Greenfield Lake	1.9							4.9		
Hamlet City Lake	-0.8						-0.5	-0.5		-1.8
Hanging Rock Lake					-3.2				-2.1	
Harris Lake							0.3		0.9	-0.3
High Point Lake	1.4	2.6	3.0				1.7	1.2		
High Rock Lake	3.8	4.0		4.6	3.8	2.5			3.5	3.3
Hiwassee Lake	-3.5	-4.3						-4.2		
Hope Mills Lake				1.6			2.8	1.5		
Hyco Lake			-2.1	-2.3	-0.3	-2.4	-2.2	-4.0	-1.5	-3.5
Johns Pond	6.5		6.4					5.4		
Jones Lake	-5.8						-5.3			
Kannapolis Lake									1.2	
Kernersville Reservoir								0.4		
Kerr Reservoir	-0.7	1.1	-0.8		-0.7		0.1	0.7		
Kings Mountain Reservoir									-3.3	
Lake Adger									-2.7	
Lake Ben Johnson								1.3		
Lake Benson	2.6		0.3				2.4	-0.5		
Lake Brandt	2.3	2.9						2.3		
Lake Bunch									-4.0	
Lake Burlington										1.7
Lake Butner								-2.0		
Lake Concord									3.6	
Lake Corriher									1.1	
Lake Crabtree										5.4
Lake Devin									2.5	
Lake Emory								3.8		

Table 4. Historical NCTSI Values, 1981-1990, continued.

LAKE	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Lake Fisher									4.7	
Lake Gaston	-1.2	1.9	-1.4	-1.5	-1.3		-1.4		-1.1	
Lake Hickory	1.1	1.5	1.5	1.1	1.0				-0.4	
Lake Higgins										1.1
Lake Hunt	-1.9							-2.1		
Lake James	-1.7	-2.5		-3.9		-2.6			-3.6	
Lake Johnson	-1.3		-1.0				-2.8			
Lake Julian										-3.0
Lake Junaluska	2.7		-0.4		-2.0		2.7			
Lake Lee									6.1	
Lake Lure	-1.9	-0.7	-3.0		-0.8				-2.3	
Lake Mattamuskeet	1.0		1.4	0.6	1.5					
Lake Michie								2.1		
Lake Monroe									3.3	
Lake Norman	-1.9	-2.4	-0.7			-2.1				
Lake Orange								0.0		
Lake Phelps	-3.4	-4.0	-3.1	-3.1	-1.3	-2.4			-3.3	
Lake Raleigh							0.4	-0.2		
Lake Reese									-1.1	
Lake Rhodhiss	2.2		2.4	0.3	1.5	2.3			-1.1	
Lake Roxboro								-0.2		
Lake Sequoyah								1.3		
Lake Stewart									3.1	
Lake Tabor	1.9							-0.9		
Lake Tahoma										-4.1
Lake Tillery	-2.2	3.4	-1.3	-0.3		-0.3			-0.6	
Lake Tom-a-Lex	3.4	4.2	2.1		1.9				1.9	
Lake Townsend										1.1
Lake Waccamaw	-1.5	-1.8	-0.3			-1.6	-0.3			-2.7
Lake Wheeler	-1.1	1.7	1.3		-0.8		1.3			
Lake Wright									-0.9	
Lake Wylie	0.7	1.3	1.2	1.2	0.9	1.4			1.3	1.5
Little River Dam										1.5
Little River Reservoir								-0.8		
Long Lake								-1.4		
Lookout Shoals Lake	0.4	-0.9	-1.0			0.2			0.0	
Lower Moccasin Lake								2.1		
Maiden Lake										2.5
Maxton Pond	1.8		8.9				1.2			
Mayo Lake			-2.5	-2.3	-3.4	-3.8	-1.8			-2.8
McCrary Lake									-4.0	
Merchants Millpond	4.4		2.8	3.2	4.3	3.7				
Mott Lake										-3.4
Mountain Island Lake	-1.3	-0.8				-1.8				
Nantahala Lake	-6.3	-5.8							-6.6	
Oak Hollow Lake	-1.2							-0.3		
Old Town Reservoir								-2.3		
Pages Lake	-0.9							0.5		
Pittsboro Lake	3.9						2.7			
Pungo Lake	9.9		9.4	8.7						
Quaker Creek Lake										2.5
Reidsville Lake	-1.9						0.1	-1.7		
Richland Lake										-1.1
Roanoke Rapids Lake	0.8	0.2	-1.8	-2.0	-0.7		-0.6			
Roberdel Lake									1.1	
Ross Lake									3.9	
Roxboro Lake								1.4		
Salem Lake	3.5	4.4	-0.4			0.7			1.9	
Salters Lake	-0.4							-2.0		

Table 4. Historical NCTSI Values, 1981-1990, continued.

LAKE	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Santeetlah Lake	-3.6	-3.8					-3.3			-3.5
Singletary Lake	-2.0						-3.0			
Summit Lake									-2.9	
Swan Creek Lake									0.7	
Tar River Reservoir									2.6	
Thorpe Reservoir								-5.4	-3.9	-4.9
Toisnot Reservoir								4.0		
Tuckertown Reservoir		4.5		3.6		1.6			2.0	
University Lake										2.8
Upper Moccasin Lake								4.6		
W. Kerr Scott Reservoir	-1.0	-2.3			-2.1				-1.9	
Wadesboro City Pond									2.9	
Water Lake									-2.9	
Waterville Lake										5.0
Wendell Lake								7.7		
White Lake	-6.0	-3.5			-5.4		-5.3	-5.5		-4.4
White Millpond								6.8		
Wiggins Mill Reservoir								3.8		
Winston Lake										-1.7
Wolf Creek Reservoir								-4.1		

which was first detected in North Carolina in 1981. As of this writing, hydrilla has been found in 54 lakes. Forty-three of these are in the Neuse River basin. Alligatorweed, elodea, water primrose, and other macrophytes also infest several lakes (see the section on macrophytes in "Methods and Definitions" for more information). The Division of Water Resources administers an Aquatic Weed Control Program, which provides chemical control of hydrilla, alligatorweed, and elodea.

Sedimentation appears to be another problem, particularly for lakes in the piedmont region of North Carolina. This region is characterized by high agricultural land use and increasing urban development. Both factors contribute to erosion and hence the filling in of lakes. Incoming sediments transport nutrients to lakes from the surrounding watershed and decrease reservoir storage capacity over time.

Toxic metals represent a significant water quality problem in a few lakes. Advisories posted by the State Health Director recommend limiting consumption of fish from three lakes. Fish collected from the Abbotts Creek arm of High Rock Lake have elevated levels of mercury. Selenium, another toxic metal, impaired Hyco and Belews Lakes by altering the natural fish community. Selenium originally entered these lakes from coal-fired power plant discharges. The discharges have been eliminated, and the biota are expected to recover over time.

Water supply protection is a growing area of concern. More than 50 lakes serve as public drinking water supplies in North Carolina. Until recently the Lake Assessment Program had not evaluated the attainment of uses specific to water supplies. Samples for metals, hardness, and chloride have been collected from these lakes since 1988, and results are included in this report.

Little is known about pesticides and other organic pollutants in the state's lakes. Laboratory analyses for these compounds are very costly, and resources do not allow wide-scale monitoring at this time. In the future, however, more attention will be focused on testing for these pollutants in cases where contamination is suspected.

Options for Lake Management

Lake protection and management is the responsibility of many people, including lake owners, lake users, and government agencies. The involvement of local citizens is vital to the success of lake protection and restoration programs. Citizens should contact the appropriate regional office of the Department of Environment, Health, and Natural Resources (EHNR) when water quality complaints (such as fish kills and algal blooms) require an immediate response:

EHNR Office	Phone
Asheville	(704) 251-6208
Fayetteville	(919) 486-1541
Mooresville	(704) 663-1699
Raleigh	(919) 571-4700
Washington	(919) 946-6481
Wilmington	(919) 395-3900
Winston-Salem	(919) 896-7007

Several agencies in state government assist local communities with lake-related problems. The Water Quality Section of DEM conducts the Lake Assessment Program. This section also handles water quality issues, including water supply protection programs, classifications and standards, and problems related to both point and nonpoint sources of pollution. DEM will maintain its efforts to protect the state's lakes and reservoirs through continued monitoring and assessment. When water quality problems are documented, lake restoration and improved management will be implemented to minimize or eliminate the problems.

The Division of Water Resources manages the Aquatic Weed Control program, as well as issues related to water planning, hydrology, and water supply assistance (919/733-4064). The Boating and Inland Fisheries Section of the Wildlife Resources Commission provides information on fisheries and boating access (919/733-3633). Interested citizens can also contact their county Soil Conservation Service and Cooperative Extension Service representatives. These agencies help landowners implement best management practices to control erosion and sedimentation.

Management approaches are formulated only after careful analysis of a lake's present condition and the designated uses of the lake. Citizens can often benefit from professional advice, since the protection of a lake and its watershed involves many factors. In addition, the different demands that users place upon a lake may conflict with each other, or with the lake's capacity to support those demands. The Lake and Reservoir Restoration Guidance Manual (U.S. EPA 1990) is an excellent resource for citizens interested in lake management. Copies may be requested from:

Clean Lakes Program
Nonpoint Sources Branch (WH-585)
U.S. Environmental Protection Agency
401 M Street
Washington, DC 20460

The Lake and Reservoir Restoration Guidance Manual was prepared by the North American Lake Management Society (NALMS), which also has information that can help citizens organize a lake management plan. For more information contact: NALMS, One Progress Boulevard, Box 27, Alachua, Florida 32615, or phone (904) 462-2554.

METHODS and DEFINITIONS

SAMPLING PROTOCOL

Lakes were sampled during late summer (late July through early September), the period of peak algal biomass. This was done to reflect "worst case" trophic conditions. Most lakes were sampled only once in any single year. When lakes were sampled more frequently, one sampling date most representative of late summer conditions was chosen for inclusion in the report.

Most lakes had two or more monitoring stations. The number of stations varied with lake size and morphometry. For example, a riverine impoundment might have had three stations: one at the deepest location near the dam, one in the middle stretch, and one at the upstream end of the lake. Very small lakes and lakes that are known to be well mixed were sampled at only one location.

Water quality parameters related to trophic assessment such as chlorophyll-a and nutrients were collected at every lake. Some lakes were monitored for additional parameters such as fecal coliform bacteria or heavy metals. The additional coverage depended on the classification of the lake. For example, class B waters, which are protected for swimming, were sampled for fecal coliform bacteria. Metals samples were collected at water supplies and at lakes where metals have been found at problematic levels. Parametric coverage is noted in each individual lake summary.

Temperature, dissolved oxygen, pH, and conductivity were measured in the field at one-meter intervals to a depth of 10 meters, and then at five-meter intervals until the bottom was reached. All field instruments were calibrated before and after sampling .

Samples were collected from the surface, the photic zone, and the hypolimnion. Surface samples were collected by hand at 0.15 meter below the surface, and included alkalinity, fecal coliforms, metals, and water supply parameters (chloride, hardness, iron, manganese, and aluminum). The metals most frequently sampled were cadmium, chromium, copper, nickel, lead, zinc, and mercury. The photic zone (estimated as twice the secchi depth) was sampled using a device that collects vertical composites. These samples were analyzed for turbidity, solids, chlorophyll-a, ammonia, nitrate-nitrite, total Kjeldahl nitrogen, total phosphorus, and ortho-phosphate. Hypolimnetic samples were collected at 0.5 meter above the lake bottom for ammonia, nitrate-nitrite, total Kjeldahl nitrogen, total phosphorus, and ortho-phosphate.

All samples were collected and preserved using standard operating procedures. Chemical analyses were conducted at the DEM Laboratory in Raleigh, North Carolina, using methods approved by EPA. Data were entered into the EPA STORET data base by the Information Services Branch. Phytoplankton and macrophytes were identified by the Biological Monitoring Group as described below.

DEFINITION OF WATER QUALITY TERMS

Many terms are used throughout the report to describe lake water quality (table 5). The section entitled "Ecological Concepts" discusses many of these in detail.

PHYTOPLANKTON

General Information

Phytoplankton (or algae) are small unicellular or colonial plants that float freely in the open water of lakes. As photosynthetic organisms, they are the primary source of energy in the aquatic food web. Because phytoplankton are ubiquitous in lakes and respond rapidly to changing environmental conditions, they are valuable indicators of water quality when analyzed in conjunction with physical, chemical and hydrologic data.

Table 5. Definition of terms used in the lake assessment summaries.

Lake name	The official name as determined from U.S. Geological Survey topographic maps. Many lakes in North Carolina have been given more than one name; therefore, other commonly used names of the lake are reported in the first paragraph of text.
County	The county in which the dam is located.
Surface area	The surface area of the lake as determined by planimetry from U. S. Geologic Survey topographic maps.
Class	Surface water classification of the lake (see table 1).
Basin	The river basin in which the lake is located (see Figure 1).
USGS Topo	For man-made impoundments, the map listed is the U. S. Geologic Survey Topographic map which contains the dam location. For natural lakes, it is the map which contains the majority of the surface area of the lake.
Lake type	Whether the water body is a natural lake, small impoundment, or reservoir.
Latest NCTSI	The North Carolina Trophic State Index value calculated from the most recent water quality data. Further information on the NCTSI is presented in the text.
Sampling date	The date on which the lake was visited by North Carolina Division of Environmental Management personnel to collect chemical and biological data.
Secchi depth	This is a measure of water transparency expressed in meters. This parameter is used in the calculation of the NCTSI value for the lake. The depth listed is an average value from all sampling locations in the lake.
Total phosphorus	Total phosphorus (TP) includes all forms of phosphorus which occur in water. This nutrient is essential for the growth of aquatic plants and is often the nutrient that limits the growth of phytoplankton. It is used to calculate the NCTSI. The concentration listed is a lake-wide average from all sampling stations.
Total organic nitrogen	A large fraction of the total nitrogen in fresh waters may occur in organic forms (dissolved or particulate). Total Organic Nitrogen (TON) can represent a major reservoir of nitrogen in aquatic systems during summer months. Similar to phosphorus, this concentration can be related to lake productivity and is used in the calculation of the NCTSI. The concentration listed is a lake-wide average from all sampling stations.
Chlorophyll-a	Chlorophyll-a is an algal pigment that is used as an approximate measure of algal biomass. The concentration of chlorophyll-a is used in the calculation of the NCTSI, and the value listed is a lake-wide average from all sampling locations.
Trophic state	This is a relative description of the biological productivity of a lake based on the calculated NCTSI value (see text for more explanation).
Additional coverage	Samples collected to supplement the routine monitoring for lake trophic status. These are typically analyses for the presence of fecal coliform bacteria and heavy metals in surface waters. "Water Supply Parameters" include metals, hardness, and chloride.
Conductivity	This is a measure of the ability of water to conduct an electrical current. This measure increases as water becomes more mineralized. The concentrations listed are the range of values observed in surface readings from the sampling locations.
Dissolved oxygen	The range of surface concentrations found at the sampling locations.
Temperature	The range of surface temperatures found at the sampling locations.
pH	The range of surface pH readings found at the sampling locations. This value is used to express the relative acidity or alkalinity of water.

Phytoplankton populations are limited by many variables including, but not restricted to: flow, light penetration, canopy, predation, and nutrient availability. Moderate populations are beneficial to lakes as they produce oxygen during photosynthesis and serve as food for zooplankton and fish. However, in eutrophic situations where nutrients are elevated, phytoplankton may over multiply, resulting in undesirably high dissolved oxygen and pH levels during the day, and anaerobic (low or no oxygen) conditions at night. This can result in fish kills. In addition to dissolved oxygen problems, large populations of phytoplankton can result in discolored water, unattractive surface blooms, and taste and odor problems, depending on the species present. Domination by a single species may also disrupt the normal food chain.

The section entitled "Ecological Concepts" provides an overview of seasonal changes in the algal community and how phytoplankton fit in the food chain. It should be noted that most of the lakes in this report were sampled during mid-summer and were dominated by blue-green algae. This is a result of their ability to thrive in warm water, the ability of some species to fix atmospheric nitrogen when other sources of nitrogen are low, and the fact that predators generally prefer other types of algae.

Methods of Analysis

Phytoplankton identification and enumeration were conducted using a modification of an inverted microscope technique first described by Utermoehl (1958). Algal samples were gently shaken to disperse organisms evenly without damaging appendages such as flagella. Each sample was then poured into tube chambers with volumes of 5, 10, and 25 milliliters. After settling a minimum of 8 hours, a chamber was examined on the microscope. Using a whipple grid in a 25X eyepiece, algae were counted and identified until 100 of the most abundant organisms were encountered or 30 grids (20X objective) were counted. Both number of cells and units were recorded for each organism.

Results include a list of species encountered; cells per milliliter and organisms per milliliter (density); biovolume for each species and class; and totals for each station and date. Data were analyzed using SAS programs.

Key of Algal Classes

Phytoplankton collected from lakes in North Carolina fall into several taxonomic classes. Table 6 contains a general description of these classes and provides a key to the abbreviations and common names used in this report. For additional information, the reader is encouraged to consult Bold and Wynne (1985).

Biovolume, Density, & Chlorophyll-a

Some measure of phytoplankton population size is necessary for the analysis of productivity in a system. Biovolume (mm^3/m^3), density (units/ml), and chlorophyll-a are used in this report. Biovolume is the volume of all living algae in a unit area at a given point in time. To reach this estimate, individual cells in a known amount of sample are counted. Cells are measured to obtain their cell volume which is used in calculating biovolume (NRCD 1987). Density is a measure of the number of units or individual algae present in a sample. A unit consists of a single filament or a colony for multicellular organisms. When counting, both the number of cells and the number of units are recorded so that both biovolume and density may be estimated.

When analyzing phytoplankton, biovolume and density are both used to prevent bias toward larger or smaller species of phytoplankton. Small species generally contain less chlorophyll-a. Large numbers of small algae often contribute significantly to density, although chlorophyll-a concentrations and biovolume estimates remain low. An example of small species resulting in low biovolume and high density is Burlington Reservoir, where Anabaenopsis raciborskii and Anabaenopsis phillipinensis, two small filamentous blue-greens, were the dominant species. In contrast, one or two large euglenophytes may result in high biovolume while density remains low.

Chlorophyll-a concentration is often used to estimate algal biovolume, especially when expertise with phytoplankton taxonomy is not available. It is important to realize that

Table 6. Taxonomic classes of phytoplankton found in North Carolina lakes. The three-letter abbreviation at left refers to the legend of the bar graphs found in each lake assessment report. The scientific name of each algal class is followed by the group's common name and a brief description.

	SCIENTIFIC NAME	COMMON NAME	DESCRIPTION
CYA	Cyanophyceae	blue-green algae	Blue-greens are the most primitive class of algae, and they occupy more diverse habitats than any other group. Some species produce toxins that affect both humans and animals. The blue-green species most often causing nuisance surface blooms in North Carolina are Anacystis cyanae (Microcystis aeruginosa) and Aphanizomenon flos-aquae. These two species are capable of fixing nitrogen from the air, allowing them to continue growing after nitrogen in the water has been depleted.
CHL	Chlorophyceae	green algae	This is a very large class of algae containing unicellular, colonial, and filamentous species. Green algae are normally found in highest numbers in the spring and fall when temperatures are cooler. Some genera such as Chlamydomonas form blooms in the spring or fall in organically enriched waters.
CRY	Cryptophyceae		Most species in this class are naked (without a cell wall), unicellular, and motile. Cryptomonas erosa, Cryptomonas ovata and Chroomonas minuta are three of the most common species. These algae are found in lakes all over the state.
XAN	Xanthophyceae	yellow-green algae	This class is similar to the greens; however, an absence of starch and conspicuous carotenoids results in the predominantly yellow-green color of these algae. Species from this class are uncommon, but occur most often during the spring and fall.
EUG	Euglenophyceae		Euglenophytes are widespread. Most are motile and may produce powdery surface blooms when organic nutrient concentrations are high. Surface blooms of euglenas range in color from yellow to red, sometimes resembling paint specks or powder on the water. Blooms are most commonly reported in sewage lagoons.
CHR	Chrysophyceae	golden, golden-brown algae	Most chrysophytes are unicellular with silica scales and spines. Some have an external lorica or "shell." Some species such as Dinobryon prefer low phosphorus (Wetzel, 1975) and are therefore common in oligotrophic systems.
BAC	Bacillariophyceae	diatoms	Silicified cell walls distinguish this particularly widespread class. Some species form filaments or colonies while others are solitary, living on the bottoms of streams and lakes. Melosira is one of the more common genera. Diatoms prefer cooler weather and usually are not important in the summer. However, in shaded and cooler systems they can contribute significantly to the phytoplanktonic standing crop.
DIN	Dinophyceae	dinoflagellates	This class is composed of motile cells partially or completely encircled by a tranverse or spiral groove. Two flagella give dinoflagellates a forward rotating motion. Most genera of this class are marine; however, the two most common marine genera, Ceratium and Peridinium, are also the most common freshwater dinoflagellates. Dinoflagellates are frequently found in lakes of the coastal plain.
PRY	Prymnesiophyceae	golden flagellates	These flagellated unicellular algae are characterized by a haptonema, which is an attachment organelle. Chrysochromulina breviturrita is the most common golden flagellate in the lake samples. A high chlorophyll to biovolume ratio in Chrysochromulina may result in high chlorophyll concentrations even when density and biovolume are low.

chlorophyll-a concentrations vary between species, which can result in an over- or under-estimation of algal standing crop. Therefore, a more reliable picture of trophic state is provided by chlorophyll-a data combined with phytoplankton analysis.

When evaluating phytoplankton data, a density of 10,000 units/ml and a biovolume of 5,000 mm^3/m^3 and are considered "bloom" or nuisance-level proportions. Depending on the species present, chlorophyll-a concentrations may range from 35 to 50 µg/l at these biovolumes and densities. North Carolina's state standard for chlorophyll-a is 40 µg/l (or 15 µg/l in designated trout waters). Moderate algal populations would start at 5,000 units/ml and 2,500 mm^3/m^3 with chlorophyll-a values between 10 and 30 µg/l. Summaries of algal blooms reported in North Carolina are available in other publications by DEM (1988a; 1989c; 1990b; 1991b).

Another factor to consider when reviewing phytoplankton biovolume and density estimates is the species composition. Throughout the lake summaries it is noted which classes dominated or composed most of the biovolume at a station. A well-mixed distribution of classes usually indicates a healthy system. In some of the more eutrophic lakes such as Jordan Lake, one class may contribute a larger amount of biovolume than any other class. In extreme cases, this type of dominance can disrupt the food chain causing low fish populations and nuisance algal blooms.

MACROPHYTES

General Information

Aquatic macrophytes are vascular plants found floating, submerged, or emergent in water bodies. These aquatic plants are important to the surface water environment because they provide food, shelter, and reproductive habitat to numerous fish and wildlife. Natural controls maintain most native species at levels compatible with man's uses of the water. Non-native or exotic plants are not subject to these same controls and, as a result, can become so vast and numerous that they interfere with the uses of the waterbody. If left unchecked, these plants can destroy fish and waterfowl habitats as well as render a body of water worthless for any beneficial human uses.

Collection, identification, and estimation of abundance are the first steps in an integrated management approach to monitor and control aquatic macrophytes. Incorporating aquatic weed identification within the lakes monitoring program helps identify potential problem areas and supplements the information provided by other monitoring activities.

Methods of Collection

Methods for collecting aquatic macrophytes are unique compared to the collection of other chemical and biological samples. Fresh samples were used for identification whenever possible. An aquatic weeds report form was filled out for each sample. This form provided information on location, depth, and approximate coverage. Whenever possible, plants were collected during the peak growing season at the time of flower or fruit development, so that the specimen contained all parts of the plant used in identification.

After collection, the sample was wrapped in several layers of damp paper (newspaper or paper towels). The specimen, aquatic weeds report, and a completed sample tag were placed in a plastic bag and transferred on ice to the DEM Laboratory. Plants were maintained under refrigeration at 4°C or, if absolutely necessary, preserved in an airtight glass vessel with 1 part 10% buffered formalin, 3 parts water, and a trace of powdered copper. Species identification was to the lowest possible taxonomic level.

A more detailed description of methods used to collect and evaluate phytoplankton and aquatic macrophytes may be found in NRCD (1987).

Important Species

The following is a list of aquatic macrophytes that have been observed to cause problems in North Carolina:

HYDRILLA (Hydrilla verticillata): Hydrilla is a particularly noxious aquatic macrophyte and has been found in several reservoirs in the Neuse River Basin. Hydrilla spreads rapidly once it is introduced and can quickly impair beneficial uses of a water body.

BRAZILIAN ELODEA (Egeria densa): This imported weed is in the same family as hydrilla and has very similar growth characteristics. However, unlike hydrilla, Egeria is cold-adapted and acts as a perennial plant in North Carolina. The distribution of this macrophyte is growing in North Carolina.

SLENDER SPIKERUSH (Eleocharis spp.): This weed is a problem mainly in the Coastal Plain of the state. Typical habitats include saturated drainage ditches, farm ponds, and lakes. The chief damage caused by this weed is in ponds and small lakes, where heavy growths interfere with line fishing, irrigation, and are considered by most property owners to be aesthetically displeasing.

ALLIGATORWEED (Alternanthera philoxeroides) and WATER PRIMROSE (Ludwigia spp.): These two species are listed together because of similarity of habitat and damage caused. Both of these weeds are common in drainage canals and ponds throughout coastal North Carolina. Damage in the canals is due to reduced water flow and therefore drainage capacity. In ponds, both weeds interfere with irrigation and fishing.

AMERICAN LOTUS (Nelumbo lutea): This perennial plant produces stems, leaves, and flower stalks from a subterranean rhizome each year. Leaves may be floating or emergent, while flowers are always emergent. It is common to find pure stands of several acres, or lotus may occur with other macrophytes like alligatorweed and water primrose.

DUCKWEED (Lemna spp., Spirodela spp., and Wolffia spp.): These small, floating plants are oten mistaken for algae. They are common in quiescent waters such as ponds or coves of lakes, especially in the coastal plain. Several species typically occur together. All of the members of this family reproduce rapidly and may wash up along lake shorelines, where they may cause unsightly conditions.

NOTE: "Ecological Concepts" is an excerpt from the Lake and Reservoir Restoration Guidance Manual (U.S. EPA 1990), which was reprinted courtesy of the North American Lake Management Society. Some of the material contained herein may not be directly pertinent to North Carolina lakes. Rather, this section provides an introduction to lake ecology and the factors that influence lake water quality.

ECOLOGICAL CONCEPTS

Lake and Reservoir Ecosystems

Lake management must be based on an understanding that lakes are complex and dynamic ecosystems.

Viewed simply as water systems, lakes are influenced by a set of hydrologic conditions, the watershed, the shape of the lake basin, the lake water, and the bottom sediments. These physical and chemical components, in turn, support a community of organisms that is unique to lake environments (Fig. 2-1). The biota enrich the complexity of lake ecosystems; they not only have a myriad of links to one another but also affect a lake's physical and chemical features. All of these components of lakes—physical, chemical, and biological—are in constant change, and the chemical and biological components are particularly dynamic.

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

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

Because lakes are highly interactive systems, it is impossible to alter one characteristic, such as the amount of weeds or the clarity of the water, without affecting some other aspect of the system, such as fish production.

For example, a lake association might decide to remove weeds by mechanical means, and, in the process, accidentally destroy important habitat needed for fish survival and increase proliferation of algae, which would feed on nutrients inadvertently released during the weed harvesting. If the lake association then decided on chemical treatment to solve the algae problem and help clear up the water, the next step in this sequence of events could be increased penetration of sunlight through the water, which would encourage new weed growth.

Ecology is the scientific study of the interrelationships among organisms and their environment. Managing a lake for maximum benefit requires an understanding of how its ecosystems are structured and how they function. This lake management example is hypothetical, but variations on such unexpected results occur repeatedly when programs are implemented without adequate knowledge of lake ecology. It also illustrates a common confusion between causes and symptoms. Not only did the lake association members fail to consider how lake organisms interacted with one another, they also did not determine why weeds and algae were growing profusely and whether this aquatic plant production should be viewed as a problem or an asset.

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

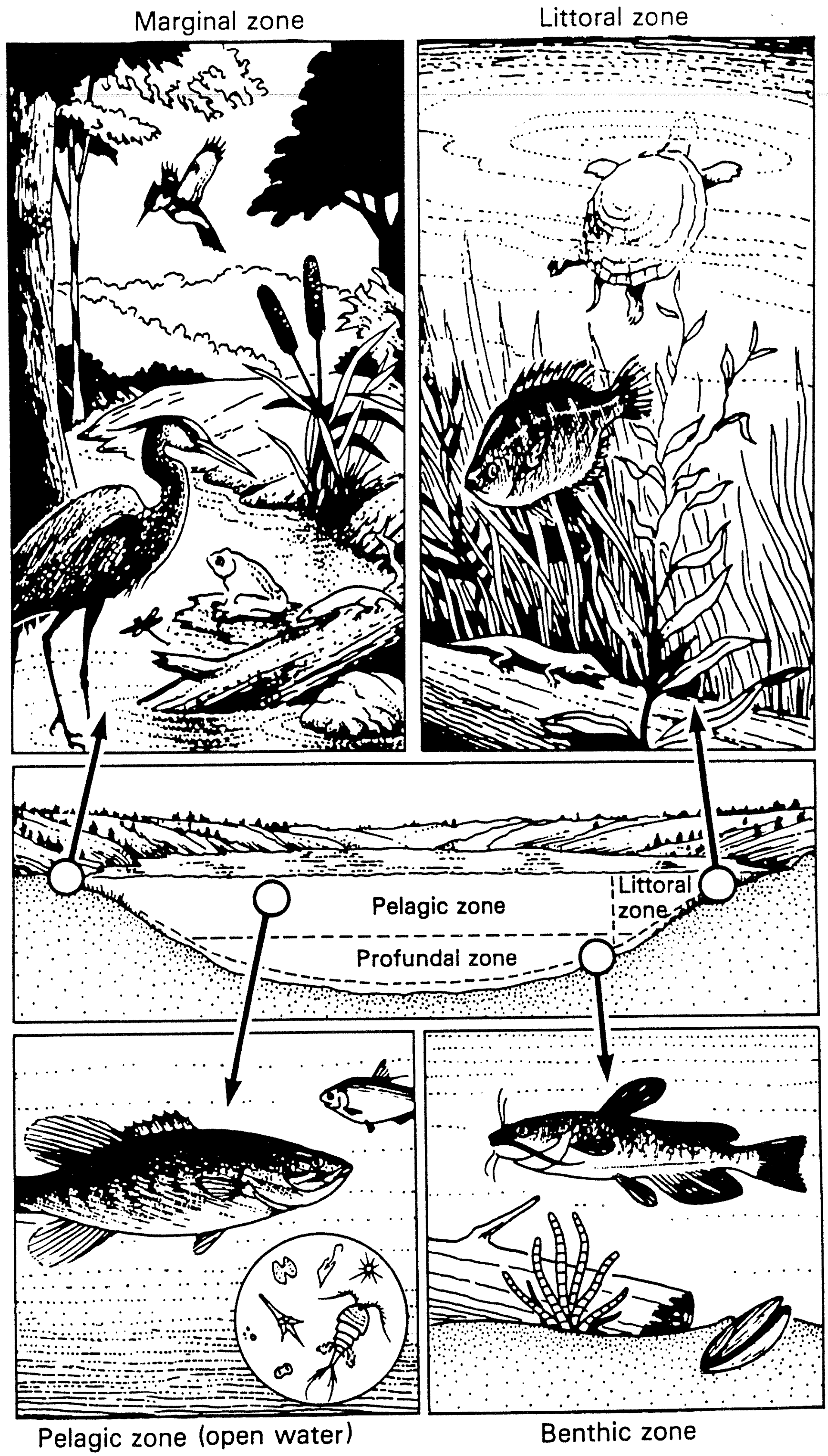


Figure 2-1.—The location and nature of typical lake communities, habitats, and organisms. In addition to the lake's watershed, all of these components are part of the lake ecosystem.

Limnology is the scientific study of the physical, chemical, geological, and biological factors that affect aquatic productivity and water quality in freshwater ecosystems—lakes, reservoirs, rivers, and streams. An understanding of limnology is the backbone of sound lake management.

This chapter is not intended to be a text on either aquatic ecology or limnology. Rather, its goal is to provide the background information necessary to understand the causes of lake degradation problems and to identify the most applicable lake management and restoration approaches.

Limnology *is the scientific study of the physical, chemical, geological, and biological factors that affect aquatic productivity and water quality in freshwater ecosystems—lakes, reservoirs, rivers, and streams.*

The Lake and Its Watershed

Water, dissolved materials carried in water, and particulates, such as soil, enter the lake from its watershed.

Lakes are constantly receiving these materials from watersheds, acid precipitation and dust from the atmosphere, and energy from the sun and wind. Therefore, water quality and productivity are as much influenced by what can (and will) go into the lake as by what is already there. Important factors include watershed topography, local geology, soil fertility and erodibility, vegetation in the watershed, and other surface water sources such as runoff and tributary streams. See the boxed section and Figure 2-A on the hydrologic cycle, which describes major natural phenomena controlling water supply availability.

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

Water

The amount of water entering the lake from its watershed controls volume and several other factors that influence the lake's overall health. A lake, like any water tank, takes a predictable amount of time to fill and to empty, given a certain rate of flow. Unlike rivers, lakes essentially slow the flow of water; thus, any water entering the lake will remain in it for a period called the *hydraulic residence time* (see boxed section and Fig. 2-B). Water quality reflects the history of the lake water, as well as the condition of new incoming water.

Because of hydraulic residence time, management programs directed at improving incoming water and, therefore, lake water quality, will face a lag period between the time that incoming water quality gets better and the time that change becomes evident in the lake. The longer the hydraulic residence time, the greater the lag.

Since water affects and is affected by the biota, sediments, and existing water chemistry, additional delays between changes in the quality of incoming water and that of in-lake water may also occur.

Dissolved Materials

One of the most important materials dissolved in water is oxygen. Sources of dissolved oxygen include inflowing water, transfer from the atmosphere (gas exchange), and photosynthetic production by aquatic plants.

Oxygen production by plants is discussed later in this chapter. Oxygen is consumed or removed from the lake by outflow, loss to the atmosphere, nonbiological combination with chemicals in the water and mud (chemical oxygen demand or COD), or plant, bacterial, and animal respiration. Biochemical oxygen demand (BOD), which is a common measure used to describe the rate of oxygen consumption by organisms and materials under dark conditions, varies with the amount of organic matter and bacteria in the water. Municipal wastewater discharges have very high BOD, for example.

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

The Hydrologic Cycle

Because precipitation and surface water runoff directly influence the nature of lake ecosystems, a good way to begin to learn about lakes is to understand the hydrologic (water) cycle. The circulation of water from atmosphere to Earth and back to the atmosphere is a process that is powered by the sun. About three-fourths of the precipitation that falls on land is returned to the atmosphere as vapor through evaporation and transpiration from terrestrial plants and emergent and floating aquatic plants. The remaining precipitation either is stored in ice caps, or drains directly off the land into surface water systems (such as streams, rivers, lakes, or oceans) from which it eventually evaporates, or infiltrates the soil and underlying rock layers and enters the groundwater system. Groundwater enters lakes and streams through underwater seeps, springs, or surface channels and then evaporates into the atmosphere.

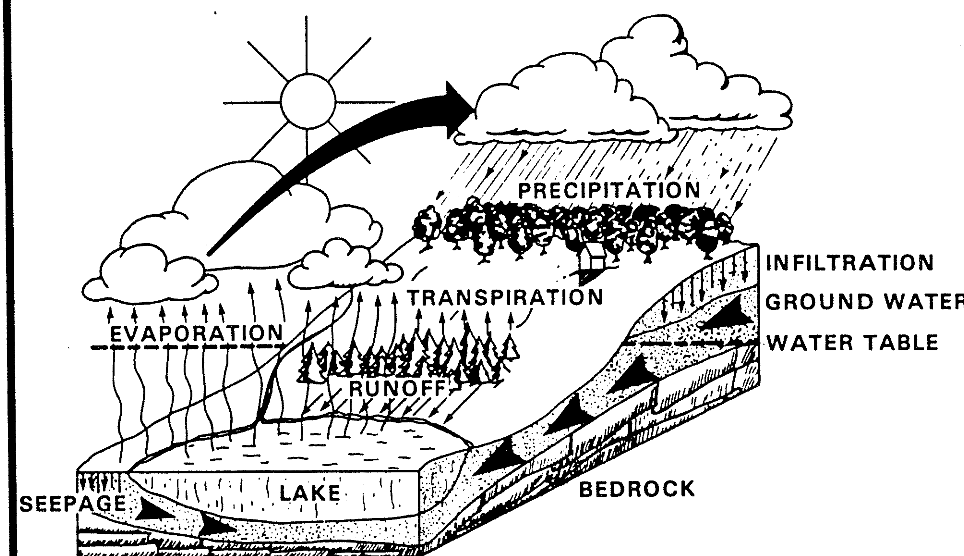


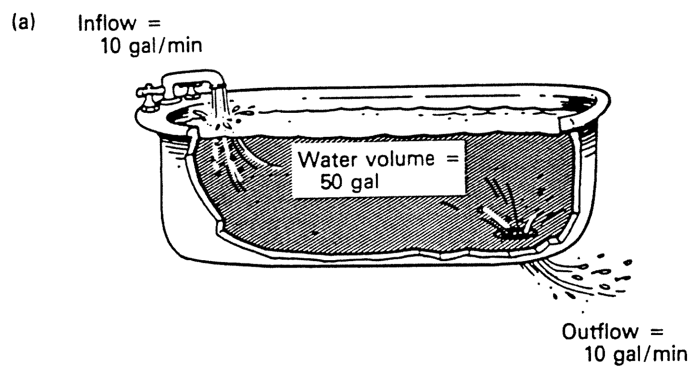
Figure 2-A.—Hydrologic cycle.

Lakes and reservoirs have a water "balance," as described in this simple equation: water input = water output +/- the amount of water stored in the lake. Inputs are direct precipitation, groundwater, and surface stream inflow, while outputs are surface discharge (outflow), evaporation, losses to groundwater, and water withdrawn for domestic, agricultural and industrial purposes. If inputs are greater than outputs, lake levels rise as water is stored. Conversely, when outputs are greater—for example, during a summer drought—lake levels fall as losses exceed gains.

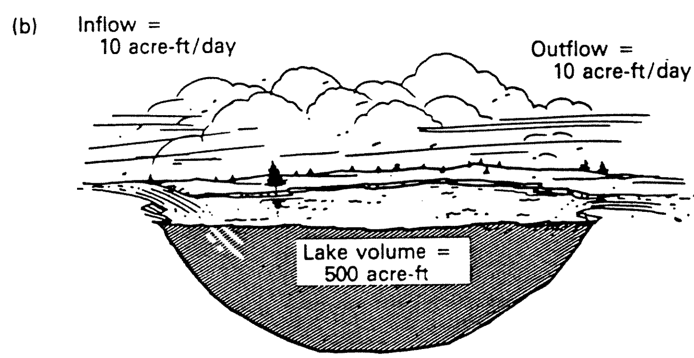
Some lakes, called *seepage lakes*, form where the groundwater flow system intersects with the land surface. Seepage lakes are maintained primarily by groundwater inflow, and their water levels fluctuate with seasonal variations in the local water table. *Drainage lakes*, on the other hand, are fed primarily by inflowing rivers and streams; therefore, their water levels vary with the surface water runoff from their watersheds. In both cases, the balance between hydrologic inputs and outputs influences the nutrient supply to the lake, the lake's water residence time, and, consequently, the lake's productivity and water quality.

Hydraulic Residence Time

The average time required to completely renew a lake's water volume is called the hydraulic residence time. For instance, it might take 5 minutes to completely fill a bathtub with the tap fully open and the bottom drain closed. The hydraulic residence time of the tub, then, is 5 minutes. With the tap and drain only half open, the hydraulic residence time would be 10 minutes.



Hydraulic residence time = Volume ÷ Flow Rate
= 50 gal ÷ 10 gal/min = 5 min



Water residence time = 500 acre-ft ÷ 10 acre-ft/day = 50 days

Figure 2-B.—Hydraulic residence time is an important factor to consider in restoration programs. The simple formula given in the figure assumes that inflow is equal to outflow.

If the lake basin volume is relatively small and the flow of water is relatively high, the hydraulic residence time can be so short (10 days or less) that algal cells produced in the water column are washed out faster than they can grow and accumulate.

An intermediate water residence time allows both an abundant supply of plant nutrients and adequate time for algae to assimilate them, to grow, and then accumulate.

Longer water residence times from 100 days to several years provide plenty of time for algal biomass to accumulate if there are sufficient nutrients present. The production of algae may ultimately be limited by the supply of nutrients. If the nutrient supply is high, algal biomass will be very large. The combined effects of nutrient income (or "nutrient loading") and hydraulic residence time on the production of algae is the basis of methods for predicting changes in the lake's condition following variations in one or both of these processes (such as the diversion of wastewater flows.) These methods are discussed in Chapter 4.

When the loss of oxygen from the water exceeds the input of oxygen from various sources, the oxygen content of the lake water is decreased. If the dissolved oxygen becomes severely depleted, anoxic conditions can occur that lead to odors, fishkills, increased phosphorus and ammonia concentrations, and other undesirable effects.

Inflowing stream water also carries the two principal plant nutrients—nitrogen and phosphorus—in both dissolved organic and inorganic forms. Nitrogen and phosphorus are required for the biological production of phytoplankton (free-floating microscopic algae) and macrophytes (larger floating and rooted plants). (See **Organic Matter Production and Consumption** in this chapter.)

Surface and subsurface drainage from fertile (nutrient-rich) watersheds results in biologically productive lakes, and drainage from infertile (nutrient-poor) watersheds results in biologically unproductive lakes. The relative fertility of watersheds and, thus, of lakes varies locally and regionally, as is discussed in the boxed section on regional differences in lake water quality and biological productivity.

Soils, weathered minerals, and decomposing organic matter in the watershed are the main natural sources of phosphorus and nitrogen. However, manmade sources such as agriculture, crop and forest fertilizers, and wastewater discharges commonly increase the rate of nutrient income or loading from watersheds and are the major causes of biological overproduction in many lakes (Table 2-1). Watershed disturbances such as logging and mining, which remove natural vegetation, can greatly increase the amount of silt and nutrients exported from the land to the lake (see Chapter 5). Finally, pesticides, herbicides, toxic pollutants, chemicals in wastewater discharges, and industrial waste materials may also enter the lake with incoming water.

Table 2-1.—Representative values for nutrient export rates and input rates for various land uses. All values are medians and are only approximations owing to the highly variable nature of data on these rates.

LAND USE	TOTAL PHOSPHORUS	TOTAL NITROGEN
A. Export rates (kg/ha/yr)[1,2]		
Forest	0.2	2.5
Nonrow crops	0.7	6.0
Pasture	0.8	14.5
Mixed agriculture	1.1	5.0
Row crops	2.2	9.0
Feedlot, manure storage	255.0	2920.0
B. Total atmospheric input rates (kg/ha/yr)[1,3]		
Forest	0.26	6.5
Agricultural rural	0.28	13.1
Urban industrial	1.01	21.4
C. Wastewater input rates (kg/capita/yr)[4]		
Septic tank input[5]	1.45	4.65

[1] Values in this table are all in kg ha yr, which is the standard for such measurements. To convert to pounds per acre per year, multiply by 0.892.
[2] Source: Reckhow et al. 1980, Figure 3.
[3] Source: Reckhow et al. 1980, Table 13.
[4] Source: Reckhow et al. 1980, Table 14.
[5] This is prior to absorption to soil during infiltration; generally, soils will absorb 80 percent or more of this phosphorus

Regional Differences in Lake Water Quality, Productivity, and Suitability

Lake water quality and productivity are influenced directly by the nature of the lake watershed; that is, by the watershed topography, soil fertility and erodibility, vegetation, and hydrology. Similarly, but on a larger scale, the character of lakes located in regional drainage systems are broadly influenced by the regional geology, topography, hydrology, soils, and vegetative cover. Both the lake watershed and regional conditions exert natural controls on lake trophic status, water quality, and biological productivity. For example, a deep alpine lake located in a granitic watershed in the Colorado Rockies is almost certain to have pristine, crystal clear, high quality water but very low biological productivity and poor fishing. On the other hand, a turbid reservoir in southern Mississippi or Alabama may be considered to have poor water quality because of its high turbidity, high concentrations of nutrients and organic matter, and frequent occurrences of algal blooms; however, this impoundment will likely support a productive sport fishery and be highly valued for its trophy bass.

North American lakes have extremely variable water quality, biological productivity, and fish community structure. This variability is due in large part to regional differences in the nature of lake watersheds and to a tremendous local diversity in lake morphometry (i.e., shape, depth, volume, surface area). Studies of the relationship between lake morphometry, water chemistry, and fish yield have generally shown that nutrient-rich, shallower lakes are typically more biologically productive and have higher fish yields per unit area than deeper, less fertile lakes. Along a water quality or trophic-status continuum ranging from oligotrophic (nutrient-poor, biologically unproductive, good water quality) through eutrophic (nutrient-rich, productive, poor water quality) lake conditions, there is also a continuum of fishery yield and fish community structure.

Generally, the better the lake water quality, the poorer the fishery yield (and vice versa) and, depending on the desired uses of a particular lake, there is often potential conflict between fishery optimization and water quality-related lake management objectives. Necessarily, maximum fishery yield results from high biological productivity and high plankton biomass (Jones and Hoyer, 1982; Wagner and Oglesby, 1984), while high water quality, high water transparency, low treatment costs, and the greatest aesthetic appeal are usually associated with low plankton biomass (Fig. 2-C). Consequently, without clearly established lake management priorities, maximized (or even improved) fish production may be incompatible with water quality-related lake management objectives.

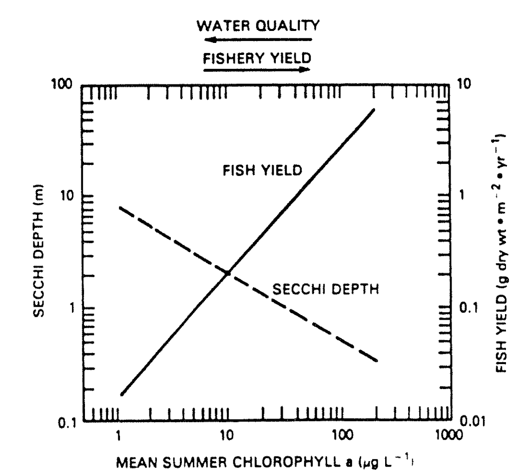


Figure 2-C.—Relationship between lake characteristics (e.g., water clarity, algal biomass) and management objectives (e.g., water quality, fishery yield). Modified from Wagner and Oglesby (1984).

Given the strong natural controls that the regional setting and the nature of the watershed exert on lake conditions, it is clear that particular lakes are best suited for particular uses. To be most effective, lake managers must first identify those uses that a lake can best support and then develop a compatible lake and watershed management plan to take advantage of the lake's natural condition.

Particulates

Organic matter, clays, and silt particles wash from the watershed into the lake. Where the land is disturbed, the soil loss is apt to be high. Even removing brush and replacing it with a poor stand of lawn can increase the rate of erosion. Although erodibility among soil types varies, it is one factor that must be considered in watershed management programs.

In addition to soil loss from the land through rainfall and snowmelt, streams may scour soil from their banks. Wind also carries some particulates, such as dust and pollen, directly to lakes. Inputs of suspended particles result in increased turbidity, which decreases water transparency and light availability and reduces plant growth.

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

Lakes are extremely efficient sediment traps. Filling in with silt is part of a lake's natural aging pattern, but poor land management practices can speed up the process significantly. Suspended sediment particles that can be easily carried by rivers and streams settle out once they reach the relatively quiescent lake environment. As a consequence, particle-associated nutrients, organic matter, and toxic contaminants are often retained in lake sediments, and the influx of herbicides, pesticides, and toxics adhered to soil particles is becoming an increasingly common problem for lakes.

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

Incoming silt is another problem. Silt-laden water can reduce penetration of sunlight and, consequently, the light available to algae. Many species of fish are sight feeders; they cannot locate prey efficiently in muddy waters. Silt deposits can also prevent successful hatching of fish eggs that require clean surfaces. Finally, excessive levels of silt can irritate the gills of fish, causing respiratory difficulties and poor health.

The **Sedimentation and Decomposition** section in this chapter discusses how organic matter in the water affects dissolved oxygen. Particles of organic matter can enter the lake suspended in tributary streams or can originate from aquatic plants and animals within the lake itself. Controlling soil loss from the watershed is treated in Chapter 5 in the discussion of best management practices. The use of dredging to deepen a lake and remove sediments is discussed in Chapter 6.

Effects of Lake Depth

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

Shallow lakes tend to be more biologically productive than deep lakes because of the large area of bottom sediments relative to the volume of water, more complete wind mixing of the lake water, and the large, very shallow (littoral) areas along the lake perimeter that can be colonized by rooted and floating macrophytes. Indeed, shallow lakes may be dominated by plant production in littoral areas and have little open water habitat. Large inputs of silt and incomplete decomposition of macrophytes can make lakes become shallow rapidly and, usually, shallow lakes have a shorter hydraulic residence time.

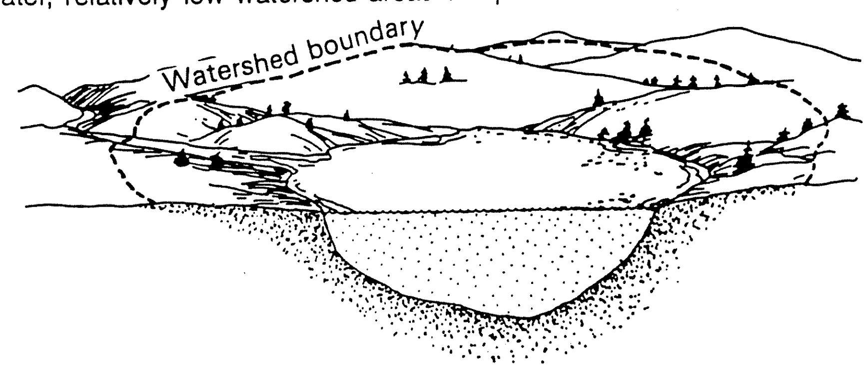
Pelagic zone: *This is the open area of a lake, from the edge of the littoral zone to the center of the lake.*

Deep, steep-sided lakes usually stratify thermally during the summer, which prevents complete mixing of the lake water. These lakes may have fewer areas that are shallow enough for rooted aquatic plants to receive light and grow. Thus, deep lakes generally have a high proportion of open water (pelagic) habitat, and their food webs tend to be based on the organic matter produced by planktonic algae or phytoplankton. Many reservoirs have large areas of shallow water, but flood control operations often cause water level fluctuations that discourage well-developed stands of aquatic weeds along the shoreline.

Manmade Lakes

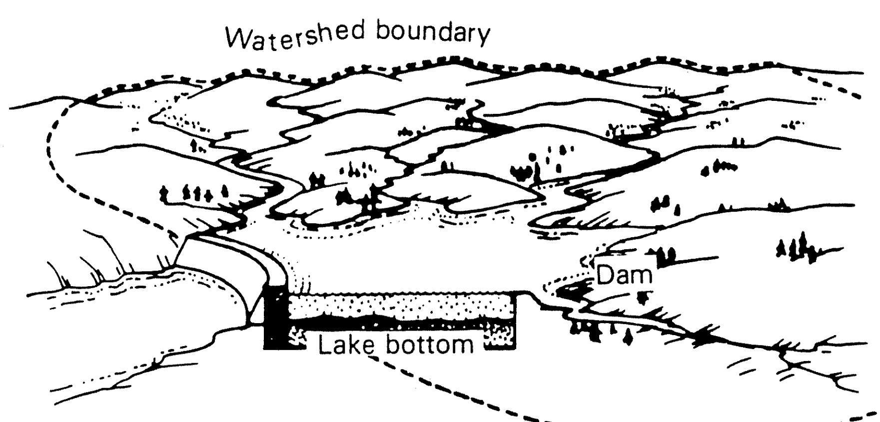
In contrast to the glacial lakes that may be thousands of years old, most manmade impoundments have been constructed within the past 100 years. Ponds, stock tanks, and small reservoirs have been formed for agricultural use, municipal water supply, soil and water conservation, sport fishing, and recreation. Large reservoirs are usually constructed by Federal agencies by impounding major rivers and are operated for multiple purposes that include water supply, flood control, and hydroelectric power generation.

The purpose and location of an impoundment usually determine its basin size, and the topography of the inundated valley dictates the basin shape. The geology, soil type, and vegetation in the valley and the watershed directly affect reservoir productivity and water quality. Because reservoirs are often flooded river valleys, many of these manmade lakes are long and narrow rather than circular or ovoid like many natural lakes, and they tend to have irregular shorelines (Fig. 2-2). Additionally, while natural lakes tend to have diffuse sources of inflowing water, relatively low watershed areas compared to lake surface area, and long



Natural Lakes

- Smaller watershed area
- Longer hydraulic residence time
- Simpler shape, shoreline
- Surface outlet



Reservoirs

- Larger drainage area
- Shorter hydraulic residence time
- More complex shape, shoreline
- May have surface and/or subsurface outlet(s).

Figure 2-2.—General comparison of reservoirs to natural lakes.

hydraulic residence times, reservoirs usually differ in all of these traits, and these differences account for the great variety in water quality and productivity that can occur between and among lakes and reservoirs.

Typically, a reservoir has one or two major tributaries, a very large watershed compared to lake surface, and relatively short hydraulic residence times. The inputs of dissolved and particulate organic and inorganic materials from the watershed are also likely to be very high. Of course, the most distinctive difference between natural lakes and reservoirs is the subsurface outlet commonly possessed by large reservoirs with dams designed for hydroelectric power generation.

Actually, there are probably more similarities than differences between natural lakes and reservoirs. The physical, chemical, and biological conditions in both overlap greatly, as illustrated in Figure 2-3. With regard to the environmental factors that control water quality and biological productivity, reservoirs occupy an intermediate position between natural lakes and rivers on a conceptualized continuum of aquatic environments (Kimmel and Groeger, 1984). Hydraulic residence time is the characteristic that most influences the relative productivity and water quality of natural lakes and reservoirs (Soballe and Kimmel, 1987).

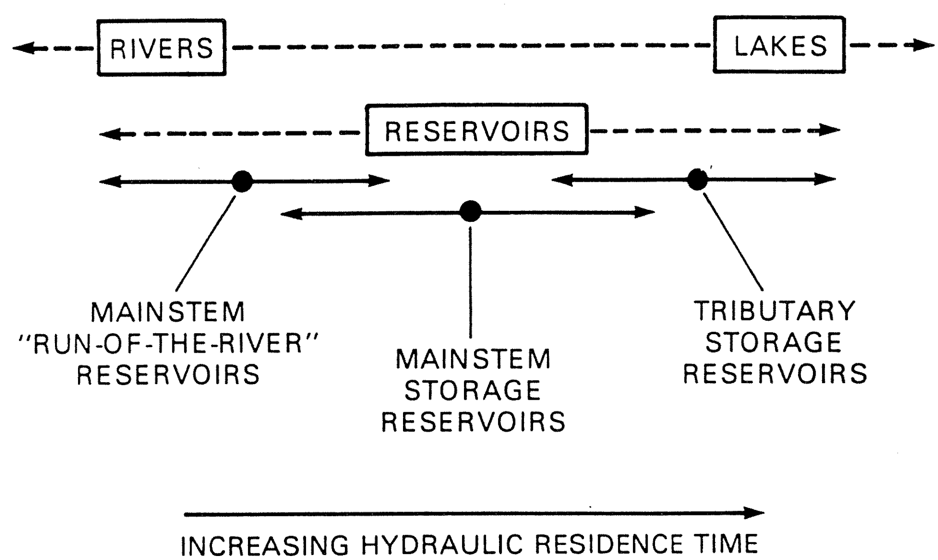


Figure 2-3.—Reservoirs occupy an intermediate position between rivers and natural lakes along a continuum of aquatic ecosystems ranging from rivers to natural lakes. Water residence time and the degree of riverine influence are primary factors determining the relative positions of different types of reservoirs (mainstem-run-of-the-river, mainstem storage, and tributary storage impoundments) along the river-lake continuum. Modified from Kimmel and Groeger (1984).

Lake Processes

Lake Stratification and Mixing

In spring and early summer, the combination of solar heating and wind mixing of near-surface water layers brings about the warming of the upper portion of the lake water column and the stratification of many lakes and reservoirs into layers of water with different temperatures and densities (Fig. 2-4). Rapidly flushed, shallow lakes that are exposed to strong winds, however, do not normally develop persistent thermal stratification. Refer to the boxed section on the unique properties of water for a discussion of the water temperature–density relationship that results in the thermal stratification of lakes.

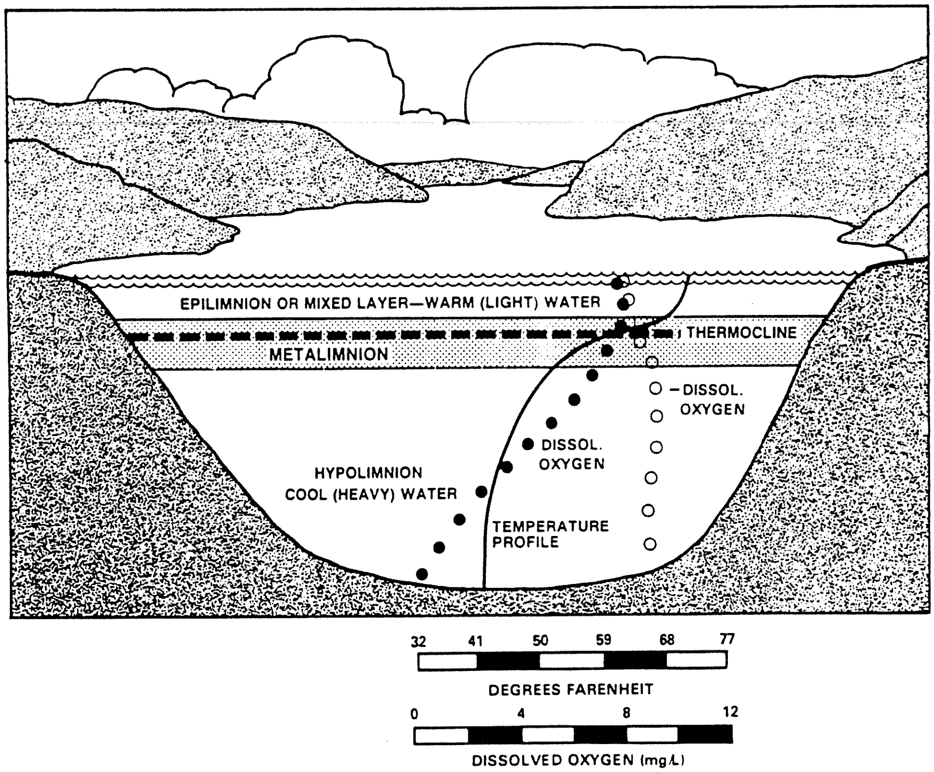


Figure 2-4.—A cross-sectional view of a thermally stratified lake in mid-summer. The water temperature profile (curved solid line) illustrates how rapidly the water temperature decreases in the metalimnion compared to the nearly uniform temperatures in the epilimnion and hypolimnion. The metalimnetic density gradient associated with this region of rapid temperature change provides a strong, effective barrier to water column mixing during the summer months. Open circles represent the dissolved oxygen (DO) profile in an unproductive (oligotrophic) lake: the DO concentration increases slightly in the hypolimnion because oxygen solubility is greater in colder water. Solid circles represent the DO profile in a productive (eutrophic) lake in which the rate of organic matter decomposition is sufficient to deplete the DO content of the hypolimnion.

During summertime thermal stratification, a warmer, less dense layer of water (the *epilimnion*) floats on a cooler, denser water layer (the *hypolimnion*). These two layers are separated by a zone of rapidly changing temperature and density called the *metalimnion*. The term "metalimnion" is often used loosely, but the classical definition is the stratum of water of rapid thermal change with depth, above and below which are zones of uniformly warm (epilimnion) and cold (hypolimnion) water layers. The *thermocline*, defined as a horizontal plane of water across the lake through the point of the greatest temperature change, is within the metalimnion.

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

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

Mixing Processes

The most important lake mixing mechanisms are wind, inflowing water, and outflowing water. Wind affects the surface waters of all lakes, but the effectiveness of wind in mixing the entire water column is sharply curtailed in some lakes during the summer. During summertime thermal stratification, a lake usually cannot be completely mixed by wind. When the lake water cools in the fall, the temperature-controlled zonation breaks down and the water column mixes completely.

The Unique Properties of Water

Water is a unique substance, and to understand how lakes behave, it is useful to understand water's physical and chemical properties. The molecular structure of water and the way in which water molecules associate with each other dictate these properties:

1. Water is an excellent solvent; many gases, minerals, and organic compounds dissolve readily in it.

2. Water is a liquid at natural environmental temperatures and pressures. Although this property seems rather common and obvious, in fact, it is quite important. If water behaved at ordinary temperatures and pressures as do chemically similar inorganic compounds, it would be present only as a vapor, and lakes would not exist.

3. The temperature-density relationship of water is also unique. Most liquids become increasingly dense (more mass, or weight, per unit volume) as they cool. Water also rapidly becomes more dense as its temperature drops, but only to a certain point (Fig. 2-D). Water reaches its maximum density at 39.2°F (3.94°C), then it decreases slightly in density until it reaches 32°F (0°C), the freezing point. At this point, ice forms and its density decreases sharply. Ice, therefore, is much lighter than liquid water and forms at the surface of lakes rather than at the lake bottom.

   A second important consequence of the temperature-density relationship of water is the thermal stratification of lakes. Energy is required to mix fluids of differing densities, and the amount of energy necessary is related to the difference in density. In the case of the water column mixing in lakes, this energy is provided primarily by wind. Therefore, the changes in water density that accompany rapidly decreasing water temperatures in the metalimnion during summer stratification are of great importance. The metalimnetic density gradient provides a strong and effective barrier to water column mixing.

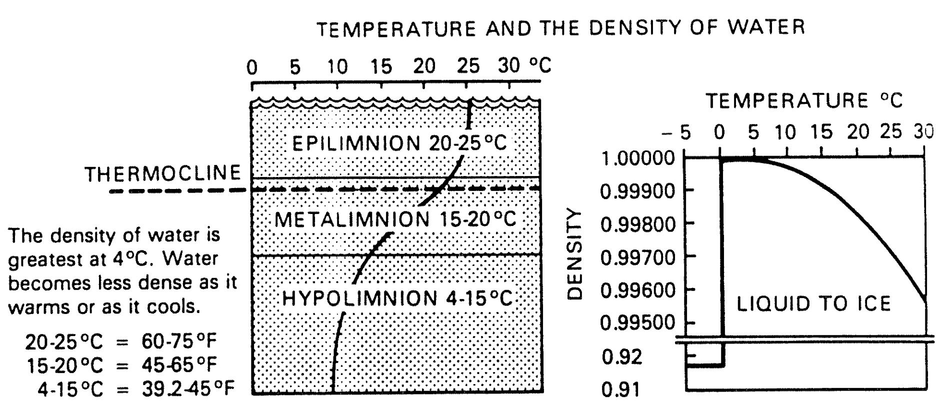


Figure 2-D.—The temperature-density relationship of water enables deep lakes to stratify during summer. (*See explanation in side column.)

**The layer of greatest temperature change, the metalimnion, presents a barrier to mixing. The thermocline is not a layer, but a plane through the point of maximum temperature change. The epilimnion and hypolimnion are relatively uniform in temperature. As the graph illustrates, ice is much less dense (lighter) than water. Warm water is less dense than cold water, but not as light as ice. Density changes most rapidly at warm temperatures.*

4. Water also has an unusually high specific heat. Specific heat is the amount of energy required to change the temperature of 1 g of water by 1°C. Water also has a high latent heat of fusion, which is the energy required to melt 1 g of ice at 0°C. These properties make lakes slow to thaw and warm in the spring and slow to cool and freeze in the fall, thus providing exceptionally stable thermal environments for aquatic organisms.

   Additionally, because water gains and loses heat slowly, the presence of large lakes can exert a significant influence on local and regional climate. A good example is the Great Lakes, which have a dramatic effect on both the air temperature and on the precipitation in the States and Provinces surrounding them.

In stratified lakes, the thickness of the epilimnion is considered to be the depth to which water is consistently mixed by wind. How deep (or thick) this layer becomes during the summer depends upon how resistant the water column is to mixing. The greater the temperature difference between the epilimnion and the hypolimnion, the more wind energy is required to mix the water column completely to the bottom of the lake. The density gradient (change in density) of the metalimnion acts as a physical barrier to the complete mixing of the epilimnion and hypolimnion.

In the spring, just after thermal stratification is established, the hypolimnion is rich in dissolved oxygen from early spring mixing of the water column and plant oxygen production. However, because of the barrier properties of the thermocline, the hypolimnion is isolated from gas exchanges with the atmosphere during the summer and is often too dark for photosynthetic production of oxygen by green plants. In a productive lake, the hypolimnion can become oxygen-depleted during the period of summer thermal stratification as its reserve of dissolved oxygen is consumed by the decomposition (respiration) of organic matter.

This event has very important consequences for lake productivity and fishery management and is one of the major targets of lake restoration activities. Most fish require relatively high dissolved oxygen levels and cannot survive in an oxygen-deficient hypolimnion; however, the epilimnion may be too warm for their survival. Additionally, under anoxic conditions, nutrients such as nitrogen and phosphorus are released from the bottom sediments to the water column, where they ultimately promote additional algal production organic matter decomposition, and more severe hypolimnetic oxygen depletion.

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

As the epilimnion cools in the late summer and fall, the temperature difference between layers decreases, and mixing becomes easier. With the cooling of the surface, the mixing layer gradually extends downward until the entire water column is again mixed and homogeneous (Fig. 2-5). This destratification process is often referred to as the fall overturn.

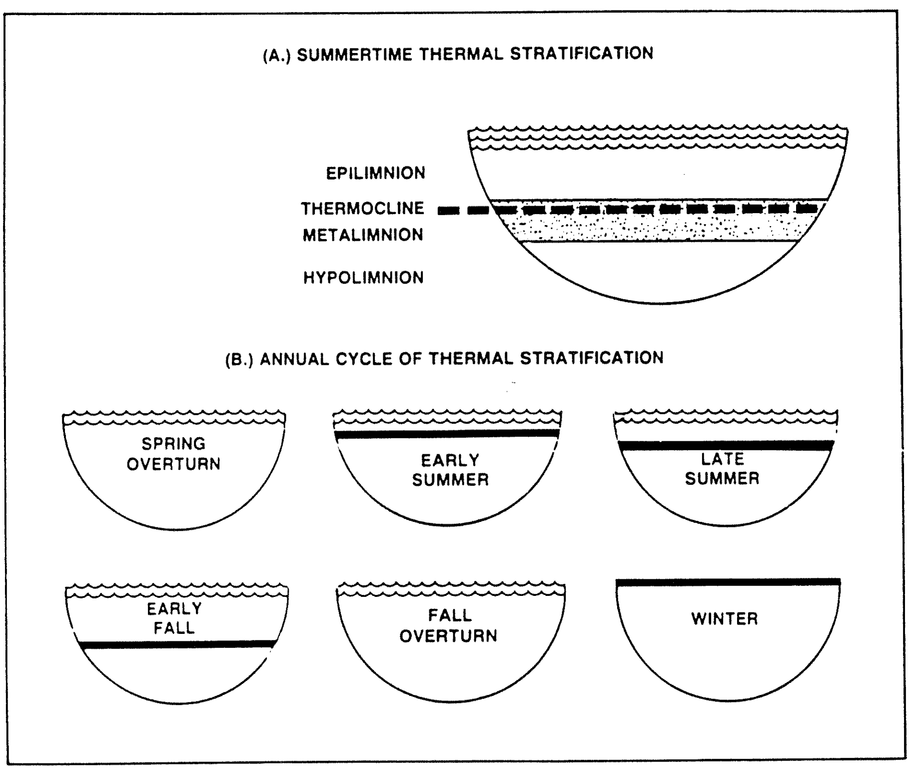


Figure 2-5.—Seasonal patterns in the thermal stratification of North Temperate Zone lakes and reservoirs: (A) summertime stratification; (B) the annual cycle of lake thermal stratification.

Water Movements

The wind-driven vertical mixing of the water column, just discussed, is only one of several types of water movements in lakes.

The downstream flow of water usually controls the transport of dissolved and suspended particles, particularly in river-like lakes and in many large, manmade impoundments dominated by major tributaries. Many natural lakes, however, have numerous, diffuse inflows (including subsurface inflows) and a surface outlet. In such lakes, the downstream flow of water from the watershed is not a major influence on lake water movements. Commonly, however, large reservoirs have deep subsurface (often hypolimnetic) outlets from the dam that tend to promote subsurface density flows (Fig. 2-6). A density flow occurs when inflowing water is cooler and thus denser than the epilimnetic water and, therefore, sinks or plunges to a depth of equivalent water temperature or density before continuing its downlake flow.

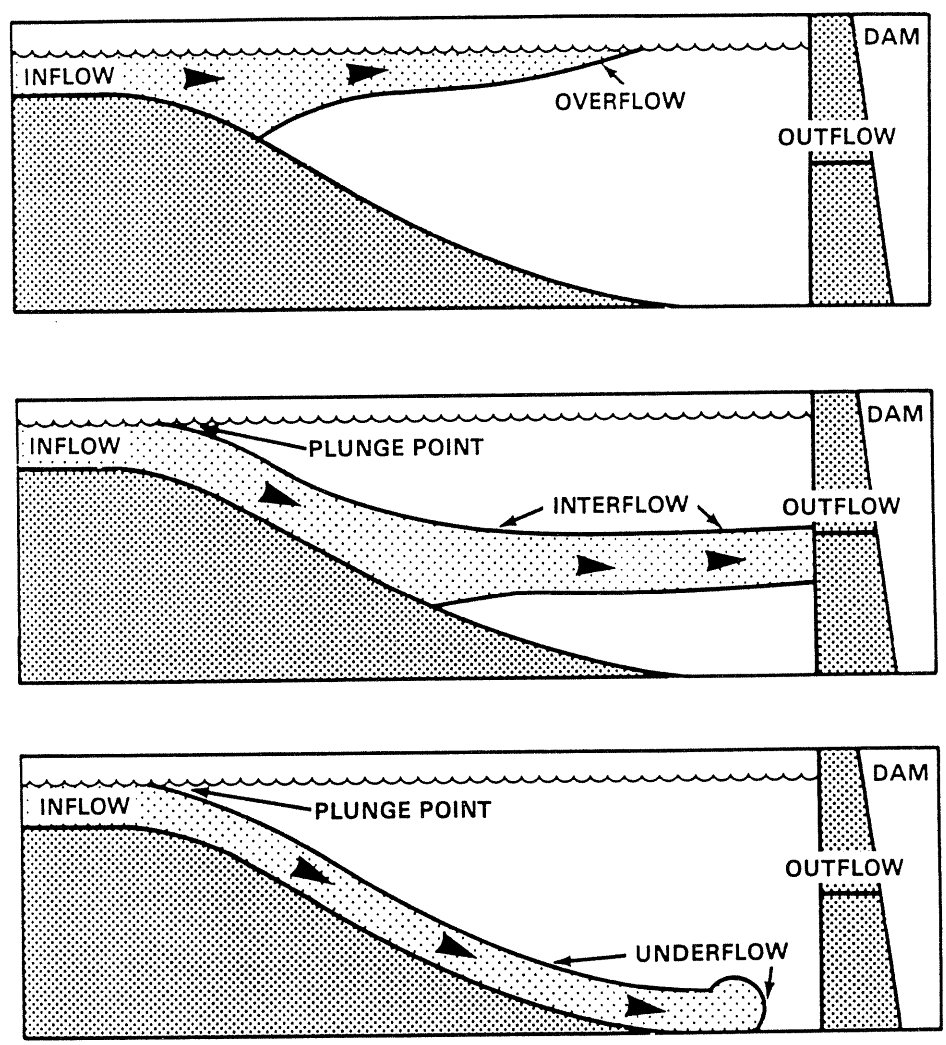


Figure 2-6.—Types of density flows in reservoirs. Often the inflowing river water and the reservoir water differ in temperature, and therefore, in the density. If the river inflow is warmer than the reservoir, the less dense river water will spread over the reservoir surface as an overflow (upper panel). If the river inflow is of an intermediate temperature and density, it will plunge from the surface and proceed downstream as an interflow at the depth at which the river water and reservoir water densities are equal (middle panel). If the river inflow is cooler and denser than the entire reservoir water mass, the inflowing river water will plunge from the surface and flow along the reservoir bottom as an underflow (lower panel). Modified from Wunderlich (1971).

Under stratified conditions, these density flows may pass through an entire reservoir along the bottom or at an intermediate depth without contributing significant amounts of nutrients or oxygen to the upper mixed layer. This is a common phenomenon in series of deep-discharge impoundments. Cold water released from an upstream reservoir may traverse the next reservoir in the series as a discrete subsurface flow. This short-circuiting underflow may even be perceived as desirable for water quality because it allows nutrient-laden water to flow through the reservoir without contributing to nuisance levels of algal production. Fishermen, however, may view this short circuit with less enthusiasm because a reduction in algal production may be detrimental to overall lake production of fish.

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

Organic Matter Production and Consumption

Photosynthesis and Respiration

Planktonic algae (phytoplankton) and macrophytes use the energy from sunlight, carbon dioxide, and water to produce sugar, water, and molecular oxygen (Fig. 2-7). The sun's energy is stored in the sugar as chemical bond energy. The green pigment, chlorophyll, is generally required for plants to do this. Sugar, along with certain inorganic elements such as phosphorus, nitrogen, and sulfur, is then converted by plant cells into organic compounds such as proteins and fats. The rate of photosynthetic uptake of carbon to form sugar is called *primary productivity*. The amount of plant material produced and remaining in the system is called *primary production* and analogous to the standing crop or biomass of plants in a farmer's field. While in-lake photosynthesis normally is the dominant source of or-

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

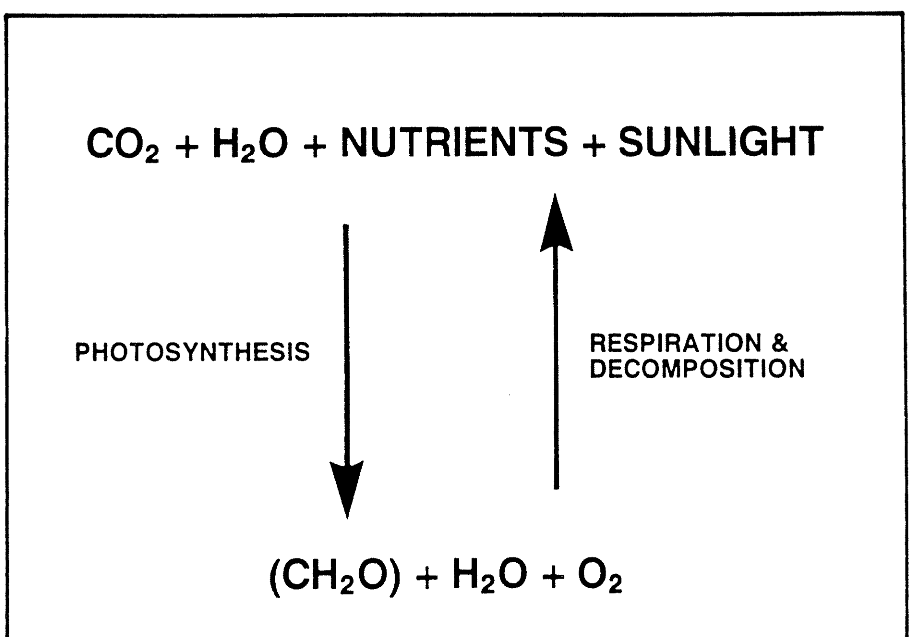


Figure 2-7.—The equilibrium relationship between photosynthesis and respiration-decomposition processes. The photosynthetic conversion of light energy, carbon dioxide (CO_2), water (H_2O), and nutrients into organic matter produces oxygen (O_2) and results in nonequilibrium concentrations of carbon, nitrogen, sulfur, and phosphorus in organic compounds of high potential energy. Respiration-decompostion processes tend to restore the equilibrium by consuming oxygen and decomposing organic materials to inorganic compounds.

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

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

ganic matter for the lake's food web, most lakes also receive significant inputs of energy in the forms of dissolved and particulate organic matter from their watersheds.

In the process of photosynthesis, molecular oxygen is produced as well, and this is the primary source of dissolved oxygen in the water and of oxygen in the atmosphere. Oxygen is usually required to completely break down organic molecules and release their chemical energy. Plants and animals release this energy through a process called *respiration.* Its end products—energy, carbon dioxide, and water—are produced by the breakdown of organic molecules in the presence of oxygen (Fig. 2-7).

Because of the requirement for light, the primary (photosynthetic) production of organic matter by aquatic plants is restricted to the portion of the lake water column that is lighted (also called the *photic zone*). The thickness of the photic zone depends upon the transparency of the lake water and corresponds to the depth to which at least 1 percent of the surface light intensity penetrates. Below this, in the *aphotic zone*, the available light is too weak to support a significant amount of photosynthetic production.

Phytoplankton production is controlled primarily by water temperature, light availability, nutrient availability, hydraulic residence time, and plant consumption by animals. Macrophyte production is controlled more by temperature, light, and bottom soil types. Most rooted macrophytes obtain their nutrients from the bottom sediments rather than the water and are restricted by light penetration to the shallow littoral water.

When light is adequate for photosynthesis, the availability of nutrients often controls phytoplankton productivity. In the lake, differences between plant requirements for an element and its availability exert the most significant limit on lake productivity. Table 2-2 compares the relative supply of essential nutrients to their demand for plant growth. Phosphorus and nitrogen are the least available elements, and therefore they are the most likely to limit lake productivity.

Table 2–2.—**The listed elements are required for plant growth. Plant demand is represented by the percentage of these essential elements in the living tissue of freshwater plants. Supply is represented by the proportions of these elements in world mean river water. The imbalance between demand and supply is an important factor in limiting plant growth (after Vallentyne, 1974).**

ELEMENT	SYMBOL	DEMAND BY PLANTS (%)	SUPPLY IN WATER (%)	DEMAND: SUPPLY RATIO[1]
Oxygen	O	80.5	89	1
Hydrogen	H	9.7	11	1
Carbon	C	6.5	.0012	5,000
Silicon	Si	1.3	.00065	2,000
NITROGEN	**N**	**.7**	**.000023**	**30,000**
Calcium	Ca	.4	.0015	<1,000
Potassium	K	.3	.00023	1,300
PHOSPHORUS	**P**	**.08**	**.000001**	**80,000**
Magnesium	Mg	.07	.0004	<1,000
Sulfur	S	.06	.0004	<1,000
Chlorine	Cl	.06	.0008	<1,000
Sodium	Na	.04	.0006	<1,000
Iron	Fe	.02	.00007	<1,000

[1] Percent of element in plant tissue ÷ percent in available water. The higher the ratio, the more scarce the nutrient. Phosphorus, in particular, is likely to limit plant growth in a lake. If more phosphorus is supplied, however, plant growth is likely to accelerate unless and until limited by some other factor.

Phosphorus in particular can often severely limit the biological productivity of a lake. The by-products of modern society, however, are rich sources of this element. Wastewaters, fertilizers, agricultural drainage, detergents, and municipal sewage contain high concentrations of phosphorus, and if allowed to enter the lake, they can stimulate algal productivity. Such high productivity, however, may result in nuisance algal blooms, noxious tastes and odors, oxygen depletion in the water column, and undesirable fishkills during winter and summer.

Since phosphorus is most often the nutrient that limits algal productivity, it is usually the element that is the focus of many lake management or restoration efforts aimed at reducing algal production and improving lake water quality. Phosphorus loading can be reduced, for example, by chemical flocculation in advanced wastewater treatment plants or controlled in the watershed by using proper agricultural and land management practices, improving septic systems, and applying fertilizer carefully (see Chapter 5).

In the past 20 years, there have been increasing efforts to minimize phosphorus inputs to lakes as a way to curb eutrophication. Methods for precipitating or inactivating phosphorus within the lake are discussed in Chapter 6 under Algae/Techniques With Long-Term Effectiveness. A method for determining the amount of phosphorus coming from the watershed is discussed in Chapter 3, and a formula for calculating the amount is given in Chapter 4. In contrast, however, poor fishing may be considered the problem of highest priority for infertile lakes in some regions and improving the fishery yield may be the primary lake management objective. In such cases, additions of phosphorus- and nitrogen-containing fertilizers may be used as a lake management tool to increase phytoplankton production, plankton standing crop, and ultimately, to enhance fish production.

Phytoplankton Community Succession

As the growing season proceeds, a succession of algal communities typically occurs in a lake (Fig. 2-8). Phytoplankton biomass usually tends to be high in the spring and early summer by virtue of increasing water temperature and light availability, relatively high nutrient availability, and low losses to zooplankton grazing (consumption by microscopic animals). As grazing pressure increases and nutrient availability declines from early to midsummer, algal biomass declines. It rises again in the late summer and fall when water column mixing increases the supply of nutrients and other conditions provide a favorable environment for the growth of algae. Sometimes, particularly in very productive lakes, blue-green algae form floating scums on the surface of the lake. Algal production and biomass are usually low in the winter because of low water temperatures and low light availability.

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

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

Sedimentation and Decomposition

Sedimentation occurs when particles (silt, algae, animal feces, and dead organisms) sink through the lake water column onto the lake bottom. Sedimentation is a very important process that affects phytoplankton biomass levels, phytoplankton community succession, and transfers of organic matter, nutrients, and particle-associated contaminants from the lake's upper layers to the bottom sediments. One reason for the dominance of blue-green algae in some lakes is their ability to regulate their buoyancy and, therefore, to counter sedimentation. Sedimentation of particulate organic matter from the water column to the lake bottom provides a critical linkage between planktonic

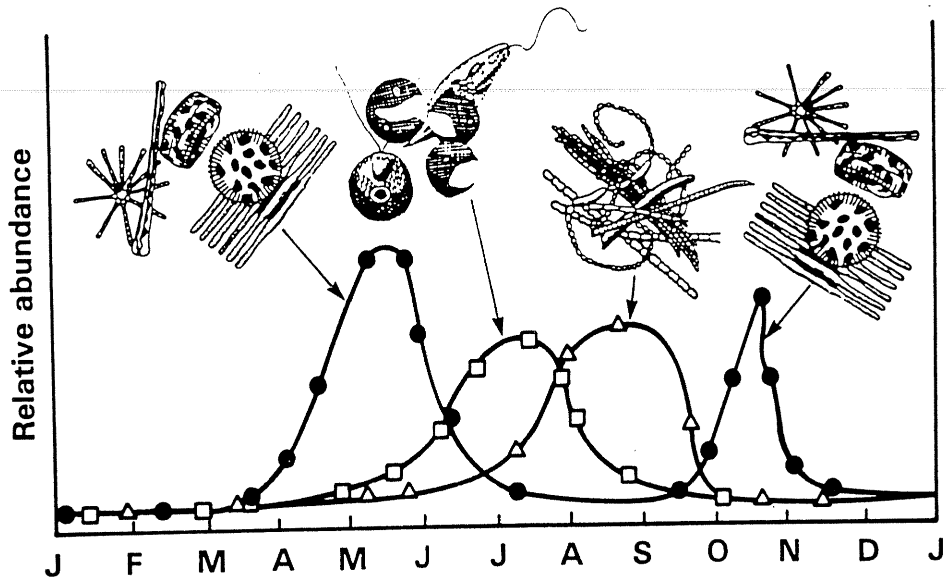


Figure 2-8.—A typical seasonal succession of lake phytoplankton communities. Diatoms dominate the phytoplankton in the spring and the autumn, green algae in midsummer, and blue-green algae (cyanobacteria) in late summer.

primary production and the growth of bottom-dwelling organisms (such as aquatic insect larvae, clams, and crayfish) that eat this detrital organic matter and, in turn, are eaten by larger predatory organisms, such as fish and turtles.

Settling plankton, zooplankton feces, and other organic detritus particles are degraded in the water column and in the bottom sediments through oxygen-consuming decomposition processes. *Organic matter decomposition*, a collective term for the net conversion of organic material back to inorganic compounds (see Fig. 2-7), occurs through the respiratory activities of all organisms, including bacteria, fungi, and other microbes.

In the hypolimnion of productive lakes, the sedimentation of organic matter from the surface waters is extensive. And because algae and other suspended particles are abundant, light penetration through the water column to the hypolimnion is limited or absent and photosynthesis cannot occur. Under these conditions, the oxygen consumed in the hypolimnion and bottom sediments during the decomposition (respiration) of this organic matter greatly exceeds the oxygen produced. Also, as described earlier, the hypolimnion is isolated from the atmosphere by a temperature or water density barrier to mixing known as the metalimnion. The result, in productive thermally stratified lakes, is a depletion and sometimes a complete absence of dissolved oxygen in the hypolimnion (see Fig. 2-4). A similar result can occur, though more slowly, in shallow, productive lakes with a prolonged snow and ice cover.

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

The chemical and physical changes associated with oxygen depletion are marked. They include increased nutrient release from the bottom sediments, destruction of oxygenated habitats for aquatic animals, and incomplete decomposition of sedimented organic matter (Fig. 2-9). These symptoms are often characteristic of lake trophic status (see description of trophic status in **Lake Aging and Cultural Eutrophication** in this chapter).

■ **Oligotrophic lakes:** Insufficient organic matter is produced in the epilimnion to reduce hypolimnetic oxygen concentrations significantly; the hypolimnion remains relatively oxygenated throughout the year.

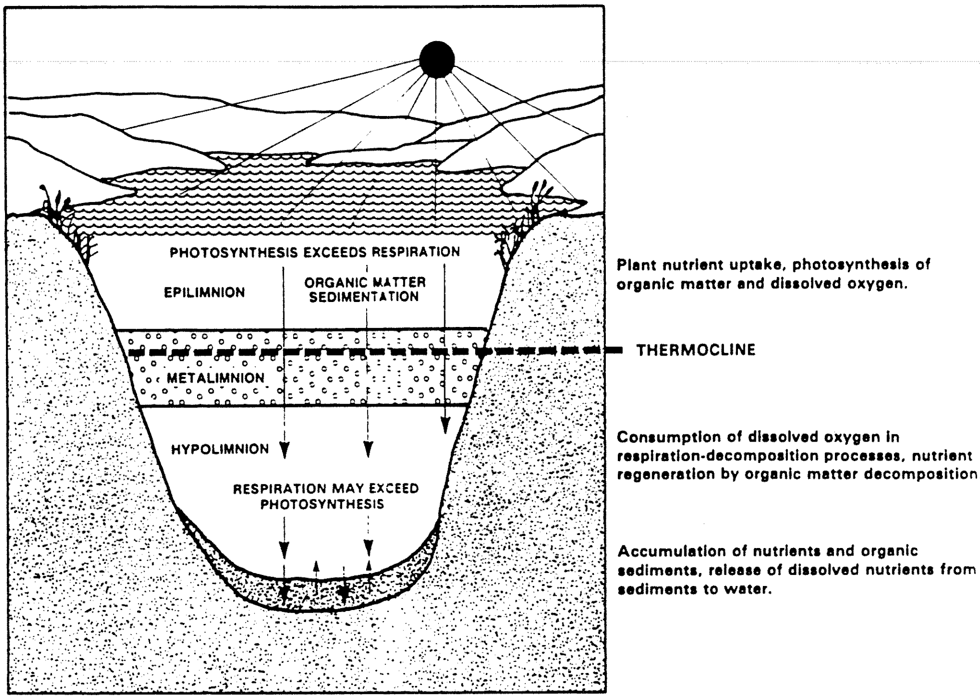


Figure 2-9.—Influence of photosynthesis and respiration-decomposition processes and organic matter sedimentation on the distribution of nutrients, organic matter, and dissolved oxygen in a stratified lake.

■ **Eutrophic lakes:** Organic matter decomposition can rapidly exhaust the dissolved oxygen in unlighted zones, leading to anoxia in the hypolimnion. During midsummer, when a temperature–oxygen squeeze can develop in stratified lakes, cool water fish such as trout cannot occupy the oxygen-depleted lower waters and must stay in less than ideal warmer upper waters.

In anoxic conditions, metals such as iron, manganese, and sulfur and the nutrients phosphorus and ammonium (a nitrogen compound) become increasingly soluble and are released from the sediments into the hypolimnion. Summer partial mixing events, which can occur during the passage of summer cold fronts with wind and cold rains, can transport some of these released nutrients to the lake surface where they may stimulate more algal production. At fall turnover, these metals and nutrients reenter the photic zone and may also stimulate algal blooms. Nutrients that reenter the water column from sediments constitute an "internal nutrient load" to the lake. Lake managers must be aware of this internal source of nutrients in addition to the nutrients entering from the watershed.

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

Food Web Structure, Energy Flow, and Nutrient Cycling

In-lake plant production usually forms the organic matter base of the lake's food web. Although some waterbodies (especially rapidly flushed reservoirs) receive important supplements of organic matter from river and stream inflow, most lakes require a reliable level of algal and macrophyte production to maintain productive food webs (Adams et al. 1983).

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

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

Some of the organic matter produced photosynthetically by the lake's primary producers (algae and macrophytes) is consumed by herbivores (grazers) that range from tiny zooplankton to snails to grazing minnows. Herbivores, such as the zooplankton, are fed on by planktivores (including predatory zooplankton and planktivorous fish) that, in turn, provide a food source for the higher-level consumers such as piscivorous fish (bass, walleye, trout) and fish-eating birds (kingfishers, herons, ospreys, eagles). This general progression of feeding levels (also called trophic levels) from primary producers, to herbivores, to planktivores, to the larger predators, constitutes the *food chain* (Fig. 2-10). The actual complex of feeding the interactions that exists among all of the lake's organisms is called the *food web*.

As shown in Fig. 2-10, the food chain concept also involves the flow of energy among the lake organisms and the recycling of nutrients. The energy flow originates with the light energy from the sun, which is converted by green plant photosynthesis into the chemical bond energy represented by the organic matter produced by the plants. Each subsequent consumer level (herbivore, planktivore, piscivore) transfers only a fraction (usually only about 10 to 20 percent) of the energy received on up the chain to the next trophic level (Kozlovsky, 1968; Gulland, 1970).

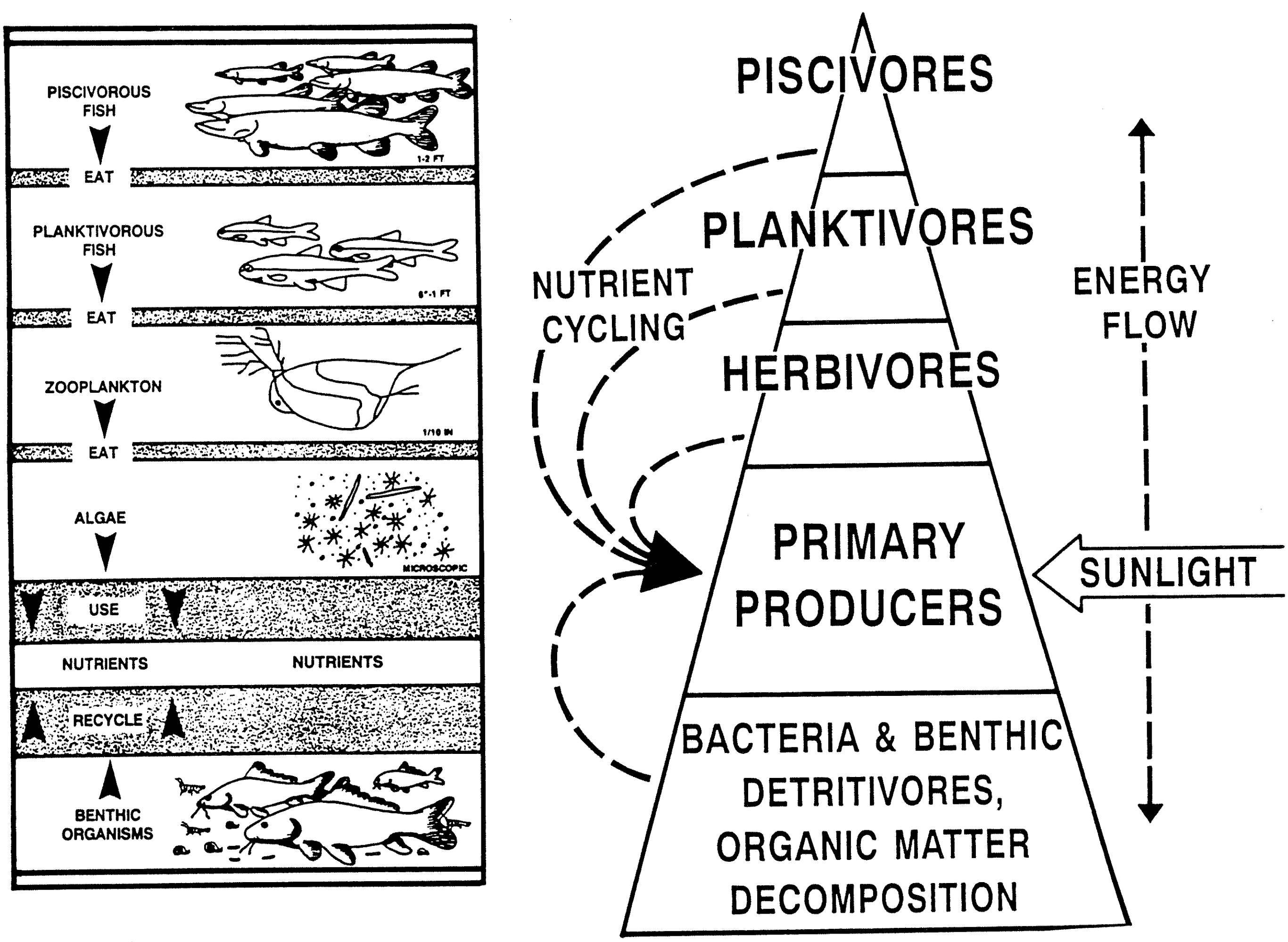


Figure 2-10.—The food-chain concept refers to the progression of feeding (or trophic) levels from primary producers, to herbivores, to higher predators. As shown, this process involves both the transfer of energy among lake organisms and the recycling of nutrients. Because the available energy decreases at each trophic level, a large food base of primary producers, herbivores, and planktivores is required to support a few large game fish.

In practice, this means that a few large game fish depend on a large supply of smaller fish, which depend on a very large supply of smaller herbivores, which depend on a successively much larger base of photosynthetic production by phytoplankton and other aquatic plants. Finally, by constantly producing wastes and eventually dying, all of these organisms provide nourishment to detritivores (detritus-eating organisms) and to bacteria and fungi, which derive their energy by decomposing organic matter. Organic matter decomposition results in the recycling of nutrients that are required for further plant production.

A more complex view of energy flow and nutrient cycling in a lake or reservoir ecosystem is shown in Fig. 2-11. Much of the organic matter input from the watershed directly supports the growth of detritivores, bacteria, and fungi. A significant fraction of the in-lake primary production provides food for herbivores and, ultimately, for higher consumers (as described before); however, much of the in-lake plant production may also become detritus and provide nourishment to both planktonic and benthic detritus feeders. Sorption of dissolved organic compounds to suspended detritus particles, microbial colonization of these particles, and particle aggregation or clumping produces microbial-detrital aggregates large enough to be consumed by filter-feeding zooplankton. Additionally, the sedimentation of detritus particles to the lake bottom provides energy to the benthic detritivores, which are preyed upon by the higher consumers. Nutrient regeneration occurs at virtually every level of the food web, and only a small fraction of the organic matter produced ultimately accumulates as permanent bottom sediment.

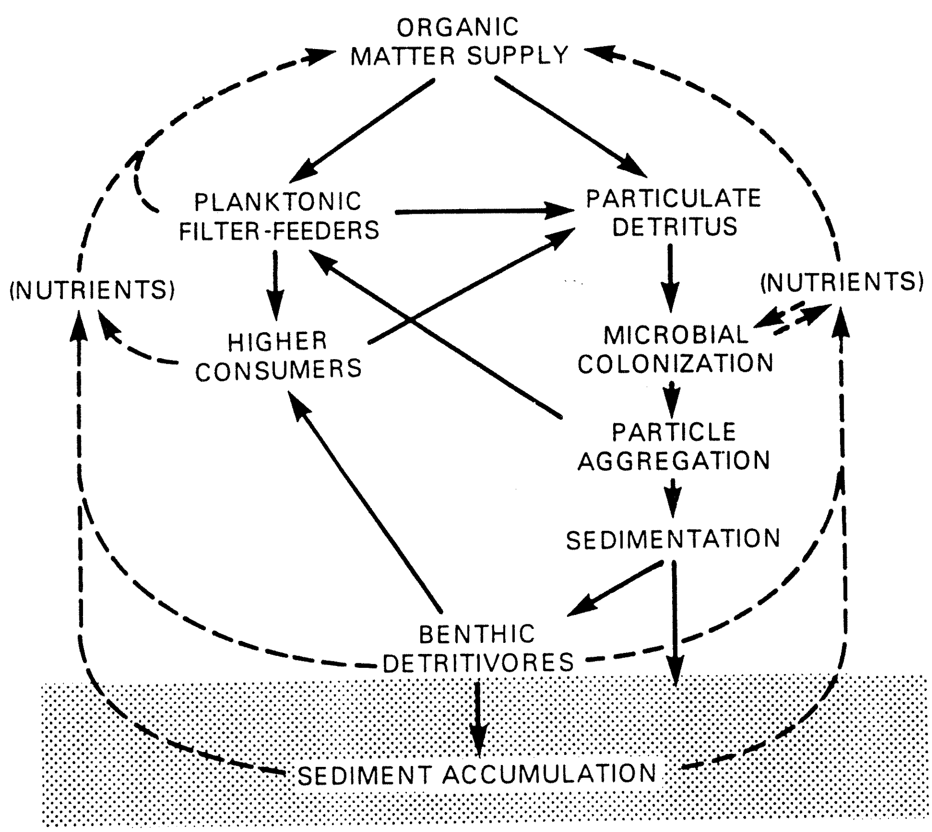


Figure 2-11.—A more complex view of energy flow and nutrient recycling in a lake or reservoir. Solid lines represent pathways of energy flow, and dashed lines indicate nutrient recycling. Refer to the text for a detailed explanation. Modified from Goldman and Kimmel (1978).

Lake Aging and Cultural Eutrophication

Lakes are temporary features of the landscape. The Great Lakes, for example, have had their current shapes for only about 12,000 years. Over tens to many thousands of years, lake basins change in size and depth as a result of climate, movements in the earth's crust, shoreline erosion, and the accumulation of sediment. Lake eutrophication is a natural process resulting from the gradual accumulation of nutrients, increased productivity, and a slow filling in of the basin with accumulated sediments, silt, and organic matter from the watershed.

The original shape of the basin and the relative stability of watershed soils strongly influence the lifespan of a lake (see the boxed section and Fig. 2-D on lake basin origin and shape).

The classical lake succession sequence (Fig. 2-12) is usually depicted as a unidirectional progression through the following series of phases or trophic states:

- *Oligotrophy:* Nutrient-poor, biologically unproductive
- *Mesotrophy:* Intermediate nutrient availability and biological productivity
- *Eutrophy:* Nutrient-rich, highly productive
- *Hypereutrophy:* Pea-soup conditions, the extreme end of the eutrophic stage

These lake trophic states correspond to gradual increases in lake productivity from oligotrophy to eutrophy (Fig. 2-12).

Evidence obtained from sediment cores (see Chapter 3), however, indicates that changes in lake trophic status are not necessarily gradual or unidirectional. If their watersheds remain relatively undisturbed, lakes can retain the same trophic status for many thousands of years. Oligotrophic Lake Superior is a good example of this. In contrast, rapid changes in lake nutrient status and productivity are often a result of human-induced disturbances to the watershed rather than gradual enrichment and filling of the lake basin through natural means.

Human-induced cultural eutrophication occurs when nutrient, soil, or organic matter loads to the lake are dramatically increased. A lake's lifespan can be shortened drastically by activities such as forest clearing, road building, cultivation, residential development, and wastewater treatment discharges because these activities increase soil and nutrient loads that eventually move into the lake. Chapter 5 explains watershed influences from these activities in the sections on nonpoint and cultural sources.

Some lakes, however, are naturally eutrophic. It is important to recognize that many lakes and reservoirs located in naturally fertile watersheds have little chance of being anything other than eutrophic. Unless some other factor such as turbidity or hydraulic residence time intervenes, these lakes will naturally have very high rates of primary production.

Natural and man-made lakes undergo eutrophication by the same processes—nutrient enrichment and basin filling—but at very different rates. Reservoirs become eutrophic more rapidly than natural lakes, as a rule, because

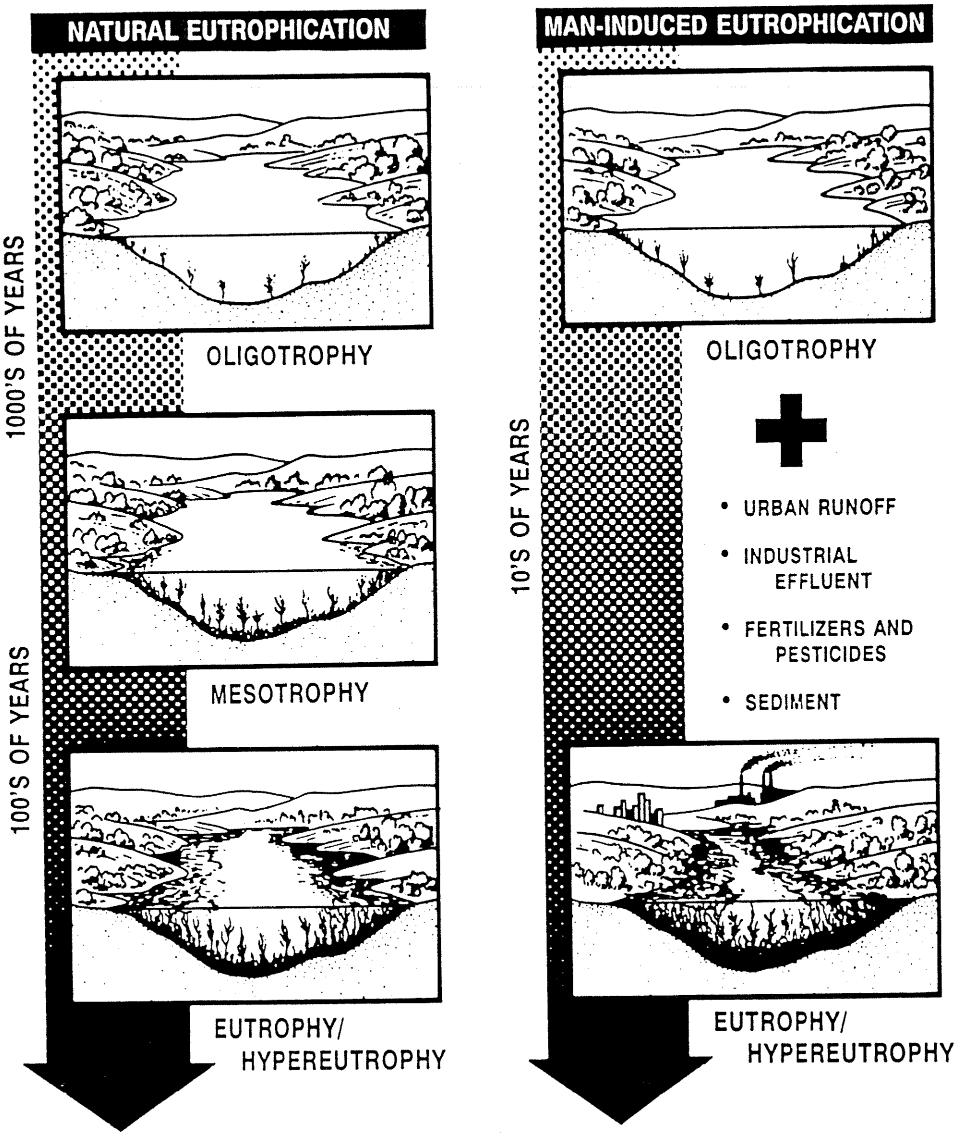


Figure 2-12.— *(left column)* The progression of natural lake aging or eutrophication through nutrient-poor (oligotrophy) to nutrient-rich (eutrophy) sites. Hypereutrophy represents extreme productivity characterized by algal blooms or dense macrophyte populations (or both) plus a high level of sedimentation. The diagram depicts the natural process of gradual nutrient enrichment and basin filling over a long period of time (e.g., thousands of years).

(right column) Man-induced or cultural eutrophication in which lake aging is greatly accelerated (e.g., tens of years) by increased inputs of nutrients and sediments into a lake, as a result of watershed disturbance by humans.

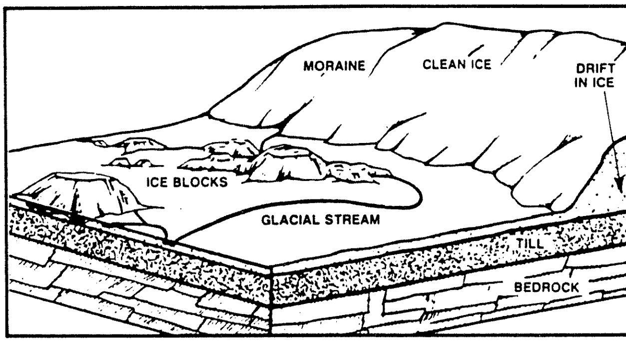
most reservoirs receive higher sediment and nutrient loads than do most natural lakes. They may even be eutrophic when initially filled. Reservoirs, especially those with hypolimnetic outlets, are considerably more efficient at trapping sediments than at retaining nutrients, and therefore the filling of their basins with river-borne silts and clays is the dominant aging process for these waterbodies.

However, reservoirs often do not go through the classical trophic progression from oligotrophy to eutrophy, as described for natural lakes. In fact, newly filled impoundments usually go through a relatively short period of trophic in-

Lake Basin Origin and Shape

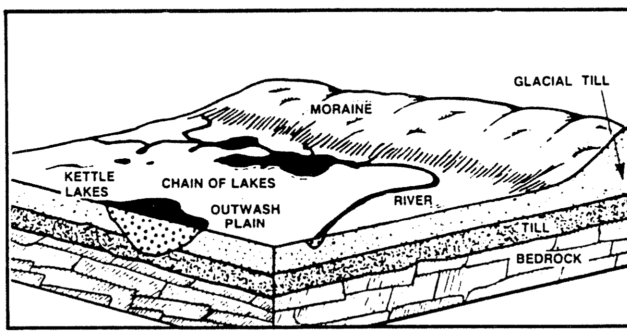
The origin of the lake basin often determines the size and shape of the lake, which, in turn, influences the lake's productivity, water quality, the habitats it offers, and its lifespan.

Glacial activity has been the most common origin of lake basins in North America (Fig. 2-E). Glacial lakes of Canada and the upper midwestern United States were formed about 8,000 to 12,000 years ago. Some lake basins resulted from large-scale glacial scouring—the wearing away of bedrock and deepening of valleys by expansion and recession of glaciers. Deep depressions left by receding glaciers filled with meltwater to form lakes. The Finger Lakes of upper New York State were formed this way.



DURING GLACIATION

About 3,000 years ago the last glaciers began to retreat from the North American continent. Many of the small lakes in the upper midwest and north central states as well as Canada were formed by huge ice blocks buried in the loose rock and soil and deposited by the glaciers. When the buried ice blocks melted they left holes in the glacial till which filled with water from the melting glaciers.



AFTER GLACIATION

Chains of lakes formed along some streams that drained the melting glaciers. Other lakes were created between the moraines and the retreating ice mass from the melting water.

MORAINE

A Moraine is a ridge of low rolling hills made up of unsorted rocks and soil deposited when the glacial ice mass melted.

Figure 2-E.—The effects of glaciation in shaping lake basins.

Kettle or "pothole" lakes, which formed in the depressions left by melting ice blocks, are very common throughout the upper midwestern United States and large portions of Canada. These lakes and their watersheds are popular home and cottage sites and recreational areas. The size and shape of the kettle lake basins reflect the size of the original ice block and how deeply it was buried in the glacial debris.

Natural lakes have also been formed by volcanism; Crater Lake in Oregon is an example. Large-scale movements of large segments of the earth's crust, called *tectonic activity*, created Reelfoot Lake in Tennessee and Lake Tahoe in California, among others.

Solution lakes are formed where groundwater has dissolved limestone; Florida has a number of these lakes. Lakes may also originate from shifting of river channels; oxbow lakes are stranded segments of meandering rivers. Finally, natural lakes can also be created by the persistence of the dam-building beaver.

stability in which a highly productive period (termed the "trophic upsurge") is followed by a decline in lake productivity (called the "trophic depression"), and the eventual establishment of a less productive but more stable trophic state (Fig. 2-13). The trophic upsurge results largely from nutrient inputs from both external sources (the watershed) and internal sources (leaching of nutrients from the flooded soils of the reservoir basin and from the decomposition of terrestrial vegetation and litter), which results in high productivity of both plankton and fish.

The trophic depression is, in fact, the initial approach of the reservoir system toward its natural productivity level dictated by the level of external nutrient inputs. However, reservoir fish production depends on a complex of factors that affect both trophic and habitat resources. Flooding of soils, vegetation, and litter as the new reservoir fills contributes to both abundant food and expanding habitat. As the reservoir matures, both food and habitat resources decline, fish production decreases, and the fish community stabilizes.

The trophic upsurge and depression or "boom and bust" period of trophic instability in reservoirs has received much attention from limnologists and fishery biologists because it inevitably produces both initial concerns about poor water quality and simultaneously raises false hopes for a higher level of fishery yield than can be sustained over the long term. Ultimately, in reservoirs and in natural lakes, the nature of the watershed (or human-induced changes of the watershed) will determine the water quality, biological productivity, and trophic status of the system.

Ecology's Place in Lake Protection, Restoration, and Management

The goal of this chapter on ecological and limnological concepts is to provide the reader with a basic background for understanding the environmental factors controlling lake productivity, water quality, and trophic status. This background is intended to help the reader evaluate the potential benefits and limitations on lake protection and restoration approaches and techniques described in the rest of this Manual.

This Manual emphasizes two basic, complementary approaches to lake restoration and management for water quality:

1. Treat the causes of eutrophication. This approach involves limiting lake fertility by controlling nutrient availability.

2. Treat the products of overfertilization and thus control plant production in the lake.

Methods employed to control nutrient availability include proper watershed management practices, advanced treatment of wastewater, and diversion of wastewater and stormwater (see Chapter 5). Hypolimnetic withdrawal, dilution and flushing, phosphorus precipitation and inactivation, sediment oxidation, sediment removal, and hypolimnetic aeration are techniques to deal with nutrients already in the lake system; they are discussed in Chapter 6.

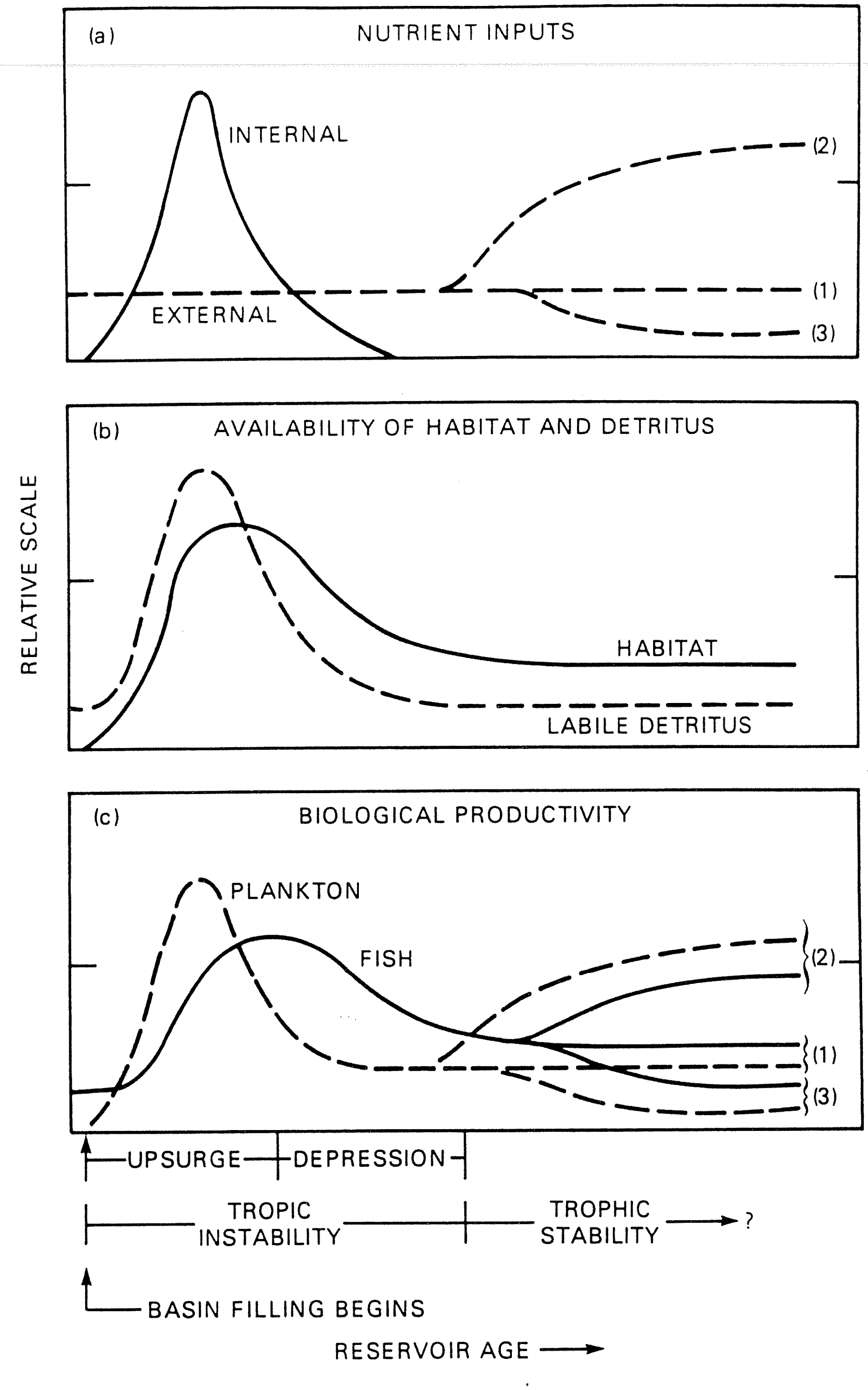


Figure 2-13.—Factors influencing biological productivity or "trophic progression" in a reservoir in the initial years after impoundment: (a) internal nutrient loading from the flooded reservoir basin and external nutrient loading from the watershed, (b) availability of habitat (flooded vegetation) and labile terrestrial detritus supporting macroinvertebrates and fish, and (c) plankton and fish production. The initial period of trophic instability (i.e., upsurge and depression) is followed by a less productive, but more stable, period in the maturing reservoir (1). However, disturbances or land-use changes in the watershed can result in increases (2) or decreases (3) in external nutrient loading and, consequently, in reservoir productivity. Modified from Kimmel and Groeger (1986).

Methods used to control plant biomass include artificial circulation, water-level drawdown, harvesting, chemical treatments (herbicides and algicides), biological controls, and shading and sediment covers for macrophyte control. Chapter 6 also provides details on these techniques.

How to determine what needs to be treated and where problems may originate is discussed in Chapter 3. Chapter 5 gives further information on watershed influences and how to manage them.

Most of what we know about lake and reservoir restoration has been learned in the last 15 years through experience gained from many studies conducted in the United States, Canada, Europe, and Scandinavia. Experience gained from previous restoration efforts clearly leads to the following conclusions:

1. There is no panacea for lake management or restoration problems; different situations require different approaches and solutions.

2. A complex set of physical, chemical, and biological factors influences lake ecosystems and affects their responsiveness to restoration and management efforts.

3. Because of the tight coupling between lakes and their watersheds, good conservation practices in the watershed are essential for improving and protecting lake water quality. Efforts to control both external loading of nutrients from the watershed and internal nutrient loading and recycling are often required to produce a noticeable improvement in water quality.

4. The physical, chemical, and biological components of lake ecosystems are intricately linked. Lake restoration or management efforts to enhance water quality by limiting nutrient availability and thereby reducing algal production will also decrease fish production. Decisions must be made and priorities must be set.

5. To be successful, lake restoration and management objectives must be compatible with the uses that the natural condition of the lake (and its watershed) can support most readily.

In summary, the character of a lake or reservoir is determined by a complex set of physical, chemical, and biological factors that vary with lake origin, the regional setting, and the nature of the watershed. Important factors include hydrology, climate, watershed geology, watershed to lake ratio, soil fertility, hydraulic residence time, lake basin shape, external and internal nutrient loading rates, presence or absence of thermal stratification, lake habitats, and lake biota.

In some situations, a natural combination of these factors may dictate that a lake will be highly productive (eutrophic) and management or restoration efforts to transform such a system to an unproductive, clear-water (oligotrophic) state would be ill-advised. However, if a lake has become eutrophic or has developed other water quality problems as a result of, for example, increased nutrient loading from the watershed, then these effects can be reversed and the lake's condition can be improved or restored by an appropriate combination of management efforts in the watershed and in the lake itself. The best situation is one where steps are taken to protect the lake's watershed before problems develop.

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PART TWO

Water Quality Summaries

CONTENTS

PART TWO

Water Quality Summaries

BROAD RIVER BASIN

DESCRIPTION OF REGION

The Broad River Basin covers 3,900 km^2 in the mountain and upper piedmont regions of North Carolina. Major tributaries of the Broad River include the First Broad River, Second Broad River and the Green River which join the Broad River before it flows into South Carolina. Buffalo Creek is a smaller tributary that originates in North Carolina and joins the Broad River in South Carolina. Land use in the basin is predominantly forest and agriculture.

OVERVIEW OF WATER QUALITY

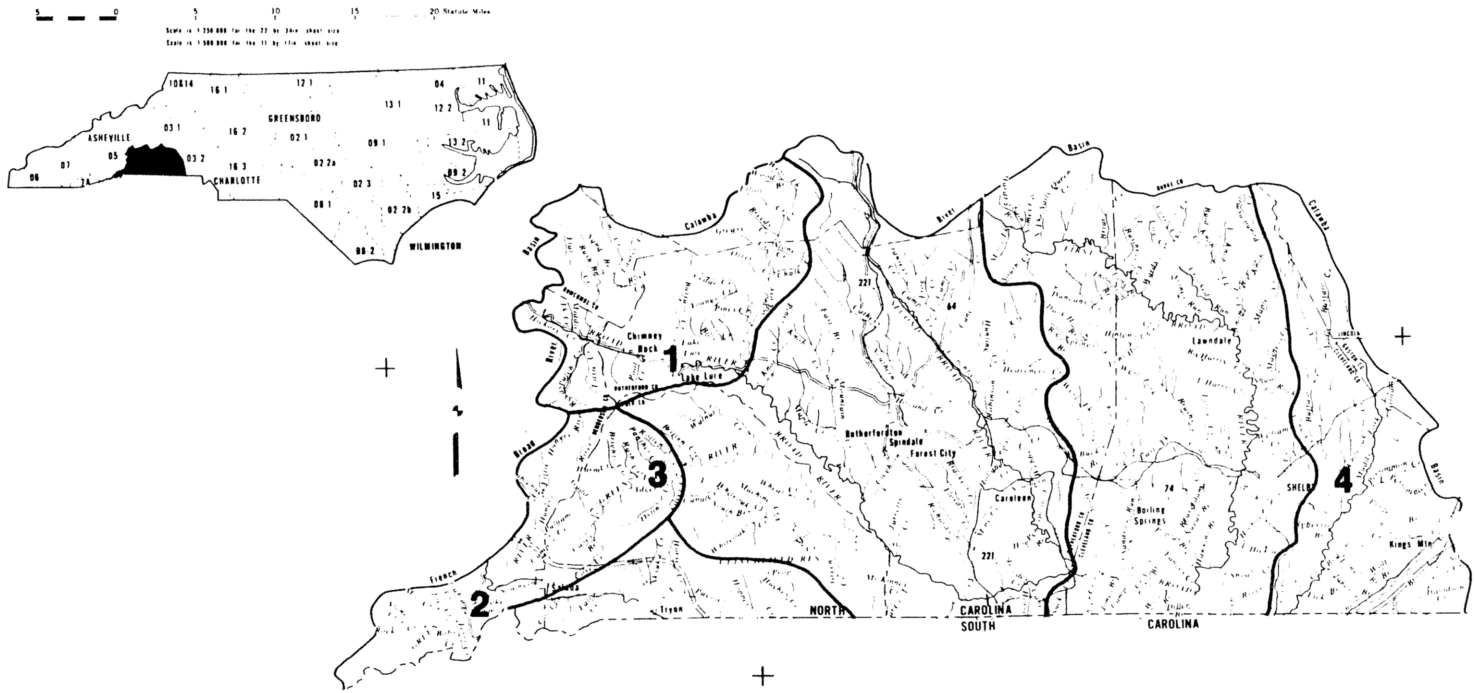
The streams and rivers in the Broad River basin generally have a high level of water quality though there are localized areas which experience degradation. The region is characterized by highly erodable soils and extensive agricultural land use which contributes to the excessive sedimentation observed in some areas. Nonpoint pollution from agriculture and other sources has also impaired streams in this basin (NRCD 1988b, NRCD 1988c).

Point source dischargers in the basin are predominantly located near the municipalities. The Buffalo-Muddy Fork watershed has had problems with water quality associated with point source discharges (NRCD 1988c).

Four lakes are included in this section of the report. The first three are within 20 - 25 miles of each other in the Upper Broad River basin. Lake Lure is a recreational impoundment of the Broad River. Lake Summit and Lake Adger, impoundments of the Green River, are used for recreation and as water supplies. Kings Mountain Reservoir is a water supply for the City of Kings Mountain. It also provides a recreational resource for nearby residents. All four of the lakes support their designated uses and no significant problems with water quality were observed at the time of these assessments.

Broad

Broad River Basin



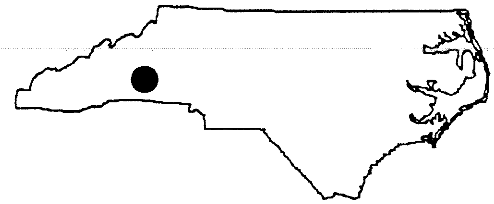
MAP #	LAKE
1	Lake Lure
2	Summit Lake
3	Lake Adger
4	Kings Mountain Reservoir

Adapted from U.S.G.S./A.M.S. 1:250,000 U.S. Series

North Carolina Department of
Natural Resources and Community Development

Division of Enviromental Management

LAKE LURE



COUNTY:	Rutherford	BASIN:	Broad
SURFACE AREA:	607 hectares (1,500 acres)	USGS TOPO:	Lake Lure, N.C.
CLASS:	B - TR	LAKE TYPE:	Reservoir

LATEST NCTSI:	- 2.3	TROPHIC STATE:	Oligotrophic
SAMPLING DATE:	August 1, 1989	ADDITIONAL COVERAGE:	None
SECCHI DEPTH:	2.4 m	CONDUCTIVITY:	26 - 31 µmhos/cm^2
TOTAL PHOSPHORUS:	0.02 mg/l	DISSOLVED OXYGEN:	7.9 - 8.3 mg/l
TOTAL ORGANIC NITROGEN:	0.14 mg/l	TEMPERATURE:	27.5 - 27.9 °C
CHLOROPHYLL-A:	13 µg/l	pH:	7.4 - 7.7 s.u.

Lake Lure is a large impoundment located in the mountains of southwestern North Carolina, adjacent to the town of Lake Lure. The shoreline has been developed with houses and vacation lodges. The lake has a maximum depth of 20 meters. Major tributaries to the lake are the Broad River, Buffalo Creek, and Pool Creek. The hilly drainage area of Lake Lure covers 232 km^2. Land use within the watershed is predominantly forest with some urban and agricultural uses. The lake is owned by the Town of Lake Lure.

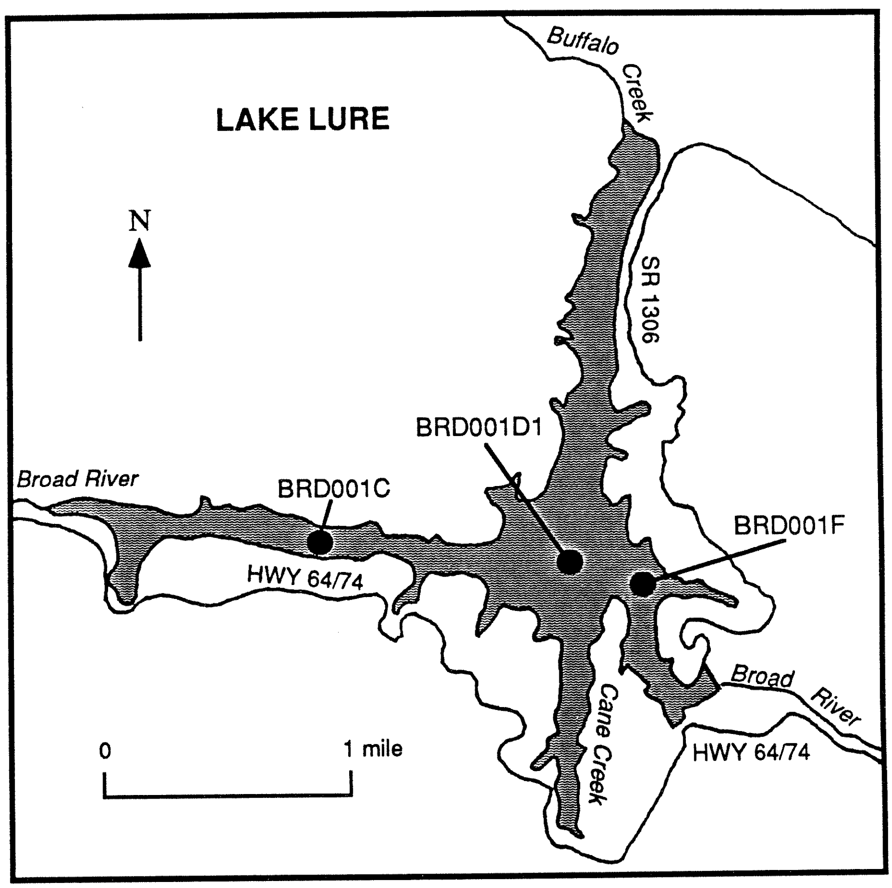
Lake Lure was sampled on August 1, 1989. Stratified conditions at the two deeper stations were noted while mixed conditions existed in the shallowBroad River arm of the lake. Chlorophyll-a and nutrient levels were low to moderate at all three stations. The highest chlorophyll-a concentrations were found near the dam.

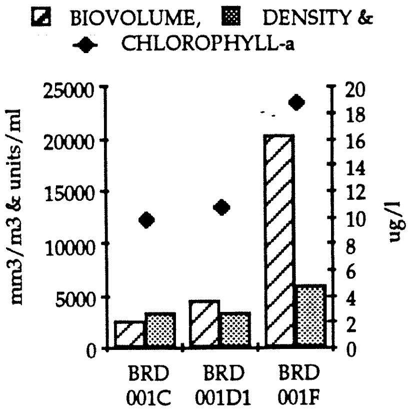
As in 1983 and 1985, estimates of phytoplanktonic biovolume for 1989 were dominated by Tabellaria fenestrata, a large diatom. Near the dam T. fenestrata contributed more than 80% of the biovolume and over 10% of the density. This diatom prefers mesotrophic to eutrophic lakes and ponds (Patrick and Reimer 1966). Algal populations at the upper station (BRD001C) were more mixed with Anabaena levanderi, a filamentous blue-green alga, and Chrysochromulina species, a prymnesiophyte, codominating biovolume and density with T. fenestrata.

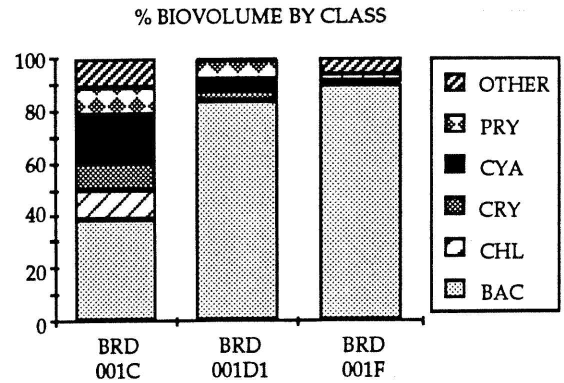
Estimates of phytoplanktonic biovolume and density at BRD001F were indicative of algal bloom conditions with a biovolume estimate greater than 5,000 mm^3/m^3. The chlorophyll-a concentration was 19 µg/l, which is high for a mountain lake and violates the state standard of 15 µg/l for trout waters. Although the chlorophyll-a concentration was not as high as would be expected from biovolume and density estimates, this observation can be attributed to the dominance of T. fenestrata which contains little chlorophyll-a compared to its biovolume.

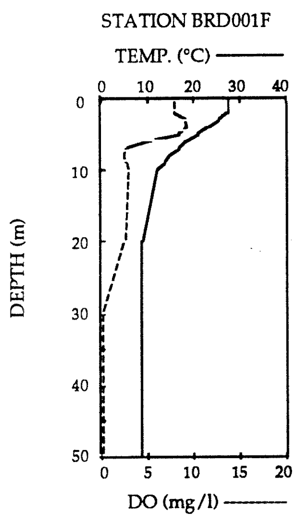
The TSI in 1989 was -2.3, indicating Lake Lure was oligotrophic, however; the elevated algal populations at BRD001F indicate that monitoring of the cove areas of this lake may be warranted. Mid-lake sampling often misses the more impacted cove areas of a lake where nutrient concentrations are not as diluted and retention times may be longer allowing phytoplankton populations to multiply to bloom levels.

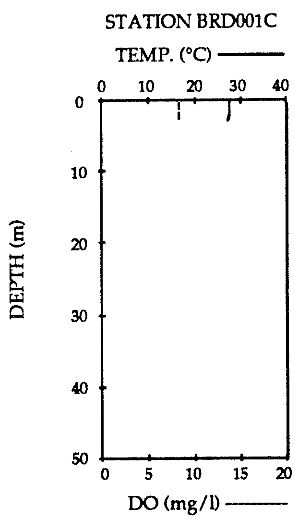
The TSI score in 1989 is lower than values recorded in 1985 (-0.8) and 1982 (-1.9), but slightly higher than in 1983 (-3.0). Differences in TSI scores might be attributable to the several months of dry weather before the 1985 survey and the rainy weather before the sampling in 1989. The variability in the TSI scores for this lake underscore the need for further monitoring of the lake. At the time of the assessment, chlorophyll-a violated the standard for trout waters (15 µg/l) at one of the three stations (BRD001F).

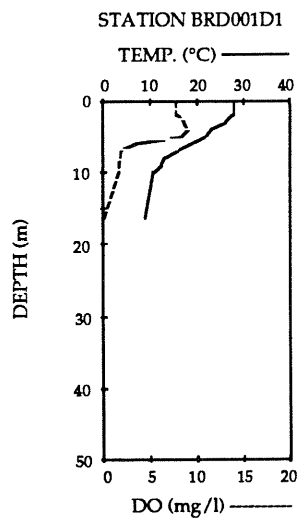



BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/m3 & units/ml
ug/l
BRD 001C
BRD 001D1
BRD 001F

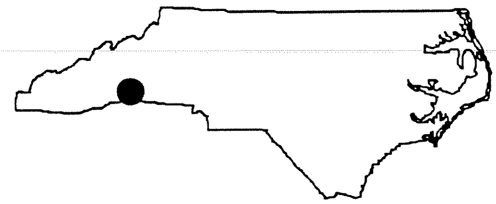

% BIOVOLUME BY CLASS
OTHER
PRY
CYA
CRY
CHL
BAC
BRD 001C
BRD 001D1
BRD 001F


STATION BRD001F
TEMP. (°C)
DEPTH (m)
DO (mg/l)


STATION BRD001C
TEMP. (°C)
DEPTH (m)
DO (mg/l)


STATION BRD001D1
TEMP. (°C)
DEPTH (m)
DO (mg/l)

LAKE SUMMIT



COUNTY:	Henderson	**BASIN:**	Broad
SURFACE AREA:	130 hectares (232 acres)	**USGS TOPO:**	Zirconia, N.C.
CLASS:	WS -TR, B - TR	**LAKE TYPE:**	Reservoir

LATEST NCTSI:	- 2.9	**TROPHIC STATE:**	Oligotrophic
SAMPLING DATE:	August 3, 1989	**ADDITIONAL COVERAGE:**	Water Supply Parameters
SECCHI DEPTH:	2.6 m	**CONDUCTIVITY:**	22 -37 μmhos/cm^2
TOTAL PHOSPHORUS:	0.01 mg/l	**DISSOLVED OXYGEN:**	8.4 - 8.5 mg/l
TOTAL ORGANIC NITROGEN:	0.18 mg/l	**TEMPERATURE:**	25.0 - 25.4 °C
CHLOROPHYLL-A:	11 μg/l	**pH:**	6.0 - 6.7 s.u.

Lake Summit is a 130-hectare impoundment located in Henderson County in the mountains of southwestern North Carolina. The lake is owned by Duke Power and used to produce hydroelectric power.

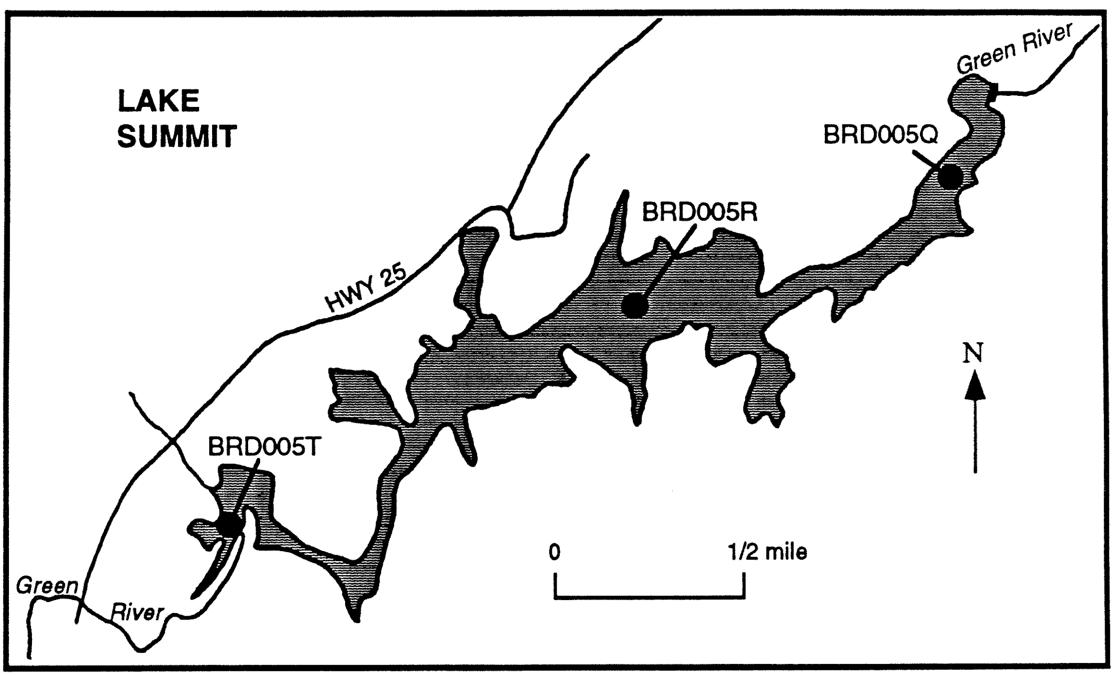
The dam was built and the lake filled in 1920. Volume of the lake is 11.5 x 10^6 m^3, and its average retention time is 75 days. The maximum and mean depths of the lake are 24 and 10 meters respectively. The major tributary is the Green River. The 107 km^2 drainage area is mostly forested with the rest of the watershed composed of small farms. Many homes and several camps encircle the lake which is used extensively for recreational purposes (fishing, swimming, boating, etc.).

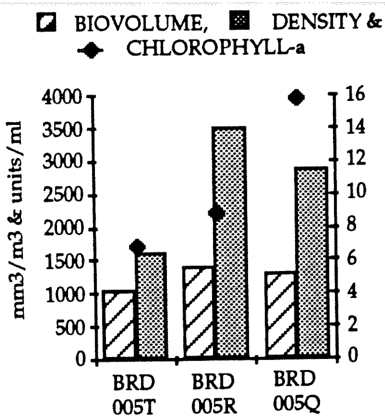
The Lake Summit Property Owners' Association requested "Outstanding Resource Waters" status for the lake in 1988 for protection of water quality in the lake. Field sampling was performed in January, 1989 in response to this request. The request was ultimately denied. For more information on this investigation, please see the Lake Summit (Green River) Outstanding Resource Waters Evaluation by DEM (1989a). Duke Power sampled Lake Summit in 1982-1983 for a study on acid rain. Researchers at UNC also sampled the lake in 1975. Data from these two sampling efforts were similar to DEM data except that chlorophyll-a values were lower than reported by DEM.

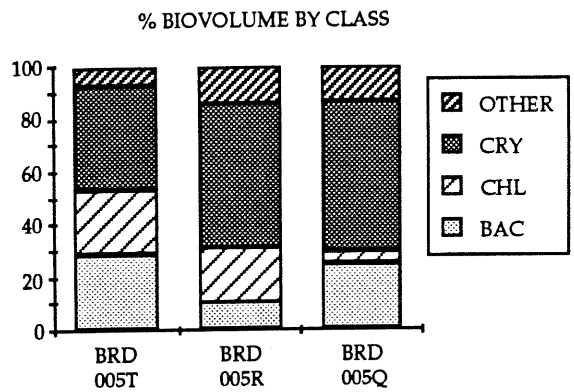
Lake Summit was sampled on August 3, 1989, following two days of heavy rain. The lake was stratified at the two deeper sampling stations while the upstream shallower station (BRD005T) was mixed. Nutrients were low throughout the lake. Chlorophyll-a slightly exceeded the state standard of 15 µg/l at BRD005Q, the most downstream station near the dam. The highest residue values were found at this station also. This is surprising since residue values are usually highest near the headwaters of a lake. Metals were sampled at station BRD005Q. All values were below laboratory detection levels except for aluminum (63 µg/l), which was not a violation of water quality standards.

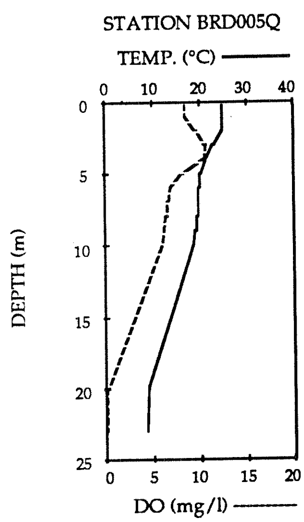
Cryptophytes, green algae, and diatoms accounted for most of the algal community in Lake Summit. Cryptomonas ovata, a cryptophyte, dominated biovolume estimates throughout the lake. This alga is commonly found throughout North Carolina. Estimates of biovolume, density, and chlorophyll-a for August were similar to estimates in January 1989. As in January, Chrysochromulina species was found at both BRD005Q and BRD005R; however, Chrysochromulina contributed less than 10% of the biovolume and density at each station. In January, Chrysochromulina accounted for greater than 30% of the biovolume and density estimates at all three stations. Chrysochromulina, normally a cool water species, has also been identified in eutrophic piedmont reservoirs during the summer months.

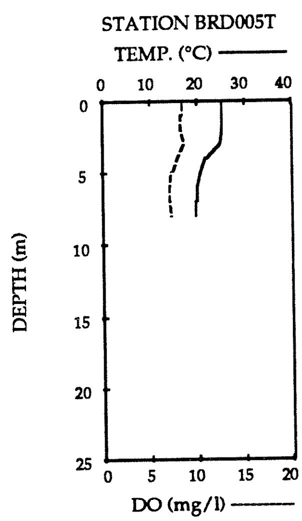
The TSI was -2.9 in 1989 which indicates Lake Summit is oligotrophic. Phytoplanktonic biovolume and density estimates and chlorophyll-a concentrations were moderate to low throughout the lake, supporting this trophic state classification. All uses of this reservoir were met.

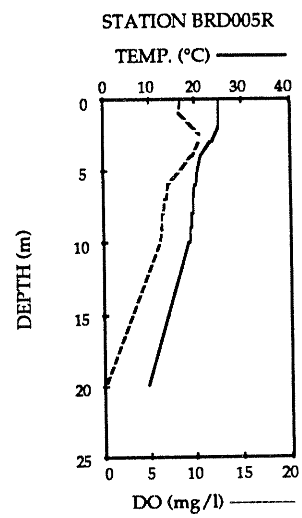



BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/m3 & units/ml
ug/l
4000
3500
3000
2500
2000
1500
1000
500
0
16
14
12
10
8
6
4
2
0
BRD 005T
BRD 005R
BRD 005Q

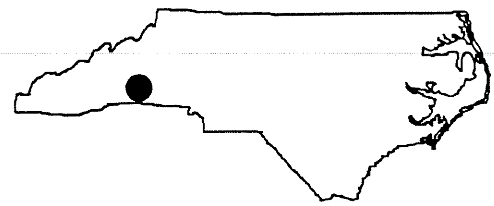

% BIOVOLUME BY CLASS
100
80
60
40
20
0
OTHER
CRY
CHL
BAC
BRD 005T
BRD 005R
BRD 005Q


STATION BRD005Q
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0
5
10
15
20
25
0 5 10 15 20
DO (mg/l)


STATION BRD005T
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0
5
10
15
20
25
0 5 10 15 20
DO (mg/l)


STATION BRD005R
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0
5
10
15
20
25
0 5 10 15 20
DO (mg/l)

LAKE ADGER



COUNTY:	Polk	BASIN:	Broad
SURFACE AREA:	186 hectares (460 acres)	USGS TOPO:	Mill Spring, N.C.
CLASS:	C	LAKE TYPE:	Reservoir

LATEST NCTSI:	- 2.7	TROPHIC STATE:	Oligotrophic
SAMPLING DATE:	August 1, 1989	ADDITIONAL COVERAGE:	None
SECCHI DEPTH:	1.8 m	CONDUCTIVITY:	4 -25 μmhos/cm^2
TOTAL PHOSPHORUS:	0.03 mg/l	DISSOLVED OXYGEN:	8.3 - 8.4 mg/l
TOTAL ORGANIC NITROGEN:	0.08 mg/l	TEMPERATURE:	25.7 - 27.3 °C
CHLOROPHYLL-A:	9 μg/l	pH:	7.0 - 7.6 s.u.

Lake Adger is a 186-hectare impoundment located in the mountains of southwestern North Carolina. Duke Power owns the lake and uses it to generate power at the Turner Shoals Hydroelectric Plant. Fishing and boating are common on the reservoir.

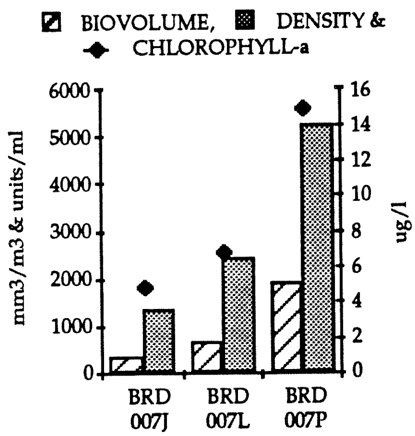
The dam was built in 1925, filling the lake to a volume of 14.4 x 10^6 m^3. Maximum depth is 22 meters and mean depth is eight meters. The average retention time is 21 days. The major tributary to the lake is the Green River. Most of the 346-km^2 watershed contains woodlands and croplands.

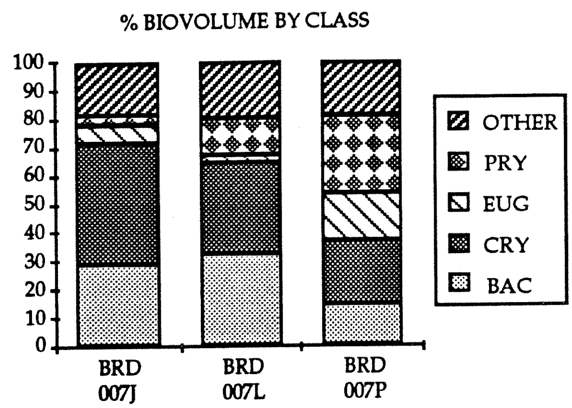
Lake Adger was sampled on August 1, 1989. Physical measurements indicated stratified conditions at the two deeper sampling stations while the shallower station (BRD007J) was mixed. Total organic nitrogen and chlorophyll-a levels were low throughout the lake. Total phosphorus was moderately elevated compared to other mountain lakes. The highest nutrient values were found at station BRD007J, while chlorophyll-a was highest near the dam. Turbidity and residue were highest at the upstream station. No state standards for these parameters were violated.

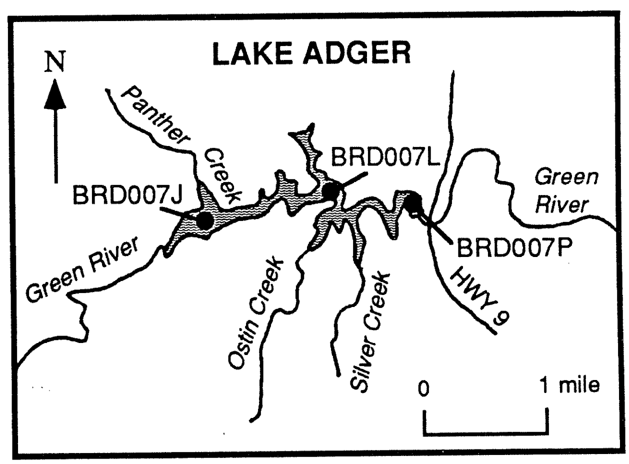
As with chlorophyll-a concentrations, highest algal biovolume and density estimates were seen at the lower station, BRD007P. This station is located near the dam where the retention time of 21 days allows phytoplankton to assimilate the available nutrients and reach higher populations than at the upper stations.

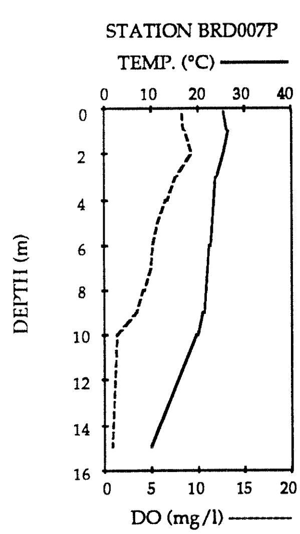
Estimates of phytoplanktonic biovolume were dominated by the cryptophytes, Cryptomonas erosa and Chroomonas caudata and the prymnesiophyte, Chrysochromulina breviturrita. C. erosa and C. caudata are found throughout the state. C. breviturrita, normally a cool water species, has also been identified in eutrophic piedmont reservoirs during the summer months.

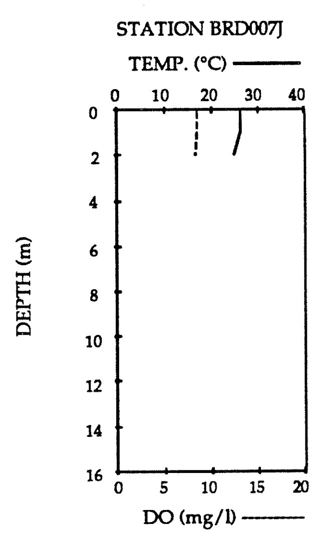
The TSI in 1989 was -2.7. This classifies Lake Adger as oligotrophic. Estimates of algal density and biovolume support the oligotrophic status. At the time of assessment, no violations of state water quality standards were observed at Lake Adger. The lake appeared to have good water quality that supported all designated uses (aquatic life propagation/protection and secondary recreation).

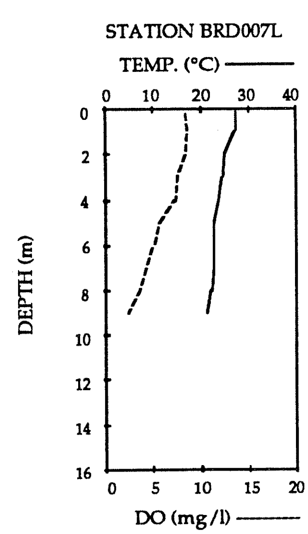




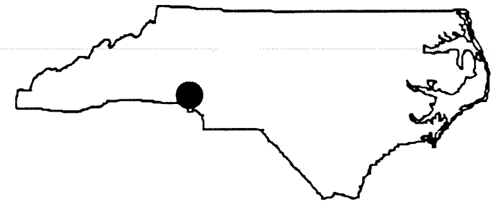








KINGS MOUNTAIN RESERVOIR



COUNTY:	Cleveland	BASIN:	Broad
SURFACE AREA:	530 hectares (1,310 acres)	USGS TOPO:	Waco, N.C.
CLASS:	WS	LAKE TYPE:	Reservoir

LATEST NCTSI:	- 3.3	TROPHIC STATE:	Oligotrophic
SAMPLING DATE:	August 2, 1989	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	2.0 m	CONDUCTIVITY:	45 - 50 µmhos/cm^2
TOTAL PHOSPHORUS:	0.01 mg/l	DISSOLVED OXYGEN:	7.9 -8.2 mg/l
TOTAL ORGANIC NITROGEN:	0.15 mg/l	TEMPERATURE:	30.0 - 30.6 °C
CHLOROPHYLL-A:	7 µg/l	pH:	7.3 - 7.6 s.u.

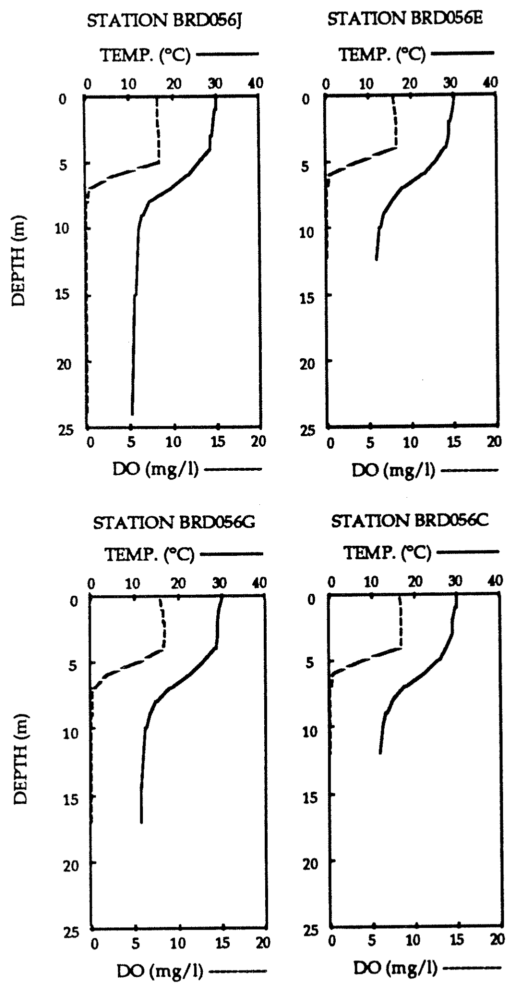
Kings Mountain Reservoir (also known as Moss Lake) is a water supply for the City of Kings Mountain. The impoundment, built in 1963, has a maximum depth of 28 meters. Major inflows to the lake include Buffalo Creek and White Oak Creek. The drainage area measures 169 km^2 and is characterized by rolling hills and rural land use. Access to the lake is strictly controlled by a special set of regulations for the many recreational users of the lake. These regulations have been adopted to assure safety as well as to protect water quality.

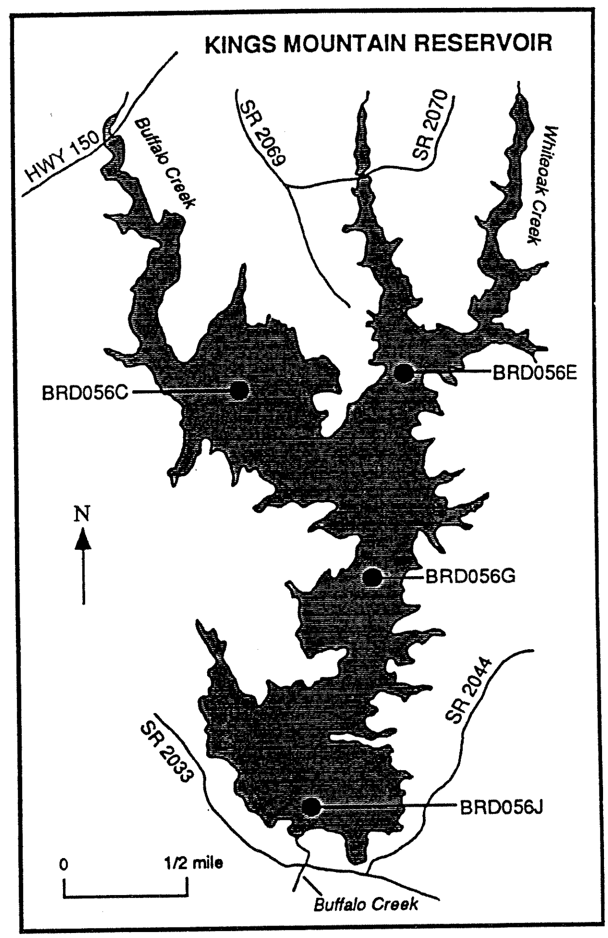
On August 2, 1989, the lake was sampled after a brief rain the previous night. The lake was stratified and showed no unusual physical characteristics. Nutrients, solids, and chlorophyll-a concentrations were low indicating good conditions of water quality.

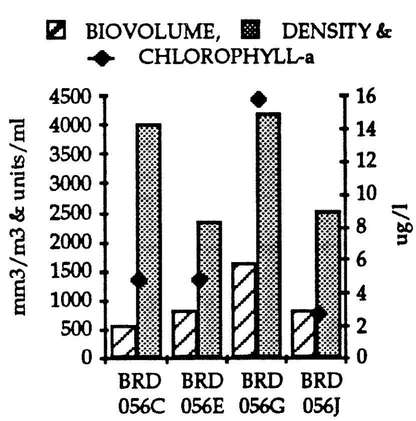
Phytoplanktonic populations in Kings Mountain Reservoir were dominated by cryptophytes, blue-greens, diatoms, and prymnesiophytes. Lyngbya species A, a small, filamentous, blue-green alga, dominated density at all stations. At BRD056C in the Buffalo Creek arm, Lyngbya species A also dominated biovolume estimates. This alga is commonly found in reservoirs and lakes throughout North Carolina and usually dominates biovolume in enriched systems. Cryptomonas ovata (cryptophyte), Cyclotella species 3 (diatom), and Anabaena levanderi (blue-green) were also dominant species by biovolume.

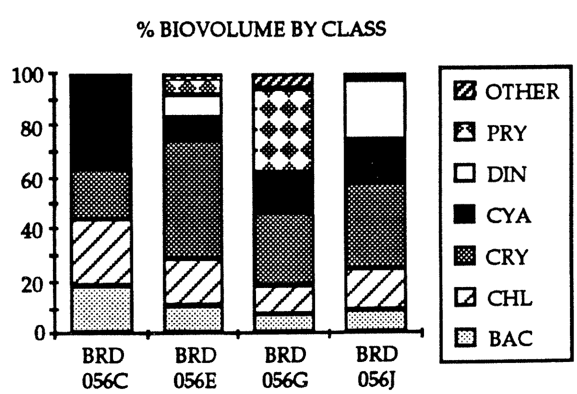
Highest biovolume, density, and chlorophyll-a concentrations were seen at BRD056G, which is located near the middle of the lake. The dominant species of phytoplankton at this station was a Chrysochromulina species. This alga contains a large amounts of chlorophyll-a relative to its size. Biovolume and density estimates at this station were moderate.

Low to moderate estimates of algal biovolume and density throughout the lake supported the trophic status classification of oligotrophic (TSI of -3.3). Kings Mountain Reservoir is an example of a small, multi-use reservoir which provides recreation as well as good quality of water.









CAPE FEAR RIVER BASIN

DESCRIPTION OF REGION

The Cape Fear River Basin originates in the middle piedmont and flows through the lower piedmont, sandhills, inner coastal plain, and outer coastal plain regions of the state. This river basin, the largest beginning and ending in the state, covers an area of 23,700 km^2 in 24 counties.

The lower piedmont section of this basin (Cape Fear Basin Map #1) contains the drainage areas of the Haw, Deep, and New Hope Rivers. There are many point source dischargers located in this area with the greatest concentration found on the Haw River and its tributaries. Urban areas in this region include Asheboro, Burlington, Durham, Greensboro, High Point, and Sanford.

The sandhills region (Cape Fear Basin Map #2) includes the Little River, Upper Little River, and Rockfish Creek. This region is characterized by porous soils with high infiltration rates which reduces the potential for erosion. Fertilizer and pesticide application rates in this sub-basin are average (NRCD 1985). The Fayetteville area, including most of the Fort Bragg Military Reservation, is located in this part of the basin.

Three major tributaries to the Cape Fear River (Black River, South River, and Northeast Cape Fear River) are found in the coastal plain region of the basin (Cape Fear Basin Map #2 and #3). The towns of Burgaw, Mount Olive, and Wallace are located in this agricultural area. Erosion rates are generally low though the region has high rates of fertilizer and pesticides application.

The outer coastal plain region of this basin (Cape Fear Basin Map #3) contains the lower Cape Fear River, the Northeast Cape Fear River, and associated estuaries. Major urban areas include Wilmington, Elizabethtown, and Dunn. This region contains three large protected areas in state ownership: Bladen Lakes State Forest, Holly Shelter State Gamelands, and Angola Bay State Gamelands.

OVERVIEW OF WATER QUALITY

The lower piedmont section of the basin contains the watersheds of the Haw and Deep River. These watersheds have the highest concentration of industries in North Carolina. Both receive numerous point source discharges, including industrial and municipal wastewater treatment plants. In this area, water quality degradation is often associated with the larger cities. Portions of the Haw and Deep Rivers are affected by point source discharges near High Point, Randleman, and Asheboro (Deep River), and Greensboro and Burlington (Haw River) (NRCD 1988c). Urban and nonpoint source runoff also contribute to the water quality degradation in this region, particularly where soils are highly erodable (NRCD 1988b).

Most streams in the sandhills region of the basin have a high level of water quality. These streams receive a high percentage of groundwater input and are slightly humic and acidic due to soil types in the watershed. Point source dischargers and stormwater runoff have contributed to water quality degradation around the city of Fayetteville and the Fort Bragg Military Reservation (NRCD 1985).

The Northeast Cape Fear River drainage area is characterized by slow-moving, black water streams. Some streams in this area drain the largely undeveloped areas near the Angola Bay Game Refuge and the Holly Shelter Game Refuge and have a high level of water quality.

In the outer coastal plain region, the Cape Fear River widens, becomes slow-moving, and tidally influenced. Some water quality problems associated with point source discharges have been observed in the Wilmington area. The City of Wilmington is one of the busiest ports in North Carolina and a large number of point source dischargers are located near the city (NRCD 1988c).

Twenty-eight lakes are included in this section of the report. Of these, twelve are water supply reservoirs serving adjacent to urban areas. Lake Hunt, although not a water supply itself, regulates flow into Reidsville Lake, a mesotrophic water supply used by the Town of Reidsville.

Three lakes are located upstream of Lake Townsend, the water supply for the City of Greensboro: Lake Higgins, Lake Brandt, and Richland Lake. Burlington Reservoir and Lake Burlington exhibit water quality characteristics typical of moderately productive lake systems. Quaker Creek Reservoir provides the City of Graham with potable water, but is being replaced by a larger reservoir. Cane Creek and University Lake provide drinking water to the City of Chapel Hill. Pittsboro Lake and Hope Mills Lake are eutrophic which indicates that the potential for water quality problems exist in these productive lake systems. High Point Lake is another eutrophic water supply, which, along with Oak Hollow Lake, provides High Point with water.

B. Everett Jordan Reservoir is a multi-purpose reservoir which is one of the most eutrophic lakes in North Carolina. It receives numerous point source discharges from both the Haw River and New Hope Creek drainage areas. The New Hope Creek arm of the reservoir, particularly around the confluence of Morgan Creek, is adversely affected by wastewater discharges and experiences degraded conditions in the summer months. The entire watershed upstream from this area has been designated NSW in order to limit nutrient levels in the reservoir.

Harris Lake is owned by Carolina Power and Light (CP&L) and serves as a source of cooling water for the Shearon Harris Nuclear Power Plant. The lake is currently classified as mesotrophic and fully supports its designated uses.

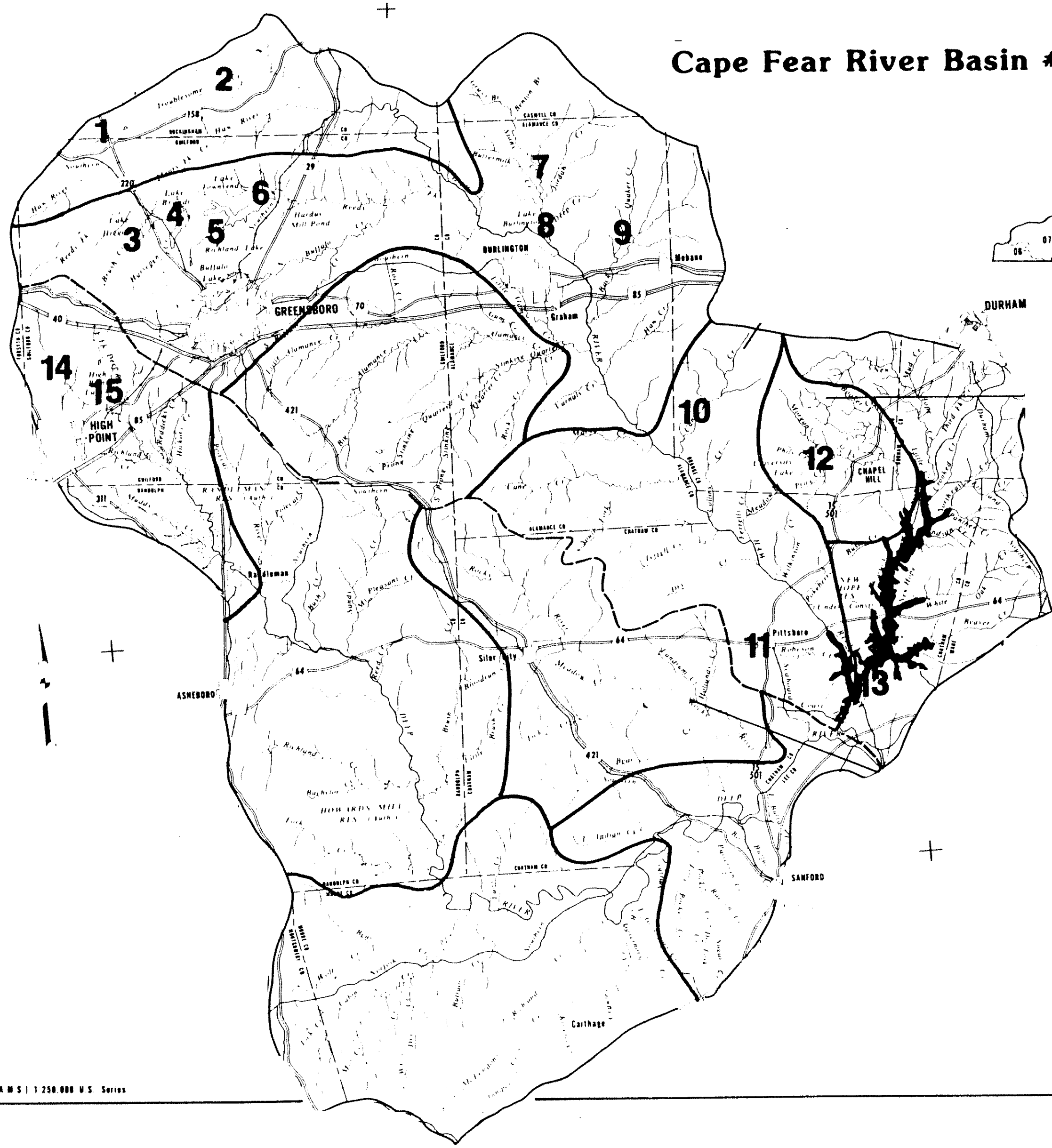
Old Town Reservoir is a lake with good water quality in the sandhills region of North Carolina. It is included in this report because the City of Southern Pines requested that a water quality assessment be made to evaluate development schemes. Mott Lake is another sandhills lake with good water quality. It is located in the Fort Bragg Military Reservation. DEM also sampled Upper and Lower Moccasin Lakes near Sanford. These two, small recreational lakes were found to be eutrophic.

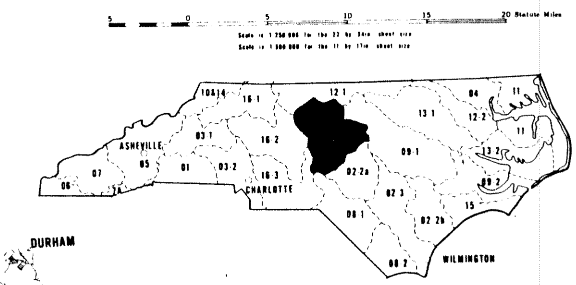
Greenfield Lake is a hypereutrophic lake located in downtown Wilmington. This lake's naturally high productivity has been aggravated by additional nutrient inputs from point and nonpoint sources. Boiling Springs Lake is a black-water recreational reservoir in the Boiling Springs retirement area near Southport.

The remaining five lakes in this basin are natural bay lakes located in the outer coastal plain of the state. They all have characteristically acidic water associated with the lakes in this region. These lakes - White Lake, Jones Lake, Salters Lake, Bay Tree Lake, and Singletary Lake - have high water quality and fully support their designated uses.

Cape Fear #1

Cape Fear River Basin #1



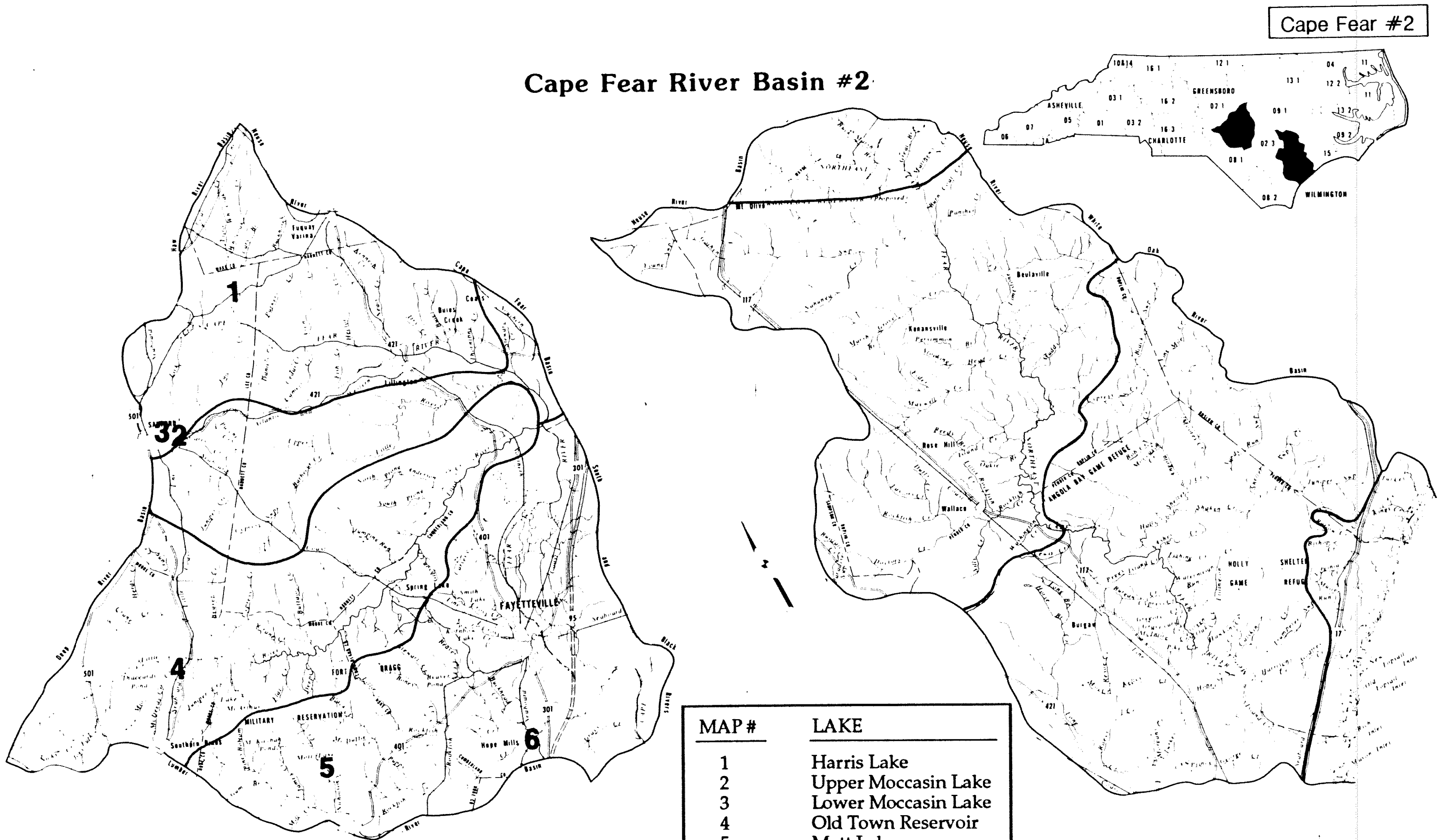


MAP #	LAKE
1	Lake Hunt
2	Reidsville Lake
3	Lake Higgins
4	Lake Brandt
5	Richland Lake
6	Lake Townsend
7	Burlington Reservoir
8	Lake Burlington
9	Quaker Creek Reservoir
10	Cane Creek Reservoir
11	Pittsboro Lake
12	University Lake
13	B. Everett Jordan Lake
14	Oak Hollow Lake
15	High Point Lake

North Carolina Department of
Natural Resources and Community Development
Division of Enviromental Management

Adapted from U.S.G.S.(A.M.S.) 1:250,000 U.S. Series

Cape Fear River Basin #2



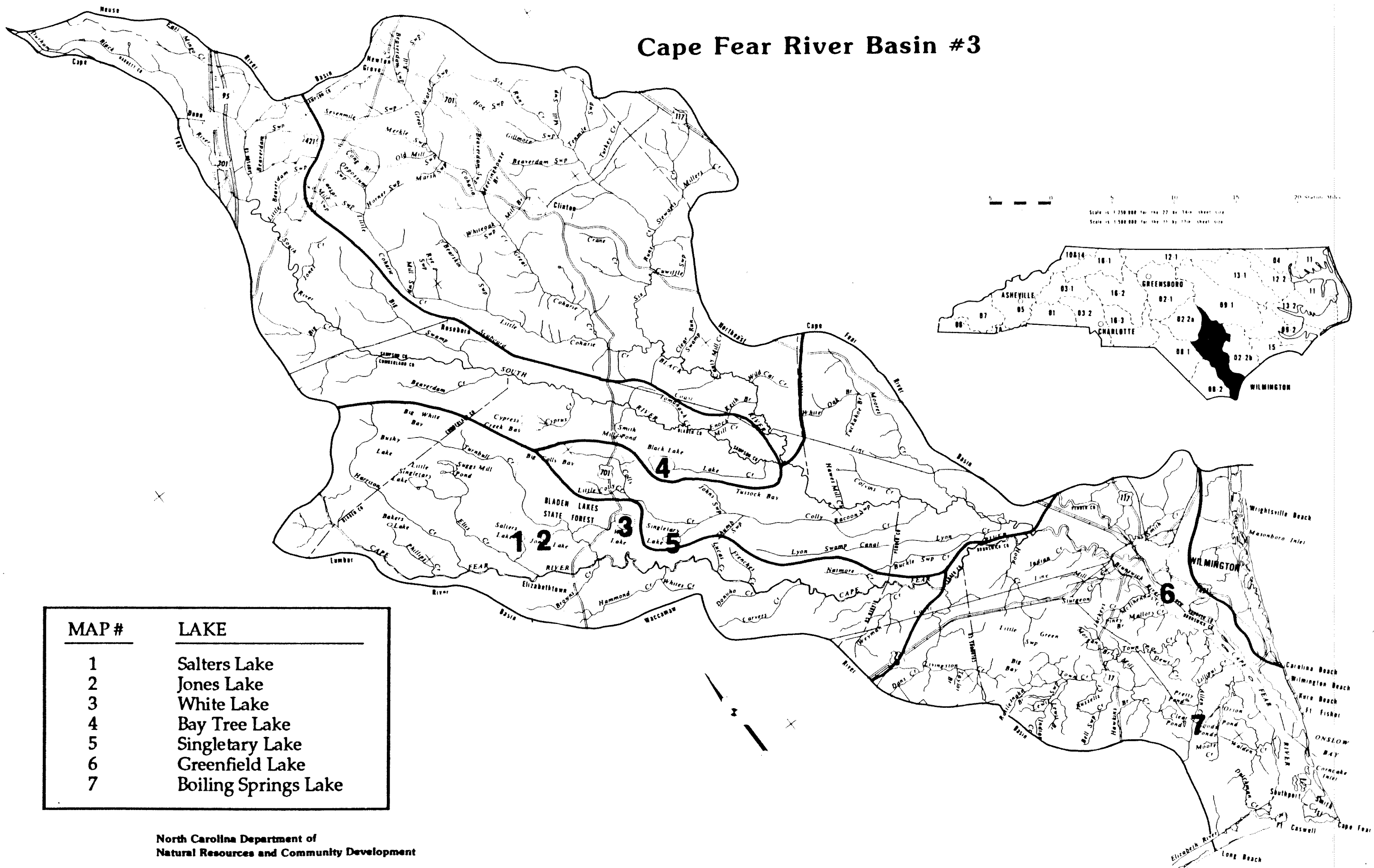
MAP #	LAKE
1	Harris Lake
2	Upper Moccasin Lake
3	Lower Moccasin Lake
4	Old Town Reservoir
5	Mott Lake
6	Hope Mills Lake

North Carolina Department of
Natural Resources and Community Development

Division of Enviromental Management

Adapted from U S G S (A M S) 1:250 000 U.S. Series

Cape Fear River Basin #3



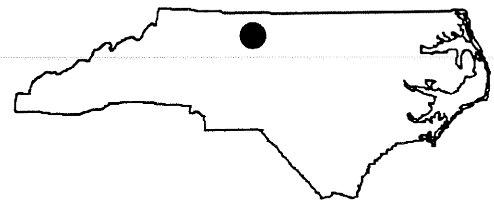
MAP #	LAKE
1	Salters Lake
2	Jones Lake
3	White Lake
4	Bay Tree Lake
5	Singletary Lake
6	Greenfield Lake
7	Boiling Springs Lake

North Carolina Department of
Natural Resources and Community Development

Division of Enviromental Management

Adapted from U.S.G.S.(A.M.S.) 1:250,000 U.S. Series

LAKE HUNT



COUNTY:	Rockingham	BASIN:	Cape Fear
SURFACE AREA:	73 hectares (180 acres)	USGS TOPO:	Reidsville, N.C.
CLASS:	B NSW	LAKE TYPE:	Reservoir

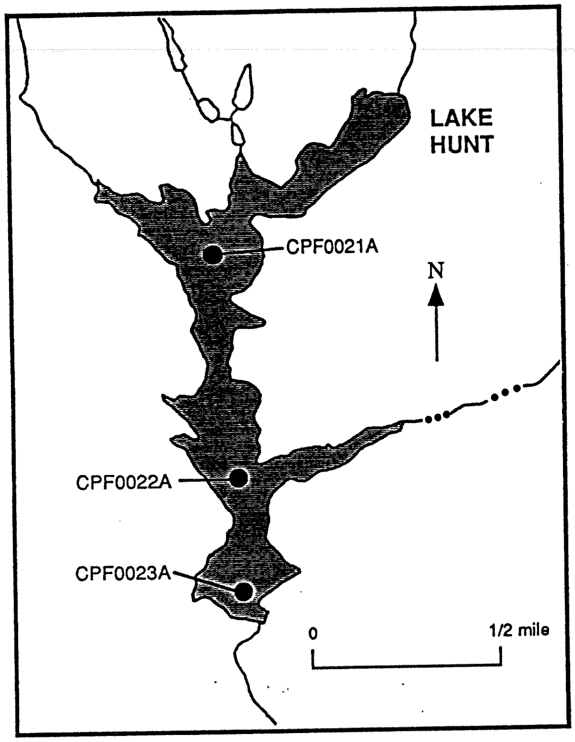
LATEST NCTSI:	- 2.1	TROPHIC STATE:	Oligotrophic
SAMPLING DATE:	August 16, 1988	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	2.3 m	CONDUCTIVITY:	40 - 50 µmhos/cm^2
TOTAL PHOSPHORUS:	0.02 mg/l	DISSOLVED OXYGEN:	7.4 - 8.6 mg/l
TOTAL ORGANIC NITROGEN:	0.24 mg/l	TEMPERATURE:	30.7 - 31.2 °C
CHLOROPHYLL-A:	5 µg/l	pH:	8.2- 8.7 s.u.

Lake Hunt is a recreational lake located in Reidsville, North Carolina. The city owns the lake which was completed on August 30, 1956. Maximum depth at the spillway is 10 meters and the volume of the impoundment is $2.8 \times 10^6 m^3$. Lake Hunt was the primary water supply for the City of Reidsville until Reidsville Lake was built in 1979. Residential development upstream is replacing farmland. Lake Hunt is fed by an unnamed tributary to Troublesome Creek.

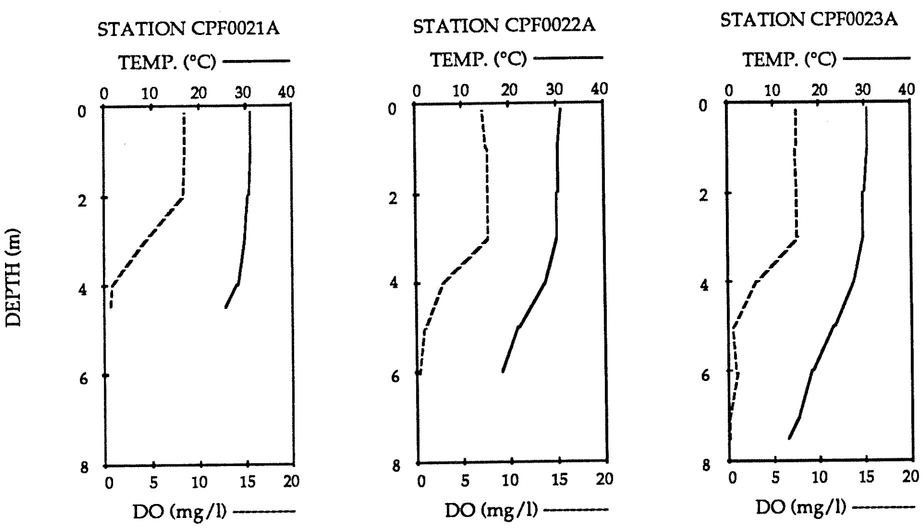
Sample results from August 16, 1988 reveal that water quality in Lake Hunt is exceptional in comparison to other piedmont lakes of similar size. Secchi readings were high (2.3 meters), while nutrients and chlorophyll-a were low. High pH readings, usually indicative of algal activity, were also recorded.

The three stations that were sampled for estimates of algal populations indicated low algal productivity. Sphaerocystis schroeteri, a small, colonial, green alga, dominated the biovolume and density estimates. Seventy-seven and sixty-eight percent of the density and biovolume respectively were represented by this species.

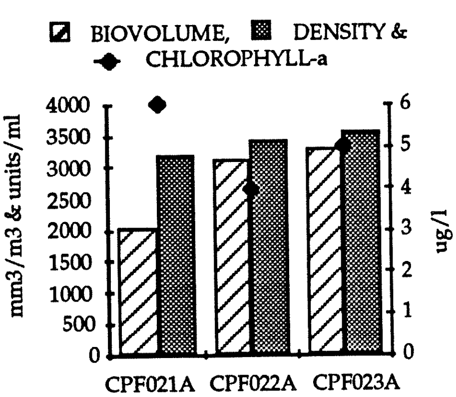
Lake Hunt had a TSI of -2.1 in 1988, indicating that it was oligotrophic. All uses of the lake were fully supported.



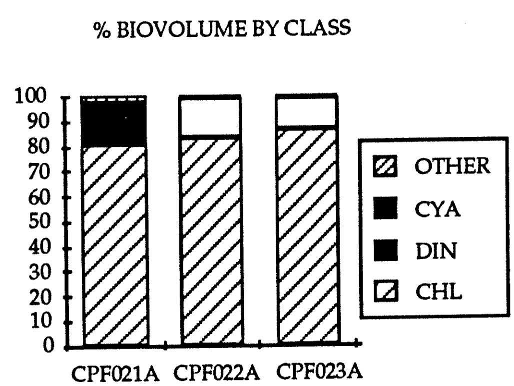
LAKE HUNT
CPF0021A
N
CPF0022A
CPF0023A
0
1/2 mile



STATION CPF0021A
STATION CPF0022A
STATION CPF0023A
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0 2 4 6 8
0 5 10 15 20
DO (mg/l)

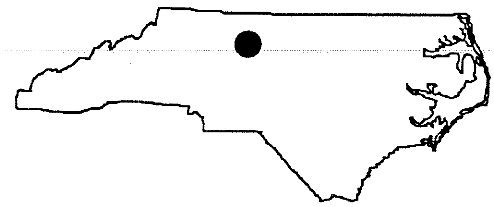


BIOVOLUME, DENSITY & CHLOROPHYLL-a
mm3/m3 & units/ml
4000 3500 3000 2500 2000 1500 1000 500 0
ug/l
6 5 4 3 2 1 0
CPF021A CPF022A CPF023A



% BIOVOLUME BY CLASS
100 90 80 70 60 50 40 30 20 10 0
CPF021A CPF022A CPF023A
OTHER
CYA
DIN
CHL

REIDSVILLE LAKE



COUNTY:	Rockingham	BASIN:	Cape Fear
SURFACE AREA:	304 hectares (750 acres)	USGS TOPO:	Reidsville, N.C.
CLASS:	WS NSW	LAKE TYPE:	Reservoir

LATEST NCTSI:	- 1.7	TROPHIC STATE:	Mesotrophic
SAMPLING DATE:	August 16, 1988	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	1.6 m	CONDUCTIVITY:	60 μmhos/cm^2
TOTAL PHOSPHORUS:	0.02 mg/l	DISSOLVED OXYGEN:	7.2 - 8.2 mg/l
TOTAL ORGANIC NITROGEN:	0.225 mg/l	TEMPERATURE:	31.7 - 32.3 ^{o}C
CHLOROPHYLL-A:	6.5 μg/l	pH:	7.2 - 7.8 s.u.

Reidsville Lake is an auxiliary water supply reservoir located on Troublesome Creek just outside of the City of Reidsville in Rockingham County. The lake is owned by the City of Reidsville and is classified WS-III. The reservoir has a volume of 4.3×10^4 m^3 and a drainage area covering 136 km^2 of land. The topography of the watershed is characterized by rolling hills with mainly agricultural land use.

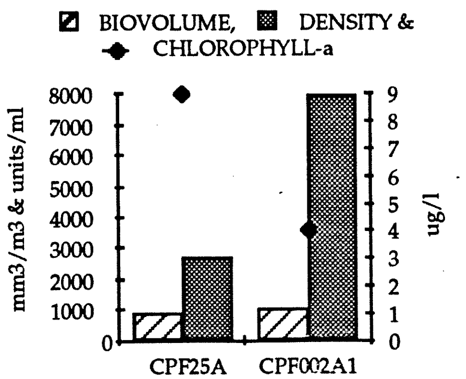
Reidsville Lake was sampled on August 16, 1988. Physical measurements indicated that stratified conditions existed at both sampling locations. Dissolved oxygen was stratified at both stations, but only the station near the dam exhibited thermal stratification. The lake had moderate nutrient concentrations and low chlorophyll-a values. Nutrient levels were similar at the two lake stations with bottom water samples showing higher concentrations than photic zone samples. This condition is commonly observed in stratified lakes. Heavy metals were below state standards or action levels.

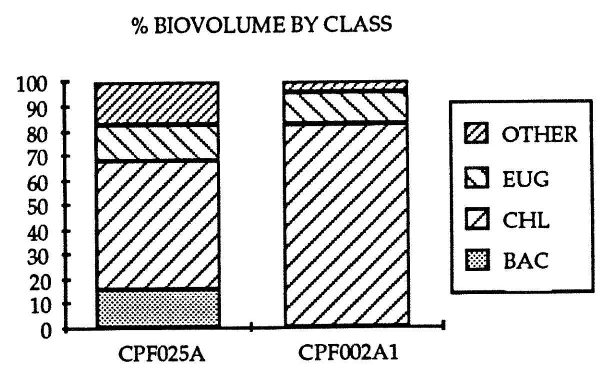
Phytoplanktonic biovolume and density estimates for Reidsville Lake were moderate and dominated by green algae. Mougeotia sp., a large filamentous green alga, dominated algal biovolume at the upstream station. Near the dam, Staurastrum tetracerum and other Staurastrum species, unicellular green algae, dominated biovolume estimates. The species present in Reidsville Lake were typical of lakes experiencing low to moderate nutrient inputs. The high biovolume at the upper station was due to the large size of the Mougeotia filaments.

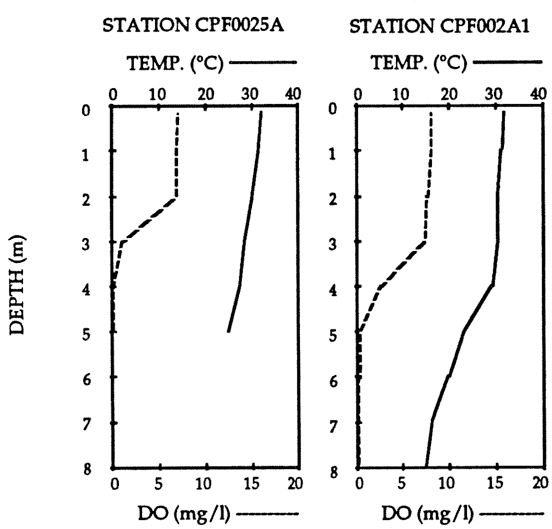
Water shield (Brasenia schreberi) and Elodea (Egeria densa) were found in aquatic weed samples. These macrophytes are common in this area. The seeds and leaves of water shield are eaten by waterfowl, and the plant provides excellent cover for fish and small invertebrates. Elodea also provides cover for fish and small invertebrates but heavy infestations may impair boating activities and other recreational uses.

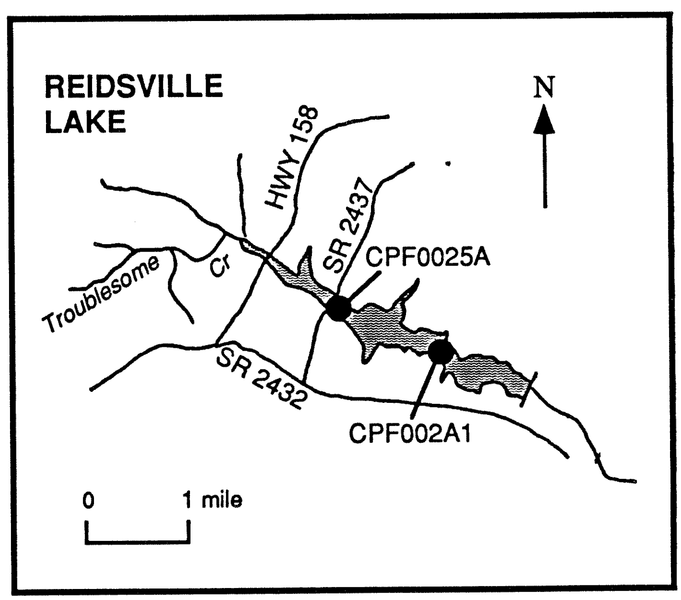
Water shield (Brasenia schreberi) and elodea (Egeria densa) are found in abundance in Reidsville Lake. Field observations in 1987 noted that about 40% of the surface area of the lake is covered with Elodea. Because recreational activities such as water skiing and fishing have not been affected, there are currently no control efforts planned for the lake.

The TSI in 1988 was -1.7 which was similar to the 1982 value of -1.9, but lower than the 1987 value of -0.1. Lack of precipitation in 1987 may have influenced the TSI by increasing the hydraulic retention time in the lake. The increased retention time may have concentrated nutrients and elevated algal growth and densities.

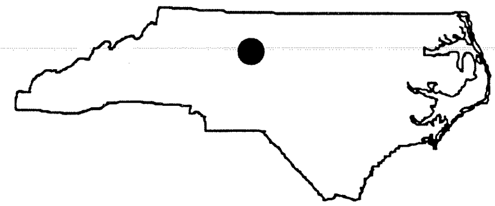








LAKE HIGGINS



COUNTY:	Guilford	BASIN:	Cape Fear
SURFACE AREA:	116 hectares (287 acres)	USGS TOPO:	Summerfield, N.C.
CLASS:	WS	LAKE TYPE:	Reservoir

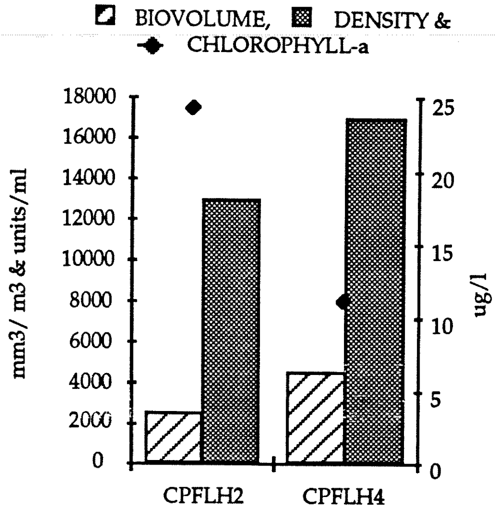
LATEST NCTSI:	1.1	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	August 6, 1990	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	0.75 m	CONDUCTIVITY:	67 - 69 μmhos/cm^2
TOTAL PHOSPHORUS:	0.03 mg/l	DISSOLVED OXYGEN:	7.7 - 7.9 mg/l
TOTAL ORGANIC NITROGEN:	0.33 mg/l	TEMPERATURE:	28.0 - 28.1°C
CHLOROPHYLL-A:	18 μg/l	pH:	7.9 - 8.2 s.u.

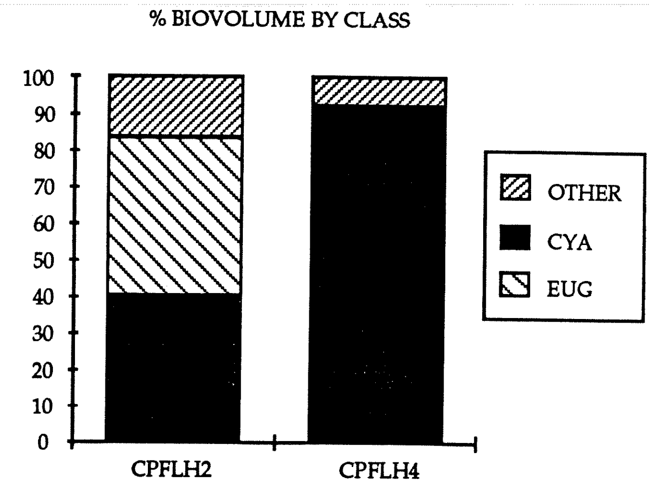
Lake Higgins is one of three lakes used by the City of Greensboro as a water supply. This reservoir drains into Lake Brandt which discharges into Lake Townsend. Built in 1957, Lake Higgins holds 3 x 10^6 m^3 with a maximum depth of six meters, and a mean depth of 3.5 meters. The creek feeding the lake drains 29 km^2 of mostly forested land. In a cooperative agreement with the Wildlife Resources Commission, all three lakes on this creek are regularly stocked with sport fish.

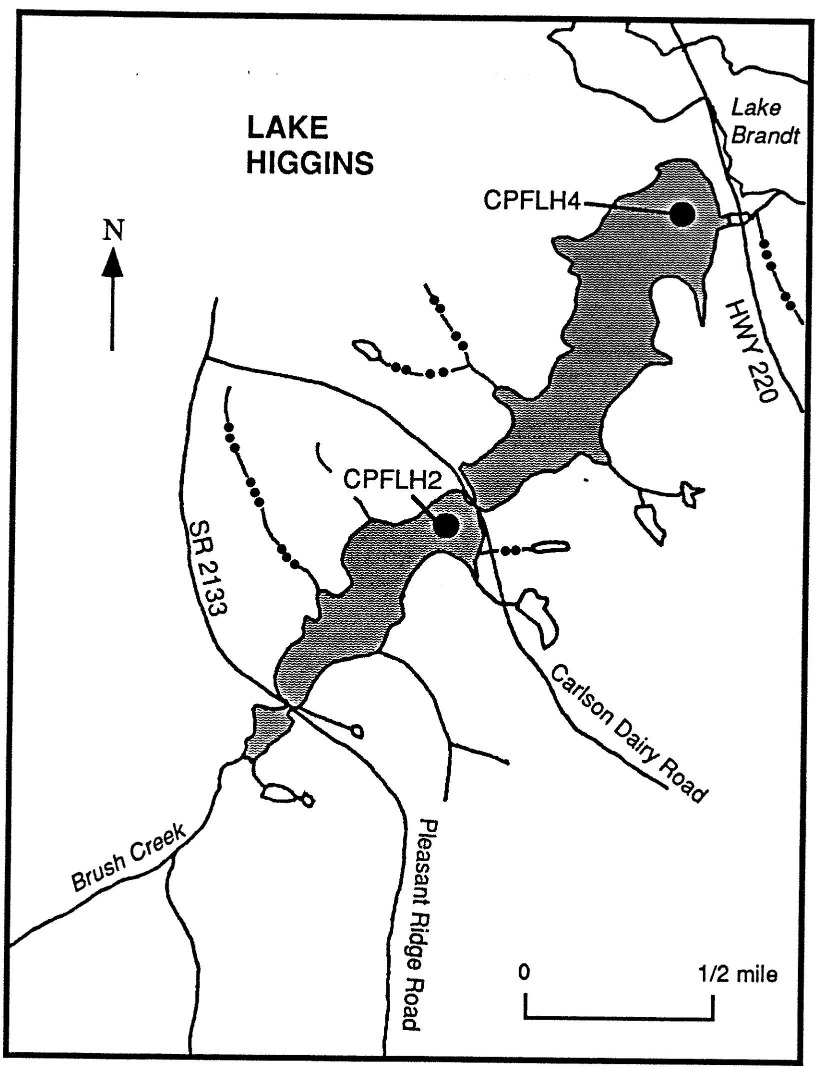
Lake Higgins was stratified near the dam on August 6, 1990. A 12°C difference between the epilimnion and the hypolimnion was documented. Levels of nutrients and chlorophyll-a indicated that this lake was moderately productive. Metals were detected at low levels.

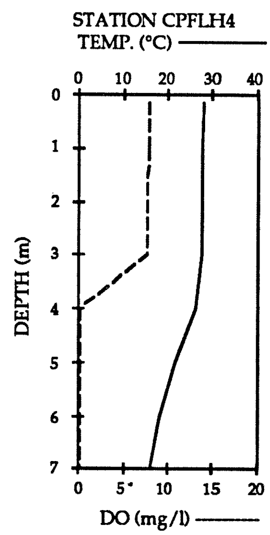
Estimates of the density and biovolume for the phytoplankton in Lake Higgins were moderate. Algal biovolume was 2,466 and 4,538 mm^3/m^3 and density was 12,665 and 16,640 units/ml for CPFLH2 and CPFLH4 respectively. Blue-green and euglenoid algae co-dominated at CPFLH2. Aphanizomenon flos-aquae, a large, filamentous, blue-green alga, and three large species of the euglenoid Trachelomonas composed 80% of the biovolume.

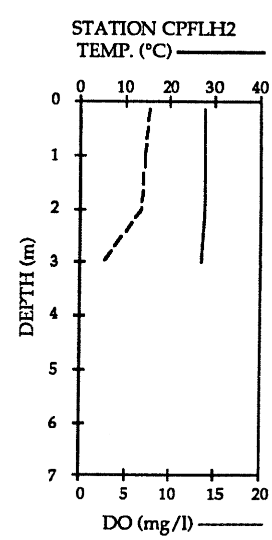
Based on the TSI in 1990, Lake Higgins was eutrophic. No water quality standards were violated at the lake, and uses were fully supported.


BIOVOLUME, DENSITY & CHLOROPHYLL-a
mm3/ m3 & units/ml
ug/l
CPFLH2
CPFLH4

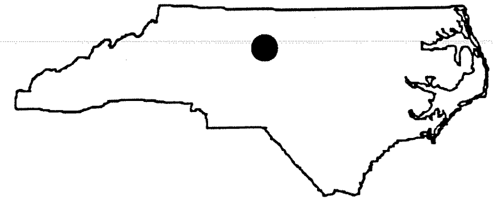

% BIOVOLUME BY CLASS
OTHER
CYA
EUG
CPFLH2
CPFLH4


LAKE HIGGINS
N
CPFLH4
CPFLH2
Lake Brandt
HWY 220
SR 2133
Carlson Dairy Road
Brush Creek
Pleasant Ridge Road
0
1/2 mile


STATION CPFLH4
TEMP. (°C)
DEPTH (m)
DO (mg/l)


STATION CPFLH2
TEMP. (°C)
DEPTH (m)
DO (mg/l)

LAKE BRANDT



COUNTY:	Guilford	BASIN:	Cape Fear
SURFACE AREA:	287 hectares (410 acres)	USGS TOPO:	Lake Brandt, N.C.
CLASS:	WS NSW	LAKE TYPE:	Reservoir

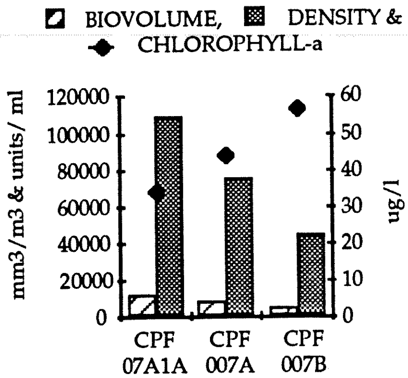
LATEST NCTSI:	2.3	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	August 23, 1988	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	0.8 m	CONDUCTIVITY:	32 - 85 µmhos/cm^2
TOTAL PHOSPHORUS:	0.04 mg/l	DISSOLVED OXYGEN:	6.3 - 12.6 mg/l
TOTAL ORGANIC NITROGEN:	0.37 mg/l	TEMPERATURE:	29.1 - 29.8°C
CHLOROPHYLL-A:	45 µg/l	pH:	7.3 - 9.3 s.u.

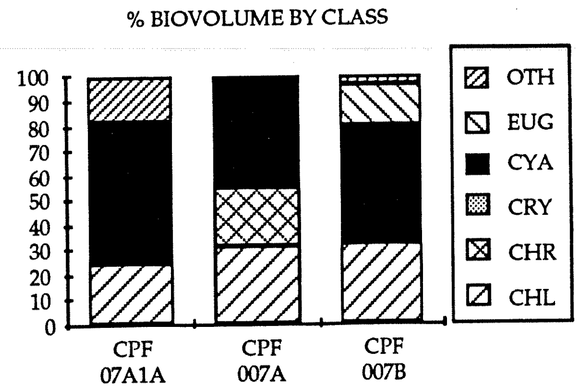
Lake Brandt is one of two primary water supplies for Greensboro, the third largest city in North Carolina. The City of Greensboro withdraws between 50,000 and 95,000 m^3 of water from Lake Brandt per day. The volume of the lake is 8.4 x 10^7 m^3 with a maximum depth of seven meters and an average depth of two meters. The original size of Lake Brandt was 170 hectares when it was impounded in 1925. The lake was enlarged to 287 hectares in 1959. Reedy Fork Creek and Horsepen Creek are the main tributaries to the lake which drains 104 km^2 in a mostly agricultural watershed.

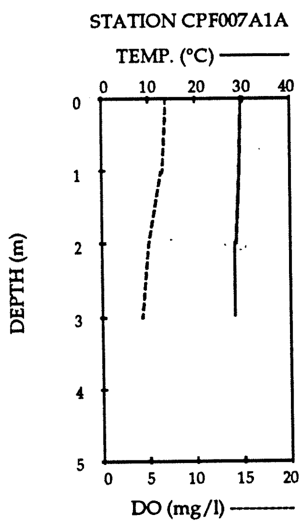
Lake Brandt was sampled on August 23, 1988. The lake was stratified at the dam. High surface pH and dissolved oxygen concentrations at this station indicated elevated photosynthetic activity. Nutrient levels were high. The chlorophyll-a standard was violated at two of the three stations.

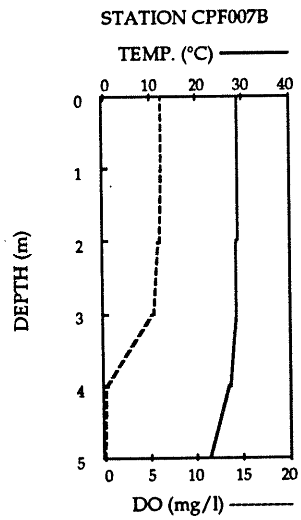
Algal samples collected from three stations in Lake Brandt were dominated by blue-green algae. Anabaenopsis phillipinensis and A. raciborskii made up 50% of the biovolume and at least 30% of the density. Elevated chlorophyll-a levels and dominance by these blue-green species were evidence of nutrient-enriched conditions.

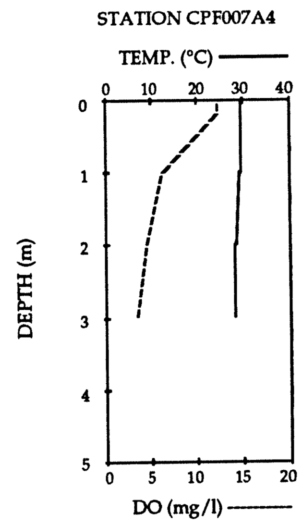
A TSI for Lake Brandt of 2.3 in 1988 indicated it was eutrophic. All uses were being fully supported at the time of sampling, but violations of the chlorophyll-a standard and the importance of the reservoir warrant continued monitoring of Lake Brandt.

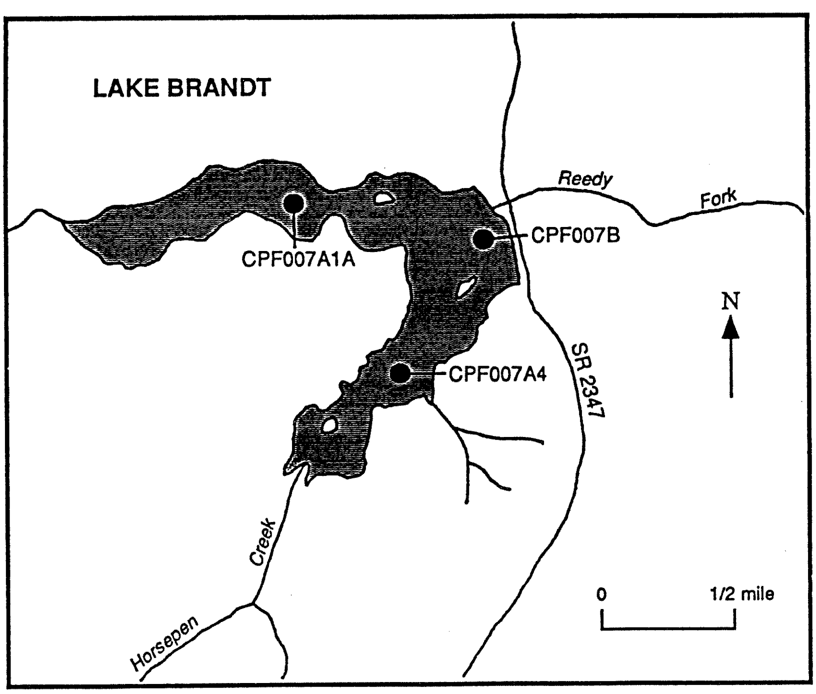

BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/m3 & units/ ml
120000
100000
80000
60000
40000
20000
0
60
50
40
30
20
10
0
ug/l
CPF 07A1A
CPF 007A
CPF 007B


% BIOVOLUME BY CLASS
100
90
80
70
60
50
40
30
20
10
0
CPF 07A1A
CPF 007A
CPF 007B
OTH
EUG
CYA
CRY
CHR
CHL

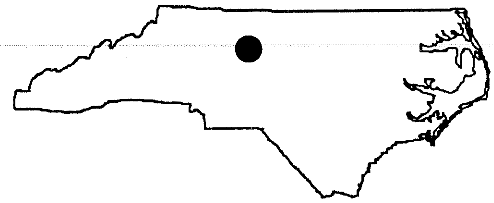

STATION CPF007A1A
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0
1
2
3
4
5
0 5 10 15 20
DO (mg/l)


STATION CPF007B
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0
1
2
3
4
5
0 5 10 15 20
DO (mg/l)


STATION CPF007A4
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0
1
2
3
4
5
0 5 10 15 20
DO (mg/l)


LAKE BRANDT
Reedy
Fork
CPF007A1A
CPF007B
CPF007A4
SR 2347
N
Creek
Horsepen
0
1/2 mile

RICHLAND LAKE



COUNTY:	Guilford	BASIN:	Cape Fear
SURFACE AREA:	105 hectares (260 acres)	USGS TOPO:	Lake Brandt, N.C.
CLASS:	WS	LAKE TYPE:	Reservoir

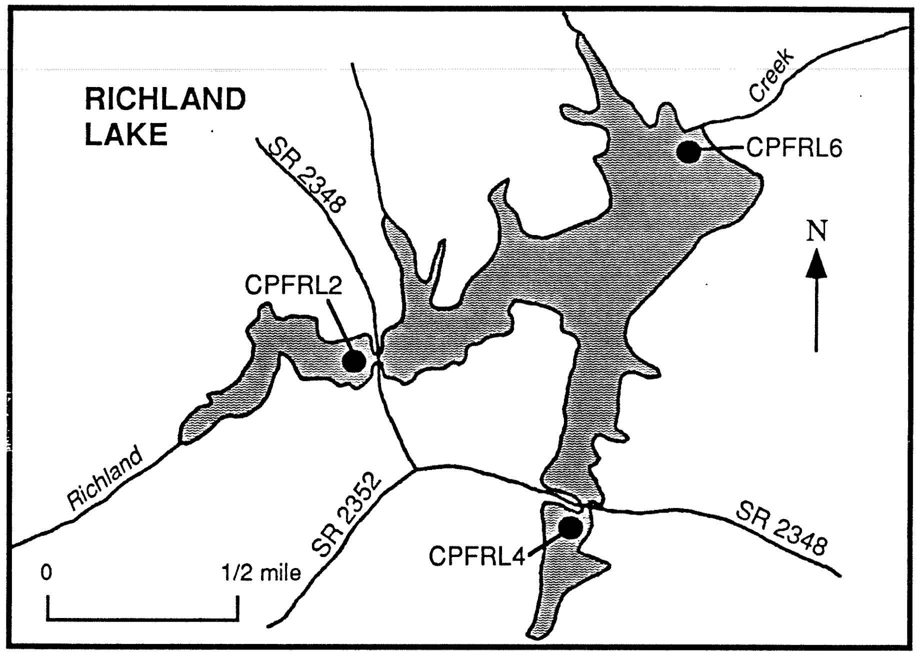
LATEST NCTSI:	-1.1	TROPHIC STATE:	Mesotrophic
SAMPLING DATE:	August 6, 1990	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	1.4 m	CONDUCTIVITY:	68 - 69 µmhos/cm^2
TOTAL PHOSPHORUS:	0.02 mg/l	DISSOLVED OXYGEN:	6.6 - 7.2 mg/l
TOTAL ORGANIC NITROGEN:	0.28 mg/l	TEMPERATURE:	27.9 - 28.1°C
CHLOROPHYLL-A:	7 µg/l	pH:	7.0 - 7.5 s.u.

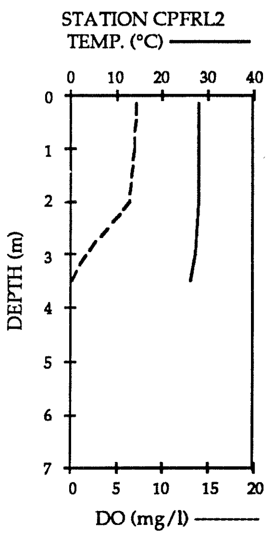
Cone Mills built Richland Lake (also known as Lake Jeanette) in 1942. Located upstream of Lake Townsend in northwestern Greensboro, the reservoir holds 4.2×10^6 m^3. Maximum depth is 10 meters and average depth is 3.5 meters. Richland Creek, the major inflow to Richland Lake, drains 23 km^2 of heavily developed urban and residential land.

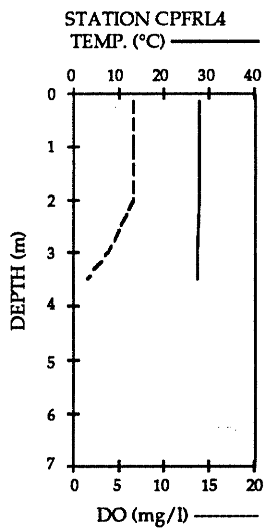
Richland Lake was sampled on August 6, 1990. Physical measurements indicated nearly neutral pH and a well-defined thermocline between four and five meters. Nutrients and chlorophyll-a were low. Manganese and iron were found in the water column at levels well within the standards set by North Carolina Administrative Code.

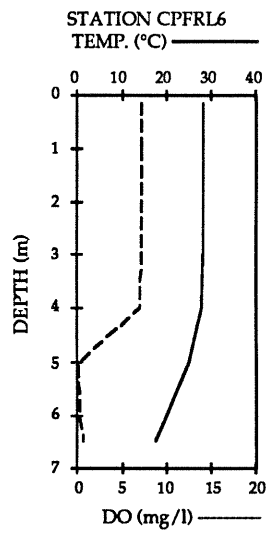
Estimates of algal biovolume and density were low, ranging from 100 to 300 mm^3/m^3 and 500 to 3,100 units/ml respectively. The filamentous blue-green algae, Anabaena levanderi and Lyngbya species, composed half of the biovolume and were codominant at CPFRL2 and CPFRL4. Staurastrum tetracerum, a green alga, represented half the biovolume at the dam.

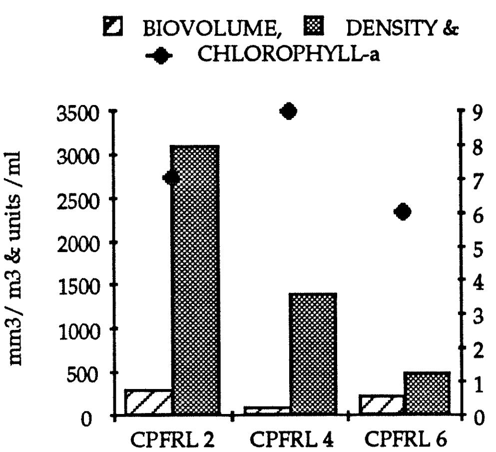
Of the four lakes in this watershed, Richland Lake exhibited the best water quality in terms of trophic parameters. It is the only one of these lakes considered to be mesotrophic. All uses were fully supported at the time of assessment and no violations of water quality standards were found.



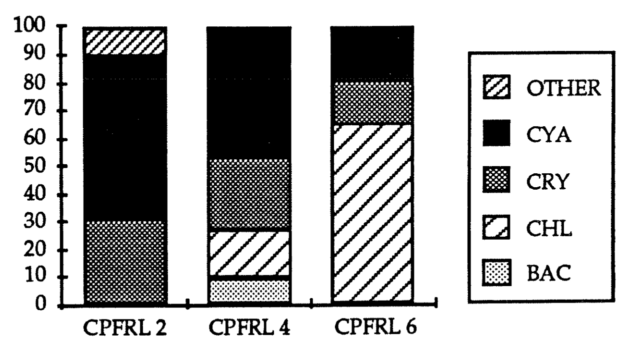




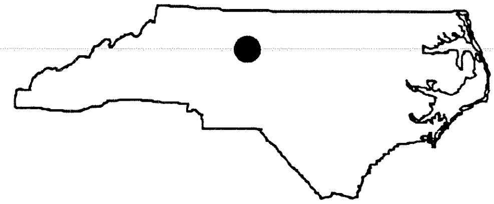




% BIOVOLUME BY CLASS



LAKE TOWNSEND



COUNTY:	Guilford	BASIN:	Cape Fear
SURFACE AREA:	652 hectares (1,610 acres)	USGS TOPO:	Brown's Summit, N.C.
CLASS:	WS	LAKE TYPE:	Reservoir

LATEST NCTSI:	1.1	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	August 6, 1990	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	0.9 m	CONDUCTIVITY:	68 - 71 µmhos/cm^2
TOTAL PHOSPHORUS:	0.04 mg/l	DISSOLVED OXYGEN:	7.7 - 8.3 mg/l
TOTAL ORGANIC NITROGEN:	0.32 mg/l	TEMPERATURE:	28.1 - 28.6°C
CHLOROPHYLL-A:	17 µg/l	pH:	7.5 - 8.0 s.u.

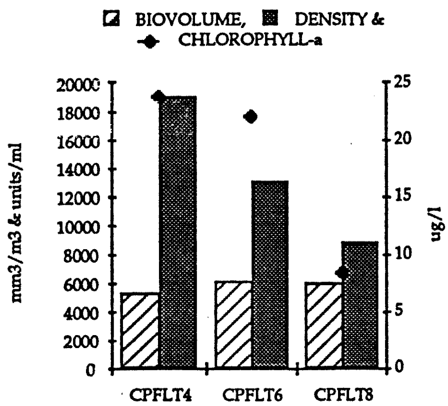
Lake Townsend was built in 1969 by the City of Greensboro to provide drinking water for the area. The depth of the lake averages three meters with a maximum depth of eight meters and a volume of 2.5×10^7 m^3. Although mean retention time of this reservoir is not known, it takes an estimated seven to eight months for water to travel from Lake Higgins to the dam at Lake Townsend. The reservoir drains 272 km^2, including the watersheds of Lake Higgins, Lake Brandt, and Richland Lake. Land in the drainage area is forested and urbanized. Townsend is used by boaters, swimmers and fishermen.

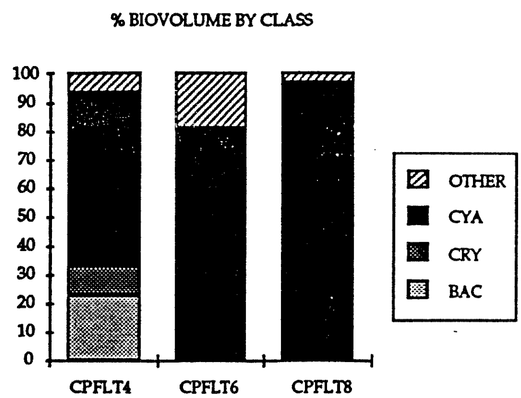
The lake was three feet below normal when sampled on August 6, 1990. Stratification was documented at the dam. Chlorophyll-a and turbidity were lower at the dam than at the other two stations. Nutrients were moderate throughout the lake. Metals were detected at low levels near the dam.

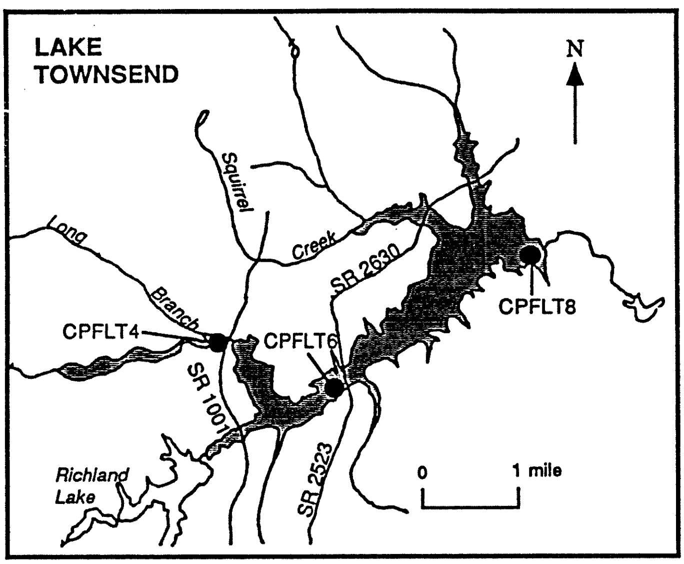
Throughout Lake Townsend, Aphanizomenon flos-aquae, a filamentous, blue-green alga, dominated algal biovolume which averaged approximately 5,800 mm^3/m^3 at each station. Several other species of small filamentous blue-green algae, including Anabaenopsis raciborskii, A. phillipinensis, and Lyngbya species A influenced the algal densities, but the relative size of these algae had little effect on the biovolume. A combination of single-cell diatoms and green algae were responsible for the elevated density at CPFLT4.

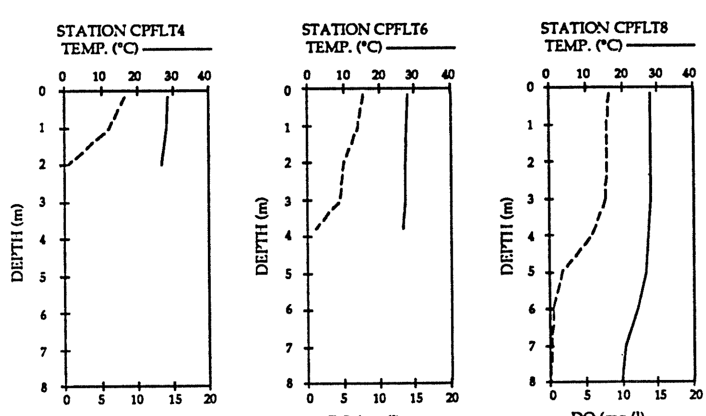
Two species of aquatic macrophytes were recorded from this body of water. Egeria species (egeria) and Ludwigia uruguayensis (water primrose) are submersed and emergent species respectively. Neither of these plants present a threat to the intended uses of the lake at the current population levels; however, both are capable of establishing nuisance conditions which interfere with recreation.

A TSI of 1.1 indicated that Lake Townsend was eutrophic in 1990. All uses of the lake were supported by its water quality. Given the large population served by this reservoir, it should continue to be monitored by DEM in the future.

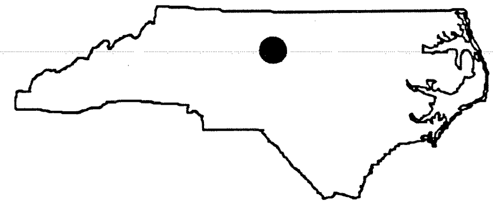








BURLINGTON RESERVOIR



COUNTY:	Alamance	**BASIN:**	Cape Fear
SURFACE AREA:	304 hectares (750 acres)	**USGS TOPO:**	Lake Burlington, N.C.
CLASS:	WS NSW	**LAKE TYPE:**	Reservoir

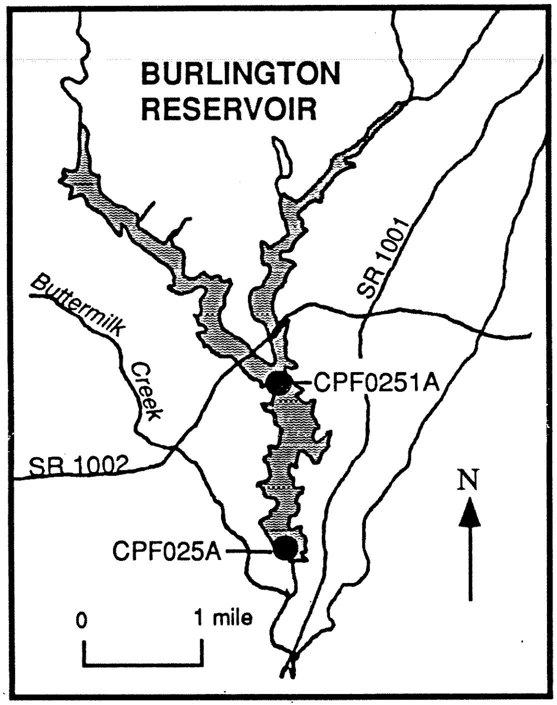
LATEST NCTSI:	0.0	**TROPHIC STATE:**	Mesotrophic
SAMPLING DATE:	August 16, 1988	**ADDITIONAL COVERAGE:**	Water Supply Parameters
SECCHI DEPTH:	1.3 m	**CONDUCTIVITY:**	96 µmhos/cm^2
TOTAL PHOSPHORUS:	0.03 mg/l	**DISSOLVED OXYGEN:**	6.8 - 7.2 mg/l
TOTAL ORGANIC NITROGEN:	0.3 mg/l	**TEMPERATURE:**	29.0 - 29.5°C
CHLOROPHYLL-A:	12 µg/l	**pH:**	7.3

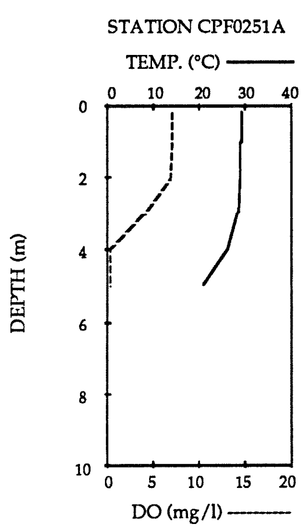
Burlington Reservoir (also called Lake Cammack) is an auxiliary water supply formed at the confluence of Stoney Creek and Toms Creek in Alamance County. The reservoir, owned by the City of Burlington, is classified WS-III. The lake has an average depth of four meters and a volume of 12.2 x 10^6 m^3. The drainage area covers 73 km^2, which is mainly forested and agricultural land.

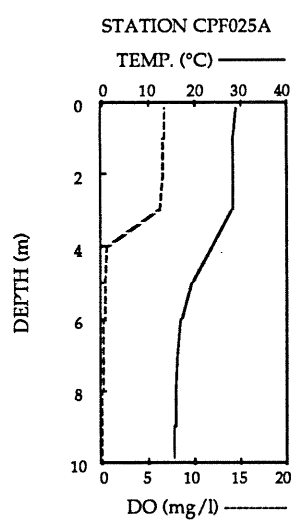
Burlington Reservoir was sampled on August 16, 1988. Physical measurements indicated that the lake was stratified at both sampling stations with the thermocline occurring at a depth of three to five meters. Photic zone nutrient concentrations were moderate and consistent throughout the lake. Nutrient concentrations in the hypolimnion were higher than those in the photic zone, a situation commonly found in stratified lakes.

Estimates of phytoplanktonic density and biovolume reflected the moderate nutrient concentrations. Estimates from the lower end of the reservoir were dominated by Rhizosolenia eriensis (Bacillariophyta). The large size of this diatom is evidenced by the fact that 40% of the total biovolume was derived from only 2% of the total density.

Trophic state index values have remained constant at Burlington Reservoir: 0.0 in both 1987 and 1988, and 0.2 in 1982. At the time of the last assessment, no violations of state water quality standards were observed at Burlington Reservoir, and the lake supported its designated uses.


BURLINGTON
RESERVOIR
Buttermilk Creek
SR 1001
SR 1002
CPF0251A
CPF025A
N
0
1 mile


STATION CPF0251A
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0 2 4 6 8 10
0 5 10 15 20
DO (mg/l)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TEMP. (°C)
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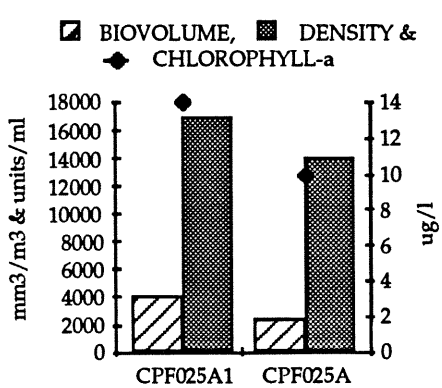
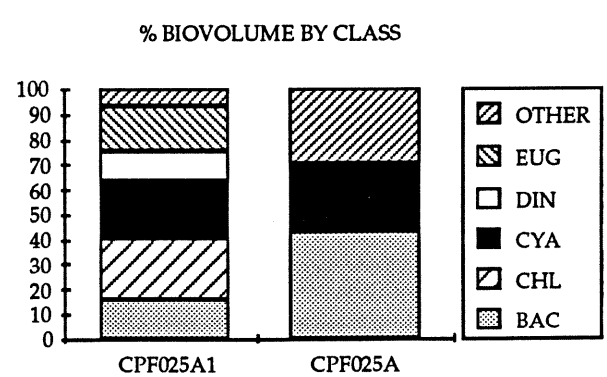
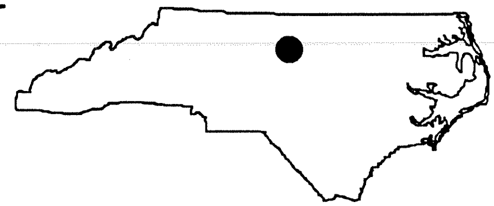
DEPTH (m)
0 2 4 6 8 10
0 5 10 15 20
DO (mg/l)


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/m3 & units/ml
18000 16000 14000 12000 10000 8000 6000 4000 2000 0
14 12 10 8 6 4 2 0
ug/l
CPF025A1
CPF025A


% BIOVOLUME BY CLASS
100 90 80 70 60 50 40 30 20 10 0
CPF025A1
CPF025A
OTHER
EUG
DIN
CYA
CHL
BAC

LAKE BURLINGTON



COUNTY:	Alamance	BASIN:	Cape Fear
SURFACE AREA:	55 hectares (137 acres)	USGS TOPO:	Lake Burlington, N.C.
CLASS:	WS	LAKE TYPE:	Reservoir

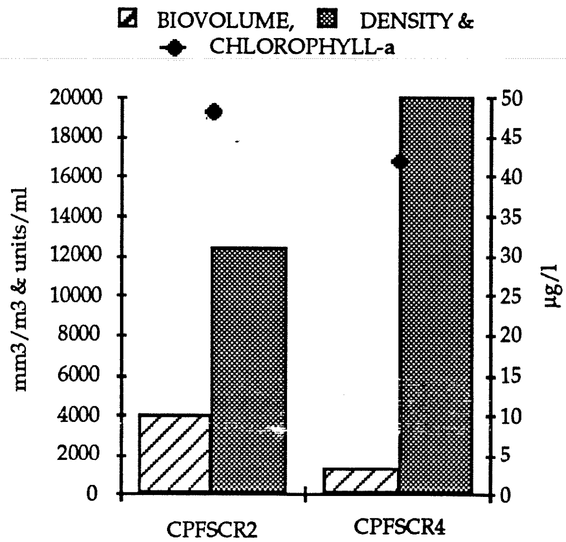
LATEST NCTSI:	1.7	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	July 19, 1990	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	0.7 m	CONDUCTIVITY:	98 μmhos/cm^2
TOTAL PHOSPHORUS:	0.04 mg/l	DISSOLVED OXYGEN:	8.6 - 8.8 mg/l
TOTAL ORGANIC NITROGEN:	0.235 mg/l	TEMPERATURE:	27.9 - 28.5°C
CHLOROPHYLL-A:	45 μg/l	pH:	8.2 - 8.3 s.u.

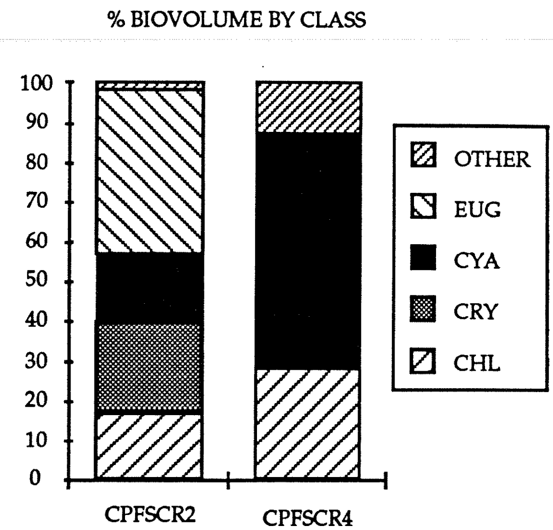
Lake Burlington (also known as Stony Creek Reservoir) was built in 1928 by the City of Burlington as a water supply. Volume in the lake is 1.5×10^6 m^3 with maximum and average depths of eight and two meters respectively. Approximately 38,000 m^3 per day are extracted from the lake. Mean retention time is approximately 40 days. Stony Creek and Toms Creek drain the 285 km^2 watershed which is characterized by rolling hills. Agriculture is the most common land use upstream of the lake.

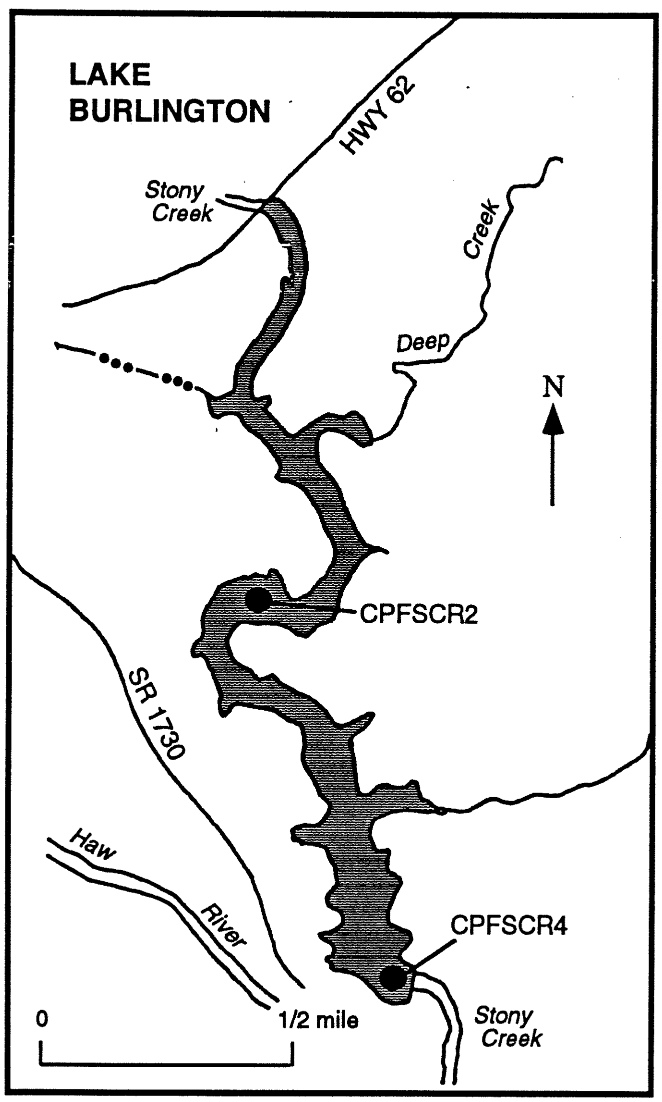
Lake Burlington was sampled on July 19, 1990. The lake was brownish with some suspended solids near the surface. Mild stratification was evident along with high surficial pH. Nutrients were elevated and the chlorophyll-a standard was violated at both stations. Metals were not detected in surface samples collected from the dam.

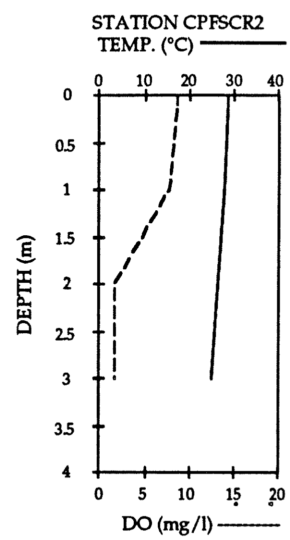
Estimates of phytoplanktonic density in Lake Burlington were representative of an algal bloom (12,368 and 19,652 units/ml). Two small, filamentous, blue-green algae, Anabaenopsis raciborskii and Lyngbya species A, dominated algal communities at both sampling stations. These species are often found in other eutrophic piedmont reservoirs during the summer.

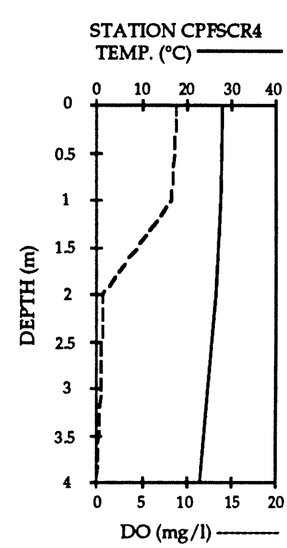
Lake Burlington was classified as eutrophic in 1990. Chlorophyll-a violations were documented and bloom conditions were found. Although some enrichment problems exist, Lake Burlington fully supported designated uses.


BIOVOLUME, DENSITY & CHLOROPHYLL-a
mm3/m3 & units/ml
µg/l
CPFSCR2
CPFSCR4

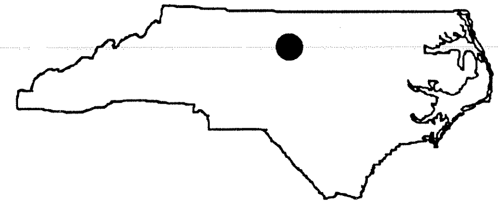

% BIOVOLUME BY CLASS
OTHER
EUG
CYA
CRY
CHL
CPFSCR2
CPFSCR4


LAKE BURLINGTON
HWY 62
Stony Creek
Deep Creek
N
CPFSCR2
SR 1730
Haw River
CPFSCR4
Stony Creek
0
1/2 mile


STATION CPFSCR2
TEMP. (°C)
DEPTH (m)
DO (mg/l)


STATION CPFSCR4
TEMP. (°C)
DEPTH (m)
DO (mg/l)

QUAKER CREEK RESERVOIR



COUNTY:	Alamance	BASIN:	Cape Fear
SURFACE AREA:	57 hectares (140 acres)	USGS TOPO:	Mebane, N.C.
CLASS:	WS	LAKE TYPE:	Reservoir

LATEST NCTSI:	2.5	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	July 19, 1990	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	0.8 m	CONDUCTIVITY:	90 - 93 µmhos/cm^2
TOTAL PHOSPHORUS:	0.05 mg/l	DISSOLVED OXYGEN:	7.4 - 7.5 mg/l
TOTAL ORGANIC NITROGEN:	0.375 mg/l	TEMPERATURE:	28.6 - 29.6°C
CHLOROPHYLL-A:	43.5 µg/l	pH:	7.7 - 8.1 s.u.

Quaker Creek Reservoir was built by the City of Graham in 1965 to be used as a water supply. Maximum depth in this reservoir is seven meters with a volume of approximately 1.6 x 10^6 m^3. Quaker and Scrub Creeks drain the 145 km^2 watershed. Half of this drainage area is forested with the majority of the remaining land used for agriculture.

This summary represents the first and last data collection by DEM on Quaker Creek Reservoir because the City of Graham and the City of Mebane have contracted to build a new water supply lake which will include what was Quaker Creek Reservoir. The new reservoir, tentatively named Graham-Mebane Reservoir, will be completed by mid-1991 and will be 274 hectares.

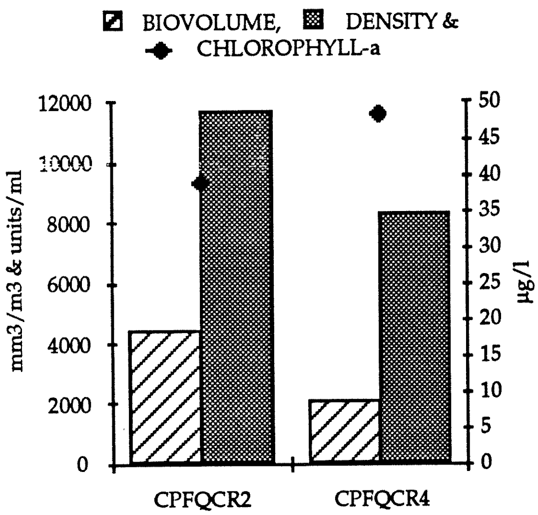
Quaker Creek Reservoir is classified WS-III, but Graham and Mebane have petitioned for reclassification of the new reservoir to WS-I. Fishing and skiing are common at the reservoir.

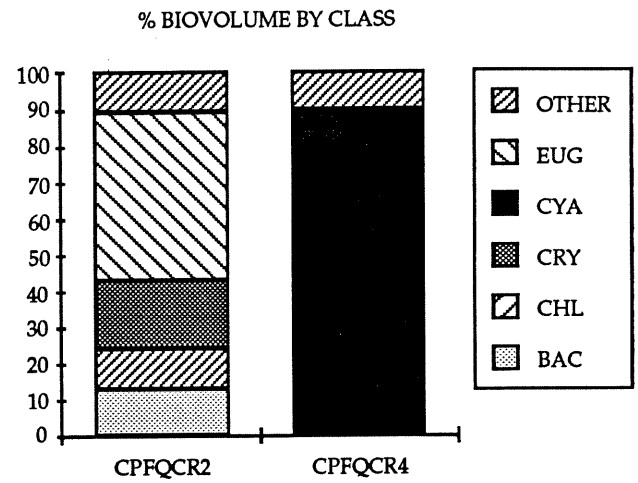
Quaker Creek Reservoir was stratified near the dam with anoxia occurring below three meters. Conductivity increased with depth, but pH decreased with depth. The water was brownish but relatively few suspended solids were noticed. Total phosphorus was elevated and one chlorophyll-a violation was documented at the dam. Metals were not detected in surface water samples.

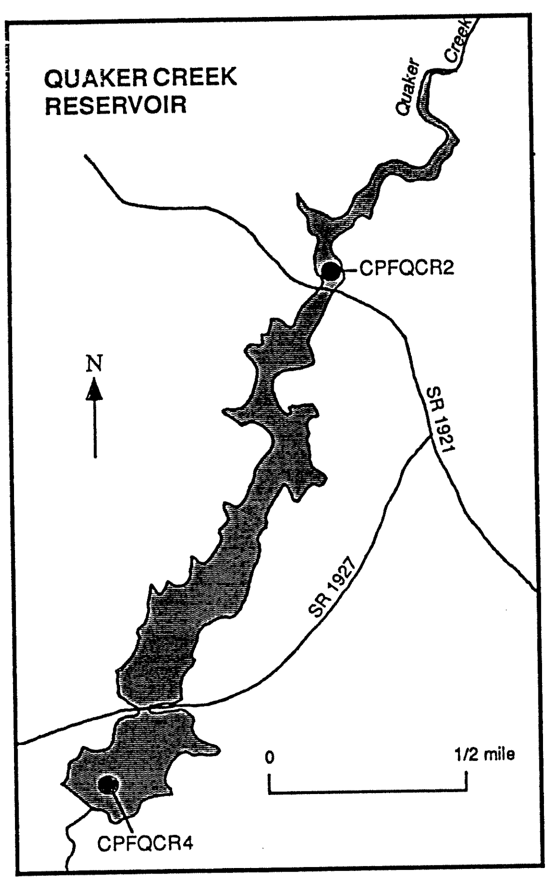
The moderate to high levels of algal biovolume and density are indicative of the eutrophic status of Quaker Creek Reservoir. The euglenophytes, Trachelomonas hispida,

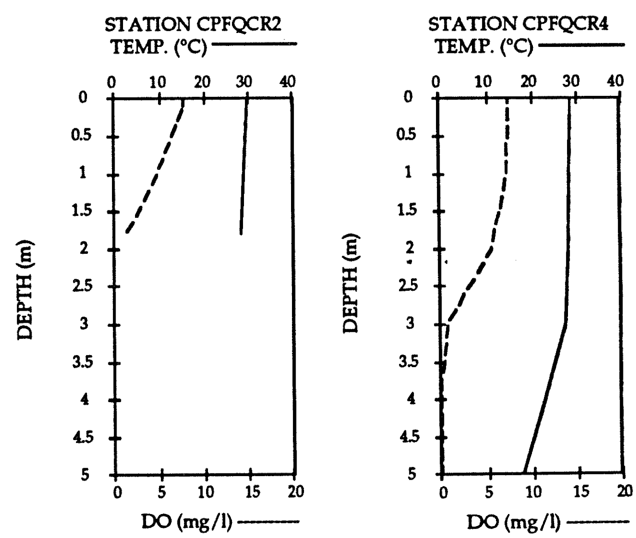
T. species, and Euglena polymorpha, constituted almost 50% of the total biovolume (4,413 mm^3/m^3) at CPFQCR2. Blue-green algae were dominant at station CPFQCR4 . Aphanizomenon flos-aquae (a large, filamentous, blue-green alga) made up 96% of the biovolume, and Aphanocapsa delicatissima (a small, colonial, blue-green alga) constituted 78% of the algal density.

A TSI of 2.5 indicated that Quaker Creek Reservoir was eutrophic. Although productivity was high in this lake, it fully supported designated uses in 1990.

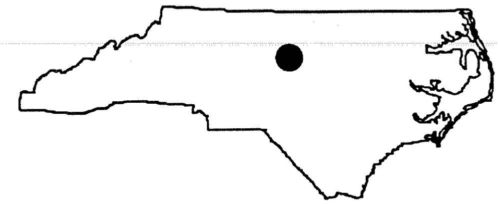








CANE CREEK RESERVOIR



COUNTY:	Orange	BASIN:	Cape Fear
SURFACE AREA:	202 hectares (500 acres)	USGS TOPO:	Chapel Hill, N.C.
CLASS:	WS	LAKE TYPE:	Reservoir

LATEST NCTSI:	0.7	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	August 30, 1990	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	1.1 m	CONDUCTIVITY:	74 - 83 µmhos/cm^2
TOTAL PHOSPHORUS:	0.03 mg/l	DISSOLVED OXYGEN:	5.6 - 7.4 mg/l
TOTAL ORGANIC NITROGEN:	0.3 mg/l	TEMPERATURE:	28.5 - 29.1°C
CHLOROPHYLL-A:	23.5 µg/l	pH:	6.4 - 6.7 s.u.

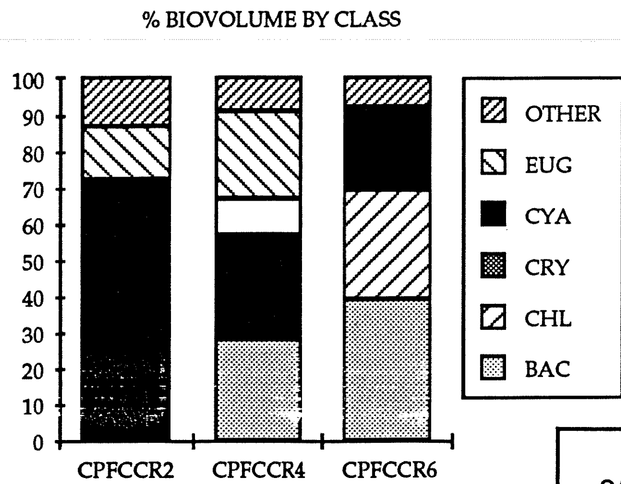
Cane Creek Reservoir was built in 1989 by Orange Water and Sewer Authority (OWASA) as a water supply for the City of Chapel Hill. The volume of the reservoir is 1.1 x 10^7 m^3 with a maximum depth of approximately 16.5 meters and an average depth of 2.5 meters. The majority of the 82 km^2 watershed is forested with some agriculture. Two main tributaries entering the lake are Cane Creek and Turkey Hill Creek.

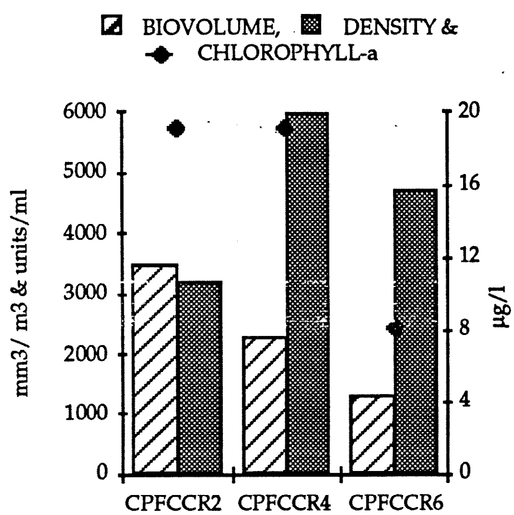
As part of a watershed protection plan, OWASA monitors tributaries to Cane Creek Reservoir on a weekly basis. Approximately 10,000 trees are planted each year through this program to stabilize stream banks and provide habitat for wildlife.

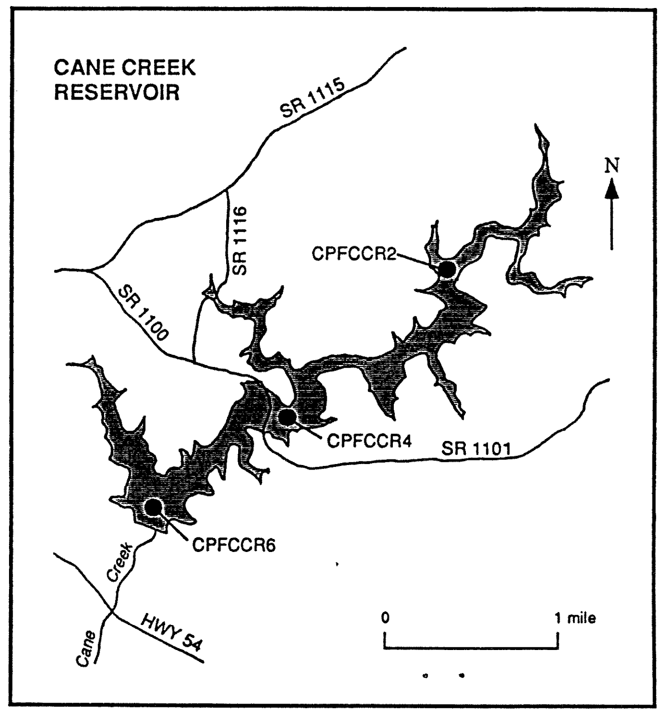
Cane Creek Reservoir was monitored on August 30, 1990. Below four meters, oxygen approached zero in the stratified water column. Turbidity and residue were low, however, phosphorus and chlorophyll-a denoted enriched conditions.

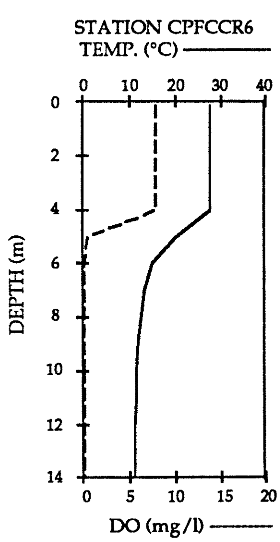
Algal measurements taken from Cane Creek Reservoir were moderately high, with algal biovolume estimates lower towards the dam. Anabaena portoricensis (a large, filamentous, blue-green alga) composed 60% of the biovolume estimate at CPFSCR2. Merismopedia tenuissima, a tiny, colonial blue-green alga, was the cause of the increased density estimates toward the dam.

Cane Creek is eutrophic as indicated by its TSI of 0.7. No violations of water quality standards were observed and all uses were fully supported at the time of this assessment.


% BIOVOLUME BY CLASS
100
90
80
70
60
50
40
30
20
10
0
CPFCCR2
CPFCCR4
CPFCCR6
OTHER
EUG
CYA
CRY
CHL
BAC


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/ m3 & units/ml
µg/l
6000
5000
4000
3000
2000
1000
0
20
16
12
8
4
0
CPFCCR2 CPFCCR4 CPFCCR6


CANE CREEK
RESERVOIR
SR 1115
SR 1116
SR 1100
SR 1101
HWY 54
Cane
Creek
CPFCCR2
CPFCCR4
CPFCCR6
N
0
1 mile


STATION CPFCCR6
TEMP. (°C)
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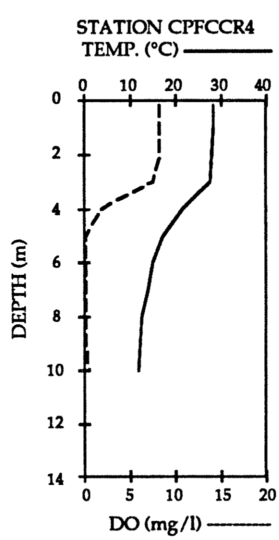
DEPTH (m)
0
2
4
6
8
10
12
14
0 5 10 15 20
DO (mg/l)


STATION CPFCCR4
TEMP. (°C)
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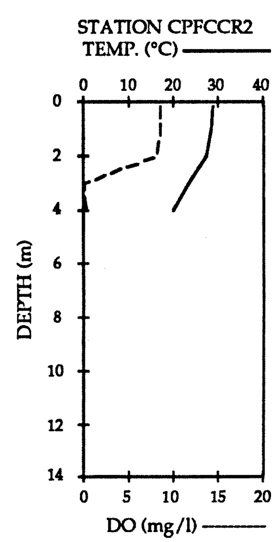
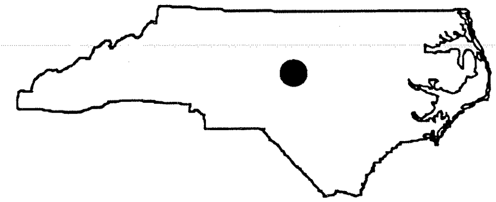
DEPTH (m)
0
2
4
6
8
10
12
14
0 5 10 15 20
DO (mg/l)


STATION CPFCCR2
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0
2
4
6
8
10
12
14
0 5 10 15 20
DO (mg/l)

PITTSBORO LAKE



COUNTY:	Chatham	BASIN:	Cape Fear
SURFACE AREA:	15 hectares (38 acres)	USGS TOPO:	Pittsboro, N.C.
CLASS:	WS, NSW	LAKE TYPE:	Reservoir

LATEST NCTSI:	2.7	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	August 4, 1987	ADDITIONAL COVERAGE:	Fecal, Metals, and Pesticides
SECCHI DEPTH:	0.7 m	CONDUCTIVITY:	44 - 81 µmhos/cm^2
TOTAL PHOSPHORUS:	0.055 mg/l	DISSOLVED OXYGEN:	7.8 - 9.1 mg/l
TOTAL ORGANIC NITROGEN:	0.475 mg/l	TEMPERATURE:	31 °C
CHLOROPHYLL-A:	26.5 µg/l	pH:	7.4 - 7.6 s.u.

Pittsboro Lake is a small auxiliary water supply reservoir located just outside the Town of Pittsboro in Chatham County. The lake is a system of two separate ponds connected by a canal that becomes dry during periods of low precipitation. The lake is owned by the Town of Pittsboro and is classified WS-III. The impoundment is shallow with a maximum depth of two meters at the dam on the lower pond. The 21 km^2 drainage area is mainly agricultural with some forested and residential land use.

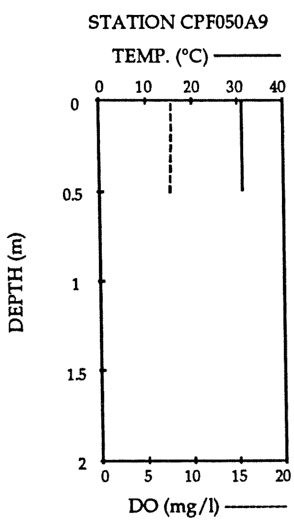
Pittsboro Lake was sampled on August 4, 1987, when the canal connecting the two ponds was dry. Physical measurements indicated that the station on the lower pond (CPF050B) was stratified while the shallow station on the upper pond (CPF050A9) was mixed. Field observations noted that the water was a "dirty brown color" and had a low secchi depth of 0.7 m. Dark turbid waters are often associated with eutrophic lake systems. Nutrient and chlorophyll-a concentrations were elevated in Pittsboro Lake with higher chlorophyll-a found in the upper pond. Fecal coliform bacteria levels were at or below laboratory detection limits. Heavy metal concentrations were below laboratory detection limits except zinc, which was within water quality standards.

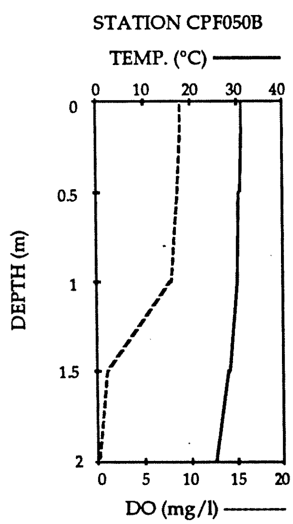
Phytoplanktonic samples collected at Pittsboro Lake were dominated by blue-green algae, euglenophytes, and green algae. Anabaenopsis raciborskii, a small blue-green alga commonly found in enriched piedmont reservoirs was dominant at both stations.

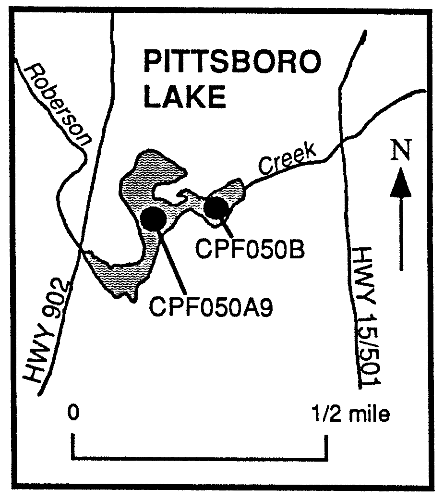
Ankistrodesmus falcatus, a green alga, and several species of Euglena, euglenophytes, were also prevalent at both stations. Pittsboro Lake was sampled in 1981 when the dominance of algal classes was similar to that found in 1987, although species composition varied.

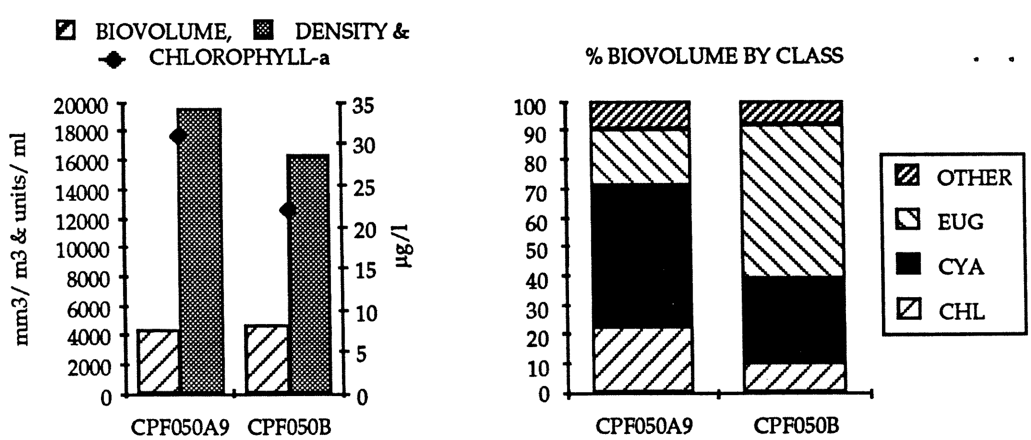
The moderately high chlorophyll-a levels and elevated estimates of density and biovolume reflect the eutrophic status of this lake. In a shallow, well-mixed reservoir such as Pittsboro Lake, high productivity is not surprising, as adequate nutrients and light are available for phytoplanktonic growth.

In 1987 the TSI was 2.7 which is lower than the value of 3.9 documented in 1984. A TSI value this high indicates the potential for water quality problems exists in this productive lake. At the time of assessment, no violations of state water quality standards were observed at Pittsboro Lake and the impoundment fully supported designated uses.

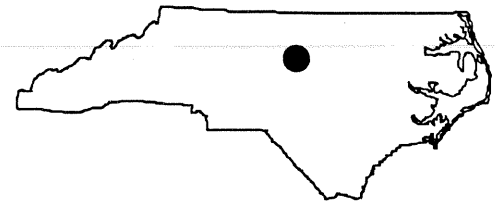








UNIVERSITY LAKE



COUNTY:	Orange	BASIN:	Cape Fear
SURFACE AREA:	83 hectares (205 acres)	USGS TOPO:	Chapel Hill, N.C.
CLASS:	WS	LAKE TYPE:	Reservoir

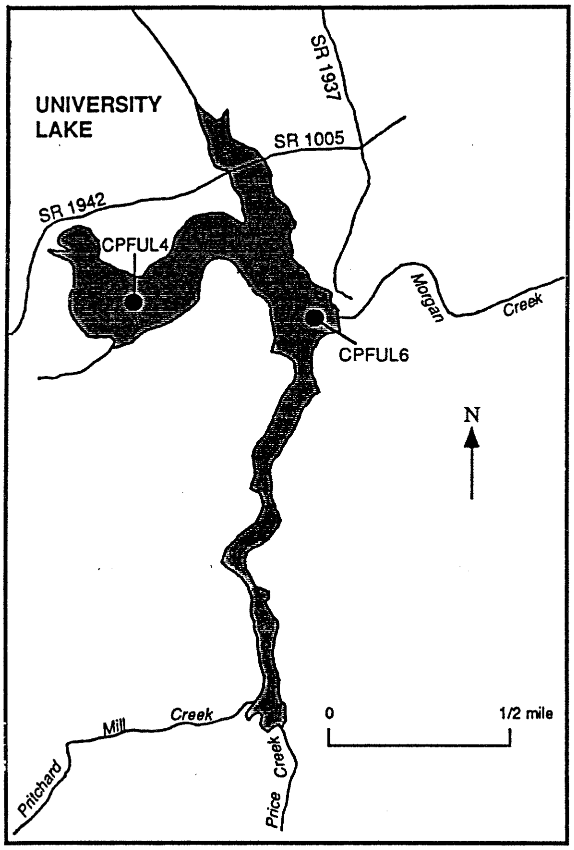
LATEST NCTSI:	2.8	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	August 30, 1990	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	0.65 m	CONDUCTIVITY:	86-87 µmhos/cm^2
TOTAL PHOSPHORUS:	0.07 mg/l	DISSOLVED OXYGEN:	6.4 - 7.3 mg/l
TOTAL ORGANIC NITROGEN:	0.4 mg/l	TEMPERATURE:	27.5 - 28.1 °C
CHLOROPHYLL-A:	25.5 µg/l	pH:	6.6 - 6.8 s.u.

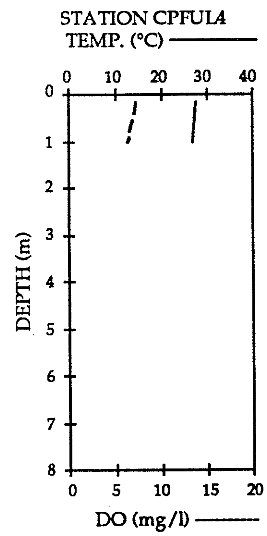
Originally impounded in 1932, University Lake was raised three feet in 1970, increasing the volume to 2.6 x 10^6 m^3. Maximum depth is seven meters and average depth is approximately 1.5 meters. Orange Water and Sewer Authority leases the lake from the University of North Carolina to provide drinking water for the City of Chapel Hill. Some recreational fishing and boating are also allowed on the lake. Nearly three quarters of the 75 km^2 watershed is forested with some agriculture and residential development. Tributaries to the lake include Morgan Creek, Phils Creek, Prices Creek, and Prichards Mill Creek.

University Lake was sampled on August 30, 1990. The water column was stratified at the dam. Total phosphorus, total organic nitrogen, and chlorophyll-a were elevated.

Estimates of phytoplanktonic biovolume and density from University Lake were high (2,700 to 6,000 mm^3/m^3 and 17,500 to 31,100 units/ml respectively) and dominated by Aphanizomenon flos-aquae . This large, filamentous cyanophyte composed 75% of the biovolume at each station but only 3% of the density. The elevated chlorophyll-a at CPFUL4 can be attributed to the presence of Chlorella vulgaris, a small green alga that was not observed at CPFUL6. Ceratophyllum demersum (coontail) and Sagittaria species (duck potato) are two aquatic plants found in this body of water.

A TSI of 2.8 was calculated for University Lake, indicating it was eutrophic. All uses were being supported at the time of this assessment.


UNIVERSITY
LAKE
SR 1937
SR 1005
SR 1942
CPFUL4
CPFUL6
Morgan
Creek
N
0
1/2 mile
Mill
Creek
Pritchard
Price
Creek


STATION CPFUL4
TEMP. (°C)
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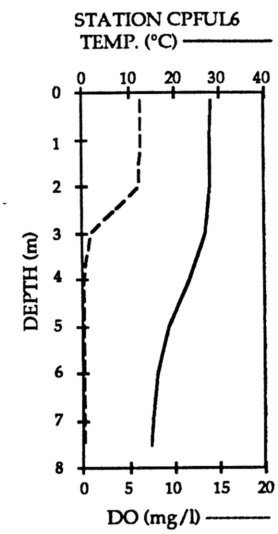
DEPTH (m)
0 1 2 3 4 5 6 7 8
0 5 10 15 20
DO (mg/l)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TEMP. (°C)
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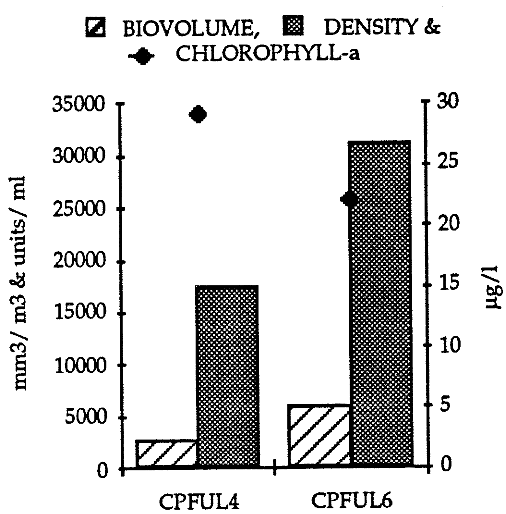
DEPTH (m)
0 1 2 3 4 5 6 7 8
0 5 10 15 20
DO (mg/l)


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/ m3 & units/ ml
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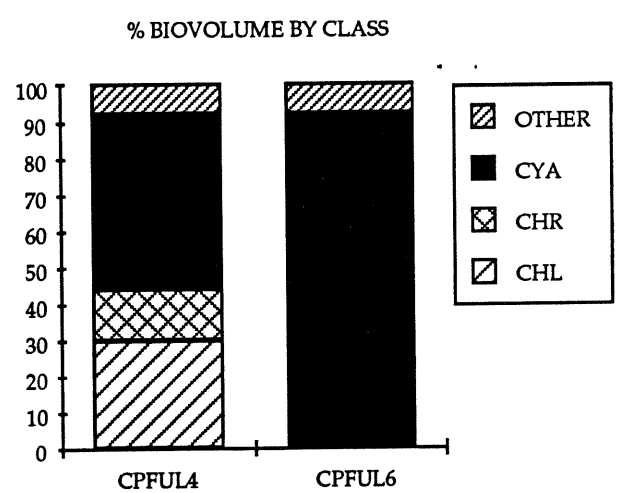
30 25 20 15 10 5 0
µg/l
CPFUL4
CPFUL6


% BIOVOLUME BY CLASS
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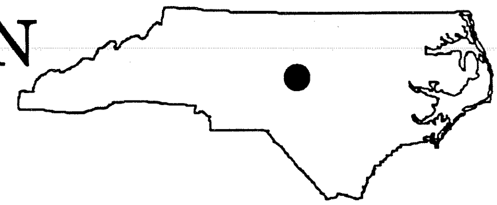
CPFUL4
CPFUL6
OTHER
CYA
CHR
CHL

B. EVERETT JORDAN RESERVOIR



COUNTY:	Chatham	BASIN:	Cape Fear
SURFACE AREA:	5787 hectares (14,300 acres)	USGS TOPO:	Merry Oaks, N.C.
CLASS:	WS, B, C - NSW	LAKE TYPE:	Reservoir

LATEST NCTSI:	4.5	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	August 2, 1990	ADDITIONAL COVERAGE:	Fecal, Metals
SECCHI DEPTH:	0.4 m	CONDUCTIVITY:	119 - 228 µmhos/cm^2
TOTAL PHOSPHORUS:	0.09 mg/l	DISSOLVED OXYGEN:	6.6 - 8.6 mg/l
TOTAL ORGANIC NITROGEN:	0.56 mg/l	TEMPERATURE:	27.6 - 28.9 °C
CHLOROPHYLL-A:	40 µg/l	pH:	7.1 - 7.6 s.u.

B. Everett Jordan Reservoir (Jordan Lake) is located in Chatham County in the eastern piedmont of North Carolina. The lake was created by the United States Army Corps of Engineers for various purposes including flood control, fish and wildlife habitat, recreation, and water supply. The dam was completed in 1974; however, initial filling of the lake did not occur until late 1981 as a result of legal and construction problems.

Jordan Lake is used extensively for boating, swimming, fishing, and other recreation. The lake has not yet been used as a water supply, but several municipalities have approval to use water from the lake in the future.

Major inflows into Jordan Lake are the Haw River and New Hope and Morgan Creeks. The Haw River has an average hydraulic retention time of five days and accounts for 70-90% of the annual flow through Jordan Lake. The New Hope arm of the lake has an average hydraulic retention time of 418 days.

Maximum depth of Jordan Lake is approximately 20 meters with a mean depth of five meters and a total volume of 265×10^6 m^3. Jordan Lake is about eight kilometers in length on the Haw River arm and 27 kilometers long on the New Hope Creek arm at full pool elevation with 241 kilometers of shoreline. The watershed of Jordan Lake is approximately 4,403 km^2. Land uses include forest, agriculture, and urban centers with much of the area undergoing industrial and residential development . Many industrial and municipal point sources discharge into the tributaries of the lake. Nonpoint sources of pollution also affect the lake.

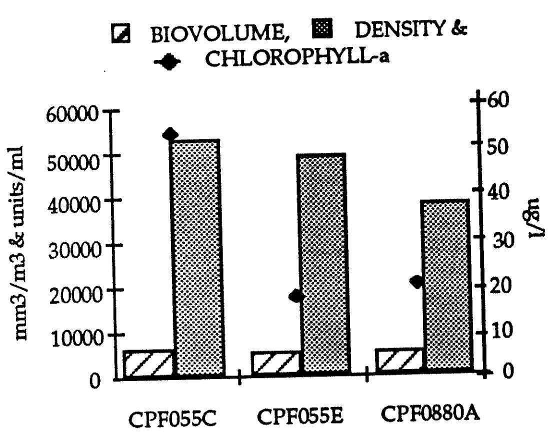
Monitoring of Jordan Lake has been performed extensively by state and university researchers since the lake was filled. Monthly monitoring of the lake by DEM began in 1983. Elevated nutrient and chlorophyll-a levels have frequently been found in the lake along with periodic blooms of blue-green algae. Jordan Lake is one of the most eutrophic lakes in North Carolina.

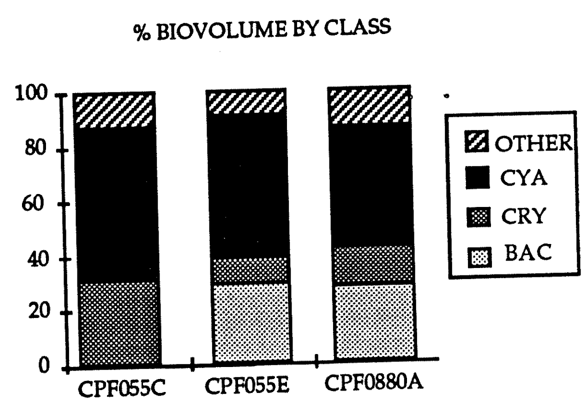
Jordan Lake was sampled on August 2, 1990. Nutrient levels were elevated with highest levels generally found in the upstream areas of the lake. Chlorophyll-a levels were elevated in the upstream areas of the Haw and New Hope arms as well. Violations of the state chlorophyll-a standard were found at CPF055C (54 µg/l) in the Haw River arm, and at CPF086F (64 µg/l) and CPF081A1C (76 µg/l) in the New Hope Creek arm. Physical measurements indicated stratified conditions at the deeper stations with anoxic conditions below six meters. Aluminum and manganese levels were detected in the New Hope Creek arm downstream to SR 1008, but levels did not dictate concern. All fecal coliform bacteria levels were below the laboratory reporting limit of 10/100 ml. Total residue concentrations were highest at stations near the headwaters of the lake due to the proximity of point and nonpoint sources upstream.

Summer algal assemblages on Jordan Lake are still dominated by small, filamentous, blue-green algae. Oscillatoria geminata was the most abundant blue-green algal species present. Commonly found in piedmont reservoirs during the summer, this alga accounts for the high estimates of density (38,606-52,231 units/ml) observed at all three sampling stations. The diatom, Rhizosolenia eriensis, codominated with O. geminata at two sampling stations.

The TSI in August 1990 was 4.5. This score is similar to past values and indicates that Jordan Lake is bordering between eutrophic and hypereutrophic conditions. In 1989, Jordan Lake was considered to be threatened by the large amount of point and nonpoint source pollution entering the lake.

Individuals interested in learning more about Jordan Lake may consult publications prepared by NRCD (1983a, 1983b, 1985b, 1986c) and the U.S. Army Corps of Engineers (1983, 1984, 1985a).





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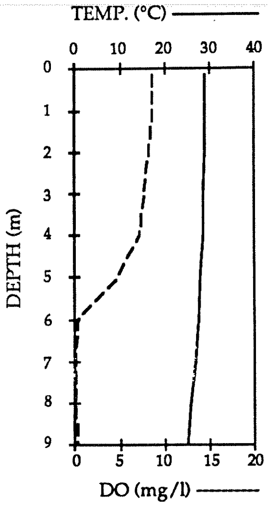

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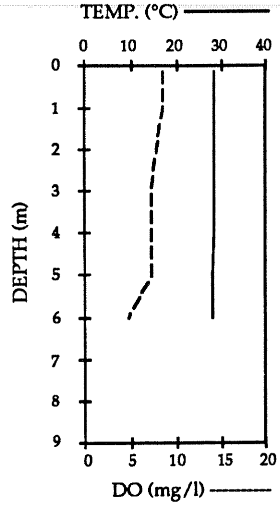

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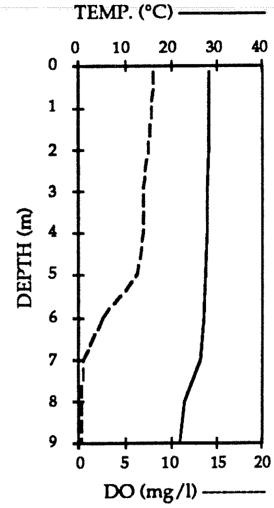

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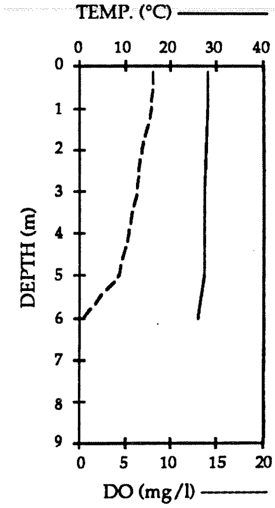

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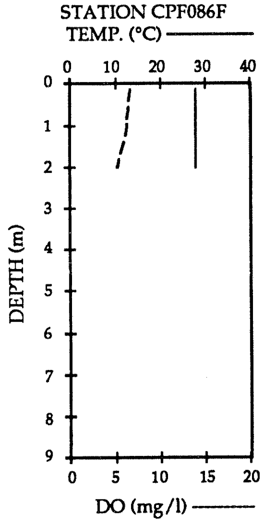

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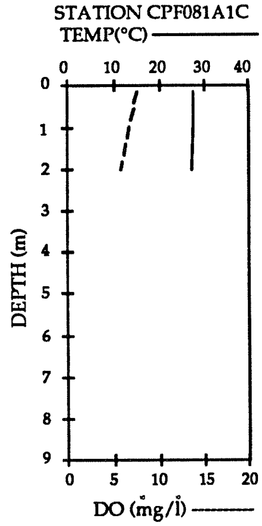

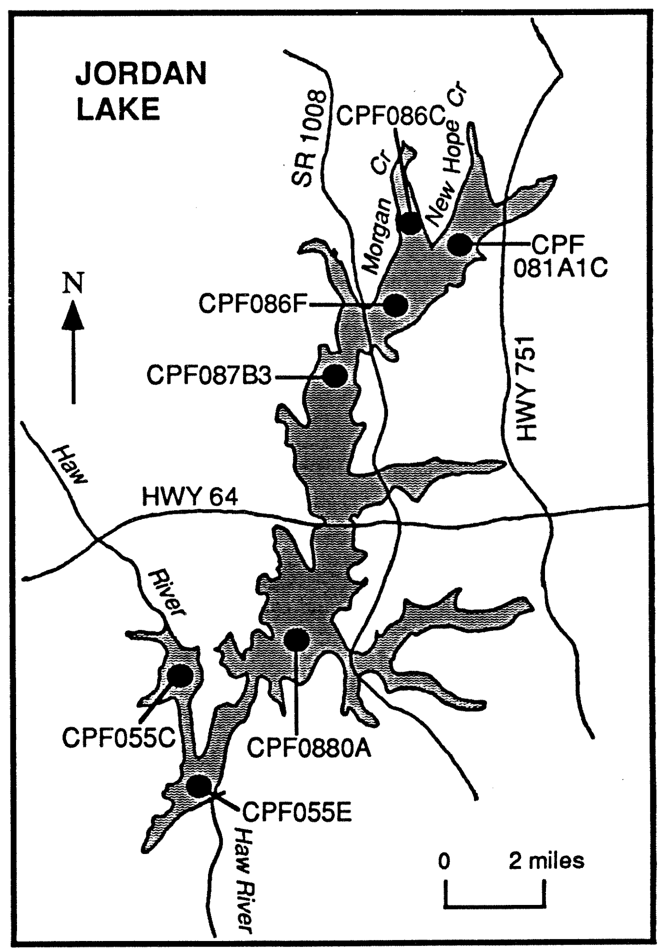

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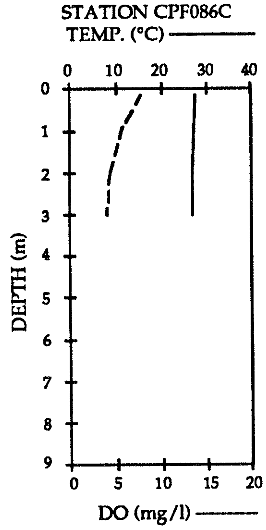
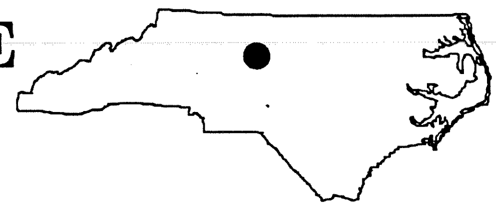


OAK HOLLOW LAKE



COUNTY:	Guilford	BASIN:	Cape Fear
SURFACE AREA:	291 hectares (720 acres)	USGS TOPO:	Guilford, N.C.
CLASS:	WS	LAKE TYPE:	Reservoir

LATEST NCTSI:	- 0.3	TROPHIC STATE:	Mesotrophic
SAMPLING DATE:	August 17, 1988	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	1.2 m	CONDUCTIVITY:	97 µmhos/cm^2
TOTAL PHOSPHORUS:	0.02 mg/l	DISSOLVED OXYGEN:	7.9 - 8.3 mg/l
TOTAL ORGANIC NITROGEN:	0.3 mg/l	TEMPERATURE:	30.5 - 30.9 °C
CHLOROPHYLL-A:	14 µg/l	pH:	8.2 - 8.4 s.u.

Oak Hollow Lake (also known as High Point Reservoir), an impoundment of the East Fork Deep River, was created by the City of High Point to establish a second water supply for the city (High Point Lake was the first). Boating, fishing, and swimming are common on the lake. The volume of the lake is 11 x 10^6 m^3, and maximum depth is 11 meters. The rolling 142 km^2 watershed is characterized by urban, residential and agricultural land uses. Future industrial development is scheduled upstream. In addition, two golf courses adjoin the lake.

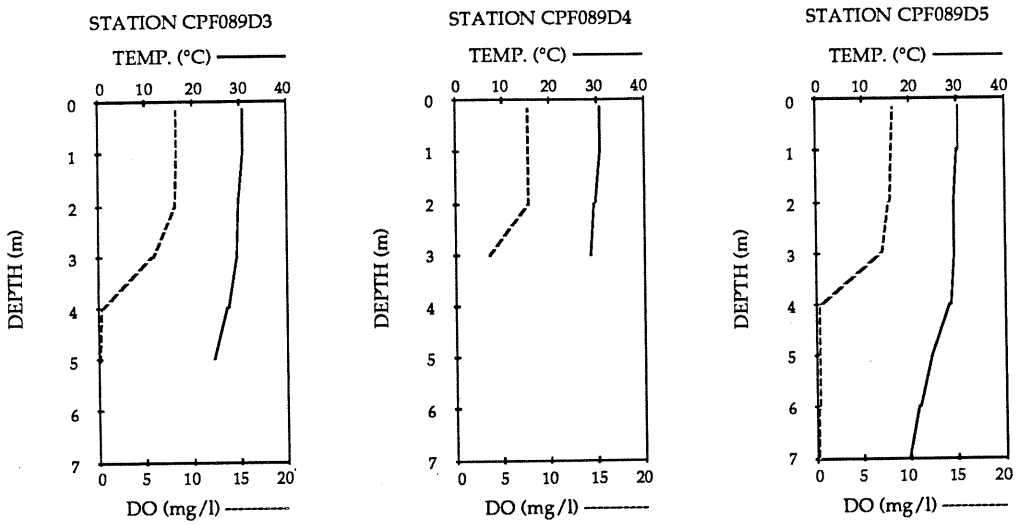
Oak Hollow Lake was sampled on August 17, 1988. Stratification was apparent at the two deeper stations. Elevated pH levels were recorded at all three stations, suggesting moderate algal activity. Nutrient and chlorophyll-a concentrations were also moderate.

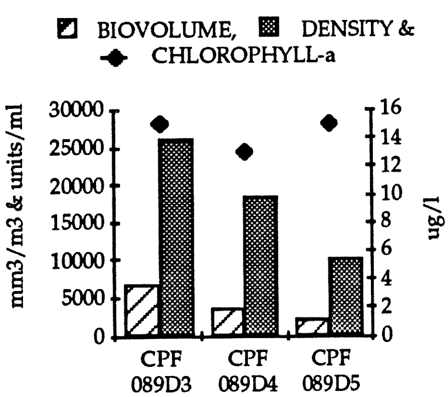
Phytoplankton were sampled at three stations. One third of the biovolume at each station was derived from green (Chlorophyta) and blue-green algae (Cyanophyta). Staurastrum tetracerum was the most prevalent green algae and Anabaenopsis raciborskii, A. phillipinensis, Anabaena levanderi, and Lyngbya species were codominant blue-green species. These species of blue-green algae are common in eutrophic lakes in North Carolina.

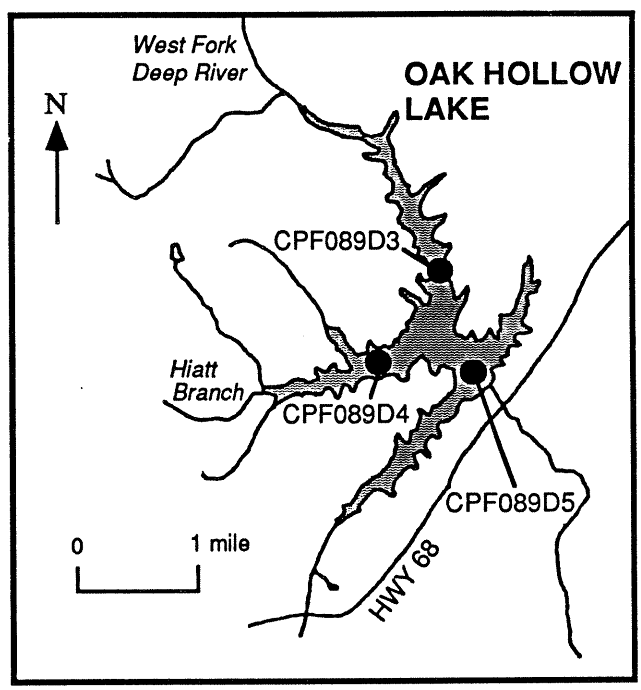
An algal bloom was recorded in July of 1990. Density and biovolume estimates ranged from 36,684 to 55,200 units/ml and 2,955 to 6,718 mm^3/m^3 respectively. The predominance of Anabaena levanderi and Anabaenopsis raciborskii, small, filamentous, blue-green algae, probably accounted for the extremely high estimates of density.

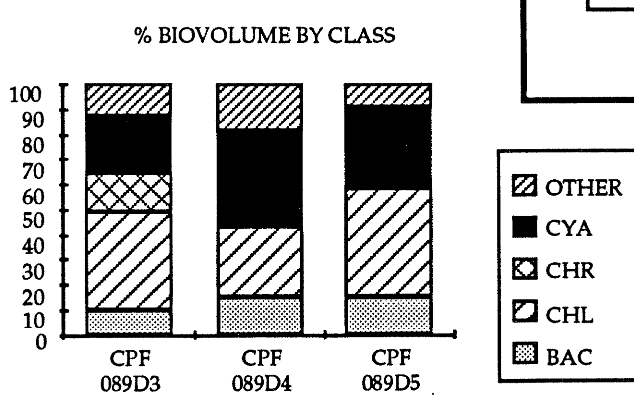
This lake also supports a substantial population of aquatic macrophytes, including water primrose (Ludwigia species) and elodea (Egeria densa).

Oak Hollow Lake had a TSI of -0.3, denoting mesotrophic conditions. All uses were supported at the time of sampling.

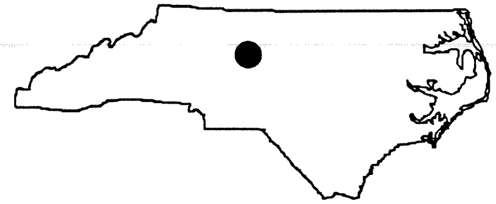








HIGH POINT LAKE



COUNTY:	Guilford	BASIN:	Cape Fear
SURFACE AREA:	121 hectares (300 acres)	USGS TOPO:	High Point East, N.C.
CLASS:	WS	LAKE TYPE:	Reservoir

LATEST NCTSI:	1.2	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	August 17, 1988	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	1.0 m	CONDUCTIVITY:	109 - 113 µmhos/cm^2
TOTAL PHOSPHORUS:	0.02 mg/l	DISSOLVED OXYGEN:	8.2 - 9.6 mg/l
TOTAL ORGANIC NITROGEN:	0.265 mg/l	TEMPERATURE:	31.6 - 32.6 °C
CHLOROPHYLL-A:	29.5 µg/l	pH:	8.5 - 8.9 s.u.

High Point Lake, built in 1928 by the City of High Point, is used as a water supply and for recreation. Maximum depth in the lake is 10 meters and volume is 4.75×10^6 m^3.

Urban/residential areas, and pasture/row crop farms dominate the 155 km^2 drainage area. The two arms of the lake are fed by the East Fork Deep River and the West Fork Deep River.

The City of High Point contracted the United States Geological Survey to conduct a baseline study of the High Point Lake watershed to provide data for a long-term water quality monitoring program. The study began in September 1988 and ended in 1990. A $25 million bond referendum was passed in 1989 to protect these lakes.

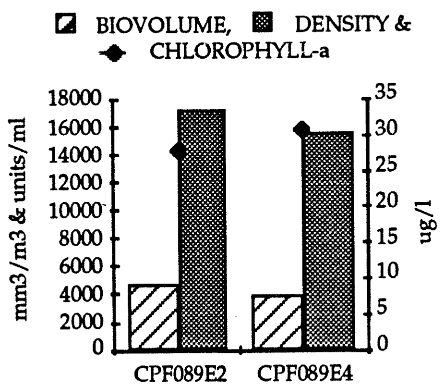
High Point Lake was sampled on August 17, 1988. Although temperature was only slightly stratified, dissolved oxygen concentrations were strongly stratified, approaching zero at the bottom of the water column. Chlorophyll-a concentrations were somewhat elevated. Nutrient levels were moderate, and solids and turbidity were within acceptable levels.

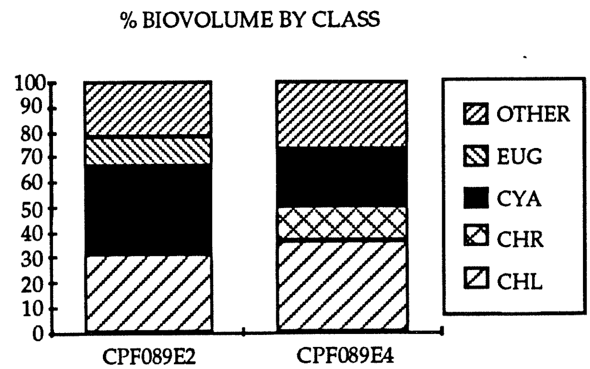
Algal biovolume and density estimates were moderate to high. Twenty-three species of green algae (Chlorophyta) were present at each station and constituted over 30% of the biovolume. Anabaena levanderi, Anabaenopsis raciborskii, Anabaenopsis phillipinensis, and Lyngbya species A (Cyanophyta) constituted at least 25% of the biovolume.

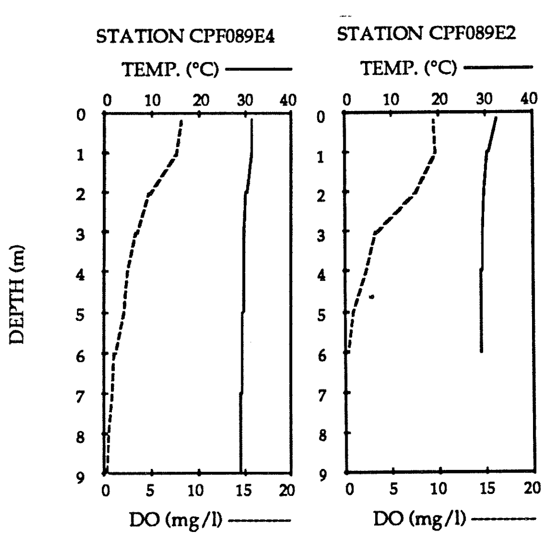
A bloom sample collected in July 1988 was composed of filamentous blue-green algae. Biovolume estimates ranged from 1,770 to 4,024 mm^3/m^3, while density estimates ranged from 10,132 to 17,468 units/ml. The predominance of Anabaena levanderi and Anabaenopsis raciborskii, small, filamentous, blue-green algae, probably contributed to these relatively high estimates of density.

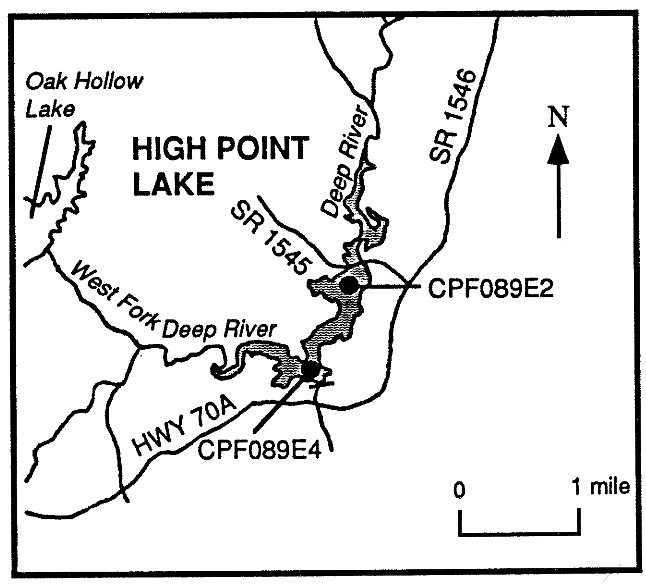
This lake also contains a large population of elodea (Egeria densa). Elodea is an aquatic macrophyte similar in appearance and habitat to hydrilla, but unlike hydrilla, it is a native species to North Carolina.

High Point Lake had a TSI of 1.2 in 1988. The reservoir has been consistently classified by DEM as eutrophic. At the time of sampling, all uses were fully supported.

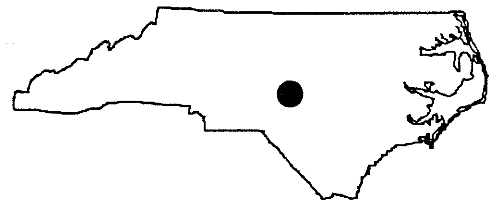








HARRIS LAKE



COUNTY:	Chatham	**BASIN:**	Cape Fear
SURFACE AREA:	1,680 hectares (4,150 acres)	**USGS TOPO:**	Cokesbury, N.C.
CLASS:	B	**LAKE TYPE:**	Reservoir

LATEST NCTSI:	-0.3	**TROPHIC STATE:**	Mesotrophic
SAMPLING DATE:	August 8, 1990	**ADDITIONAL COVERAGE:**	Fecals
SECCHI DEPTH:	2.0 m	**CONDUCTIVITY:**	60 - 67 µmhos/cm^2
TOTAL PHOSPHORUS:	0.03 mg/l	**DISSOLVED OXYGEN:**	8.2 - 8.3 mg/l
TOTAL ORGANIC NITROGEN:	0.38 mg/l	**TEMPERATURE:**	29.5 - 30.2°C
CHLOROPHYLL -A:	9 µg/l	**pH:**	6.6 - 8.0 s.u.

Harris Lake is a 1,680-hectare impoundment constructed in 1983 to provide cooling water for the Shearon Harris Nuclear Power Plant. It is also used for recreation. The lake is owned by Carolina Power and Light (CP&L) and is classified B. Future plans for the lake area include a county park with picnicking, pier fishing, and boating access, and NCSU has plans for a forestry research station.

Harris Lake is located on Buckhorn Creek. Other significant tributaries to the lake include White Oak Creek, Little White Oak Creek, Thomas Creek, and Tom Jack Creek. Maximum depth in the lake is 18 meters, mean depth is six meters and the shoreline length is 64 kilometers. Harris Lake has a drainage area covering 181 km^2 of land that is characterized by rolling hills. Land use in the watershed consists primarily of forest and agriculture.

Harris Lake was sampled on August 29,1990. Physical measurements indicated that the lake was stratified at all sampling locations with the thermocline occurring at a depth of three to five meters. Nutrient concentrations were moderate and relatively uniform throughout the lake. Chlorophyll-a values were low except near the dam. Fecal coliform bacteria and levels of heavy metals were below laboratory detection limits.

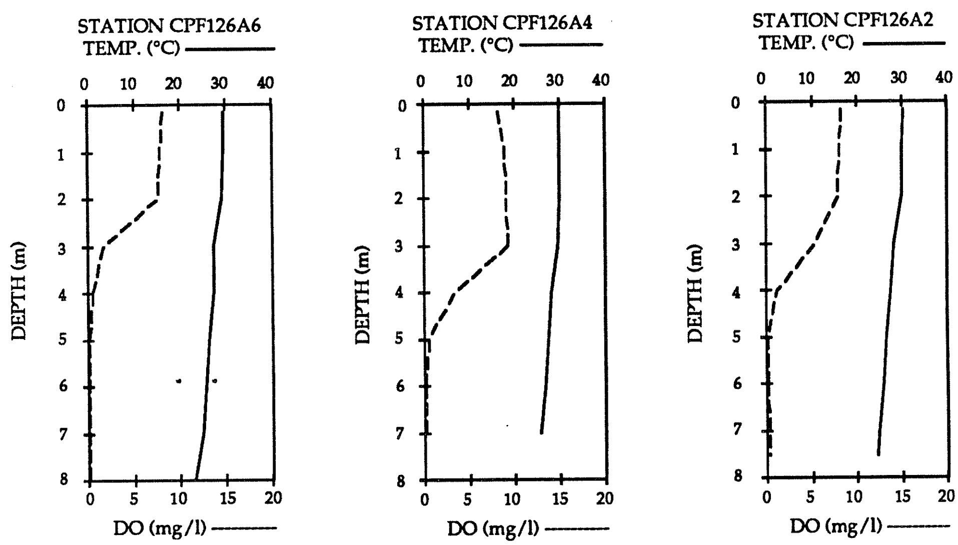
Estimates of algal biovolume were low in 1990, ranging from 829 to 1,267 mm^3/ m^3, but the density estimates were high. Lyngbya species, a small filamentous blue-green, was the dominant alga at all three stations. Densities ranged from 6,900 to 14,936 units/ml and were higher toward the dam.

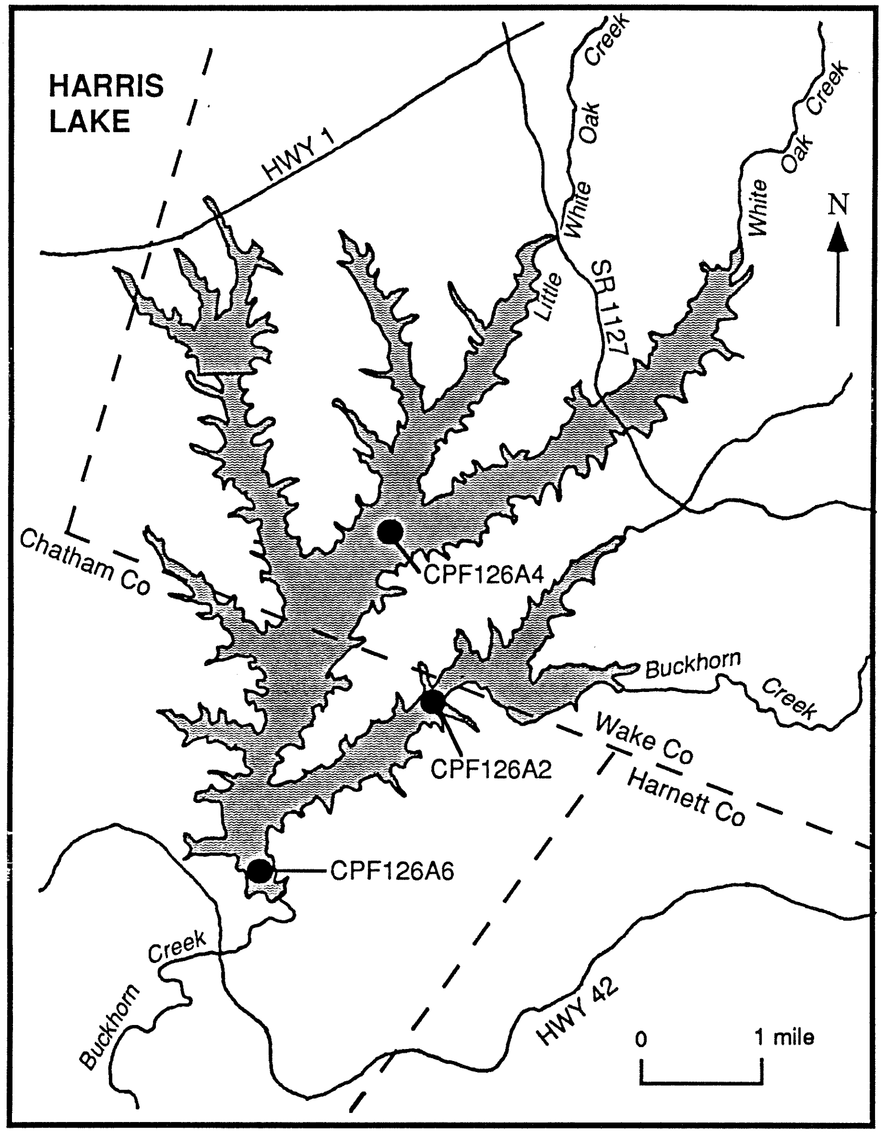
Results of sampling in 1989 revealed similar estimates of density (7,424 to 12,360 units/ml) but higher biovolumes (1,697 to 3,432 mm^3/m^3). In 1989, the station on White Oak Creek (CPF126A4) was dominated by Aphanizomenon flos-aquae (filamentous blue-green). Algal assemblages at the other two stations were made up of Chlorella species, Aphanizomenon flos-aquae, Euglena species, and two species of Peridinium.

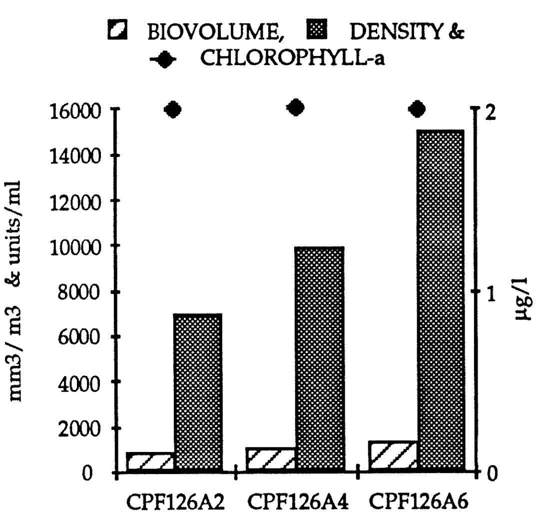
This relatively new lake contains an extremely diverse population of aquatic macrophytes. At least 55 species of aquatic plants have been collected and identified from this body of water (Carolina Power and Light, 1990a). The majority of the biomass within the lake is represented by the following species: Hydrilla verticillata (hydrilla); Potamogeton diversifolius and P. berchtoldii (pondweeds); Najas gracillima, N. guadalupensis, and N. minor (naiads); and Brasenia schreberi (water shield).

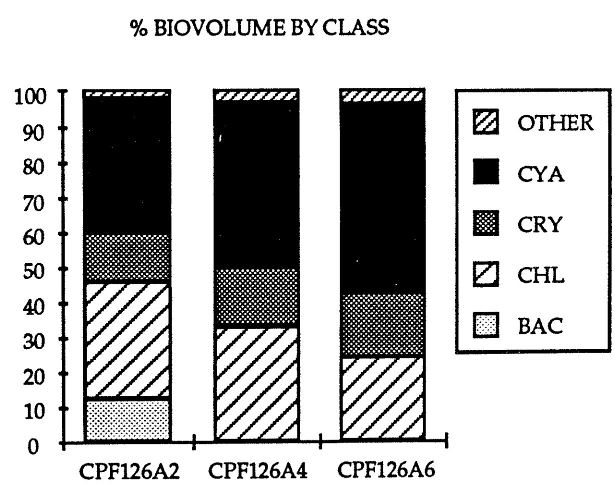
Because hydrilla often spreads rapidly, it is the only species that CP&L is actively trying to control. Since it was found in Harris Lake several years ago, CP&L has spent over $30,000 in efforts to control this macrophyte. Although the hydrilla does not yet present any operational problems, biologists are concerned that it will displace endemic vegetation. A bathymetric survey of the lake revealed that 40% of the lake could eventually be colonized by hydrilla.

The TSI was -0.3 in 1990, indicating mesotrophic conditions. At the time of assessment, no violations of state water quality standards were observed and water quality in the reservoir fully supported designated uses.

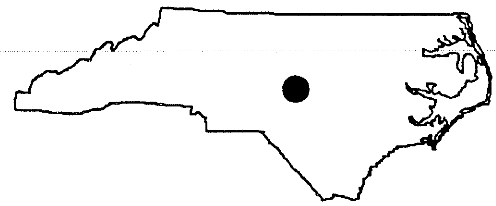



HARRIS
LAKE
HWY 1
White Oak Creek
White Oak Creek
Little
SR 1127
N
Chatham Co
CPF126A4
Buckhorn
Creek
Wake Co
Harnett Co
CPF126A2
CPF126A6
Creek
Buckhorn
HWY 42
0
1 mile


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/ m3 & units/ml
µg/l
16000
14000
12000
10000
8000
6000
4000
2000
0
2
1
0
CPF126A2
CPF126A4
CPF126A6


% BIOVOLUME BY CLASS
100
90
80
70
60
50
40
30
20
10
0
CPF126A2
CPF126A4
CPF126A6
OTHER
CYA
CRY
CHL
BAC

UPPER MOCCASIN LAKE



COUNTY:	Lee	BASIN:	Cape Fear
SURFACE AREA:	2.3 hectares (5.7 acres)	USGS TOPO:	Broadway, N.C.
CLASS:	WS	LAKE TYPE:	Reservoir

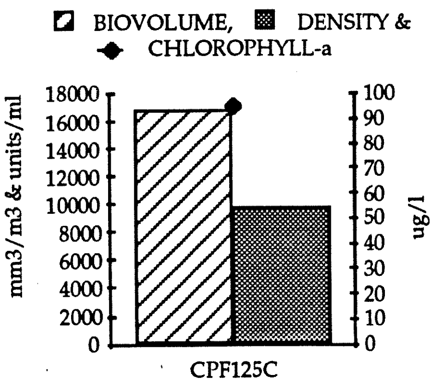
LATEST NCTSI:	4.6	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	August 10, 1988	ADDITIONAL COVERAGE:	Fecal
SECCHI DEPTH:	0.6 m	CONDUCTIVITY:	64 µmhos/cm^2
TOTAL PHOSPHORUS:	0.05 mg/l	DISSOLVED OXYGEN:	11.8 mg/l
TOTAL ORGANIC NITROGEN:	0.73 mg/l	TEMPERATURE:	29.4 °C
CHLOROPHYLL-A:	95 µg/l	pH:	9.2 s.u.

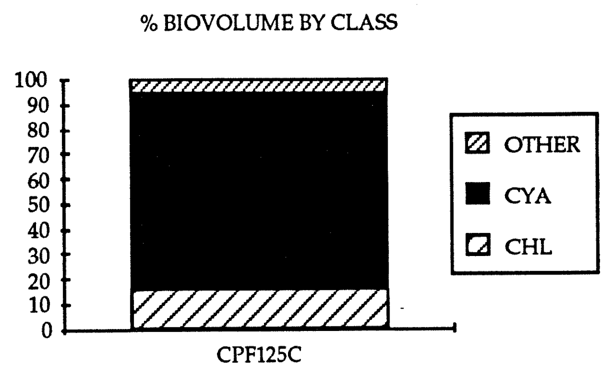
Upper Moccasin Lake is located in the San-Lee Recreational and Environmental Education Park, near the City of Sanford. The Lee County Parks and Recreation Commission owns and operates the lake which is used for fishing and canoeing. Upper Moccasin Lake has a surface area of 2.3 hectares, a maximum depth of approximately four meters, and is fed by several small, unnamed tributaries. The lake empties directly into Lower Moccasin Lake, which in turn drains into an unnamed tributary to Lick Creek. Land use in the 5.7 km^2 watershed is predominantly agricultural and residential. Topography is characterized by rolling hills.

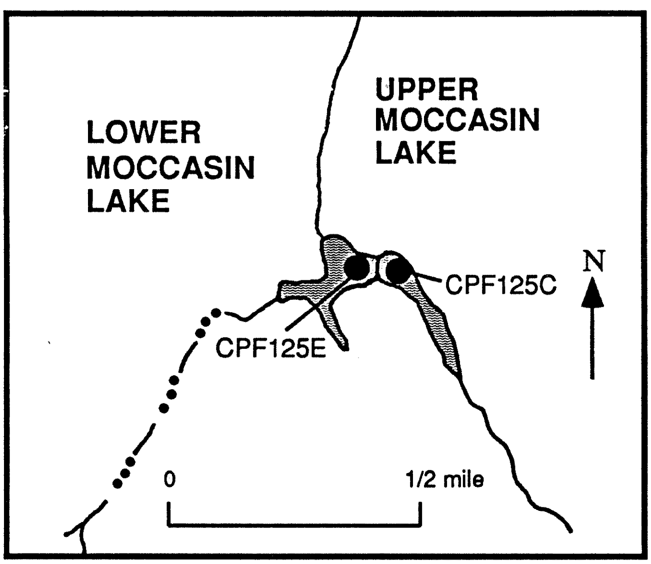
One station was sampled in Upper Moccasin Lake on August 10, 1988. Physical data showed that the lake was stratified. High surface pH and dissolved oxygen concentrations indicated algal activity was higher here than in Lower Moccasin Lake. This observation was corroborated by an extremely elevated chlorophyll-a value (95 µg/l) which exceeded the state water quality standard of 40 µg/l. The water appeared green and turbid and had a low secchi of 0.6 meters. Nutrients, especially total organic nitrogen, were high. Fecal coliforms were not detected.

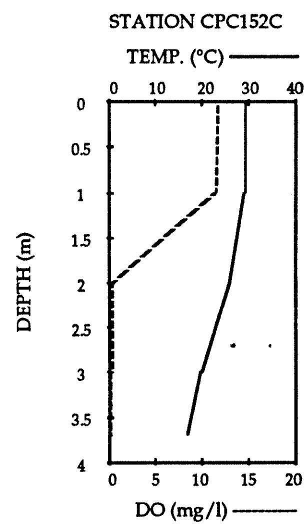
Relatively high levels of phytoplankton were collected from this lake. The estimate of phytoplanktonic biovolume (16,802 mm^3/m^3) exceeded the threshold indicative of an algal bloom. Phytoplanktonic density (9,841 units/ml) approached bloom levels . Anabaena catenula , a cyanophyte, dominated 79% and 70% of the algal biovolume and density. Domination by a single species, especially a blue-green algae, can lead to alterations in the food chain.

A TSI score of 4.6 was calculated for Upper Moccasin Lake, indicating highly eutrophic conditions. This lake was sampled for the first time in 1988; therefore, no historical water quality data were available for comparison. Uses were supported in Upper Moccasin Lake, but continuing nutrient enrichment could threaten those uses. Agricultural practices and a fish hatchery located in the watershed may contribute to the elevated nutrients in this lake, but investigations into the source have not been conducted.

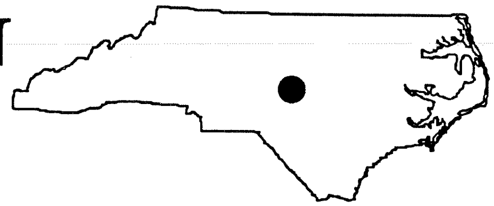








LOWER MOCCCASIN LAKE



COUNTY:	Lee	BASIN:	Cape Fear
SURFACE AREA:	3.4 hectares (8.4 acres)	USGS TOPO:	Sanford, N.C.
CLASS:	WS	LAKE TYPE:	Reservoir

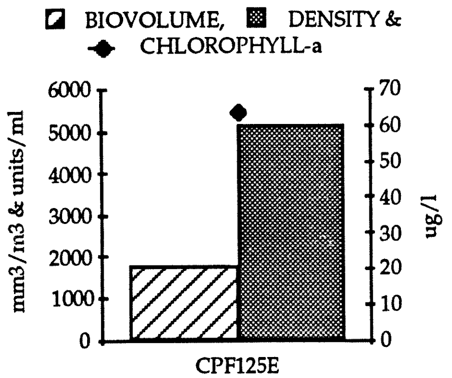
LATEST NCTSI:	2.1	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	August 10, 1988	ADDITIONAL COVERAGE:	Fecal
SECCHI DEPTH:	2.3 m	CONDUCTIVITY:	56 µmhos/cm^2
TOTAL PHOSPHORUS:	0.08 mg/l	DISSOLVED OXYGEN:	8.8 mg/l
TOTAL ORGANIC NITROGEN:	0.33 mg/l	TEMPERATURE:	29.7 °C
CHLOROPHYLL-A:	64 µg/l	pH:	7.9 s.u.

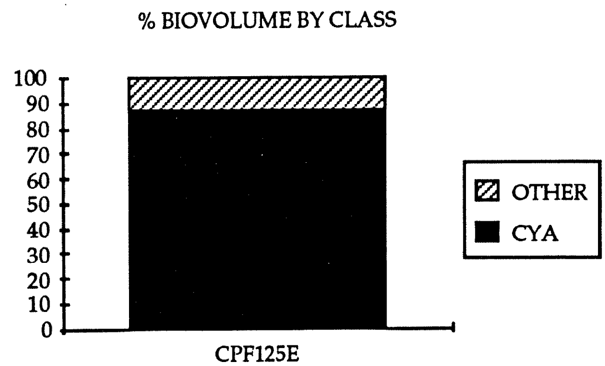
Lower Moccasin Lake is located in the San-Lee Recreational and Environmental Education Park near the City of Sanford. The Lee County Parks and Recreation Commission presently owns and operates the lake, which served as Sanford's water supply until 1975. Lower Moccasin Lake has a surface area of 3.4 hectares and a maximum depth of approximately five meters, and is used for fishing and canoeing. It is fed by Upper Moccasin Lake and two unnamed tributaries, and drains into an unnamed tributary to Lick Creek. The 8.9 km^2 watershed is characterized by rolling hills with agricultural, residential, and light commercial/industrial land uses.

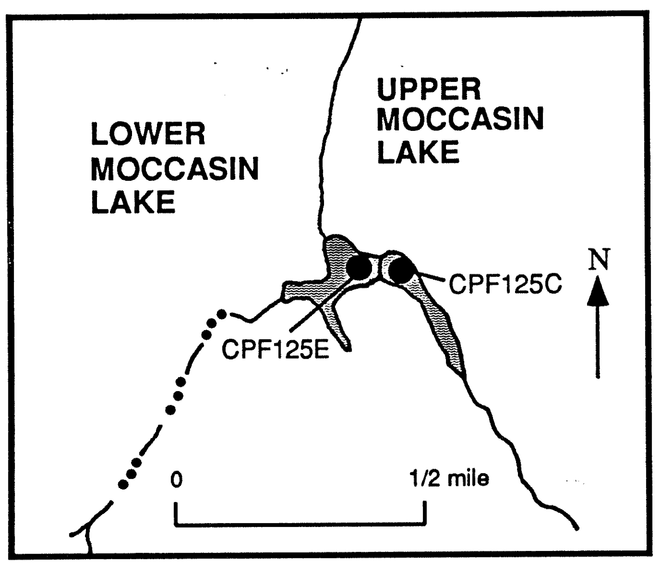
One station was sampled in Lower Moccasin Lake on August 10, 1988. Physical data showed that the lake was stratified, with nearly anoxic conditions below two meters. Surface pH and dissolved oxygen levels indicated algal activity was elevated. This was corroborated by a high chlorophyll-a value (64 µg/l) which exceeded the state water quality standard of 40 µg/l. Total phosphorus was high. Fecal coliforms were detected, but were well within the state limit of 200/100 ml.

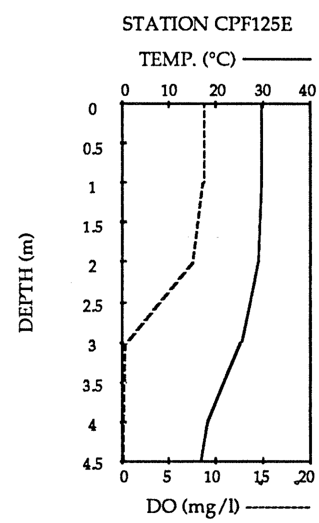
One sample was collected from Lower Moccasin Lake for phytoplankton analysis. Estimates of both biovolume and density were dominated by blue-green algae. Oscillatoria articulata composed 78% of the algal biovolume and Merismopedia tenuissima made up 62% of the density. Large populations of these blue-green algae account for the high chlorophyll-a level.

A TSI score of 2.1 was calculated for Lower Moccasin Lake, indicating eutrophic conditions. Monitoring results suggest that Upper Moccasin Lake captured some of the nutrient inputs from its tributary, thus providing protection for Lower Moccasin Lake. These lakes were not sampled before 1988; therefore, no historical water quality data were available for comparison. Uses in Lower Moccasin Lake are fully supported.

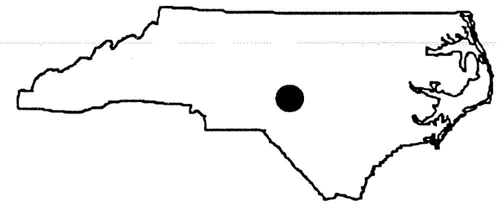








OLD TOWN RESERVOIR



COUNTY:	Moore	BASIN:	Cape Fear
SURFACE AREA:	24 hectares (60 acres)	USGS TOPO:	Southern Pines, N.C.
CLASS:	WS	LAKE TYPE:	Reservoir

LATEST NCTSI:	- 2.3	TROPHIC STATE:	Oligotrophic
SAMPLING DATE:	September 15, 1988	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	1.8 m	CONDUCTIVITY:	16 μmhos/cm^2
TOTAL PHOSPHORUS:	0.01 mg/l	DISSOLVED OXYGEN:	7.2 - 7.4 mg/l
TOTAL ORGANIC NITROGEN:	0.25 mg/l	TEMPERATURE:	25.5 - 26.0 °C
CHLOROPHYLL-A:	7.5 μg/l	pH:	5.2 - 5.8 s.u.

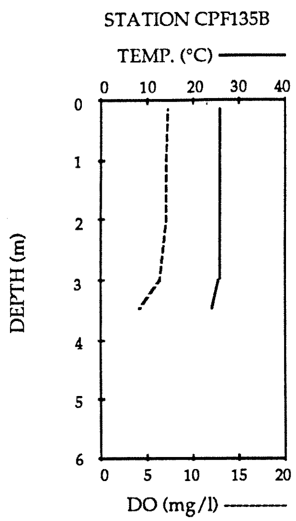
Located north of Southern Pines in the sandhills, Old Town Reservoir is an impoundment of Mill Creek. Built in 1925, this former water supply is now used for recreation. Maximum depth in the lake is seven meters, and average depth is four meters. Lake volume is 2.4×10^5 m^3. The watershed is relatively undeveloped except for a golf course. Condominium developments in the watershed were also under consideration in 1988.

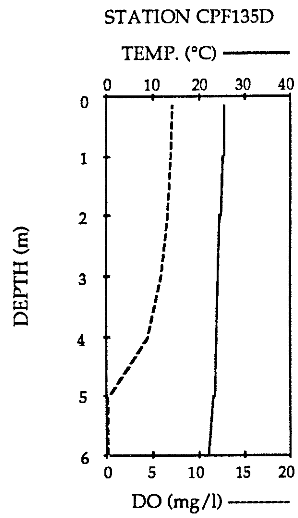
Samples collected on September 15, 1988 indicated good water quality in Old Town Reservoir. Oxygen and temperature measurements show slight stratification in the lake. Conductance was low, indicating an absence of inorganic pollution. Nutrient concentrations were low in the lake and water clarity was good. Metals were below laboratory detection limits with the exception of iron, which is typically found in surface waters across the state.

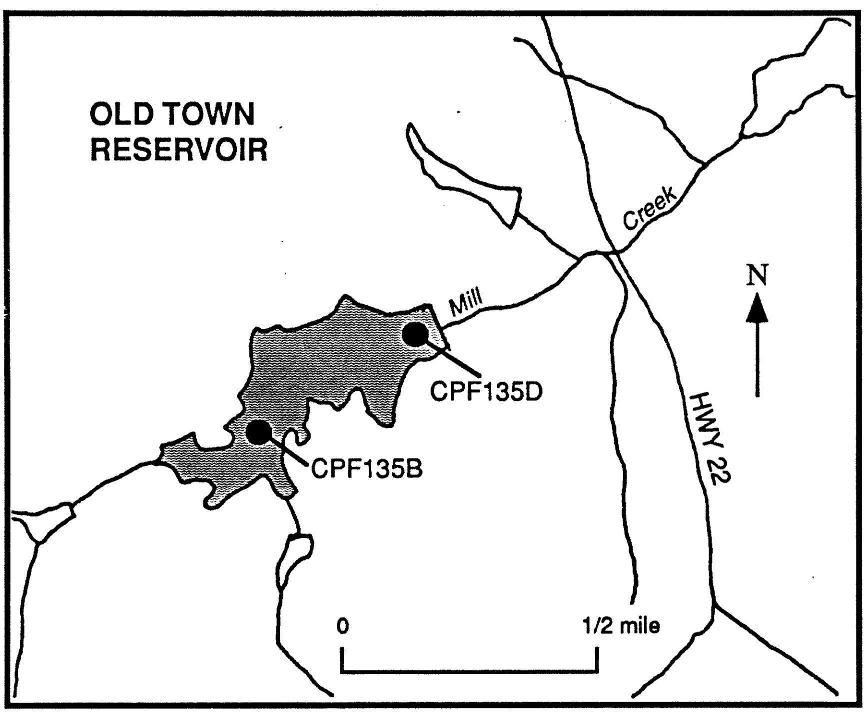
Phytoplankton from Old Town Reservoir were dominated by small colonial blue-green algae (Cyanophyta). Gloeocapsa gelatinosa dominated the biovolume estimate and was codominant with Merismopedia tenuissima for algal density.

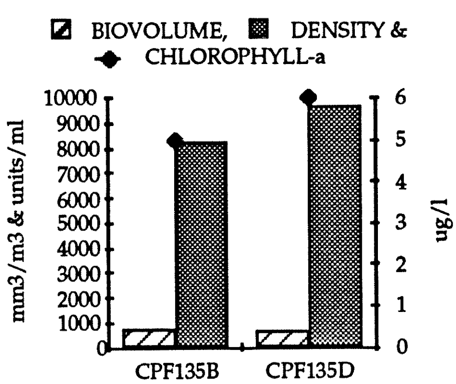
Aquatic macrophytes observed in this lake include elodea (Egeria densa), arrowhead (Sagitttaria species), and water lily (Nymphaea species).

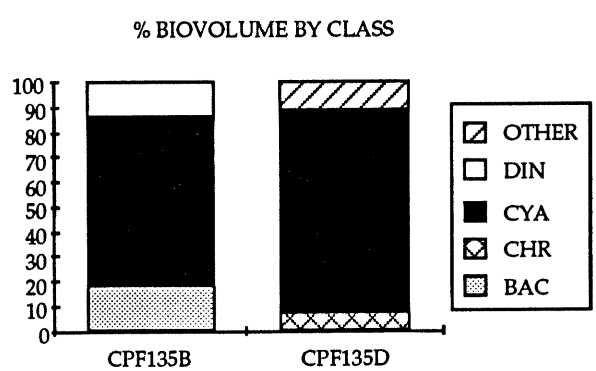
Old Town Reservoir is an oligotrophic lake with a TSI of -2.3. All uses are fully supported, and no violations of water quality standards were found.


STATION CPF135B
TEMP. (°C)
DEPTH (m)
DO (mg/l)

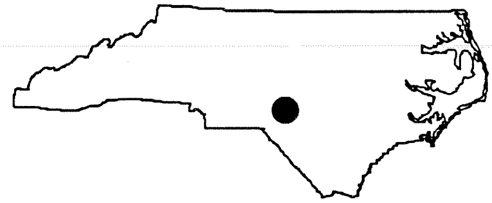

STATION CPF135D
TEMP. (°C)
DEPTH (m)
DO (mg/l)


OLD TOWN
RESERVOIR
Mill
Creek
CPF135D
CPF135B
HWY 22
N
0
1/2 mile


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/m3 & units/ml
ug/l
CPF135B
CPF135D


% BIOVOLUME BY CLASS
OTHER
DIN
CYA
CHR
BAC
CPF135B
CPF135D

MOTT LAKE



COUNTY:	Hoke	BASIN:	Cape Fear
SURFACE AREA:	61 hectares (150 acres)	USGS TOPO:	Nicholson Creek, N.C.
CLASS:	C	LAKE TYPE:	Reservoir

LATEST NCTSI:	-3.4	TROPHIC STATE:	Oligotrophic
SAMPLING DATE:	July 26, 1990	ADDITIONAL COVERAGE:	None
SECCHI DEPTH:	1.1 m	CONDUCTIVITY:	15 µmhos/cm^2
TOTAL PHOSPHORUS:	0.01 mg/l	DISSOLVED OXYGEN:	6.6 - 6.7 mg/l
TOTAL ORGANIC NITROGEN:	0.145 mg/l	TEMPERATURE:	28.9 - 29.0 °C
CHLOROPHYLL-A:	3 µg/l	pH:	3.9- 7.0 s.u.

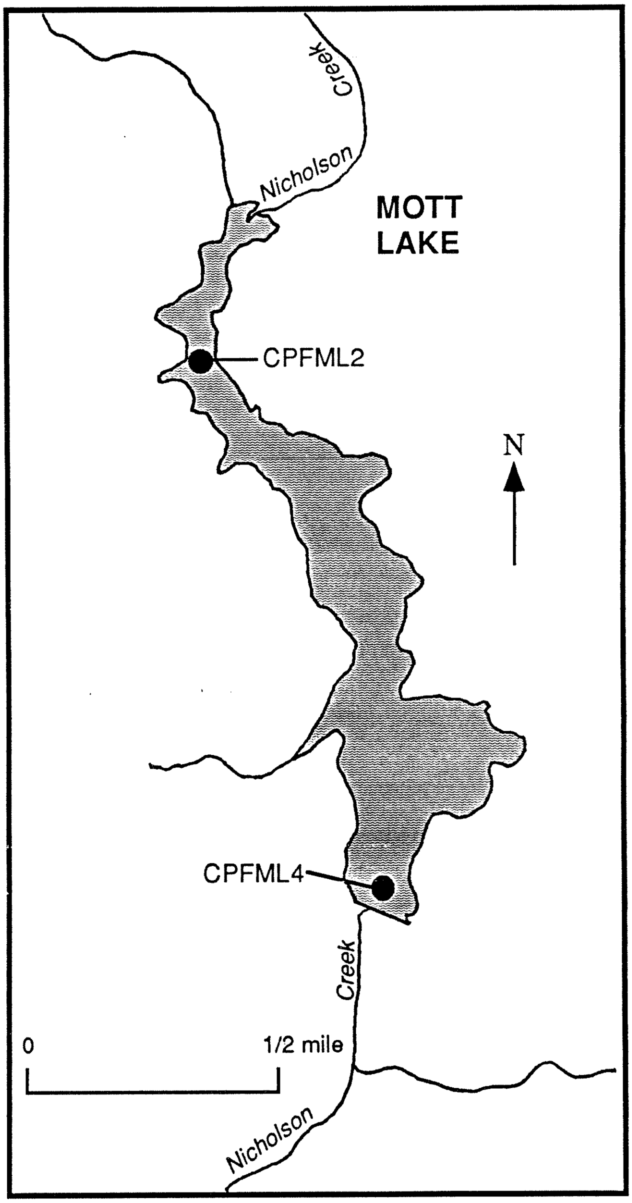
Named for a ranger killed during service, Mott Lake is owned by the United States Army and is located within Fort Bragg Military Reservation. The lake was built in the 1940's as a Civilian Conservation Corps Project. The dam was rehabilitated in 1986, and the height of the structure increased by one foot.

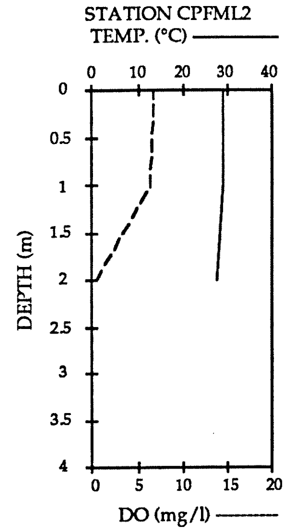
Nicholson Creek drains the 33 km^2 watershed which is used for various military training activities, notably for target bombing. Land which has not been cleared by these activities is mostly forested.

Mott Lake was sampled on July 26, 1990. Dissolved oxygen was near 100% saturation. Conductivities were low, as is typical for this region of the state. Causes of the variable pH levels in the lake are not known. Turbidity values were moderately high (15 NTU), and evidence of sedimentation was noted during the assessment. Nutrients and chlorophyll-a, on the other hand, were low.

Estimates of phytoplanktonic biovolume and density were low with correspondingly low levels of chlorophyll-a. Merismopedia punctata (a small, colonial, blue-green alga) dominated algal biovolume estimates. M. punctata and Lyngbya species (a small, filamentous, blue-green alga) dominated algal density estimates.

Mott Lake was classified oligotrophic (TSI of -3.4). Potential sedimentation of the lake justifies continued monitoring even though all uses were supported in 1990.


MOTT
LAKE
Nicholson
Creek
CPFML2
N
CPFML4
Creek
Nicholson
0
1/2 mile


STATION CPFML2
TEMP. (°C)
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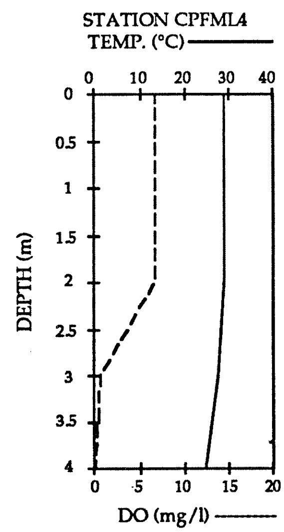
DEPTH (m)
0 0.5 1 1.5 2 2.5 3 3.5 4
0 5 10 15 20
DO (mg/l)


STATION CPFML4
TEMP. (°C)
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DEPTH (m)
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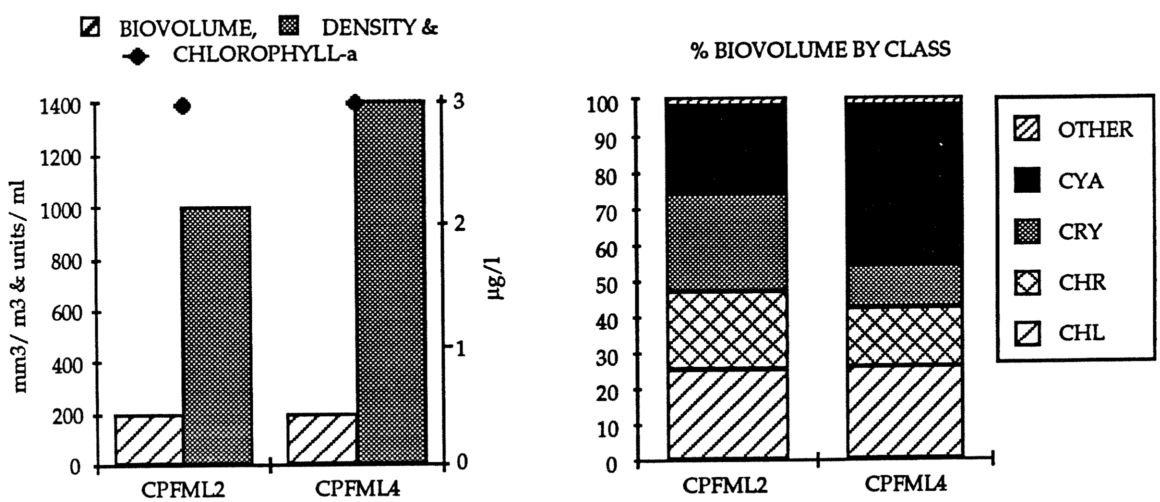
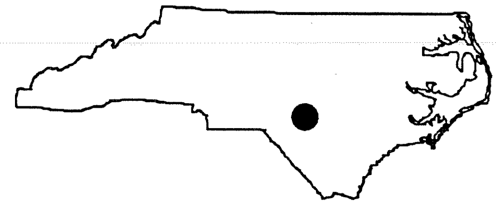
0 5 10 15 20
DO (mg/l)


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/ m3 & units/ ml
0 200 400 600 800 1000 1200 1400
µg/l
0 1 2 3
CPFML2
CPFML4
% BIOVOLUME BY CLASS
0 10 20 30 40 50 60 70 80 90 100
CPFML2
CPFML4
OTHER
CYA
CRY
CHR
CHL

HOPE MILLS LAKE



COUNTY:	Cumberland	BASIN:	Cape Fear
SURFACE AREA:	45 hectares (110 acres)	USGS TOPO:	Hope Mills, N.C.
CLASS:	WS, B	LAKE TYPE:	Reservoir

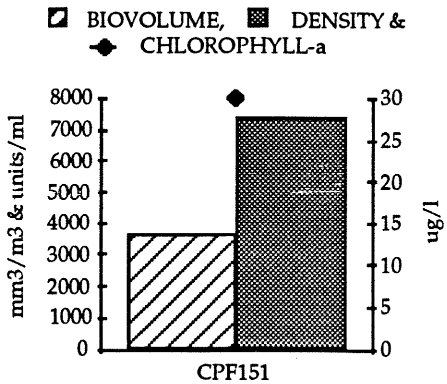
LATEST NCTSI:	1.5	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	July 12, 1988	ADDITIONAL COVERAGE:	Fecal, Water Supply Parameters
SECCHI DEPTH:	1.0 m	CONDUCTIVITY:	41 µmhos/cm^2
TOTAL PHOSPHORUS:	0.05 mg/l	DISSOLVED OXYGEN:	8.0 mg/l
TOTAL ORGANIC NITROGEN:	0.28 mg/l	TEMPERATURE:	27.5 °C
CHLOROPHYLL- A:	30 µg/l	pH:	6.0 s.u.

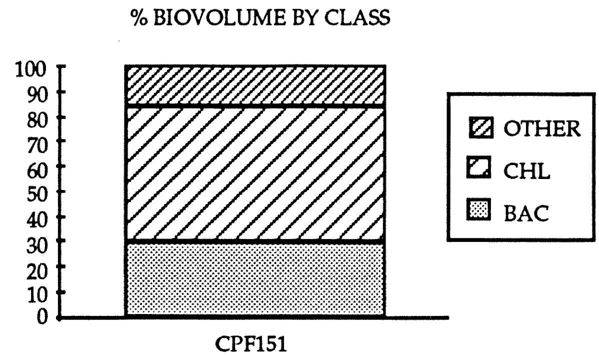
Hope Mills Lake is a small, shallow reservoir located on Little Rockfish Creek in the town of Hope Mills, North Carolina. The original dam was built in 1839 and rebuilt around 1921. The dam is owned and operated by Dixie Yarn Incorporated and was constructed to provide an emergency fire-fighting water supply for the Hope Mills Plant (located adjacent to the reservoir). A secondary purpose of the dam was to provide hydroelectric power to the Town of Hope Mills. Neither of these uses is presently required, and the lake is maintained for recreation. The lake has a drainage area of 67 km^2 which is mostly forested with some urban and agricultural areas. The lake is classified WS III, B.

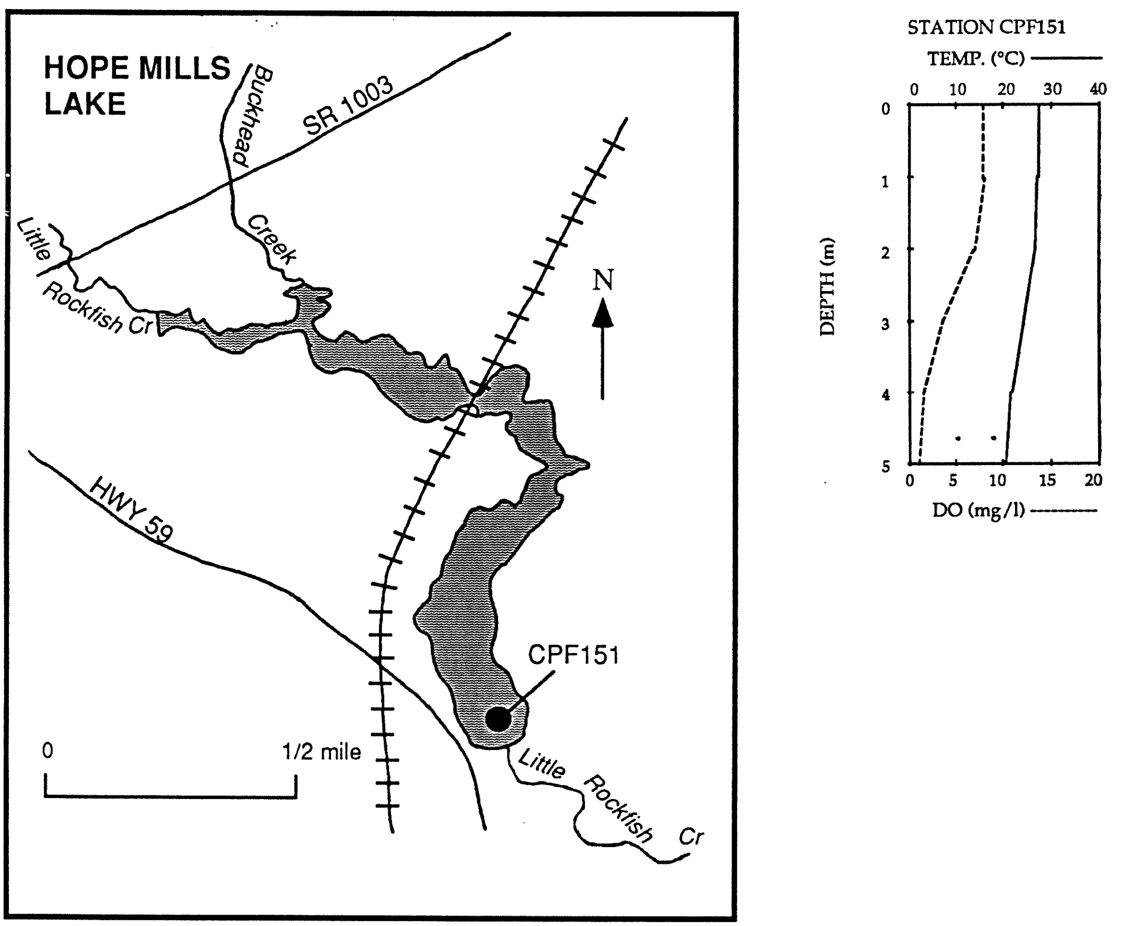
Hope Mills Lake was sampled on July 12, 1988. Total phosphorus and chlorophyll-a levels were elevated throughout the lake. Fecal coliform bacteria counts were well within state standards.

The one phytoplankton sample collected from this lake in 1988 had moderate amounts of algae. Numerous species were represented, but the dominant species by biovolume was Staurastrum tetracerum (Chlorophyta). Twenty-nine other species of green algae were present in the sample. Fifty-four percent of the total biovolume was derived from this class. This lake also supports a large aquatic plant population of spatterdock (Nuphar luteum).

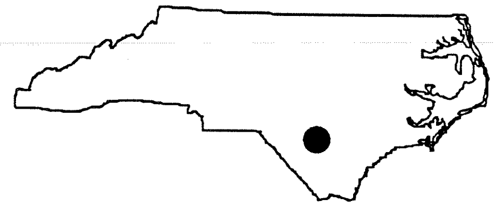
The TSI in 1988 was 1.5 which is similar to the 1984 TSI of 1.6. Elevated chlorophyll-a levels and high biovolume and density estimates are reflective of the eutrophic classification of this lake. The well-mixed water of Hope Mills Lake enhances nutrient recycling, and subsequently high standing crops of phytoplankton. At the time of assessment, no water quality standards were exceeded, and the lake fully supported designated uses.







SALTERS LAKE



COUNTY:	Bladen	BASIN:	Cape Fear
SURFACE AREA:	127 hectares (315 acres)	USGS TOPO:	Dublin, N.C.
CLASS:	C	LAKE TYPE:	Millpond

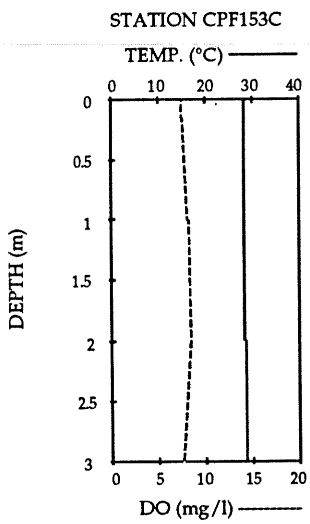
LATEST NCTSI:	- 2.0	TROPHIC STATE:	Dystrophic
SAMPLING DATE:	July 12, 1988	ADDITIONAL COVERAGE:	None
SECCHI DEPTH:	1.75 m	CONDUCTIVITY:	84 - 86 μmhos/cm^2
TOTAL PHOSPHORUS:	0.02 mg/l	DISSOLVED OXYGEN:	7.7 - 8.3 mg/l
TOTAL ORGANIC NITROGEN:	0.18 mg/l	TEMPERATURE:	28.4 - 28.5 °C
CHLOROPHYLL-A:	7 μg/l	pH:	3.3 s.u.

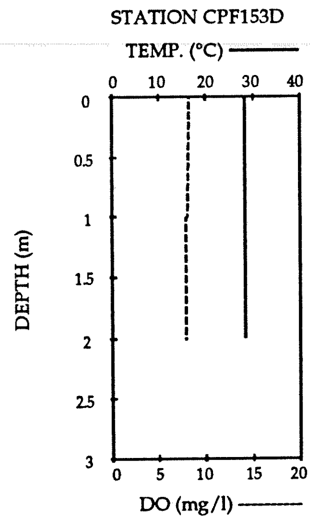
Salters Lake is a shallow, coastal bay lake owned by the State of North Carolina. Bladen Lake State Forest is the protected area which contains the lake. All of the 6.9 square kilometer coastal drainage area is wetland or forest. Maximum depth of the lake is two meters.

Productivity in Salters Lake is low with no sources of pollution in the drainage area. Acidic water was reflected in the pH of 3.3. The water column was mixed with dissolved oxygen concentrations reaching saturation levels. All of these characteristics are commonly found in tannic, black water lakes, although pH values at Salters Lake are among the lowest recorded in North Carolina lakes.

Low to moderate estimates of phytoplanktonic biovolume and density were collected from two stations on this lake. Cryptomonas erosa, C. ovata, Chroomonas minuta, and C. caudata (Cryptophyta) dominated the plankton collected and identified. All of these species are commonly found in North Carolina lakes.

TSI values and past research on Salters Lake would indicate that it is oligotrophic or mesotrophic (Weiss and Kuenzler, 1976). However, the lake is more appropriately characterized as dystrophic. All designated uses were fully supported at the time of this assessment.


STATION CPF153C
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0
0.5
1
1.5
2
2.5
3
0 5 10 15 20
DO (mg/l)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TEMP. (°C)
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DEPTH (m)
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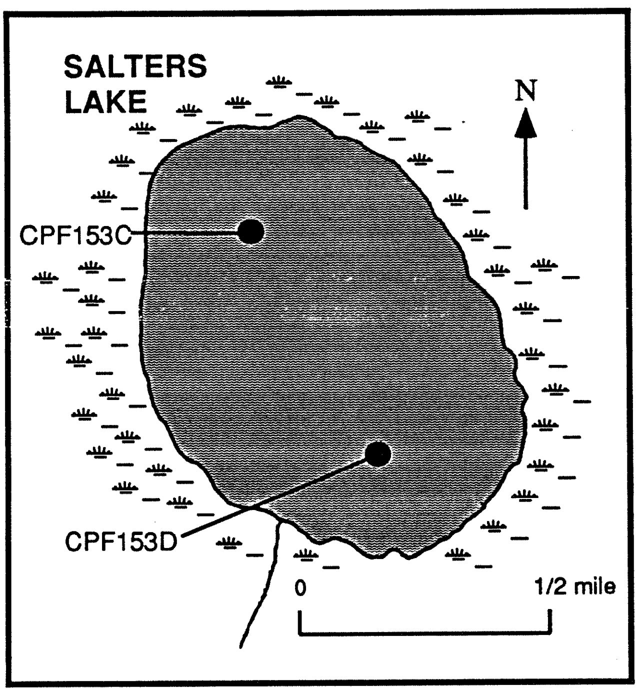
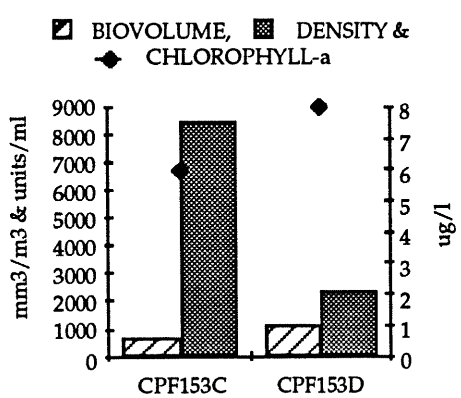
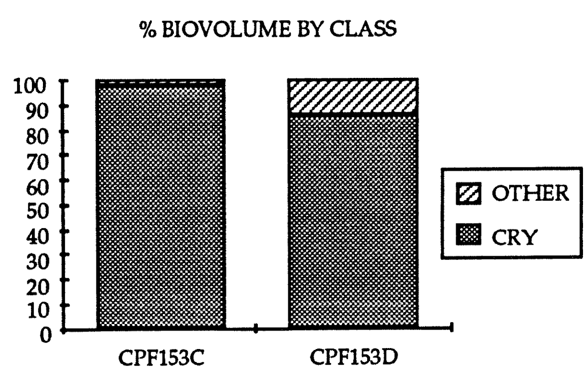
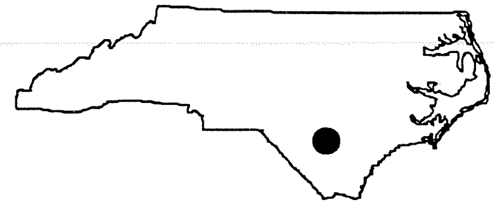
0.5
1
1.5
2
2.5
3
0 5 10 15 20
DO (mg/l)


SALTERS
LAKE
N
CPF153C
CPF153D
0
1/2 mile


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/m3 & units/ml
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
ug/l
8
7
6
5
4
3
2
1
0
CPF153C
CPF153D


% BIOVOLUME BY CLASS
100
90
80
70
60
50
40
30
20
10
0
OTHER
CRY
CPF153C
CPF153D

JONES LAKE



COUNTY:	Bladen	BASIN:	Cape Fear
SURFACE AREA:	91 hectares (225 acres)	USGS TOPO:	Elizabethtown North, N.C.
CLASS:	B	LAKE TYPE:	Natural

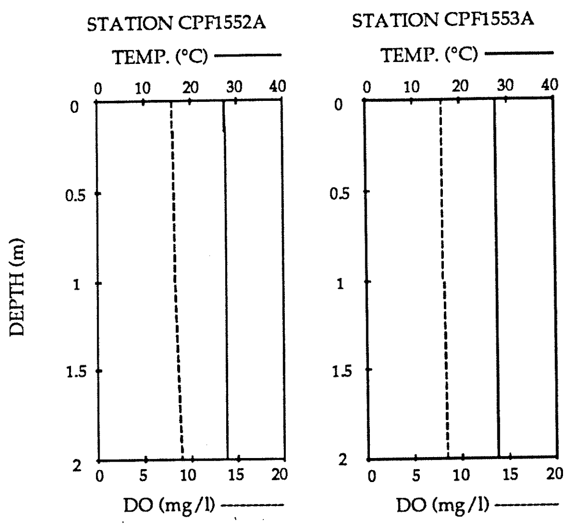
LATEST NCTSI:	-5.3	TROPHIC STATE:	Dystrophic
SAMPLING DATE:	September 3, 1987	ADDITIONAL COVERAGE:	Metals
SECCHI DEPTH:	2.15 m	CONDUCTIVITY:	91 µmhos/cm^2
TOTAL PHOSPHORUS:	0.01 mg/l	DISSOLVED OXYGEN:	8.2 mg/l
TOTAL ORGANIC NITROGEN:	0.125 mg/l	TEMPERATURE:	27.5 - 27.7 °C
CHLOROPHYLL-A:	1 µg/l	pH:	3.2 - 3.3 s.u.

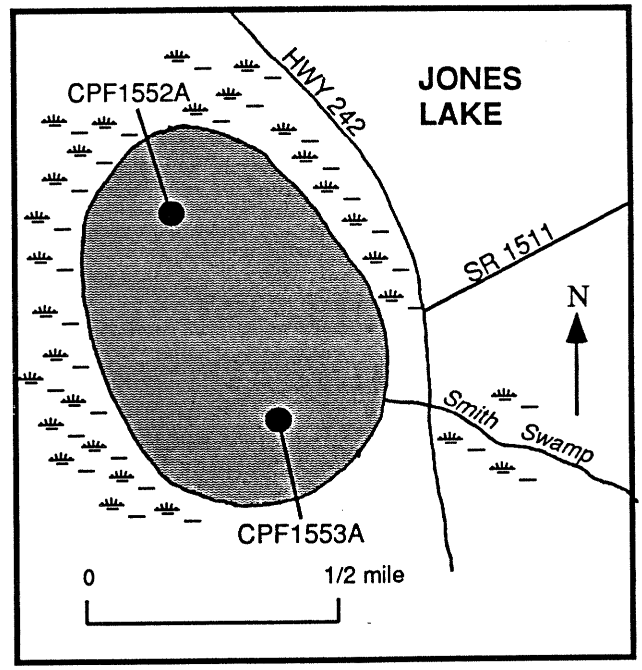
Jones Lake is a small, shallow, natural lake situated in the flat swampy terrain of Jones Lake State Park. Jones Lake has a maximum depth of three meters. Like other Carolina Bay Lakes, Jones Lake receives almost no overland inputs of water, relying instead on precipitation and groundwater for recharge. The lake is classified for recreation.

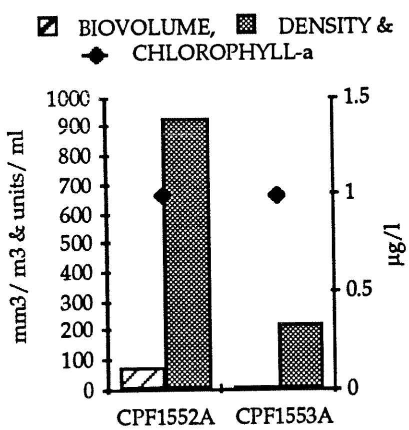
Jones Lake was sampled on September 3, 1987. Physical measurements indicated that the lake was well mixed. Typical of Carolina Bay Lakes, Jones Lake is acidic and nutrient-poor. This lake receives leachate from the surrounding swamp, contributing to the low pH. Low chlorophyll-a reflected the low availability of nutrients. Heavy metal concentrations were below laboratory detection limits.

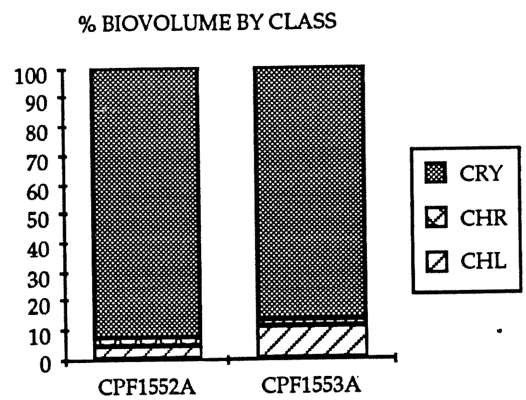
Phytoplankton composition from both stations was similar and contained low standing crop. Cryptophytes made up over 85% of the biovolume and density at both stations. Cryptomonas erosa, a dominant cryptophyte in Jones Lake, is often found in stagnant waters and swamps (Prescott 1962). Other dominants, Chroomonas minuta and Chroomonas caudata, are evidently tolerant to acidic conditions. Cryptophytes are capable of growing under a wide range of conditions from nutrient-poor to nutrient-rich waters (Smith 1950).

In 1987 the TSI was -5.3 which is similar to the 1982 value of -5.8. The low nutrient concentrations, acidic waters, and low algal populations have all contributed to this low TSI score. Based on these data and professional observations, Jones Lake was classified as dystrophic. At the time of assessment, no violations of state water quality standards were observed at Jones Lake and the lake fully supported designated uses.

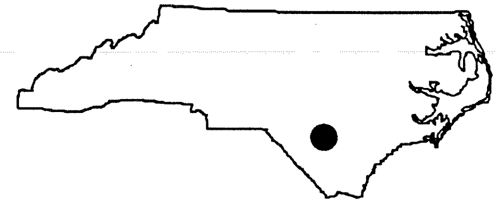








WHITE LAKE



COUNTY:	Bladen	BASIN:	Cape Fear
SURFACE AREA:	425 hectares (1,050 acres)	USGS TOPO:	White Lake, N.C.
CLASS:	B	LAKE TYPE:	Natural

LATEST NCTSI:	-4.4	TROPHIC STATE:	Oligotrophic
SAMPLING DATE:	July 24, 1990	ADDITIONAL COVERAGE:	Fecal
SECCHI DEPTH:	2.4 m	CONDUCTIVITY:	99 - 100 µmhos/cm^2
TOTAL PHOSPHORUS:	0.01 mg/l	DISSOLVED OXYGEN:	7.6 - 7.9 mg/l
TOTAL ORGANIC NITROGEN:	0.09 mg/l	TEMPERATURE:	29.8 - 30.2 °C
CHLOROPHYLL-A:	6 µg/l	pH:	3.3 - 3.4 s.u.

White Lake is a Carolina Bay Lake located east of Elizabethtown, North Carolina. Similar to other bay lakes, White Lake is shallow with a maximum depth of 3.2 meters and an average depth of 2.2 meters. The lake has a volume of 9.45×10^6 m^3, 7.7 kilometers of shoreline and a mean hydraulic retention time of 292 days. Although the State of North Carolina owns the property around the lake to the mean high water mark, the land above this demarcation is privately owned. The land adjacent to White Lake is extensively developed with motels, rooming houses, campgrounds, permanent residences, mobile home parks and weekend cottages.

The lake is presently designated Class B and is used extensively for swimming, skiing, boating and fishing. The lake receives the majority of its water from precipitation. Lands surrounding the lake are primarily swamps and forests.

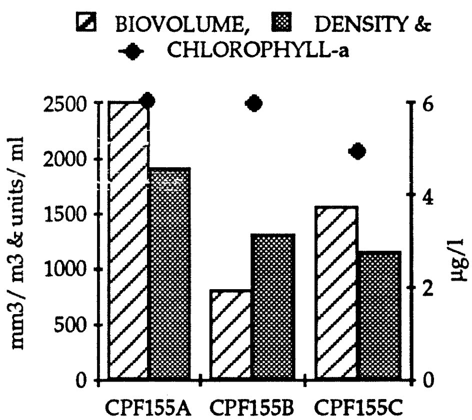
White Lake was sampled on July 24, 1990. Physical measurements indicated that the lake was mixed. Nutrient and chlorophyll-a levels were low and uniform between the three lake stations. The waters of White Lake are acidic with surface pH ranging from 3.3 to 3.4 standard units. Acidic waters are typical of Carolina Bay Lakes and are the result of tannins and other materials that leach from the surrounding swamps. White Lake is tinted blue however, in contrast to the black or tea color of other such bay lakes. Fecal coliforms were below laboratory detection limits in all samples.

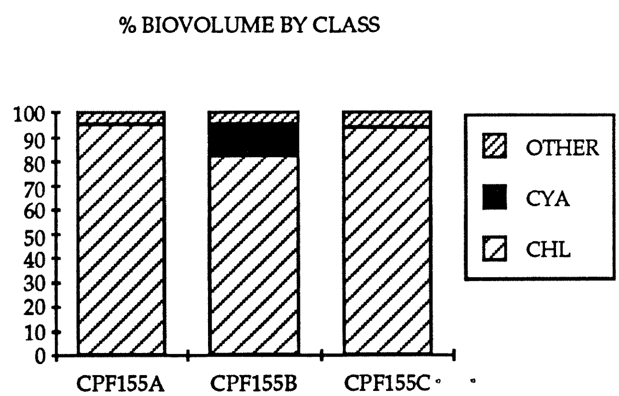
Two species of aquatic macrophytes found in White Lake were Eriocaulon species (pipewort) and Eleocharis species (spike rush). These are common to clear, soft, low nutrient water bodies. Pipewort is one of the few aquatic plants that can exist and thrive under these environmental conditions and is extremely important to the ecology of the lake for stabilization of the sandy substrate and creation of habitat for other aquatic life. Field observations in 1988 found no nuisance growths of macrophytes in the lake and no uses of the lake were impaired or restricted by existing populations of macrophytes.

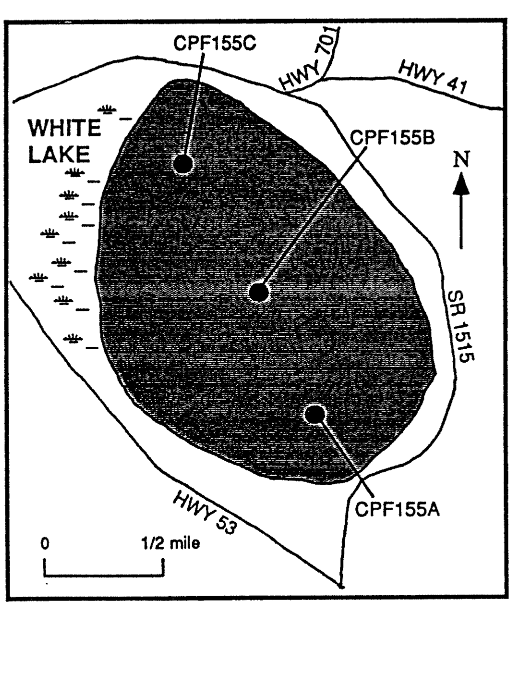
Low estimates of algal density and biovolume reflected the oligotrophic state of White Lake. The greater biovolume at CPF155A is explained by the presence of a filamentous green alga, Spirogyra species. This alga constituted 51% of the biovolume but only 1% of the density at CPF155A. Spirogyra floats on the surface which can result in an underestimation of its contribution to biovolume and density estimates. Species composition, density, and biovolume at CPF155B and CPF155C were similar in 1985 with Peridinium pusillum (Dinophyceae) dominating the biovolume.

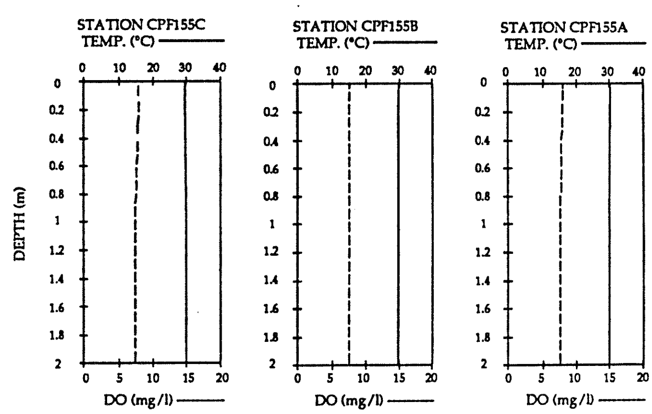
Accumulations of Ulothrix and Spirogyra along the shore of the lake have been responsible for complaints by citizens over the past 40 years. The decaying algae is apparently dislodged from the bottom of the lake during periods of low water. However, these aesthetic problems are usually short-lived and improve when lake level returns to normal.

The TSI was -4.4 in 1990 which is similar to historical values. White Lake consistently has one of the lowest TSI values in North Carolina. At the time of assessment, no violations of state water quality standards were observed at White Lake and the lake was fully supporting its designated uses.

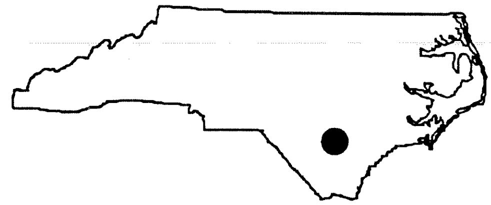








BAY TREE LAKE



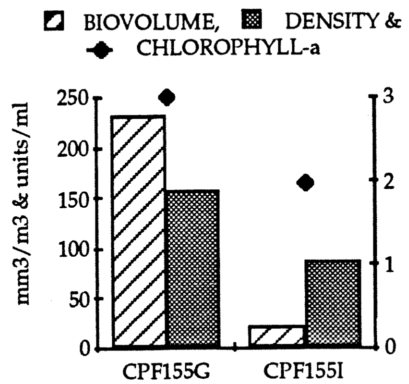
COUNTY:	Bladen	BASIN:	Cape Fear
SURFACE AREA:	567 hectares (1,400 acres)	USGS TOPO:	White Lake, N.C.
CLASS:	C - SW	LAKE TYPE:	Natural

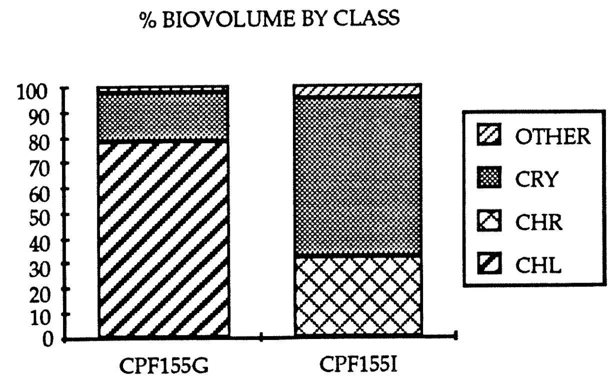
LATEST NCTSI:	- 3.1	TROPHIC STATE:	Dystrophic
SAMPLING DATE:	July 31, 1989	ADDITIONAL COVERAGE:	None
SECCHI DEPTH:	1.45 m	CONDUCTIVITY:	129 - 134 µmhos/cm^2
TOTAL PHOSPHORUS:	0.015 mg/l	DISSOLVED OXYGEN:	7.0 - 7.6 mg/l
TOTAL ORGANIC NITROGEN:	0.175 mg/l	TEMPERATURE:	29.8 - 30.6 °C
CHLOROPHYLL- A:	2.5 µg/l	pH:	4.7 s.u.

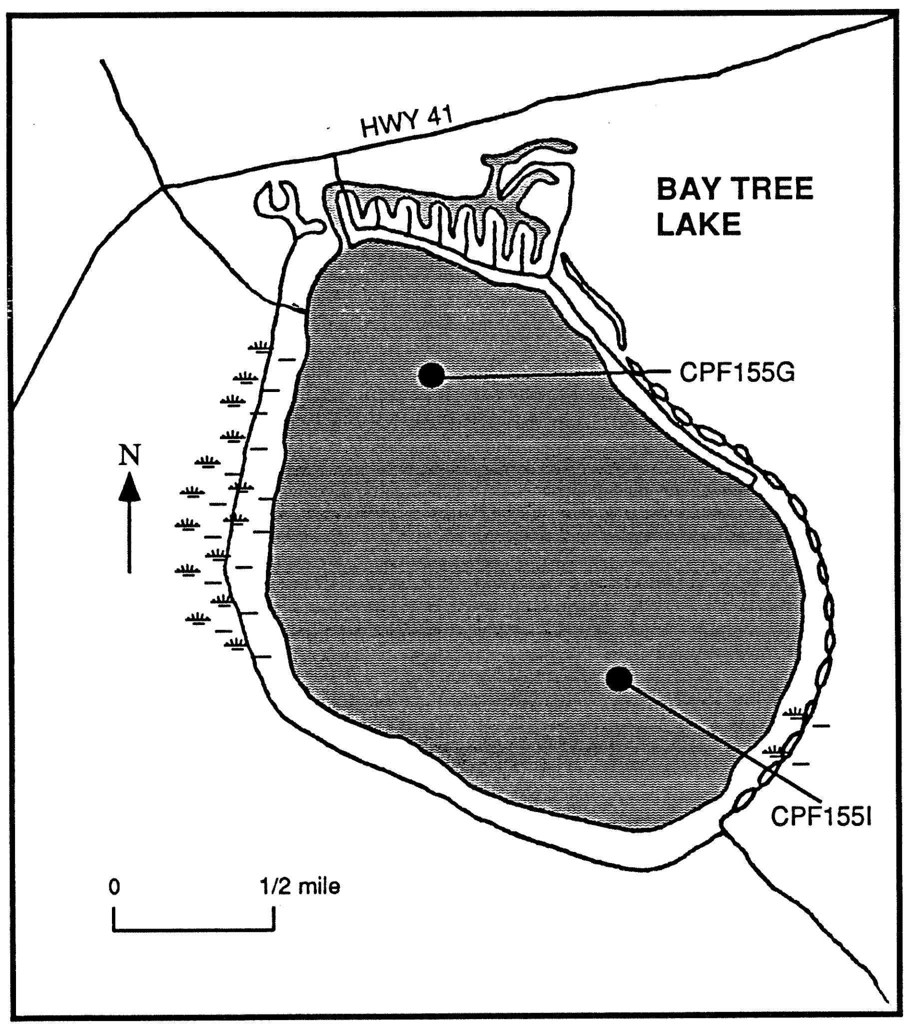
Bay Tree Lake (also called Black Lake) is a shallow, natural lake located on the coastal plain near Elizabethtown, North Carolina. The lake is within Bay Tree State Park and is owned by the State of North Carolina. Typical of Carolina Bay Lakes, Bay Tree Lake receives no significant overland inflows. Maximum depth of this lake is 1.8 meters. Bay Tree Lake has a network of drainage canals built on its northern and eastern shores. The surrounding land is primarily flat, composed of wetlands and upland forests. The lake is classified C-Swamp and is used for fishing and recreation.

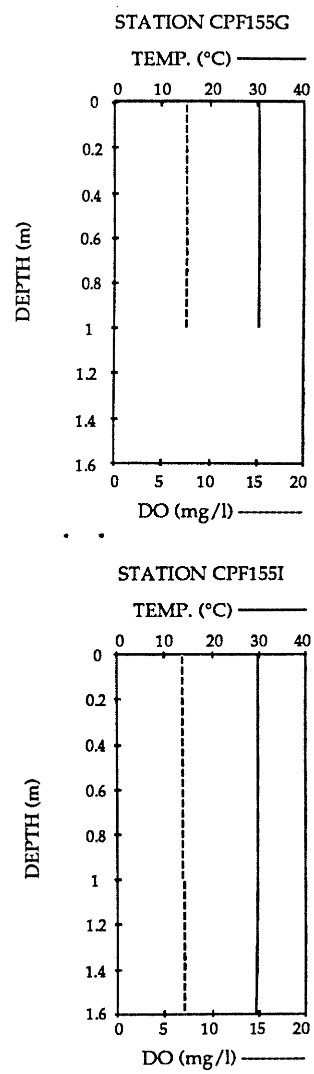
Bay Tree Lake was sampled on July 31, 1989. Physical measurements indicated that the lake was mixed with temperature and dissolved oxygen values remaining constant throughout the water column. Surface pH measurements were low, a common condition in tannic, swampy areas. Nutrient and chlorophyll-a concentrations were low at both sampling stations, as were estimates of algal density and biovolume. Fecal coliform bacteria were below laboratory detection limits. Heavy metal concentrations were also below laboratory detection limits with the exception of copper which was within state action levels.

The TSI was -3.1 in 1989. The lake is classified dystrophic because of dark, tannic waters, low chlorophyll-a concentrations and moderate nutrient levels. At the time of assessment, no violations of state water quality standards were observed at Bay Tree Lake, and the lake was fully supporting its designated uses.

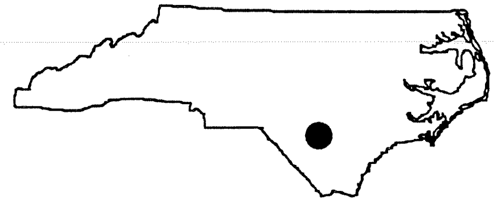

BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/m3 & units/ml
ug/l
CPF155G
CPF155I


% BIOVOLUME BY CLASS
OTHER
CRY
CHR
CHL
CPF155G
CPF155I


HWY 41
BAY TREE
LAKE
CPF155G
CPF155I
N
0
1/2 mile


STATION CPF155G
TEMP. (°C)
DEPTH (m)
DO (mg/l)
STATION CPF155I
TEMP. (°C)
DEPTH (m)
DO (mg/l)

SINGLETARY LAKE



COUNTY:	Bladen	BASIN:	Cape Fear
SURFACE AREA:	231 hectares (572 acres)	USGS TOPO:	Singletary Lake, N.C.
CLASS:	B - SW	LAKE TYPE:	Natural

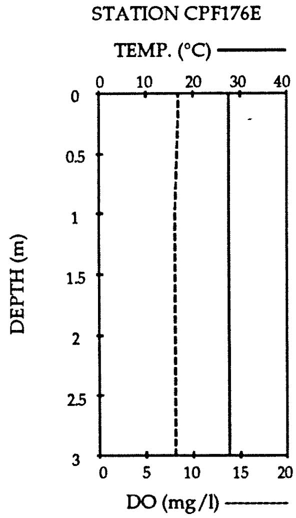
LATEST NCTSI:	- 3.0	TROPHIC STATE:	Dystrophic
SAMPLING DATE:	September 3, 1987	ADDITIONAL COVERAGE:	Metals
SECCHI DEPTH:	1.4 m	CONDUCTIVITY:	90 - 94 µmhos/cm^2
TOTAL PHOSPHORUS:	0.01 mg/l	DISSOLVED OXYGEN:	8.0 - 8.6 mg/l
TOTAL ORGANIC NITROGEN:	0.19 mg/l	TEMPERATURE:	27.5 - 29.1 °C
CHLOROPHYLL-A:	4 µg/l	pH:	3.2 - 3.3 s.u.

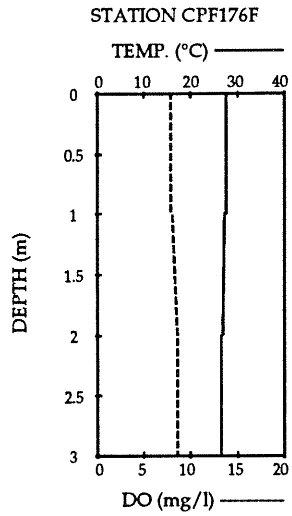
Singletary Lake, located near Black Lake and White Lake in Bladen County, is a natural Carolina Bay Lake. The surrounding terrain is flat and swampy with almost no overland water inputs. The lake is owned by the State of North Carolina and used for swimming, boating, and fishing. This lake is classified B-Swamp.

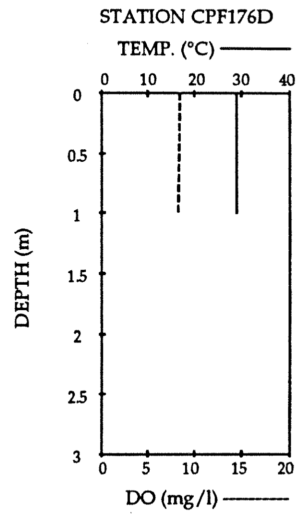
Singletary Lake was sampled on September 3, 1987. Physical measurements indicated that the lake was well mixed. Nutrient and chlorophyll-a concentrations were low and uniform throughout the lake. Singletary Lake is acidic with a pH of 3.2 to 3.3 standard units. Tannins leaching through the swamps surrounding the lake contribute to its low pH. Heavy metal concentrations were below laboratory detection limits with the exception of zinc. Zinc concentrations were 12 µg/l at CPF176D and 28 µg/l at CPF176F, well below the state action level of 50 µg/l.

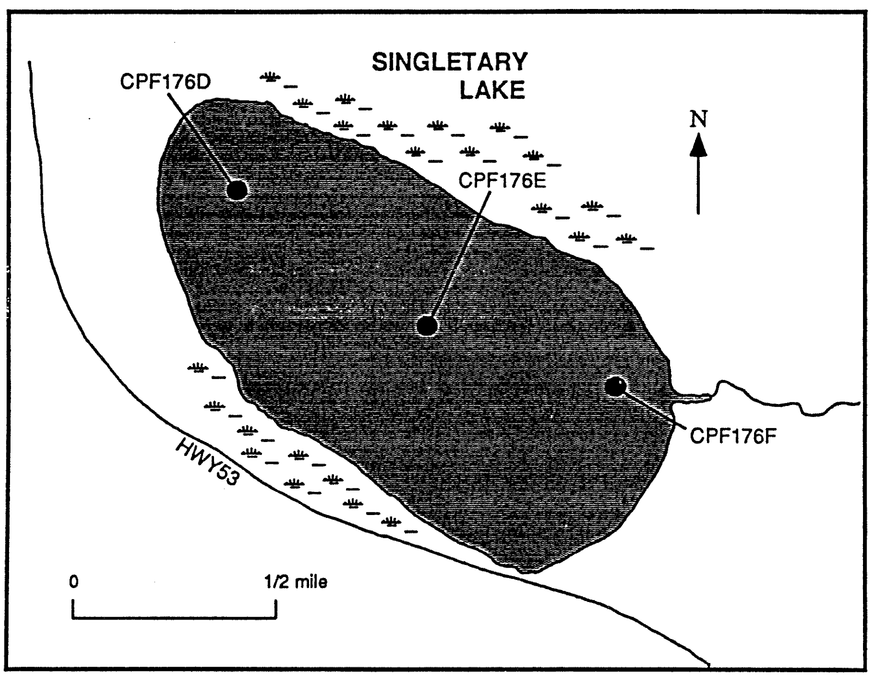
Phytoplankton samples were collected from one station (CPF176F) in 1987. Cryptophytes comprised over 81% of the algal biovolume and density. Cryptomonas erosa, the dominant species, commonly occurs in swamps and waters throughout the coastal plain. Singletary Lake contained low algal biovolume (733 mm^3/m^3) and density (1,180 units/ml).

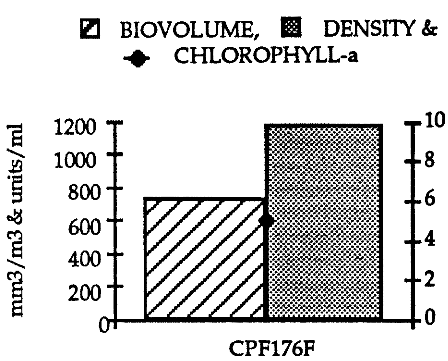
The TSI in 1987 was -3.0 which is lower than the 1982 value of -2.0. The lake is dystrophic with waters that are characteristically acidic and nutrient-poor. At the time of assessment, no violations of state water quality standards were observed and designated uses of Singletary Lake were fully supported.

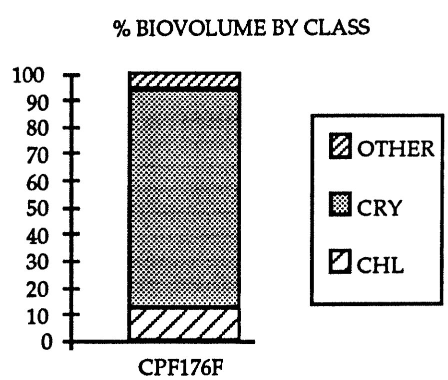

STATION CPF176E
TEMP. (°C)
DEPTH (m)
DO (mg/l)


STATION CPF176F
TEMP. (°C)
DEPTH (m)
DO (mg/l)

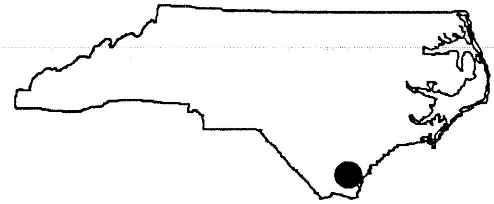

STATION CPF176D
TEMP. (°C)
DEPTH (m)
DO (mg/l)


SINGLETARY
LAKE
CPF176D
CPF176E
CPF176F
N
HWY53
0
1/2 mile


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/m3 & units/ml
ug/l
CPF176F


% BIOVOLUME BY CLASS
OTHER
CRY
CHL
CPF176F

GREENFIELD LAKE



COUNTY:	New Hanover	BASIN:	Cape Fear
SURFACE AREA:	46 hectares (115 acres)	USGS TOPO:	Wilmington, N.C.
CLASS:	C-SW	LAKE TYPE:	Reservoir

LATEST NCTSI:	4.9	TROPHIC STATE:	Hypereutrophic
SAMPLING DATE:	September 21, 1988	ADDITIONAL COVERAGE:	None
SECCHI DEPTH:	1.2 m	CONDUCTIVITY:	184 - 188 µmhos/cm^2
TOTAL PHOSPHORUS:	0.13 mg/l	DISSOLVED OXYGEN:	4.2 - 5.4 mg/l
TOTAL ORGANIC NITROGEN:	0.75 mg/l	TEMPERATURE:	24.7 - 24.9 °C
CHLOROPHYLL-A:	90.5 µg/l	pH:	6.7 - 6.9 s.u.

Greenfield Lake is a swampy, cypress-filled lake owned by the City of Wilmington. Built in the early 1920's, Greenfield Lake has a maximum depth of 3.7 meters and a mean depth of 1.5 meters. Ninety-five percent of the watershed (8.5 km$^{2)}$ is urban. Sewer line overflows and urban stormwater runoff cause algal blooms, weed infestations, and fish kills in Greenfield Lake.

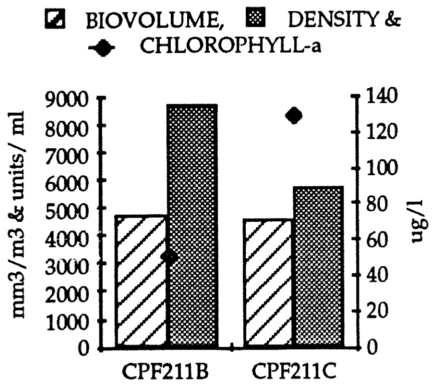
Several steps have been taken by the city to alleviate some of the filling/weed/algal problems. Copper sulfate is sometimes used to temporarily reduce the algae in the lake. A major dredging project was begun in the late 1970's, and a second such project should be completed in 1992.

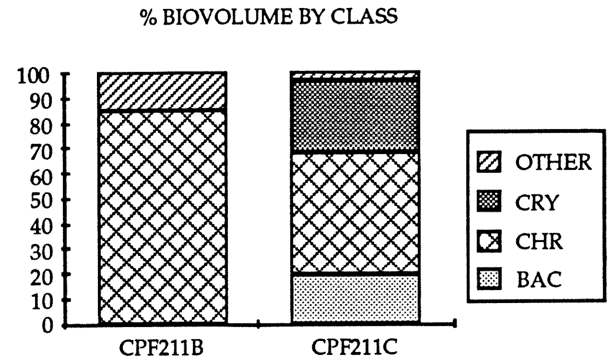
Greenfield Lake was sampled at two stations on September 21, 1988. The water column was not stratified and duckweed covered approximately 70% of the lake. Total nitrogen and total phosphorus were extremely high, and turbidity concentrations were above the state standard of 25 NTU at CPF211C (40 NTU). The chlorophyll-a standard was violated at both stations.

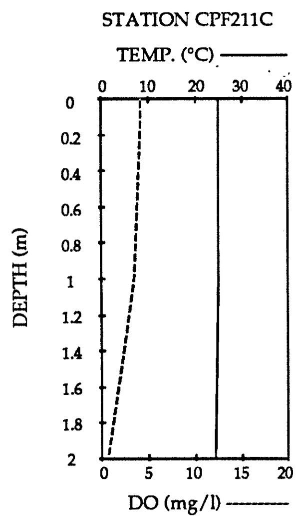
Greenfield Lake continues to experience problems associated with eutrophication. Aquatic macrophytes, including several species of duckweed and Chara species as well as mats of filamentous algae, continue to grow in the shallow reaches of the lake. The mats of algae were composed of Spirogyra, Ulothrix, Hydrodictyon, and Oedogonium species.

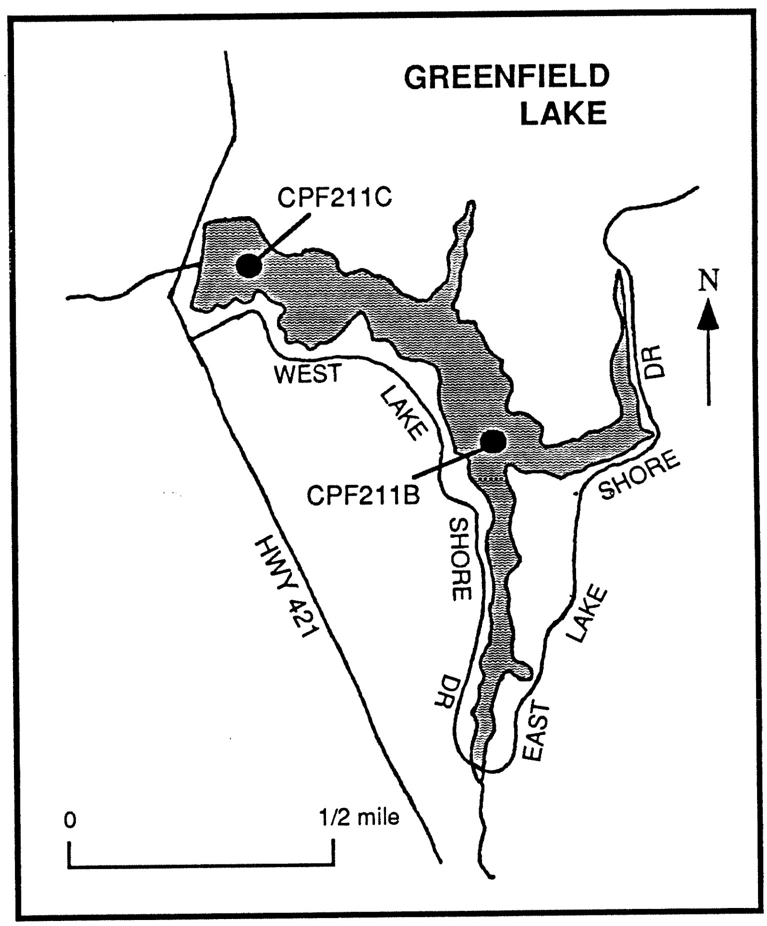
Phytoplankton were dominated by Synura caroliniana (Chrysophyta). Chlorophyll-a concentrations of 51 and 130 µg/l reflect the elevated estimates of algal density and biovolume.

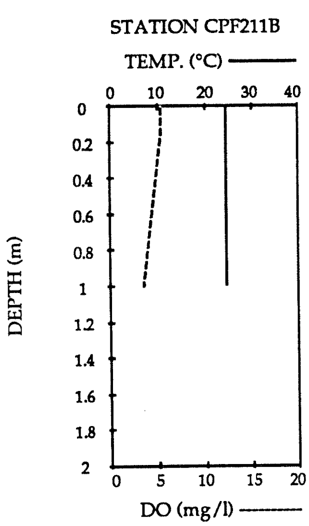
A TSI of 4.9 was recorded in 1988. This is higher than the 1981 TSI, but insufficient data exists to discern a trend. The 1989-1990 305(b) Report listed the lake as not supporting its uses.



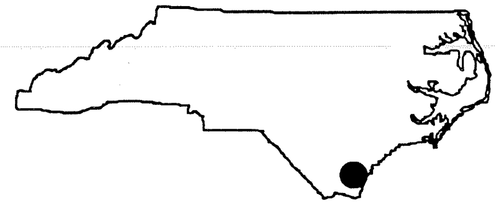








BOILING SPRINGS LAKE



COUNTY:	Brunswick	BASIN:	Cape Fear
SURFACE AREA:	453 hectares (1,120 acres)	USGS TOPO:	Carolina Beach, N.C.
CLASS:	B	LAKE TYPE:	Reservoir

LATEST NCTSI:	-2.3	TROPHIC STATE:	Dystrophic
SAMPLING DATE:	July 23, 1990	ADDITIONAL COVERAGE:	Fecals
SECCHI DEPTH:	0.7 m	CONDUCTIVITY:	78 - 80 µmhos/cm^2
TOTAL PHOSPHORUS:	0.01 mg/l	DISSOLVED OXYGEN:	6.2 - 6.8 mg/l
TOTAL ORGANIC NITROGEN:	0.27 mg/l	TEMPERATURE:	28.2 - 30.3 °C
CHLOROPHYLL-A:	2 µg/l	pH:	6.4 - 7.0 s.u.

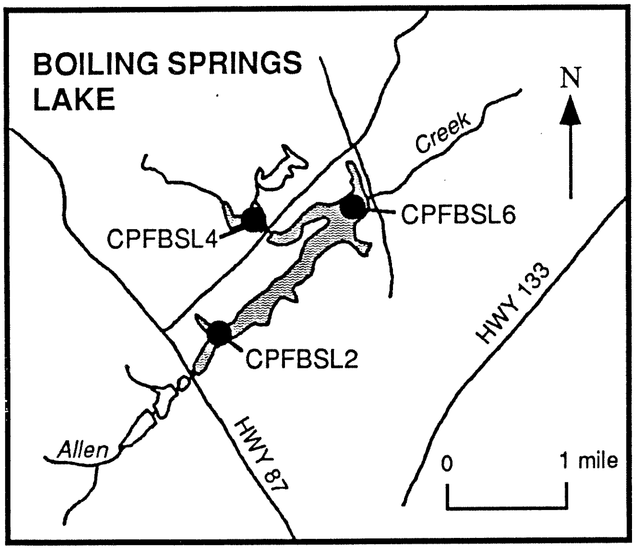
Allen Creek was impounded in 1961 to form Boiling Springs Lake, a blackwater coastal lake in eastern Brunswick County. The Town of Boiling Springs, which owns the lake, has grown around this and several smaller lakes.

Several springs feed the lake which is seven or eight meters deep near the dam. Average depth is approximately two meters. Land use upstream of the lake is mostly forested and residential. The lake is used for fishing and boating.

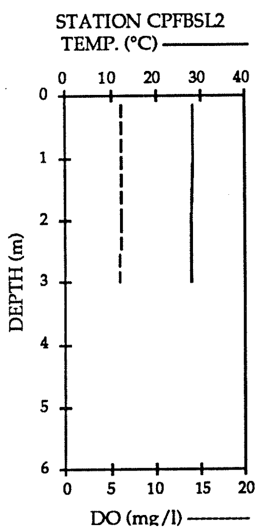
On July 23, 1990, DEM sampled the lake. Most of the lake is mixed with pH values just below neutral. Generally, blackwater lakes are more acidic than Boiling Springs Lake. Nutrients and chlorophyll-a concentrations were low.

Estimates of algal biovolume and density were low at all three sampling stations ranging from 30-150 mm^3/m^3 and 150-600 units/ml respectively. Cryptophytes and chlorophytes dominated the algal biovolume throughout this lake.

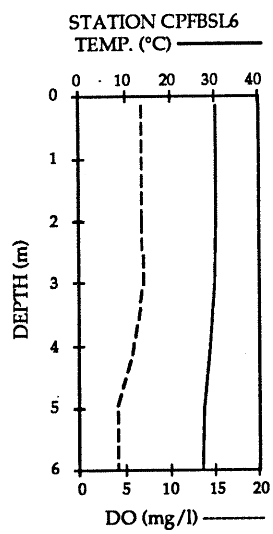
Boiling Springs Lake is dystrophic with a TSI of -2.3. All uses were supported and no violations of water quality standards were found.



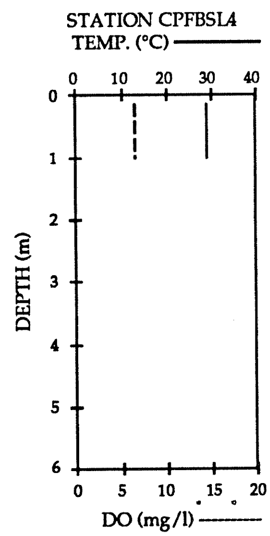
BOILING SPRINGS LAKE
N
Creek
CPFBSL4
CPFBSL6
CPFBSL2
HWY 133
HWY 87
Allen
0
1 mile



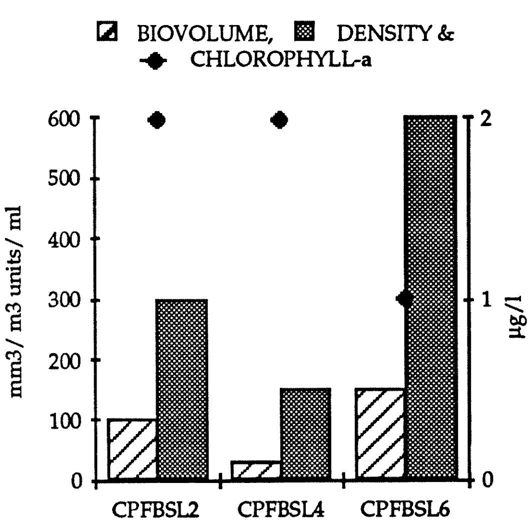
STATION CPFBSL2
TEMP. (°C)
DEPTH (m)
DO (mg/l)



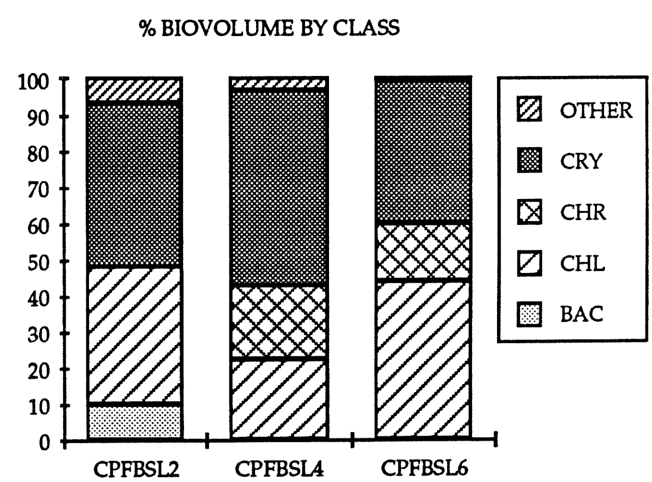
STATION CPFBSL6
TEMP. (°C)
DEPTH (m)
DO (mg/l)



STATION CPFBSL4
TEMP. (°C)
DEPTH (m)
DO (mg/l)



BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3 / m3 units / ml
µg/l
CPFBSL2
CPFBSL4
CPFBSL6



% BIOVOLUME BY CLASS
OTHER
CRY
CHR
CHL
BAC
CPFBSL2
CPFBSL4
CPFBSL6

CATAWBA RIVER BASIN

DESCRIPTION OF REGION

The Catawba River Basin covers 8,500 km^2 in the south central portion of western North Carolina. The Catawba River rises from the eastern slopes of the Blue Ridge Mountains and flows eastward, then southward, to the North Carolina-South Carolina border near Charlotte. The headwaters of the Catawba River are formed by swiftly flowing, cold-water streams originating in the steep terrain of the mountains. Such streams are typically found at high elevations in Avery, Caldwell, McDowell, and Burke Counties.

Once out of the mountains, the flow of the Catawba River is regulated by a series of hydroelectric dams. These reservoirs, commonly referred to as the Catawba Chain Lakes, include Lake James, Lake Rhodhiss, Lake Hickory, Lookout Shoals Lake, Lake Norman, Mountain Island Lake, and Lake Wylie.

Although the topography of the upper river basin is characterized by mountains, lesser hills give way to a rolling terrain near the state line. As the basin enters the inner piedmont from the mountains, land use in the basin shifts from forest to agricultural and urban uses.

OVERVIEW OF WATER QUALITY

In the upper region of the basin, most of the streams feeding the Catawba River have high water quality (NRCD 1985). As the river continues into the inner piedmont, nonpoint runoff from agricultural operations has caused nutrient enrichment, sedimentation, and pesticide problems in the streams, rivers and lakes of the area (NRCD 1985). The major rivers in this area include the Upper, Middle, and Lower Little Rivers.

Urban runoff is another contributor to nonpoint source pollution found in this river basin. Though urban areas are not plentiful in the upper portions of the basin, the lower Catawba region contains numerous cities including the growing metropolitan area surrounding Charlotte. In this region, urban growth has affected the water quality of the lakes, streams and rivers.

There are over 300 permitted point source dischargers in the Catawba River basin, mostly centered around the cities of Marion, Lenoir, Morganton, Lincolnton, Gastonia and Charlotte. Degraded biological integrity has resulted from some of these point source discharges (NRCD 1985).

All of the Catawba chain lakes are included in this section. As in other series of reservoirs, the water quality of each impoundment is influenced by discharge from the upstream reservoir as well as inputs from the surrounding watershed.

The first impoundment located on the Catawba River is Lake James which has exhibited the highest water quality of all of the lakes in the Catawba chain. The next three impoundments in the chain (Lake Rhodhiss, Lake Hickory and Lookout Shoals Lake) are classified as mesotrophic or eutrophic. Enriched conditions found at some of these reservoirs may be caused by agricultural runoff and municipal dischargers located in this region. Although nutrient concentrations in these reservoirs are sufficient to support substantial algal populations, short retention times and limited light availability generally keep algae from reaching potentially higher levels.

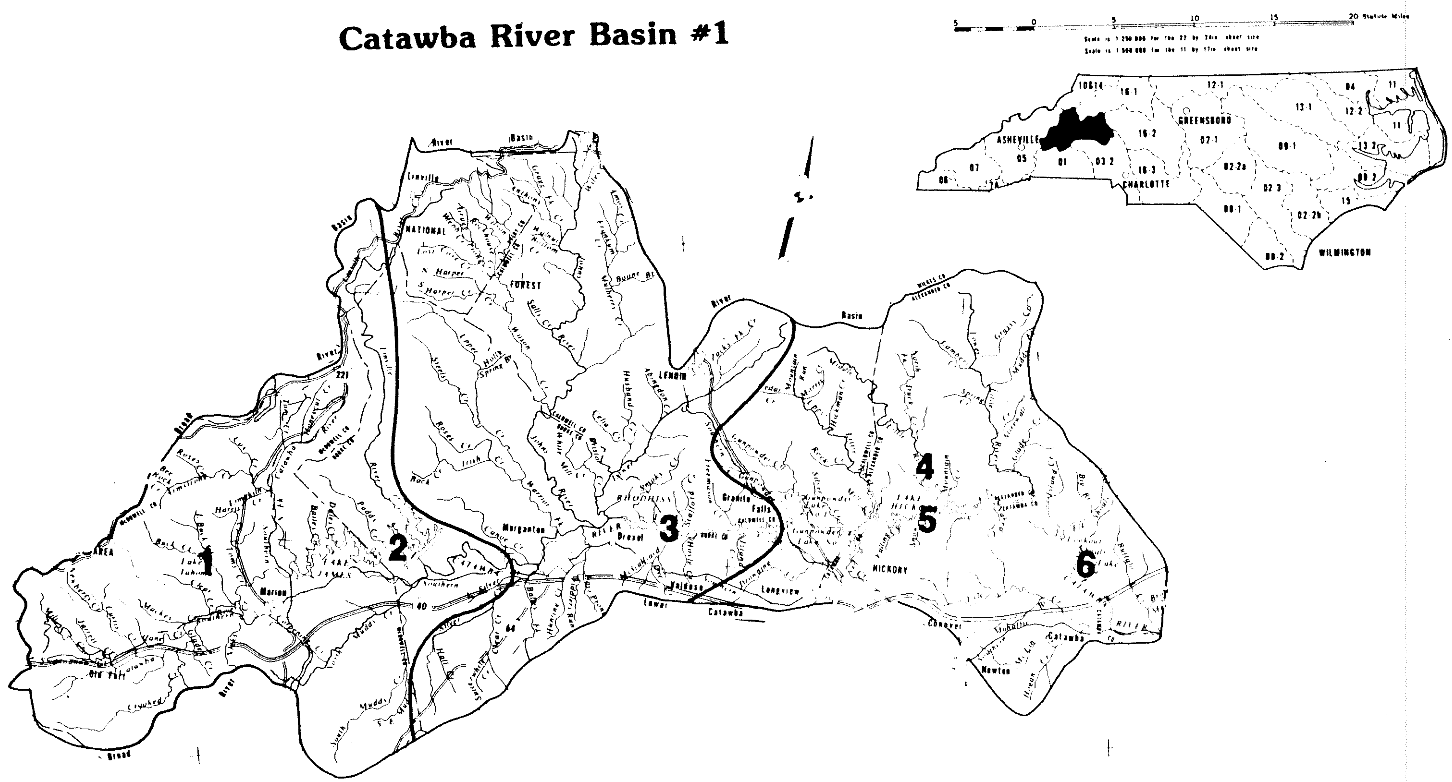
Lake Norman is located on the Catawba River below Lookout Shoals Lake and has historically exhibited good water quality. Water released from Lake Norman forms Mountain Island Lake which is moderately productive. The final impoundment on the Catawba River in North Carolina is Lake Wylie. It is classified eutrophic and is experiencing localized sedimentation and nutrient enrichment problems.

As of 1990, all of the Catawba lakes assessed in this report fully supported designated uses. Only Lake Wylie was classified as threatened as a result of eutrophic conditions and the potential for further water quality problems that exist at the lake.

Four lakes other than the chain lakes are included in this section. Lake Tahoma is a recreational lake located to the north of Marion. Little River Dam is a small impoundment once used for power generation which flows into Lake Hickory. Maiden Lake and Bessemer City Lake are two small water supply reservoirs which are part of the South Fork Catawba River sub-basin. All four of these smaller lakes fully support the uses ascribed to each reservoir.

Catawba #1

Catawba River Basin #1



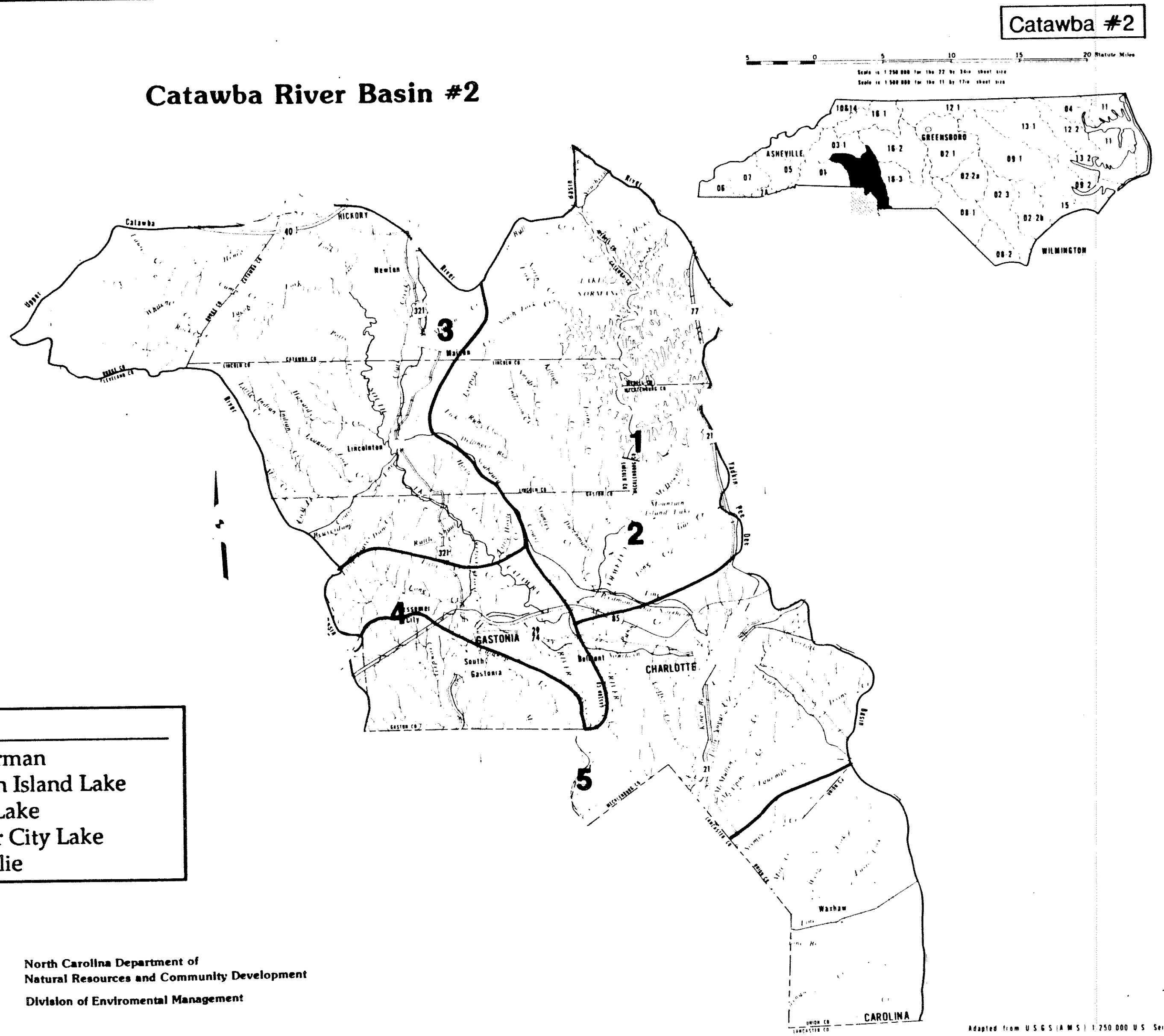
MAP #	LAKE
1	Lake Tahoma
2	Lake James
3	Lake Rhodhiss
4	Little River Dam
5	Lake Hickory
6	Lookout Shoals Lake

North Carolina Department of
Natural Resources and Community Development

Division of Enviromental Management

Adapted from U S G S (A M S) 1 250 000 U S Series

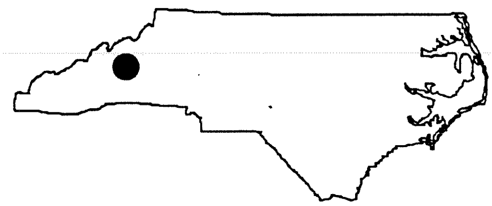
Catawba River Basin #2



MAP #	LAKE
1	Lake Norman
2	Mountain Island Lake
3	Maiden Lake
4	Bessemer City Lake
5	Lake Wylie

North Carolina Department of
Natural Resources and Community Development
Division of Enviromental Management

LAKE TAHOMA



COUNTY:	McDowell	**BASIN:**	Catawba
SURFACE AREA:	65 hectares (161 acres)	**USGS TOPO:**	Marion West, N.C.
CLASS:	B-Tr	**LAKE TYPE:**	Reservoir

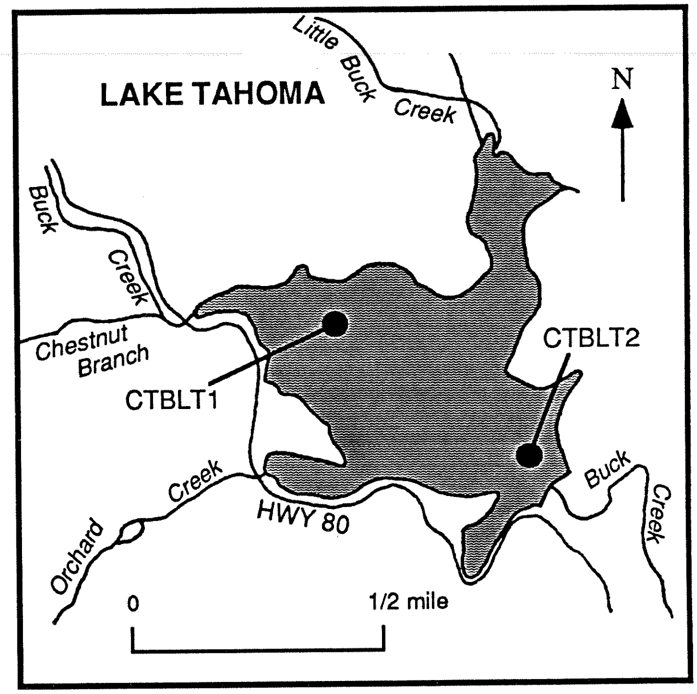
LATEST NCTSI:	-4.1	**TROPHIC STATE:**	Oligotrophic
SAMPLING DATE:	August 2, 1990	**ADDITIONAL COVERAGE:**	None
SECCHI DEPTH:	6.65 m	**CONDUCTIVITY:**	25- 26 µmhos/cm^2
TOTAL PHOSPHORUS:	0.015 mg/l	**DISSOLVED OXYGEN:**	7.8 - 8.2 mg/l
TOTAL ORGANIC NITROGEN:	0.14 mg/l	**TEMPERATURE:**	26.0 - 26.1 °C
CHLOROPHYLL-A:	7 µg/l	**pH:**	5.4 - 6.2 s.u.

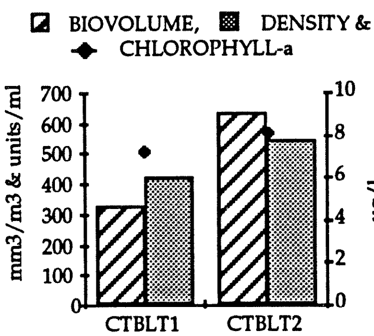
Lake Tahoma was built in the 1920's to produce hydroelectric power, but it is now used for recreation. It is owned by Lake Tahoma, Incorporated - a corporation of property owners living around the lake.

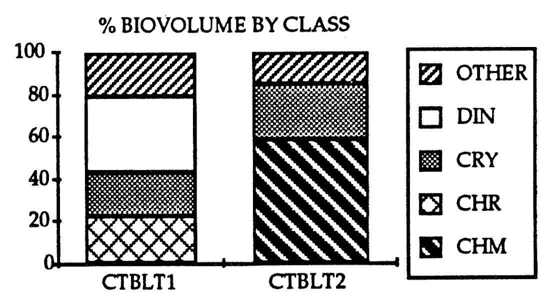
Secchi readings at Lake Tahoma were among the highest ever measured in North Carolina. The water column was stratified and slightly acidic. Some musk grass (chara) and water lilies (nymphaea) were found along the shoreline. Nutrients and chlorophyll-a were low.

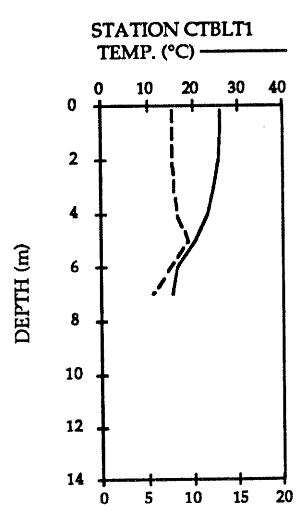
Algal biovolumes and densities in Lake Tahoma were also low. Cryptophytes were dominant at both stations, while Peridinium wisconsinense, a common dinoflagellate, and chrysophytes common to oligotrophic waters (Dinobryon species, Mallomonas species and Ochromonas species) were prevalent at the upper station (CTBLT1). Gonyostomum semen, a large chloromonadophyte, accounted for more than 50% of the algal biovolume at downstream station, (CTBLT2).

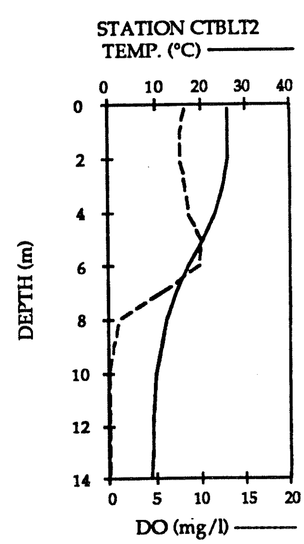
A TSI of -4.1 indicates that Lake Tahoma is oligotrophic. No violations of water quality standards were noted and uses were fully supported at the time of assessment.


LAKE TAHOMA
N
Little Buck Creek
Buck Creek
Chestnut Branch
CTBLT1
CTBLT2
Orchard Creek
HWY 80
Buck Creek
0
1/2 mile

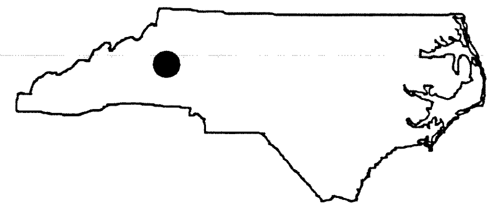

BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/m3 & units/ml
ug/l
CTBLT1
CTBLT2


% BIOVOLUME BY CLASS
OTHER
DIN
CRY
CHR
CHM
CTBLT1
CTBLT2


STATION CTBLT1
TEMP. (°C)
DEPTH (m)
DO (mg/l)


STATION CTBLT2
TEMP. (°C)
DEPTH (m)
DO (mg/l)

LAKE JAMES



COUNTY:	Burke	BASIN:	Catawba
SURFACE AREA:	2,635 hectares (6,510 acres)	USGS TOPO:	Glen Alpine, N.C.
CLASS:	WS, B, C	LAKE TYPE:	Reservoir

LATEST NCTSI:	- 3.6	TROPHIC STATE:	Oligotrophic
SAMPLING DATE:	August 10, 1989	ADDITIONAL COVERAGE:	Fecal, Water Supply Parameters
SECCHI DEPTH:	2.4 m	CONDUCTIVITY:	33 - 55 µmhos/cm^2
TOTAL PHOSPHORUS:	0.02 mg/l	DISSOLVED OXYGEN:	8.5 - 8.8 mg/l
TOTAL ORGANIC NITROGEN:	0.16 mg/l	TEMPERATURE:	25.2 - 26.3 °C
CHLOROPHYLL-A:	2 µg/l	pH:	6.7 - 7.0 s.u.

Lake James was created by three dams which impounded waters of the Catawba River and the Linville River on the eastern edge of the Appalachian Mountains. Construction of the dams began in 1916 and was completed in 1923. The Catawba River, the North Fork of the Catawba River, and the Linville River are major tributaries. The lake has 241 kilometers of shoreline, a maximum depth of 36 meters, and a mean depth of 14 meters. It is the most upstream of all the impoundments in the Catawba Chain Lakes system. Lake James has a drainage basin covering 984 km^2, which is primarily forested and is characterized by rolling hills.

Lake James is owned by Duke Power Company and is classified WS-III and B. It has a mean hydraulic retention time of 208 days. The waters of Lake James are used to generate electricity at the Bridgewater Hydroelectric Plant and for recreational purposes.

When Lake James was sampled on August 10, 1989, it was stratified at all stations with the thermocline occurring at a depth of 8 to 10 meters. The physical-chemical data were indicative of a lake with low productivity and high water quality which is typical of reservoirs in western North Carolina. Surface water samples from each station were analyzed for metals and fecal coliforms. All values for these parameters were below laboratory detection limits.

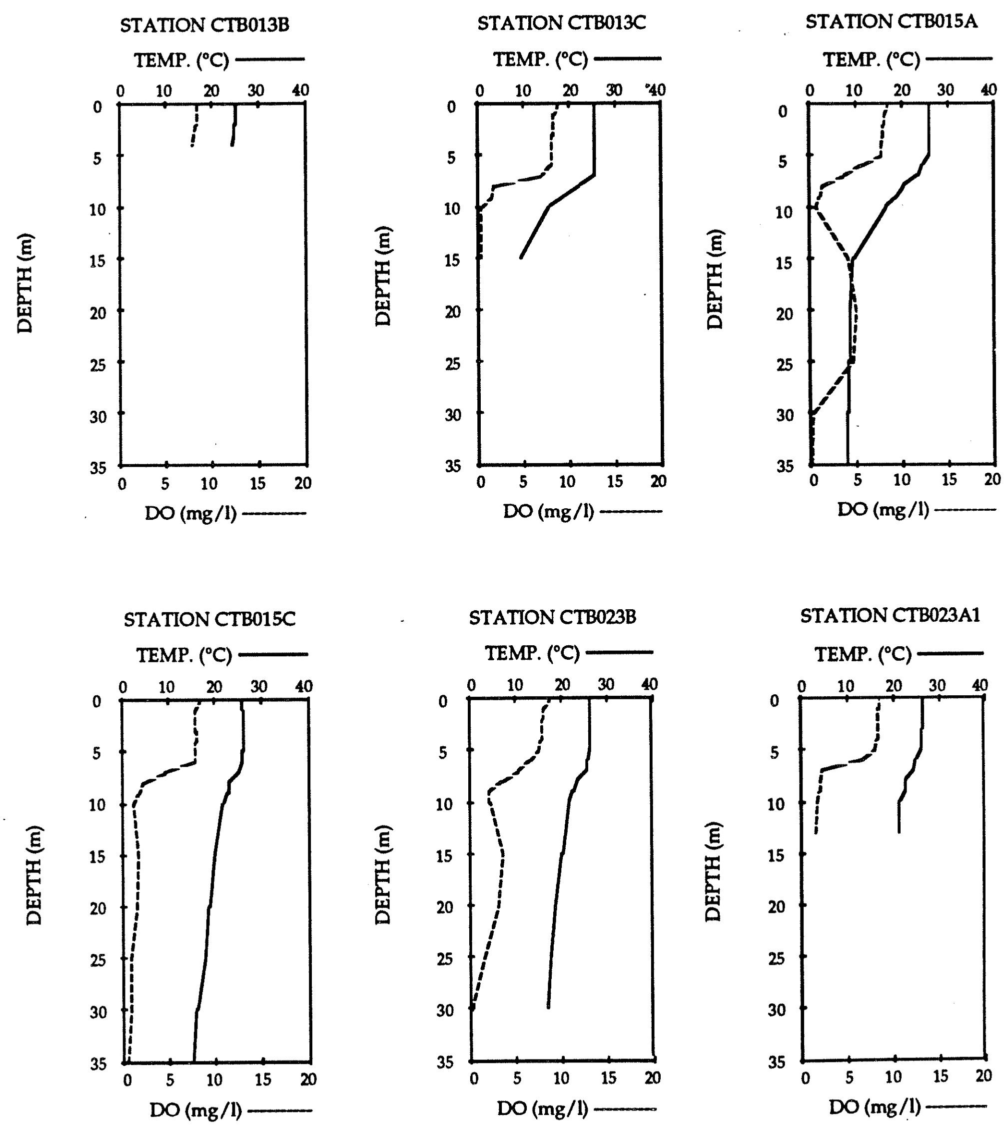
Overall, estimates of algal biovolume and density were moderate throughout Lake James. Highest phytoplankton densities occurred at the uppermost stations: CTB103B and CTB013C on the Catawba River arm and

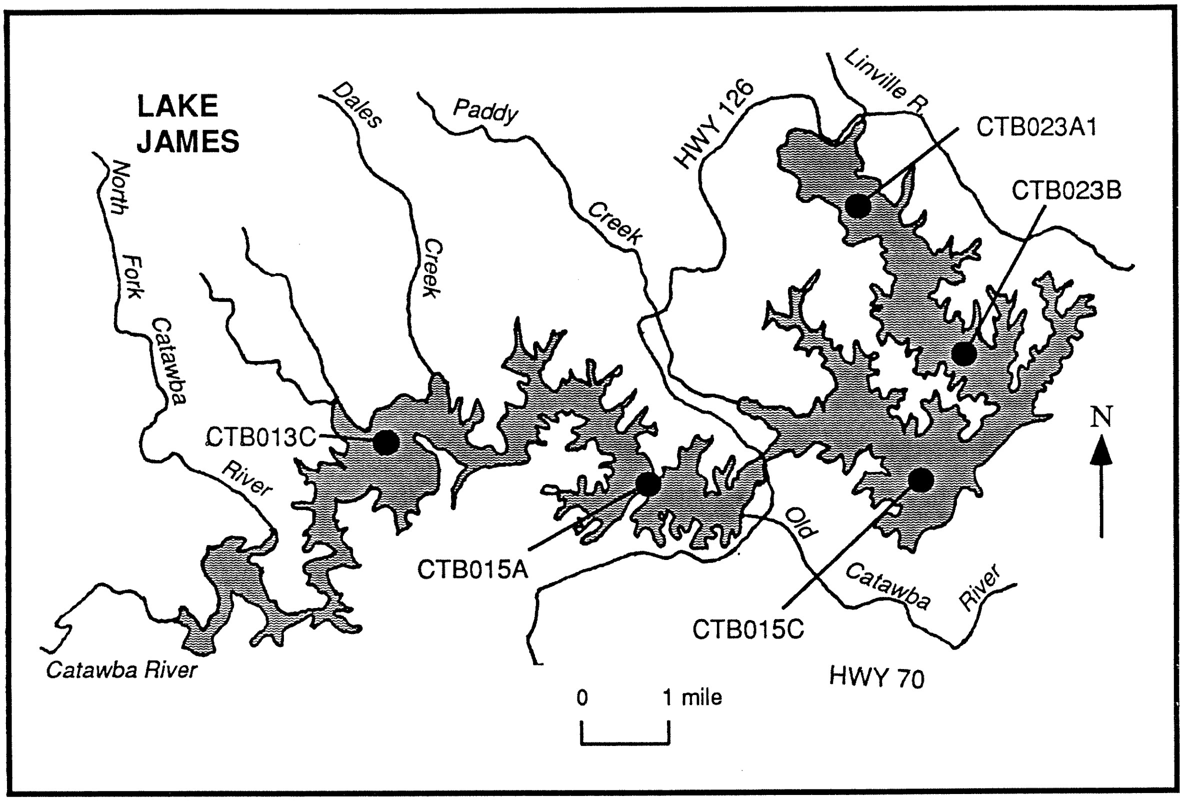
CTB023A1 located on the Linville River arm. Chlorophyll-a concentrations were low at all stations because small, filamentous cyanophytes were dominant.

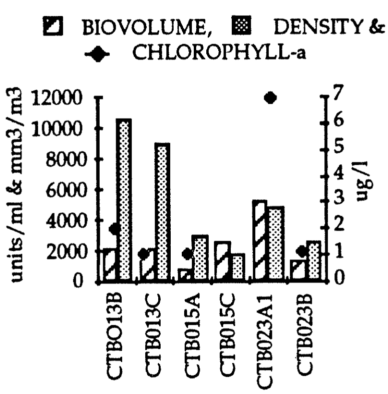
While diatoms (Rhizosolenia eriensis) were most prevalent at the three upper Catawba River stations, dinoflagellates common to piedmont reservoirs (Peridinium spp.) comprised over 40% of the biovolume estimates in the Linville River arm and at the station nearest to the dam.

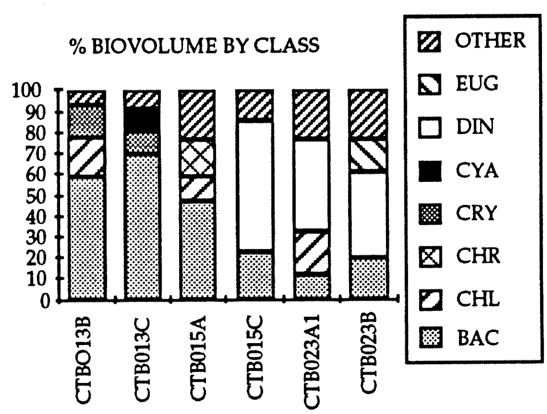
The TSI in 1989 was -3.6, which is similar to historical values. A comparison of the 1989 data with historical data taken from the USEPA National Eutrophication Survey in 1974, suggests that the water quality of the lake has not significantly changed over this time period. Lakewide averages of nitrogen and chlorophyll-a were somewhat higher in the 1974 study.

Historical data for Lake James have consistently described a high level of water quality and the data from 1989 are consistent with this observation. The 1989 TSI value is the lowest of all of the Catawba Chain Lakes sampled in this year. At the time of assessment, no violations of state water quality standards were observed, and uses were fully supported at Lake James.

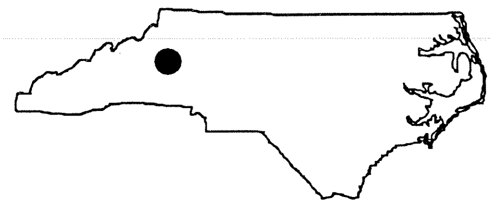



LAKE
JAMES
North Fork Catawba River
Dales Creek
Paddy Creek
HWY 126
Linville R.
CTB023A1
CTB023B
CTB013C
CTB015A
CTB015C
Old Catawba River
Catawba River
HWY 70
0 1 mile
N


BIOVOLUME, DENSITY & CHLOROPHYLL-a
units/ml & mm3/m3
ug/l
12000
10000
8000
6000
4000
2000
0
7
6
5
4
3
2
1
0
CTBO13B
CTB013C
CTB015A
CTB015C
CTB023A1
CTB023B


% BIOVOLUME BY CLASS
100
90
80
70
60
50
40
30
20
10
0
CTBO13B
CTB013C
CTB015A
CTB015C
CTB023A1
CTB023B
OTHER
EUG
DIN
CYA
CRY
CHR
CHL
BAC

LAKE RHODHISS



COUNTY:	Caldwell/Burke	BASIN:	Catawba
SURFACE AREA:	1,423 hectares (3,515 acres)	USGS TOPO:	Granite Falls, N.C.
CLASS:	WS, B	LAKE TYPE:	Reservoir

LATEST NCTSI:	- 1.1	TROPHIC STATE:	Mesotrophic
SAMPLING DATE:	August 10, 1989	ADDITIONAL COVERAGE:	Fecal, Water Supply Parameters
SECCHI DEPTH:	1.1 m	CONDUCTIVITY:	68 - 82 µmhos/cm^2
TOTAL PHOSPHORUS:	0.06 mg/l	DISSOLVED OXYGEN:	7.9 - 8.6 mg/l
TOTAL ORGANIC NITROGEN:	0.17 mg/l	TEMPERATURE:	19.8 - 24.8 °C
CHLOROPHYLL-A:	3 µg/l	pH:	6.7 s.u.

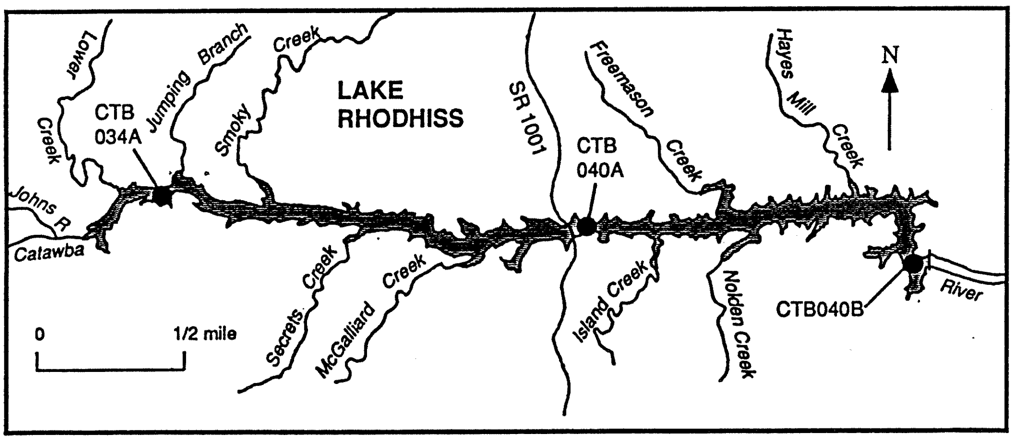
Lake Rhodhiss is owned by Duke Power Company and is formed by the discharge of Lake James into the Catawba River and by the Johns River. The lake was filled upon completion of the Rhodhiss Hydroelectric Station in 1925. Rhodhiss is a relatively narrow lake. Located between Lake James and Lake Hickory on the Catawba River, it has 145 kilometers of shoreline, a maximum depth of 16 meters, and a mean depth of 6 meters. Lake Rhodhiss has a volume of 83.4 x 10^6 m^3 and a mean hydraulic retention time of 21 days. The lake has a drainage basin of 2,823 km^2 characterized by rolling hills. Three-fourths of the land in the watershed is forested. The waters of the lake are classified WS-III and B and are used for recreational purposes as well as to generate hydroelectric power.

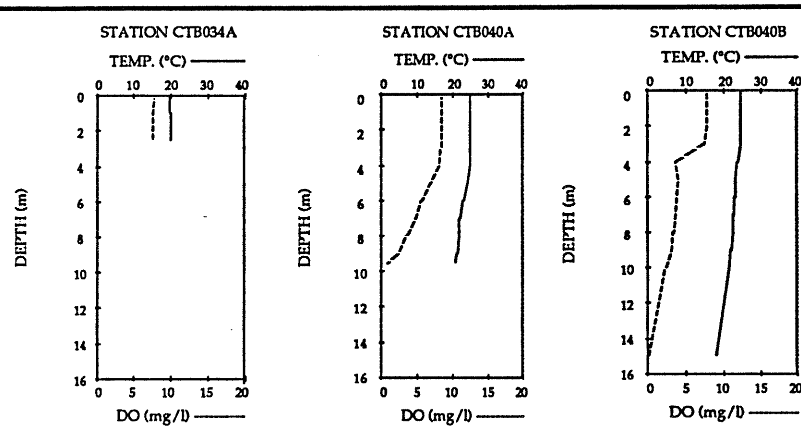
Lake Rhodhiss was sampled on August 10, 1989. Physical measurements indicated a moderately stratified lake with partial mixing at the shallow upper reaches of the lake (CTB034A) and more defined stratification at the deeper, lower end of the impoundment. The upper lake station (CTB034A) had elevated nutrient levels which may be a result of several municipal dischargers located on tributaries to the lake. Red color was also observed at this station, indicating textile dye waste. The lower two stations exhibited photic zone nutrient and algal density concentrations typical of productive, enriched lakes. Nutrients were greater at the bottom of the water column than at the surface. This phenomenon commonly occurs in lakes with an anoxic hypolimnion. Under these conditions, nutrients tend to be released from the sediments into the water column.

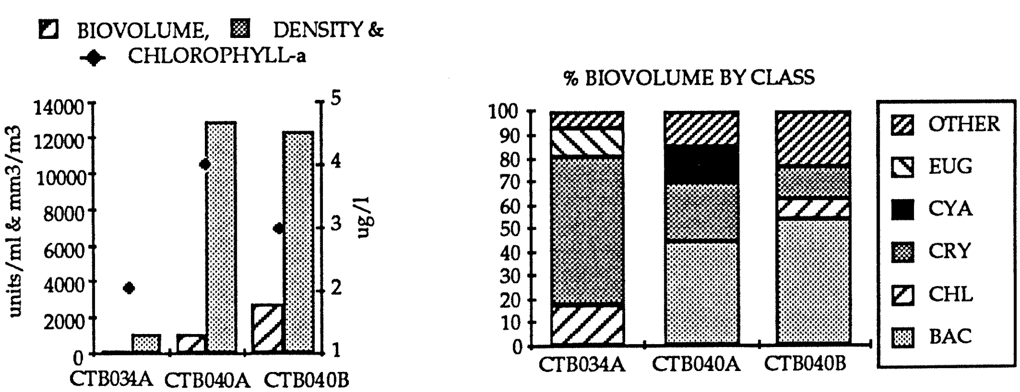
Phytoplanktonic biovolumes in Lake Rhodhiss were all relatively low, and increased in a downstream progression. Chlorophyll-a values were correspondingly low, signifying little algal growth. The slightly elevated densities of phytoplankton at downstream stations CTB040A and CTB040B were caused by the presence of a ubiquitous cryptophyte, Chroomonas minuta.

Compared to 1986, Lake Rhodhiss contained less phytoplankton and lower chlorophyll-a. Heavy rains and consequently higher flows in 1989 may have caused "washouts" of phytoplankton.

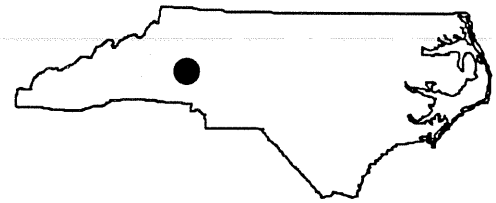
The 1989 TSI was -1.1, which usually indicates mesotrophic conditions. This was the lowest TSI since the lake was first sampled in 1982. However, data from other visits show that the lake is more appropriately classified eutrophic. Precipitation was high before sampling in 1989, and appears to have decreased retention time, thereby limiting algal growth. At the time of assessment, no violations of state standards were observed, and the water quality of Lake Rhodhiss fully supported designated uses.







LITTLE RIVER DAM



COUNTY:	Alexander	BASIN:	Catawba
SURFACE AREA:	66 hectares (162 acres)	USGS TOPO:	Bethlehem, N.C.
CLASS:	C	LAKE TYPE:	Reservoir

LATEST NCTSI:	1.5	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	July 31, 1990	ADDITIONAL COVERAGE:	None
SECCHI DEPTH:	0.9 m	CONDUCTIVITY:	31 µmhos/cm^2
TOTAL PHOSPHORUS:	0.04 mg/l	DISSOLVED OXYGEN:	8.7 mg/l
TOTAL ORGANIC NITROGEN:	0.35 mg/l	TEMPERATURE:	29.4 °C
CHLOROPHYLL-A:	24 µg/l	pH:	7.2 s.u.

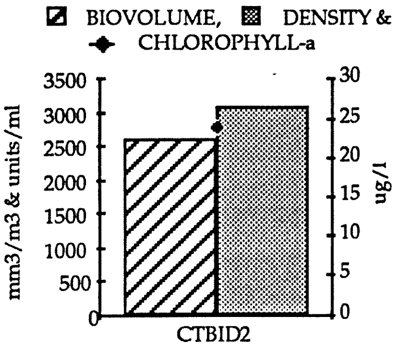
Hydroelectric power was first generated at Little River Dam in November of 1919. The lake was owned by several utilities until Western Carolina Power Company was absorbed by Duke Power Company, the owner of the lake. On June 30, 1969, Duke Power Company retired the lake from power production.

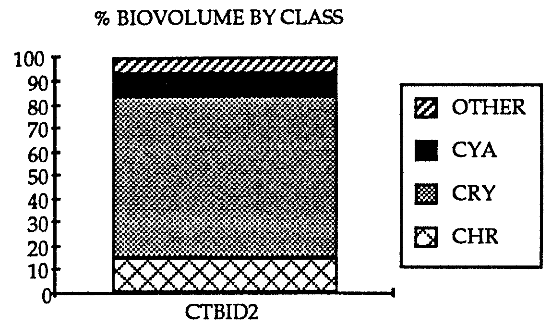
Little River Dam drains a hilly, 64 km^2-watershed which is mainly forested. Some residences exist around the shoreline. The lake is not used extensively by the public, although it is fished by some of the nearby residents.

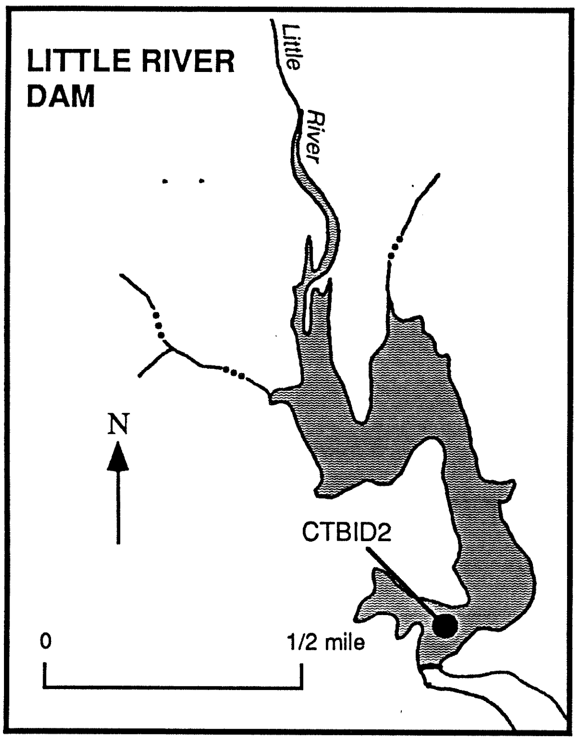
Little River Dam was samped on July 31, 1990. Physical measurements indicated stratification with dissolved oxygen approaching zero below two meters and a 18.4 °C difference between temperatures at the surface of the water and the hypolimnion. Nutrients and chlorophyll-a were elevated, but no violations of water quality standards were found.

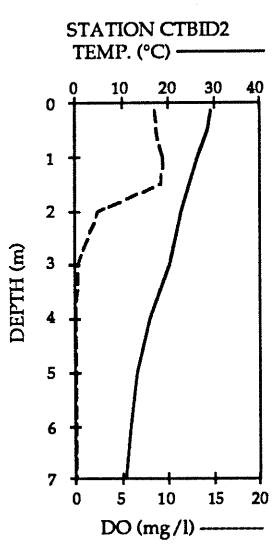
Estimates of phytoplanktonic biovolume were dominated by 69% cryptophytes, an algal class that is widespread throughout the state. Small chrysophytes and colonial blue-green algae, predominately Gomphosphaeria lacustris accounted for the other algal biovolume dominants. The phytoplanktonic biovolume (2,607 mm^3/m^3), and density (3,098 units/ml) were moderate.

A TSI of 1.5 indicated Little River Dam is eutrophic. At the time of this assessment, the lake fully suported designated uses.

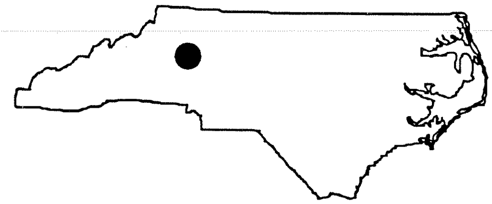

BIOVOLUME, DENSITY &
CHLOROPHYLL-a
3500
3000
2500
2000
1500
1000
500
0
mm3/m3 & units/ml
30
25
20
15
10
5
0
ug/l
CTBID2


% BIOVOLUME BY CLASS
100
90
80
70
60
50
40
30
20
10
0
CTBID2
OTHER
CYA
CRY
CHR


LITTLE RIVER
DAM
Little
River
N
CTBID2
0
1/2 mile


STATION CTBID2
TEMP. (°C)
0
10
20
30
40
0
1
2
3
4
5
6
7
DEPTH (m)
0
5
10
15
20
DO (mg/l)

LAKE HICKORY



COUNTY:	Alexander/Catawba	BASIN:	Catawba
SURFACE AREA:	1,659 hectares (4,100 acres)	USGS TOPO:	Millersville, N.C.
CLASS:	WS, B	LAKE TYPE:	Reservoir

LATEST NCTSI:	- 0.4	TROPHIC STATE:	Mesotrophic
SAMPLING DATE:	August 9, 1989	ADDITIONAL COVERAGE:	Fecal, Water Supply Parameters
SECCHI DEPTH:	1.15 m	CONDUCTIVITY:	48 - 63 μmhos/cm^2
TOTAL PHOSPHORUS:	0.03 mg/l	DISSOLVED OXYGEN:	8.1 - 9.4 mg/l
TOTAL ORGANIC NITROGEN:	0.35 mg/l	TEMPERATURE:	26.6 - 27.5 °C
CHLOROPHYLL-A:	5 μg/l	pH:	7.5 - 7.7 s.u.

Lake Hickory is a run-of-the-river impoundment located between Lake Rhodhiss and Lookout Shoals Lake on the Catawba River. The lake was filled when construction on the Oxford Hydroelectric Plant was completed in 1928. Lake Hickory has 169 kilometers of shoreline, a maximum depth of 26 meters, a mean depth of 10 meters and an average hydraulic retention time of 33 days.

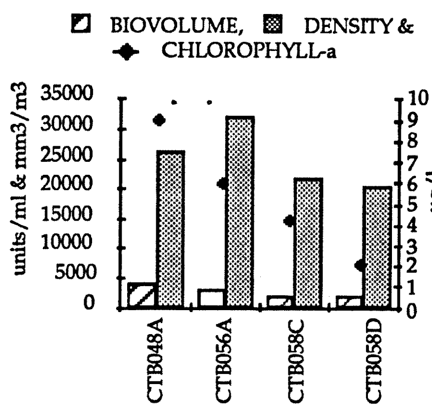
The drainage basin for Lake Hickory covers 3,393 km^2 characterized by rolling hills. Approximately half of the area is forested and another one-third is agricultural. The major tributaries into Lake Hickory are the Catawba River, Middle Little River, and Gunpowder Creek. The lake is owned by the Duke Power Company, and the waters of the lake are used to generate hydroelectric power and for recreation. Lake Hickory has several municipal wastewater dischargers located in the watershed which have contributed to the eutrophic conditions observed over the years.

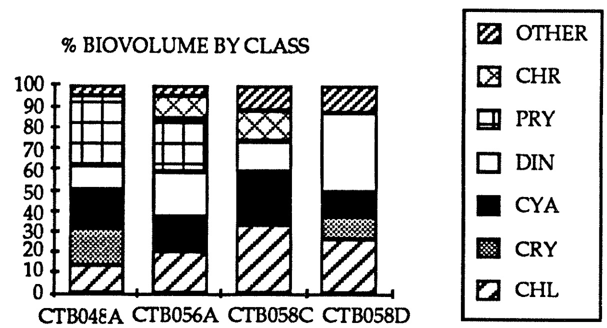
Lake Hickory was sampled on August 7, 1989 and exhibited mild thermal stratification at stations near the dam. Analyses for metals and fecal coliform bacteria found no levels above laboratory detection limits at any of the lake stations.

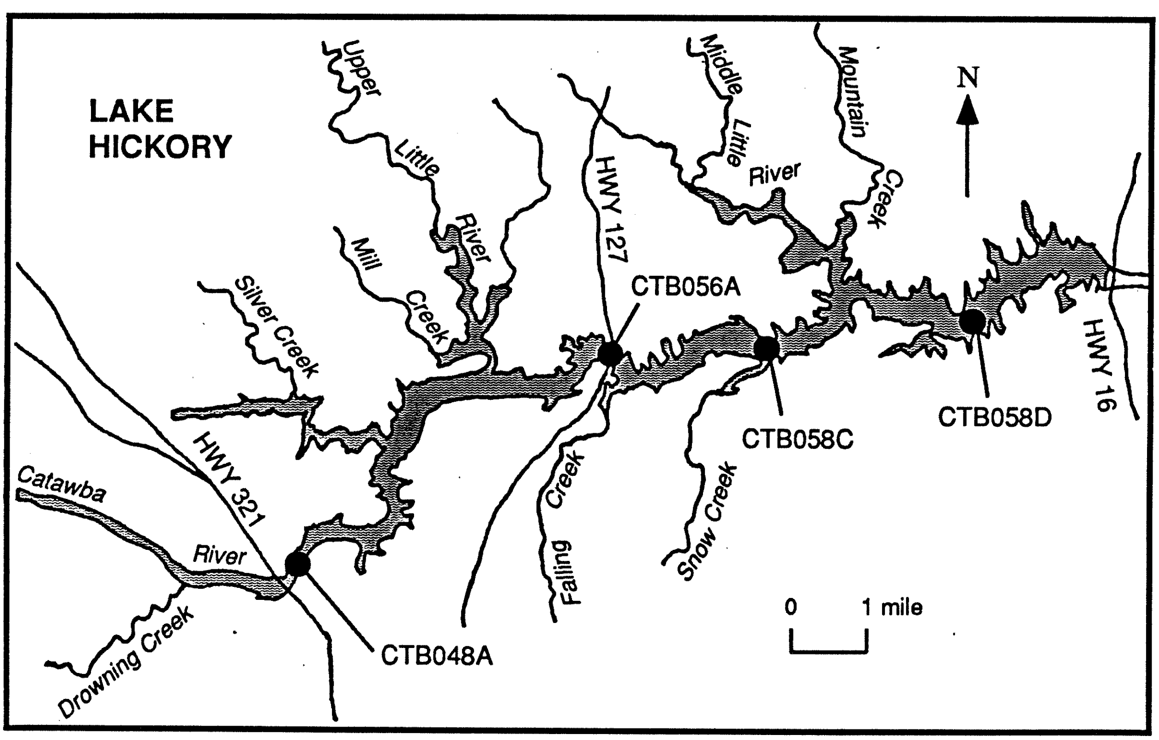
As in past years, algal communities in Lake Hickory were dominated by small, filamentous cyanophytes (Anabaenopsis phillipinensis, Lyngbya spp., and A. raciborskii) along with small chrysophytes (Ochromonas species 3). While density estimates were elevated because of the presence of these small species, biovolumes and corresponding chlorophyll-a concentrations were moderately low, and decreased in a downstream progression. Algal species composition by biovolume remained fairly consistent between sampling stations at Lake Hickory.

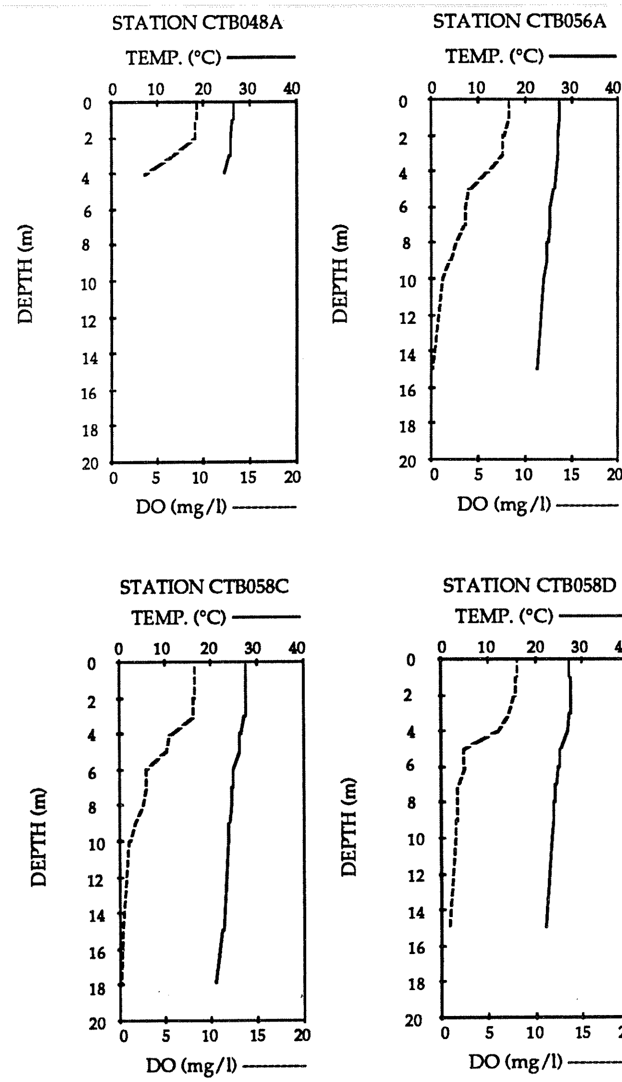
While TSI's consistently rank Lake Hickory as eutrophic, phytoplanktonic density and biovolume estimates have been relatively low, especially when compared with the other lakes in this chain. The only indicator of possible eutrophic conditions were the dominant species. Lyngbya species, Anabaenopsis raciborskii, A. phillipinensis, and Oscillatoria geminata were present at all stations. These species are common to eutrophic piedmont lakes and reservoirs.

The TSI in 1989 was -0.4, which is lower than previously recorded values. Flow data for these years shows that 1989 was the wettest year of sampling. This suggests that high flow may have decreased the TSI value as a result of dilution and decreased retention time in the lake. At the time of assessment, no violations of state water quality standards were observed at Lake Hickory and the lake fully supported designated uses.

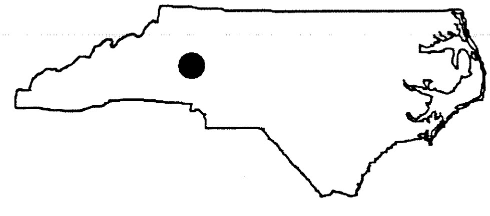







STATION CTB048A
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0 2 4 6 8 10 12 14 16 18 20
0 5 10 15 20
DO (mg/l)
STATION CTB056A
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0 2 4 6 8 10 12 14 16 18 20
0 5 10 15 20
DO (mg/l)
STATION CTB058C
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0 2 4 6 8 10 12 14 16 18 20
0 5 10 15 20
DO (mg/l)
STATION CTB058D
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0 2 4 6 8 10 12 14 16 18 20
0 5 10 15 20
DO (mg/l)

LOOKOUT SHOALS LAKE



COUNTY:	Catawba/Iredell	BASIN:	Catawba
SURFACE AREA:	514 hectares (1,270 acres)	USGS TOPO:	Stoney Point, N.C.
CLASS:	WS, B	LAKE TYPE:	Reservoir

LATEST NCTSI:	0.0	TROPHIC STATE:	Mesotrophic
SAMPLING DATE:	August 9, 1989	ADDITIONAL COVERAGE:	Fecal, Water Supply Parameters
SECCHI DEPTH:	1.0 m	CONDUCTIVITY:	49 - 50 µmhos/cm^2
TOTAL PHOSPHORUS:	0.03 mg/l	DISSOLVED OXYGEN:	7.2 - 8.7 mg/l
TOTAL ORGANIC NITROGEN:	0.24 mg/l	TEMPERATURE:	25.8 - 26.3 °C
CHLOROPHYLL-A:	14 µg/l	pH:	6.3 - 6.7 s.u.

Lookout Shoals Lake is one of the smaller Catawba chain lakes with a surface area of 514 hectares and 63 kilometers of shoreline. The lake is owned by Duke Power and is located between Lake Hickory and Lake Norman on the Catawba River. Construction of the Lookout Shoals Dam was begun in 1914 and was completed in 1916, making it the first dam built on the Catawba River in North Carolina by J. B. Duke. Lookout Shoals Lake has a drainage basin covering 3,755 km^2, a maximum depth of 21 meters, a mean depth of nine meters, and a mean hydraulic retention time of seven days, the shortest of any in the Catawba River basin. The waters of the lake are used to generate electricity at the Lookout Shoals Hydroelectric plant and for recreation. The lake is currently classified as WS III from its headwaters to Elk Shoal Creek and WS III and Class B from Elk Shoal Creek to Lookout Shoals Dam.

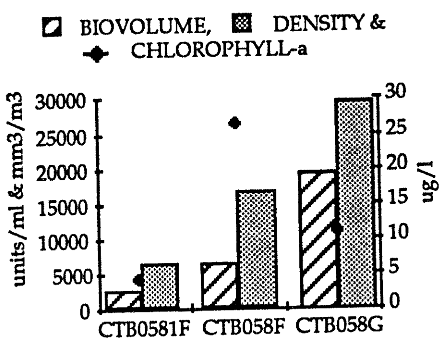
Water quality in Lookout Shoals Lake is more reflective of releases from upstream impoundments (Lake Hickory, Lake Rhodhiss, and Lake James) than conditions in the surrounding watershed. When sampled on August 8, 1989, the dissolved oxygen and temperature data indicated that mildly stratified conditions existed at all of the lake stations. The nutrient data revealed slightly higher concentrations in the upper section of the lake (station CTB0581F) than at the mid-lake and dam stations. Analyses of surface waters for fecal coliform bacteria and metals found no concentrations above laboratory detection limits.

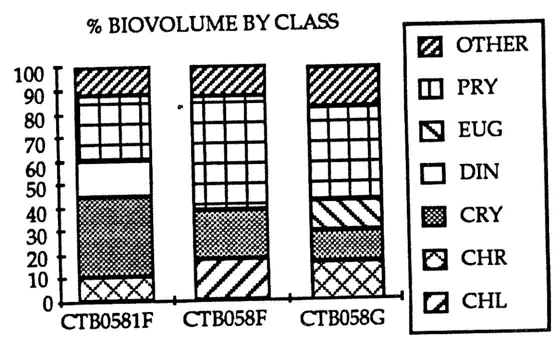
Algal biovolumes and densities in Lookout Shoals Lake increased in a downstream progression and were highest near the dam. Species composition was relatively similar at the three stations. As in upstream reservoirs (Lakes Hickory, Rhodhiss and James), small cyanophytes, Lyngbya spp., along with cryptophytes, were dominant by density.

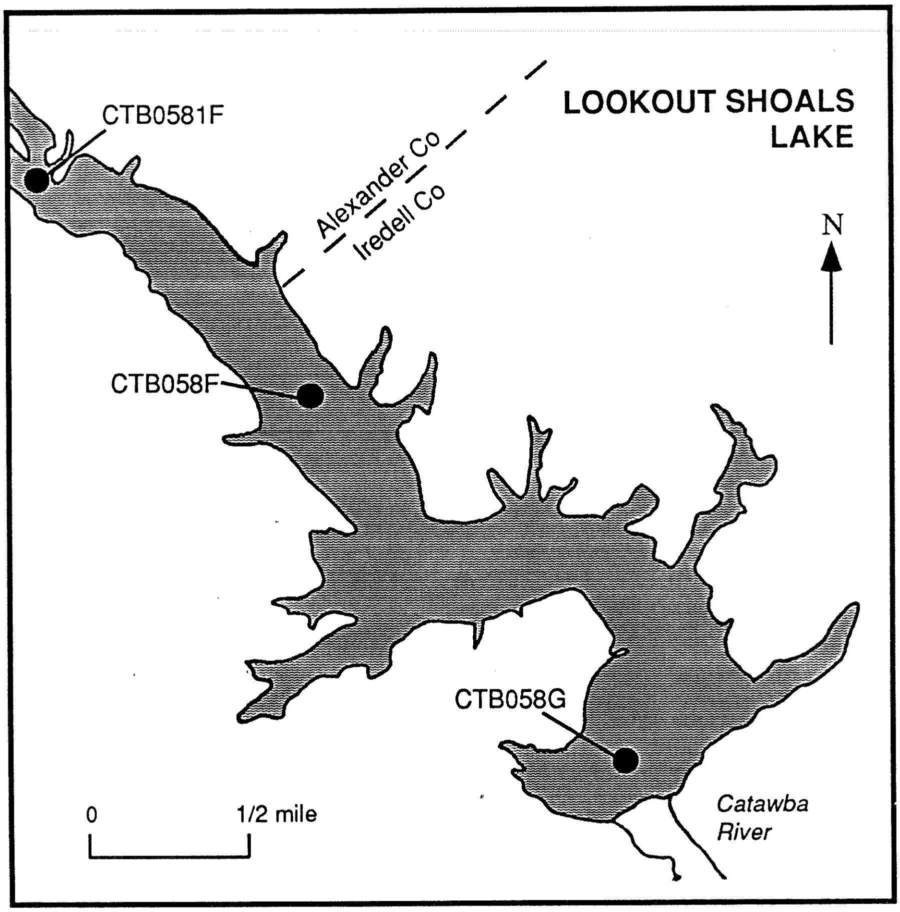
The highest chlorophyll-a (27 ug/l) was found at the middle station which contained nearly 50% Chrysochromulina breviturrita (a prymnesiophyte). This species is often associated with elevated chlorophyll-a concentrations.

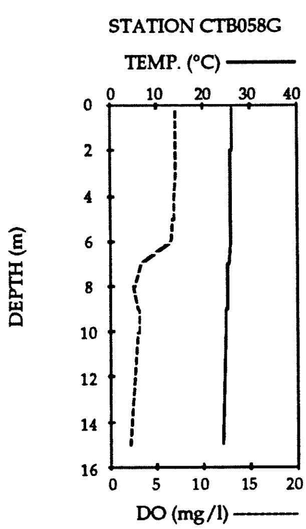
The 1989 TSI was calculated to be 0.0 which is between the previous two values of 0.2 and -0.9. This range in TSI values is not unexpected for any lake given the natural variation of the parameters involved. Lookout Shoals Lake has consistently bordered between the eutrophic and mesotrophic classifications.

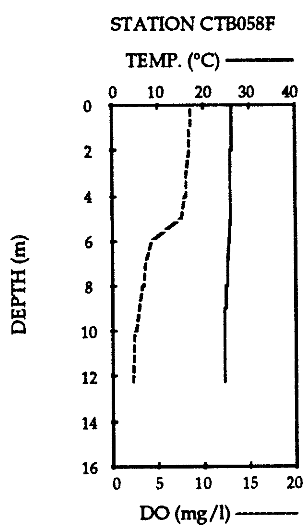
At the time of assessment, no violations of state water quality standards were observed at Lookout Shoals Lake and the lake fully supported designated uses.

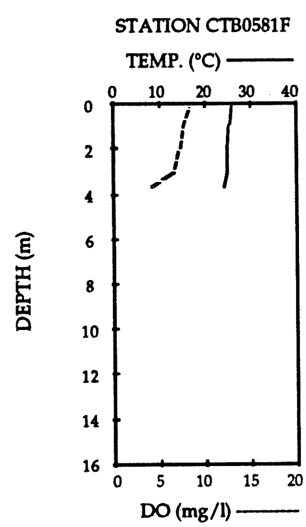




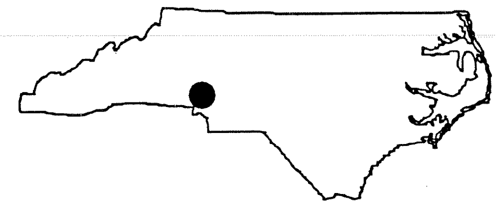

LOOKOUT SHOALS LAKE
CTB0581F
CTB058F
CTB058G
Alexander Co
Iredell Co
N
0
1/2 mile
Catawba River


STATION CTB058G
TEMP. (°C)
DEPTH (m)
DO (mg/l)


STATION CTB058F
TEMP. (°C)
DEPTH (m)
DO (mg/l)


STATION CTB0581F
TEMP. (°C)
DEPTH (m)
DO (mg/l)

LAKE NORMAN



COUNTY:	Lincoln/Mecklenburg	BASIN:	Catawba
SURFACE AREA:	13157 hectares (32510 acres)	USGS TOPO:	Lake Norman South, N.C.
CLASS:	WS, B	LAKE TYPE:	Reservoir

LATEST NCTSI:	- 2.1	TROPHIC STATE:	Mesotrophic
SAMPLING DATE:	August 19, 1986	ADDITIONAL COVERAGE:	Fecal, Metals
SECCHI DEPTH:	2.7 m	CONDUCTIVITY:	76 - 90 μmhos/cm^2
TOTAL PHOSPHORUS:	0.02 mg/l	DISSOLVED OXYGEN:	7.4 - 8.4 mg/l
TOTAL ORGANIC NITROGEN:	0.18 mg/l	TEMPERATURE:	27 - 28 °C
CHLOROPHYLL-A:	11 μg/l	pH:	6.5 - 7.1 s.u.

Lake Norman, the largest man-made lake in North Carolina, covers 13,157 hectares and provides a shoreline of more than 837 kilometers when filled to capacity. Located between Lookout Shoals Lake and Mountain Island Lake on the Catawba River, the lake extends nearly 55 kilometers from the Cowans Ford Dam to the tailrace of Lookout Shoals Lake. Construction of the Cowans Ford Dam began in 1959 and the dam and hydroelectric station were completed in 1967. Lake Norman is owned by Duke Power Company, and the water from the lake is used in two ways to generate electricity. It is used to power the hydroelectric generators at Cowans Ford Dam, and to cool the steam that drives the turbines at the Marshall Steam Station and McGuire Nuclear Station.

Lake Norman has a maximum depth of 36 meters, a mean depth of 10 meters, and a mean hydraulic retention time of 239 days. The lake is the largest of the Catawba Chain Lakes and drains a watershed of approximately 4,636 km^2 with the Catawba River, Lyle Creek, and Buffalo Shoals Creek as its major tributaries. The topography of the drainage area is characterized by rolling hills with forested and agricultural land uses. The waters of the lake are classified WS-III from Lookout Shoals Dam to Lyle Creek and WS-III and B from Lyle Creek to Cowans Ford Dam.

During the years 1974 through 1980, Duke Power Company conducted an intensive survey of Lake Norman to collect aquatic ecosystem data. The study reported that Lake Norman exhibited physical, chemical, and biological characteristics typical of other piedmont reservoirs. The lake receives relatively low inputs of pollutants compared to other reservoirs in the region, and this has allowed the lake to maintain its mesotrophic classification (Duke Power 1982).

The lake was sampled on August 19, 1986 by DEM. Physical parameters indicated that the lake was stratified. Consistent with earlier observations, concentrations of nutrients and chlorophyll-a were generally higher at upstream stations than at stations closer to the dam, with overall values reflective of a moderately productive lake. Heavy metals were below laboratory detection limits. Bacterial analyses for fecal coliforms showed a range of values from 90 to 890 MFFCC/100 ml, with the highest numbers found at the upstream stations.

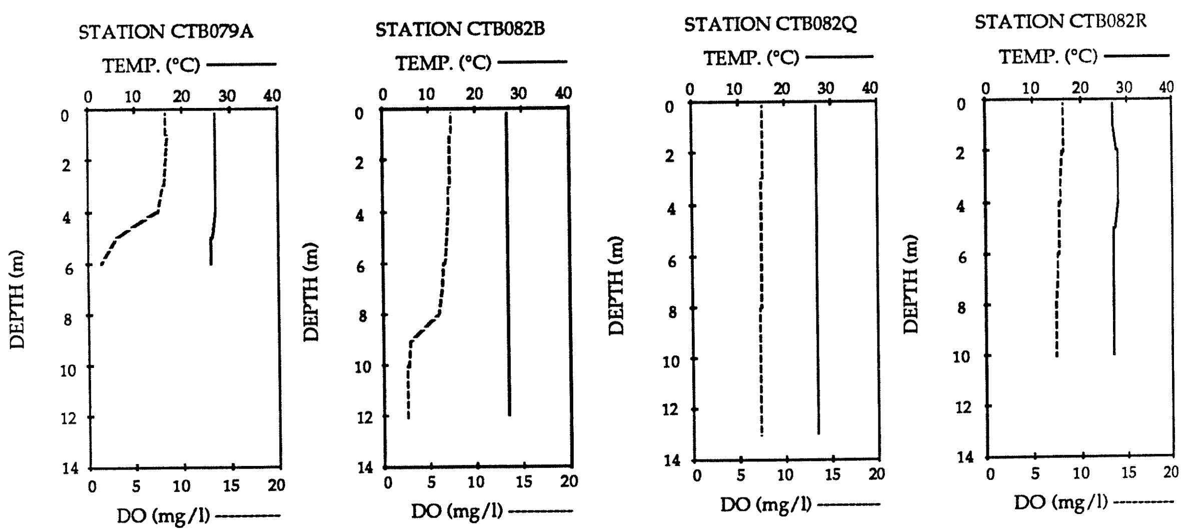
Phytoplanktonic populations reflected the moderate nutrient concentrations found in Lake Norman during August 1986. The exception was station CTB079A where density was near bloom levels (15,984 units/ml). Cyanophytes, Anabaenopsis raciborskii and two Lyngbya species, dominated density measurements at this station; however, biovolume estimates were dominated by the euglenophyte, Trachelomonas hispida punctata, and numerous small chlorophytes. The summer of 1986 was dry with little rain during June and July, increasing the impact of point sources in the upper end of the lake.

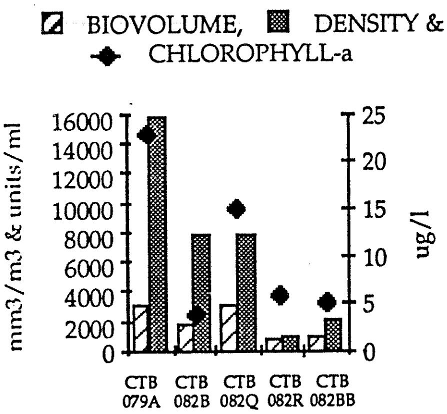
Dinoflagellates dominated the biovolume at the lower lake stations, CTB082B and CTB082R, and at CTB082Q in the Reeds Creek arm. Duke Power reported similar assemblages of phytoplankton in these areas of the lake in 1984 (Duke Power 1985). Euglenophytes (Trachelomonas species) dominated density and biovolume at the two stations closest to the dam during 1986.

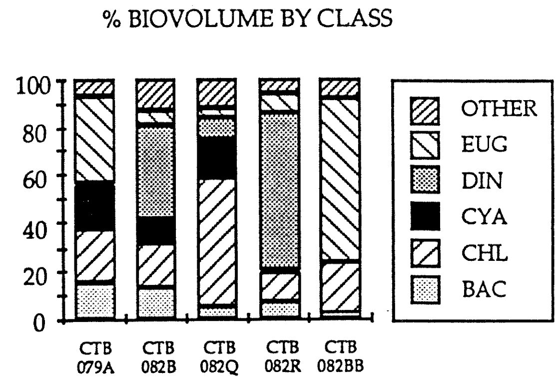
While density and biovolume estimates for 1986 were similar to results from 1983 at CTB082B, there was a shift from domination by cryptophytes and chlorophytes to primarily dinoflagellates and euglenophytes. During October and November of 1985, algal bloom samples were received from this area of the lake (NRCD 1986a). These samples were dominated by Anacystis cyanae (Microcystis aeruginosa), a blue-green alga that forms surface scums. Chlorophyll-a concentrations at the three sites sampled ranged from 1300 - 8700 µg/l. Duke Power has documented similar bloom events and is presently examining Anacystis dynamics and their relation to lake hydrodynamics and nutrient loading (Duke Power 1987).

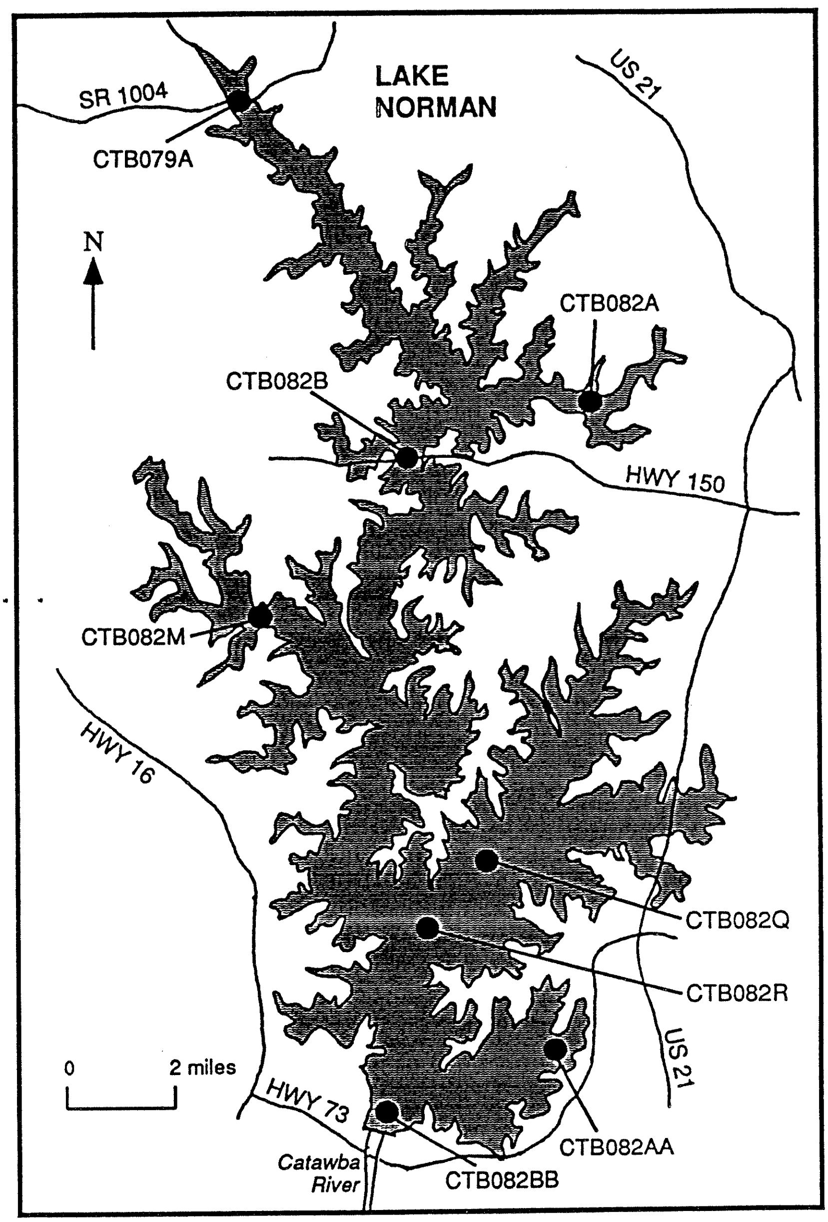
The TSI value in 1986 was -2.1, which is lower than the value of -0.7 in 1983, and the value of -1.9 in 1981. This is consistent with the findings of the Duke Power study, and suggests that the water quality of the lake has not significantly changed over this time period.

Overall, Lake Norman has been able to maintain a relatively high level of water quality over time. Although some localized problems may occur in the embayments - as seen in Lake Wylie and Kerr Reservoir - these effects are muted by the large amount of dilution water in the mainstem. At the time of assessment, no violations of state water quality standards were observed at Lake Norman and the lake fully supported designated uses.

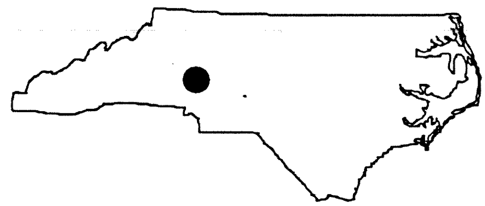



BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/m3 & units/ml
16000
14000
12000
10000
8000
6000
4000
2000
0
25
20
15
10
5
0
ug/l
CTB 079A
CTB 082B
CTB 082Q
CTB 082R
CTB 082BB


% BIOVOLUME BY CLASS
100
80
60
40
20
0
OTHER
EUG
DIN
CYA
CHL
BAC
CTB 079A
CTB 082B
CTB 082Q
CTB 082R
CTB 082BB


LAKE NORMAN
SR 1004
US 21
CTB079A
N
CTB082A
CTB082B
HWY 150
CTB082M
HWY 16
CTB082Q
CTB082R
0
2 miles
HWY 73
CTB082AA
Catawba River
CTB082BB

MOUNTAIN ISLAND LAKE



COUNTY:	Gaston/Mecklenburg	BASIN:	Catawba
SURFACE AREA:	1.309 hectares (3,235 acres)	USGS TOPO:	Mountain Island Lake, N.C.
CLASS:	WS, B	LAKE TYPE:	Reservoir

LATEST NCTSI:	- 1.8	TROPHIC STATE:	Mesotrophic
SAMPLING DATE:	August 25, 1986	ADDITIONAL COVERAGE:	Metals
SECCHI DEPTH:	2.1 m	CONDUCTIVITY:	102 - 130 µmhos/cm^2
TOTAL PHOSPHORUS:	0.02 mg/l	DISSOLVED OXYGEN:	7.2 - 8.5 mg/l
TOTAL ORGANIC NITROGEN:	0.21 mg/l	TEMPERATURE:	28 - 29 °C
CHLOROPHYLL-A:	9 µg/l	pH:	6.6 - 6.7 s.u.

Mountain Island Lake is located between Lake Norman and Lake Wylie on the Catawba River. Duke Power Company owns the lake, which was filled when construction of the Mountain Island Hydroelectric Station was completed in 1924. Mountain Island is a relatively narrow lake with a surface area of 1,309 hectares and 98 kilometers of shoreline. The lake has a maximum depth of 16 meters, a mean depth of five meters, a volume of 71 x 10^6 m^3, and a mean hydraulic retention time of only 12 days.

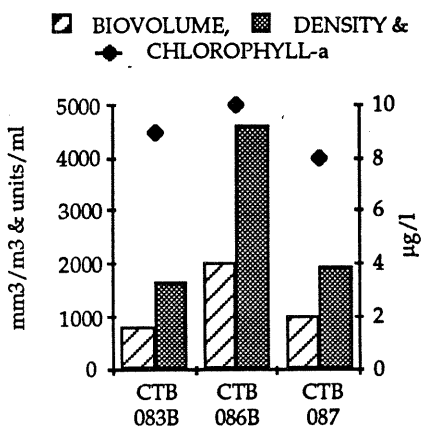
The drainage area of Mountain Island Lake encompasses 4,817 km^2 of land characterized by very hilly terrain. Approximately half of the watershed is forested, one quarter is agricultural, and the remainder is urban. The waters of Mountain Island Lake are used to supply water for the City of Charlotte and by Duke Power to generate electricity at the Riverbend Steam Station and the Mountain Island Station. The lake is classified WS III from Cowans Ford Dam to the water intake at the River Bend Steam Station and as WS III and Class B water from the water intake to the dam.

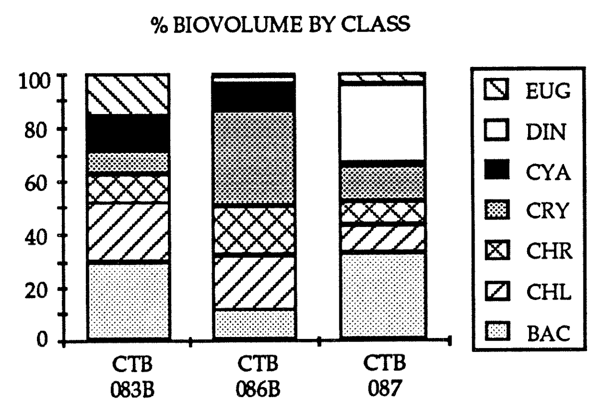
Mountain Island Lake was sampled on August 25, 1986. Physical measurements showed that the shallow, upper section of the lake (station CTB0083B) was well mixed, but that the two downstream stations were stratified. Nutrient levels were moderate in the photic zone, reflecting the mesotrophic status of the lake. No significant differences were observed in water quality parameters between stations. Heavy metals were not detected in the lake.

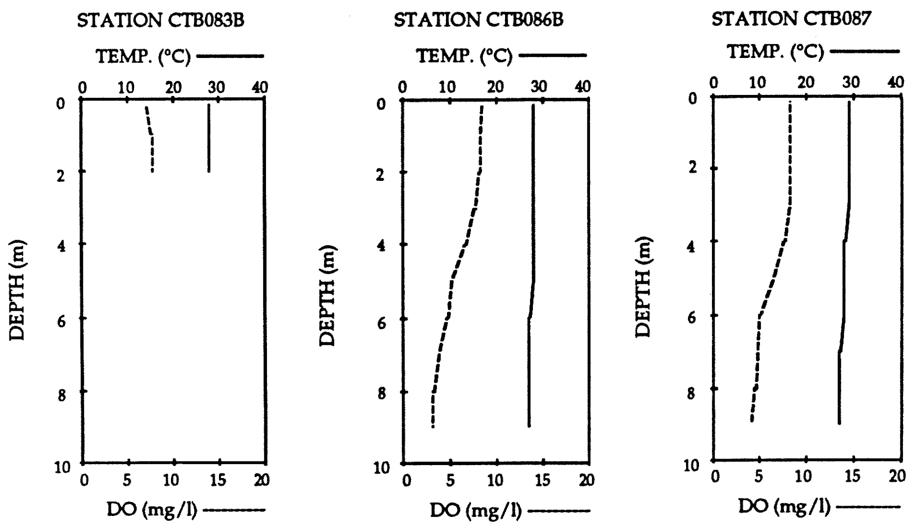
Diatoms and cryptophytes dominated algal assemblages in Mountain Island Lake. Short retention time and low nutrient concentration resulted in low phytoplanktonic density and biovolume at all stations. As with most mesotrophic systems there was a variety of species present, especially small green algae.

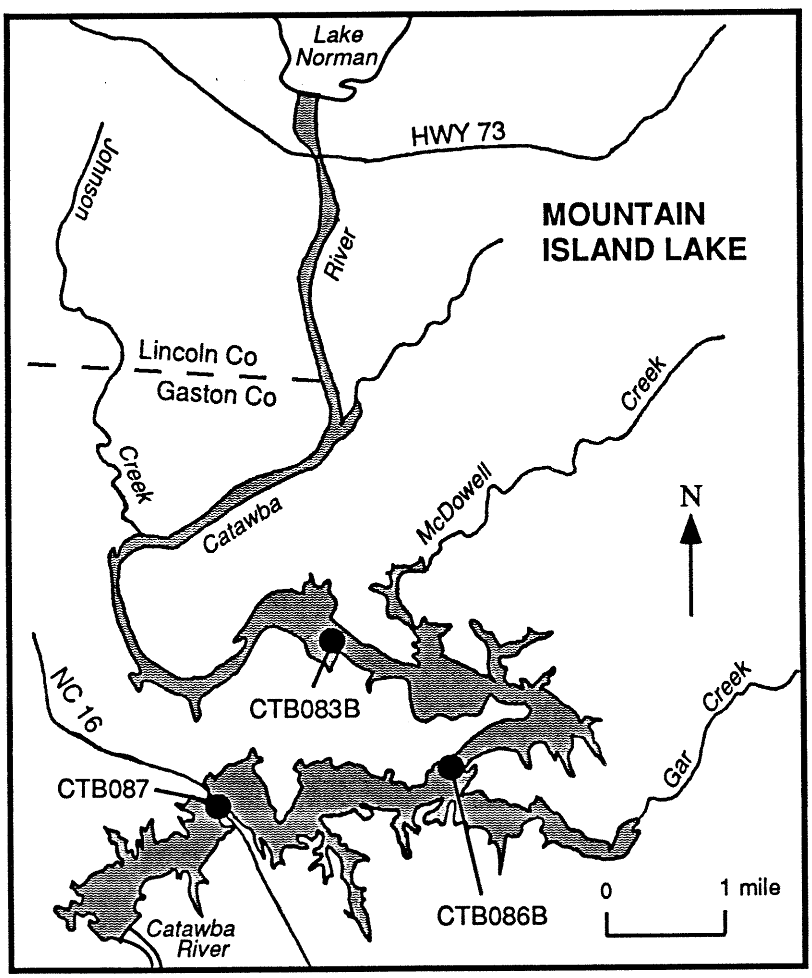
The highest density and biovolume were seen at CTB086B which is located near the middle of the lake. Chroomonas caudata, a small cryptophyte, dominated both density and biovolume in this area of the lake. This station is located below the mouth of McDowell Creek which receives discharge from Charlotte Mecklenburg Utility District WWTP. CTB083B and CTB087 had assemblages similar to Lake Norman with Trachelomonas species 5 among the dominant species at both stations.

The TSI in 1986 was -1.8 which is slightly lower than the 1982 TSI value of -0.8. Because Mountain Island Lake is located just downstream from Lake Norman, its water quality is dependent upon the quality of the discharge from that reservoir. As Lake Norman has had good water quality, this in turn has helped maintain relatively good water quality in Mountain Island Lake. At the time of assessment, no violations of state water quality standards were observed and the lake fully supported designated uses.

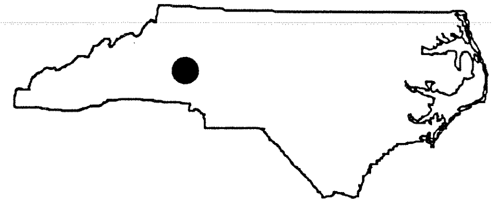





STATION CTB083B
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0 2 4 6 8 10
0 5 10 15 20
DO (mg/l)
STATION CTB086B
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0 2 4 6 8 10
0 5 10 15 20
DO (mg/l)
STATION CTB087
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0 2 4 6 8 10
0 5 10 15 20
DO (mg/l)


Lake Norman
HWY 73
Johnson
Creek
River
MOUNTAIN ISLAND LAKE
Lincoln Co
Gaston Co
Creek
Catawba
McDowell
N
CTB083B
NC 16
Creek
Gar
CTB087
CTB086B
0
1 mile
Catawba River

MAIDEN LAKE



COUNTY:	Catawba	BASIN:	Catawba
SURFACE AREA:	6 hectares (14 acres)	USGS TOPO:	Sanford, N.C.
CLASS:	WS	LAKE TYPE:	Reservoir

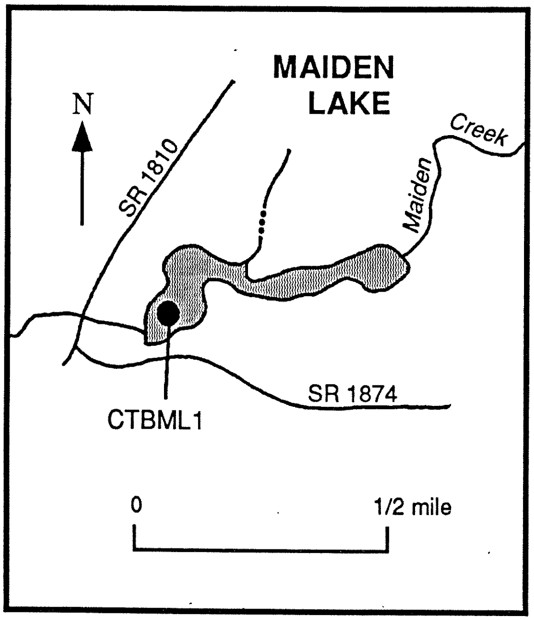
LATEST NCTSI:	0.8	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	July 31, 1990	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	0.7 m	CONDUCTIVITY:	32 µmhos/cm^2
TOTAL PHOSPHORUS:	0.03 mg/l	DISSOLVED OXYGEN:	8.7 mg/l
TOTAL ORGANIC NITROGEN:	0.27 mg/l	TEMPERATURE:	28. °C
CHLOROPHYLL-A:	17 µg/l	pH:	6.9 s.u.

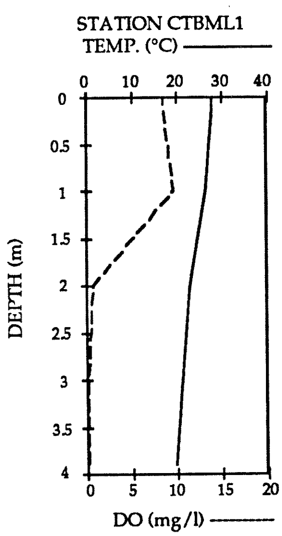
Maiden Lake is the water supply for the Town of Maiden. Built in the mid-1960's, the reservoir is fed by Maiden Creek and several springs. Depth of the lake averages three meters. An increase in silt content has been evident since mid-1990, probably a result of land clearing for a nursery upstream of the lake. The drainage area is 52 km^2, and an average of 7,600 m^3 of water are withdrawn per day to supply the town.

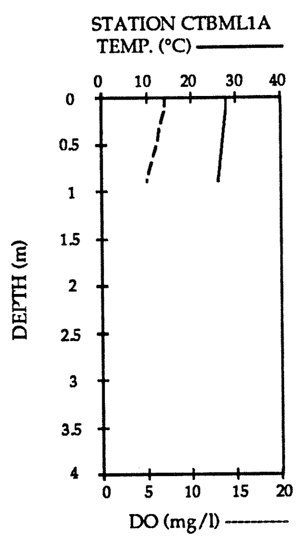
Maiden Lake was stratified and exhibited neutral pH on July 31, 1990. High turbidity (15 NTU) and low secchi values were evidence of poor water clarity. Nutrients were moderate as was chlorophyll-a. Manganese and iron were detected, but at levels well within state standards.

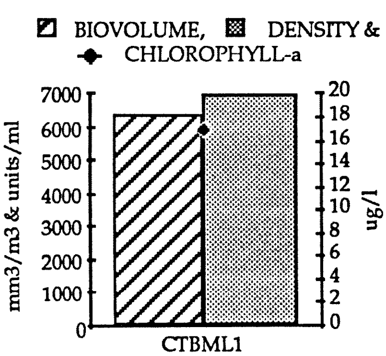
An algal biovolume estimate of 6,394 mm^3/m^3 was found in Maiden Lake. A filamentous cyanophyte, Anabaena subcylindrica, and a large chloromonadophyte, Gonystomum semen, accounted for most of the biovolume. A separate sample collected from an obvious algal bloom at Maiden Lake contained 93% blue-greens. Most prevalent were the buoyant filamentous algae Anabaena subcylindrica and Aphanizomenon flos-aquae, which are common components of summer algal blooms in the piedmont.

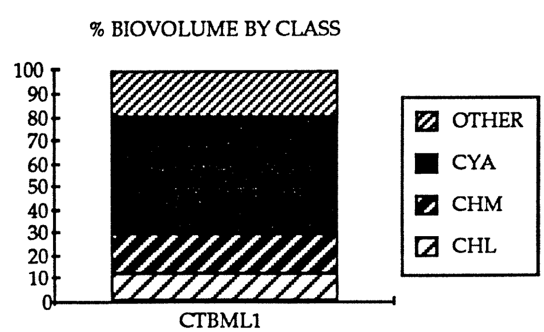
Maiden Lake was eutrophic with a TSI of 0.8 in 1990. Water quality in the reservoir fully supported designated uses and no water quality standards were violated; however, blue-green algal blooms and sedimentation warrant continued monitoring


MAIDEN LAKE
N
SR 1810
Creek
Maiden
SR 1874
CTBML1
0
1/2 mile

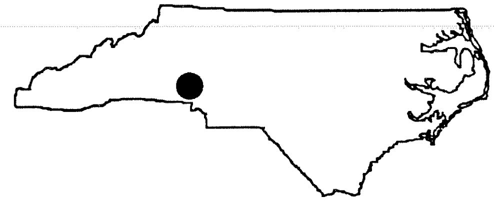

STATION CTBML1
TEMP. (°C)
DEPTH (m)
DO (mg/l)


STATION CTBML1A
TEMP. (°C)
DEPTH (m)
DO (mg/l)


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/m3 & units/ml
ug/l
CTBML1


% BIOVOLUME BY CLASS
OTHER
CYA
CHM
CHL
CTBML1

BESSEMER CITY LAKE



COUNTY:	Gaston	**BASIN:**	Catawba
SURFACE AREA:	6 hectares (15 acres)	**USGS TOPO:**	Bessemer City, N.C.
CLASS:	WS	**LAKE TYPE:**	Reservoir

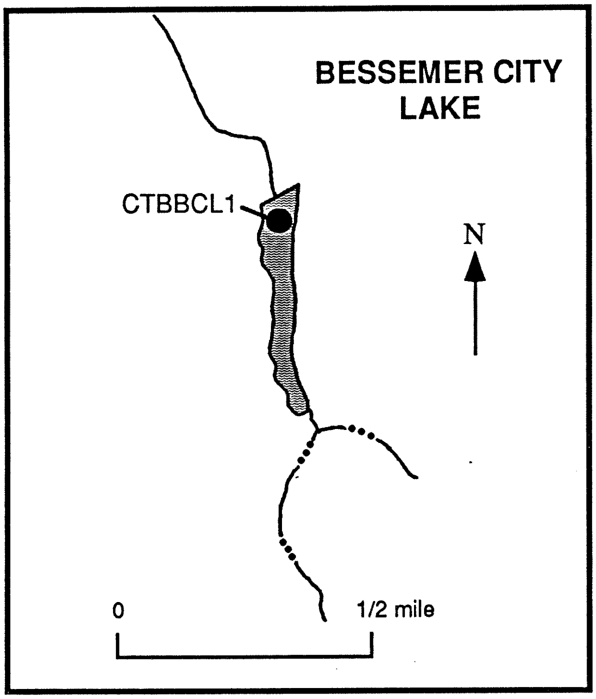
LATEST NCTSI:	-1.7	**TROPHIC STATE:**	Mesotrophic
SAMPLING DATE:	July 30, 1990	**ADDITIONAL COVERAGE:**	Water Supply Parameters
SECCHI DEPTH:	3.2 m	**CONDUCTIVITY:**	77 µmhos/cm^2
TOTAL PHOSPHORUS:	0.02 mg/l	**DISSOLVED OXYGEN:**	8.4 mg/l
TOTAL ORGANIC NITROGEN:	0.28 mg/l	**TEMPERATURE:**	31.2 °C
CHLOROPHYLL-A:	9 µg/l	**pH:**	8.1 s.u.

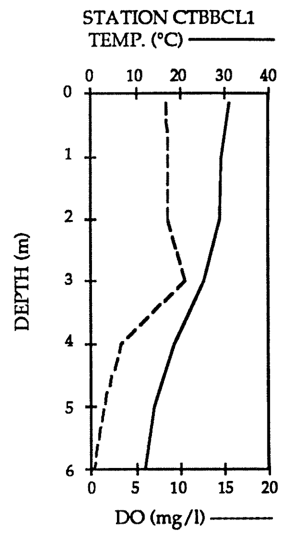
This small impoundment is the primary water supply for Bessemer City in Gaston County. Public access is restricted. The drainage area is approximately 1 km^2, and is characterized by rolling hills. Land use in the watershed is mostly forest with small residential and agricultural areas.

Bessemer City Lake was sampled on July 30, 1990. The lake was stratified with a 19.4 °C difference between surface and bottom temperatures. Slightly elevated pH values indicated algal activity. The excellent water clarity of the lake was reflected by high secchi and low turbidity measurements. Toxic heavy metals were not detected. Iron and manganese were found at low levels. Nutrients were low in the photic zone. Ammonia and nitrite-nitrate were higher at the bottom of the lake where a strong sulfide odor was also noted.

Moderately low algal biovolume, density and chlorophyll-a concentrations were found at Bessemer City Lake. Ubiquitous cryptophytes (Cryptomonas spp. and Chroomonas spp.) accounted for 61% of the biovolume while common chlorophytes were responsible for another 14%.

Exhibiting moderate productivity, Bessemer City Lake was mesotrophic in 1990. No water quality standards were violated and the lake fully supported designated uses.


BESSEMER CITY LAKE
CTBBCL1
N
0
1/2 mile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DEPTH (m)
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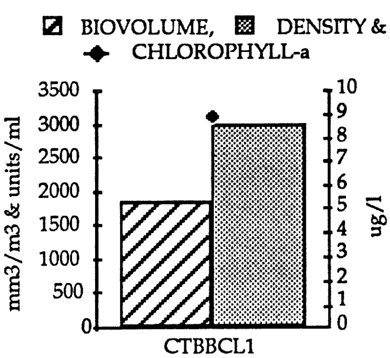
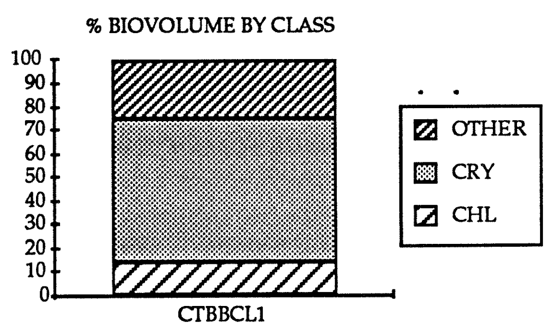
0 5 10 15 20
DO (mg/l)


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/m3 & units/ml
3500 3000 2500 2000 1500 1000 500 0
10 9 8 7 6 5 4 3 2 1 0
ug/l
CTBBCL1


% BIOVOLUME BY CLASS
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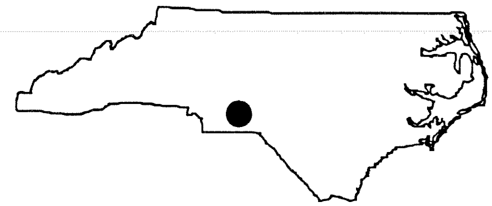
CTBBCL1
OTHER
CRY
CHL

LAKE WYLIE



COUNTY:	Gaston/Mecklenburg	BASIN:	Catawba
SURFACE AREA:	5039 hectares (12,450 acres)	USGS TOPO:	Lake Wylie, N.C.
CLASS:	WS, B	LAKE TYPE:	Reservoir

LATEST NCTSI:	1.5	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	August 7, 1990	ADDITIONAL COVERAGE:	Fecal, Water Supply Parameters
SECCHI DEPTH:	0.8 m	CONDUCTIVITY:	103 - 185 µmhos/cm^2
TOTAL PHOSPHORUS:	0.06 mg/l	DISSOLVED OXYGEN:	6.6 - 8.1 mg/l
TOTAL ORGANIC NITROGEN:	0.23 mg/l	TEMPERATURE:	28.5 - 31.6 °C
CHLOROPHYLL-A:	26 µg/l	pH:	6.9 - 8.4 s.u.

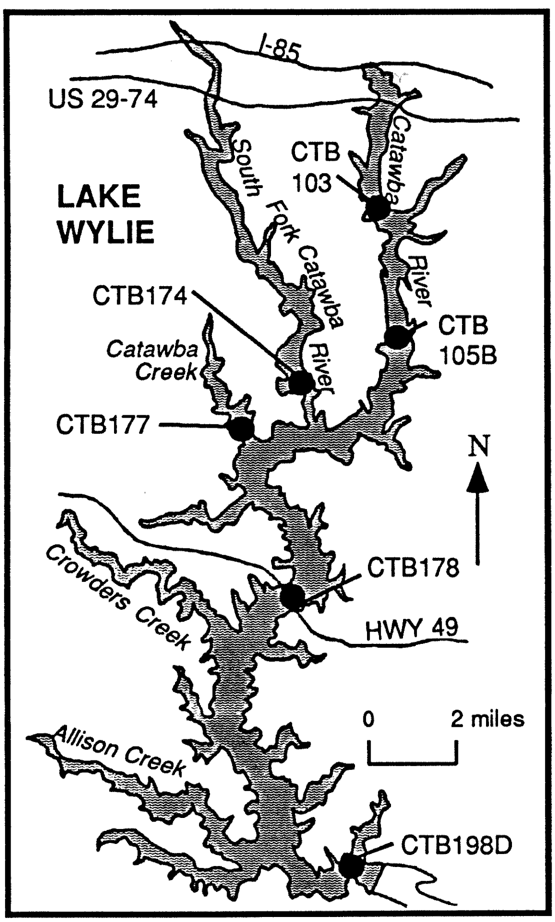
Lake Wylie is a man-made impoundment which was constructed in 1904 with a hydroelectric dam located near Fort Mills, South Carolina. The dam was rebuilt in 1924, creating the present shoreline of 526 kilometers with the upper portion of the lake in North Carolina and the majority of the lower portion in South Carolina. The lake is owned by Duke Power Company and is located in Gaston and Mecklenburg Counties in North Carolina and York County in South Carolina. The lake is used to generate electricity and for recreation.

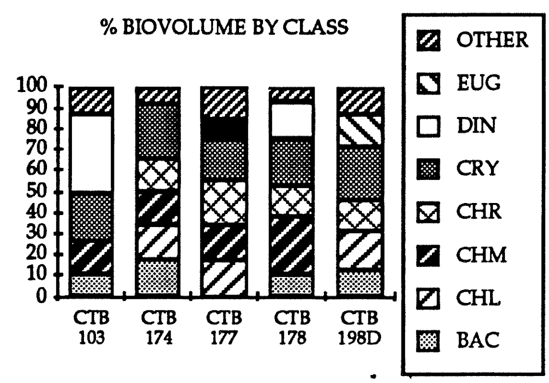
The lake has a drainage area of 7,822 km^2. Major tributaries include the Catawba River, the South Fork Catawba River, Crowders Creek, Catawba Creek and Allison Creek. Land use in the watershed is mostly forest, although agriculture and urban uses also affect water quality. The lake has a maximum depth of 21 meters, a mean depth of seven meters and a mean hydraulic retention time of 39 days. The lake is classified WS-III from Mountain Island Dam to the Interstate Highway 85 bridge at Belmont, and WS-III, B from the Interstate 85 bridge to the North Carolina-South Carolina state line.

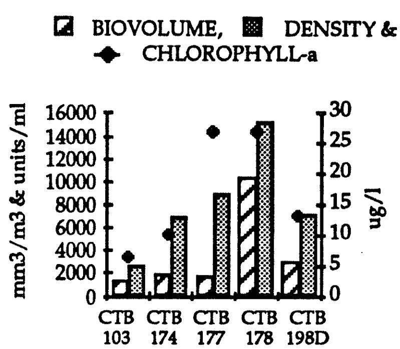
When the lake was sampled on August 7, 1990, most of the stations were weakly stratified. Only the two downstream stations (CTB178 and CTB198D) exhibited thermal stratification and low dissolved oxygen values in the hypolimnion. Nutrient data collected on this day showed elevated values, typical of an enriched lake. The highest nutrient and chlorophyll-a values were found in the South Fork Catawba River arm. This river receives many discharges from private, municipal, and industrial wastewater treatment plants.

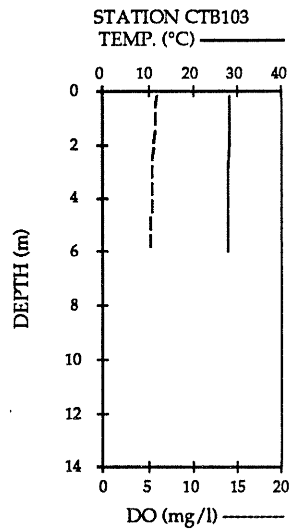
Populations of phytoplankton at most stations in Lake Wylie were dominated by chloromonadophytes, cryptophytes and chrysophytes. Elevated algal populations occurred near the mouth of Catawba Creek (CTB177) and in the mainstem (CTB178). Both of these stations contained the highest chlorophyll-a concentrations of 27 µg/l. Near the middle of the lake, station CTB178 experienced "bloom levels" of predominately small cryptophytes and Gonyostomum semen, a large chloromonadophyte. Catawba Creek (CTB177), one of the most eutrophic arms of Lake Wylie, also contained a high density of Oscillatoria geminata, a small filamentous blue-green which is common to eutrophic waters. Overall, phytoplankton analysis and chlorophyll-a concentrations indicate an enriched system.

The TSI was 1.4 in 1990 which is similar to historical values. At the time of assessment, a violation of the state water quality standard for chlorophyll-a was observed at Lake Wylie. The lake is classified as threatened as a result of the eutrophic conditions observed in the lake. DEM regional personnel have expressed concern regarding the increase in discharge requests into the lake which has already experienced fish kills and algal bloom problems. Nuisance algal blooms could cause use impairment if increased nutrient loading continues. The eutrophication of Lake Wylie is the subject of a special joint investigation being conducted by NCDEM and the South Carolina Department of Health and Environmental Control.








STATION CTB103
TEMP. (°C)
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DEPTH (m)
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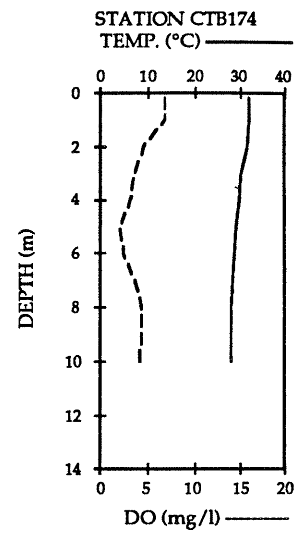
0 5 10 15 20
DO (mg/l)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TEMP. (°C)
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DEPTH (m)
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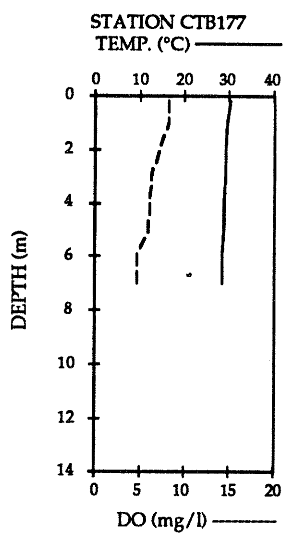
0 5 10 15 20
DO (mg/l)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TEMP. (°C)
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DEPTH (m)
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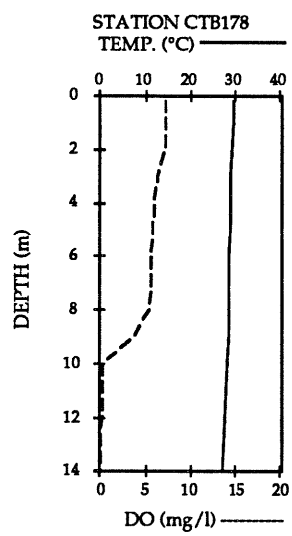
0 5 10 15 20
DO (mg/l)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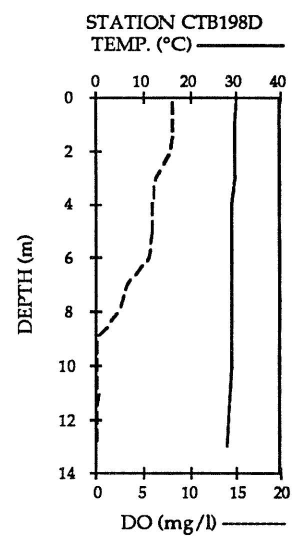
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0 2 4 6 8 10 12 14
0 5 10 15 20
DO (mg/l)


STATION CTB198D
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0 2 4 6 8 10 12 14
0 5 10 15 20
DO (mg/l)

CHOWAN RIVER BASIN

DESCRIPTION OF REGION

The Chowan River Basin covers 3,405 km^2 in the coastal plain of northeastern North Carolina, though most of the drainage basin (9,259 km^2) lies in Virginia. The Chowan River is formed at the confluence of the Nottoway and Blackwater Rivers just downstream from where the Nottoway River enters North Carolina. The Meherrin River, the third major tributary to the Chowan River, also originates in Virginia and flows southeasterward before joining the Chowan River in North Carolina. The Chowan River widens and becomes estuarine as it flows across the coastal plain before finally entering Albemarle Sound. The North Carolina portion of the basin lies within the counties of Bertie, Chowan, Gates, and Northampton.

In North Carolina, the Chowan River lies entirely in the inner coastal plain. Land use in the basin is dominated by forest and wetland while most of the remaining land use is agricultural. Murfreesboro, Ahoskie, and Edenton are the largest towns un the basin.

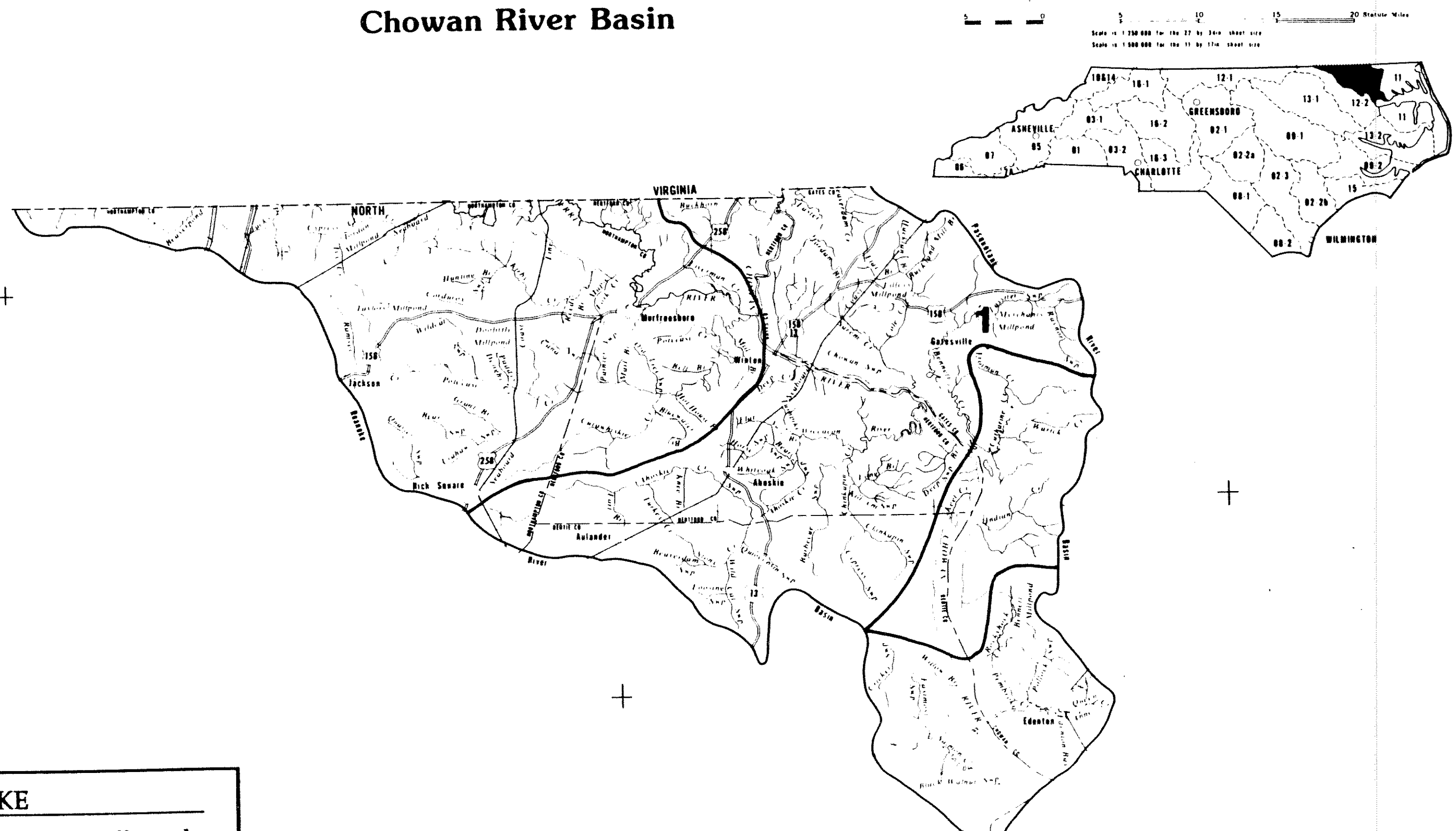
OVERVIEW OF WATER QUALITY

The Chowan River has had problems with eutrophication. The lower portion of the Chowan River is estuarine and has slow water exchange. Non-point source runoff in both the North Carolina and Virginia portions of the basin significantly increases nutrient loading in the Chowan Basin. Point sources in Virginia also have significant impacts on water quality in North Carolina (NRCD 1985).

A positive step in controlling nutrient loading was taken by North Carolina when the Environmental Management Commission classified the Chowan Basin as Nutrient Sensitive Waters (NSW). This classification requires the input of nutrients to the river to be limited. The Chowan River was classified NSW in September 1979. Since that time, most wastewater treatment plants have ceased discharge to surface water and now use land application as a means of waste disposal. In addition, North Carolina and Virginia are proceeding with a management strategy to reduce the amount of nutrients released by non-point sources to the basin in an effort to reduce the frequency and magnitude of nuisance algal blooms that have been observed in the basin (NRCD 1985).

Merchants Millpond is the only lake included in this section of the report. Located in the northeastern portion of the basin, the pond discharges into Bennetts Creek, a tributary of the Chowan River. Water quality in Merchants Millpond has been adversely affected by non-point source runoff from agricultural and livestock operations, and it has been impacted by aquatic weeds. It is considered partially supporting its designated use for recreation and wildlife propagation.

Chowan River Basin



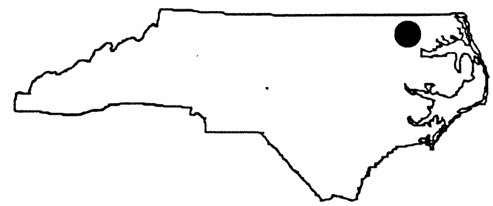
MAP #	LAKE
1	Merchants Millpond

North Carolina Department of
Natural Resources and Community Development

Division of Enviromental Management

Adapted from U.S.G.S.(A.M.S.) 1:250 000 U.S. Series

MERCHANTS MILLPOND



COUNTY:	Gates	BASIN:	Chowan
SURFACE AREA:	182 hectares (450 acres)	USGS TOPO:	Merchants Millpond, N.C.
CLASS:	C NSW	LAKE TYPE:	Reservoir

LATEST NCTSI:	3.7	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	September 4, 1986	ADDITIONAL COVERAGE:	Fecal, Metals
SECCHI DEPTH:	0.7 m	CONDUCTIVITY:	112 - 138 µmhos/cm^2
TOTAL PHOSPHORUS:	0.08 mg/l	DISSOLVED OXYGEN:	3.0 - 3.7 mg/l
TOTAL ORGANIC NITROGEN:	0.58 mg/l	TEMPERATURE:	22 - 24 °C
CHLOROPHYLL-A:	33.5 µg/l	pH:	6.0 - 6.3 s.u.

Merchants Millpond, located in Gates County in the coastal plain region of North Carolina, has a rich and varied history. Originally called Norfleets Millpond, it was constructed in 1811 and contained a grist mill, a wheat mill and a saw mill. By the turn of the century, the mill was the largest in Gates County and became its chief trade center. A new mercantile business established at the pond enabled local farmers to shop while their whole grain corn and wheat were transformed into meal and flour. Thus, the millpond was given the name "merchants".

The mill was in operation until shortly before World War II. In 1973, the millpond and some adjacent lands were donated to the North Carolina Division of Parks and Recreation by Mr. A. B. Coleman, and Merchants Millpond State Park was established. In December of that year, the Nature Conservancy conveyed the title of 3.7 km^2 of woodlands on the north side of the millpond to the state of North Carolina, and this area defines the current boundaries of the park (NRCD 1978).

Merchants Millpond is a shallow lake with a maximum depth of 2.4 meters and major inflow coming from Lassiter Swamp Creek. The millpond has a drainage area of 205 km^2 which is characterized by both flat and gently rolling terrain. Land use is mostly forest or wetlands, approximately one quarter urban, and some agriculture. The pond is classified C NSW and is used for recreational and educational purposes.

Merchants Millpond was sampled on September 4, 1986. Physical measurements indicated that, in spite of its shallow depth, it was stratified near the dam, while the other station was mixed. The pond had elevated nutrient concentrations. Similarly, chlorophyll-a was high, with CHO0153A having a concentration of 52 µg/l, a violation of North Carolina's freshwater standard of 40 µg/l. Analyses for fecal coliform bacteria found levels within state standards. Heavy metal analysis detected low levels of zinc (12 µg/l) at CHO0153A but found 48 µg/l of copper at CHO0154A, a concentration above the State Action Level of 15 µg/l. Reasons for this high copper value are not known.

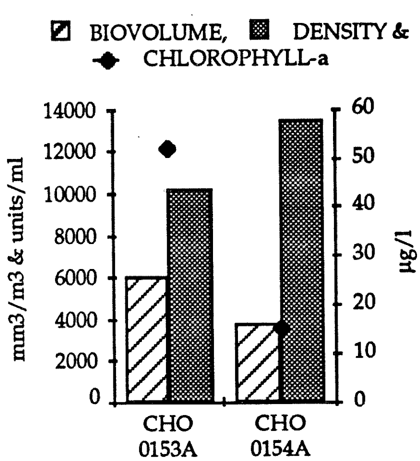
Euglenophytes dominated the algal biovolume at the eastern end near Lassiter swamp (CHO0153A), representing 50% of the 6,048 mm^3/m^3. At the western end near the dam euglenophytes were codominant, with chrysophytes, cryptophytes, and dinoflagellates comprising approximately 50% of the biovolume. Historically this lake has been dominated by euglenophytes (NRCD 1984). Euglenophytes are considered indicators of organic enrichment.

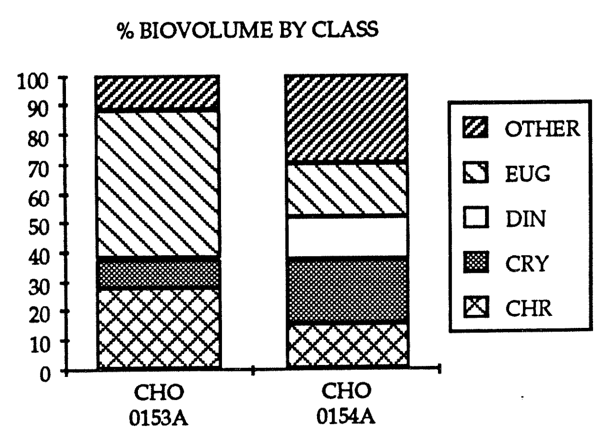
Non-point source runoff from agriculture and livestock operations adversely affect this shallow millpond which is also severely impacted by aquatic weeds. The abundant aquatic macrophytes observed include: elodea (Elodea nutallii), parrot's feather (Myriophyllum heterophyllum), and duckweeds (Azolla caroliniana, Spirodella polyrhiza, and Wolffiella floridana). Other weeds collected , although not as abundant, include smartweed (Polygonum sp.), bladderwort (Utricularia inflata), milfoil (Myriophyllum aquaticum), pickerelweed (Pontederia "lanceolata"), two species of primrose (Ludwigia "linearis"and Ludwigia sp.) and two species of pondweed (Potamogeton foliosus and Potamogeton sp.).

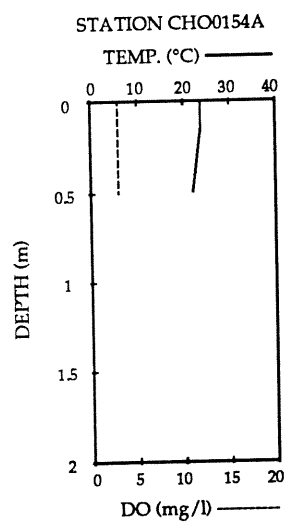
To curtail the growth of aquatic vegetation, the Division of Parks and Recreation has considered a drawdown of the water level in Merchants Millpond. In response to these plans, DEM conducted a special study of water quality in 1988 and 1989. The study concluded that, although winter drawdown is suggested to reduce the immediate problems with duckweed in the millpond, it will not eliminate the source of this problem. Since the natural aquatic succession of Merchants Millpond is being accelerated by anthropogenic activities in the watershed, the implementation of best management practices to reduce inputs of nutrients and sediment is warranted.

The TSI 3.7 in 1986. This value is similar to a value of 2.8 in 1983 and 4.4 in 1981, suggesting that the pond has maintained a eutrophic status over this time period.

Merchants Millpond is classified as partially supporting its designated use. Fishing, boating, and wildlife propagation have been impaired by the magnitude of macrophyte infestation and sedimentation. Additional biological and water quality monitoring is warranted to ensure that further problems do not occur at the pond. At the present time, various control options are being evaluated to alleviate the macrophyte and sedimentation problems.



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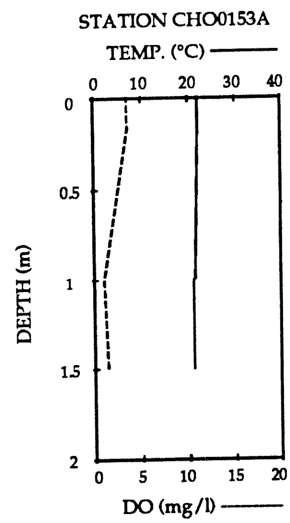
0 0.5 1 1.5 2
DEPTH (m)
0 5 10 15 20
DO (mg/l)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DEPTH (m)
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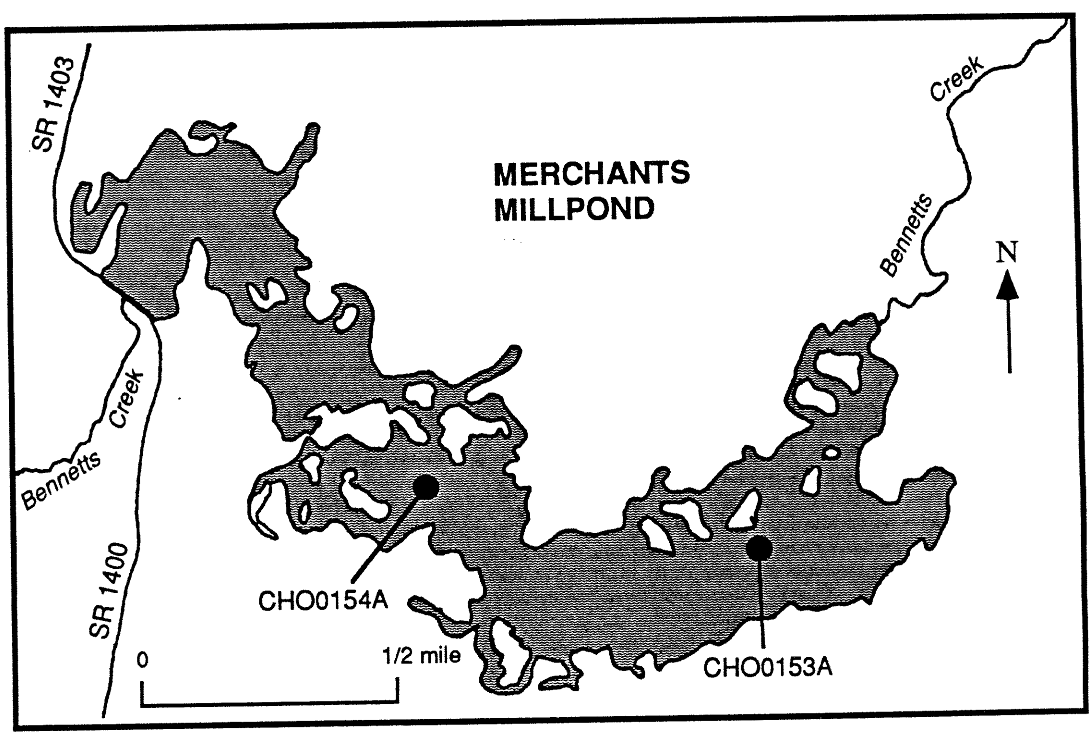
DO (mg/l)


MERCHANTS MILLPOND
SR 1403
SR 1400
Bennetts Creek
Bennetts Creek
N
CHO0154A
CHO0153A
0
1/2 mile

FRENCH BROAD RIVER BASIN

DESCRIPTION OF REGION

The French Broad river basin drains 7,360 km^2 in the western mountains of North Carolina. The basin is composed of three separate drainage areas: the French Broad River in the central region, the Pigeon River in the southern section, and the Nolichucky River in the northern section. Each of these rivers flow in a northwesterly direction prior to crossing the state line into Tennessee.

Land in the drainage area is primarily forested and agricultural. Much of the river basin is within the undeveloped watersheds of the Nantahala and Pisgah National Forests. Small sections of the Pigeon River Basin are in the Great Smoky Mountains National Park. The economy of the region is based on silviculture and tourism. Asheville, Henderson, and Waynesville are urban areas which lie in the French Broad River basin.

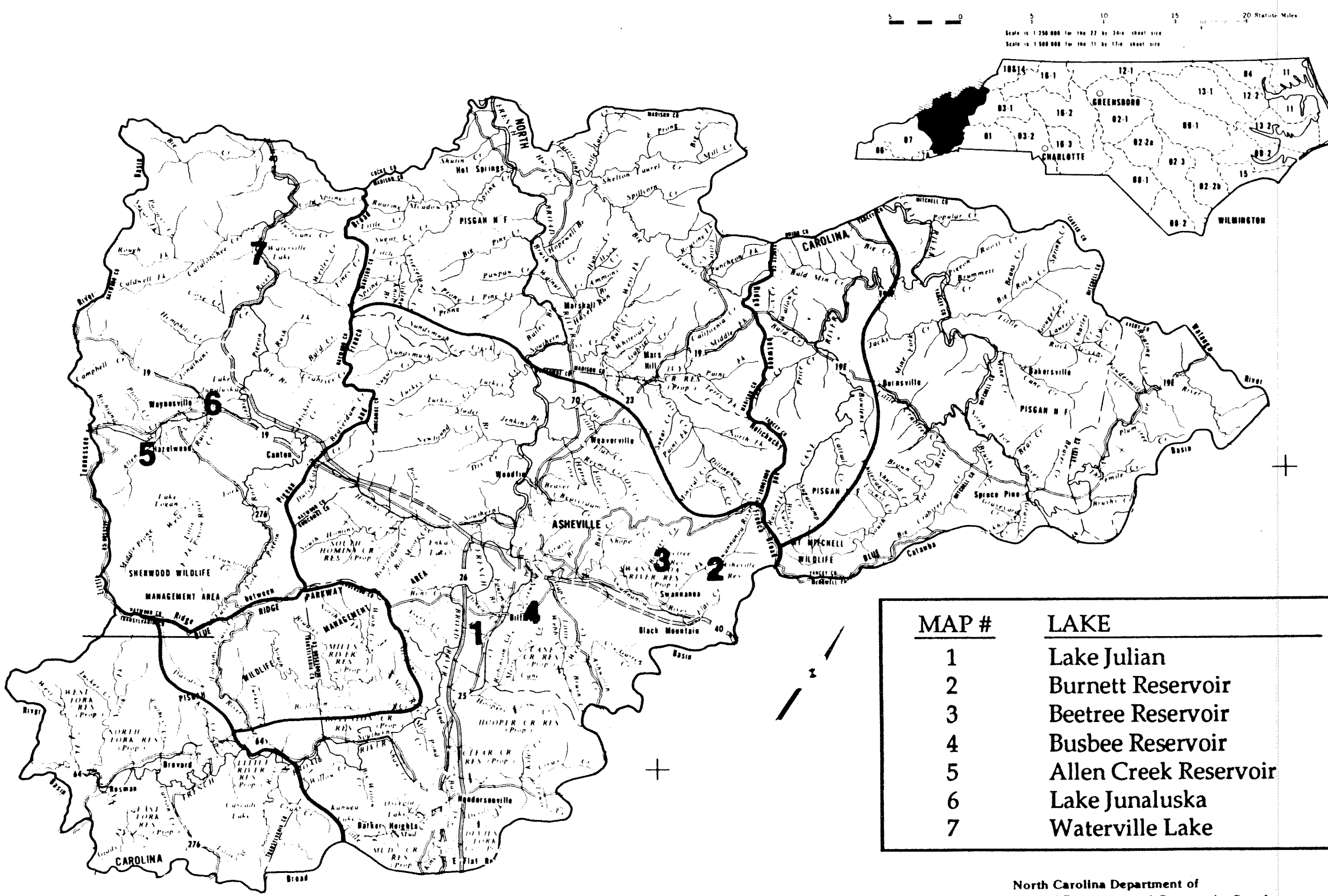
OVERVIEW OF WATER QUALITY

The large area of undeveloped land in this basin has contributed to the generally high level of water quality. The headwaters of the French Broad River are located within the Pisgah National Forest and have excellent water quality (NRCD 1988c). As the French Broad River cuts through the basin, it receives tributary flow from several streams receiving municipal discharges. Localized water quality problems have been associated with these discharges, as well as urban runoff from the metropolitan Asheville area (NRCD 1988c).

There are seven lakes included in this section of the report. Lake Julian is a cooling water lake owned by the Carolina Power and Light Company, which lies on a small tributary to the French Broad River. Burnett Reservoir and Beetree Reservoir are tributary to the Swannanoa River. They are water supplies for the City of Asheville, and both possess excellent water quality. Busbee Reservoir is a small water supply for Biltmore Estate which, like Lake Julian, is located on a small tributary to the French Broad River. Allen Creek Reservoir, a water supply for the City of Waynesville, lies in the upper Pigeon River sub-basin. It too has excellent water quality.

The remaining two lakes - Lake Junaluska and Waterville Lake - also drain into the Pigeon River, but both have water quality problems. Activities in Haywood County related to land development have contributed high sediment loads to Lake Junaluska. The lake is eutrophic though it fully supported designated uses at the time of assessment. Effluent from Champion Paper Company and several municipal wastewater discharges have contributed to poor water quality in Waterville Lake (NRCD 1988c).

French Broad River Basin

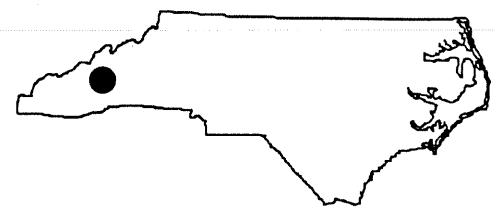


MAP #	LAKE
1	Lake Julian
2	Burnett Reservoir
3	Beetree Reservoir
4	Busbee Reservoir
5	Allen Creek Reservoir
6	Lake Junaluska
7	Waterville Lake

North Carolina Department of
Natural Resources and Community Development
Division of Enviromental Management

Adapted from U.S.G.S. (A.M.S.) 1:250,000 U.S. Series

LAKE JULIAN



COUNTY:	Buncombe	BASIN:	French Broad
SURFACE AREA:	130 hectares (320 acres)	USGS TOPO:	Skyland, N.C.
CLASS:	C	LAKE TYPE:	Reservoir

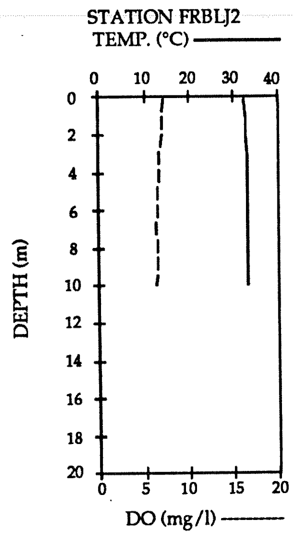
LATEST NCTSI:	-3.0	TROPHIC STATE:	Oligotrophic
SAMPLING DATE:	July 31, 1990	ADDITIONAL COVERAGE:	None
SECCHI DEPTH:	2.2 m	CONDUCTIVITY:	91 - 93 µmhos/cm^2
TOTAL PHOSPHORUS:	0.01 mg/l	DISSOLVED OXYGEN:	6.2 - 7.2 mg/l
TOTAL ORGANIC NITROGEN:	0.2 mg/l	TEMPERATURE:	32.5 - 33.8 °C
CHLOROPHYLL-A:	6 µg/l	pH:	7.4 - 7.9 s.u.

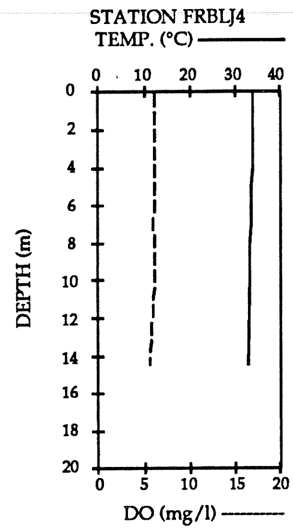
Carolina Power and Light Company built Lake Julian in 1963 to cool power generators at its plant in Skyland, North Carolina. The volume of the lake is unknown but maximum and mean depths are 37 meters and 20 meters respectively. During most of the year there is no discharge from the lake. The watershed is mainly residential and urban.

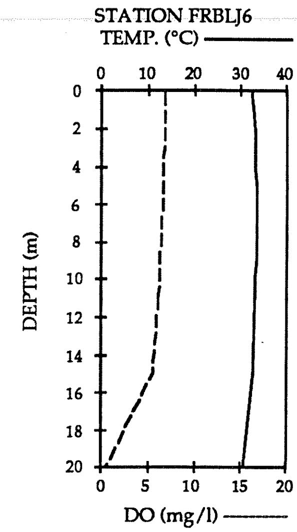
Physical measurements indicated that Lake Julian was not stratified. Temperatures were above 30°C throughout the water column. Nutrient and chlorophyll-a concentrations were low; nevertheless, phytoplanktonic populations approached bloom levels at one station.

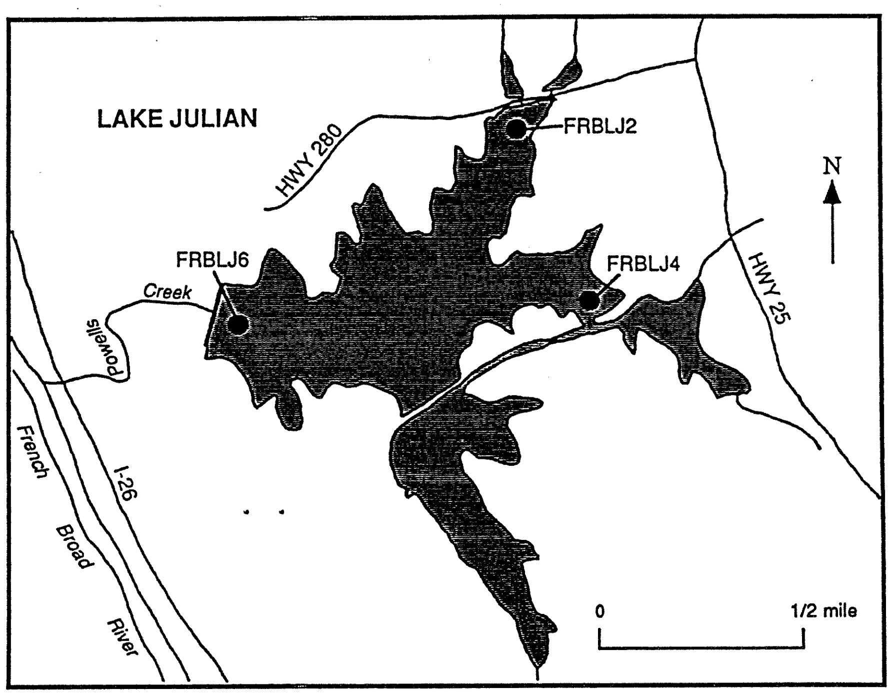
At station FRBLJ2, estimates of algal biovolume and density were at bloom levels, because desmids were abundant. Desmids are green algae which usually prefer slightly acidic, soft water. Desmids were also abundant at the other two stations, although density and biovolume were moderate. Lyngbya species A and Anabaenopsis raciborskii, two filamentous blue-green species, were also present in small numbers. These blue-green algae are commonly found in eutrophic bodies of water; however, elevated water temperatures may help account for their presence in this lake.

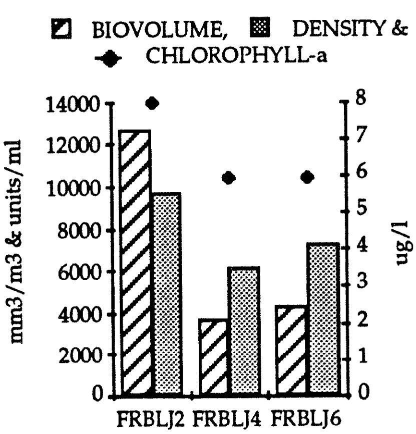
Lake Julian is oligotrophic with a TSI of -3.0. All uses were supported at the time of this assessment and no water quality standards were violated.

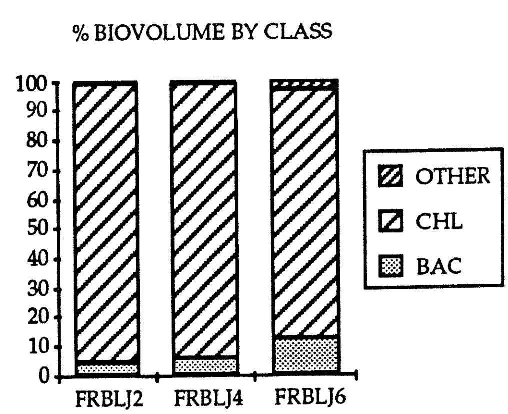

STATION FRBLJ2
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0 2 4 6 8 10 12 14 16 18 20
0 5 10 15 20
DO (mg/l)


STATION FRBLJ4
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0 2 4 6 8 10 12 14 16 18 20
0 5 10 15 20
DO (mg/l)

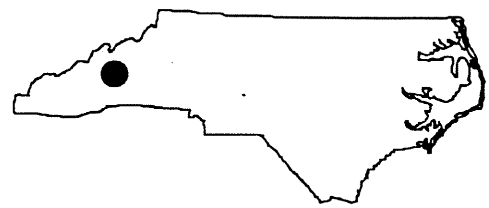

STATION FRBLJ6
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0 2 4 6 8 10 12 14 16 18 20
0 5 10 15 20
DO (mg/l)


LAKE JULIAN
FRBLJ2
HWY 280
N
FRBLJ6
FRBLJ4
Creek
Powells
HWY 25
French
I-26
Broad
River
0
1/2 mile


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
14000 12000 10000 8000 6000 4000 2000 0
mm3/m3 & units/ml
8 7 6 5 4 3 2 1 0
ug/l
FRBLJ2 FRBLJ4 FRBLJ6


% BIOVOLUME BY CLASS
100 90 80 70 60 50 40 30 20 10 0
FRBLJ2 FRBLJ4 FRBLJ6
OTHER
CHL
BAC

BURNETT RESERVOIR



COUNTY:	Buncombe	BASIN:	French Broad
SURFACE AREA:	134 hectares (330 acres)	USGS TOPO:	Montreat, N.C.
CLASS:	WS	LAKE TYPE:	Reservoir

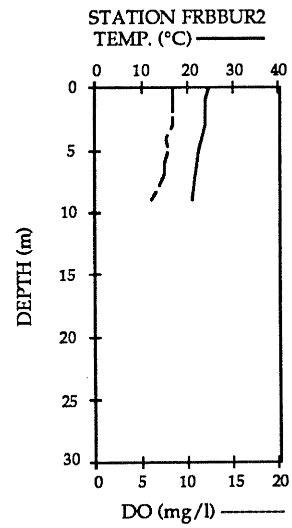
LATEST NCTSI:	-4.9	TROPHIC STATE:	Oligotrophic
SAMPLING DATE:	July 31, 1990	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	4.85 m	CONDUCTIVITY:	2 - 10 μmhos/cm^2
TOTAL PHOSPHORUS:	0.01 mg/l	DISSOLVED OXYGEN:	7.6 - 8.5 mg/l
TOTAL ORGANIC NITROGEN:	0.16 mg/l	TEMPERATURE:	24.8 - 26.5 °C
CHLOROPHYLL-A:	2.5 μg/l	pH:	7.2 - 7.4 s.u.

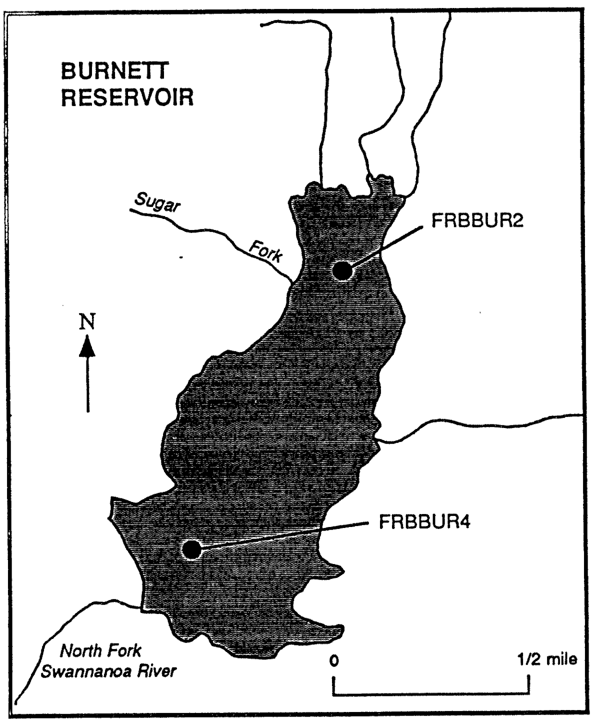
Burnett Reservoir (also known as North Fork Reservoir) was built in 1954 to provide drinking water for the City of Asheville. Maximum depth in the 22 x 10^6 m^3 reservoir is approximately 37 meters, and average depth is 12 meters. Burnett Reservoir has eight kilometers of shoreline. The undisturbed, six-square kilometer watershed is drained by the North Fork Swannanoa River, Sugar Fork, and several unnamed tributaries. Asheville and Waynesville purchased the land upstream of their respective water supply reservoirs and left it undeveloped. As discussed below, and in the entries for Beetree Reservoir and Allen Creek Reservoir, this restriction of development has helped maintain good water quality in these lakes.

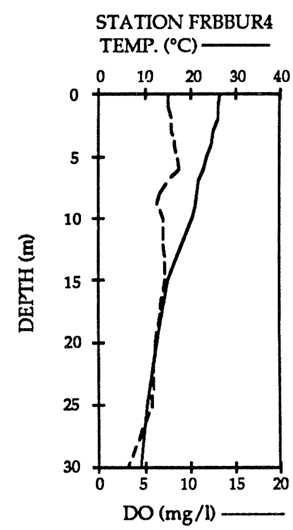
Although Burnett Reservoir was thermally stratified, dissolved oxygen levels stayed above 5.0 mg/l to a depth of 30 meters. Water clarity was high, and pH was nearly neutral. As in a few other lakes in the mountains of North Carolina, conductivity was extremely low, registering zero at several depths in the water column. This reflects an absence of inorganic pollution. Chlorophyll-a and nutrients were low, indicating minimal productivity. Iron and aluminum were detected, but at levels within water quality standards.

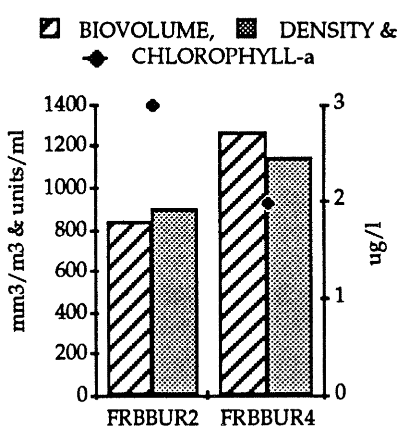
Estimates of algal density and biovolume were low. Cyclotella stelligera, a centrid diatom, was the dominant species at both stations.

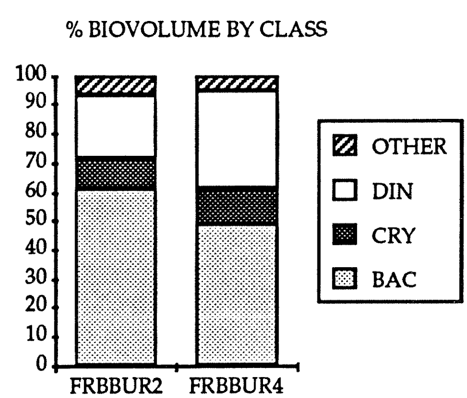
Burnett Reservoir is an oligotrophic lake of good quality. All uses of Burnett Reservoir were fully supported at the time of this assessment. This and other lakes with protected watersheds provide an opportunity to document the water quality of small reservoirs in the mountains of North Carolina that are minimally impacted by human activities.



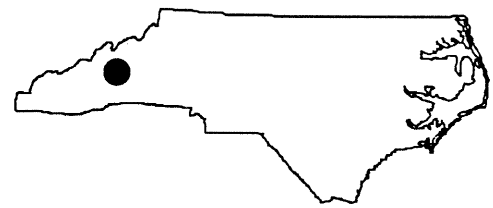








BEETREE RESERVOIR



COUNTY:	Buncombe	BASIN:	French Broad
SURFACE AREA:	22 hectares (55 acres)	USGS TOPO:	Craggy Pinnacle, N.C.
CLASS:	WS	LAKE TYPE:	Reservoir

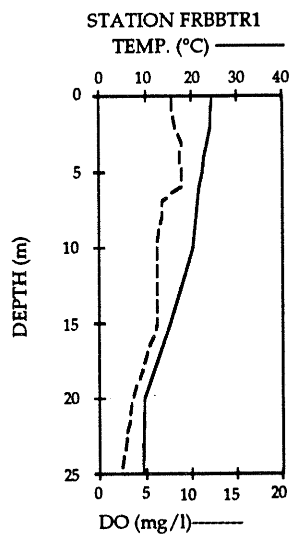
LATEST NCTSI:	-4.2	TROPHIC STATE:	Oligotrophic
SAMPLING DATE:	July 31, 1990	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	5.0 m	CONDUCTIVITY:	17 µmhos/cm^2
TOTAL PHOSPHORUS:	0.01 mg/l	DISSOLVED OXYGEN:	8.0 mg/l
TOTAL ORGANIC NITROGEN:	0.16 mg/l	TEMPERATURE:	24.7 °C
CHLOROPHYLL-A:	6 µg/l	pH:	7.6 s.u.

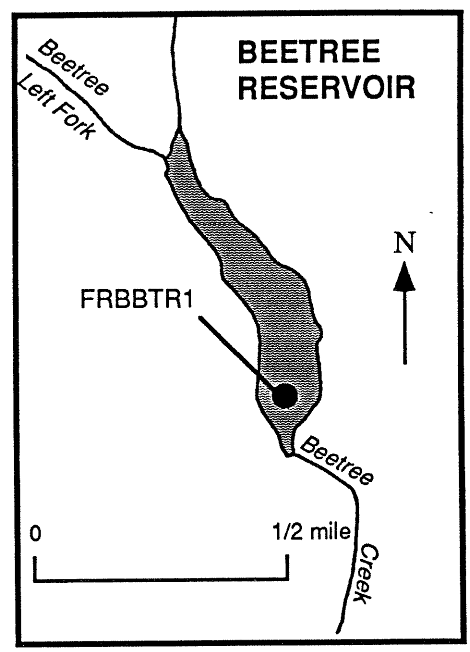
Beetree Creek was impounded in 1926 to form Beetree Reservoir, a water supply for the City of Asheville. The lake, which holds 1.9 x 10^6 m^3, has a maximum depth of 30 meters and a mean depth of 10 meters. The shoreline of the lake measures 2.4 kilometers. City of Asheville owns all of the 20 km^2 watershed which is undeveloped. The lake is not used for recreation, and access is restricted.

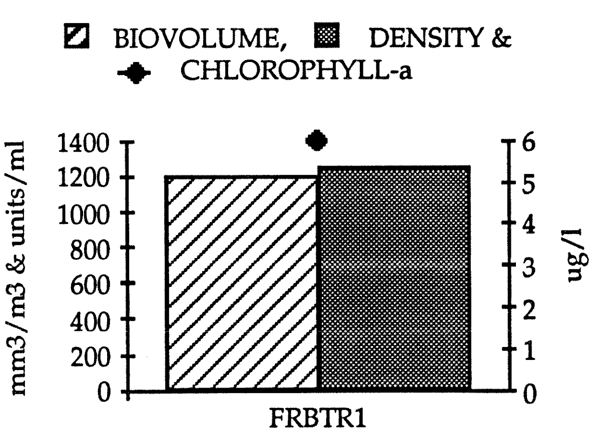
Beetree Reservoir was sampled on July 31, 1990. Physical and chemical results indicated good water quality in the lake. Low conductivities and clear water suggested no inorganic pollution. The lake was thermally stratified, although dissolved oxygen was greater than 6.0 mg/l in the top 15 meters of the water column. Phosphorus was below laboratory detection limits as were metals, with the exception of zinc which was well within the standard.

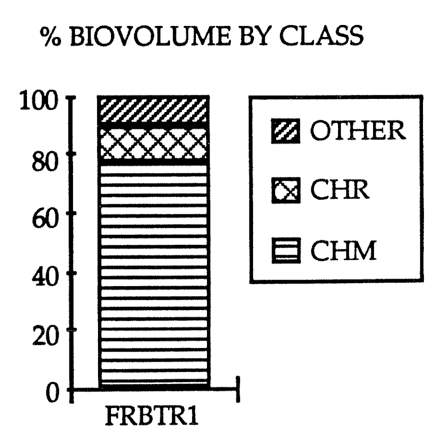
Algal biovolume, density and chlorophyll-a concentrations were low, reflecting the oligotrophic state of Beetree Reservoir. Dinobryon bavaricum, a heterotrophic chrysophyte, dominated estimates of density. Dinobryons are commonly found in unpolluted systems. Gonyostomum depressum, a chloromonadophyte, dominated estimates of biovolume because its cell volume is large.

A TSI of -4.2 indicated Beetree Reservoir is oligotrophic. The undisturbed drainage area upstream of the lake will help insure continued high quality water. At the time of assessment, no standards were violated and all uses were supported.

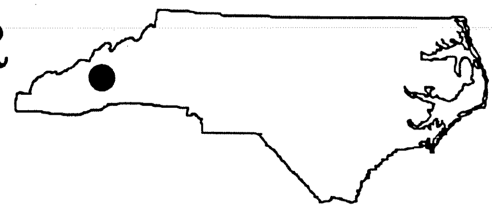

STATION FRBBTR1
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0
5
10
15
20
25
0 5 10 15 20
DO (mg/l)


BEETREE RESERVOIR
Beetree
Left Fork
FRBBTR1
N
Beetree
Creek
0
1/2 mile


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/m3 & units/ml
1400
1200
1000
800
600
400
200
0
ug/l
6
5
4
3
2
1
0
FRBTR1


% BIOVOLUME BY CLASS
100
80
60
40
20
0
OTHER
CHR
CHM
FRBTR1

BUSBEE RESERVOIR



COUNTY:	Buncombe	BASIN:	French Broad
SURFACE AREA:	3 hectares (8 acres)	USGS TOPO:	Asheville, N.C.
CLASS:	C	LAKE TYPE:	Reservoir

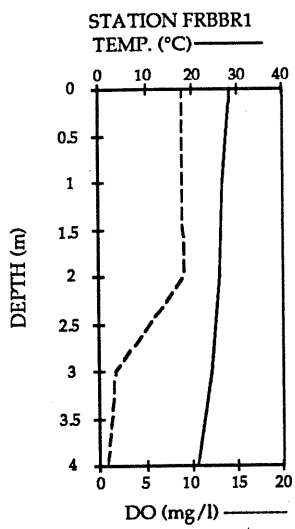
LATEST NCTSI:	-6.3	TROPHIC STATE:	Oligotrophic
SAMPLING DATE:	July 31, 1990	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	1.7 m	CONDUCTIVITY:	17 μmhos/cm^2
TOTAL PHOSPHORUS:	0.01 mg/l	DISSOLVED OXYGEN:	8.9 mg/l
TOTAL ORGANIC NITROGEN:	0.02 mg/l	TEMPERATURE:	28.3 °C
CHLOROPHYLL-A:	8 μg/l	pH:	7.8 s.u.

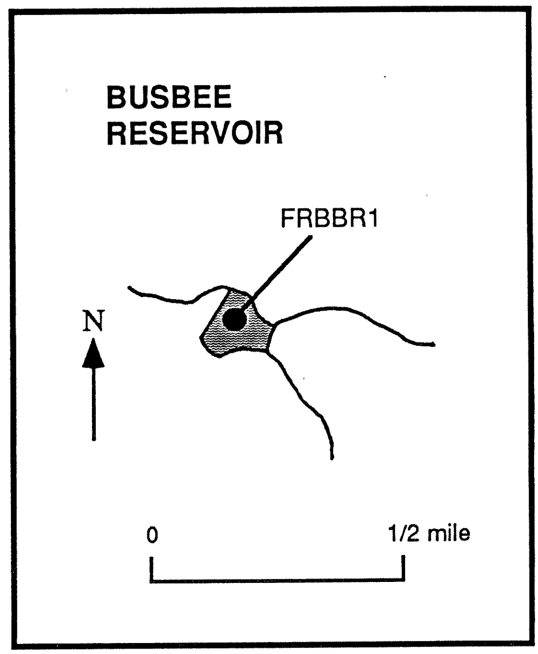
Busbee Reservoir was constructed around the turn of the century to provide drinking water for Biltmore Estate. It has a surface area of three hectares and a volume of 3.8×10^5 m^3. Maximum and average depth are five and two meters respectively. Plans to use the water for irrigation have been made because the estate will be connected to the City of Asheville water supply system in the future.

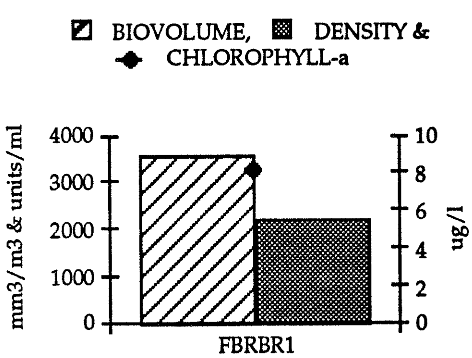
Busbee Reservoir was sampled on July 31, 1990. Physical parameters indicated it was stratified even though the lake is shallow. Although secchi depth was moderate, nutrients and chlorophyll-a were low. Zinc, iron, and manganese were detected, but all were within state standards.

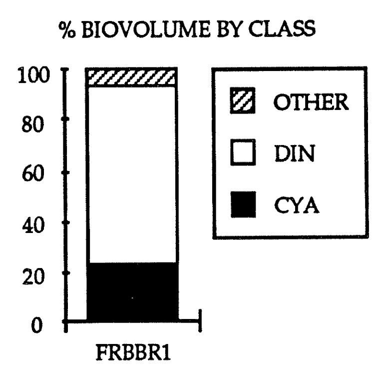
Algal densities were moderate with Selenastrum species, a unicellular green alga, and Anabaena levanderi, a blue-green alga, contributing most of the density. Blue-green algae prefer warmer temperatures which may explain their co-dominance in this system (Bold and Wynne 1985). Biovolume estimates were also moderate with Peridinium aciculiferum, a dinoflagellate, constituting 70%.

A TSI of -6.3 indicates Busbee Reservoir is oligotrophic. The extremely low total organic nitrogen concentration helps account for the low TSI value . All uses were fully supported at the time of this assessment.

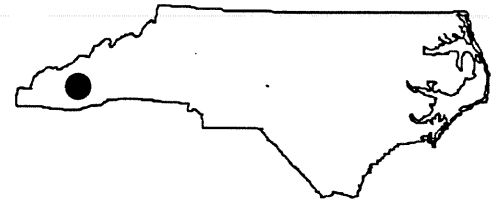

STATION FRBBR1
TEMP. (°C)
0
10
20
30
40
0
0.5
1
1.5
2
2.5
3
3.5
4
DEPTH (m)
0
5
10
15
20
DO (mg/l)


BUSBEE
RESERVOIR
FRBBR1
N
0
1/2 mile


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/m3 & units/ml
4000
3000
2000
1000
0
10
8
6
4
2
0
ug/l
FBRBR1


% BIOVOLUME BY CLASS
100
80
60
40
20
0
OTHER
DIN
CYA
FRBBR1

ALLEN CREEK RESERVOIR



COUNTY:	Haywood	BASIN:	French Broad
SURFACE AREA:	49 hectares (120 acres)	USGS TOPO:	Hazelwood, N.C.
CLASS:	WS	LAKE TYPE:	Reservoir

LATEST NCTSI:	-6.6	TROPHIC STATE:	Oligotrophic
SAMPLING DATE:	August 1, 1990	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	3.9 m	CONDUCTIVITY:	13 µmhos/cm^2
TOTAL PHOSPHORUS:	0.01 mg/l	DISSOLVED OXYGEN:	7.4 - 8.0 mg/l
TOTAL ORGANIC NITROGEN:	0.05 mg/l	TEMPERATURE:	22.3 - 23.4 °C
CHLOROPHYLL-A:	2.5 µg/l	pH:	7.1 - 7.5 s.u.

Allen Creek Reservoir is a small water supply located in the mountains of North Carolina. Construction of the lake was frought with delays in the late 1970's, and was eventually finished in December 1981. Volume in the lake is 3.3×10^6 m^3 with maximum and average depths of 23 meters and 14 meters respectively. The City of Waynesville owns the lake which provides approximately four million gallons of potable water per day.

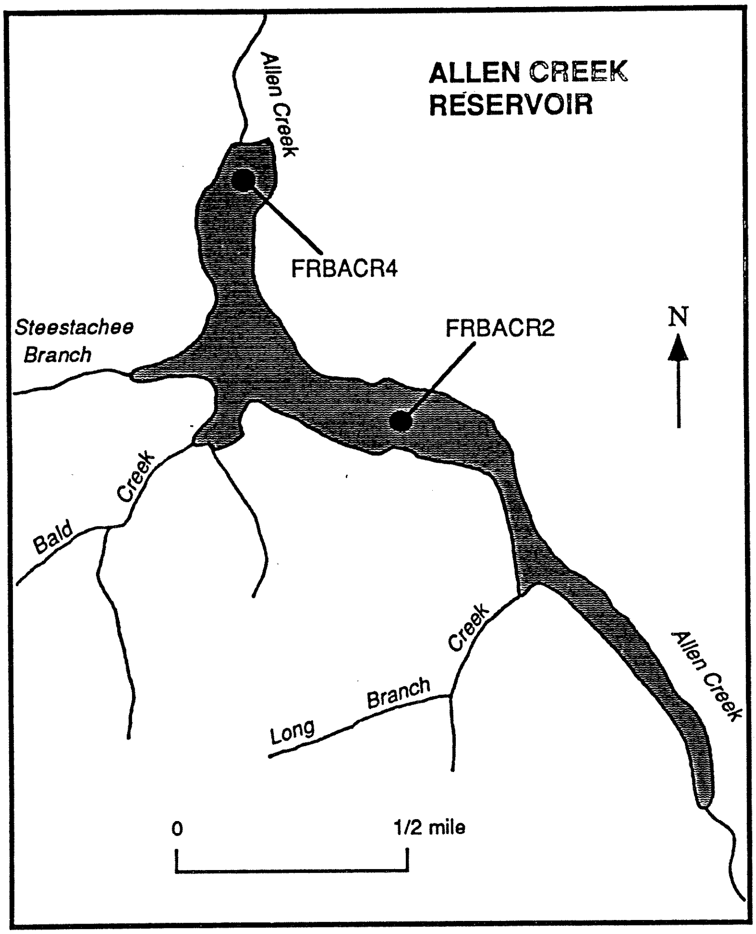
Waynesville owns over 90% of the 34 km^2, undeveloped watershed. With the exception of some access roads and the Blue Ridge Parkway, the drainage area is forested. Several tributaries flow into Allen Creek Reservoir, including Steestachee Branch, Bald Creek, Long Branch Creek and Allen Creek.

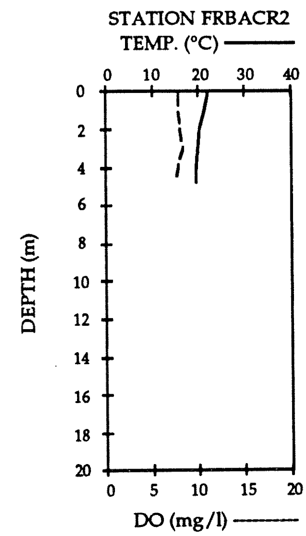
Allen Creek Reservoir was sampled on August 1, 1990. The lake was stratified with low conductivity and low turbidity. There are so few solids in the lake that the water treatment plant operators sometimes have problems getting flocculation to occur during the treatment process. Nutrients and chlorophyll-a were also low.

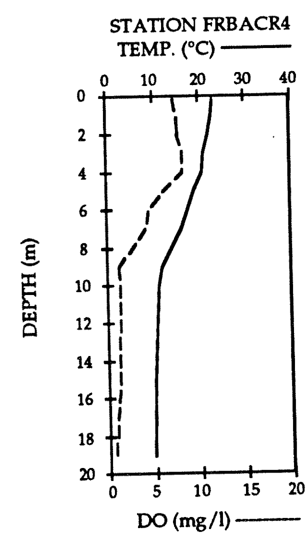
Algal biovolume and density were low at both stations, reflecting the oligotrophic state of this reservoir. Dominant species were Dinobryon species (chrysophyte) and Peridinium pusilum (dinoflagellate). Both of these phytoplankters are heterotrophic and therefore can thrive in nutrient-poor waters. Dinobryons are commonly found in unpolluted systems and relatively cool waters (Bold and Wynne 1985).

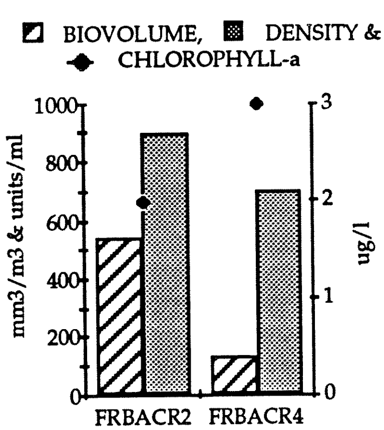
Allen Creek Reservoir is an oligotrophic lake as evidenced by a TSI of -6.6. All uses were supported at the time of assessment.

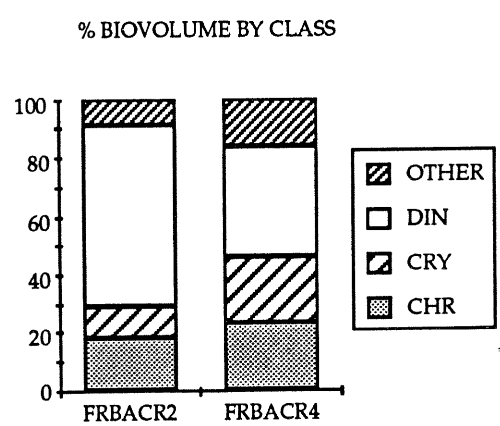
This is one of three water supply reservoirs sampled by DEM which has an undeveloped, protected watershed. It is likely to continue to have excellent water quality.



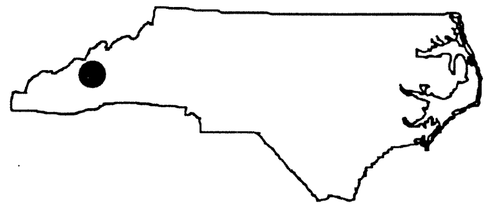








LAKE JUNALUSKA



COUNTY:	Haywood	BASIN:	French Broad
SURFACE AREA:	81 hectares (200 acres)	USGS TOPO:	Clyde, N.C.
CLASS:	B	LAKE TYPE:	Reservoir

LATEST NCTSI:	2.7	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	August 26, 1987	ADDITIONAL COVERAGE:	Metals
SECCHI DEPTH:	0.7 m	CONDUCTIVITY:	90 - 95 µmhos/cm^2
TOTAL PHOSPHORUS:	0.04 mg/l	DISSOLVED OXYGEN:	9.8 - 10.0 mg/l
TOTAL ORGANIC NITROGEN:	0.55 mg/l	TEMPERATURE:	25 - 26 °C
CHLOROPHYLL-A:	28 µg/l	pH:	8.6 - 9.0 s.u.

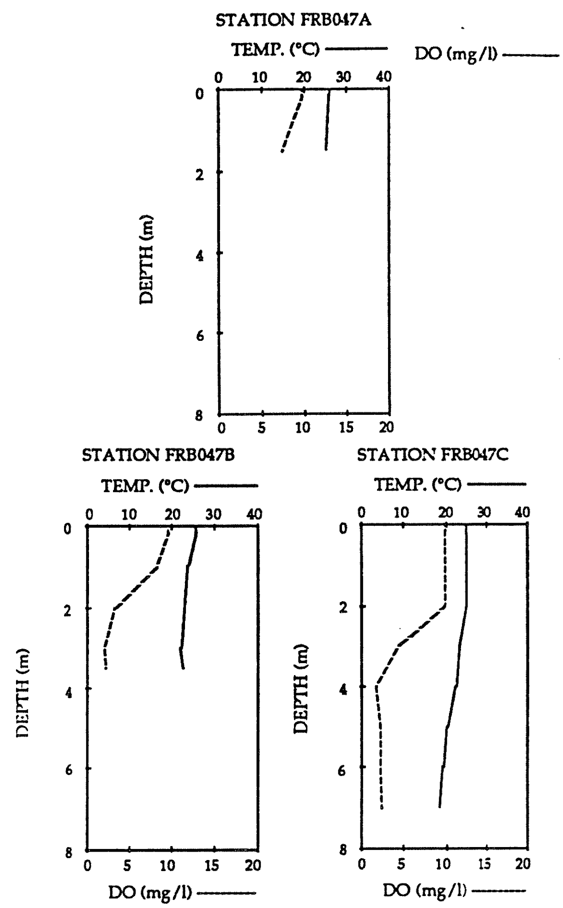
Lake Junaluska is a small reservoir located in the mountains of southwestern North Carolina. The lake is privately owned by the Methodist Church and was built by the Lake Junaluska Assembly as a meeting ground for southern Methodists. Construction of the dam at the confluence of Richland Creek and Factory Branch began in 1911 and ended in 1914. The lake has a watershed of 162 km^2, a maximum depth of seven meters, a mean depth of five and a half meters, and a volume of 4.5 x 10^6 m^3. Land in the watershed is mainly forested, with some urban areas. The mean hydraulic retention time of the lake is only 13 days.

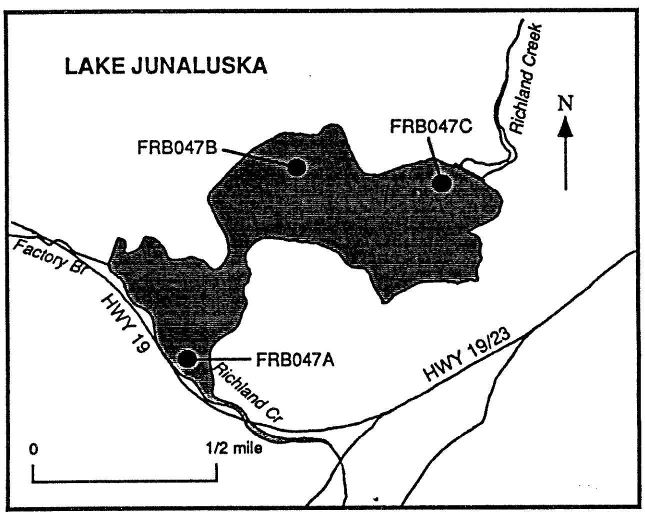
Lake Junaluska has historically had problems with sedimentation and eutrophication. The lake was dredged in 1964, in 1973, and again in 1982. Sedimentation rates in the watershed have increased greatly over the past thirty years and can be attributed to highway construction and residential and industrial growth within Haywood County (Yurkovich 1984).

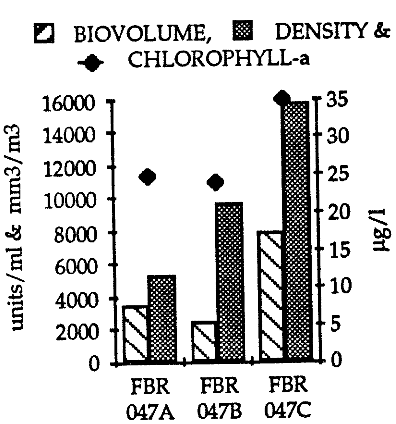
Lake Junaluska was sampled on August 26, 1987. Physical measurements indicated that the two deeper stations (FRB047B and FRB047C) were stratified, although the shallow station (FRB047A) was mixed. Nutrient concentrations were elevated with station FRB047A exhibiting the highest levels. Chlorophyll-a was also elevated. The maximum concentration of 35 µg/l was found near the dam and approached the state chlorophyll-a standard of 40 µg/l. Heavy metal analyses of surface waters revealed low levels of zinc and aluminum.

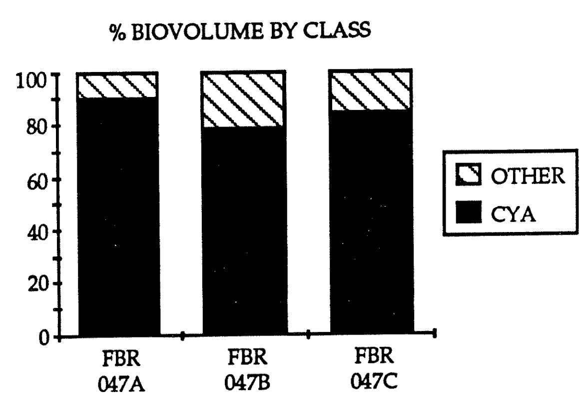
Phytoplankton from Lake Junaluska were identified in 1981, 1983, and 1987. Blue-green algae were dominant in 1981. In 1983, algal populations were composed of diatoms and green algae, typical dominants of an oligotrophic lake. In 1987, estimates of biovolume and density were moderate to high and dominated by the filamentous blue-green alga, Anabaena levanderi. Although data are limited, it appears that the algal community briefly responded to improved water quality following the dredging of Lake Junaluska in 1982.

The TSI in 1987 was 2.7, higher than in 1983 (-0.4), but equal to the value in 1981. The drawdown and dredging of the lake in 1982 temporarily improved water quality in 1983. However, the most recent data indicate the potential for water quality problems in Lake Junaluska. At the time of assessment, no violations of state water quality standards were observed at Lake Junaluska, and the reservoir fully supported designated uses. However, the eutrophic condition of the lake indicates that further monitoring is needed.

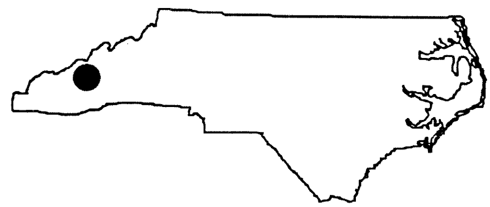








WATERVILLE LAKE



COUNTY:	Haywood	BASIN:	French Broad
SURFACE AREA:	138 hectares (340 acres)	USGS TOPO:	Waterville, N.C.
CLASS:	C	LAKE TYPE:	Reservoir

LATEST NCTSI:	5.0	TROPHIC STATE:	Hypereutrophic
SAMPLING DATE:	August 1, 1990	ADDITIONAL COVERAGE:	None
SECCHI DEPTH:	0.6 m	CONDUCTIVITY:	420 - 516 μmhos/cm^2
TOTAL PHOSPHORUS:	0.16 mg/l	DISSOLVED OXYGEN:	7.3 - 10.5 mg/l
TOTAL ORGANIC NITROGEN:	0.53 mg/l	TEMPERATURE:	24.7 - 27.2 °C
CHLOROPHYLL-A:	58.5 μg/l	pH:	8.4 - 9.0 s.u.

Built in the late 1920's, Waterville Lake (also called Walters Lake) is an impoundment of the Pigeon River which drains most of Haywood County. The reservoir holds approximately 31.2 x 10^6 m^3 and has maximum and average depths of 54 and 23 meters. Carolina Power and Light Company constructed the lake to produce hydroelectric power for Asheville and the surrounding area.

Land use in the mountainous, 1,178 km^2 drainage area includes forest, agriculture, and small urban/residential areas. The lake is used for recreation and is classified C.

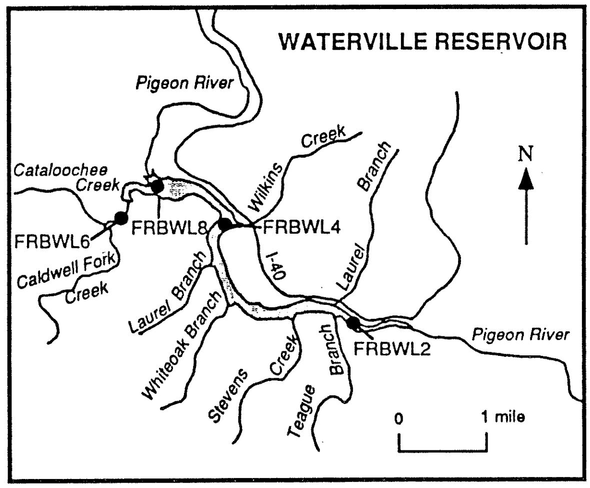
In 1988, DEM and EPA collected samples of fish to be analyzed for dioxin, a carcinogen. Elevated levels were found in fish tissue, especially in older individuals. Monitoring for dioxin will continue at Waterville Lake.

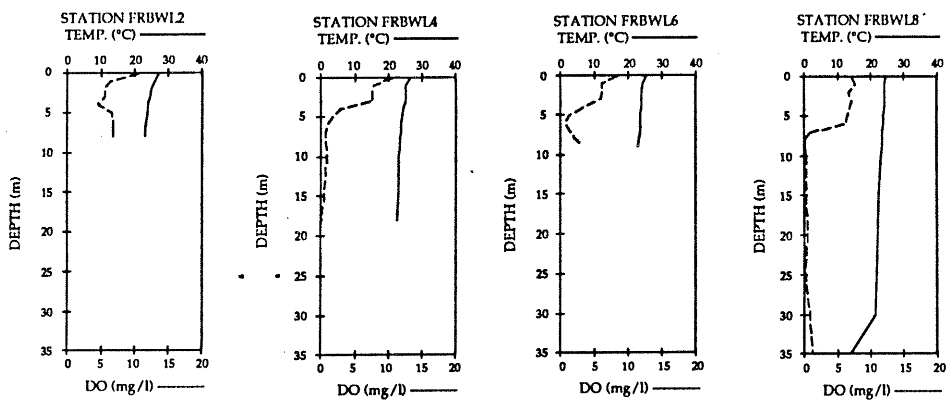
Waterville Lake had the highest conductivities of any freshwater lake in North Carolina sampled by DEM. On August 1, 1990, values over 600 μmhos/cm^2 were measured, indicating inorganic pollutants were present. In fact, only one measurement was less than 300 μmhos/cm^2. The water column was only mildly stratified in terms of temperature; however, dissolved oxygen was depleted below five meters. The humic waters of this reservoir are darkly colored, allowing little light penetration. The poor water clarity was evident in the low secchi measurement.

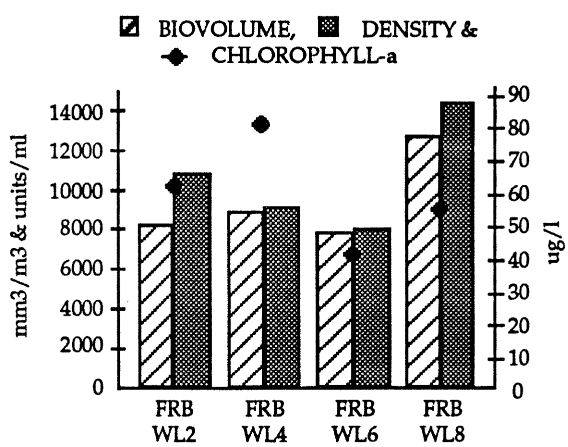
Litter and debris were scattered throughout the lake. Filamentous blue-green algae were also noted throughout the lake, and duckweed was especially abundant near the dam. Algal biovolume and density at all stations were dominated by Anabaena subcylindrica, a species of blue-green that forms surface blooms and indicates eutrophic conditions.

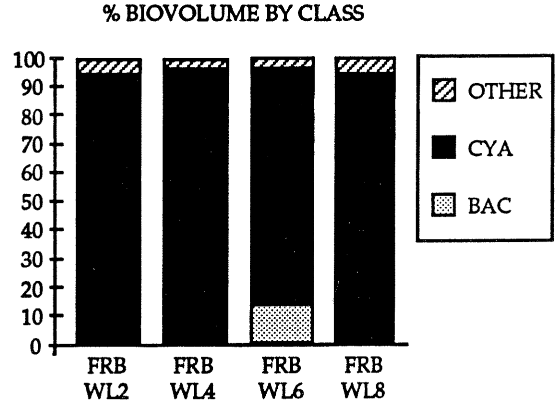
Nutrients in Waterville Lake were high, especially nitrates-nitrites, total phosphorus and orthophosphate. Violations of the 40 µg/l standard for chlorophyll-a were found at three of the four stations. Results of this isolated sampling are consistent with data collected by Carolina Power and Light Company (1990).

Waterville Lake is hypereutrophic. Major sources of nutrients upstream include the Champion Paper Company mill and several wastewater treatment plants. In addition, dioxin contamination has degraded water quality such that it does not support designated uses of the reservoir.









HIWASSEE RIVER BASIN

DESCRIPTION OF REGION

The Hiwassee River Basin covers approximately 1,658 km^2 in the southwestern corner of North Carolina. Most of the streams in the basin are located within the undeveloped Nantahala National Forest.

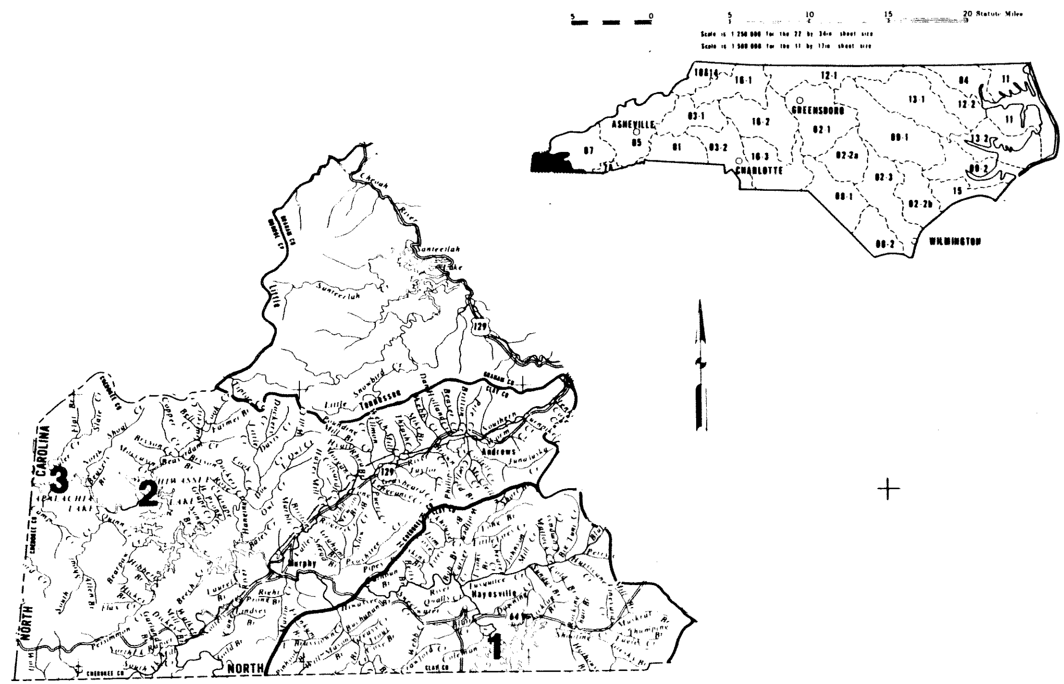
The Hiwassee River is impounded three times in North Carolina to form Chatuge Lake, Hiwassee Lake, and Apalachia Lake. The Tennessee Valley Authority (TVA) regulates water releases from these lakes for the production of hydroelectric power.

OVERVIEW OF WATER QUALITY

The streams in the Hiwassee River Basin are characterized by excellent water quality as they drain primarily undeveloped mountain areas (NRCD 1985). The few water quality problems in this region are related to flow regulation and nonpoint source runoff.

The three reservoirs included in this section of the report are all impoundments of the Hiwassee River. Lake Chatuge, Hiwassee Lake, and Apalachia Lake support low numbers of phytoplankton and are oligotrophic.

Hiwassee River Basin

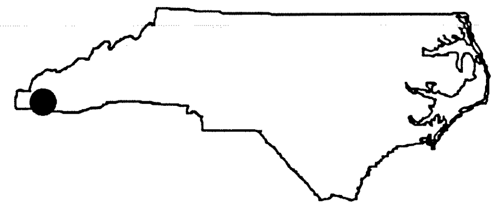


MAP #	LAKE
1	Chatuge Lake
2	Hiwassee Lake
3	Apalachia Lake

North Carolina Department of
Natural Resources and Community Development
Division of Enviromental Management

Adapted from U S G S (A M S) 1 250 000 U S Series

CHATUGE LAKE



COUNTY:	Clay	BASIN:	Hiwassee
SURFACE AREA:	2,812 hectares (6,950 acres)	USGS TOPO:	Hayesville, N.C.
CLASS:	B	LAKE TYPE:	Reservoir

LATEST NCTSI:	- 4.6	TROPHIC STATE:	Oligotrophic
SAMPLING DATE:	August 7, 1987	ADDITIONAL COVERAGE:	Metals
SECCHI DEPTH:	2.6 m	CONDUCTIVITY:	16 - 19 µmhos/cm^2
TOTAL PHOSPHORUS:	0.01 mg/l	DISSOLVED OXYGEN:	6.5 - 7.3 mg/l
TOTAL ORGANIC NITROGEN:	0.09 mg/l	TEMPERATURE:	28.4 - 30.5 °C
CHLOROPHYLL-A:	5 µg/l	pH:	5.4 - 6.1 s.u.

Chatuge Lake is a large reservoir located in the southwestern portion of the state. The lake is situated adjacent to the Nantahala National Forest and is on the Hiwassee River upstream from Hiwassee Lake and Apalachia Lake. The lake is owned by the Tennessee Valley Authority (TVA) and was constructed to provide hydroelectric power. Construction on the dam began in 1941 and ended in 1942.

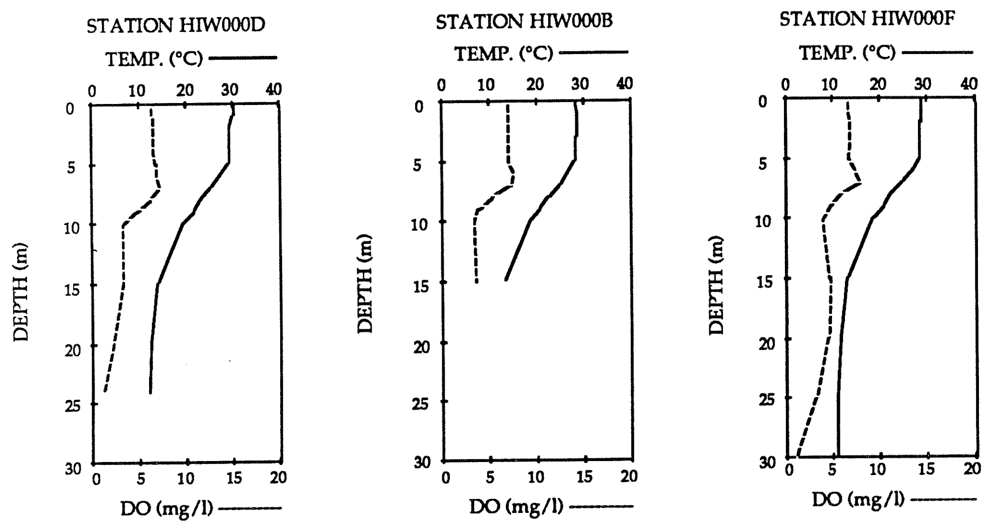
The lake has a maximum depth of 44 meters, a mean depth of 11 meters and a volume of 305 x 10^6 m^3. Chatuge Lake is particularly long (13 miles), with 212 kilometers of shoreline. The drainage area of the lake covers 484 km^2 which is mostly forested. Major tributaries to the lake include the Hiwassee River and Shooting Creek. The lake is used for recreational purposes as well as power generation.

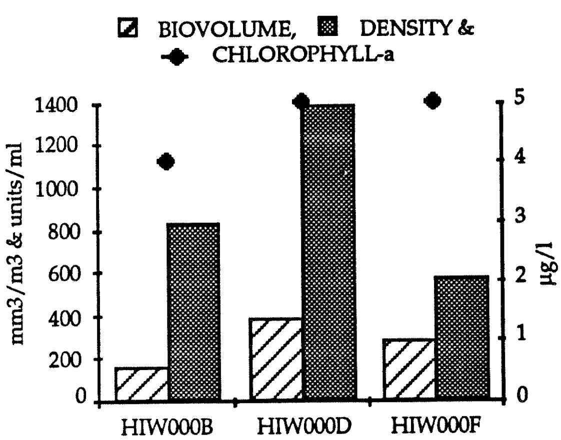
Chatuge Lake was sampled on August 7, 1987. Physical measurements indicated that stratified conditions existed at all sampling locations with the thermocline occurring at a depth of five to 10 meters. Nutrients and chlorophyll-a were low and uniform throughout the lake. Water samples from the hypolimnion had much higher nutrient concentrations than photic zone samples, a common condition in stratified lakes. Analyses of surface waters for heavy metals found detectable levels of aluminum at all lake stations. The concentration of aluminum averaged 67 µg/l in the lake.

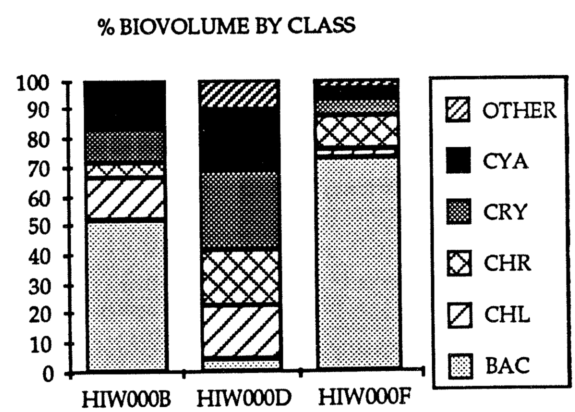
Algal characteristics, chlorophyll-a values, and nutrient concentrations support the oligotrophic classification of Chatuge

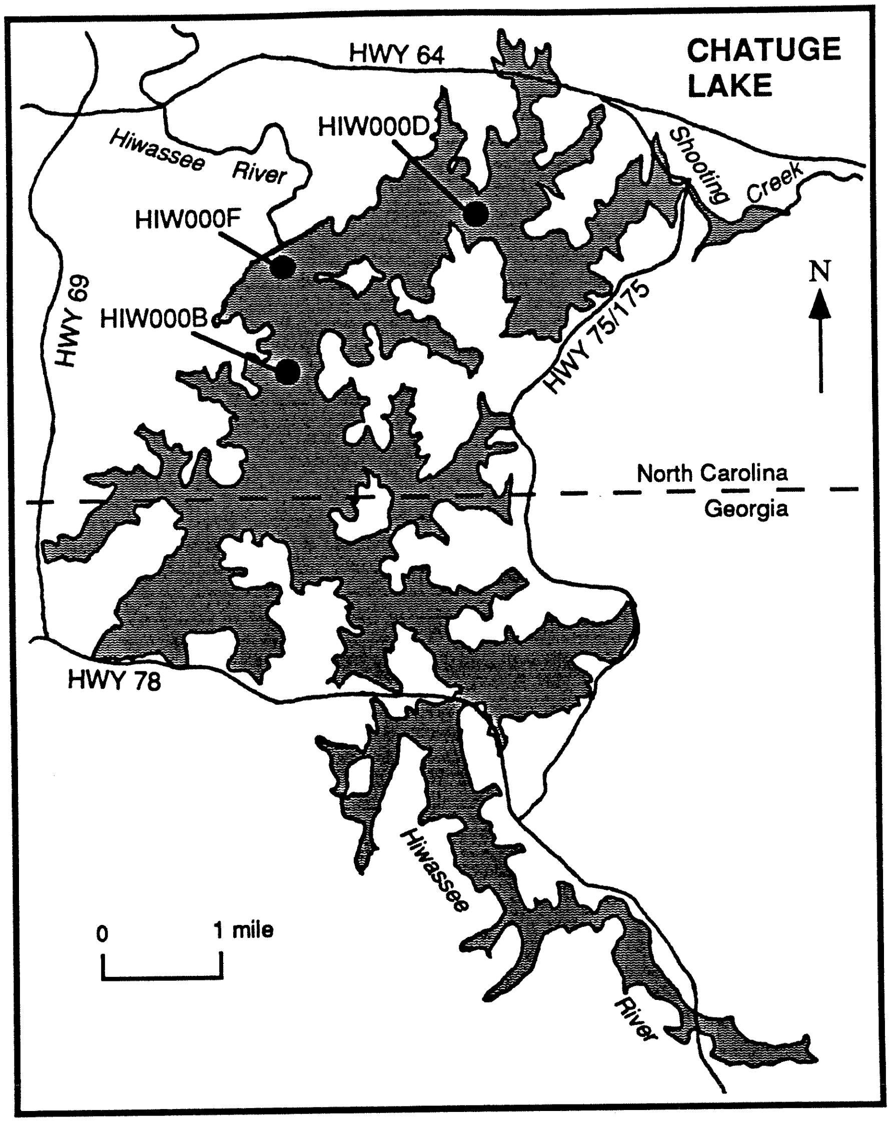
Lake. Algal density ranged from 571 to 1392 units/ml, 40% of which were Lyngbya species. Biovolume estimates varied from 164 to 392 mm^3/m^3 and were dominated by the diatom Tabellaria fenestrata.

In 1987, the TSI was -4.6 which is lower than the value of -3.1 in 1981. The low TSI is typical of large mountain reservoirs in western North Carolina. At the time of assessment, no violations of standards for water quality were observed at Chatuge Lake, and the reservoir fully supported designated uses.

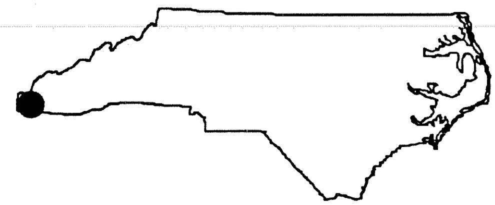







CHATUGE
LAKE
HWY 64
HIW000D
Hiwassee River
Shooting Creek
HIW000F
HIW000B
HWY 69
HWY 75/175
N
North Carolina
Georgia
HWY 78
Hiwassee
River
0
1 mile

HIWASSEE LAKE



COUNTY:	Cherokee	BASIN:	Hiwassee
SURFACE AREA:	2,539 hectares (6,275 acres)	USGS TOPO:	Unaka, N.C.
CLASS:	C	LAKE TYPE:	Reservoir

LATEST NCTSI:	- 4.2	TROPHIC STATE:	Oligotrophic
SAMPLING DATE:	July 26, 1988	ADDITIONAL COVERAGE:	None
SECCHI DEPTH:	3.6 m	CONDUCTIVITY:	23 - 29 µmhos/cm^2
TOTAL PHOSPHORUS:	0.02 mg/l	DISSOLVED OXYGEN:	7.9 - 10.1 mg/l
TOTAL ORGANIC NITROGEN:	0.14 mg/l	TEMPERATURE:	25.8 - 27.6 °C
CHLOROPHYLL-A:	2 µg/l	pH:	6.5 - 8.3 s.u.

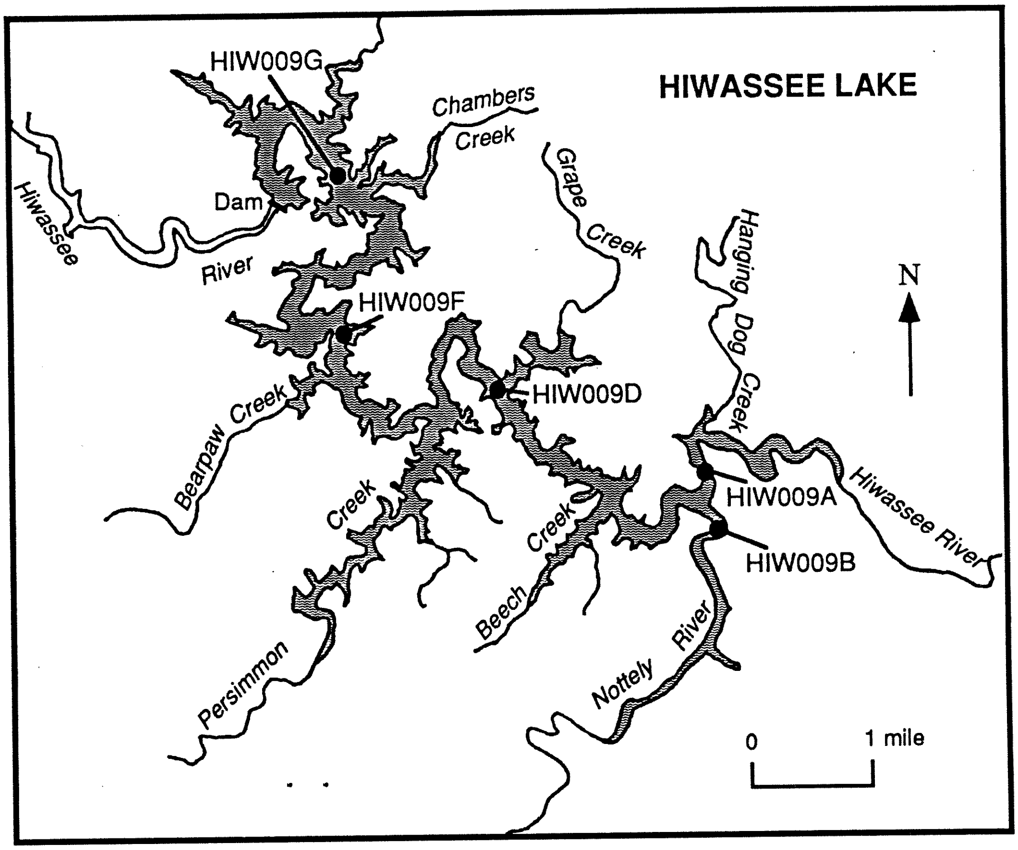
Hiwassee Lake lies in the western tip of North Carolina on the Hiwassee River near the Tennessee border. Chatuge Lake and Nottely Reservoir (in Georgia) are located well upstream. Apalachia Lake is immediately downstream. The reservoir was built by the TVA between 1936 and 1940 to provide hydroelectric power. Hiwassee Lake is the second largest TVA-owned lake in North Carolina, built at a cost of 23 million dollars.

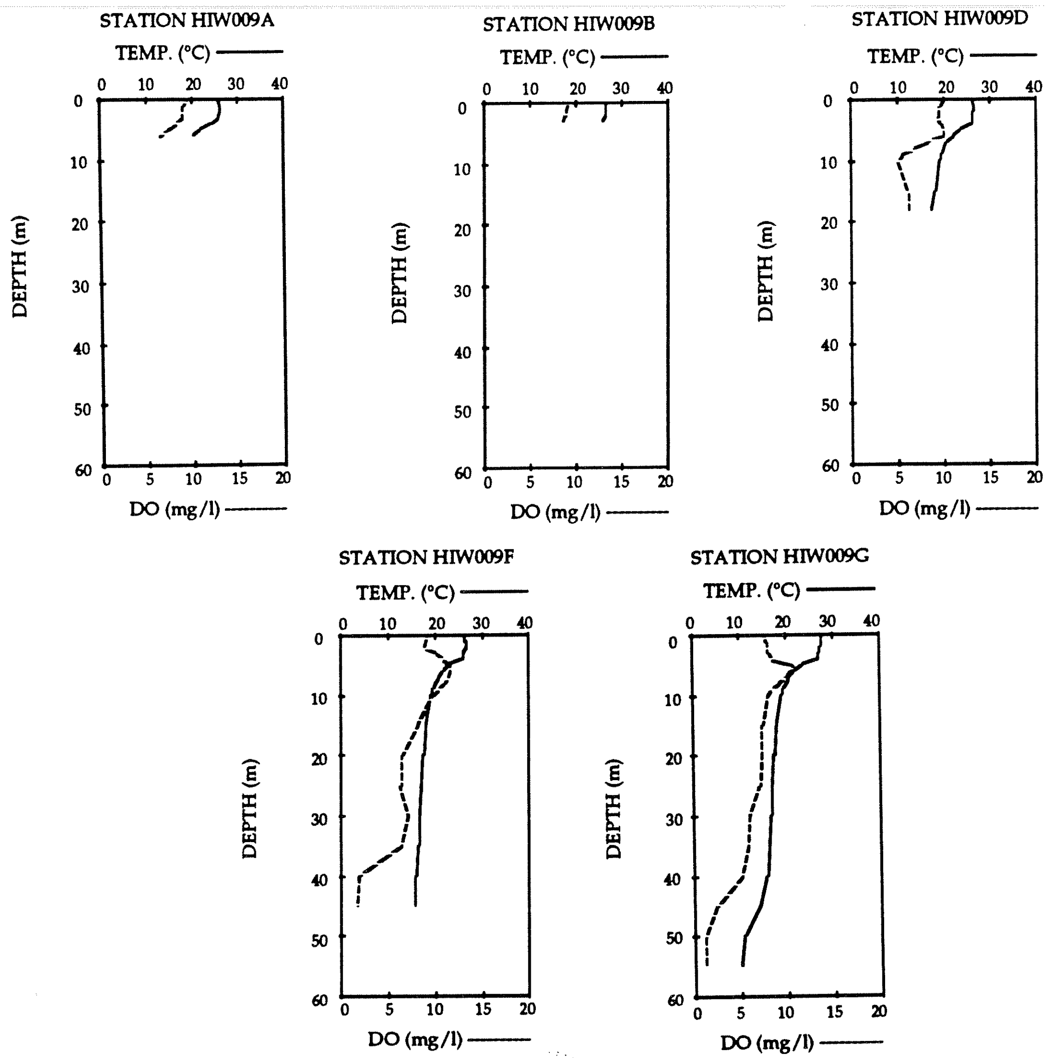
Maximum depth of the lake is 93.7 meters. Length is 35 kilometers, providing 262 kilometers of shoreline at full pool. The major inflows to the lake are Hiwassee River, Nottely River, Persimmon Creek, Valley River, Hanging Dog Creek, and Beaverdam Creek. The steeply sloped watershed measures 2,507 km^2 and is mostly forested.

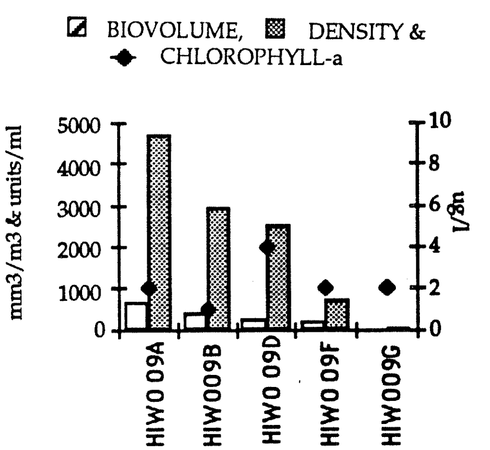
Hiwassee Lake was sampled on July 26, 1988. The lake was 10 meters lower than normal as a result of near-drought conditions. Physical measurements indicated that the lake was stratified, especially in the deeper areas. Water was clear with an emerald green color and no visible solids. Nutrient and chlorophyll-a concentrations were low, indicating low productivity. Metals were not detected in surface samples collected near the dam.

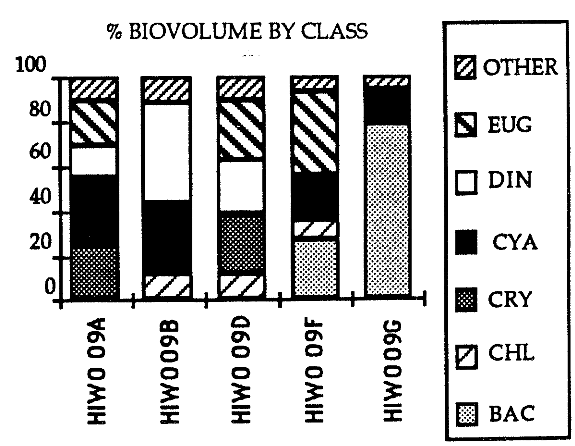
Algal density and biovolume were low. Estimates of biovolume ranged from 2 (HIW009G at the dam) to 652 (HIW009A upstream) mm^3/m^3. Density estimates ranged from 35 to 4658 units/ml with the extremes occurring at the same locations. Algal estimates were dominated by Lyngbya species A (Cyanophyta) and Peridinium species (Dinophyta). The two upstream stations (HIW009A & D) were more riverine in nature and had a higher percentage of flagellated, motile algae including Chroomonas caudata, C. amphioxeia, and Cryptomonas erosa (Cryptophytes).

Hiwassee Lake is an example of a large mountain reservoir which provides energy, flood control, and recreational opportunities. Water quality is excellent as indicated by a TSI of -4.2 in 1988. The lake should maintain an oligotrophic status for many years, barring a major change in nutrient inputs to the lake.

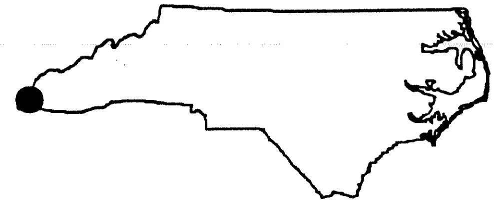



STATION HIW009A
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0 10 20 30 40 50 60
0 5 10 15 20
DO (mg/l)
STATION HIW009B
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0 10 20 30 40 50 60
0 5 10 15 20
DO (mg/l)
STATION HIW009D
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0 10 20 30 40 50 60
0 5 10 15 20
DO (mg/l)
STATION HIW009F
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0 10 20 30 40 50 60
0 5 10 15 20
DO (mg/l)
STATION HIW009G
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0 10 20 30 40 50 60
0 5 10 15 20
DO (mg/l)


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/m3 & units/ml
5000 4000 3000 2000 1000 0
10 8 6 4 2 0
ug/l
HIWO 09A
HIWO09B
HIWO 09D
HIWO 09F
HIWO09G


% BIOVOLUME BY CLASS
100 80 60 40 20 0
HIWO 09A
HIWO09B
HIWO 09D
HIWO 09F
HIWO09G
OTHER
EUG
DIN
CYA
CRY
CHL
BAC

APALACHIA LAKE



COUNTY:	Cherokee	**BASIN:**	Hiwassee
SURFACE AREA:	445 hectares (1,100 acres)	**USGS TOPO:**	Farner, N.C.
CLASS:	B, C	**LAKE TYPE:**	Reservoir

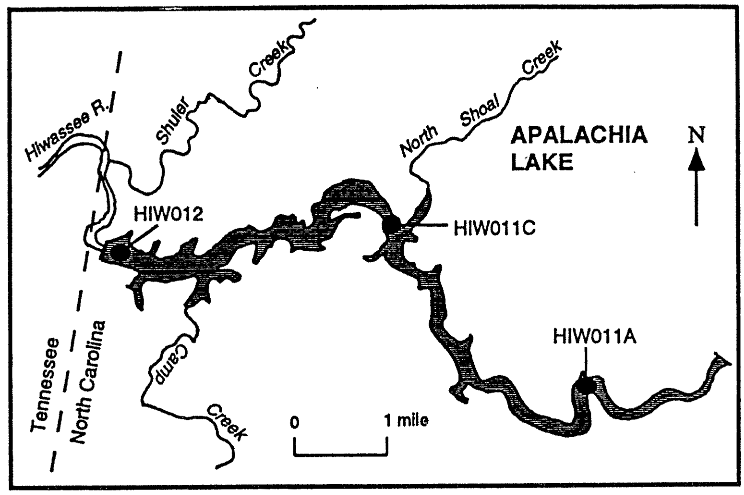
LATEST NCTSI:	- 5.3	**TROPHIC STATE:**	Oligotrophic
SAMPLING DATE:	August 4, 1987	**ADDITIONAL COVERAGE:**	Metals
SECCHI DEPTH:	3.3 m	**CONDUCTIVITY:**	19 - 21 $\mu mhos/cm^2$
TOTAL PHOSPHORUS:	0.01 mg/l	**DISSOLVED OXYGEN:**	8.1 - 9.0 mg/l
TOTAL ORGANIC NITROGEN:	0.08 mg/l	**TEMPERATURE:**	26.0 - 28.1 °C
CHLOROPHYLL-A:	4 μg/l	**pH:**	5.4 - 6.1 s.u.

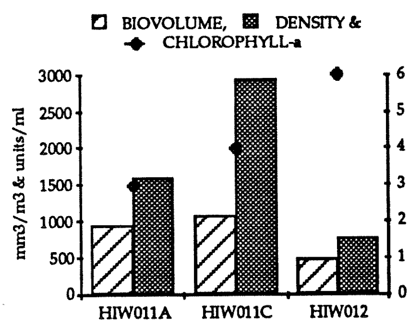
Apalachia Lake is a run-of-the-river reservoir located within the Nantahala National Forest in the mountains of western North Carolina. It is situated immediately downstream of Hiwassee Lake on the Hiwassee River. The lake is owned by the Tennessee Valley Authority and was built to generate hydroelectric power. Construction of the dam began in 1941 and was completed in 1943. Apalachia Lake has a maximum depth of 36 meters, a length of 16 kilometers and 50 kilometers of shoreline at full pool level. Major tributaries to the lake include the Hiwassee River, Camp Creek, and North and South Shoal Creeks. The drainage area covers 2,605 km^2 of mountainous terrain, almost all forested.

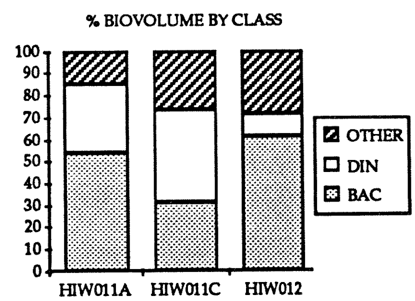
Apalachia Lake was sampled on August 4, 1987. Physical measurements indicated that the lake was stratified with the thermocline occurring at a depth of one to four meters. Nutrients and chlorophyll-a were low throughout the lake. Analyses of surface waters for heavy metals found a low level of zinc (12 μg/l) at the mid-lake station (HIW011C) and a high level of zinc (90 μg/l) at the dam station (HIW012) which exceeded the state freshwater action level of 50 μg/l. Sources of this zinc are not known.

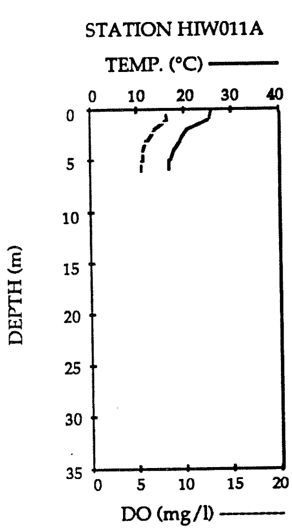
Estimates of algal density and biovolume were low. Biovolume ranged from 460 to 1,084 mm^3/m^3 and was dominated by the diatom Tabellaria fenestrata. Density ranged from 764 to 2,934 units/ml and was dominated by Ochromonas species 3 and Chrysochromulina breviturrita. Ochromonas, a golden-brown alga, is commonly found in lakes throughout North Carolina.

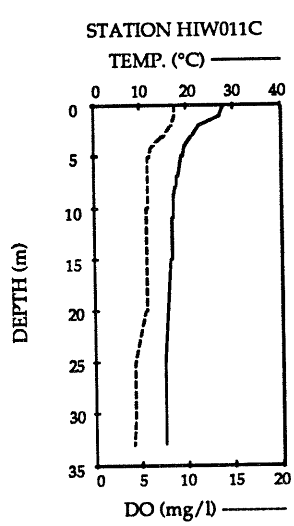
The TSI was -5.3 in 1987 which is higher than the value in 1981 (-6.2). All parameters, except for zinc at HIW012, indicated good water quality. During monitoring on August 4, 1987, Apalachia Lake fully supported designated uses.

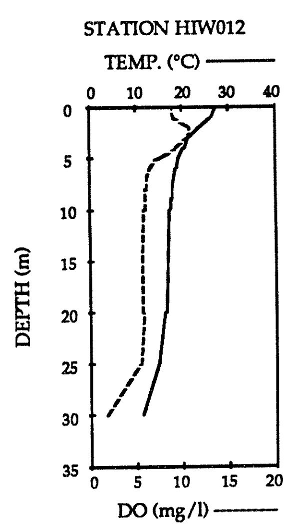












LITTLE TENNESSEE RIVER BASIN

DESCRIPTION OF REGION

The Little Tennessee River basin covers 4,672 km^2 in the counties of Swain, Macon, Clay, Graham, and Jackson. The basin is located in the western mountains of North Carolina and drains the undeveloped watersheds within the Nantahala National Forest, Great Smoky Mountains National Park, and Joyce Kilmore Memorial Forest.

There are two major rivers in the basin, the Little Tennessee River and the Cheoah River. Fontana Lake is fed by the Little Tennessee, Nantahala, and Tuckasegee Rivers. The Oconalufte River joins the Tuckasegee River upstream of Fontana Lake. Santeetlah Lake is located on the Cheoah River, which joins the mainstem of the Little Tennessee River below Fontana Lake.

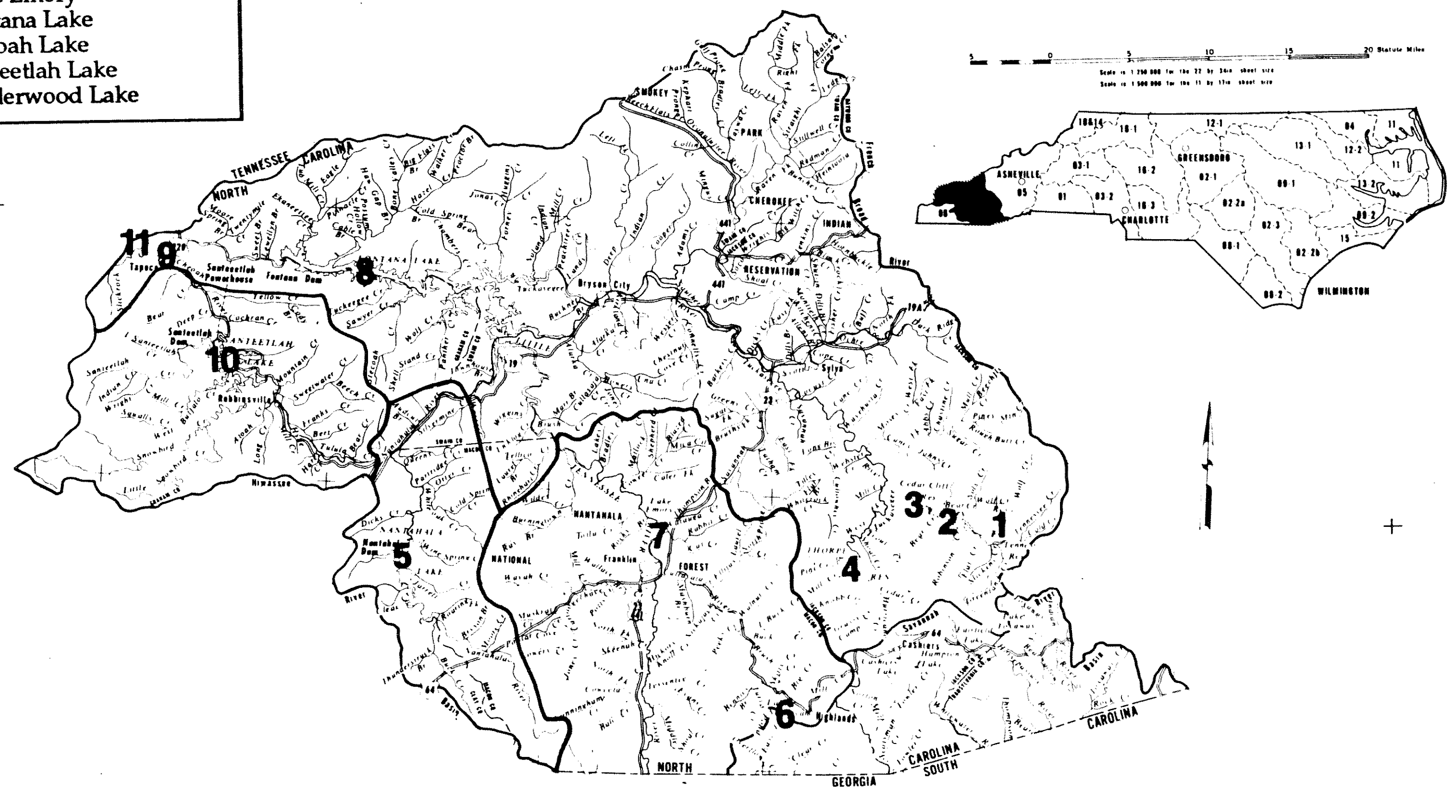
OVERVIEW OF WATER QUALITY

The water quality of the streams and rivers in the Little Tennessee River basin is generally high. The basin drains mainly undeveloped mountain areas and contains many white water rivers and trout streams. Sediment carried by nonpoint source runoff is the dominant water quality problem in this basin. Sources of nonpoint impacts to water quality include agriculture, mining operations, silviculture, and urban runoff. Additionally, flow regulation through reservoir releases affects most of the major tributaries in the basin (NRCD 1988c).

Eleven lakes are included in this section of the report. Many generate hydroelectric power and are used for recreation. Three impoundments of the Tuckasegee River - Wolf Creek Reservoir, Bear Creek Reservoir, and Cedar Cliff Lake - are included in this section. Thorpe Reservoir is an impoundment of the West Fork Tuckasegee River. Nantahala Lake lies on the Nantahala River which eventually flows into the Little Tennessee River. No water quality problems have been found in these five lakes. Lake Sequoyah and Lake Emory are eutrophic lakes which are tributary to the Little Tennessee River. Both have problems with sedimentation from nonpoint sources. Fontana Lake is a large multi-purpose reservoir located at the confluence of the Tuckasegee and Little Tennessee Rivers. Water released from Fontana Lake flows into Lake Cheoah. Santeetlah Lake discharges into the Cheoah River, which in turn joins the Little Tennessee River at the headwaters of Calderwood Lake. These three reservoirs have good water quality. At the time of assessment, nine of the 11 reservoirs in the Little Tennessee basin exhibited high water quality, and all fully supported designated uses.

Little Tennessee and Savannah

MAP #	LAKE
1	Wolf Creek Reservoir
2	Bear Creek Reservoir
3	Cedar Cliff Reservoir
4	Thorpe Reservoir
5	Nantahala Lake
6	Lake Sequoyah
7	Lake Emory
8	Fontana Lake
9	Cheoah Lake
10	Santeetlah Lake
11	Calderwood Lake



North Carolina Department of
Natural Resources and Community Development
Division of Enviromental Management

Adapted from U.S.G.S. (A.M.S.) 1:250,000 U.S. Series

WOLF CREEK RESERVOIR

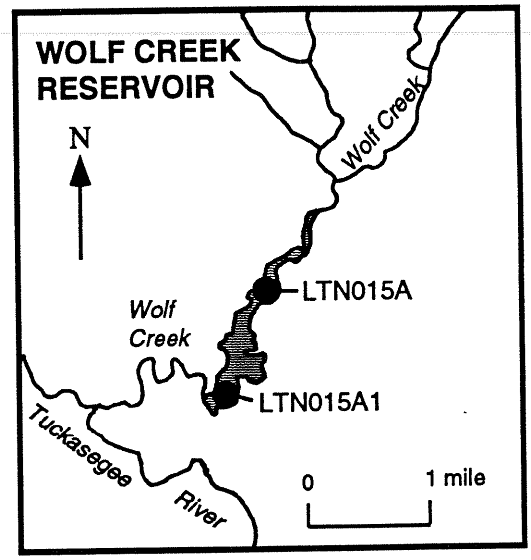
COUNTY:	Jackson	**BASIN:**	Little Tennessee
SURFACE AREA:	78 hectares (183 acres)	**USGS TOPO:**	Lake Toxaway, N.C.
CLASS:	B - TR	**LAKE TYPE:**	Reservoir

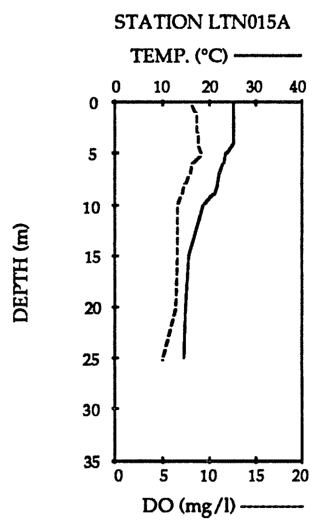
LATEST NCTSI:	- 4.1	**TROPHIC STATE:**	Oligotrophic
SAMPLING DATE:	July 26, 1988	**ADDITIONAL COVERAGE:**	Fecal
SECCHI DEPTH:	3.9 m	**CONDUCTIVITY:**	14 - 15 μmhos/cm^2
TOTAL PHOSPHORUS:	0.01 mg/l	**DISSOLVED OXYGEN:**	8.2 - 8.7 mg/l
TOTAL ORGANIC NITROGEN:	0.115 mg/l	**TEMPERATURE:**	25.3 - 25.5 °C
CHLOROPHYLL-A:	10 μg/l	**pH:**	6.3 - 6.4 s.u.

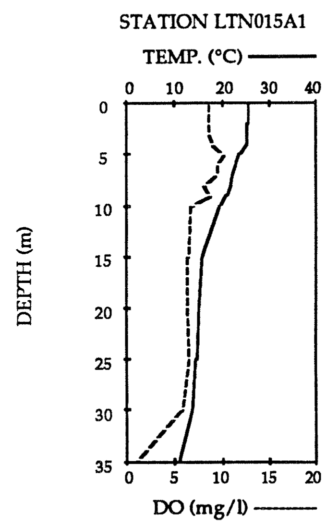
Wolf Creek Reservoir is a small hydroelectric reservoir built by Nantahala Power and Light Company in 1955 on the Tuckasegee River. Maximum depth of the lake is 55 meters. Wolf Creek Reservoir has a drainage area of 103 km^2 which is predominantly forested.

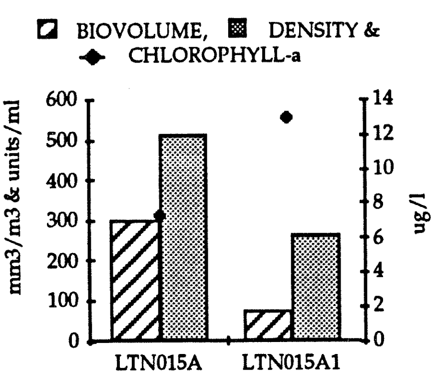
Wolf Creek Reservoir was sampled on July 26, 1988. The water column was thermally stratified. Nutrients were low, and overall water quality was good. Phytoplanktonic biovolume and density were also low in Wolf Creek Reservoir. Dinophyceae was the dominant algal class.

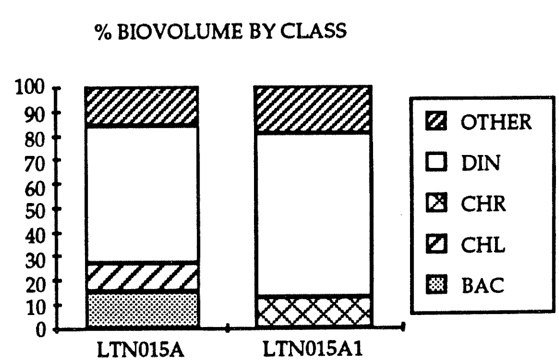
Wolf Creek Reservoir had a TSI of -4.1 in 1988, classifying it as an oligotrophic lake. Water quality fully supported all designated uses at the time of sampling. There are no known inputs of pollution from point or nonpoint sources; therefore, the lake should remain oligotrophic unless significant changes occur in the watershed.


WOLF CREEK
RESERVOIR
N
Wolf Creek
Wolf
Creek
LTN015A
LTN015A1
Tuckasegee
River
0
1 mile

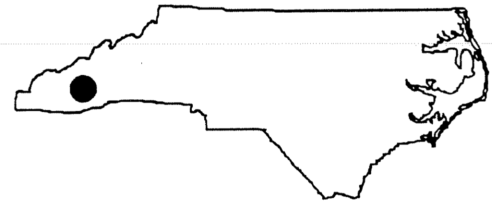

STATION LTN015A
TEMP. (°C)
DEPTH (m)
DO (mg/l)


STATION LTN015A1
TEMP. (°C)
DEPTH (m)
DO (mg/l)


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/m3 & units/ml
ug/l
LTN015A
LTN015A1


% BIOVOLUME BY CLASS
OTHER
DIN
CHR
CHL
BAC
LTN015A
LTN015A1

BEAR CREEK LAKE



COUNTY:	Jackson	BASIN:	Little Tennessee
SURFACE AREA:	192 hectares (475 acres)	USGS TOPO:	Big Ridge , N.C.
CLASS:	B - TR	LAKE TYPE:	Reservoir

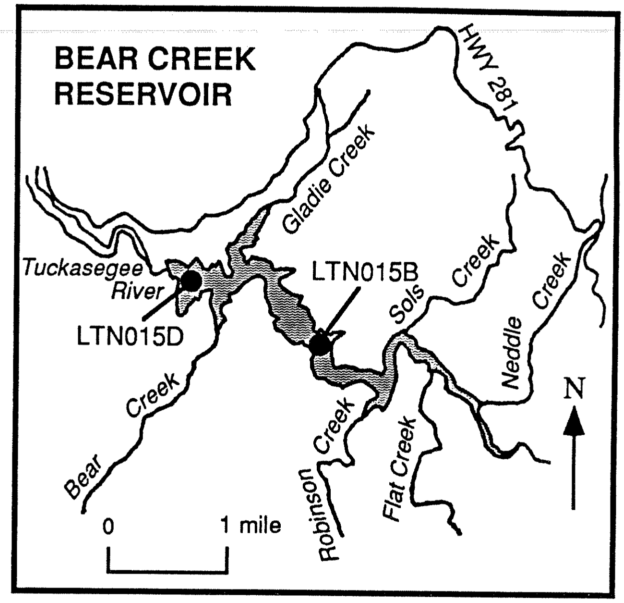
LATEST NCTSI:	- 3.6	TROPHIC STATE:	Oligotrophic
SAMPLING DATE:	July 26, 1988	ADDITIONAL COVERAGE:	Fecal
SECCHI DEPTH:	2.2 m	CONDUCTIVITY:	16 µmhos/cm^2
TOTAL PHOSPHORUS:	0.01 mg/l	DISSOLVED OXYGEN:	7.7 - 7.8 mg/l
TOTAL ORGANIC NITROGEN:	0.17 mg/l	TEMPERATURE:	26.0 - 26.5 °C
CHLOROPHYLL-A:	4 µg/l	pH:	6.3 - 6.4 s.u.

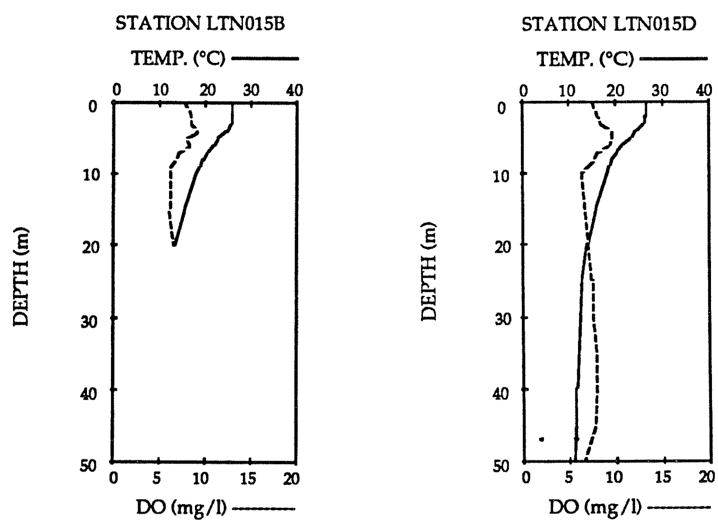
Bear Creek Lake is a water supply impoundment of the Tuckasegee River. Most of the drainage area is forested with steep slopes and clean, fast-moving streams. Bear Creek Lake was built in 1953 and holds 5.6 x 10^6 m^3 of water. Maximum depth is 66 meters. Nantahala Power and Light Company owns the lake.

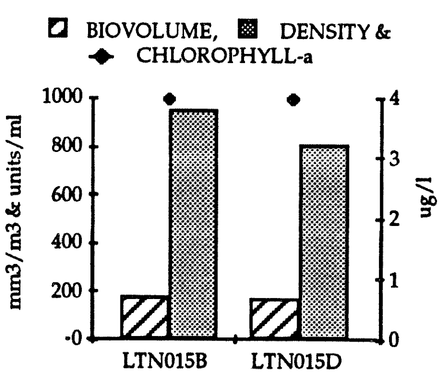
Bear Creek Lake was sampled on July 26, 1988. The lake was thermally stratified at both stations, showing a 16 °C difference between top and bottom temperatures at the dam. Surface dissolved oxygen concentrations were approximately 95% of saturation. Conductance was low throughout the water column, indicating a lack of inorganic pollutants. Nutrients and solids were also low in this reservoir.

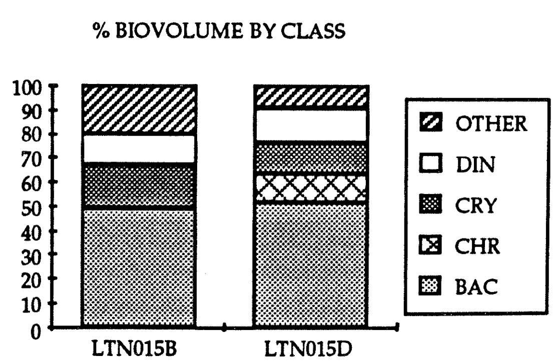
In accordance with the oligotrophic status of Bear Creek Lake, algal biovolume and density were low at both sampling stations. Rhizosolenia eriensis, a diatom common in acidic, cool mountain lakes, constituted 50% of the algal biovolume. Codominant classes of phytoplankton included cryptophytes and dinoflagellates.

Bear Creek Lake had a TSI of -3.6 in 1988, indicating it was oligotrophic. All uses of the lake were supported at the time of this assessment.

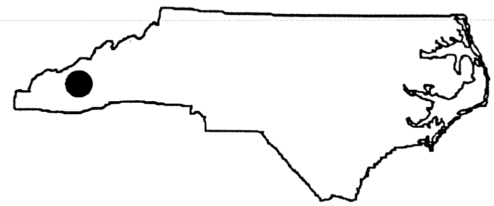

BEAR CREEK
RESERVOIR
HWY 281
Gladie Creek
Tuckasegee
River
LTN015B
LTN015D
Sols
Creek
Neddle
Creek
N
Bear
Creek
Robinson
Creek
Flat Creek
0
1 mile


STATION LTN015B
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0
10
20
30
40
50
0 5 10 15 20
DO (mg/l)
STATION LTN015D
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0
10
20
30
40
50
0 5 10 15 20
DO (mg/l)


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/m3 & units/ml
1000
800
600
400
200
-0
ug/l
4
3
2
1
0
LTN015B
LTN015D


% BIOVOLUME BY CLASS
100
90
80
70
60
50
40
30
20
10
0
LTN015B
LTN015D
OTHER
DIN
CRY
CHR
BAC

CEDAR CLIFF LAKE



COUNTY:	Jackson	BASIN:	Little Tennessee
SURFACE AREA:	59 hectares 145 acres)	USGS TOPO:	Tuckasegee, N.C.
CLASS:	B - TR	LAKE TYPE:	Reservoir

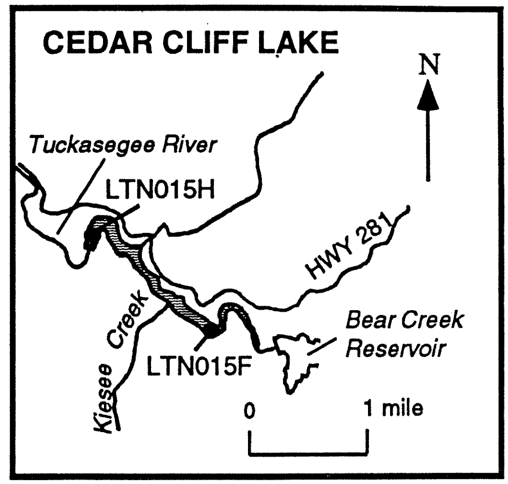
LATEST NCTSI:	- 6.0	TROPHIC STATE:	Oligotrophic
SAMPLING DATE:	July 28, 1988	ADDITIONAL COVERAGE:	Fecal
SECCHI DEPTH:	3.75 m	CONDUCTIVITY:	16 - 17 µmhos/cm^2
TOTAL PHOSPHORUS:	0.01 mg/l	DISSOLVED OXYGEN:	6.4 - 9.2 mg/l
TOTAL ORGANIC NITROGEN:	0.05 mg/l	TEMPERATURE:	24.7 - 26.7 °C
CHLOROPHYLL-A:	5 µg/l	pH:	5.9 - 6.6 s.u.

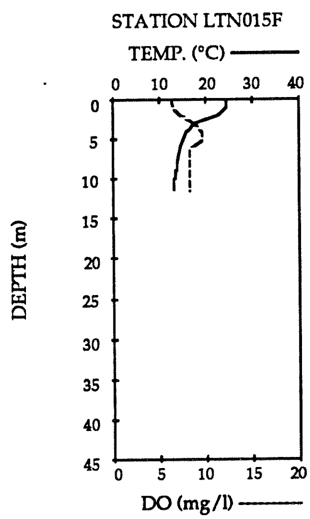
Cedar Cliff Lake is a picturesque, undisturbed mountain lake on the Tuckasegee River. The lake is owned by Nantahala Power and Light Company and was built in 1952. The volume of the lake is 7.2 x 10^6 m^3 with a maximum depth of 53 meters. The watershed measures 209 km^2 and is mostly forested. Water quality in the lake supports swimming, boating, and trout fishing. The name of the lake was probably derived from a sheer rock cliff which faces it from the north.

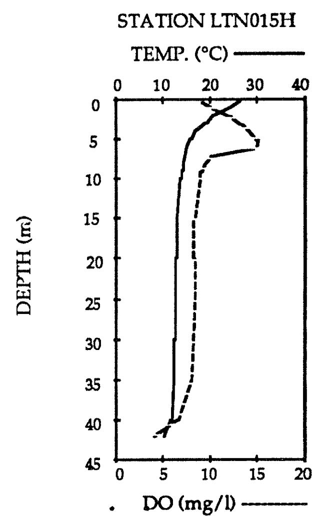
Thermal stratification was evident in the lake on July 28, 1988. High secchi depth readings concurred with visual observations of clear, emerald green water throughout the lake. Nutrient and chlorophyll-a levels were low, and fecal coliforms were not detected.

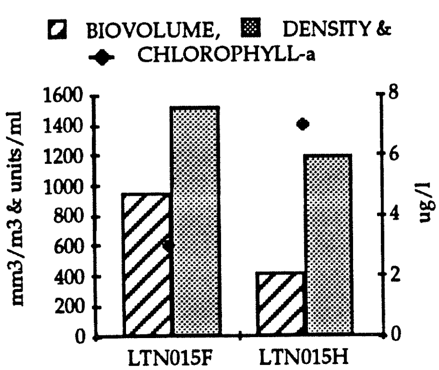
Both stations on Cedar Cliff Lake exhibited low levels of phytoplanktonic biovolume and density. Bacillariophytes and cyanophytes (Gloeocapsa species) codominated the algal biovolume at both stations. Cyanophytes commonly occur in lakes throughout North Carolina during summer months. At LTN015H, Rhizoselenia eriensis, a diatom often found in cool, acidic mountain lakes, constituted 50% of the algal biovolume. Dinoflagellates of the genus Peridinium were dominant at LTN015F, composing 60% of the biovolume.

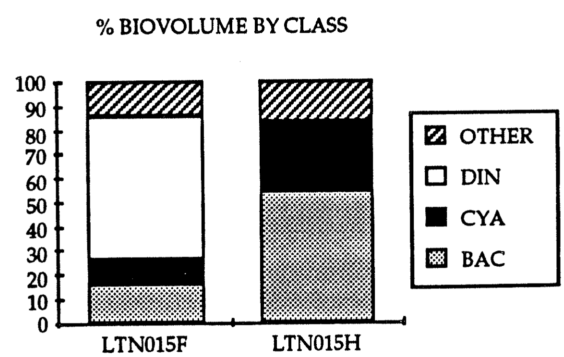
Cedar Cliff Lake had the third lowest TSI in North Carolina in 1988 (-6.0). This indicates that it is one of the cleanest lakes in North Carolina and it will continue to be a valuable environmental resource.


CEDAR CLIFF LAKE
N
Tuckasegee River
LTN015H
HWY 281
Kiesee Creek
Bear Creek Reservoir
LTN015F
0
1 mile

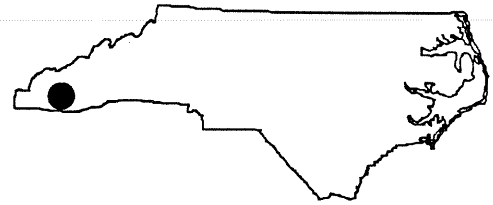

STATION LTN015F
TEMP. (°C)
DEPTH (m)
DO (mg/l)


STATION LTN015H
TEMP. (°C)
DEPTH (m)
DO (mg/l)


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/m3 & units/ml
ug/l
LTN015F
LTN015H


% BIOVOLUME BY CLASS
OTHER
DIN
CYA
BAC
LTN015F
LTN015H

THORPE RESERVOIR



COUNTY:	Jackson	BASIN:	Little Tennessee
SURFACE AREA:	592 hectares (1,462 acres)	USGS TOPO:	Glenville, N.C.
CLASS:	B	LAKE TYPE:	Reservoir

LATEST NCTSI:	-4.9	TROPHIC STATE:	Oligotrophic
SAMPLING DATE:	August 1, 1990	ADDITIONAL COVERAGE:	Fecal
SECCHI DEPTH:	3.55 m	CONDUCTIVITY:	18- 19 μmhos/cm^2
TOTAL PHOSPHORUS:	0.01 mg/l	DISSOLVED OXYGEN:	8.1 - 8.4 mg/l
TOTAL ORGANIC NITROGEN:	0.11 mg/l	TEMPERATURE:	24.2 - 24.7 °C
CHLOROPHYLL-A:	3.5 μg/l	pH:	5.8- 7.2 s.u.

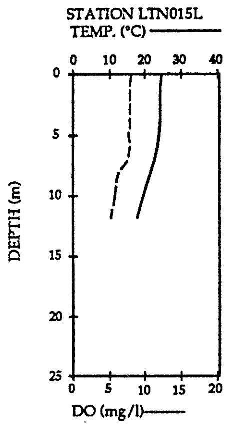
Thorpe Reservoir, also known as Glenville Lake, is a man-made impoundment of the Tuckasegee River located in Jackson County. The lake is used for recreational fishing, swimming, and boating. Owned by Nantahala Power and Light, the reservoir also has been used to generate hydroelectric power since its construction in 1941.

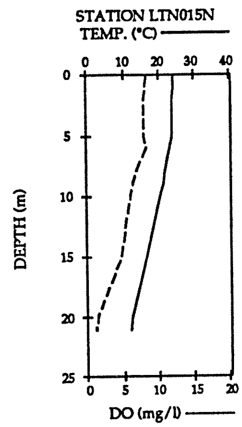
Volume of the lake is 82.6 x 10^6 m^3 with a mean retention time of 294 days. Most of the 95 km^2 drainage area is forested. The watershed is drained by the West Fork Tuckasegee River, Norton Creek, Hurricane Creek, Cedar Creek, Mill Creek, and Pine Creek.

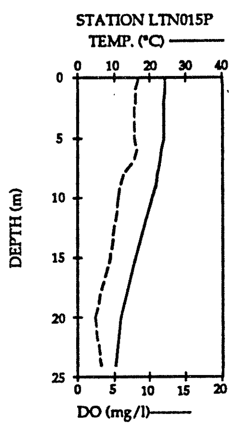
Thorpe Reservoir was stratified when sampled on August 1, 1990. Conductivity was low and increased with depth. Alkalinity and pH indicated slightly acidic conditions. High secchi values, low solids, and low turbidity denoted good water clarity. Nutrients and chlorophyll-a were low. Fecal coliform bacteria were not detected in the lake.

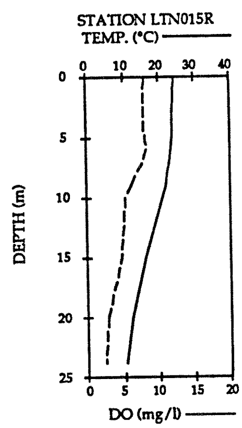
Estimates of algal biovolume and density were low and comparable at all four stations, reflecting the low availability of nutrients. Gonyostomum depressum, a large chloromonadophyte, dominated the algal biovolume at two sampling stations (LTN015L and LTN015R), whereas Peridinium species was dominant at LTN015P. LTN015N exhibited a diverse algal assemblage with no class composing more than 25% of the biovolume.

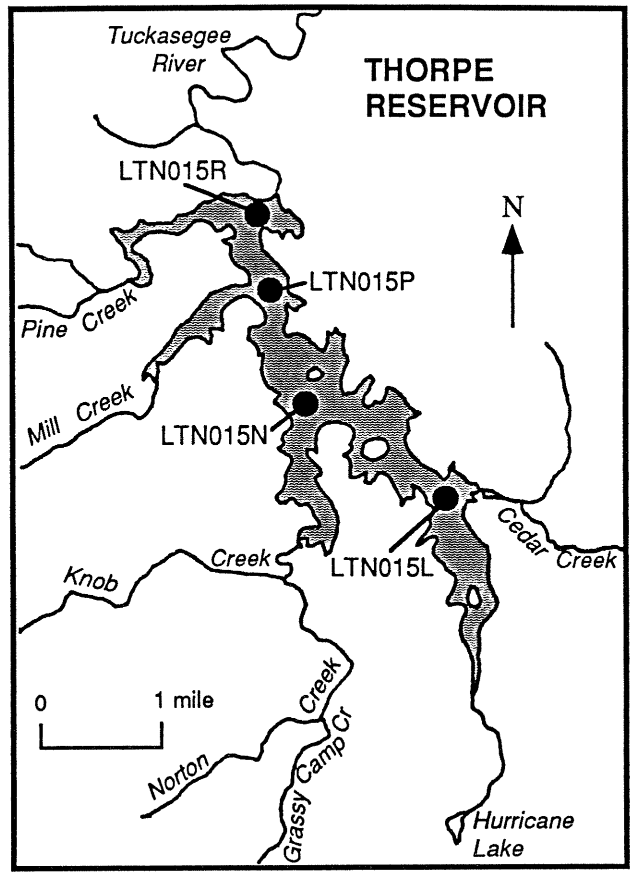
A TSI of -4.9 indicated Thorpe Reservoir is oligotrophic. Chemical and biological parameters also reflected the low productivity in the lake. No violations of water quality standards were documented and Thorpe Reservoir fully supported its designated uses.

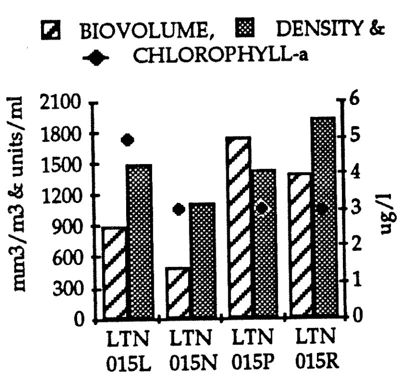

STATION LTN015L
TEMP. (°C)
DEPTH (m)
DO (mg/l)

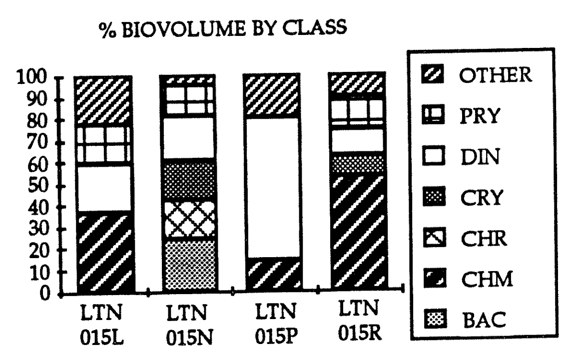

STATION LTN015N
TEMP. (°C)
DEPTH (m)
DO (mg/l)


STATION LTN015P
TEMP. (°C)
DEPTH (m)
DO (mg/l)

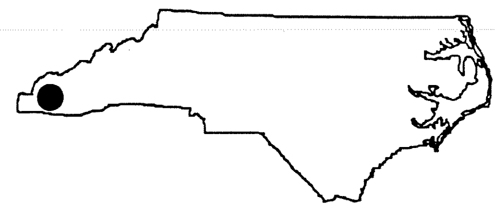

STATION LTN015R
TEMP. (°C)
DEPTH (m)
DO (mg/l)


THORPE
RESERVOIR
Tuckasegee
River
LTN015R
LTN015P
LTN015N
LTN015L
N
Pine Creek
Mill Creek
Knob Creek
Cedar Creek
Norton Creek
Grassy Camp Cr
Hurricane
Lake
0
1 mile


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/m3 & units/ml
ug/l
LTN 015L
LTN 015N
LTN 015P
LTN 015R


% BIOVOLUME BY CLASS
OTHER
PRY
DIN
CRY
CHR
CHM
BAC
LTN 015L
LTN 015N
LTN 015P
LTN 015R

NANTAHALA LAKE



COUNTY:	Macon	BASIN:	Little Tennessee
SURFACE AREA:	650 hectares (1,605 acres)	USGS TOPO:	Topton, N.C.
CLASS:	B - TR	LAKE TYPE:	Reservoir

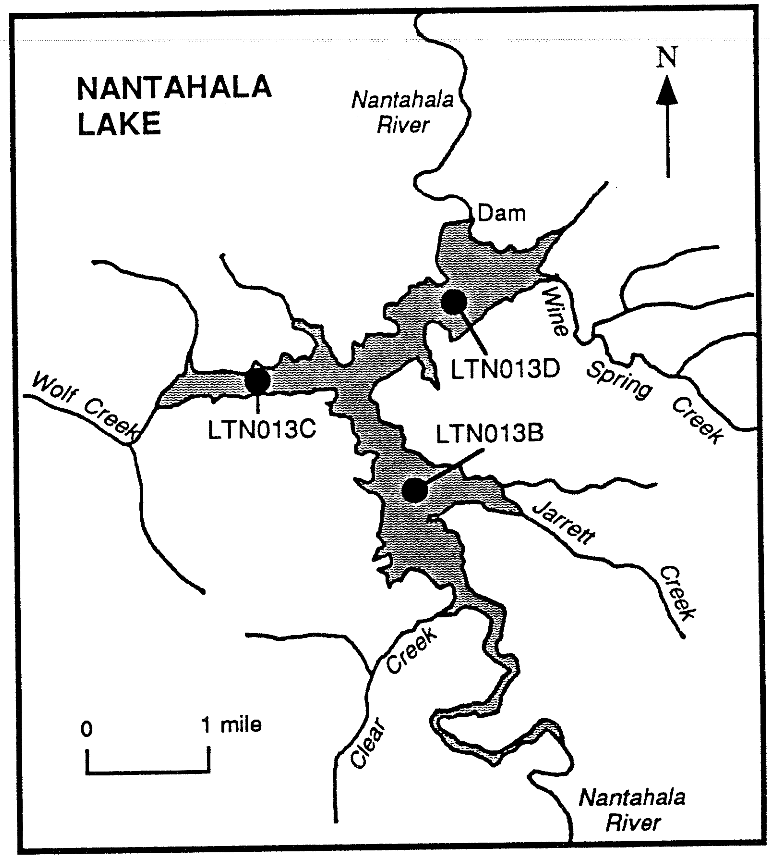
LATEST NCTSI:	- 6.6	TROPHIC STATE:	Oligitrophic
SAMPLING DATE:	August 2, 1989	ADDITIONAL COVERAGE:	None
SECCHI DEPTH:	5.5 m	CONDUCTIVITY:	8 - 10 µmhos/cm^2
TOTAL PHOSPHORUS:	0.01 mg/l	DISSOLVED OXYGEN:	8.1 - 8.4 mg/l
TOTAL ORGANIC NITROGEN:	0.1 mg/l	TEMPERATURE:	23.7 - 24.4 °C
CHLOROPHYLL-A:	1 µg/l	pH:	6.0 - 7.3 s.u.

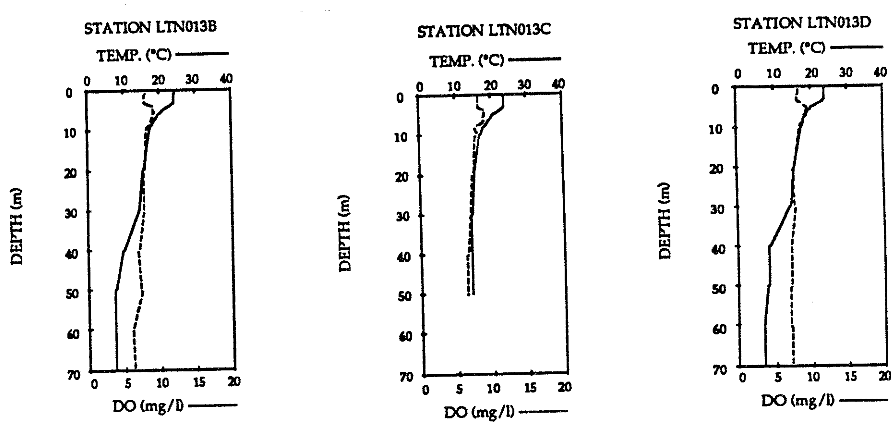
Nantahala Lake lies in the western tip of North Carolina on the Nantahala River and is used for trout fishing. Nantahala Power and Light owns the reservoir, which was impounded in 1942 for hydroelectric power. The lake holds 160×10^6 m^3 of water and is 76 meters deep at the dam at maximum pool. The rugged, mountainous drainage area measures 280 km^2 and is mostly forested.

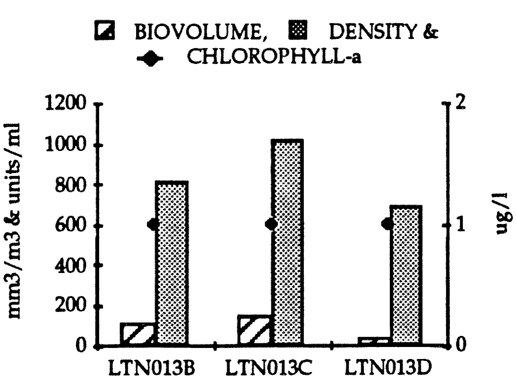
Nantahala Lake was sampled on August 2, 1989. Dissolved oxygen and temperature profiles indicate the water column stratified during the summer. Conductance was low, indicating a lack of inorganic pollution. Secchi depths were greater than five meters in Nantahala Lake, some of the highest values recorded in North Carolina. Nutrients and chlorophyll-a were low.

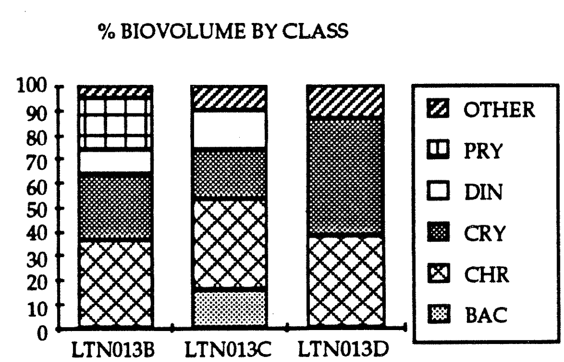
Consistent with an oligotrophic classification, Nantahala Lake exhibited low algal biovolume and density levels. Chrysophytes (Dinobryon bavaricum) and cryptophytes (Chroomonas caudata) codominated algal biovolume at all three stations. Members of the genus Dinobryon are often found in neutral to slightly alkaline waters with low nutrient levels (Wetzel, 1975).

Nantahala Lake is a large, oligotrophic mountain reservoir with high water quality. The TSI of -6.6 in 1989 was similar to past values. Designated uses of the lake were fully supported at the time of assessment.

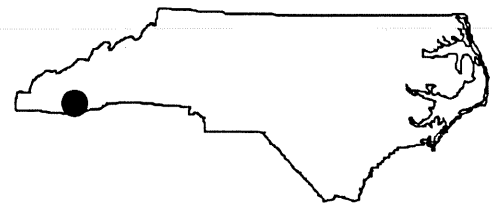

NANTAHALA
LAKE
Nantahala
River
N
Dam
Wine
Spring
Creek
LTN013D
Wolf Creek
LTN013C
LTN013B
Jarrett
Creek
Creek
Clear
0
1 mile
Nantahala
River


STATION LTN013B
TEMP. (°C)
DEPTH (m)
DO (mg/l)
STATION LTN013C
TEMP. (°C)
DEPTH (m)
DO (mg/l)
STATION LTN013D
TEMP. (°C)
DEPTH (m)
DO (mg/l)


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/m3 & units/ml
ug/l
LTN013B
LTN013C
LTN013D


% BIOVOLUME BY CLASS
OTHER
PRY
DIN
CRY
CHR
BAC
LTN013B
LTN013C
LTN013D

LAKE SEQUOYAH



COUNTY:	Macon	BASIN:	Little Tennessee
SURFACE AREA:	60 hectares (150 acres)	USGS TOPO:	Highlands, N.C.
CLASS:	WS - TR, C - TR	LAKE TYPE:	Reservoir

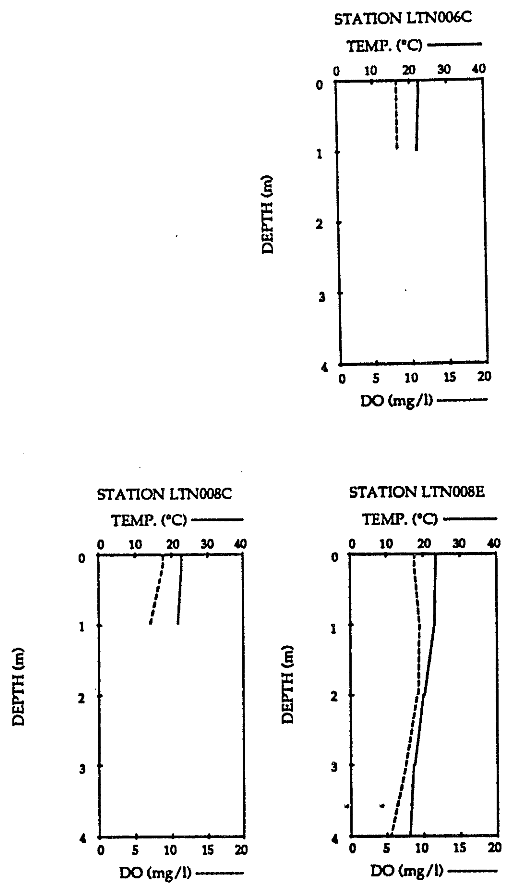
LATEST NCTSI:	1.3	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	July 27, 1988	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	0.8 m	CONDUCTIVITY:	34 - 36 µmhos/cm^2
TOTAL PHOSPHORUS:	0.05 mg/l	DISSOLVED OXYGEN:	8.3 - 8.9 mg/l
TOTAL ORGANIC NITROGEN:	0.26 mg/l	TEMPERATURE:	22.4 - 23.5 °C
CHLOROPHYLL-A:	21 µg/l	pH:	6.4 - 7.4 s.u.

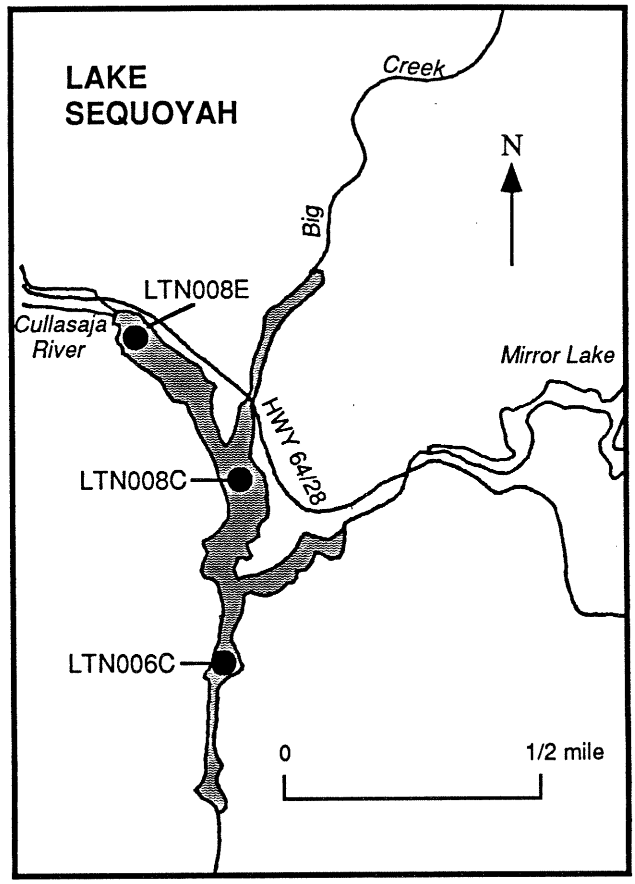
Lake Sequoyah is located near Highlands on the Cullasaja River. The Town of Highlands uses the lake as a backup water supply. At this writing, the lake is also being considered for small-scale hydroelectric power generation. This shallow lake has a maximum depth of only four meters.

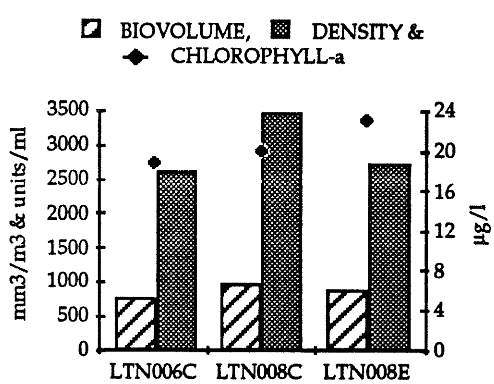
Lake Sequoyah was sampled on July 27, 1988. Stratification was noted near the dam. The other two stations were only one meter deep, and the water column was well mixed. The lake was turbid with a mean lakewide secchi of 0.8 meters. Poor water clarity was also evidenced by high turbidity values. At two of the three stations, turbidity exceeded the state standard for "Trout Waters" of 10 NTU. The chlorophyll-a standard for these waters (15 µg/l) was exceeded at all three stations. Not surprisingly, nutrients were also elevated, especially total phosphorus and inorganic forms of nitrogen (ammonia and nitrate-nitrite) Toxic heavy metals were below laboratory detection limits.

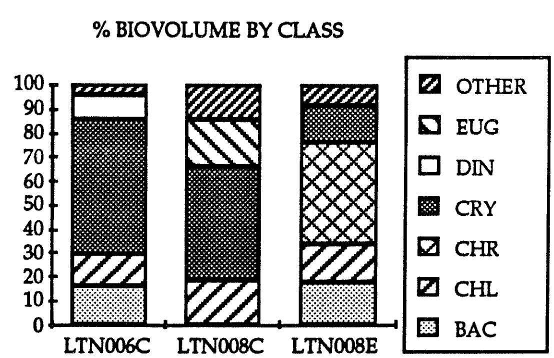
Phytoplanktonic biovolumes and densities were moderate at all three stations on Lake Sequoyah. Cryptophytes (Cryptomonas erosa and Cryptomonas ovata) dominated algal biovolume at the two upstream stations (LTN006C and LTN008C), but chrysophytes were dominant near the dam (LTN008E). Rhizosolenia eriensis, a diatom common in slightly acidic mountain lakes, was also abundant in Lake Sequoyah. Peridinium species 2, a dinoflagellate dominant at LTN006C, and Trachelomonas species 3, a euglenophyte dominant at LTN008C, represent genera often found in enriched waters (Wetzel, 1975).

Eutrophic conditions were indicated by a TSI of 1.3 in 1988. Sources of nutrient enrichment and high turbidity were not documented and should be investigated in the future.

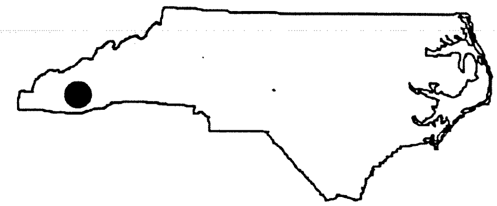








LAKE EMORY



COUNTY:	Macon	BASIN:	Little Tennessee
SURFACE AREA:	76 hectares (188 acres)	USGS TOPO:	Corbin Knob, N.C.
CLASS:	C	LAKE TYPE:	Reservoir

LATEST NCTSI:	3.8	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	July 27, 1988	ADDITIONAL COVERAGE:	None
SECCHI DEPTH:	0.4 m	CONDUCTIVITY:	40 - 43 µmhos/cm^2
TOTAL PHOSPHORUS:	0.16 mg/l	DISSOLVED OXYGEN:	8.6 - 8.7 mg/l
TOTAL ORGANIC NITROGEN:	0.34 mg/l	TEMPERATURE:	23.2 - 23.9 °C
CHLOROPHYLL-A:	22 µg/l	pH:	6.8 - 6.9 s.u.

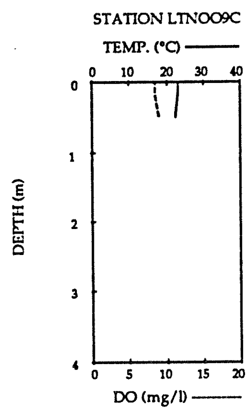
Lake Emory was built in the 1920's and bought by Nantahala Power and Light Company in 1933. The lake is quite shallow and has a short retention time. The 803 km^2 watershed is mostly agricultural.

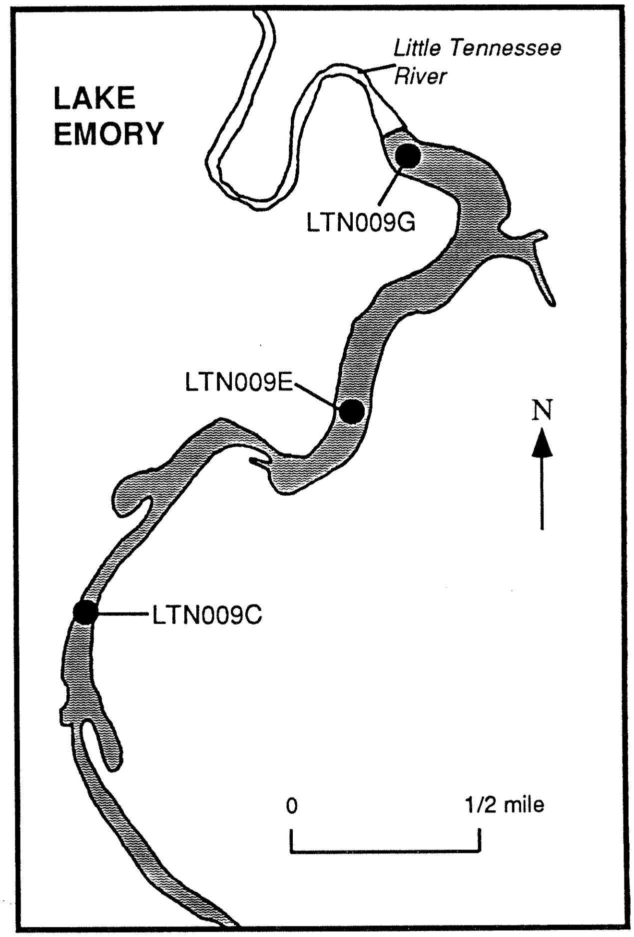
Lake Emory was sampled on July 27, 1988. Poor erosion controls upstream caused heavy sedimentation in the lake. A large amount of suspended and floating solids were noted during sampling. Stratification was not evident, probably a result of wind mixing and the short retention time of the lake. Chemical sampling corroborated visual observations of turbid water. Suspended solids were at least 18 mg/l at each station. Similarly, turbidity values were elevated (greater than 15 NTU). Chlorophyll-a and nutrients were also elevated. In particular, total phosphorus concentrations suggested highly enriched conditions.

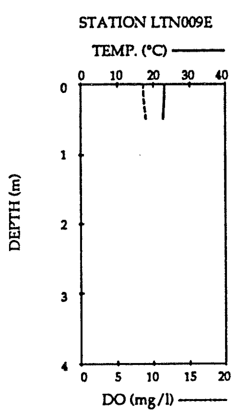
Algal biovolumes were low at all three stations on Lake Emory, but phytoplanktonic density approached the bloom threshold of 10,000 units/ml at LTN009G. This relatively high algal density can be explained by the abundance of small, unicellular, green algae.

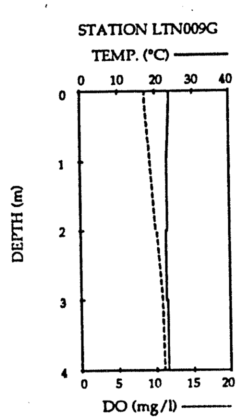
Euglenophytes and chlorophytes dominated the biovolume at each station. Because chlorophyll-a values were high relative to biovolumes, some species within these two algal classes apparently contain substantial amounts of chlorophyll-a. The prevalence of euglenophytes usually indicates organic enrichment. A further sign of eutrophy was that Melosira granulata var. angustissima, a filamentous diatom, dominated biovolume at LTN009E and LTN009G.

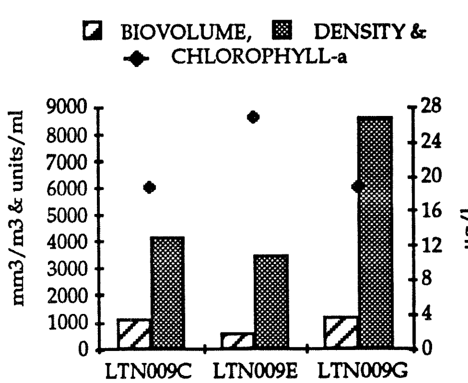
A TSI of 3.8 showed that the lake was eutrophic in 1988. Problems associated with sedimentation, turbidity, and elevated nutrients were documented. Without additional pollution/sediment controls in the watershed, Lake Emory will probably continue to be an overly enriched lake - an unusual occurrence in the mountains of North Carolina.

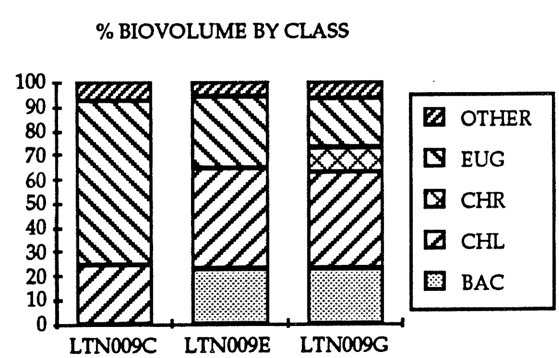




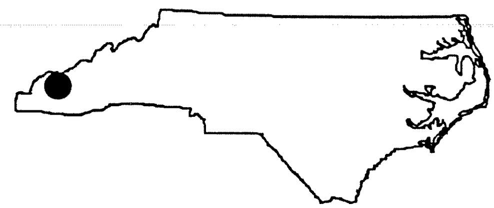








FONTANA LAKE



COUNTY:	Swain/Graham	**BASIN:**	Little Tennessee
SURFACE AREA:	4318 hectares (10,670 acres)	**USGS TOPO:**	Fontana Dam, N.C.
CLASS:	WS, B, C TR	**LAKE TYPE:**	Reservoir

LATEST NCTSI:	- 4.0	**TROPHIC STATE:**	Oligotrophic
SAMPLING DATE:	August 5, 1987	**ADDITIONAL COVERAGE:**	Metals
SECCHI DEPTH:	3.9 m	**CONDUCTIVITY:**	9 - 19 µmhos/cm^2
TOTAL PHOSPHORUS:	0.01 mg/l	**DISSOLVED OXYGEN:**	7.2 - 8.0 mg/l
TOTAL ORGANIC NITROGEN:	0.19 mg/l	**TEMPERATURE:**	27.6 - 28.6 °C
CHLOROPHYLL-A:	4 µg/l	**pH:**	5.5 - 7.2 s.u.

Fontana Lake is located along the southern boundary of the Great Smoky Mountains National Park. It provides power and flood control on the Little Tennessee River. As with other reservoirs in the area which are used for generating hydroelectric power, Fontana Lake is owned and operated by the Tennessee Valley Authority. Construction on the dam began in 1942 and was completed in 1944. At a height of over 146 meters, Fontana Lake has the highest dam east of the Mississippi River.

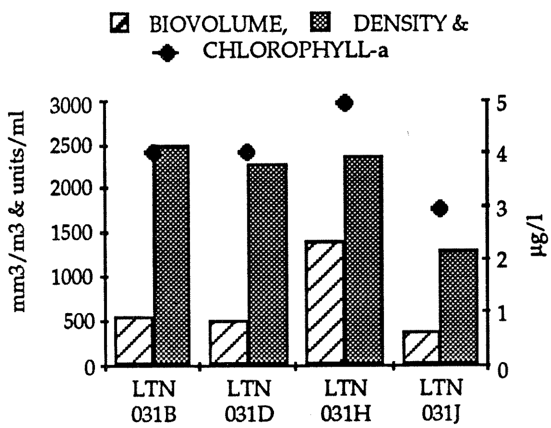
Fontana Lake has a maximum depth of 134 meters, a mean depth of 41 meters, and a volume of 1,782 x 10^6 m^3. The lake is 47 kilometers long, and the shoreline measures 400 kilometers at full pool. Mean hydraulic retention time is 179 days. Major tributaries include the Little Tennessee, Tuckasegee, and Nantahala Rivers. The drainage area of Fontana Lake covers 4,020 km^2 of mountainous terrain. Over 50% of the watershed is forested, and another 25 to 33% is pasture. Various segments of the lake are classified for use as water supply, primary recreation, secondary recreation, and/or trout waters.

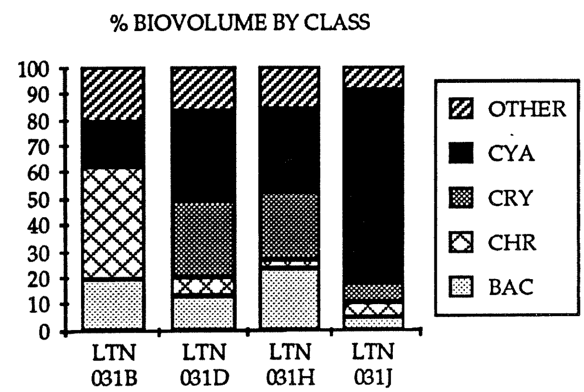
Fontana Lake was sampled on August 5, 1987. The water column was stratified at all stations. Nutrient and chlorophyll-a levels were low with the highest nutrient concentrations observed in the Nantahala River arm (station LTN031B) of the lake. Aluminum was found in low concentrations, averaging 50 µg/l. No other metals were detected.

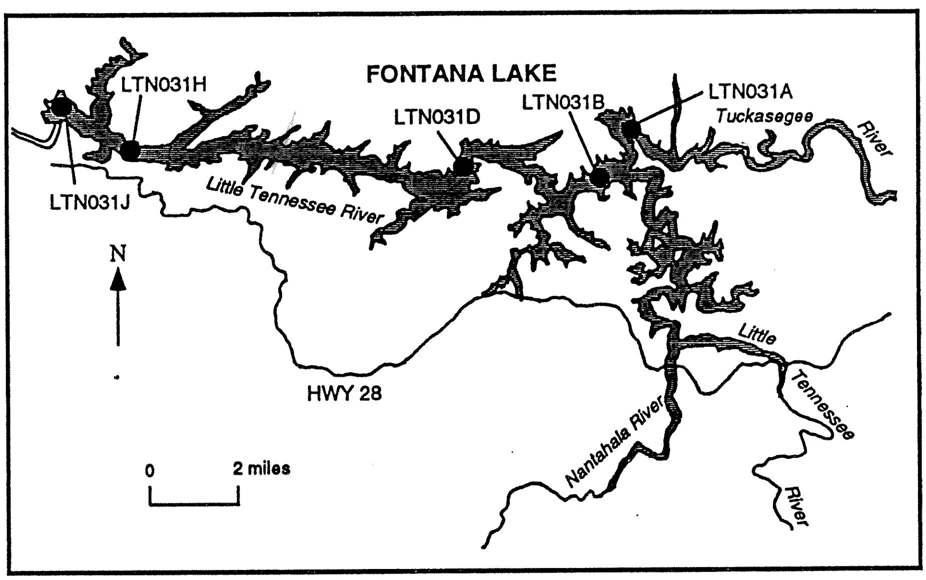
Estimates of algal biovolume and density indicated moderate to low populations in Fontana Lake. Dominant species included

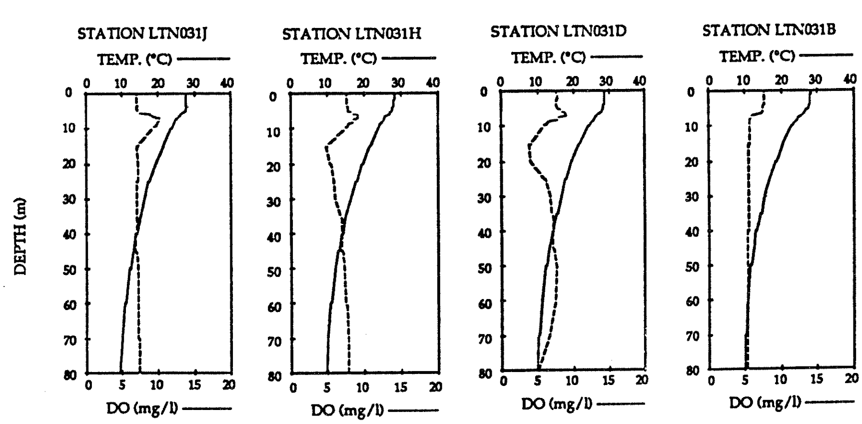
Ochromonas species, Anabaena species C, and Cryptomonas erosa. Anabaena species also dominated populations in samples from 1982. Although members of this genus are often prevalent in eutrophic lakes, overall levels of phytoplankton in Fontana Lake were low and not indicative of water quality problems.

The TSI was -4.0 in 1987, similar to a value obtained in 1981 (-3.7). Fontana Lake is oligotrophic, which is typical of large reservoirs in western North Carolina. At the time of assessment, no violations of state water quality standards were observed, and the reservoir fully supported designated uses.









LAKE CHEOAH

COUNTY:	Swain/Graham	BASIN:	Little Tennessee
SURFACE AREA:	256 hectares (632 acres)	USGS TOPO:	Tapoco, N.C.
CLASS:	C - TR	LAKE TYPE:	Reservoir

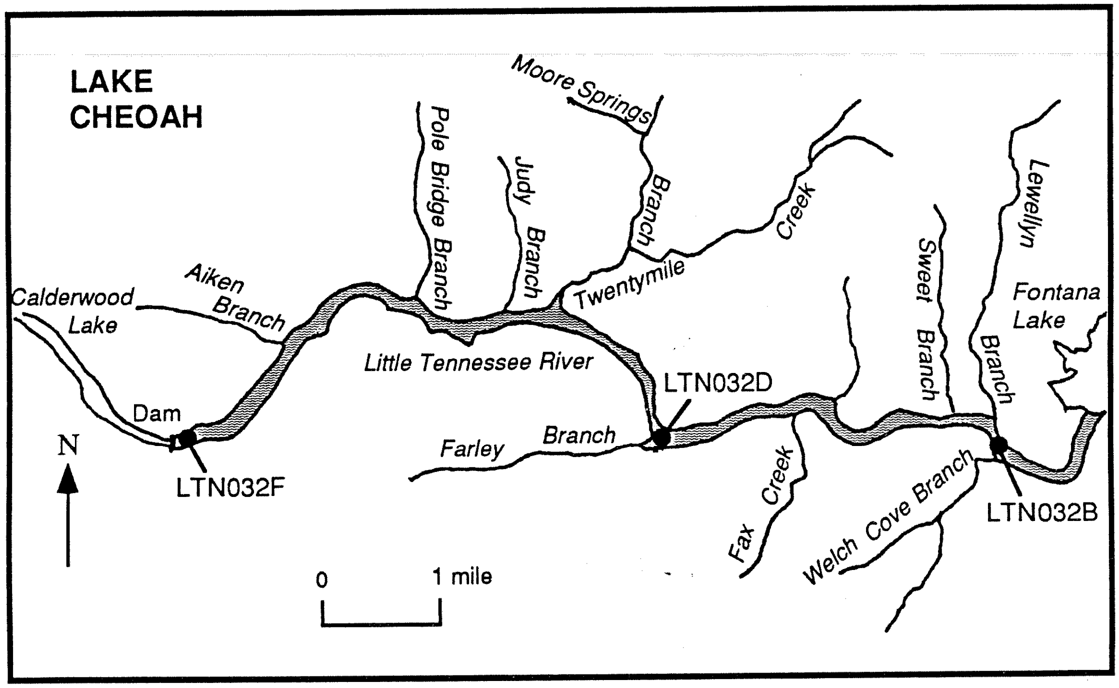
LATEST NCTSI:	- 7.4	TROPHIC STATE:	Oligotrophic
SAMPLING DATE:	July 27, 1988	ADDITIONAL COVERAGE:	None
SECCHI DEPTH:	5.3 m	CONDUCTIVITY:	18 - 20 µmhos/cm^2
TOTAL PHOSPHORUS:	0.01 mg/l	DISSOLVED OXYGEN:	9.3 - 9.8 mg/l
TOTAL ORGANIC NITROGEN:	0.06 mg/l	TEMPERATURE:	9.1 - 19.9 °C
CHLOROPHYLL-A:	1 µg/l	pH:	6.4 - 7.3 s.u.

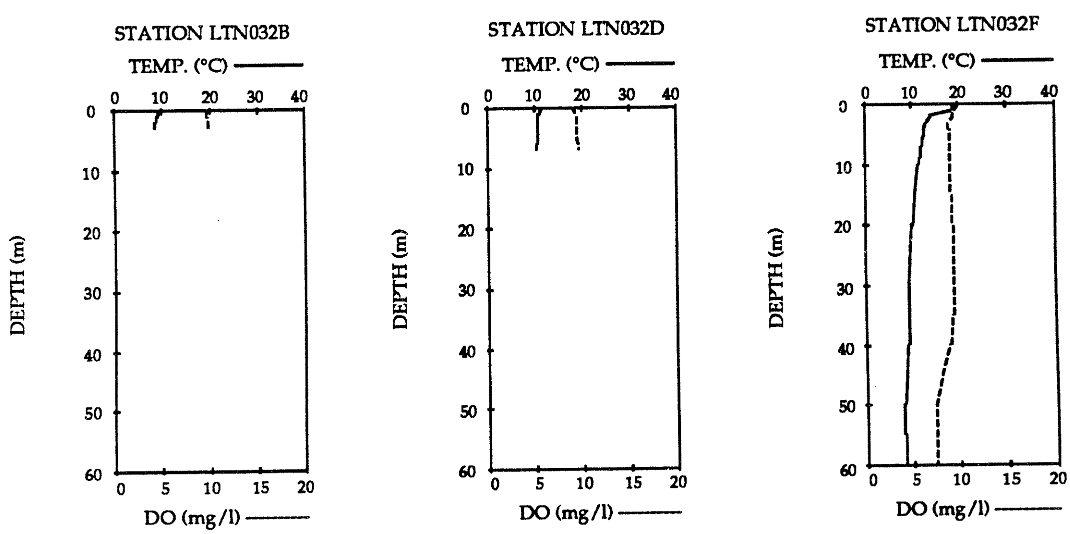
Tallassee Power Company (TAPOCO) owns Lake Cheoah, a narrow, deep impoundment of the Little Tennessee River near the North Carolina/Tennessee border. Inflow is dominated by the hypolimnetic discharge from Fontana Lake, which is located directly upstream. The headwaters of Lake Cheoah flow swiftly, and temperatures are generally low throughout the lake.

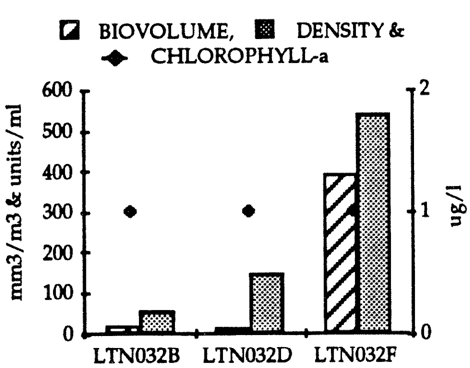
On July 27, 1988, the reservoir was stratified near the dam. Temperatures were low, especially upstream near the dam of Fontana Lake. Lake Cheoah is free of solids and has low nutrients.

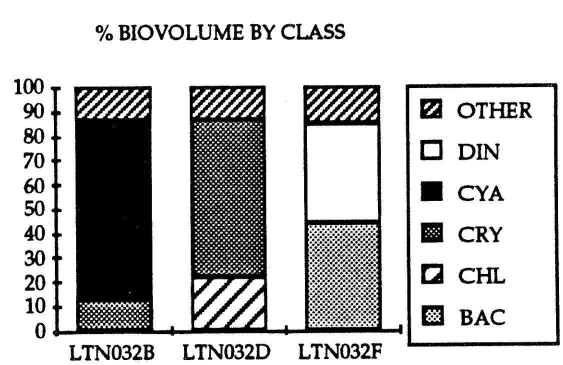
Chlorophyll-a values were also low at all stations. Algal biovolumes ranged from 14 to 391 mm^3/m^3 and densities ranged from 58 to 542 units/ml because species composition varied between stations. Lyngbya species B, a small, blue-green alga, made up 74% of the biovolume at LTN032B. Two ubiquitous cryptophytes, Chroomonas caudata and Chroomonas minuta, represented 66% of the biovolume at LTN032D. Bacillariophytes (Melosira italica) and dinoflagellates (Peridinium species) were codominant algal classes at LTN032F. The dominant species within these two classes are relatively large algae, explaining the higher biovolume at this station. An abundance of small species of cryptophytes, chrysophytes, and chlorophytes accounts for the higher density value at LTN032F.

Lake Cheoah had a TSI of -7.4 in 1988, which is the lowest TSI ever recorded in North Carolina by DEM. All uses were fully supported.

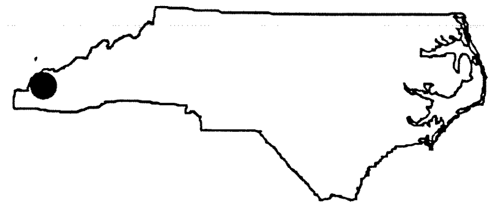

LAKE CHEOAH
Moore Springs
Pole Bridge Branch
Judy Branch
Branch
Creek
Twentymile
Lewellyn
Sweet Branch
Fontana Lake
Branch
Calderwood Lake
Aiken Branch
Little Tennessee River
LTN032D
Dam
N
Farley
Branch
Fax Creek
Welch Cove Branch
LTN032F
LTN032B
0
1 mile


STATION LTN032B
TEMP. (°C)
DEPTH (m)
DO (mg/l)
STATION LTN032D
TEMP. (°C)
DEPTH (m)
DO (mg/l)
STATION LTN032F
TEMP. (°C)
DEPTH (m)
DO (mg/l)


BIOVOLUME, DENSITY & CHLOROPHYLL-a
mm3/m3 & units/ml
ug/l
LTN032B
LTN032D
LTN032F


% BIOVOLUME BY CLASS
OTHER
DIN
CYA
CRY
CHL
BAC
LTN032B
LTN032D
LTN032F

SANTEETLAH LAKE



COUNTY:	Graham	BASIN:	Little Tennessee
SURFACE AREA:	1,153 hectares (2,850 acres)	USGS TOPO:	Tapoco, N.C.
USE:	B -TR	LAKE TYPE:	Reservoir

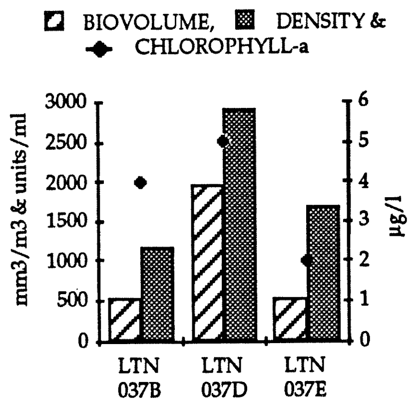
LATEST NCTSI:	-3.4	TROPHIC STATE:	Oligotrophic
SAMPLING DATE:	July 31, 1990	ADDITIONAL COVERAGE:	Fecal
SECCHI DEPTH:	3.1 m	CONDUCTIVITY:	20 - 24 µmhos/cm^2
TOTAL PHOSPHORUS:	0.01 mg/l	DISSOLVED OXYGEN:	7.7 - 8.1 mg/l
TOTAL ORGANIC NITROGEN:	0.25 mg/l	TEMPERATURE:	26.8 - 28.2 °C
CHLOROPHYLL-A:	4 µg/l	pH:	6.3 - 7.4 s.u.

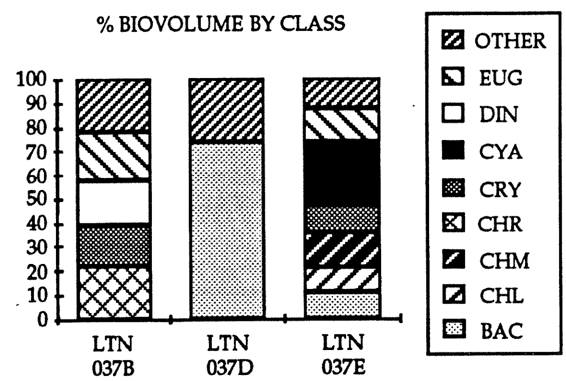
Santeetlah Lake is located on the Cheoah River in the mountains of southwestern North Carolina. The lake is owned by the Aluminum Company of America (ALCOA) and is used to generate hydroelectric power as well as for recreational purposes. Santeetlah is a deep lake with a maximum depth of 65 meters and a mean depth of 17 meters. The lake has a volume of 195 x 10^6 m^3 and a mean hydraulic retention time of 161 days. Major tributaries to Santeetlah Lake include the Cheoah River, Santeetlah River, and Snowbird Creek. The watershed is 450 km^2 of rugged, mountainous terrain, which is nearly all forested. Santeetlah Lake is designated B-Trout.

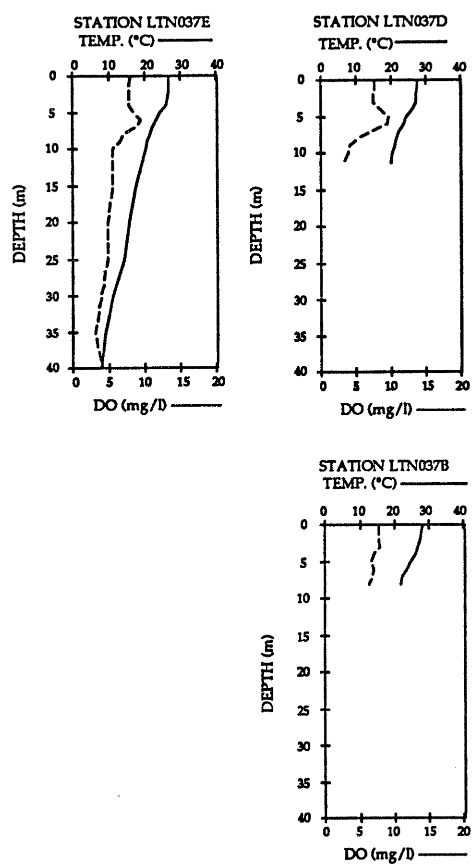
Santeetlah Lake was sampled on July 31, 1990. Physical measurements indicated stratification at all stations. Nutrient and chlorophyll-a levels were low throughout the lake. Fecal coliforms were not detected in surface water samples. Algal blooms have been documented in the West Buffalo Creek arm of the lake. Additional sampling in this area was conducted, but the cause of these blooms is unknown.

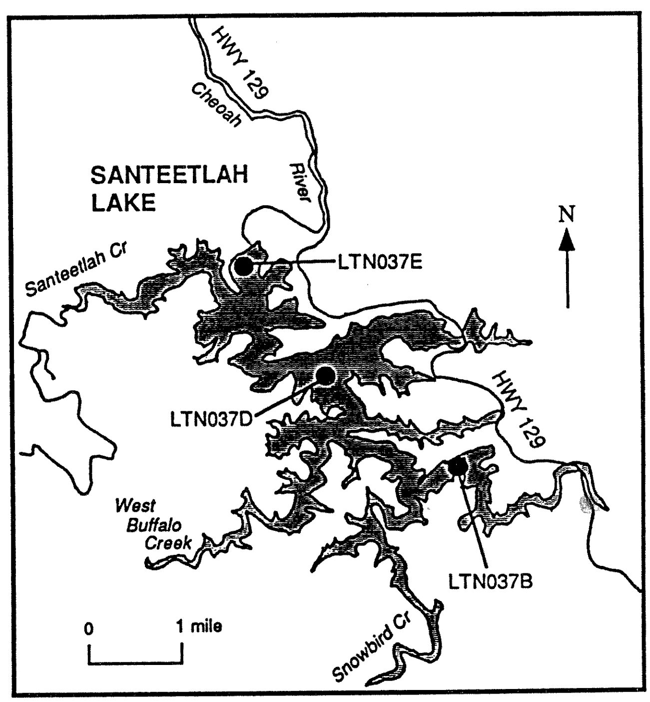
Populations of phytoplankton were small. The predominance of two species of diatoms accounts for the higher estimates of biovolume and density observed at LTN037D. Tabellaria fenestrata, a relatively large, colonial diatom, dominated the biovolume (74%), whereas Cyclotella species made up 36% of the algal density. Both species of diatoms are commonly found in oligotrophic, nutrient-poor waters (Wetzel, 1975). The other two stations had more diverse assemblages of phytoplankton with no class constituting more than 27% of the biovolume.

A TSI of -3.4 in 1990 indicated Santeetlah Lake is oligotrophic. This is consistent with previous results from the lake. Oligotrophic status is typical of large reservoirs in western North Carolina. At the time of assessment, no violations of state standards occurred, and the water quality of Santeetlah Lake supported designated uses.

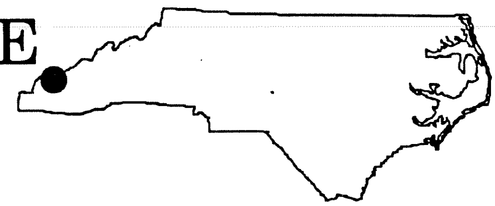








CALDERWOOD LAKE



COUNTY:	Swain/Graham	**BASIN:**	Little Tennessee
SURFACE AREA:	57 hectares (140 acres)	**USGS TOPO:**	Tapoco, N.C.
CLASS:	C - TR	**LAKE TYPE:**	Reservoir

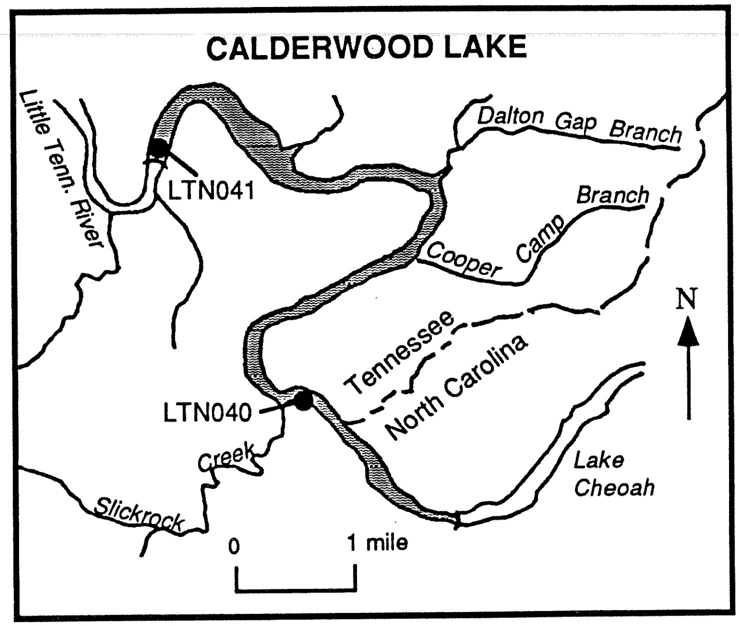
LATEST NCTSI:	- 7.3	**TROPHIC STATE:**	Oligotrophic
SAMPLING DATE:	July 27, 1988	**ADDITIONAL COVERAGE:**	None
SECCHI DEPTH:	5.75 m	**CONDUCTIVITY:**	18 - 21 µmhos/cm^2
TOTAL PHOSPHORUS:	0.01 mg/l	**DISSOLVED OXYGEN:**	8.8 - 9.0 mg/l
TOTAL ORGANIC NITROGEN:	0.055 mg/l	**TEMPERATURE:**	16.1 - 22.4 °C
CHLOROPHYLL-A:	1.5 µg/l	**pH:**	6.8 - 7.1 s.u.

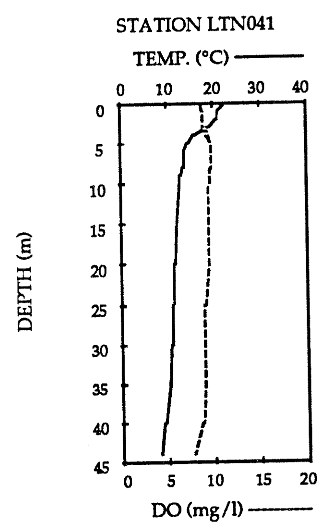
Calderwood Lake, completed in 1930 by the Aluminum Company of America (ALCOA) to produce hydroelectric power, is now owned by a subsidiary of ALCOA called the Tallassee Power Company (TAPOCO). It is located in the Great Smoky Mountains on the North Carolina/Tennessee border. The third of four lakes built by ALCOA on the Little Tennessee River, Calderwood Lake is a narrow, deeply channeled reservoir sur-rounded by two forested cliffs. The drainage area is 4,807 km^2, and the Little Tennessee River (Lake Cheoah discharge) is the major inflow.

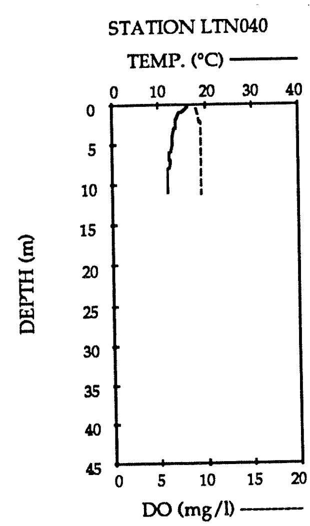
When Calderwood Lake was sampled on July 7, 1988, thermal stratification was apparent at the downstream station. The water was clear with low conductivity and neutral pH values. Nutrients in both the photic zone and the bottom were among the lowest recorded in North Carolina. Chlorophyll-a concentrations were similarly low. Secchi depth values were as high as any other lake sampled in 1988.

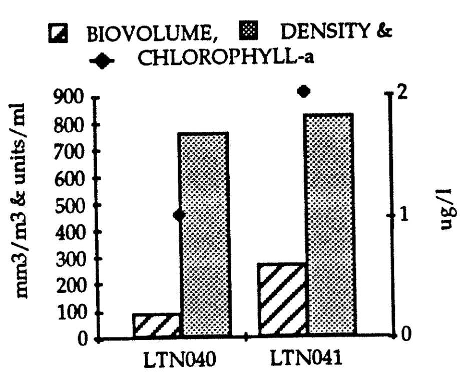
Consistent with an oligotrophic classification, phytoplanktonic biovolume and density were low in Calderwood Lake. A diverse assemblage of phytoplankton was present at LTN040. At LTN041, bacillariophytes (Rhisosolenia eriensis and Melosira longispina) composed 45% of the biovolume. Chrysophytes and cryptophytes each represented another 20% of the algal biovolume at this station.

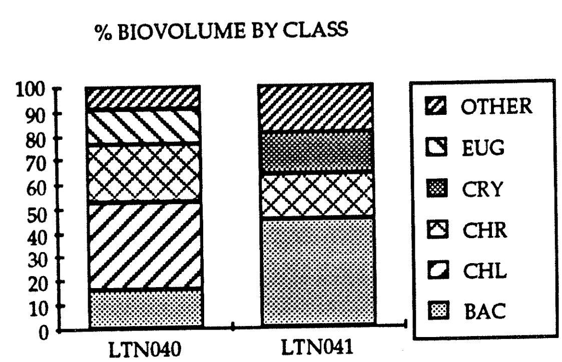
The TSI for Calderwood Lake was -7.3, the second lowest value recorded in North Carolina in 1988. Barring significant changes in the watershed or the quality of Lake Cheoah, Calderwood Lake should continue to exhibit good water quality with full support of designated uses.


CALDERWOOD LAKE
Little Tenn. River
LTN041
Dalton Gap Branch
Cooper Camp Branch
Tennessee
North Carolina
LTN040
Slickrock Creek
Lake Cheoah
N
0
1 mile


STATION LTN041
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0 5 10 15 20 25 30 35 40 45
0 5 10 15 20
DO (mg/l)


STATION LTN040
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0 5 10 15 20 25 30 35 40 45
0 5 10 15 20
DO (mg/l)


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/m3 & units/ml
900 800 700 600 500 400 300 200 100 0
ug/l
2 1 0
LTN040
LTN041


% BIOVOLUME BY CLASS
100 90 80 70 60 50 40 30 20 10 0
LTN040
LTN041
OTHER
EUG
CRY
CHR
CHL
BAC

LUMBER RIVER BASIN

DESCRIPTION OF REGION

The Lumber River Basin, including the Waccamaw River, encompasses 8,658 km^2 in the sandhills and inner coastal plain of North Carolina. The sandhills segment of the basin is confined to the upper Lumber River above US Highway 401. The river meanders southeastward after leaving the sandhills and eventually joins the Little Pee Dee River in South Carolina. The Waccamaw River lies exclusively in the outer coastal plain and drains the swampy areas of Brunswick and Columbus Counties. It also flows south into South Carolina.

Swiftly flowing streams with sandy substrate characterize the sandhills region, while slow-moving swampy streams characterize the coastal plain areas. There are two major population centers within the basin: Laurinburg and Lumberton. Forestry is the major economic activity within the basin.

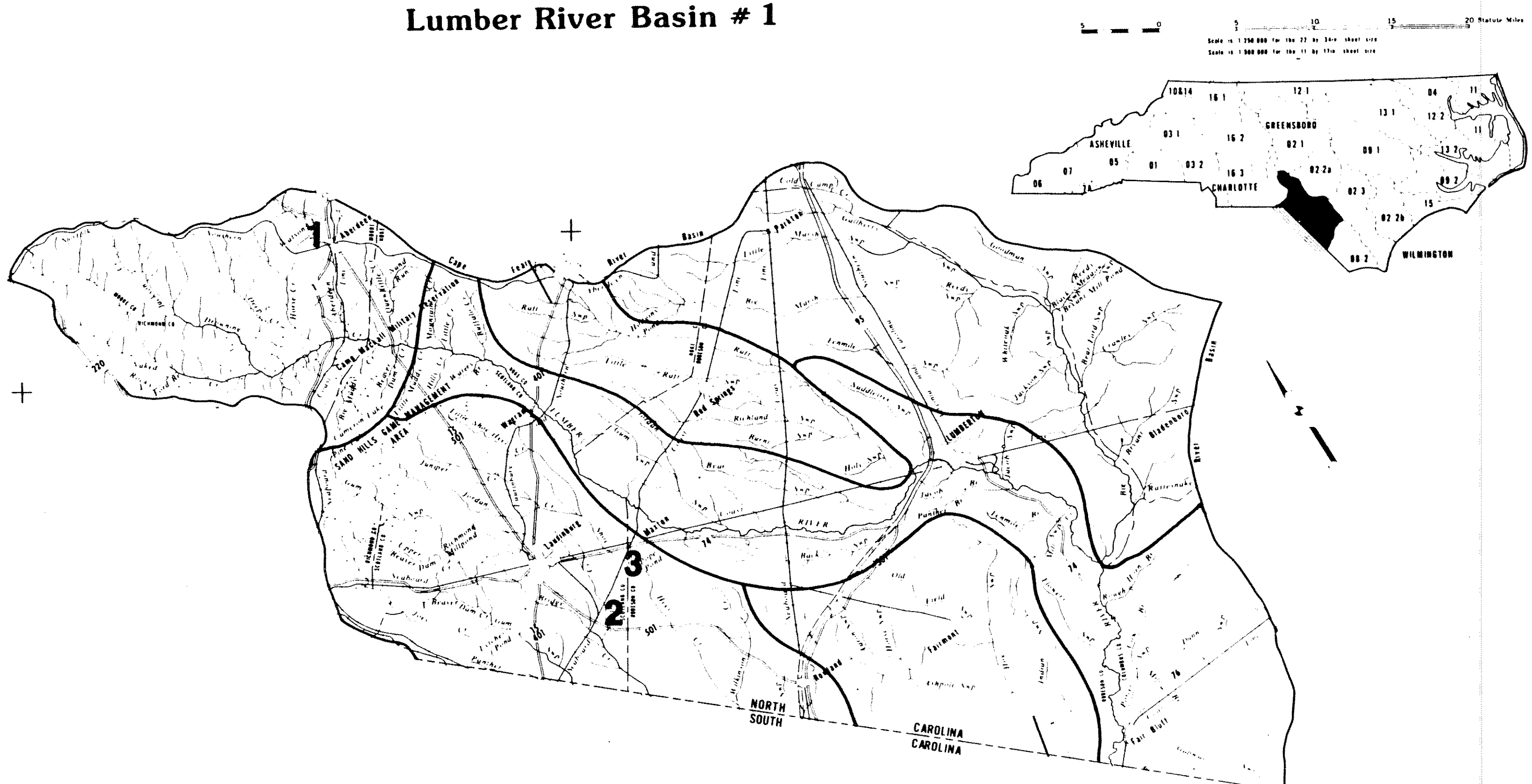
OVERVIEW OF WATER QUALITY

Although the Lumber River is a blackwater river, not all of the lakes in this basin are tannic. Much of the upper drainage area includes watersheds within the Sandhills Game Management Area and Camp MacKall Military Reservation. Large swamps cover much of the middle and lower basin, contributing water with typical swamp characteristics. Overall, water quality is good in the Lumber River Basin.

Pages Lake is located near an EPA Superfund site. Effect on the lake is under investigation. Two of the other four lakes included in this report are small, man-made impoundments located near the Town of Laurinburg. Both Maxton Pond and Johns Pond are eutrophic and suffer from elevated nutrient loading and infestations of aquatic macrophytes. Both drain into the Little Pee Dee River. In contrast, Lake Waccamaw is a natural bay lake with low to moderate levels of nutrients which supports several endangered species of fish and mollusks. Lake Tabor is a small recreational lake located in Tabor City.

Lumber #1

Lumber River Basin # 1



MAP #	LAKE
1	Pages Lake
2	Johns Pond
3	Maxton Pond

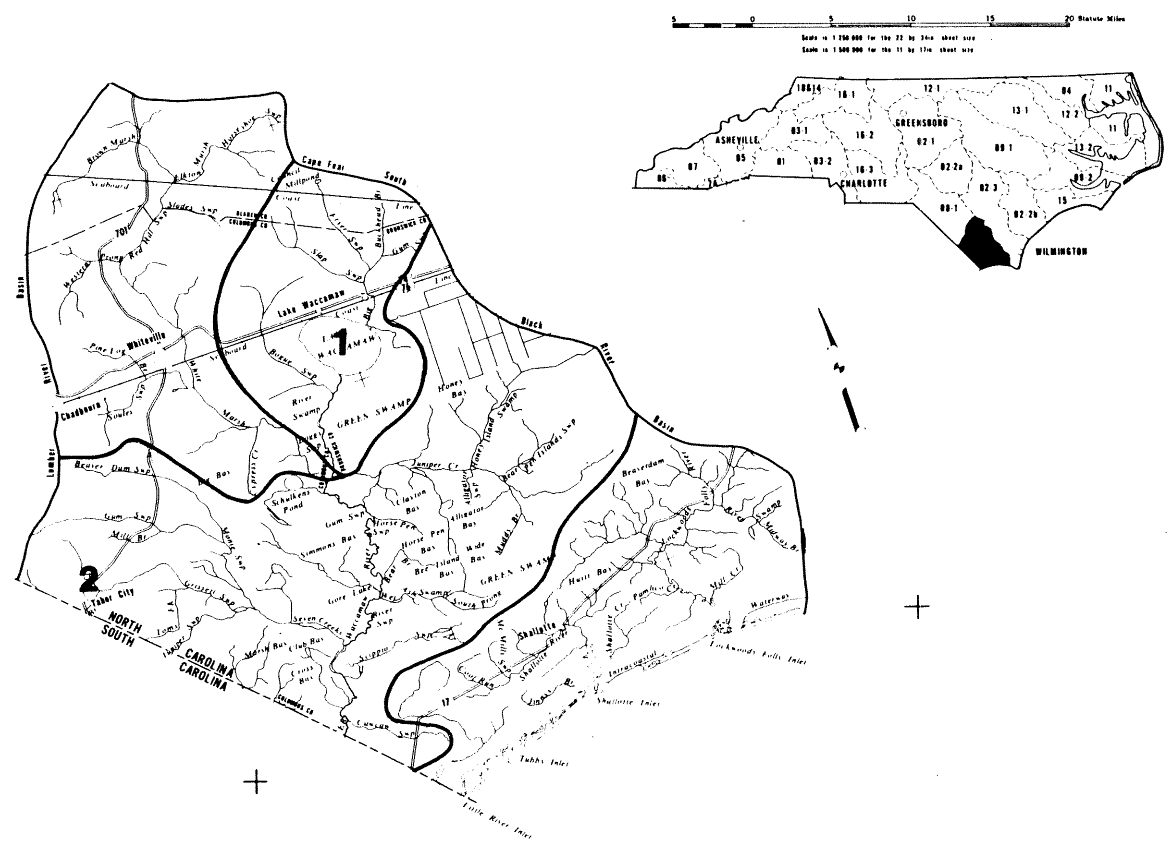
North Carolina Department of
Natural Resources and Community Development

Division of Enviromental Management

Adapted from U S G S (A M S) 1 250 000 U S Series

Lumber #2

Lumber River Basin #2

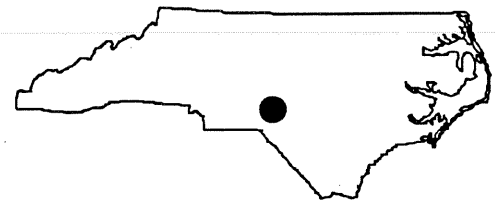


MAP #	LAKE
1	Lake Waccamaw
2	Lake Tabor

North Carolina Department of
Natural Resources and Community Development
Division of Enviromental Management

Adapted from U S G S (A M S) 1 250 000 U S Series

PAGES LAKE



COUNTY:	Moore	BASIN:	Lumber
SURFACE AREA:	16 hectares (40 acres)	USGS TOPO:	Southern Pines, N.C.
CLASS:	B	LAKE TYPE:	Reservoir

LATEST NCTSI:	0.5	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	August 10, 1988	ADDITIONAL COVERAGE:	Fecal
SECCHI DEPTH:	1.5 m	CONDUCTIVITY:	33 μmhos/cm^2
TOTAL PHOSPHORUS:	0.05 mg/l	DISSOLVED OXYGEN:	6.7 mg/l
TOTAL ORGANIC NITROGEN:	0.38 mg/l	TEMPERATURE:	30.9 ^{o}C
CHLOROPHYLL-A:	8 μg/l	pH:	6.4

Pages Lake is located on Aberdeen Creek within the Town of Aberdeen in Moore County. The town owns the impoundment which is the site of a city park. Swimming is allowed in this class B lake. The lake has a surface area of 16 hectares with a maximum depth of approximately four meters. The drainage area covers 36 km^2 and is characterized by forested, agricultural, and urban land uses.

One station in Pages Lake was sampled on August 10, 1988. Physical measurements indicated that the lake was only slightly stratified, as is typical of shallow lakes. Dissolved oxygen was nearly depleted near the lake bottom. Nitrogen levels were low to moderate, while total phosphorus was elevated.

Chlorophyll-a was lower than might be expected for the observed nutrient concentrations. This discrepancy between nutrient and chlorophyll-a levels was probably a result of extensive growths of milfoil, fragrant water lily, cow lily, and other vegetation. These rooted plants tend to reduce the availability of nutrients to phytoplankton, resulting in low chlorophyll-a concentrations.

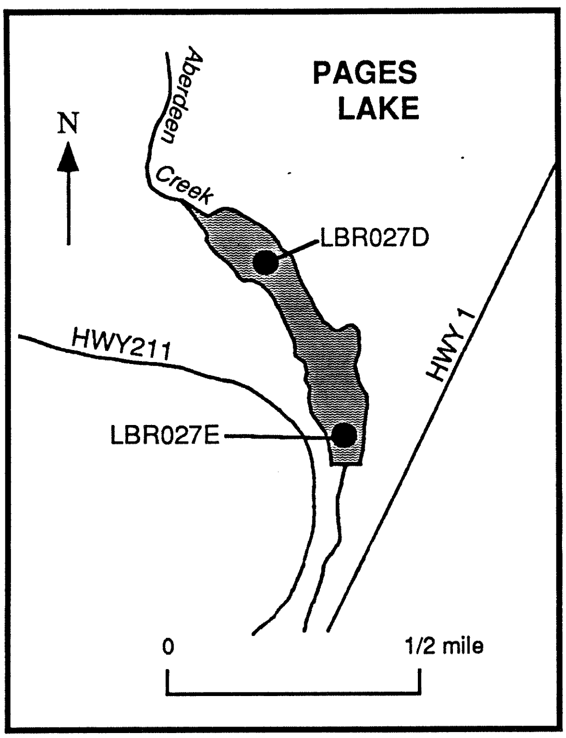
Relatively low algal biovolume and density were found in Pages Lake. Biovolume was dominated by algal classes consisting of pyrmnesiophytes, chlorophytes, bacillariophytes and cryptophytes. Chrysocromulina breviturrita, a pyrmnesiophyte usually found in eutrophic waters, represented 40% of the algal biovolume.

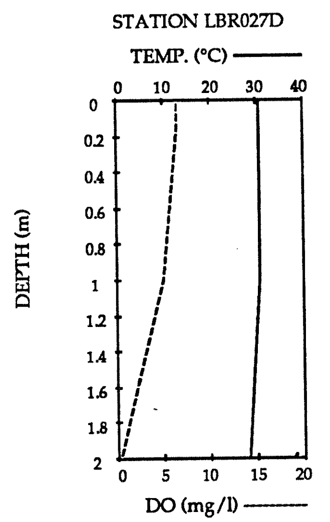
The TSI in1988 was calculated to be 0.5, indicative of mildly eutrophic conditions.

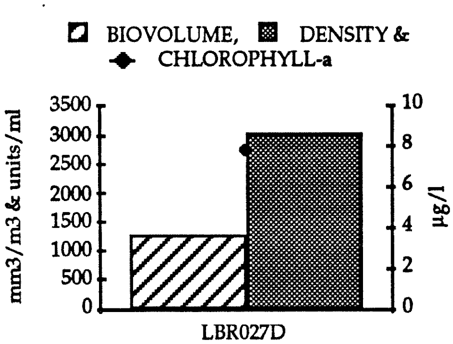
This is slightly higher than a mesotrophic TSI of -0.9 found in 1981. In 1987, DEM reported that the uses of the lake were impaired by sedimentation, weed infestations, and fluctuations of water level. Subsequently the Town removed vegetation from the public swimming area. Following the collection of new data in 1988, DEM determined that although siltation and lake productivity continue to be of concern, the public use of the lake has been fully restored by these efforts.

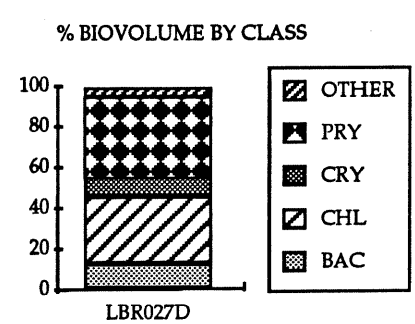
The Town of Aberdeen is the site of an EPA Superfund project. Several pesticide burial sites in the Pages Lake watershed are under investigation, including one site located near the western shore of the lake. The EPA study revealed many toxic compounds associated with the burial sites; however, only one was detected in Pages Lake. Water samples collected from one site in September 1988 contained low levels of the pesticide alpha-BHC. In a public statement dated June 9, 1989, EPA said that results from Pages Lake presented no significant public health risk.

During sampling in 1988, the pesticide 2,4-D was detected in a surface water sample at a concentration of 0.12 µg/l, far below the state standard of 100 µg/l for this compound. DEM will continue to screen for pesticides during future monitoring.

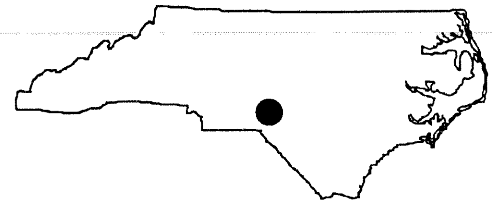








JOHNS POND



COUNTY:	Scotland	BASIN:	Lumber
SURFACE AREA:	51 hectares (126 acres)	USGS TOPO:	Johns, N.C.
CLASS:	C - SW	LAKE TYPE:	Millpond

LATEST NCTSI:	5.4	TROPHIC STATE:	Hypereutrophic
SAMPLING DATE:	July 13, 1988	ADDITIONAL COVERAGE:	None
SECCHI DEPTH:	1.1 m	CONDUCTIVITY:	70 μmhos/cm^2
TOTAL PHOSPHORUS:	0.18 mg/l	DISSOLVED OXYGEN:	6.1 mg/l
TOTAL ORGANIC NITROGEN:	0.78 mg/l	TEMPERATURE:	27.6 ^{o}C
CHLOROPHYLL-A:	80 μg/l	pH:	5.9 s.u.

Johns Pond is a shallow, private fishing pond located within the inner coastal plain of North Carolina. Leiths Creek, the only tributary, flows into a cypress swamp that forms the upper section of the pond. The drainage area for Johns Pond is 74 km^2, half of which is agricultural. Forested lands, urban areas, and water/wetlands make up the remaining land uses. The waters of the lake are currently classified C-Swamp and are used for recreational purposes.

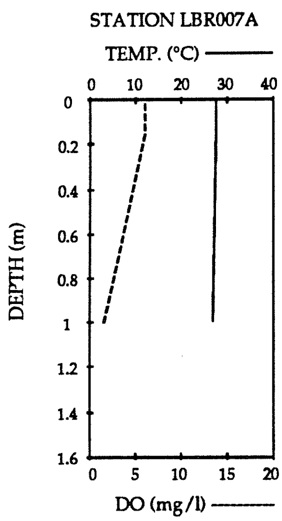
Johns Pond was sampled on July 13, 1988. Because the lake is small, Johns Pond was sampled at only one station located at the center of the pond. Field observations noted dense growths of macrophytes along most of the shoreline and a strong hydrogen sulfide odor in bottom waters. Johns Pond has luxurious growths of a duckweed, Spirodela sp.

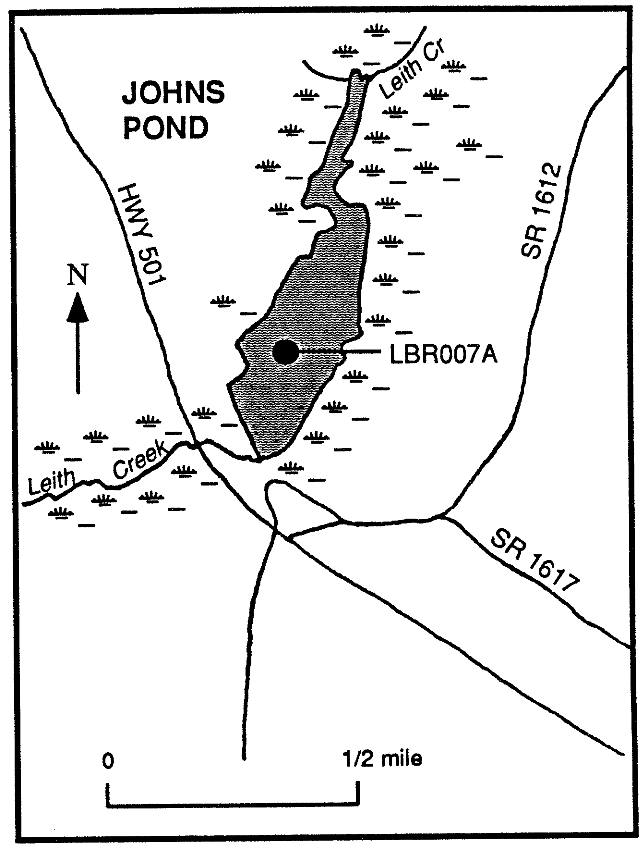
Nutrients in the photic zone were elevated with a total organic nitrogen concentration of 0.78 mg/l and a total phosphorus concentration of 0.18 mg/l. The water column was stratified with a 4.6 mg/l difference in dissolved oxygen concentration between the pond's surface and bottom. Stratification may be enhanced by macrophytes reducing circulation and light penetration to the bottom of the pond. The chlorophyll-a concentration of 80 µg/l exceeded the North Carolina standard for this parameter. Chlorophyll-a concentrations have been higher in previous years.

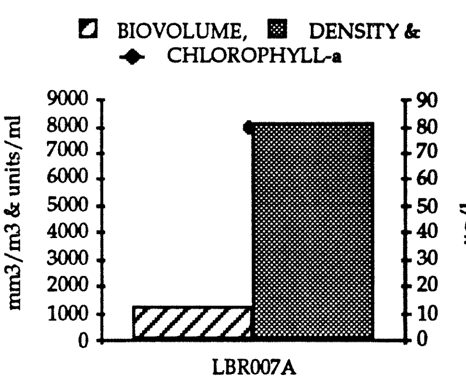
Phytoplanktonic biovolume from Johns Pond was dominated by chlorophytes, euglenophytes (Trachelomonas spp.), and chrysophytes (Mallamonas caudata). Density estimates were slightly elevated (8,152 units/ml) because of the abundance of chlorophytes and blue-green algae (Oscillatoria geminata) which represented 66% and 21% of the density, respectively. O. geminata, a small filamentous blue-green, is commonly found in enriched waters, often tinting the water green.

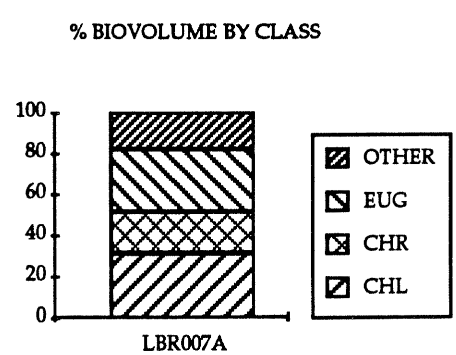
The TSI was 5.4 in 1988 which is lower than previous values. Johns Pond is consistently ranked as one of the most hypereutrophic lakes in North Carolina.

Water quality in Johns Pond partially supports its designated use. This hypereutrophic body of water is classified for fish and wildlife propagation and secondary recreation, yet these uses are only partially attained as a result of the extensive macrophytic growth, algal blooms, and sedimentation. At the present time, no control efforts have been initiated.

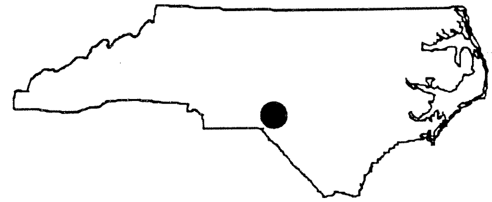








MAXTON POND



COUNTY:	Robeson	BASIN:	Lumber
SURFACE AREA:	28 hectares (70 acres)	USGS TOPO:	Maxton, N.C.
CLASS:	C - SW	LAKE TYPE:	Millpond

LATEST NCTSI:	1.2	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	September 10, 1987	ADDITIONAL COVERAGE:	None
SECCHI DEPTH:	0.8 m	CONDUCTIVITY:	50 µmhos/cm^2
TOTAL PHOSPHORUS:	0.14 mg/l	DISSOLVED OXYGEN:	7.6 mg/l
TOTAL ORGANIC NITROGEN:	0.56 mg/l	TEMPERATURE:	26.0^{o}C
CHLOROPHYLL-A:	1 µg/l	pH:	4.0 s.u.

Maxton Pond (also called Hayes Pond) is a privately owned, yet publicly accessible impoundment located just outside the town of Maxton in Robeson County. The impoundment dates back to before the turn of the century and had a grist mill and a corn mill located on its dam. It is a small, shallow pond fed by Big Shoe Heel Creek which flows through a cypress swamp into the upper end of the impoundment. The pond has a drainage area of 230 km^2 of which approximately 50% is agricultural. The remainder is either forested, urban, or water/wetland. Maxton Pond is used for recreational purposes.

Maxton Pond was sampled on September 10, 1987. Field observations noted dense growths of emergent, floating, and submerged macrophytes. Because it is small, only one station was sampled near the center of the impoundment. Though the pond is only 1.2 meters deep at the center, physical measurements indicated that the water column was weakly stratified with dissolved oxygen, temperature and pH decreasing with depth. Such stratification can occur when thick surface growth of macrophytes inhibits normal water circulation and prevents light penetration into the water column. Nutrient concentrations from the photic zone water samples were elevated and representative of a productive lake system. At the bottom of the water column, nutrient concentrations were similar to photic zone concentrations as might be expected in this weakly stratified lake.

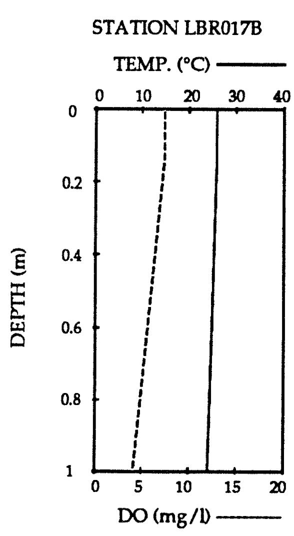
Aquatic weed sampling revealed a variety of surface and emergent macrophytes at Maxton Pond with heavy growths of duckweed being observed. The duckweeds present include Spirodella oligorhiza and Wolffia paupulifera. Other species that were found included Myriophyllum heterophyllum (watermilfoil), Nuphar luteum (cow-lily), and Polygonum densiflorum (smartweed).

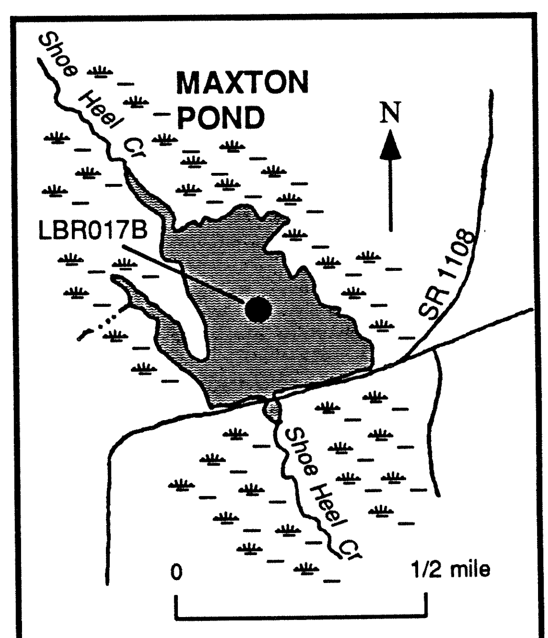
Historical information shows that populations of phytoplankton were dominated by diatoms in 1983. Sixty-two percent of the biovolume (16,130 mm^3/m^3) and 80% of the density (5,590 units/ml) were diatoms. Diatoms were again dominant in 1987 and constituted 82% of the biovolume and 53% of the density. Estimates of biovolume and density were 545 mm^3/m^3 and 382 units/ml. These low levels would be consistent with a system that had experienced a complete washout of any established populations or a system where primary productivity is dominated by macrophytes. Two species, Tabellaria fenestrata and T. flocculosa made up 67% of the total biovolume.

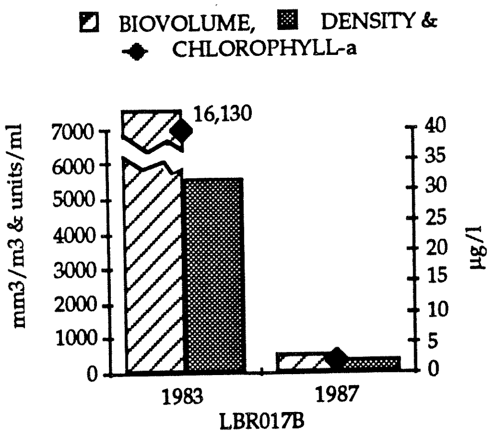
Algal populations were entirely different in abundance in 1983 and 1987 samples, as were nutrient concentrations. Excessively high nitrogen and phosphorus were present in the 1983 samples, especially in the organic fraction. Elevated chlorophyll-a concentrations (40 µg/l) and bloom levels (16,130 mm^3/m^3) of phytoplankton were also present in 1983. However, low concentrations of phytoplankton and chlorophyll-a were measured in 1987 in the presence of adequate nutrient, temperature, and light regimes.

The TSI value was 1.2 in 1987, which is indicative of the productive conditions that are typical of aging millponds. The TSI in 1987 was much lower than in 1983 (8.9). Maxton Pond was classified hypereutrophic in the 1986-1987 305b Report (NRCD 1988b) as a result of the high TSI in 1983. The differences in TSI values and the abundance of algal populations between these two sampling observations were probably a result of changes that occurred in the lake subsequent to its drawdown in late 1983. Excessive macrophytic growth in the early 1980's prompted the draining of Maxton Pond in an attempt to kill some of the weeds. The lack of monitoring between 1983 and 1987 has precluded evaluation of the effectiveness of this control effort.

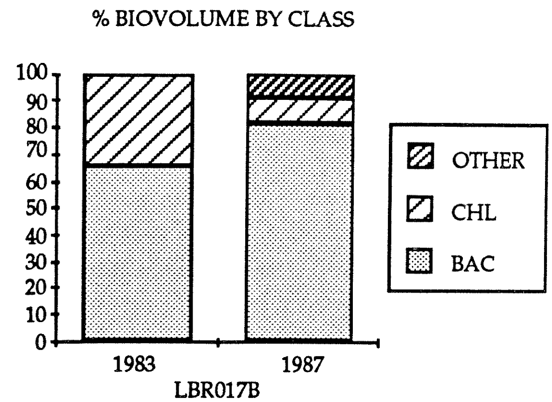
At the time of assessment, no violations of state water quality standards were observed at Maxton Pond and the lake fully supported designated uses. The extensive macrophytic growth observed indicates that the potential for future problems still exists in this pond. Personal communication with the present owners of the pond in October, 1988 revealed that Maxton Pond was drained for several months during the summer of 1988 to reduce weeds and improve recreational conditions at the lake. Further sampling is warranted at Maxton Pond to monitor water quality and weed conditions.





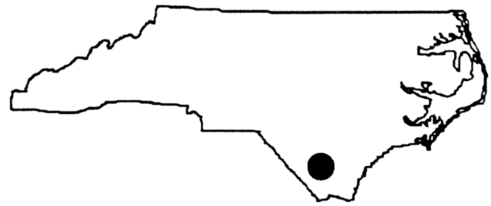


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
16,130
mm3/m3 & units/ml
µg/l
7000
6000
5000
4000
3000
2000
1000
0
40
35
30
25
20
15
10
5
0
1983
1987
LBR017B



% BIOVOLUME BY CLASS
100
90
80
70
60
50
40
30
20
10
0
1983
1987
LBR017B
OTHER
CHL
BAC

LAKE WACCAMAW



COUNTY:	Columbus	BASIN:	Lumber
SURFACE AREA: 3,622 hectares (8,950 acres)		USGS TOPO:	Whiteville, N.C.
CLASS:	B-SW	LAKE TYPE:	Natural

LATEST NCTSI:	- 2.8	TROPHIC STATE:	Oligotrophic
SAMPLING DATE:	July 23, 1990	ADDITIONAL COVERAGE:	Fecals
SECCHI DEPTH:	1.7 m	CONDUCTIVITY:	76- 84 µmhos/cm^2
TOTAL PHOSPHORUS:	0.01 mg/l	DISSOLVED OXYGEN:	7.2 - 7.4 mg/l
TOTAL ORGANIC NITROGEN:	0.36mg/l	TEMPERATURE:	29.8 - 30.0 ^oC
CHLOROPHYLL-A:	2 µg/l	pH:	7.2-7.4 s.u.

Lake Waccamaw is located in the coastal plain of North Carolina and is the largest natural lake in the southeastern portion of the state. Lake Waccamaw is owned by the State of North Carolina and is associated with an adjacent state park.

The physical characteristics of Lake Waccamaw are typical of Carolina Bay Lakes. It is shallow with a maximum depth of 3.3 meters, a mean depth of 1.5 meters and a volume of 54.3 x 10^6 m^3. The lake has two canals adjacent to the northwestern and western shores of the lake. The exact origins of the canals are unknown, though it is thought that the canals may have been dredged to provide fill material for the road that runs along the shore of the lake. The land surrounding the lake is generally flat with land use consisting primarily of wetlands and forest with some agriculture. The lake is classified B-Swamp and is used for recreational purposes.

Lake Waccamaw was sampled on July 23, 1990. Physical measurements indicated that the waters of the lake were mixed with uniform dissolved oxygen and temperature throughout the water column. The shallow, clear water facilitates light penetration to the bottom throughout much of the lake. Nutrients were relatively constant among the sampling stations and were present in low to moderate levels.

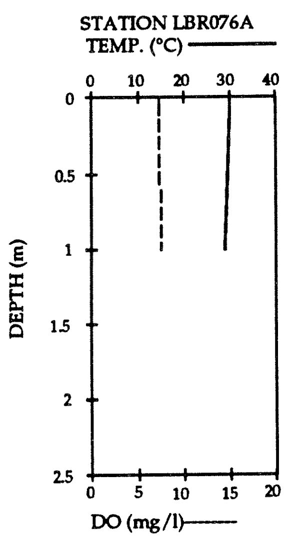
Water quality analysis on the canals surrounding Lake Waccamaw have shown that they are impacted by frequent breaks and leaks in adjacent sewer lines. These canals have experienced much higher nutrient concentrations, phytoplanktonic populations, and aquatic weed growth than the lake.

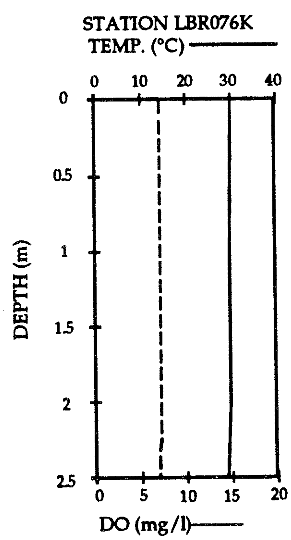
A visual survey of the emergent aquatic vegetation within the lake and the canals was completed in 1984. Smartweed (Polygonum hydropiperoides), waterfern (Azolla caroliniana), and duckweed (Spirodela oligorhiza) were present in both of the canals, but the canal at the northern end of the lake experienced the greatest growth. Four species of emergent and one submersed species of aquatic plants were found extensively in the littoral zone of the lake. Maidencane (Panicum hemitomon) was found 20 to 50 meters from shore for over half of the circumference of the lake. One large patch extended approximately one half mile from shore in the southwest corner. In many instances, the weed growth extended beyond the piers located at the edge of the lake.

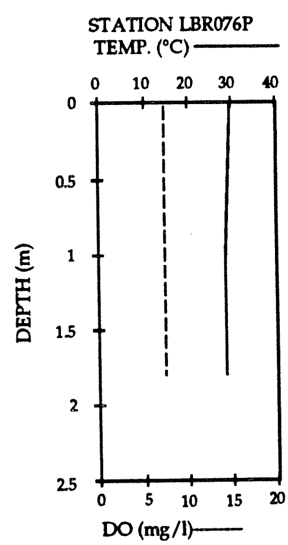
Emergent vegetation on the northeast bank was dominated by spatterdock (Nuphar luteum sagittifolium) and American lotus (Nelumbo pentapentala). In most cases these two species were not intermixed. They grew either separately or were mixed with water-pennywort (Hydrocotyle sp.) from Weaver's Landing to the east end of Highway 214 , extending 20 to 40 meters from shore.

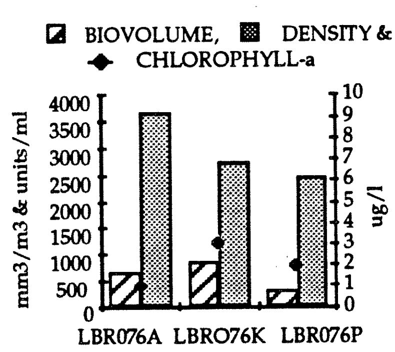
Moderately low algal biovolume and densities were found in Lake Waccamaw. Chlorophyll-a concentrations ranging from 1 to 3 µg/l further supported its oligotrophic status. The dominant algal classes were represented by diatoms, green algae, and blue-green algae. Lyngbya subtilis, a small filamentous blue-green alga which has been found in Lake Waccamaw in previous years comprised the majority of the blue-green algal density in Lake Waccamaw.

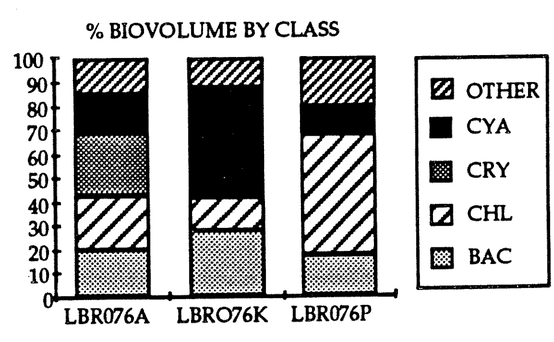
The TSI value in 1990 was -2.8 which is the lowest ever recorded for the lake. At the time of assessment no violations of state water quality standards were observed and water quality in the lake fully supported designated uses.

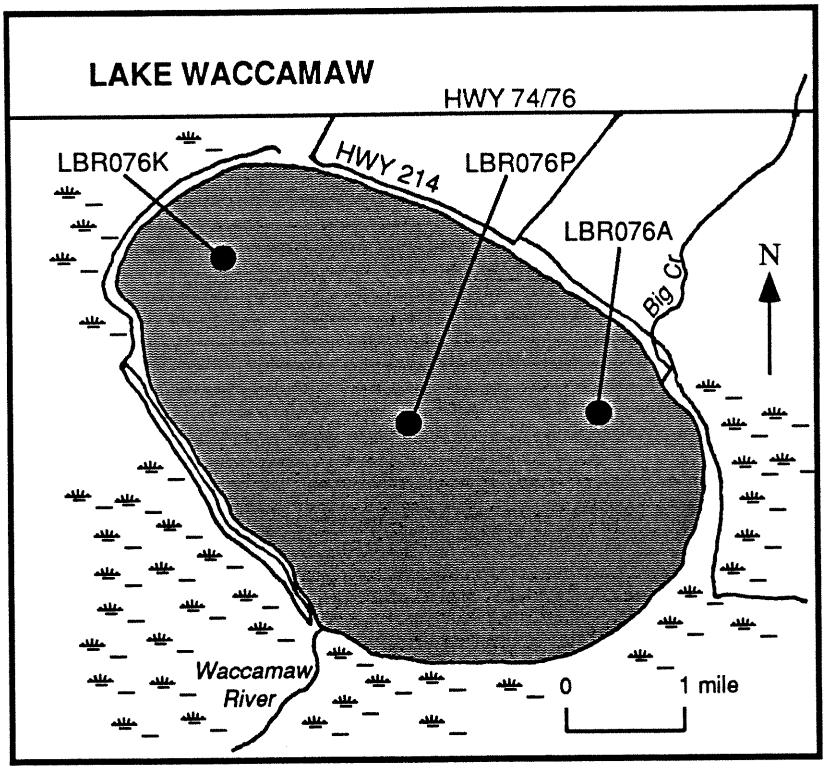




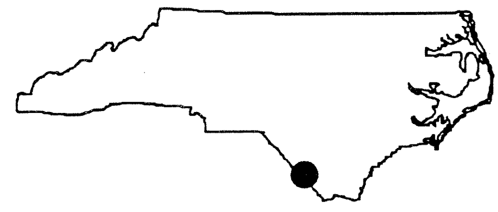







LAKE WACCAMAW
HWY 74/76
HWY 214
LBR076K
LBR076P
LBR076A
Big Cr
N
Waccamaw
River
0
1 mile

LAKE TABOR



COUNTY:	Columbus	BASIN:	Lumber
SURFACE AREA:	28 hectares (70 acres)	USGS TOPO:	Tabor City, N.C.
CLASS:	B - SW	LAKE TYPE:	Reservoir

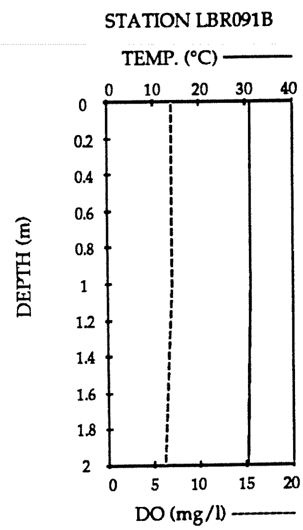
LATEST NCTSI:	- 0.9	TROPHIC STATE:	Mesotrophic
SAMPLING DATE:	July 20, 1988	ADDITIONAL COVERAGE:	Fecal
SECCHI DEPTH:	2.0 m	CONDUCTIVITY:	107 - 112 µmhos/cm^2
TOTAL PHOSPHORUS:	0.03 mg/l	DISSOLVED OXYGEN:	7.1 - 7.2 mg/l
TOTAL ORGANIC NITROGEN:	0.33 mg/l	TEMPERATURE:	31 ^oC
CHLOROPHYLL-A:	5.5 µg/l	pH:	7.6 s.u.

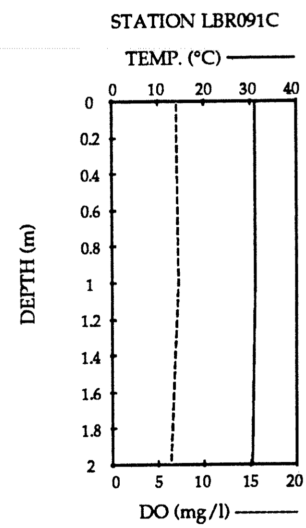
Tabor City owns a small recreational lake named Lake Tabor. Located near the border of South Carolina, Lake Tabor is used for public swimming and fishing. Approximately half of the flat coastal land in the watershed is forested, although there is also some residential and agricultural land use. Grisset Swamp is the only tributary to the lake.

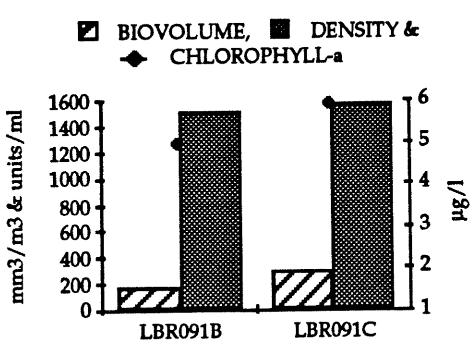
Two stations in Lake Tabor were sampled on July 20, 1988. The lake was clear and no water quality problems were found. Fecal coliform bacteria were not detected. Chlorophyll-a concentrations were low despite moderate nitrogen and phosphorus levels.

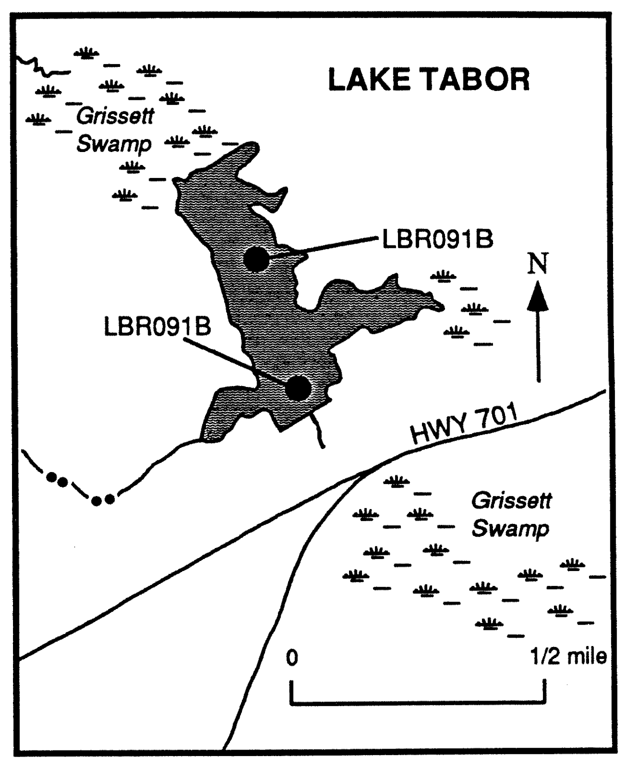
Lake Tabor contained relatively low numbers of algae. Typical algal classes including euglenophytes, cryptophytes and chlorophytes were dominant in both samples. The lowermost station (LBR091C) also contained 20% dinoflagellates by biovolume due to the presence of Ceratium hirundinella, a common phytoplanktor of lakes and ponds.

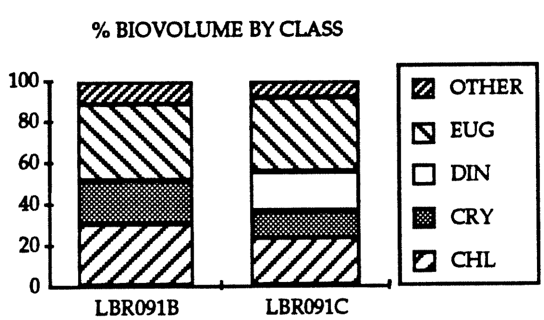
Lake Tabor was classified mesotrophic with a TSI of -0.9. For a small impoundment in the coastal region of the state, this indicated good water quality. The lake was also sampled in 1981 and was classified eutrophic with a TSI of 1.9. Organic nitrogen and chlorophyll-a were higher in 1981, accounting for this variability. All uses were supported at the time of this assessment.


STATION LBR091B
TEMP. (°C)
DEPTH (m)
DO (mg/l)


STATION LBR091C
TEMP. (°C)
DEPTH (m)
DO (mg/l)


BIOVOLUME, DENSITY & CHLOROPHYLL-a
mm3/m3 & units/ml
µg/l
LBR091B
LBR091C


LAKE TABOR
Grissett Swamp
LBR091B
LBR091B
N
HWY 701
Grissett Swamp
0
1/2 mile


% BIOVOLUME BY CLASS
LBR091B
LBR091C
OTHER
EUG
DIN
CRY
CHL

NEUSE RIVER BASIN

DESCRIPTION OF REGION

The Neuse River Basin covers 16,000 km^2 in the lower piedmont and coastal plain of North Carolina. It is the third largest basin in the state. The upper boundary of the basin begins northeast of Durham and drains the region that includes the tributaries of Falls of the Neuse Reservoir. The basin follows the Neuse River from Raleigh to Kinston and includes the tributaries to the Neuse in this region. Below Kinston, the Neuse River widens and becomes estuarine. The basin continues to the coast and includes portions of Pamlico and Carteret Counties.

The upper portion of the basin includes the Eno, Flat, and Little Rivers which flow into Falls of the Neuse Reservoir. Urban areas in this section of the basin include the town of Hillsborough, and northern and eastern parts of Durham. The water quality of Falls of the Neuse Reservoir is affected by both point source discharges and runoff from urban and agricultural areas. In particular, municipal discharges have degraded several of the tributaries feeding the upper reaches of the reservoir. In addition, the high erosion rates and the high application rates for fertilizers and pesticides experienced by this region have made sedimentation and nonpoint source pollution major water quality concerns (NRCD 1985).

The dam at Falls of the Neuse Reservoir divides the lower piedmont and inner coastal plain zones of the basin. The inner coastal plain includes large segments of the Neuse River and its tributaries: Little River, Swift Creek, and Contentnea Creek. Major urban areas include Raleigh, Smithfield, Wilson, Goldsboro, and Kinston. Approximately one-third of the land in the inner coastal plain portion of the Neuse Basin is used for agricultural purposes.

As in the piedmont portion of the Neuse River Basin, the inner coastal plain is also experiencing water quality problems related to nonpoint source pollution. For example, the Raleigh area is undergoing rapid population growth. As a result, runoff from urban areas and construction sites has caused degradation of water quality in this region. Agricultural development is also widespread in the inner coastal plain, and erosion and runoff of fertilizers and pesticides from farmlands are contributing to water quality problems.

The outer coastal plain zone of the Neuse Basin includes the lower freshwater and estuarine portion of the Neuse River. Major tributaries in this area are the Trent River and Swift Creek. Cities and towns in this area include New Bern, Trenton, Bayboro and Vanceboro. The majority of the land in this section is forest and wetlands.

OVERVIEW OF WATER QUALITY

In December 1983, the North Carolina Environmental Management Commission (EMC) designated the portion of the Neuse River basin upstream of the Falls of the Neuse Reservoir dam as Nutrient Sensitive Waters (NSW). Severe nutrient enrichment observed in the headwaters of the reservoir appeared to be aggravated by ongoing, rapid urban growth in the watershed. The lower section of the Neuse Basin was also reclassified as Nutrient Sensitive Waters by the EMC in January of 1988. Nuisance algal growth and sporadic blooms of undesirable blue-green algae (NRCD 1985, NRCD 1986a) had increased concerns over the water quality in the lower Neuse River Basin.

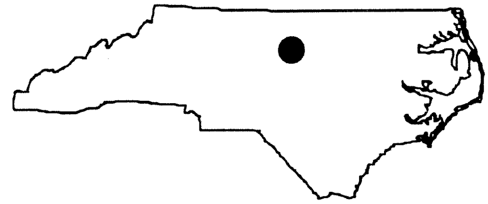
Management strategies were implemented to reduce inputs of nutrients to the Neuse River basin. More stringent limitations were placed on wastewater treatment plants. Existing plants that discharge over 50,000 gallons per day cannot exceed a total phosphorus (TP) effluent limit of 2 mg/l by May 1, 1993. All expanding or new facilities regardless of size are also required to meet the new TP discharge limit. Furthermore, the Nutrient Sensitive Waters classification authorizes the EMC to enact additional controls if they are necessary to prevent excess nutrients from polluting surface waters. Funds to reduce nonpoint source inputs of sediment and nutrients are available through the Agricultural Cost Share Program.

The lakes included in this report are in the lower piedmont or upper coastal plain and face the problems associated with this region. The majority of these lakes are very productive and can be classified as eutrophic or hypereutrophic. An example is Falls of the Neuse Reservoir. Ellerbe Creek and Knap of Reeds Creek, which feed the upper section of the reservoir, are severely impacted by wastewater treatment plant effluents and are "poor" according to biological ratings (NRCD 1988c). According to chemical criteria, Ellerbe Creek is rated "poor" and Knap of Reeds Creek is rated "fair" (NRCD 1985). The upper section of Falls of the Neuse Reservoir is hypereutrophic and has experienced several algal blooms and fish kills.

Sedimentation from agricultural and construction activities and runoff from urban areas also cause water quality degradation in this basin. Problems associated with these processes have been observed in Falls of the Neuse Reservoir, Big Lake, Bass Lake, Lake Wheeler, Lake Benson, and Lake Raleigh. As population in the area continues to grow and construction and development increase, the stresses to aquatic systems will also increase.

Infestation by the non-native aquatic macrophyte hydrilla is another common problem found in the lakes of this region. Lake Johnson, Lake Raleigh, Lake Benson, Lake Wheeler, and Big Lake have all been classified not supporting or partially supporting because hydrilla has displaced native vegetation and interferes with public uses (NRCD 1988b). Control efforts have been initiated in both Lake Wheeler and Big Lake, but it will be some time before the effectiveness of these measures can be determined.

LAKE ORANGE



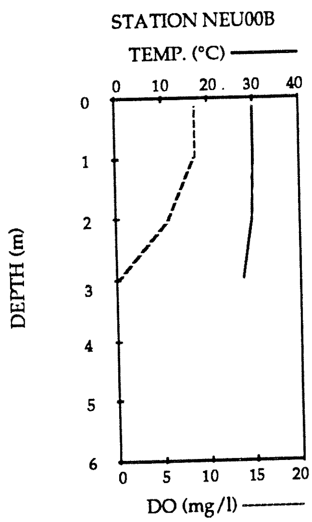
COUNTY:	Orange	**BASIN:**	Neuse
SURFACE AREA:	63 hectares (155 acres)	**USGS TOPO:**	Cedar Grove, N.C.
CLASS:	WS NSW	**LAKE TYPE:**	Reservoir

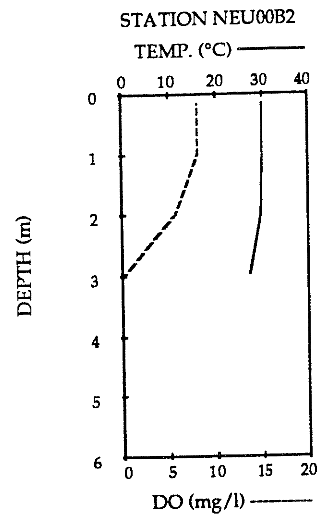
LATEST NCTSI:	0.0	**TROPHIC STATE:**	Eutrophic
SAMPLING DATE:	August 10, 1988	**ADDITIONAL COVERAGE:**	Water Supply Parameters
SECCHI DEPTH:	2.2 m	**CONDUCTIVITY:**	75 - 77 µmhos/cm^2
TOTAL PHOSPHORUS:	0.05 mg/l	**DISSOLVED OXYGEN:**	7.9 - 8.7 mg/l
TOTAL ORGANIC NITROGEN:	0.33 mg/l	**TEMPERATURE:**	30.1 - 30.3 °C
CHLOROPHYLL-A:	10 µg/l	**pH:**	8.9 - 9.1 s.u.

Lake Orange is a water supply for the City of Hillsborough. Maximum depth is eight meters. Major tributaries to Lake Orange include the East and West Fork of the Eno River. Sampled on August 10, 1988, Lake Orange was stratified with nearly anoxic conditions at the bottom of the water column. The lake was one and one half meters below normal at this time. Secchi readings were greater than two meters, reflecting good clarity in the lake. Basic pH readings were probably indicative of photosynthetic activity. Nutrients and chlorophyll-a concentrations were moderate.

Moderately low algal biovolume and density estimates along with moderate chlorophyll-a concentrations were found in Lake Orange. Dominant algal classes included chlorophytes, cyanophytes and cryptophytes. Visible flecks observed in the water column may have been caused by the filamentous blue-green alga, Oscillatoria nigra, which commonly occurs in lakes and ponds. This species represented as much as 41% of the biovolume near the dam where flecks were the most concentrated.

Lake Orange is a borderline mesotrophic-eutrophic lake. All designated uses were fully supported at the time of this sampling.


STATION NEU00B
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0 1 2 3 4 5 6
0 5 10 15 20
DO (mg/l)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TEMP. (°C)
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DEPTH (m)
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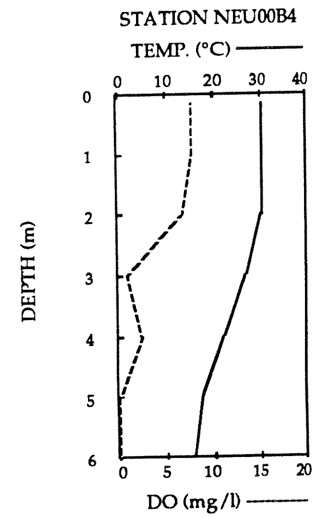
0 5 10 15 20
DO (mg/l)


STATION NEU00B4
TEMP. (°C)
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DEPTH (m)
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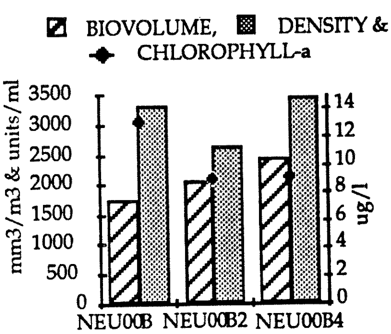
0 5 10 15 20
DO (mg/l)


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/m3 & units/ml
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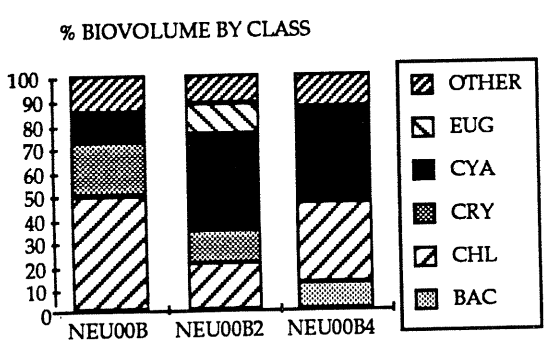
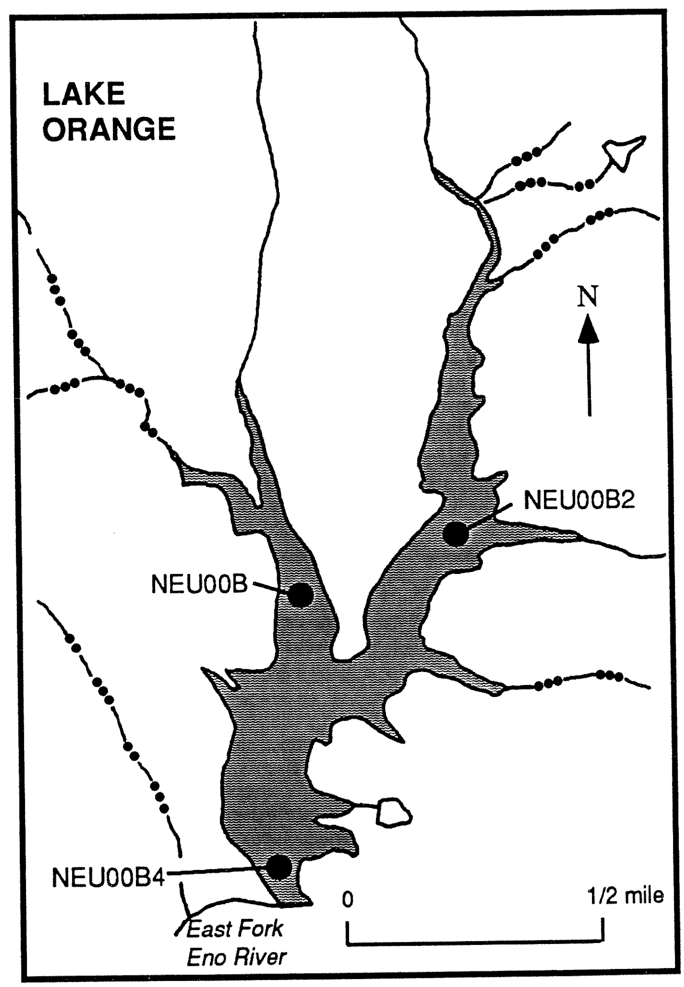
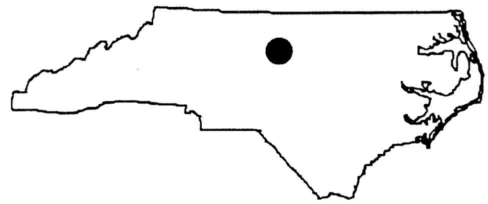
14 12 10 8 6 4 2 0
ug/l
NEU00B NEU00B2 NEU00B4


% BIOVOLUME BY CLASS
100 90 80 70 60 50 40 30 20 10 0
NEU00B NEU00B2 NEU00B4
OTHER
EUG
CYA
CRY
CHL
BAC


LAKE
ORANGE
N
NEU00B2
NEU00B
NEU00B4
0
1/2 mile
East Fork
Eno River

CORPORATION LAKE



COUNTY:	Orange	BASIN:	Neuse
SURFACE AREA:	11 hectares (28 acres)	USGS TOPO:	Efland, N.C.
CLASS:	WS NSW	LAKE TYPE:	Reservoir

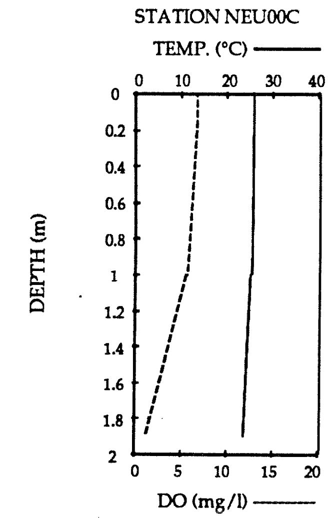
LATEST NCTSI:	0.6	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	August 10, 1988	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	1.1 m	CONDUCTIVITY:	77 - 80 µmhos/cm^2
TOTAL PHOSPHORUS:	0.06 mg/l	DISSOLVED OXYGEN:	6.8 - 7.6 mg/l
TOTAL ORGANIC NITROGEN:	0.225 mg/l	TEMPERATURE:	26.0 - 28.3 °C
CHLOROPHYLL-A:	14 µg/l	pH:	7.0 - 7.4 s.u.

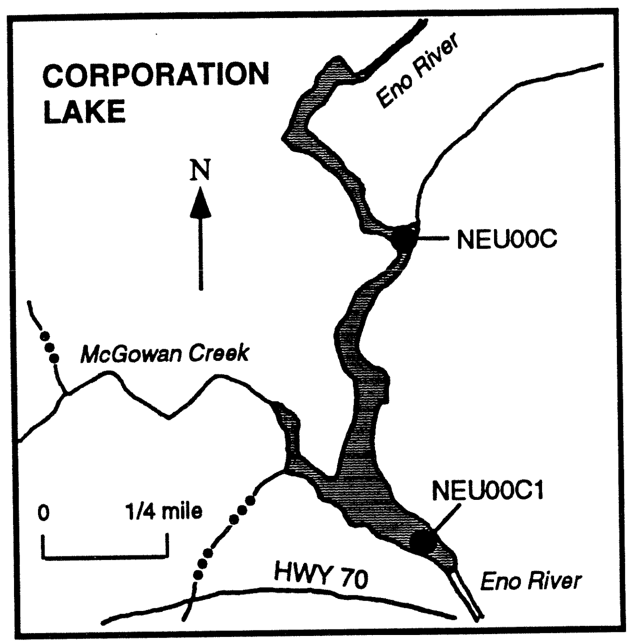
Corporation Lake is an impoundment of the Eno River downstream of Lake Orange. This piedmont reservoir was built in 1967 by Orange-Alamance Water Authority to be used as a water supply. Volume in the lake is 898,729 m^3. Maximum depth is 2.5 meters and average depth is 1.2 meters. McGowan Creek is a tributary to the reservoir. Surrounding topography is rolling with forest and agriculture dominating the land uses in the watershed.

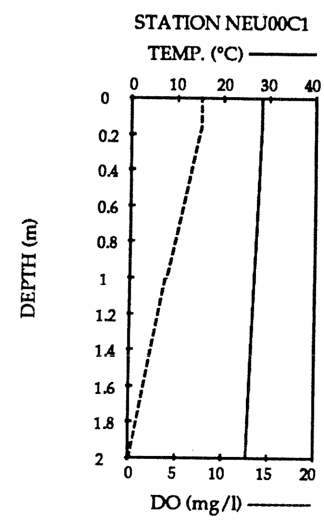
On August 10, 1988, surface mats of floating algae covered the water near the dam, but chlorophyll-a and phytoplanktonic samples collected from the photic zone did not reveal a bloom. The shallow water column was slightly stratified. Secchi readings revealed that light could have penetrated to the bottom of the lake if algal mats had not been present (readings were recorded after clearing the surface scum). Total phosphorus levels were elevated .

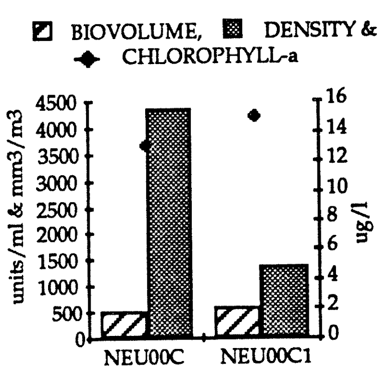
Both stations at Corporation Lake contained low algal biovolumes (509 - 602 mm^3/m^3), and moderately low densities (4,385 - 1,368 units/ml). Shading by the overlying algal mats probably limited phytoplanktonic growth in the photic zone. Since the surface mats were not included in the quantitative algal samples, biovolume and density values underestimate the true algal populations in Corporation Lake. Species composition was dominated by euglenophytes, cryptophytes and chlorophytes at both stations. The upper lake station contained a higher algal density which was attributed to an abundance of small chlorophytes and cryptophytes.

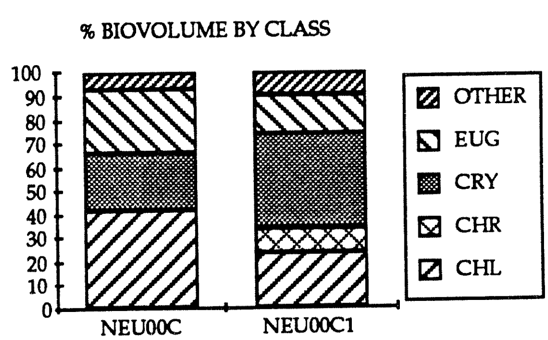
Corporation Lake was eutrophic with a TSI of 0.6. All designated uses were supported at the time of sampling; however, the dense algal mats and elevated phosphorus suggest that nutrient enrichment is a problem.



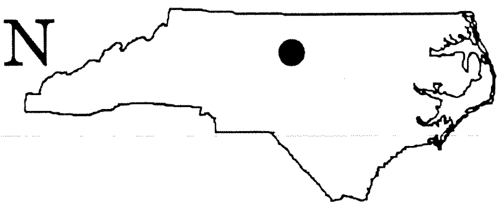








LAKE BEN JOHNSON



COUNTY:	Orange	BASIN:	Neuse
SURFACE AREA:	12 hectares (30 acres)	USGS TOPO:	Efland, N.C.
CLASS:	WS NSW	LAKE TYPE:	Reservoir

LATEST NCTSI:	1.3	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	August 10, 1988	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	1.0 m	CONDUCTIVITY:	73 µmhos/cm^2
TOTAL PHOSPHORUS:	0.07 mg/l	DISSOLVED OXYGEN:	5.9 mg/l
TOTAL ORGANIC NITROGEN:	0.34 mg/l	TEMPERATURE:	28.0 °C
CHLOROPHYLL-A:	10 µg/l	pH:	6.8 s.u.

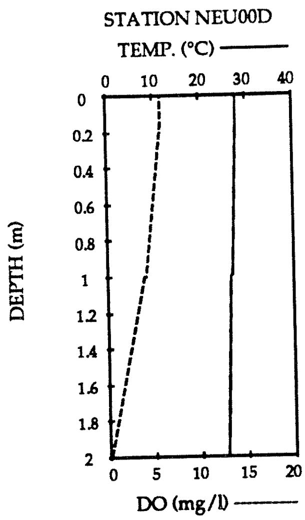
Lake Ben Johnson is formed by a run-of-the-river dam on the Eno River. The lake measures 12 hectares with a maximum depth of approximately three meters. The City of Hillsborough owns the lake which is also the back-up water supply for this municipality.

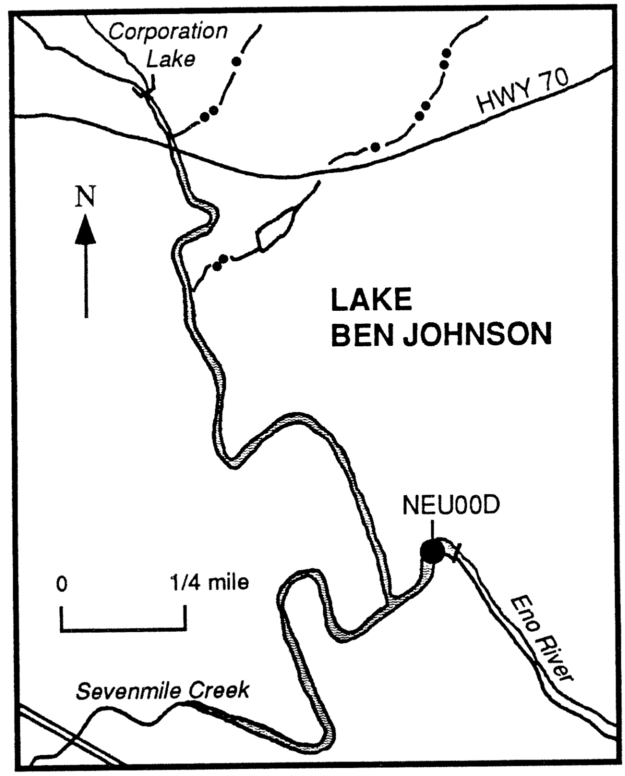
On August 10, 1988, the lake was sampled. Mild oxygen stratification was observed even though temperature was relatively uniform throughout the water column. Metals were not detected in water samples. Chlorophyll-a concentrations and turbidity were moderate, while total phosphorus was elevated.

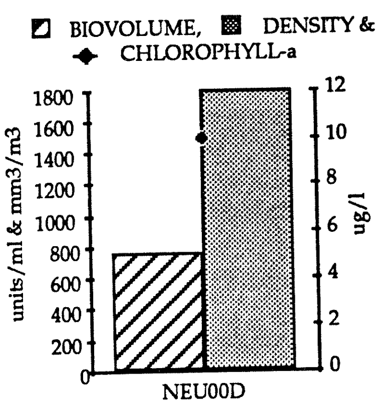
Similar to Corporation Lake located upstream, Lake Ben Johnson had relatively low phytoplanktonic biovolume and density. Dominant algal classes by biovolume included euglenophytes, cryptophytes, chlorophytes and bacillariophytes. Cyanophytes, primarily Merismopedia delicatissima were dominant by density.

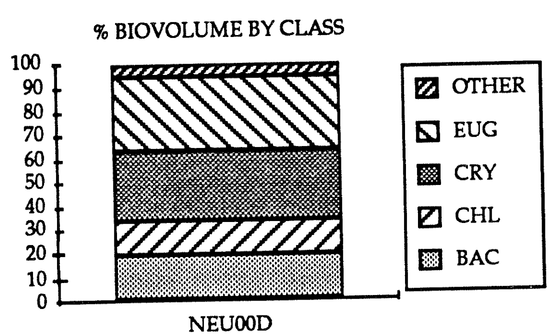
Although the standing crop of algae was not excessively high, predominance by euglenophytes (31%) supports a eutrophic rating for Lake Ben Johnson. Large numbers of euglenophytes often signify organically enriched conditions.

A TSI of 1.3 indicated that Lake Ben Johnson was eutrophic. No water quality standard violations were observed and uses were fully supported.

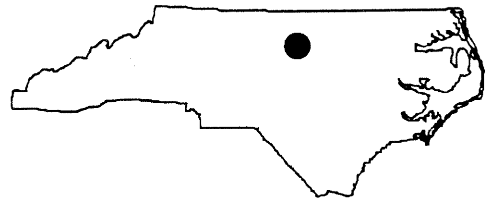

STATION NEU00D
TEMP. (°C)
0
10
20
30
40
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
DEPTH (m)
0
5
10
15
20
DO (mg/l)


Corporation
Lake
HWY 70
N
LAKE
BEN JOHNSON
NEU00D
0
1/4 mile
Eno River
Sevenmile Creek


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
1800
1600
1400
1200
1000
800
600
400
200
0
units/ml & mm3/m3
12
10
8
6
4
2
0
ug/l
NEU00D


% BIOVOLUME BY CLASS
100
90
80
70
60
50
40
30
20
10
0
NEU00D
OTHER
EUG
CRY
CHL
BAC

LITTLE RIVER RESERVOIR



COUNTY:	Durham	BASIN:	Neuse
SURFACE AREA:	214 hectares (530 acres)	USGS TOPO:	Northeast Durham, N.C.
CLASS:	WS NSW	LAKE TYPE:	Reservoir

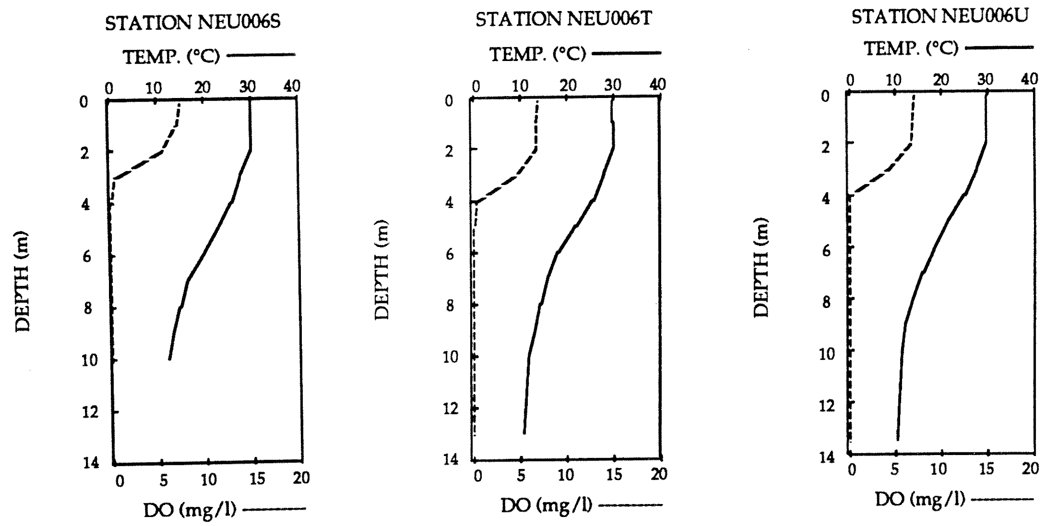
LATEST NCTSI:	- 0.8	TROPHIC STATE:	Mesotrophic
SAMPLING DATE:	July 10, 1988	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	1.3 m	CONDUCTIVITY:	92 - 94 µmhos/cm^2
TOTAL PHOSPHORUS:	0.02 mg/l	DISSOLVED OXYGEN:	7.0 - 7.6 mg/l
TOTAL ORGANIC NITROGEN:	0.36 mg/l	TEMPERATURE:	29.7 - 30.0 °C
CHLOROPHYLL-A:	6 µg/l	pH:	6.5 - 7.1 s.u.

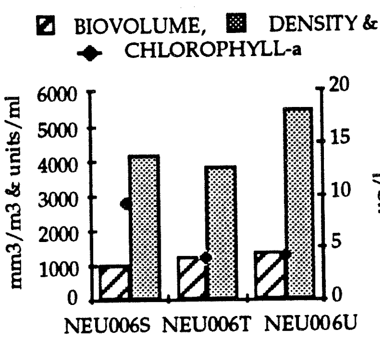
Little River Reservoir is a new water supply for the City of Durham. Filled in February 1988, the lake holds 18 x 10^6 m^3 of water and has a maximum depth is 15 meters. Average retention time is 74 days. Mountain Creek, Buffalo Creek, North Fork and South Fork Little River are the tributaries of this reservoir. Land use is about equally divided between forest, agriculture, and residential areas. The lake is classified WS-III, but the City of Durham has requested an upgrade to WS-I, which would provide much stricter controls on upstream development.

On July 10, 1988, DEM sampled Little River Reservoir for the first time. The lake was approximately two meters below normal pool. Physical parameters indicated that the lake was stratified. Anoxic conditions existed below five meters at all three stations. Temperature at the surface was nearly 20°C warmer than at the bottom of the water column. Nutrients were higher in the hypolimnion than the photic zone which is common in stratified lakes.

Relatively low algal biovolume, density, and chlorophyll-a concentrations were found in Little River Reservoir. Chlorophytes and chrysophytes were dominant at all three stations. Staurastrum spp. (chlorophytes) and Dinobryon spp. (chrysophytes), which were abundant at the three sampling sites, are common components of phytoplanktonic populations in oligotrophic lakes.

A TSI of -0.8 indicated the lake was mesotrophic. No violations of water quality standards were noted and all designated uses were fully supported.


STATION NEU006S
STATION NEU006T
STATION NEU006U
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0 2 4 6 8 10 12 14
DO (mg/l)
0 5 10 15 20


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/m3 & units/ml
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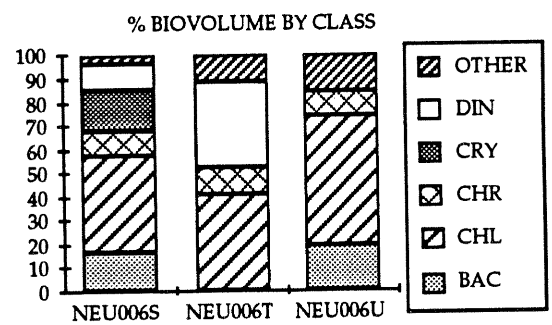
ug/l
20 15 10 5 0
NEU006S NEU006T NEU006U


% BIOVOLUME BY CLASS
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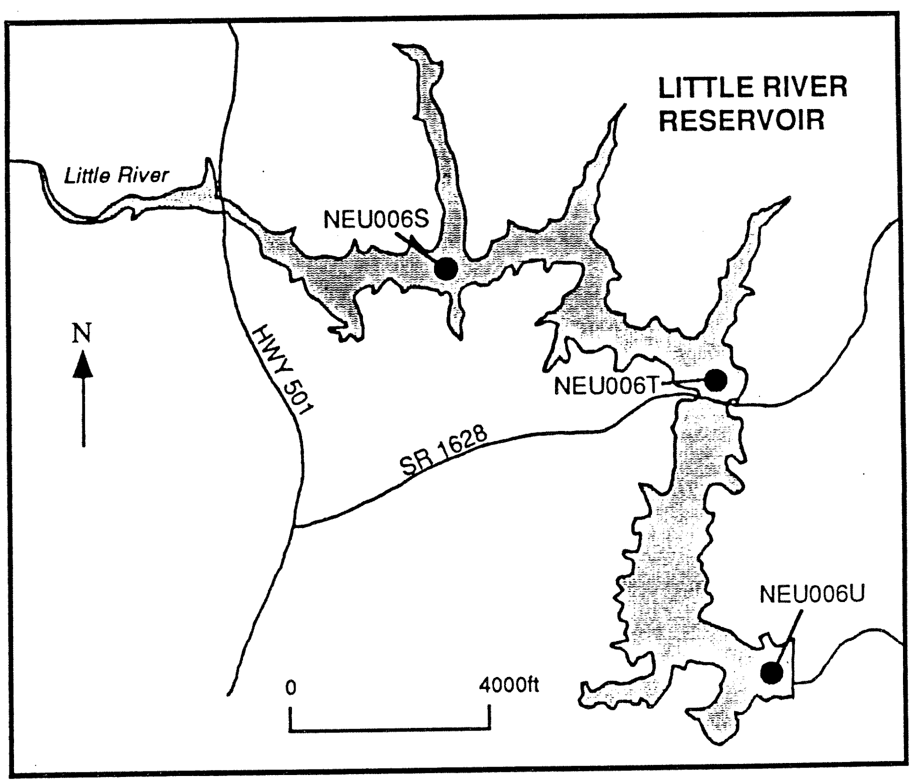
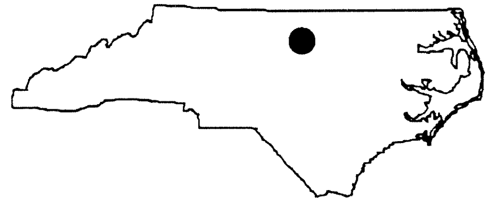
NEU006S NEU006T NEU006U
OTHER
DIN
CRY
CHR
CHL
BAC


LITTLE RIVER
RESERVOIR
Little River
NEU006S
NEU006T
NEU006U
HWY 501
SR 1628
N
0
4000ft

LAKE MICHIE



COUNTY:	Durham	BASIN:	Neuse
SURFACE AREA:	219 hectares (540 acres)	USGS TOPO:	Lake Michie, N.C.
CLASS:	WS NSW	LAKE TYPE:	Reservoir

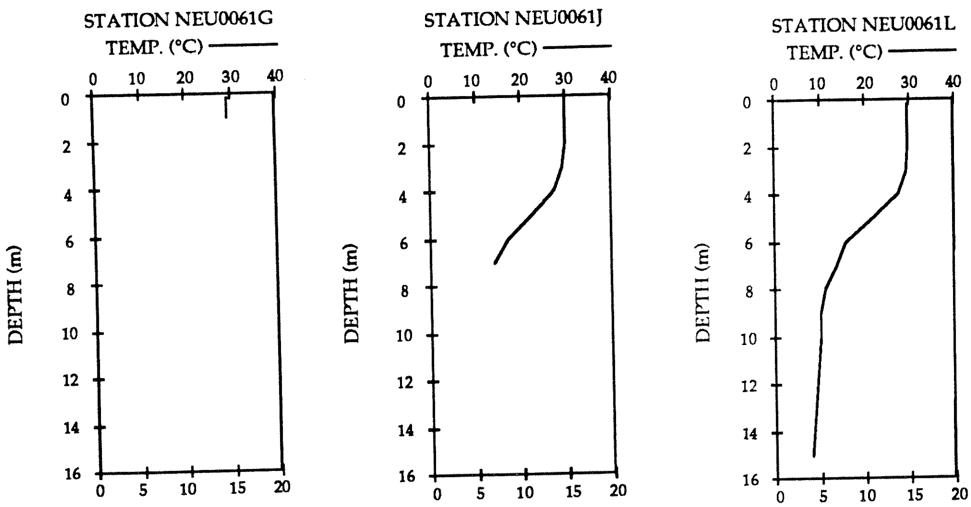
LATEST NCTSI:	2.1	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	August 10, 1988	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	1.5 m	CONDUCTIVITY:	76 - 82 µmhos/cm^2
TOTAL PHOSPHORUS:	0.07 mg/l	DISSOLVED OXYGEN:	5.8 - 6.8 mg/l
TOTAL ORGANIC NITROGEN:	0.37 mg/l	TEMPERATURE:	29.3 - 30.1 °C
CHLOROPHYLL-A:	37 µg/l	pH:	6.5 - 7.1 s.u.

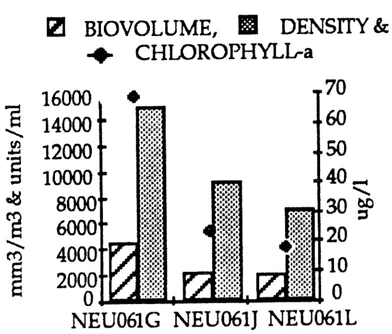
The City of Durham built Lake Michie in 1926 to serve as a water supply. Durham has petitioned the state for a reclassification of the reservoir from WS-III to WS-II. This reclassification would mandate additional protection of the upstream watershed. Maximum depth is approximately 16 meters, and volume is 15.6 x 10^6 m^3. The drainage area of this piedmont reservoir is mostly forested, although some agricultural and residential land use exists.

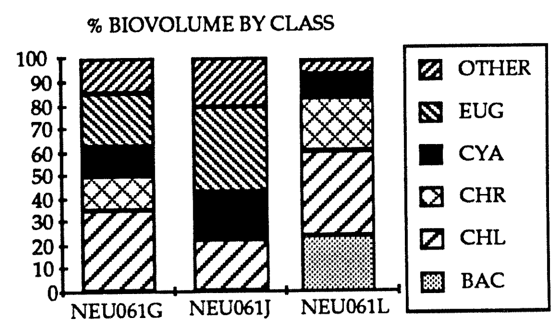
Lake Michie was sampled on August 10, 1988. The shallow upstream station was not stratified, but the two downstream stations were strongly stratified. Anoxic conditions were observed below three meters. Secchi values increased substantially from upstream to downstream. The chlorophyll-a value of 70 µg/l exceeded the state standard of 40 µg/l at the upstream station. Turbidity was also high at this station. Total phosphorus was elevated throughout the lake, especially at the upstream station.

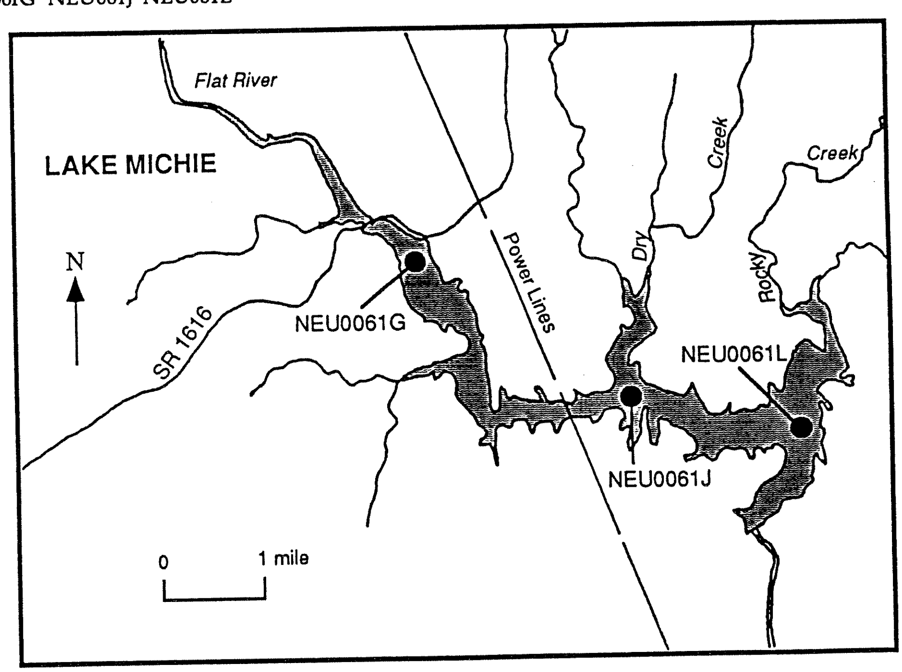
Phytoplanktonic populations were elevated at the upper station, and decreased steadily towards the dam. Chlorophytes and cyanophytes were codominant at all three stations, while euglenophytes were also prevalent at the two upper lake stations. Dominance by cyanophytes including Anabaenopsis raciborskii, Anabaena species and Lyngbya spp. at all stations indicated eutrophic conditions. Chrysochromulina breviturritta, a prymnesiophyte, was also present at the three sampling sites. Highest numbers were found at the upstream station, where they contributed to the elevated chlorophyll-a concentrations.

A TSI of 2.1 indicated that Lake Michie was eutrophic in 1988. The lake supported all designated uses, but nutrient enrichment was particularly evident in the headwaters of the lake.

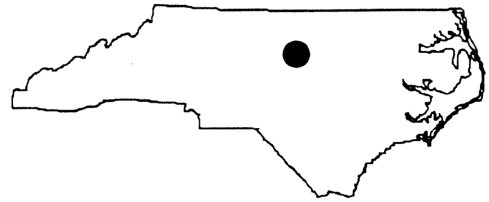








LAKE BUTNER



COUNTY:	Granville	BASIN:	Neuse
SURFACE AREA:	151 hectares (374 acres)	USGS TOPO:	Lake Michie, N.C.
CLASS:	WS NSW	LAKE TYPE:	Reservoir

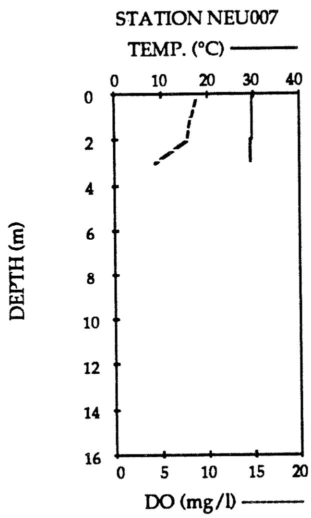
LATEST NCTSI:	- 2.0	TROPHIC STATE:	Mesotrophic
SAMPLING DATE:	August 10, 1988	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	2.6 m	CONDUCTIVITY:	60 µmhos/cm^2
TOTAL PHOSPHORUS:	0.03 mg/l	DISSOLVED OXYGEN:	7.8 - 8.8 mg/l
TOTAL ORGANIC NITROGEN:	0.225 mg/l	TEMPERATURE:	29.7 - 31.4 °C
CHLOROPHYLL-A:	4.5 µg/l	pH:	7.2 - 7.3 s.u.

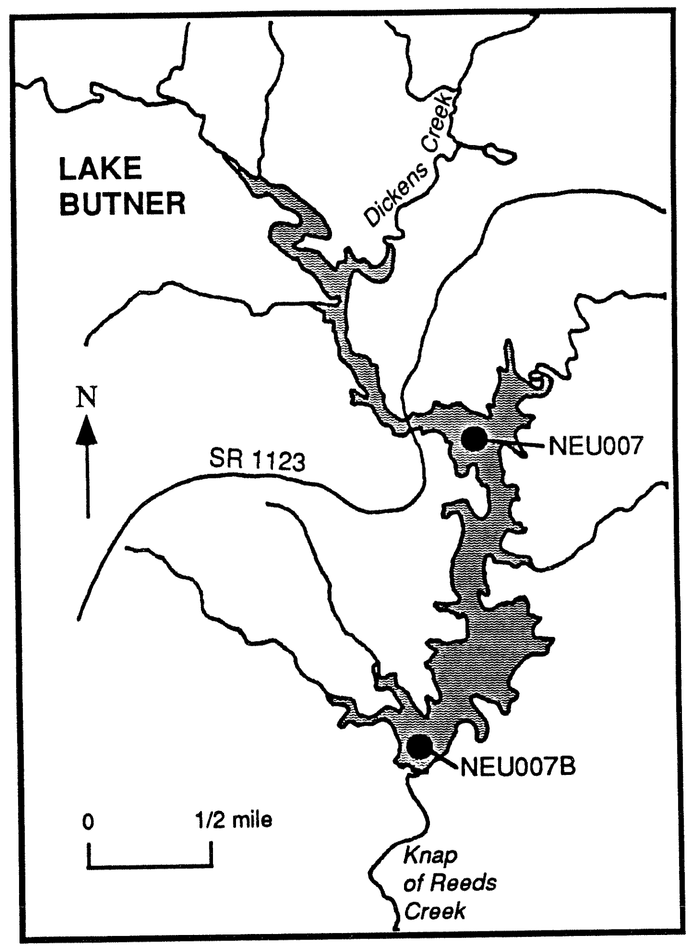
Lake Butner (also called Holt Reservoir) is an impoundment of Knap of Reeds Creek in Granville County. This lake is a water supply for the Town of Butner and is also used for recreation. Fish hatcheries being built by the North Carolina Wildlife Resources Commission will also use water from Lake Butner. The rolling topography surrounding the lake is characterized by forests and farmlands.

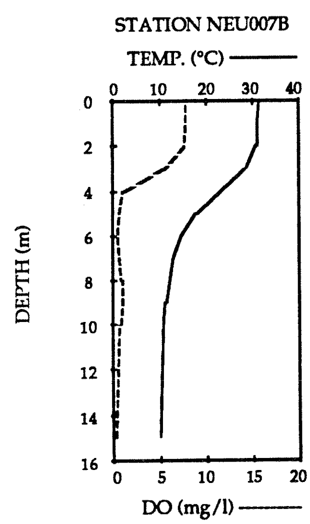
Lake Butner was sampled on August 10, 1988. Lake clarity was good as evidenced by the high secchi readings and the low levels of turbidity and solids. The lake was thermally stratified at the dam with a temperature variation of 20° C from the surface to the bottom of the water column. Dissolved oxygen approached anoxic conditions below four meters. Chemical samples indicated low concentrations of nitrogen and moderate phosphorus levels.

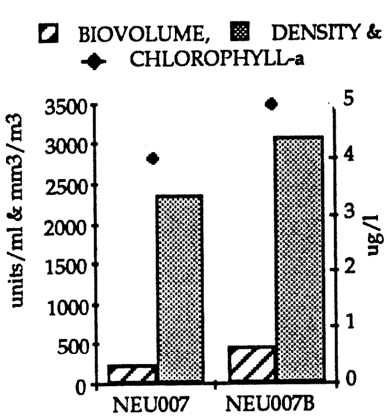
Lake Butner contained low algal biovolume (245 - 473 mm^3/m^3), density (2,358 - 3,068 units/ml) and chlorophyll-a concentrations. A diverse assemblage of chlorophytes was identified. Cyanophytes codominated at the downstream station. The cyanophyte Gomphosphaeria lacustris, which is widely distributed in ponds and lakes, represented 19% of the biovolume, while Merismopedia tenuissima, also a cyanophyte, accounted for 20% of the density. M. tenuissima commonly occurs interspersed with other lake and pond algae.

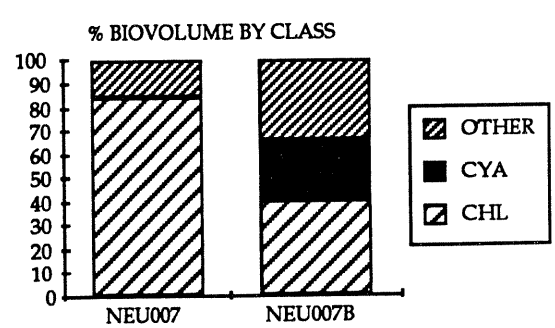
Lake Butner is a borderline mesotrophic-oligotrophic lake which has been classified mesotrophic for the purposes of this report and the North Carolina 305(b) Report. A TSI of -2.0 was documented in 1988. Water quality in the lake meets designated uses, although future monitoring should carefully examine hydrilla growth and parameters of concern to the fish hatchery.



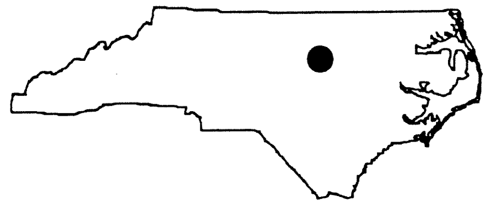








FALLS OF THE NEUSE RESERVOIR



COUNTY:	Durham/Granville/Wake	**BASIN:**	Neuse
SURFACE AREA:	5055 hectares (12490 acres)	**USGS TOPO:**	Wake Forest, N.C.
CLASS:	WS, B, C NSW	**LAKE TYPE:**	Reservoir

LATEST NCTSI:	3.7	**TROPHIC STATE:**	Eutrophic
SAMPLING DATE:	August 1, 1990	**ADDITIONAL COVERAGE:**	Fecal, Metals
SECCHI DEPTH:	0.5 m	**CONDUCTIVITY:**	82 - 178 µmhos/cm^2
TOTAL PHOSPHORUS:	0.07 mg/l	**DISSOLVED OXYGEN:**	5.0 - 8.0 mg/l
TOTAL ORGANIC NITROGEN:	0.52 mg/l	**TEMPERATURE:**	28.1 - 30.8 °C
CHLOROPHYLL-A:	32 µg/l	**pH:**	6.8 - 7.3 s.u.

Falls of the Neuse Reservoir is located at the headwaters of the Neuse River, which is formed by the confluence of the Eno and Flat Rivers in Durham County. The dam is in Wake County, approximately 16 kilometers northeast of Raleigh.

The lake is the primary water supply for the City of Raleigh. It was created by the U.S. Army Corps of Engineers to serve a variety of purposes including water supply, flood control, and recreation. Construction of the dam was completed in 1981, and the reservoir began filling in January 1983.

The surface area of the lake is 5,055 hectares, and the lake is 35 kilometers in length at normal pool. Major tributaries include the Eno, Flat, and Little Rivers, and Knap of Reeds, Ellerbe, Ledge, Lick, Little Lick, and Beaverdam Creeks. Falls of the Neuse Reservoir is wide and shallow upstream of Highway 50 and relatively narrow and deep from Highway 50 to the dam.

The drainage area is 1,994 km^2. Land use in the watershed consists of forested, agricultural, and urban and residential areas. Rapid development is occurring in the watershed.

Extensive water quality research and sampling have been performed at Falls of the Neuse Reservoir since its creation. Monitoring has been conducted by DEM, the U.S. Army Corps of Engineers, consulting firms, and academic researchers. Falls of the Neuse Reservoir has consistently rated as one of the most eutrophic lakes in North Carolina, with frequently high chlorophyll-a and nutrients levels. Recurring blue-green algal blooms and fish kills have been documented, primarily in the segment upstream of Highway 50.

Excessive loading of nutrients into the tributaries from both point and nonpoint sources have affected the water quality of the lake. Wastewater discharges from the cities of Hillsborough, Durham, Creedmoor, and Butner enter the lake through these tributaries. Because high nutrient loading was causing undesirable water quality in the headwaters, the entire drainage basin upstream of the dam was declared "Nutrient Sensitive Waters" in December 1983.

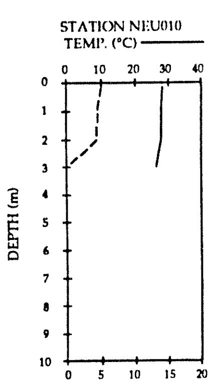
Falls of the Neuse Reservoir was sampled on August 1, 1990. Physical measurements indicated stratified conditions at the deeper stations. At these stations, the water was anoxic below four meters. A low surface dissolved oxygen value of 4.9 mg/l was measured at NEU018E. This value was above the instantaneous state criterion of 4.0 mg/l but slightly below the daily average criterion of 5.0 mg/l. Lower surface dissolved oxygen concentrations were generally found upstream of Highway 50.

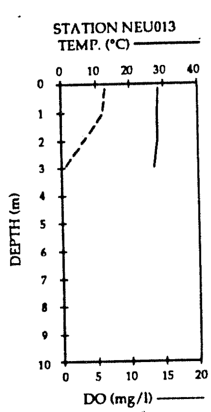
Nutrient levels were elevated, particularly upstream of Highway 50. Assimilation and sedimentation occur in this segment, and help account for lower nutrient concentrations downstream of Highway 50. Chlorophyll-a levels were also higher upstream of Highway 50 and violated the state standard of 40 µg/l at NEU013 (96 µg/l). Fecal coliform bacteria were low at all stations with no levels exceeding 10/100 ml.

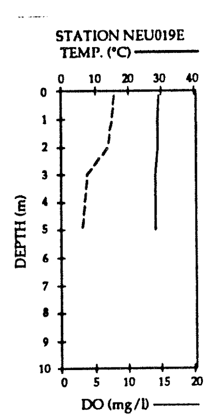
Aluminum and manganese levels were high in the upstream segment of the lake in August, as had been observed in previous sampling. One violation of the state standard for manganese of 200 µg/l was found at NEU018E (350 µg/l). These high values may be a result of high concentrations of aluminum and manganese in local soils. Runoff and erosion in the headwaters may cause levels of these metals to be high in the upstream segment of the reservoir, particularly after storm events.

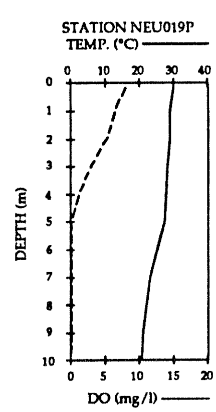
The TSI in August 1990 was 3.6, indicating that Falls of the Neuse Reservoir is eutrophic. August 1988 and August 1989 TSI scores were 4.1 and 2.7 respectively. It is important to remember that these scores were based on isolated sampling events and can vary depending on prevailing conditions. The designated uses of Falls of the Neuse Reservoir are threatened by the highly eutrophic conditions observed in the upstream reaches. Management actions have been implemented to curb nutrient inputs from both point and nonpoint sources in the watershed. Stringent phosphorus limits for wastewater discharges and restrictions on land development were designed to protect the lake from degradation. The effect of these controls will be evaluated in future monitoring efforts.

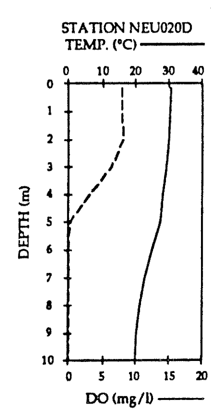
Individuals seeking additional information regarding the water quality of Falls of the Neuse Reservoir should consult additional publications produced by the Army Corps of Engineers (USACOE, 1985b; 1986; 1987; 1988) and DEM (1983a).

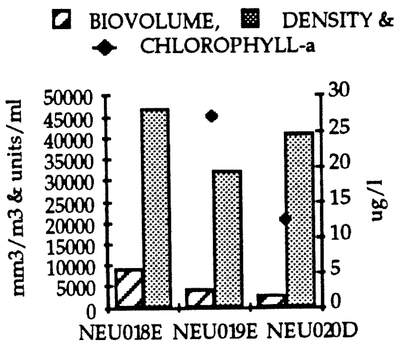











BIOVOLUME, DENSITY & CHLOROPHYLL-a
mm3/m3 & units/ml
ug/l
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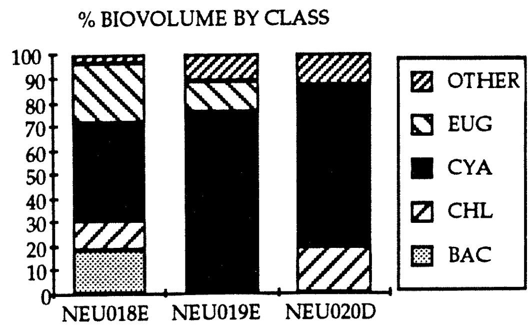
% BIOVOLUME BY CLASS
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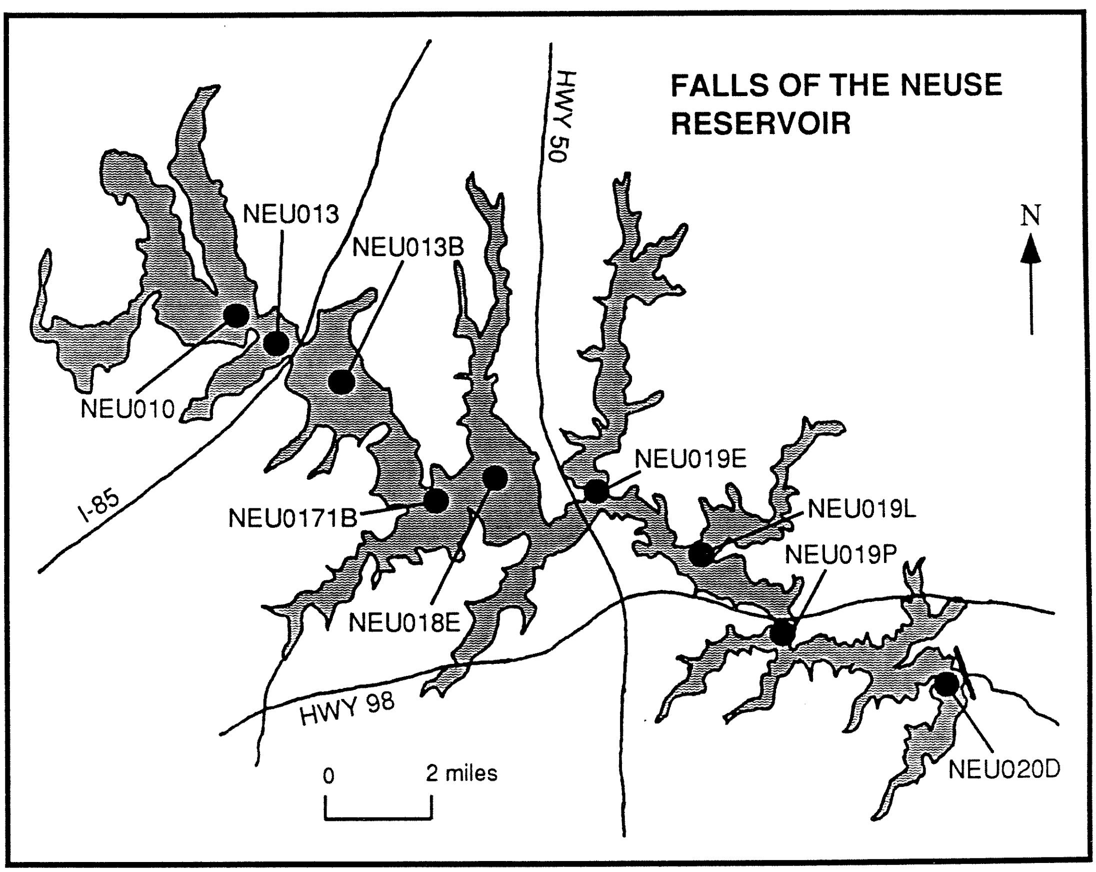
FALLS OF THE NEUSE RESERVOIR
N
HWY 50
NEU013
NEU013B
NEU010
I-85
NEU0171B
NEU019E
NEU019L
NEU019P
NEU018E
HWY 98
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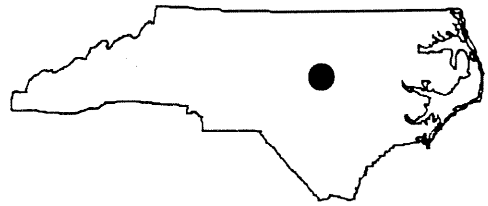
0
2 miles

BIG LAKE



COUNTY:	Wake	BASIN:	Neuse
SURFACE AREA:	25 hectares (62 acres)	USGS TOPO:	Cary, N.C.
CLASS:	B NSW	LAKE TYPE:	Reservoir

LATEST NCTSI:	1.2	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	July 31, 1987	ADDITIONAL COVERAGE:	None
SECCHI DEPTH:	0.7 m	CONDUCTIVITY:	112 - 114 µmhos/cm^2
TOTAL PHOSPHORUS:	0.03 mg/l	DISSOLVED OXYGEN:	7.2 - 7.5 mg/l
TOTAL ORGANIC NITROGEN:	0.40 mg/l	TEMPERATURE:	28.9 - 29.3 °C
CHLOROPHYLL-A:	14 µg/l	pH:	7.6 - 7.9 s.u.

Big Lake is located in Umstead State Park in northwestern Wake County. The park is situated next to the Raleigh-Durham International Airport. Water and sewer line extensions have allowed increased development near the eastern and southern borders of the park. Big Lake has a drainage basin of 18 km^2. Land use in the watershed is primarily forest and agriculture; however, residential and commercial development have increased considerably over the past several years. Big Lake has a maximum depth of five meters, a mean depth of two meters, and a mean hydraulic retention time of 25 days.

Big Lake was sampled on July 31, 1987, and was classified as eutrophic with water quality characteristics similar to other small piedmont reservoirs. Physical measurements indicated that the shallow, upper sampling station was not stratified. However, the water column near the center of the lake was stratified and anoxic below four meters. Nutrients and chlorophyll-a were moderate at both sampling locations.

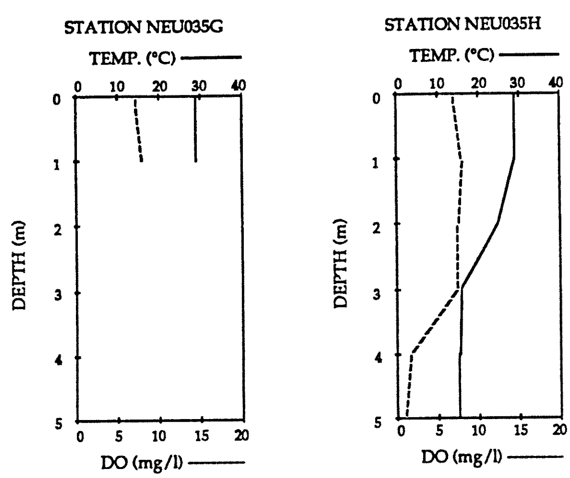
Like the other lakes in Umstead State Park (Reedy Creek Lake and Sycamore Lake), Big Lake has experienced siltation and has been infested with hydrilla for several years. The lakes are being restored through a USEPA Clean Lakes Restoration Project.

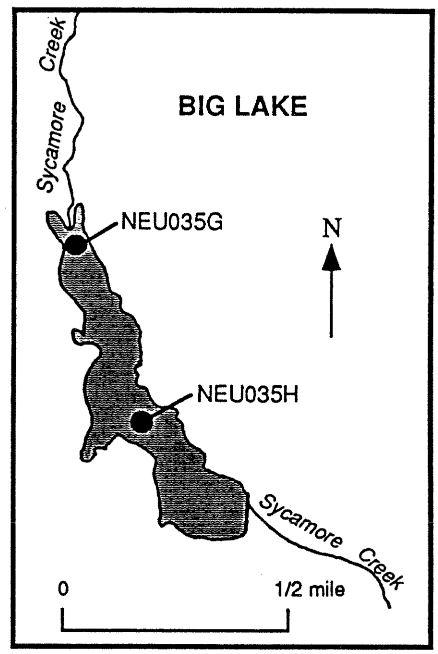
Hydrilla was first documented in Big Lake in 1983. The North Carolina Division of Water Resources began applying herbicide in September of that year. Methylene pyridone (Sonar™) was applied to the upper 14 acres of the lake in 1983, 1986 and 1987. The littoral zone of the lake near the dam was also treated with Sonar in 1984 and 1986.

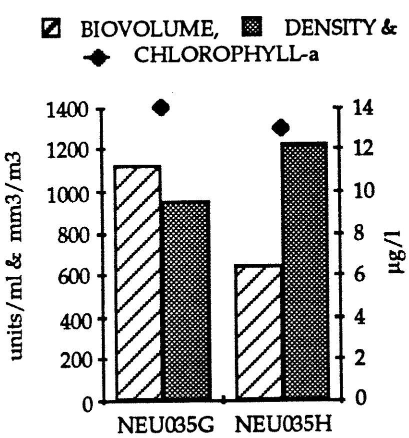
A special study was undertaken during the summer of 1987 to determine whether herbicide applications affected the algal community. Prior to treatment of the lake on July 17, 1987, Anabaena levanderi constituted over 50% of the biovolume at all stations. The accompanying graphs depict the algal community on July 31, 1987. Density and biovolume were low at both stations. Scenedesmus obliquus and Chlamydomonas species made up 36% of the density at all stations while Euglena polymorpha and Euglena acus comprised approximately 30% of the biovolume..

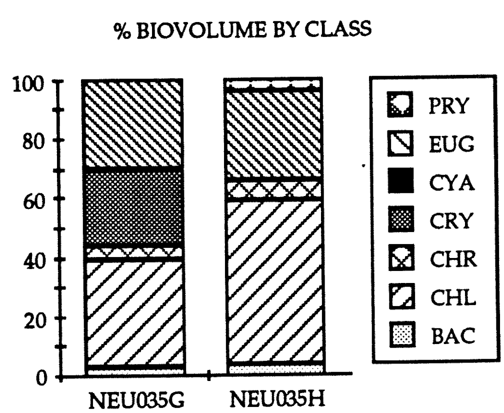
As hydrilla biomass declined, algal biovolume varied slightly while density decreased. This decrease was attributed to the replacement of small colonial blue-green algae by first flagellated algae and then diatoms. However, no immediate or long-term changes in nutrients or phytoplankton were found to be associated with the control efforts. It is important to note that high inflow rates during the study may have suppressed phytoplankton growth through transport or light limitation.

The TSI value of 1.2 in 1987 was higher than the score in 1981 (0.3). Nutrient and chlorophyll-a values were higher in 1987 than in 1982 and 1983. Big Lake does not support designated uses because hydrilla and sedimentation interfere with these uses. Future monitoring is needed to determine long range effects of restoration efforts and to document water quality changes resulting from ongoing construction and residential development in the watershed of this lake.

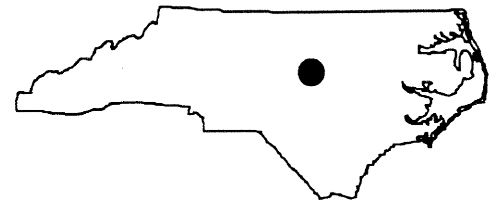








LAKE CRABTREE



COUNTY:	Wake	**BASIN:**	Neuse
SURFACE AREA:	210 hectares (520 acres)	**USGS TOPO:**	Cary, N.C.
USE:	B NSW	**LAKE TYPE:**	Reservoir

LATEST NCTSI:	5.4	**TROPHIC STATE:**	Hypereutrophic
SAMPLING DATE:	August 28, 1990	**ADDITIONAL COVERAGE:**	Fecals
SECCHI DEPTH:	0.3 m	**CONDUCTIVITY:**	97-109 µmhos/cm^2
TOTAL PHOSPHORUS:	0.1 mg/l	**DISSOLVED OXYGEN:**	3.3 - 9.3 mg/l
TOTAL ORGANIC NITROGEN:	0.68 mg/l	**TEMPERATURE:**	28.0 - 29.2 °C
CHLOROPHYLL-A:	48 µg/l	**pH:**	6.2 - 6.8 s.u.

Lake Crabtree was built in 1989 by the Soil Conservation Service as one of 11 lakes constructed for flood control in the Crabtree Creek watershed. Wake County owns a park around the lake which is used for recreation. Average depth in the lake is two meters with a maximum depth of approximately four meters. Volume is 4.7×10^5 m^3.

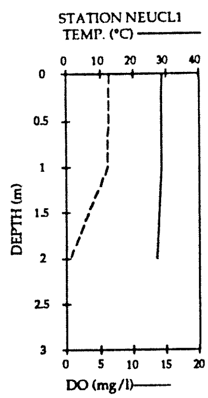
The drainage area is 133 km^2 and is primarily urban and residential. Several point sources discharge upstream of the lake. Three tributaries - Crabtree Creek, Haleys Branch, and Stirrup Iron Creek - drain portions of Cary, Morrisville, and the Raleigh-Durham International Airport. Private development has been planned for some of the shoreline.

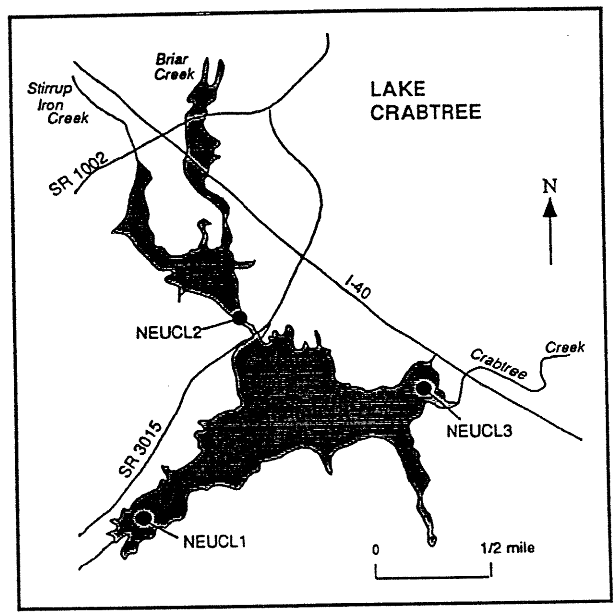
Lake Crabtree was sampled on August 28, 1990. A violation of the dissolved oxygen standard was documented at NEUCL2, and a deeper station (NEUCL3) was anoxic below two meters. There were also violations of the turbidity and chlorophyll-a standards in Lake Crabtree. Concentrations of nitrogen and phosphorus were extremely elevated. Evidence suggests that a source or sources of pollution are adversely affecting the lake. If these sources persist, one or more of the uses of this reservoir may be impaired.

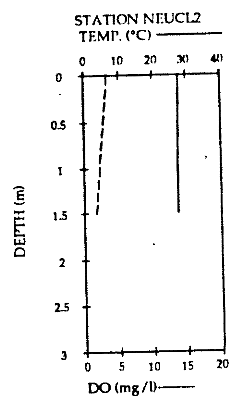
Algal populations in Lake Crabtree reflect the highly eutrophic condition of this reservoir. Elevated levels of algae were present at all three stations. Chlorophytes or green algae were most prevalent at the three sampling sites. The colonial green algae, Scenedesmus spp, which are common throughout the state, constituted the majority of the chlorophyte biovolume.

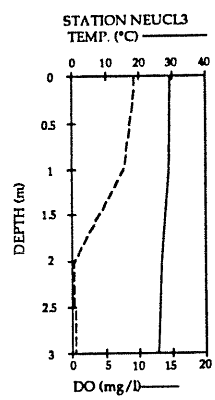
Blue-green algae such as Anabaenopsis raciborskii, A. phillipinensis and A. circularis were also found at all three stations and dominated density estimates at NEUCL1 and NEUCL3. These small filamentous cyanophytes are often found during summer in enriched waters. Euglenophytes and cryptophytes were codominant at the upper two lake stations. Also abundant at the lower station was Chrysochromulina breviturrita, a prymnesiophyte which contains a large amount of chlorophyll-a relative to its size. The downstream station which contained 17% prymnesiophytes had the highest chlorophyll-a concentration of 60 µg/l.

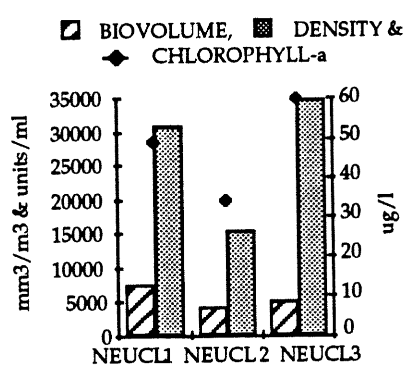
Lake Crabtree borders between a eutrophic and hypereutrophic classification. Further monitoring of this lake is clearly warranted as is a review of compliance at the upstream wastewater treatment plants.

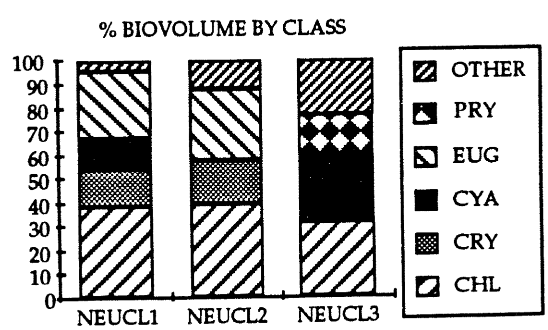




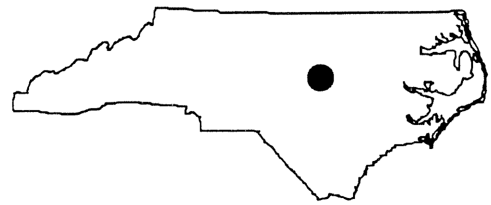








LAKE JOHNSON



COUNTY:	Wake	BASIN:	Neuse
SURFACE AREA:	70 hectares (174 acres)	USGS TOPO:	Raleigh West, N.C.
CLASS :	WS, B NSW	LAKE TYPE:	Reservoir

LATEST NCTSI:	- 2.8	TROPHIC STATE:	Mesotrophic
SAMPLING DATE:	August 6, 1987	ADDITIONAL COVERAGE:	Fecal
SECCHI DEPTH:	1.5 m	CONDUCTIVITY:	64 - 65 μmhos/cm^2
TOTAL PHOSPHORUS	0.025 mg/l	DISSOLVED OXYGEN:	7.0 mg/l
TOTAL ORGANIC NITROGEN:	0.24 mg/l	TEMPERATURE:	30.0 °C
CHLOROPHYLL-A:	1 μg/l	pH:	7.7 s.u.

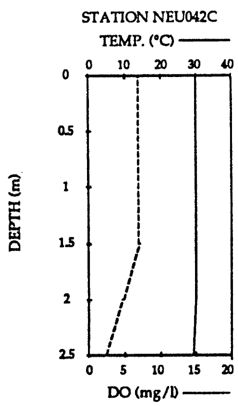
Lake Johnson is owned by the City of Raleigh and is located in Wake County where it is used for recreation. It was recently retired as an auxiliary municipal water supply. The lake is essentially subdivided into two basins by a road crossing at mid-lake. Lake Johnson has a volume of 7.0 x 10^5 m^3 and a maximum depth of six meters, and Walnut Creek is the major inflow. The watershed is 18 km^2. Land use is predominantly forest and agriculture. However, in recent years urban land uses have grown considerably.

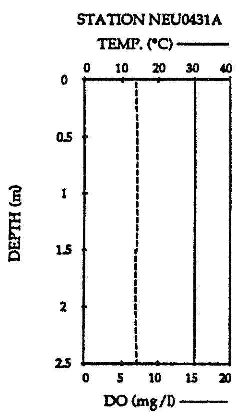
Lake Johnson was sampled on August 6, 1987. Dissolved oxygen, temperature, pH, and specific conductance measurements were typical for a moderately productive lake. Profiles of dissolved oxygen and temperature indicated that the lake was not thermally stratified. Levels of fecal coliform bacteria were below laboratory detection limits. There were no significant differences in physical, chemical, or biological measurements between the two stations.

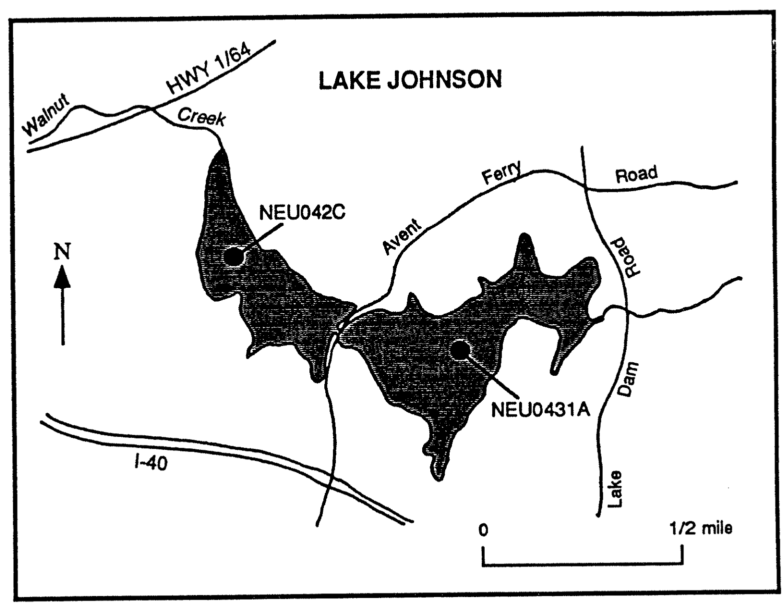
The low standing crop of phytoplankton supported an oligo-mesotrophic classification for Lake Johnson. Estimates of density from the upper basin of the lake were dominated by the green algae, Coelastrum sphaericum and Ankistrodesmus falcatus mirabilis. In the downstream basin Melosira italica alpigena, a diatom, and Merismopedia tenuissima, a blue-green alga, were the major contributors by density. Dominance by biovolume between the two sites differed, with the upper end dominated by Coelastrum sphaericum, Anabaena levanderi and Melosira italica alpigena, while biovolume in the lower section consisted mainly of Staurastrum hexacerum, Melosira italica alpigena, and Staurastrum tetracerum.

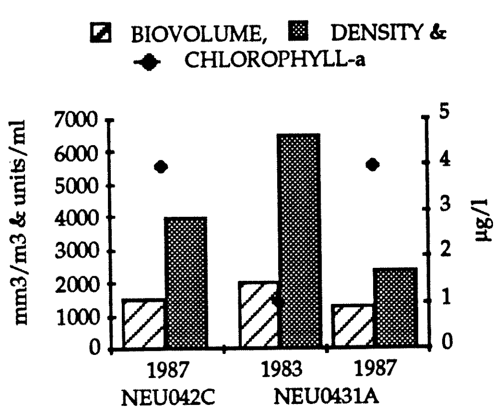
Field surveys indicate that hydrilla is present in shallow areas throughout the lake. Hydrilla is a particularly prolific aquatic macrophyte and has infested several reservoirs in the Neuse basin. To date, no measures have been taken to control the hydrilla in Lake Johnson. As large-scale infestation may alter nutrient concentrations in a reservoir, an accurate representation of the trophic state of the lake is not possible without some estimate of macrophytic coverage.

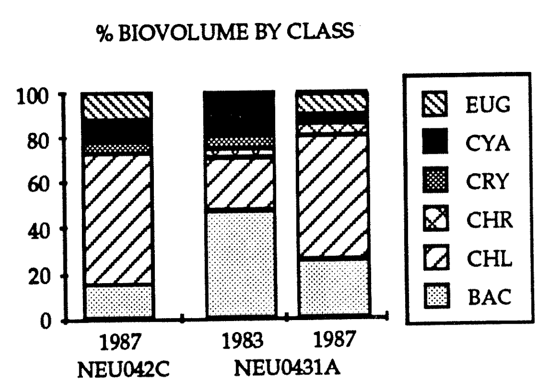
The TSI was -2.8 in 1987, which is comparable to historical values. At the time of assessment, no violations of state water quality standards were observed at Lake Johnson, but the lake was classified as partially supporting designated uses due to hydrilla infestation.



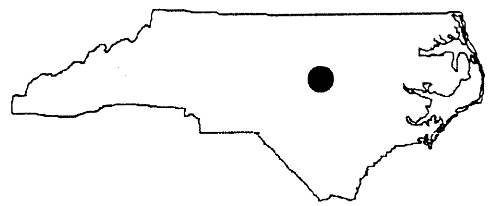








LAKE RALEIGH



COUNTY:	Wake	BASIN:	Neuse
SURFACE AREA:	36 hectares (90 acres)	USGS TOPO:	Raleigh West, N.C.
CLASS:	WS , B NSW	LAKE TYPE:	Reservoir

LATEST NCTSI:	- 0.2	TROPHIC STATE:	Mesotrophic
SAMPLING DATE:	September 15, 1988	ADDITIONAL COVERAGE:	Fecal, Water Supply Parameters
SECCHI DEPTH:	0.95 m	CONDUCTIVITY:	58 µmhos/cm^2
TOTAL PHOSPHORUS:	0.02 mg/l	DISSOLVED OXYGEN:	7.2 - 13.7 mg/l
TOTAL ORGANIC NITROGEN:	0.275 mg/l	TEMPERATURE:	24.9 - 25.3 °C
CHLOROPHYLL-A:	13.5 µg/l	pH:	5.8 - 8.4 s.u.

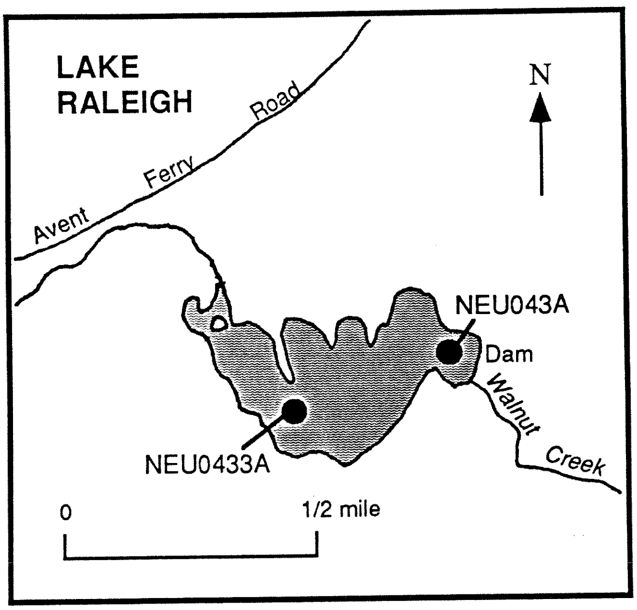
Lake Raleigh is a man-made impoundment that was once used as a water supply for the City of Raleigh. The original earthen dam was constructed in 1914 and was raised two feet in 1919. The water from the lake primarily served the downtown Raleigh area. In 1986, the North Carolina State University gained control of Lake Raleigh and the surrounding land to build a new Centennial Campus. The lake has a drainage of 32 km^2, and Walnut Creek is the main tributary. Land use in the drainage area is urban and residential with some forest and agriculture.

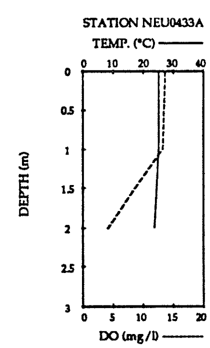
In 1988, Lake Raleigh was classified as mesotrophic. Nutrient concentrations in the photic zone were relatively low at both stations. The water column was not thermally stratified.

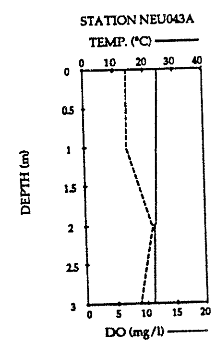
Summer algal populations and nutrient concentrations may have been affected by the presence of aquatic macrophytes. Field notes indicated that hydrilla was present along all shorelines. This aquatic macrophyte is prolific and, in the western arm of the lake, was present in waters up to two meters deep. No estimates of coverage have been made nor have control measures been undertaken to date. Increased coverage by hydrilla could impair the use of Lake Raleigh by disrupting the native biotic community and by interfering with recreation. Fathometry work would be beneficial in determining the extent of macrophytic coverage and the potential for additional coverage in the future.

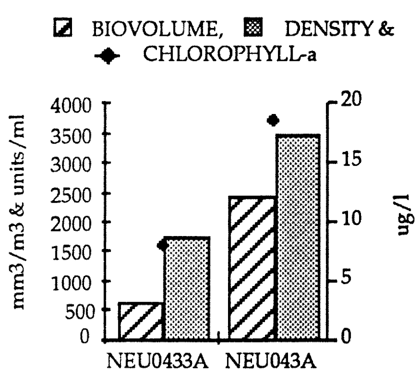
Populations of phytoplankton in Lake Raleigh were moderately low with biovolumes ranging from 653 to 2,475 mm^3/m^3 and densities extending from 1,770 to 3,506 units/ml. Chlorophyll-a concentrations increased from upstream to downstream, along with populations of phytoplankton. Euglenophytes and cyanophytes were codominant at both lake stations. In addition, station NEU0433A contained a diversity of dominant algal classes. Among the cyanophytes, Anabaena portoricensis, a large filamentous alga, was dominant.

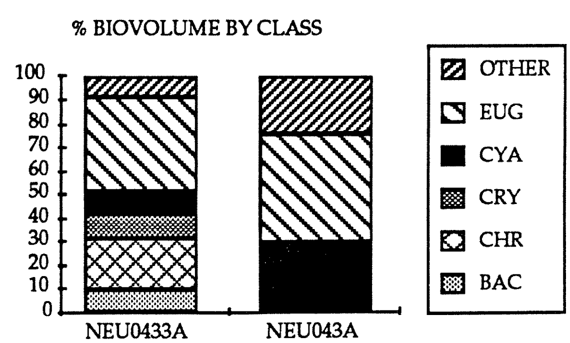
The TSI in 1988 was -0.2. Since this was only the second year that Lake Raleigh was monitored, there is insufficient historical data to determine trends in water quality. At the time of assessment, no violations of state water quality standards were observed at Lake Raleigh. However, the lake only partially supported designated uses as a result of the hydrilla infestation. Field observations around the lake in 1987, 1988 and 1989 also noted a considerable amount of construction in the watershed. As work on the Centennial Campus continues, it is likely that increased siltation of the lake and decreased water quality will occur. Additional surveillance of the lake will be useful in determining the effects of construction and subsequent development on water quality.



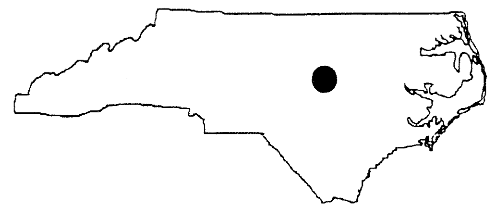








LAKE WHEELER



COUNTY:	Wake	BASIN:	Neuse
SURFACE AREA:	223 hectares (550 acres)	USGS TOPO:	Lake Wheeler, N.C.
CLASS:	WS NSW	LAKE TYPE:	Reservoir

LATEST NCTSI:	1.3	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	August 10, 1987	ADDITIONAL COVERAGE:	None
SECCHI DEPTH:	0.9 m	CONDUCTIVITY:	67 - 88 µmhos/cm^2
TOTAL PHOSPHORUS:	0.04 mg/l	DISSOLVED OXYGEN:	7.2 - 8.2 mg/l
TOTAL ORGANIC NITROGEN:	0.40 mg/l	TEMPERATURE:	25.9 - 32.7 °C
CHLOROPHYLL-A:	14 µg/l	pH:	7.2 - 8.2 s.u.

Lake Wheeler is located in southwestern Wake County upstream of Lake Benson on Swift Creek. The lake has a drainage area of 99 km^2. About half of the watershed is forested, but urban and agricultural areas are also significant. The lake is relatively shallow with a maximum depth of nine meters and an average depth of four meters. Lake Wheeler has a volume of 7,600 m^3 and an average hydraulic retention time of 72 days. In addition to serving as an auxiliary water supply for the City of Raleigh, Lake Wheeler is used extensively for recreational purposes including sail and motor boat racing, triathlon competitions, and canoe and kayak racing.

In 1987, Lake Wheeler exhibited characteristics of a eutrophic lake. Physical measurements indicated that the lake was stratified. Nutrients were slightly elevated in the upper reaches compared to moderate concentrations near the dam. This spatial pattern is typically observed in reservoirs.

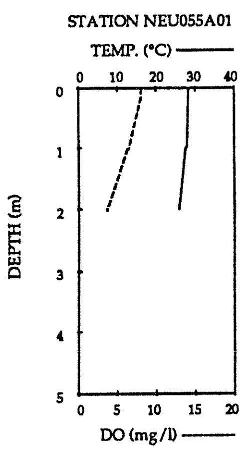
In recent years, there has been a tremendous increase in residential development in the Lake Wheeler watershed. The number of residential units is predicted to increase three-fold or four-fold by the year 2000. It has been demonstrated that residential development tends to increase phosphorus loading in a watershed. Under the developmental pressures foreseen for Lake Wheeler, water quality models have predicted that the mean phosphorus concentration of this lake may double (Clements 1984). This increase would make Lake Wheeler one of the most enriched lakes in North Carolina. The projected inputs of phosphorus would increase phytoplanktonic productivity and could lead to nitrogen limitation of the system. This change would, in turn, favor more noxious types of phytoplankton.

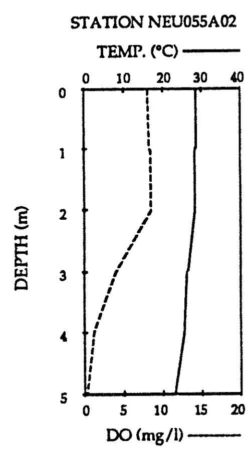
Phytoplankton were dominated in August 1987 by the blue-green algae Anabaena levanderi and Phormidium angustissimum. Cyanophytes (blue-green algae) contributed 46% of the density and 74% of the biovolume at NEU055A01 and 61% of the density and 87% of the biovolume at NEU055A02.

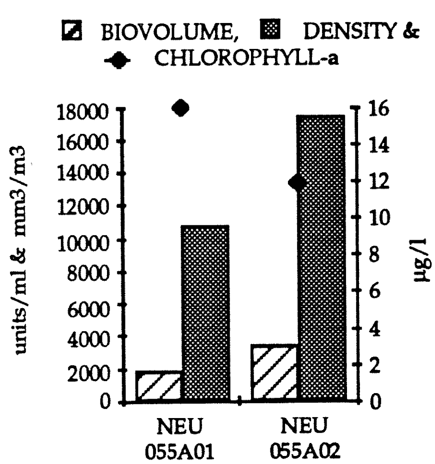
As with other shallow piedmont reservoirs, Lake Wheeler is experiencing problems with aquatic macrophytes. Roughly 50% of the lake is infested with hydrilla (Hydrilla verticillata), and the portion of the lake upstream of state road 1379 is also infested with American lotus (Nelumbo lutea). Efforts to control macrophytes have included both chemical and biological treatments. In September of 1985, 2,000 sterile grass carp were introduced into the lake as a biological control by the North Carolina Division of Water Resources and the Wildlife Resources Commission. Visual observations through 1986 indicated little or no control. Therefore, in the spring of 1987, an additional 2,000 carp were introduced into the lake.

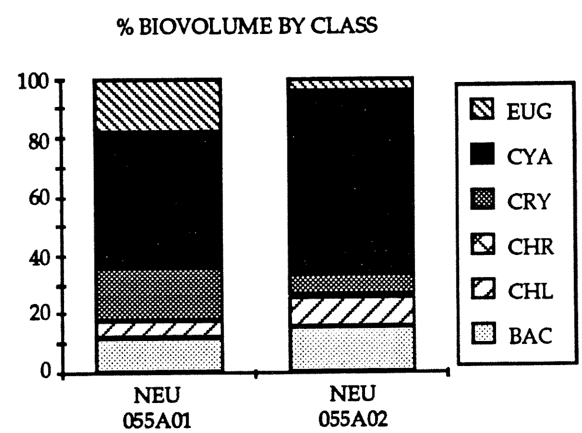
DEM conducted a two-year special study of the ensuing changes in water quality, the macrophyte community, and algal dynamics. Since the introduction of the grass carp, the area infested upstream of state road 1379 has decreased by 50%. The biomass of hydrilla is also decreasing, although there has been little change in the plant's areal distribution in the lake (EHNR 1991a).

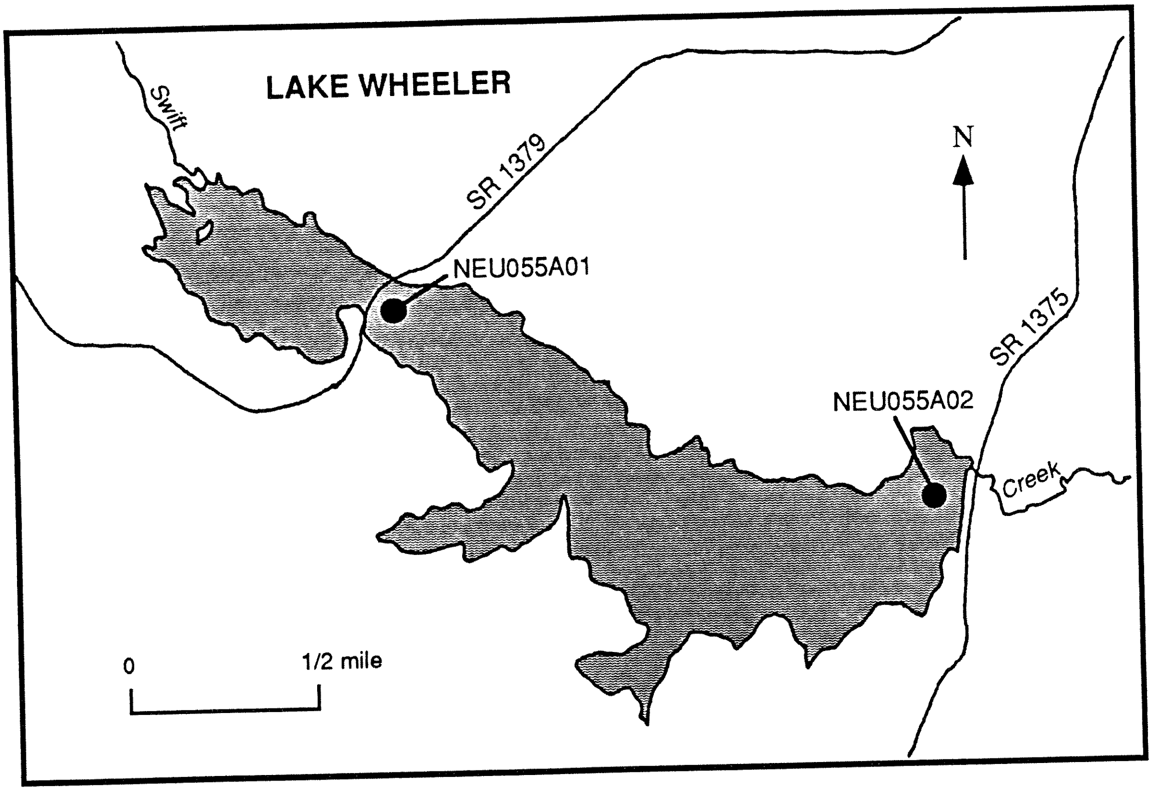
Lake Wheeler had a TSI of 1.3 indicating it is eutrophic. At the time of assessment, no violations of state water quality standards were observed at Lake Wheeler. However, the lake was classified partially supporting designated uses as a result of hydrilla infestation. DEM will continue to study the effects of the macrophyte control efforts underway at Lake Wheeler.



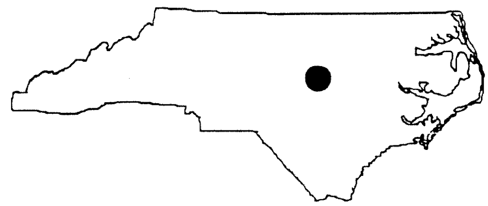







LAKE WHEELER
Swift
Creek
SR 1379
SR 1375
NEU055A01
NEU055A02
N
0
1/2 mile

LAKE BENSON



COUNTY:	Wake	BASIN:	Neuse
SURFACE AREA:	178 hectares (440 acres)	USGS TOPO:	Garner, N.C.
CLASS:	WS NSW	LAKE TYPE:	Reservoir

LATEST NCTSI:	- 0.5	TROPHIC STATE:	Mesotrophic
SAMPLING DATE:	August 15, 1988	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	1.6 m	CONDUCTIVITY:	52 - 68 µmhos/cm^2
TOTAL PHOSPHORUS:	0.025 mg/l	DISSOLVED OXYGEN:	10.1 - 14.6 mg/l
TOTAL ORGANIC NITROGEN:	0.32 mg/l	TEMPERATURE:	25.0 - 25.7 °C
CHLOROPHYLL-A:	10 µg/l	pH:.	8.8 - 9.0 s.u.

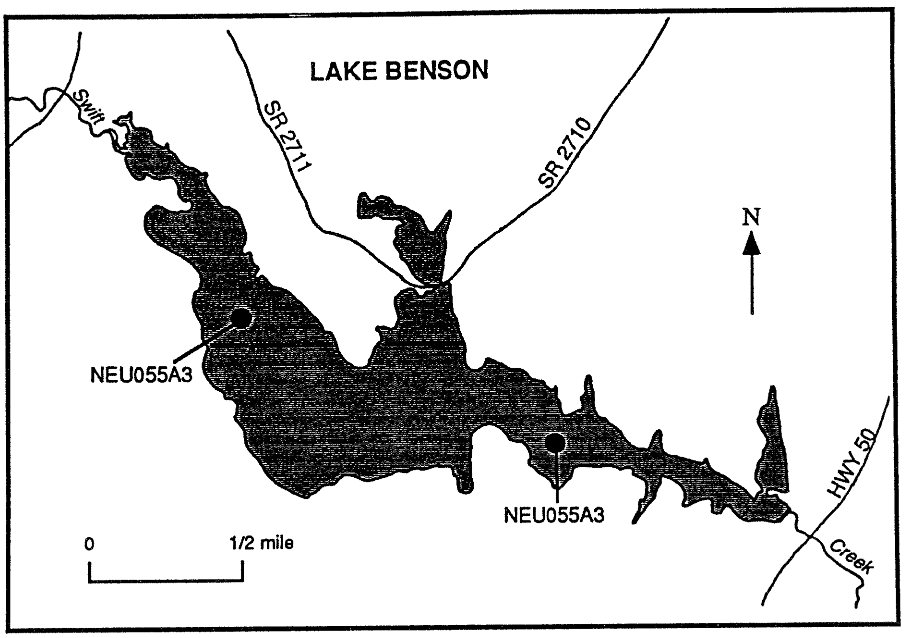
Lake Benson is located in southern Wake County. The first impoundment on the site, called Rand's Mill Pond, was built in 1844. In 1927, the City of Raleigh purchased the land and the dam for use as a water supply. The reservoir was expanded in 1953 to bring the total storage capacity to approximately 3.6 x 10^6 m^3. Currently, the lake is used as a secondary water supply and for recreation. The lake has a drainage area of 168 km^2, a surface area of 178 hectares, and a maximum depth of six meters. The primary tributary to the lake is Swift Creek. The topography of the drainage area is characterized by rolling hills. Approximately half of the watershed is forested. Urban and residential land uses are likely to increase as the Raleigh area continues to develop.

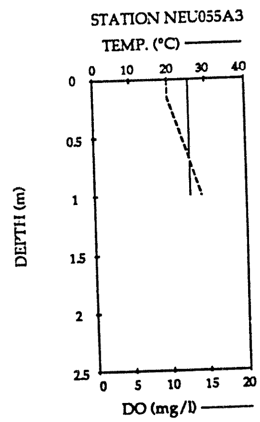
Water quality characteristics of Lake Benson were similar to other piedmont reservoirs. When sampled on September 15, 1988, the relatively shallow lake was not stratified. Nutrients were moderate and fecal coliform bacteria were below laboratory detection limits.

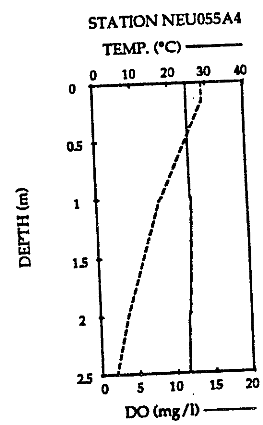
Moderately low levels of algal biovolume, density, and chlorophyll-a were found in Lake Benson in contrast to previous results in 1987. A diversity of chlorophytes and cyanophytes were dominant at both stations while cryptophytes were codominant at station NEU055A4. Small cyanophytes such as Anabaenopsis raciborskii, Phormidium angustissima, Aphanocapsa delicatissima, and Lyngbya species A contributed to the algal density. These cyanophytes are indicative of nutrient enrichment and are often found in eutrophic piedmont reservoirs.

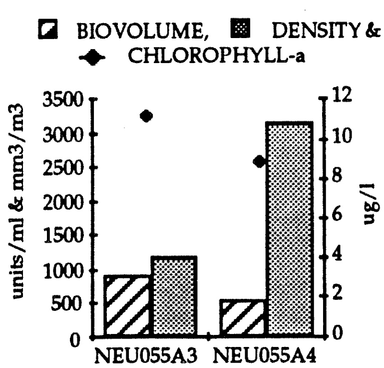
As with other reservoirs in the Neuse River Basin, Lake Benson was infested with aquatic macrophytes. The upper end of the lake supported dense growths of American lotus (Nelumbo lutea) and hydrilla (Hydrilla verticillata). Field observations indicated heavy infestation around the boathouse, dam, western edge and at the island near the center of the lake. The Department of Agriculture confirmed the presence of hydrilla in Lake Benson in 1980; however, no control measures have been undertaken.

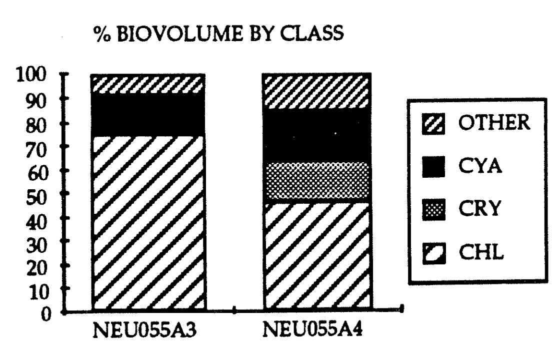
In 1988 the TSI was -0.5, which is the lowest value ever recorded at the lake. No violations of state water quality standards were observed at the time of assessment. However, Lake Benson has been categorized as partially supporting designated uses as a result of the macrophytic infestation of the lake.



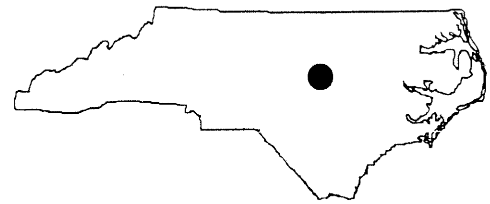








BASS LAKE



COUNTY:	Wake	BASIN:	Neuse
SURFACE AREA:	38 hectares (95 acres)	USGS TOPO:	Apex, N.C.
CLASS:	B NSW	LAKE TYPE:	Reservoir

LATEST NCTSI:	2.4	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	August 9, 1988	ADDITIONAL COVERAGE:	Fecal
SECCHI DEPTH:	0.9 m	CONDUCTIVITY:	53 - 54 µmhos/cm^2
TOTAL PHOSPHORUS:	0.06 mg/l	DISSOLVED OXYGEN:	7.3 - 7.7 mg/l
TOTAL ORGANIC NITROGEN:	0.465 mg/l	TEMPERATURE:	29.9 - 30.4 °C
CHLOROPHYLL-A:	22 µg/l	pH:	5.9 - 6.6 s.u.

Bass Lake is a private fishing lake located near Holly Springs in Wake County. The lake is primarily fed by Basal Creek, but there are also two intermittent, unnamed tributaries entering the lake. The original impoundment was created when Basal Creek was dammed to create a rice paddy. This effort was unsuccessful and subsequently the dam was raised and a gristmill installed.

Access is restricted to 50 fishing club members. A section of the lake has been donated to the Nature Conservancy and is used as a waterfowl refuge. Bass Lake is classified B NSW, and the land use around the lake is changing from forest and agriculture to residences.

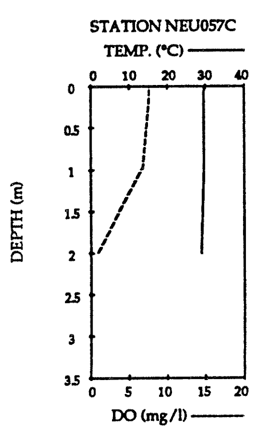
During 1986 and 1987, extensive water quality work was done on Bass Lake to determine the effects of a new residential development being constructed on the upper end of the lake. In July 1986, chlorophyll-a concentrations exceeded the North Carolina standard of 40 µg/l at both stations. Drought conditions may have contributed to these high levels. In addition, slightly elevated fecal coliform concentrations were found in the feeder streams in May 1986, but levels within the lake met water quality standards. Several minor dischargers located upstream of the lake may have contributed to the observed fecal coliforms. Overall, the study was unable to provide direct evidence of water quality degradation attributable to the new residential development.

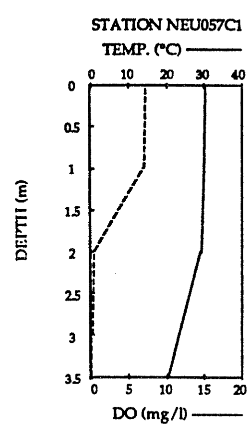
When Bass Lake was sampled on August 9, 1988, the lake was eutrophic. Low secchi depth, elevated nutrients and high chlorophyll-a values were documented. Physical measurements indicated that the lake was stratified with dissolved oxygen levels approaching zero near the bottom of the lake. Analyses for fecal coliforms revealed values well within state water quality standards.

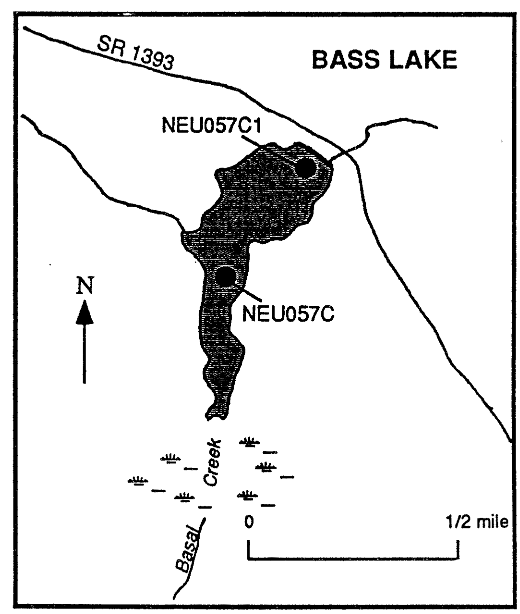
Composition of phytoplankton in 1988 was similar to that of 1987. Small filamentous blue-green algae, Anabaenopsis raciborskii and Lyngbya spp., continued to dominate Bass Lake and contributed to the high density (22,011 - 22,448 units/ml). These cyanophytes are commonly found in enriched piedmont reservoirs. Predominance by cyanophytes along with moderately high algal density reflect the eutrophic condition of Bass Lake.

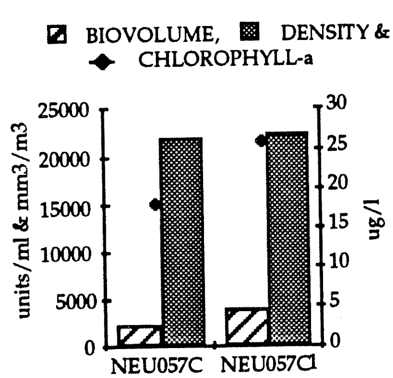
Four species of aquatic macrophytes were collected from Bass Lake in the spring of 1986: Eleocharis species (Spikerush), Potamogeton diversifolius (Pondweed), Egeria densa (Elodea), and Ceratophyllum demersum (Hornwort). These aquatic plants provide excellent cover for small fish and insects and are partially eaten by waterfowl. At the present abundance, they pose no threat to water quality.

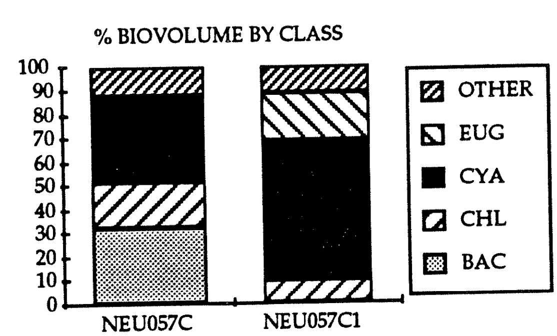
The TSI value was 2.4 in 1988, indicating Bass Lake was eutrophic. At the time of assessment, the lake fully supported designated uses. However, as residential development continues around the lake, future monitoring is warranted to ensure that the water quality of the lake is maintained.



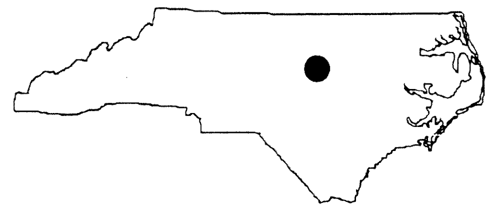








WENDELL LAKE



COUNTY:	Johnston	BASIN:	Neuse
SURFACE AREA:	40 hectares (100 acres)	USGS TOPO:	Flowers, N.C.
CLASS:	C NSW	LAKE TYPE:	Reservoir

LATEST NCTSI:	7.7	TROPHIC STATE:	Hypereutrophic
SAMPLING DATE:	August 9, 1988	ADDITIONAL COVERAGE:	None
SECCHI DEPTH:	0.7 m	CONDUCTIVITY:	71 - 72 µmhos/cm^2
TOTAL PHOSPHORUS:	0.43 mg/l	DISSOLVED OXYGEN:	5.5 - 7.0 mg/l
TOTAL ORGANIC NITROGEN:	1.045 mg/l	TEMPERATURE:	27.9 - 28.1 °C
CHLOROPHYLL-A:	130 µg/l	pH:	6.5 - 6.7 s.u.

Wendell Lake is located in Johnston County on Buffalo Creek, where it is used for recreational fishing. Access is limited to members of the Wendell Lake Fishing Club; however, water quality problems have prompted state involvement with this privately-owned lake. The lake was constructed in 1927 to power a grist mill operation. Over the years it has lost much storage capacity, and presently has a surface area of 40 hectares and a mean depth of 1.5 meters.

Land use in the watershed is agricultural, residential, forested, and wetlands. Buffalo Creek, the main tributary of the lake, is a slow-moving, blackwater creek whose flow is restricted by numerous beaver dams upstream of Wendell Lake.

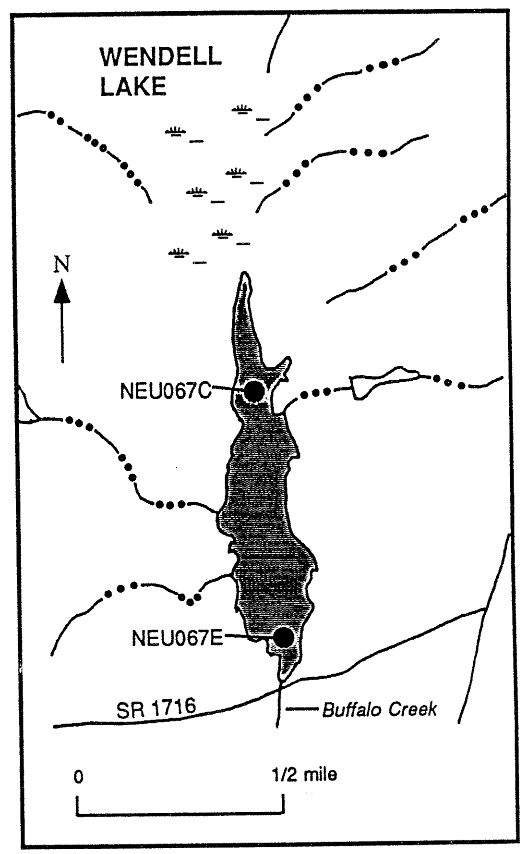
Wendell Lake was sampled on August 11, 1988. Physical data showed that the upstream station was not stratified. The station near the dam was weakly stratified in terms of temperature; however, the dissolved oxygen profile was strongly stratified, with oxygen depletion below a depth of one meter. Water transparency (secchi) measured 0.7 meters, which is low compared to similar lakes in the North Carolina piedmont. Chlorophyll-a concentrations were more than three times the state standard of 40 µg/l at both stations. Phosphorus concentrations were high, as were ammonia and organic nitrogen.

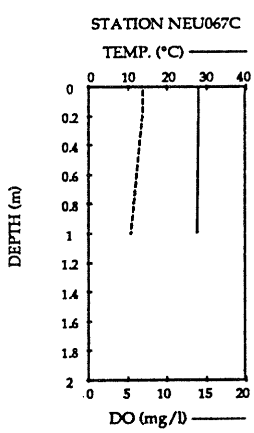
Nutrient concentrations were sufficient to support large populations of aquatic plants, as evidenced by the nuisance amounts of algae and duckweed observed in the lake. Algal populations were dominated by chlorophytes at both stations. Cyanophytes and euglenophytes were also prevalent at the upper lake station, while cryptophytes were prevalent near the dam. The biovolumes (1,474 and

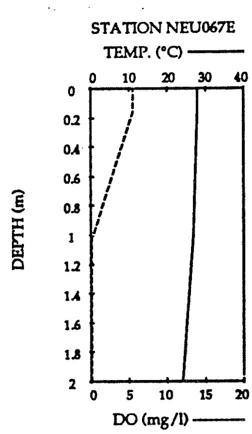
1,822 mm^3/m^3) and densities (2,640 and 4,408 units/ml) of the sample do not reflect the high chlorophyll-a concentrations found at both stations; however, the predominance of cyanophytes and euglenophytes at the upper station signifies enriched conditions.

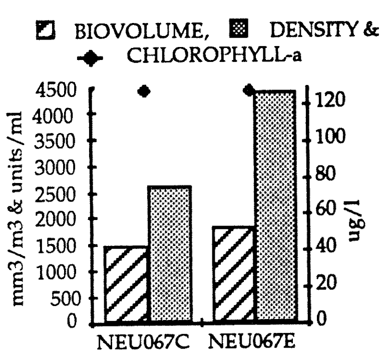
Blooms of blue-green algae were also documented in 1987, 1989, and 1990 with chlorophyll-a concentrations ranging from 130 to 270 µg/l.

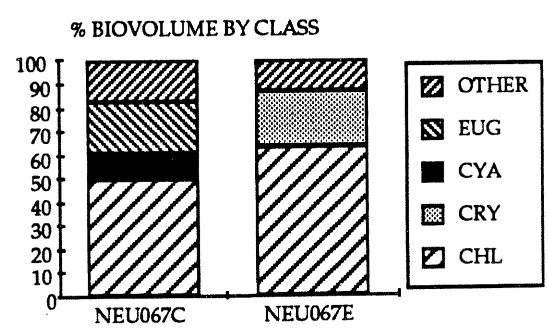
A TSI of 7.7 for Wendell Lake indicated hypereutrophic conditions. Severe depletion of oxygen at NEU067E and observations of nuisance macrophytes and phytoplankton further support this classification. Wendell Lake does not support designated uses, and efforts are underway to improve water quality conditions. Much of the nutrient enrichment seems to stem from upstream wastewater discharges into Buffalo Creek by the Town of Wendell and East Wake High School. The recently renewed permit for the Town of Wendell WWTP includes stringent phosphorus limits, and operations at the East Wake facility have improved.



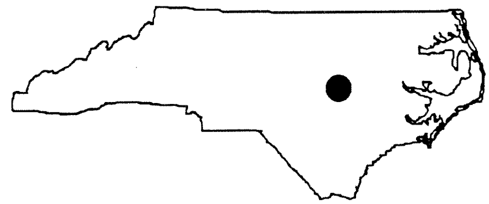








CLIFFS OF THE NEUSE LAKE



COUNTY:	Wayne	BASIN:	Neuse
SURFACE AREA:	4 hectares (10 acres)	USGS TOPO:	Williams, N.C.
CLASS:	B NSW	LAKE TYPE:	Reservoir

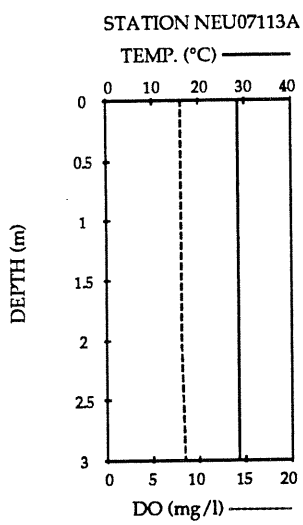
LATEST NCTSI:	- 0.9	TROPHIC STATE:	Mesotrophic
SAMPLING DATE:	July 14, 1988	ADDITIONAL COVERAGE:	Fecal
SECCHI DEPTH:	3.1 m	CONDUCTIVITY:	57 μmhos/cm^2
TOTAL PHOSPHORUS:	0.03 mg/l	DISSOLVED OXYGEN:	8.1 mg/l
TOTAL ORGANIC NITROGEN:	0.28 mg/l	TEMPERATURE:	28.7 °C
CHLOROPHYLL-A:	14 μg/l	pH:	3.8 s.u.

Cliffs of the Neuse Lake is located in a state-owned park of the same name in Wayne County. The four-hectare lake has a volume of 1.3×10^5 m^3 and a maximum depth of 18 meters. Mill Creek, the only significant tributary, was impounded to form the lake in 1953. The small (0.88 km^2) watershed is 100% forested and contained entirely in the park. A small manmade beach facilitates swimming at the lake.

Cliffs of the Neuse Lake was sampled on July 14, 1988. The water column was clear and well mixed with acidic pH concentrations, which are normal for this lake. Total phosphorus and nitrogen values were low to moderate. Chlorophyll-a concentrations were also moderate.

A slightly elevated estimate of algal biovolume (5,094 mm^3/m^3) was present, although algal density was low. The dinoflagellates Peridinium aciculiferum and Peridinium pusillum, both algae which commonly occur in the coastal plain, were responsible for the elevated biovolume.

A TSI of -0.9 indicated Cliffs of the Neuse Lake was mesotrophic in 1988. With few manmade influences, the lake is likely to remain mesotrophic for some time. All uses were supported at the time of this assessment.


STATION NEU07113A
TEMP. (°C)
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DEPTH (m)
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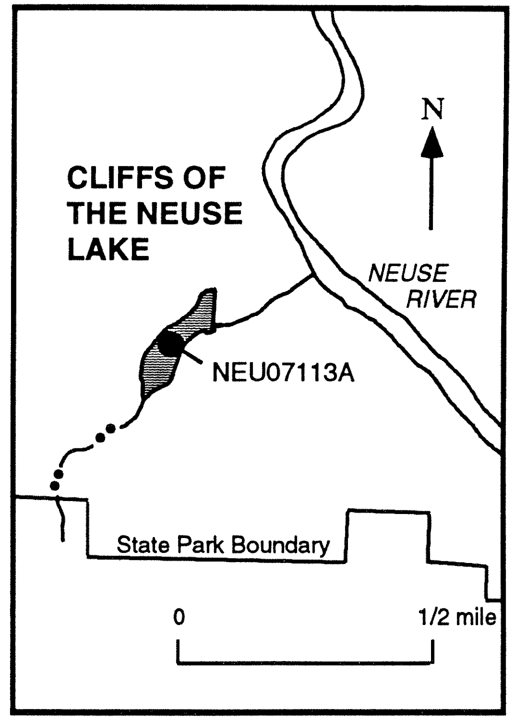
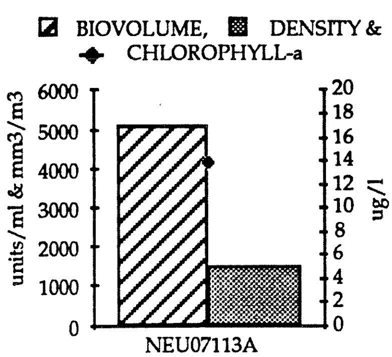

CLIFFS OF THE NEUSE LAKE
N
NEUSE RIVER
NEU07113A
State Park Boundary
0
1/2 mile


BIOVOLUME, DENSITY & CHLOROPHYLL-a
units/ml & mm3/m3
6000
5000
4000
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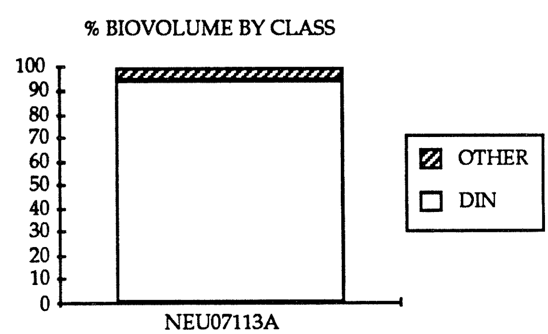
% BIOVOLUME BY CLASS
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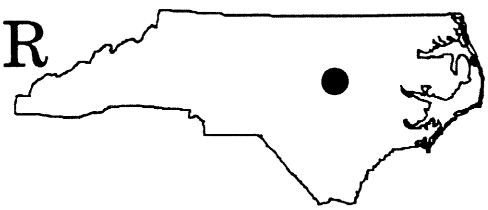
TOISNOT RESERVOIR



COUNTY:	Wilson	**BASIN:**	Neuse
SURFACE AREA:	4 hectares (10 acres)	**USGS TOPO:**	Wilson, N.C.
CLASS:	WS NSW	**LAKE TYPE:**	Reservoir

LATEST NCTSI:	4.0	**TROPHIC STATE:**	Eutrophic
SAMPLING DATE:	August 11, 1988	**ADDITIONAL COVERAGE:**	Water Supply Parameters
SECCHI DEPTH:	0.9 m	**CONDUCTIVITY:**	70 µmhos/cm^2
TOTAL PHOSPHORUS:	0.13 mg/l	**DISSOLVED OXYGEN:**	6.2 mg/l
TOTAL ORGANIC NITROGEN:	0.55 mg/l	**TEMPERATURE:**	no data
CHLOROPHYLL-A:	38 µg/l	**pH:**	6.0 s.u.

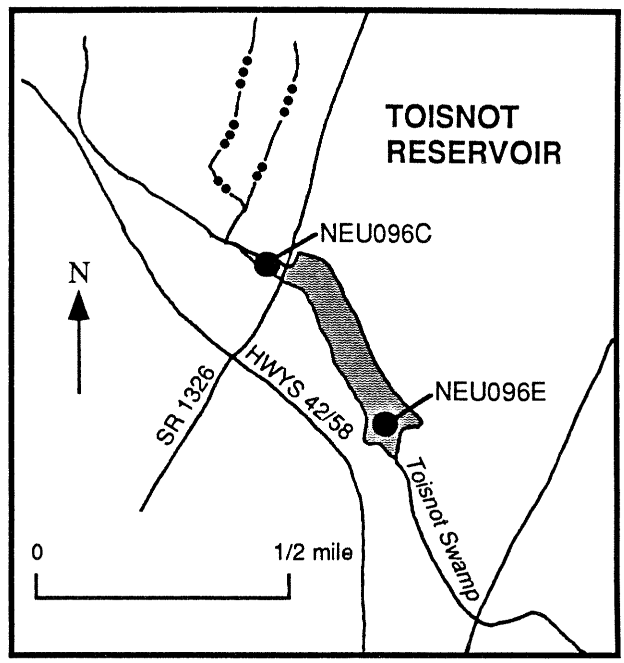
Toisnot Reservoir was built between 1961 and 1963 just north of Wilson. The drainage area is swampy and flat. This lake has experienced problems with filling and nutrients because of nonpoint source pollution. Volume of this small reservoir is 1.4 x 10^5 m^3 with an average depth of 1.5 meters. Toisnot Swamp is the major tributary. Land use categories in the watershed include agriculture, forestry, and residential areas. The lake serves as a water supply for the City of Wilson.

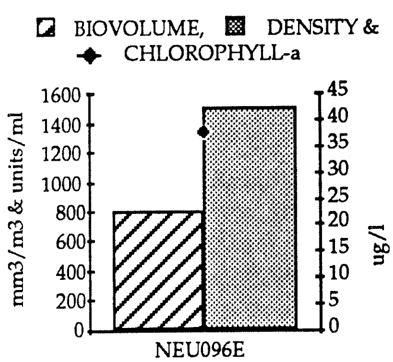
Toisnot Reservoir was sampled on August 11, 1988. At this time, Toisnot Reservoir was choked with weeds and filled with sediment. Because the lake was less than one meter deep, no vertical stratification was observed. Dissolved oxygen levels were extremely variable, depending on the specific placement of water quality measuring devices in relation to the macrophytes or mats of algae. Dense growths of aquatic plants are known to exert a strong influence on dissolved oxygen. Total phosphorus and total nitrogen were extremely high. Chlorophyll-a was just below the state standard. The water had a brownish tint characteristic of lakes dominated by swampy inflows. Turbidity and solids concentrations were low.

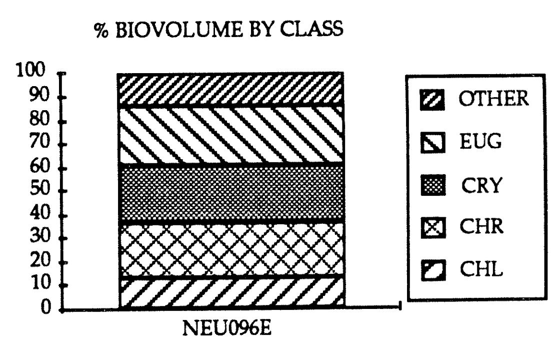
Chlorophytes, chrysophytes, cryptophytes and euglenophytes dominated the algal community in Toisnot Reservoir. Although an elevated chlorophyll-a of 38 µg/l was recorded, phytoplanktonic populations were relatively low with a biovolume of 814 mm^3/m^3 and density of 1,520 units/ml.

Dominant algal species found in Toisnot Reservoir included Mallamonas caudata, a chrysophyte, Cryptomonas erosa, a cryptophyte, and Trachelomonas volvocina, a euglenophyte, all of which are commonly found in North Carolina.

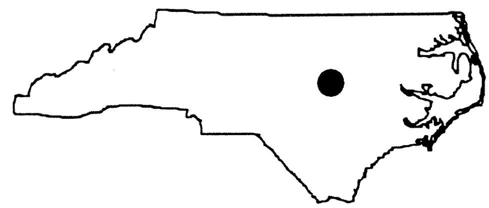
A TSI of 4.0 and on-site observations indicate Toisnot Reservoir is a hypereutrophic lake with a history of water quality problems. Uses were not met at the time of this assessment. The City of Wilson dredged the lake after this sampling event in order to increase the volume and reduce the weed populations. Dredging should have a beneficial effect on the use of this reservoir as a water supply.







BUCKHORN RESERVOIR



COUNTY:	Wilson	BASIN:	Neuse
SURFACE AREA:	304 hectares (750 acres)	USGS TOPO:	Lucama, N.C.
CLASS:	WS NSW	LAKE TYPE:	Reservoir

LATEST NCTSI:	2.7	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	August 11, 1988	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	1.05 m	CONDUCTIVITY:	15 - 69 µmhos/cm^2
TOTAL PHOSPHORUS:	0.06 mg/l	DISSOLVED OXYGEN:	6.4 - 7.1 mg/l
TOTAL ORGANIC NITROGEN:	0.5 mg/l	TEMPERATURE:	29.0 °C
CHLOROPHYLL-A:	33.5 µg/l	pH:	6.9 - 7.8 s.u.

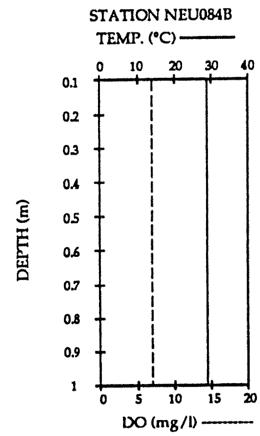
Buckhorn Reservoir is a shallow, 304-hectare water supply for the City of Wilson. Although the city currently uses Toisnot Reservoir and Wiggins Mill Reservoir as primary sources of drinking water, there are plans to increase the size of Buckhorn Reservoir. If this project is undertaken, Buckhorn Reservoir will become the main water supply for the City of Wilson.

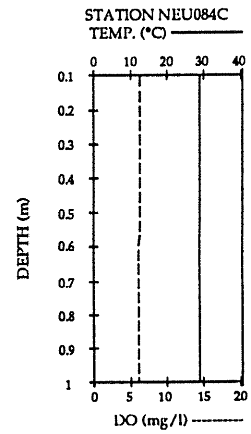
Buckhorn Reservoir was impounded in 1976. The lake has an average depth of 1.2 meters and a volume of 3.8 x 10^6 m^3. The flat terrain in the watershed is primarily farmed and forested. Turkey Creek and Moccasin Creek are the main tributaries of the lake.

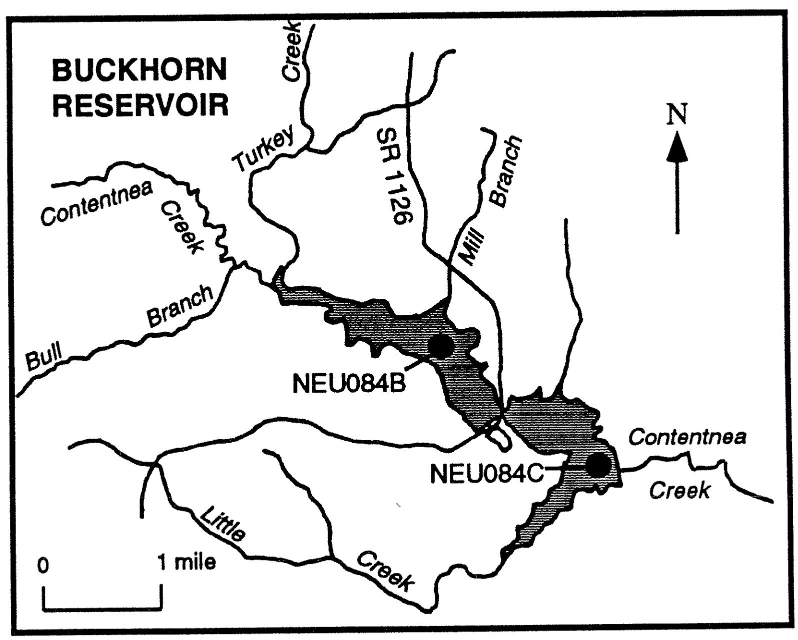
Buckhorn Reservoir was sampled on August 11, 1988. The water column of this shallow coastal reservoir was mixed. Secchi transparency readings indicated that sunlight penetrated to the lake bed. Nutrients, especially total phosphorus, were elevated in the lake. Chlorophyll-a concentrations violated the state standard of 40 µg/l near the dam.

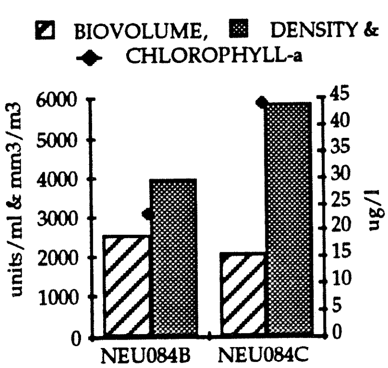
The portion of the reservoir upstream of state road 2112 was filled with aquatic weeds. Buckhorn Reservoir contained a diversity of algal classes including bacillariophytes, chlorophytes, chrysophytes, cryptophytes, cyanophytes, dinoflagellates, and euglenophytes. Euglenophytes and dinoflagellates were most prevalent. At the upstream station, cryptophytes dominated density estimates, while small filamentous blue-green algae (Lyngbya species A) were dominant near the dam. Although algal biovolumes and densities were not particularly high, elevated chlorophyll-a concentrations of 23 and 44 ug/l reflected the eutrophic nature of Buckhorn Reservoir.

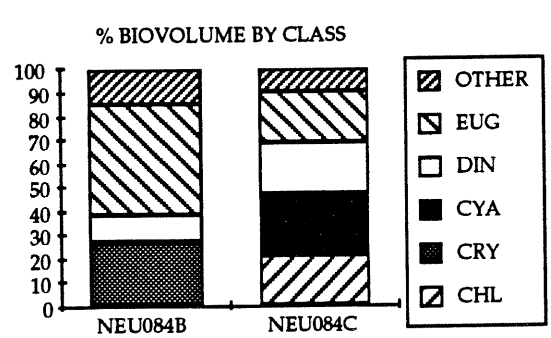
A TSI of 2.7 for Buckhorn Reservoir indicated that it was eutrophic. Buckhorn Reservoir supported designated uses, but these uses could be impaired in the future if nutrient enrichment continues.



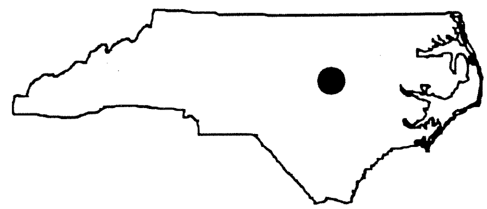








WIGGINS MILL RESERVOIR



COUNTY:	Wilson	**BASIN:**	Neuse
SURFACE AREA:	81 hectares (200 acres)	**USGS TOPO:**	Wilson, N.C.
CLASS:	WS NSW	**LAKE TYPE:**	Reservoir

LATEST NCTSI:	3.8	**TROPHIC STATE:**	Eutrophic
SAMPLING DATE:	August 11, 1988	**ADDITIONAL COVERAGE:**	Water Supply Parameters
SECCHI DEPTH:	0.7 m	**CONDUCTIVITY:**	65 - 70 µmhos/cm^2
TOTAL PHOSPHORUS:	0.075 mg/l	**DISSOLVED OXYGEN:**	7.0 - 7.1 mg/l
TOTAL ORGANIC NITROGEN:	0.465 mg/l	**TEMPERATURE:**	28.5 - 29.0 °C
CHLOROPHYLL-A:	63.5 µg/l	**pH:**	6.7 - 6.8 s.u.

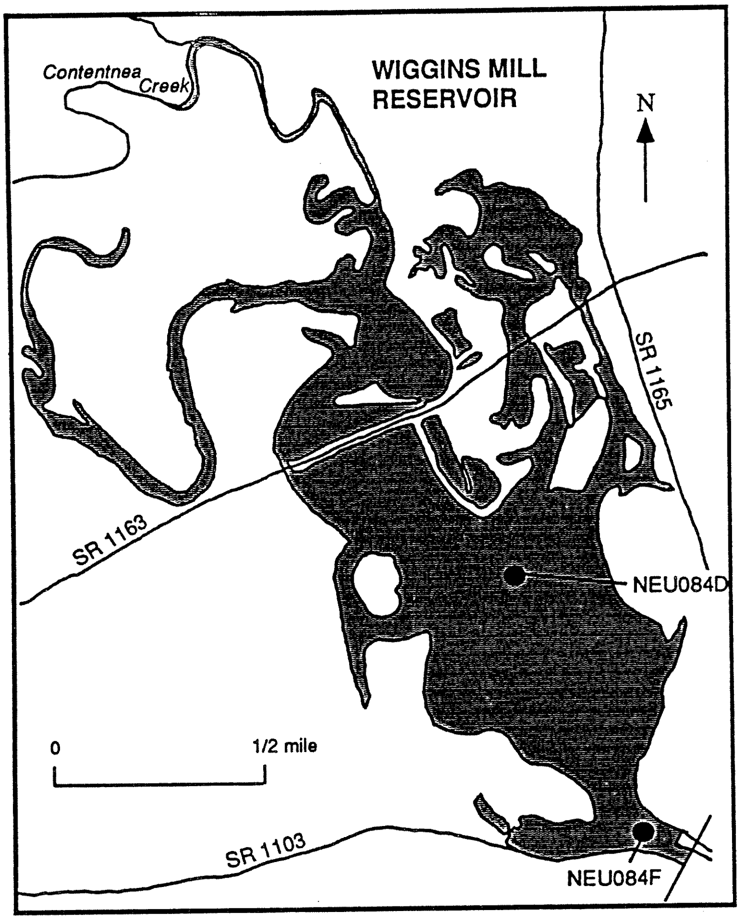
Contentnea Creek was impounded in 1915 to form Wiggins Mill Reservoir. Forty years later the dam was raised one foot, increasing the lake to 81 hectares in surface area with a volume of 5.7 x 10^5 m^3. Average depth in the reservoir is approximately half a meter. The City of Wilson owns Wiggins Mill Reservoir and uses it as a water supply. Access is restricted to boats with electric motors.

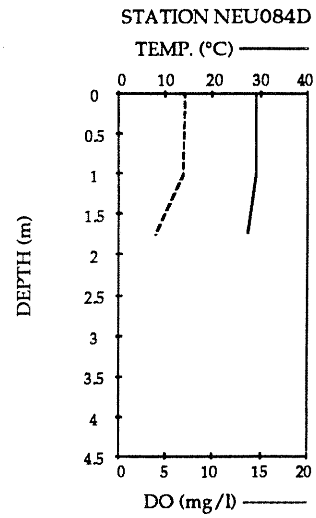
Land use in the Contentnea Creek watershed is dominated by agriculture with some forest, swamp, and residential development. Topography is flat.

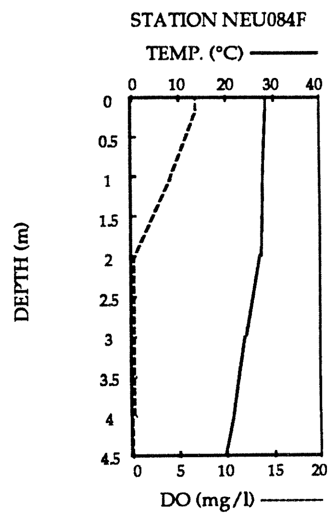
Wiggins Mill Reservoir was sampled on August 11, 1988. The water column was stratified, and water transparency was poor. Nutrients, particularly total phosphorus, were elevated. Chlorophyll-a concentrations exceeded the state standard of 40 µg/l at both stations, indicating high productivity. Metals including iron and manganese were detected at levels within state standards.

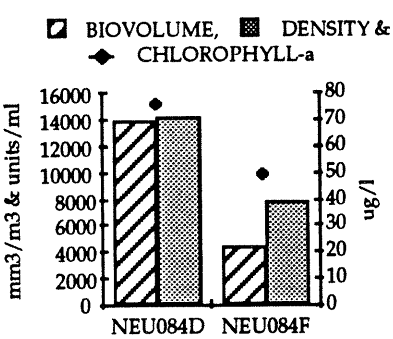
Elevated algal populations were observed in Wiggins Mill Reservoir. Biovolume ranged from 4,416 to 13,892 mm^3/m^3 with densities ranging from 7,861 to 14,325 units/ml. Levels of phytoplankton at the upstream station indicated bloom conditions. A diversity of algal classes were represented in Wiggins Mill Reservoir, including euglenophytes, cyanophytes, dinoflagellates, chrysophytes, chlorophytes and bacillariophytes.

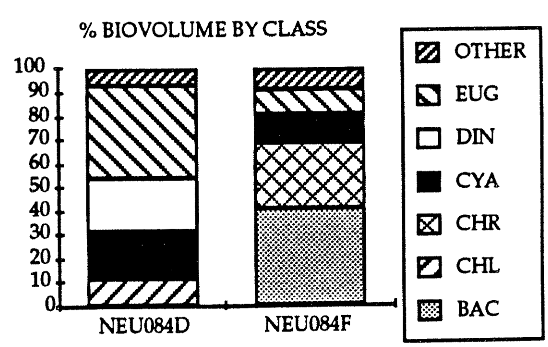
A TSI of 3.8 indicated Wiggins Mill Reservoir was eutrophic. Continued nutrient enrichment could impair uses of this lake in the future.


WIGGINS MILL
RESERVOIR
Contentnea Creek
N
SR 1165
SR 1163
NEU084D
0
1/2 mile
SR 1103
NEU084F

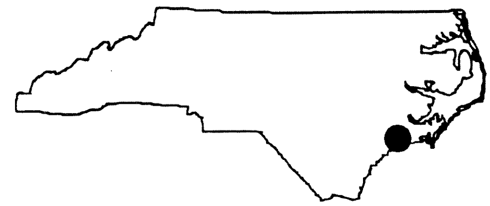

STATION NEU084D
TEMP. (°C)
0 10 20 30 40
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
DEPTH (m)
0 5 10 15 20
DO (mg/l)


STATION NEU084F
TEMP. (°C)
0 10 20 30 40
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
DEPTH (m)
0 5 10 15 20
DO (mg/l)


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/m3 & units/ml
16000
14000
12000
10000
8000
6000
4000
2000
0
80
70
60
50
40
30
20
10
0
ug/l
NEU084D NEU084F


% BIOVOLUME BY CLASS
100
90
80
70
60
50
40
30
20
10
0
NEU084D
NEU084F
OTHER
EUG
DIN
CYA
CHR
CHL
BAC

ELLIS LAKE



COUNTY:	Craven	**BASIN:**	Neuse
SURFACE AREA:	563 hectares (1,390 acres)	**USGS TOPO:**	Masontown, N.C.
CLASS:	C - SW NSW	**LAKE TYPE:**	Natural

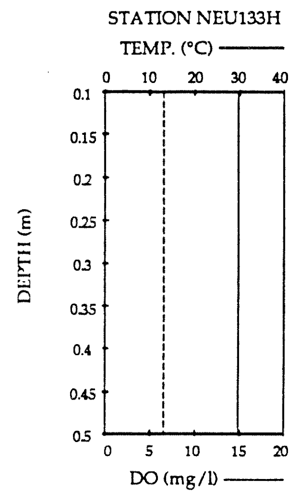
LATEST NCTSI:	- 2.9	**TROPHIC STATE:**	Dystrophic
SAMPLING DATE:	August 17, 1988	**ADDITIONAL COVERAGE:**	None
SECCHI DEPTH:	0.7 m	**CONDUCTIVITY:**	45 μmhos/cm^2
TOTAL PHOSPHORUS:	0.01 mg/l	**DISSOLVED OXYGEN:**	6.6 mg/l
TOTAL ORGANIC NITROGEN:	0.26 mg/l	**TEMPERATURE:**	29.9 °C
CHLOROPHYLL-A:	1 μg/l	**pH:**	4.5 s.u.

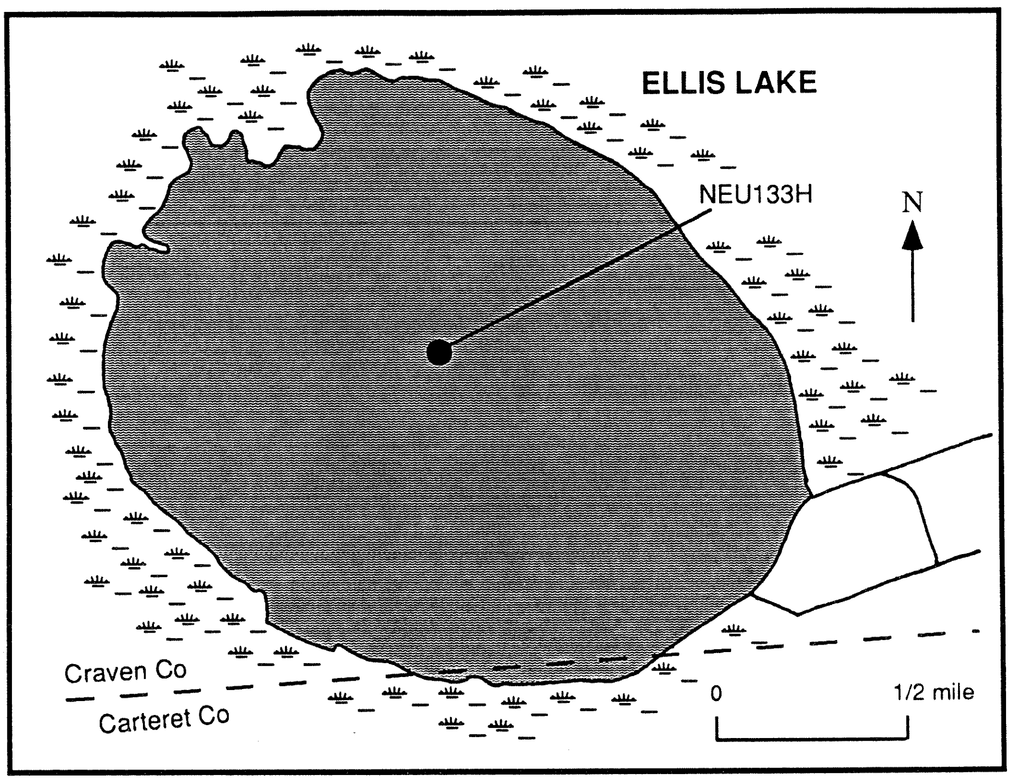
Ellis Lake (also called Lake Ellis Simon) is a natural Carolina Bay Lake which was used as a rice paddy in the late 1800's. A concrete dam was put in place in the 1930's which doubled the surface area of the lake. Lake Ellis is owned by Camp Bryan, a hunting and fishing club. The lake has a large surface area but is extremely shallow. Maximum depth is three meters, and average depth is one meter. Lake Ellis is located in the Croatan National Forest. Land surrounding the lake consists of undisturbed forest and swamp. The flat topography is typical of the outer coastal plain.

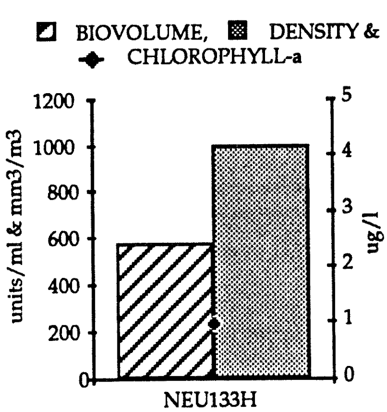
On August 17, 1988, the lake was sampled by DEM. Ellis Lake was well-mixed as would be expected in a shallow system. Acidic pH values were recorded but were not unusual for this type of blackwater lake . Nutrients and chlorophyll-a concentrations were very low.

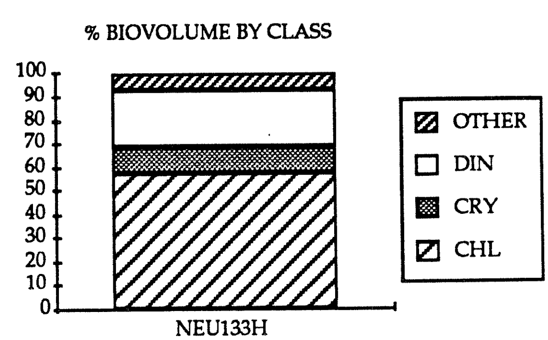
As with other Carolina Bay Lakes, estimates of algal biovolume and density were low. Chlorophytes, cryptophytes and dinoflagellates were dominant by biovolume. The dominant species, Mougeotia, a large filamentous chlorophyte, is commonly found in shallow, still, acidic waters.

A TSI of -2.9 was calculated for Ellis Lake which normally indicates oligotrophic conditions. However, the lake is considered dystrophic. All uses were supported at the time of this assessment.

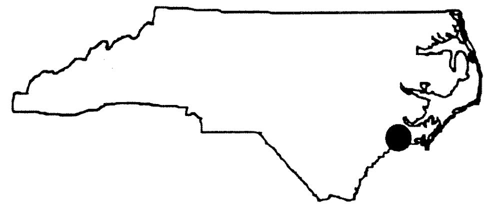

STATION NEU133H
TEMP. (°C)
0 10 20 30 40
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
DEPTH (m)
0 5 10 15 20
DO (mg/l)


ELLIS LAKE
NEU133H
N
Craven Co
Carteret Co
0
1/2 mile


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
1200
1000
800
600
400
200
0
units/ml & mm3/m3
5
4
3
2
1
0
ug/l
NEU133H


% BIOVOLUME BY CLASS
100
90
80
70
60
50
40
30
20
10
0
NEU133H
OTHER
DIN
CRY
CHL

LONG LAKE



COUNTY:	Craven	**BASIN:**	Neuse
SURFACE AREA:	445 hectares (1,100 acres)	**USGS TOPO:**	Havelock, N.C.
CLASS:	C - SW NSW	**LAKE TYPE:**	Natural

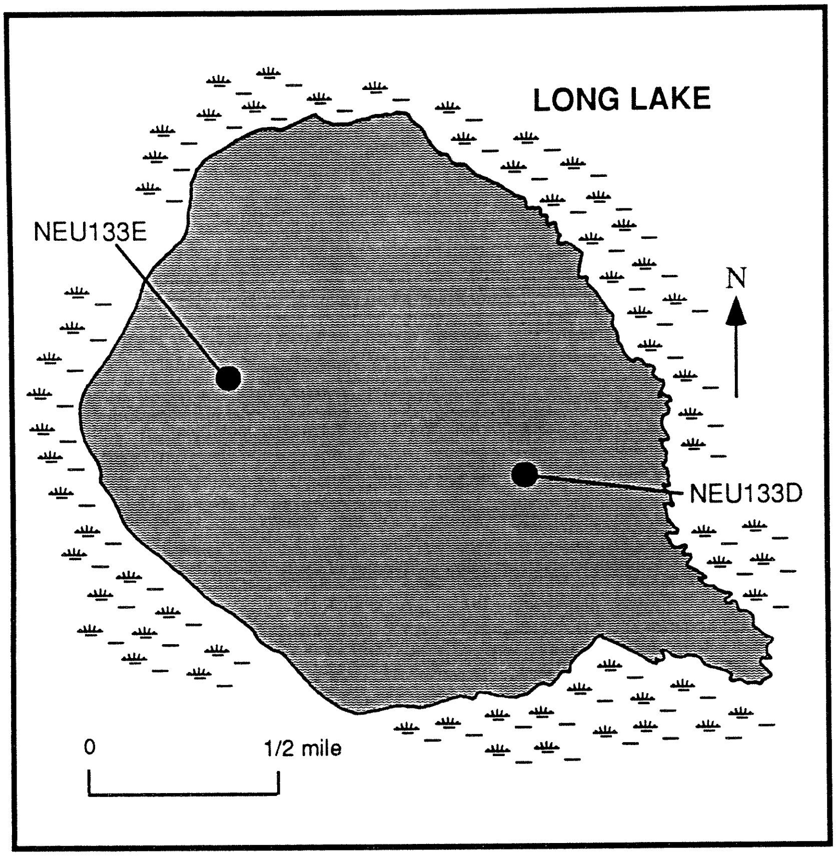
LATEST NCTSI:	- 1.4	**TROPHIC STATE:**	Dystrophic
SAMPLING DATE:	August 17, 1988	**ADDITIONAL COVERAGE:**	None
SECCHI DEPTH:	0.5 m	**CONDUCTIVITY:**	99 - 100 μmhos/cm^2
TOTAL PHOSPHORUS:	0.02 mg/l	**DISSOLVED OXYGEN:**	7.5 - 7.6 mg/l
TOTAL ORGANIC NITROGEN:	0.235 mg/l	**TEMPERATURE:**	31.5 - 32 °C
CHLOROPHYLL-A:	2 μg/l	**pH:**	4.2 s.u.

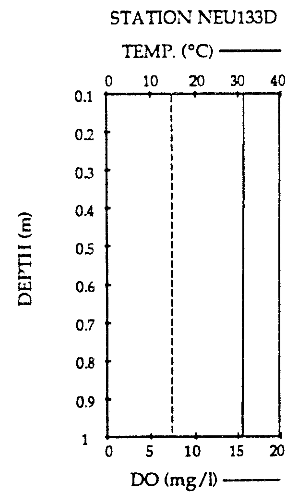
Long Lake is a blackwater Carolina Bay Lake located in the Croatan National Forest. It is owned by the United States Forest Service. Like other natural lakes nearby, Long Lake is large but shallow, with an average depth of one meter and a maximum depth of two meters. The lake is surrounded by an undisturbed pocosin swamp.

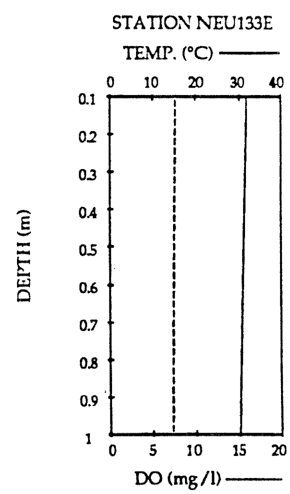
Long Lake was sampled on August 17, 1988. As is typical for Carolina Bay lakes, the water column was mixed and pH was low. Water temperature was high. Nutrients and chlorophyll-a concentrations were low, but turbidity was slightly elevated (13 NTU).

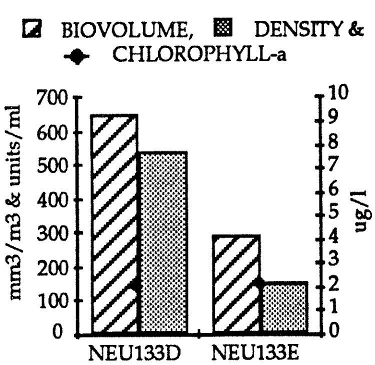
Long Lake contained low amounts of phytoplankton as would be expected in an acidic Carolina Bay lake. Algal samples were dominated by bacillariophytes (diatoms) and chlorophytes (green algae). Melosira longispina, a diatom, and Arthrodesmus incus, a green alga, were dominant in Long Lake. These species are commonly found in nutrient-poor bodies of water. Mallomonas majorensis, a chrysophyte, was also dominant at station NEU133D.

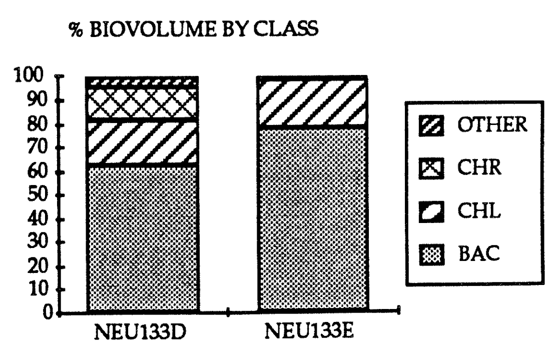
Long Lake is dystrophic with a TSI of -1.4. All uses of the lake were fully supported at the time of sampling.


LONG LAKE
NEU133E
NEU133D
N
0
1/2 mile


STATION NEU133D
TEMP. (°C)
DEPTH (m)
DO (mg/l)


STATION NEU133E
TEMP. (°C)
DEPTH (m)
DO (mg/l)


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/m3 & units/ml
ug/l
NEU133D
NEU133E


% BIOVOLUME BY CLASS
OTHER
CHR
CHL
BAC
NEU133D
NEU133E

PASQUOTANK RIVER BASIN

DESCRIPTION OF REGION

The Pasquotank River Basin covers 9,575 km^2 in nine counties (Currituck, Camden, Pasquotank, Gates, Perquimans, Washington, Tyrrell, Hyde, and Dare) in the northeastern coastal plain region of the state. Watersheds in this basin drain into Albemarle, Currituck, Croatan, Roanoke and Pamlico Sounds.

The region is characterized by extensive wetlands including pocosins, swampy forests, and marshes. Salinities in the northern sounds are usually low, thereby limiting shellfish production, but the more saline southern area has many primary nursery areas.

OVERVIEW OF WATER QUALITY

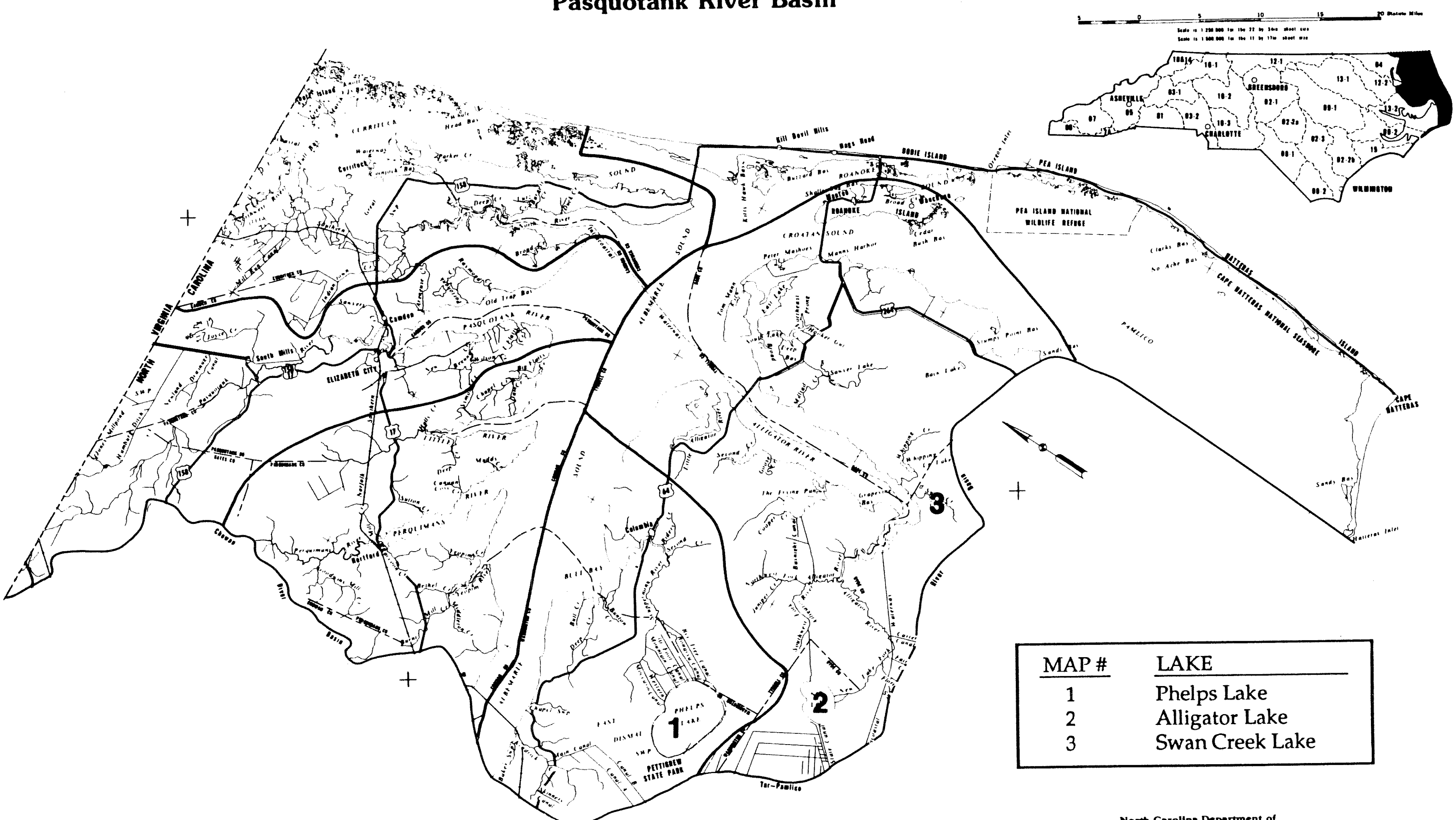
The major tributaries to the Albemarle Sound in the Pasquotank Basin are the North River, Pasquotank River, Little River, Alligator River, Perquimans River, and Scuppernong River. Agricultural runoff from swine production and "super farm" development appear to affect water quality more than point source discharges. In fact, there is only one discharger, Elizabeth City's wastewater treatment plant, with permitted flow greater than 500,000 gallons per day, and about 40 smaller dischargers in the basin (NRCD 1988c).

Land use in this basin has historically been dominated by forest and wetlands, with relatively little anthropogenic impacts to the lakes. However, recently there has been extensive conversion of land for agriculture, forestry, and peat mining. Much of the basin is federally-owned bombing ranges, wildlife preserves, or national seashore.

Three unique natural lakes from this basin are discussed in this report. Lake Phelps is a clear water lake of high quality in the southeastern portion of the basin, on the Albemarle-Pamlico peninsula. Swan Creek Lake is a remote black water lake which has been classified as an outstanding resource water (ORW). Alligator Lake is a wide but shallow lake located in the peaty area of Hyde County. All three lakes support designated uses.

Pasquotank

Pasquotank River Basin

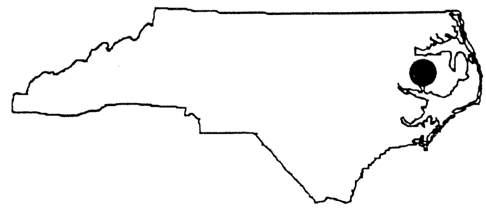


MAP #	LAKE
1	Phelps Lake
2	Alligator Lake
3	Swan Creek Lake

North Carolina Department of
Natural Resources and Community Development
Division of Enviromental Management

Adapted from U.S.G.S.(A.M.S.) 1:250,000 U.S. Series

LAKE PHELPS



COUNTY:	Washington	BASIN:	Pasquotank
SURFACE AREA:	6,718 hectares (16,600 acres)	USGS TOPO:	Creswell, N.C.
CLASS:	C-SW	LAKE TYPE:	Natural

LATEST NCTSI:	- 3.3	TROPHIC STATE:	Oligotrophic
SAMPLING DATE:	August 22, 1989	ADDITIONAL COVERAGE:	None
SECCHI DEPTH:	1.7 m	CONDUCTIVITY:	118 - 120 µmhos/cm^2
TOTAL PHOSPHORUS:	0.01 mg/l	DISSOLVED OXYGEN:	7.2 - 7.4 mg/l
TOTAL ORGANIC NITROGEN:	0.16 mg/l	TEMPERATURE:	28.2 - 28.5 ^{O}C
CHLOROPHYLL-A:	5 µg/l	pH:	4.1 - 4.6 s.u.

Lake Phelps, the second largest natural lake in North Carolina, is located in the eastern part of the state in Washington and Tyrrell Counties. It lies on a vast peninsula between Albemarle Sound on the north and the Pamlico River on the south. This peninsula contains numerous low-lying swampy areas underlain by thick organic muck and relatively well-drained areas with fertile mineral and organic soils. In the past, much of the region has been cleared of vegetation, drained, and put into large scale agricultural use (NRCD 1980).

Lake Phelps is owned by the State of North Carolina and is associated with Pettigrew State Park. The lake is principally recharged by natural precipitation with a small fraction coming from underground aquifers. There is no known overland flow into the lake as it occupies the highest elevation in the area (NRCD 1980). The lake reaches a maximum depth of three meters at the center and has a mean depth of 1.5 meters. It has an average retention time of 1,161 days, and, because it is shallow depth and wind mixed, the water column does not stratify. Lake Phelps is primarily used for recreational activities. The lake has historically been used as a water source for fighting local peat fires. During extensive peat fires in 1985, the lake was drawn down approximately 0.5 meter.

The N.C. Wildlife Resources Commission has conducted several studies of fish populations in Lake Phelps. The lake supports a high quality fishery of largemouth bass, yellow perch, and sunfishes. The white perch population suffered a major kill during the winter of 1980-1981, but has been restocked. The endangered Waccamaw killifish also inhabits the lake. Lake Phelps is also unique in that it is inhabited by Myriophyllum tenellum, a species of aquatic plant not usually found south of New Jersey.

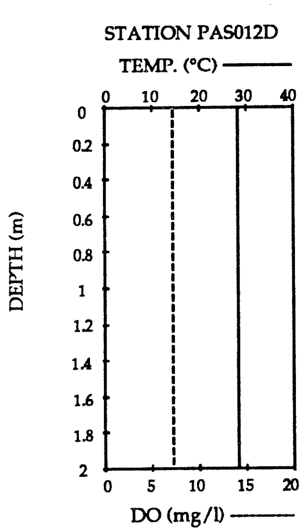
Lake Phelps was sampled on August 22, 1989. Physical measurements indicated thorough mixing of the water column at all of the sampling locations. Nutrient concentrations were low and uniformly distributed in the lake. Acidic waters were found in the lake which is typical of natural coastal plain lakes, but unlike other coastal plain lakes, the water in Lake Phelps is not colored. Concentrations of heavy metals in surface water samples were below laboratory detection limits. Nutrients, chlorophyll-a, and solids were all low in this lake.

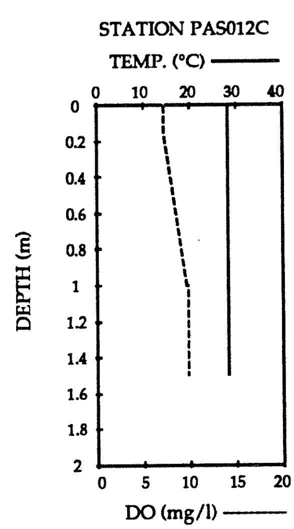
Similar to the sampling of Lake Phelps in 1986, dinoflagellates and chlorophytes codominated the algal biovolume. Cosmarium asphaerosporum strigosum (a unicellular, green algae) dominated the biovolume of this algal class at each station. This particular genus belongs to the desmid family whose members are commonly found in more oligotrophic waters. The dinoflagellate Peridinium inconspicuum was also found at all three sampling stations.

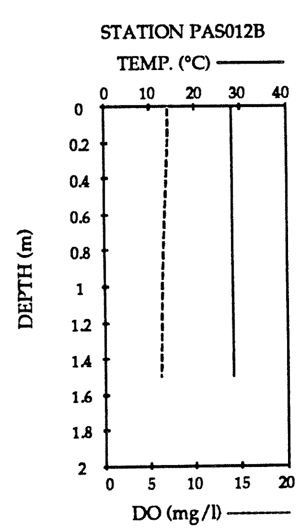
Phytoplanktonic biovolumes continue to be low in Lake Phelps, but densities at two of the three stations (PAS012B and PAS012C) reached bloom levels. A diminutive, unidentified chlorophyte was responsible for these unusually high densities.

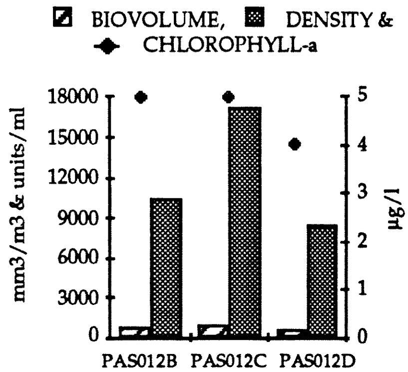
The TSI was -3.3 in 1989, indicating oligotrophic conditions. The water level was a foot higher at this time than in the past 12 months as a result of above average rainfall. Previous TSI data have consistently indicated that the lake is oligotrophic.

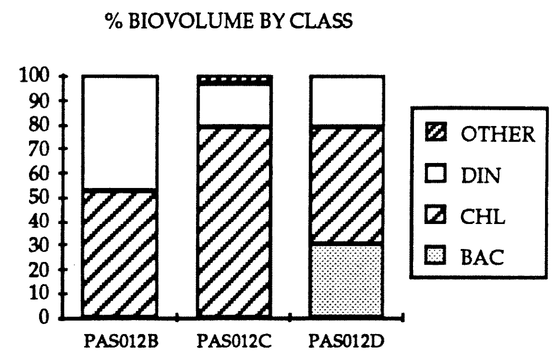
Water quality measurements made during the 1989 sampling effort did not indicate any violations of state water quality standards. Water quality in the lake fully supported designated uses. Lake Phelps has been nominated for "Outstanding Resource Waters" designation.

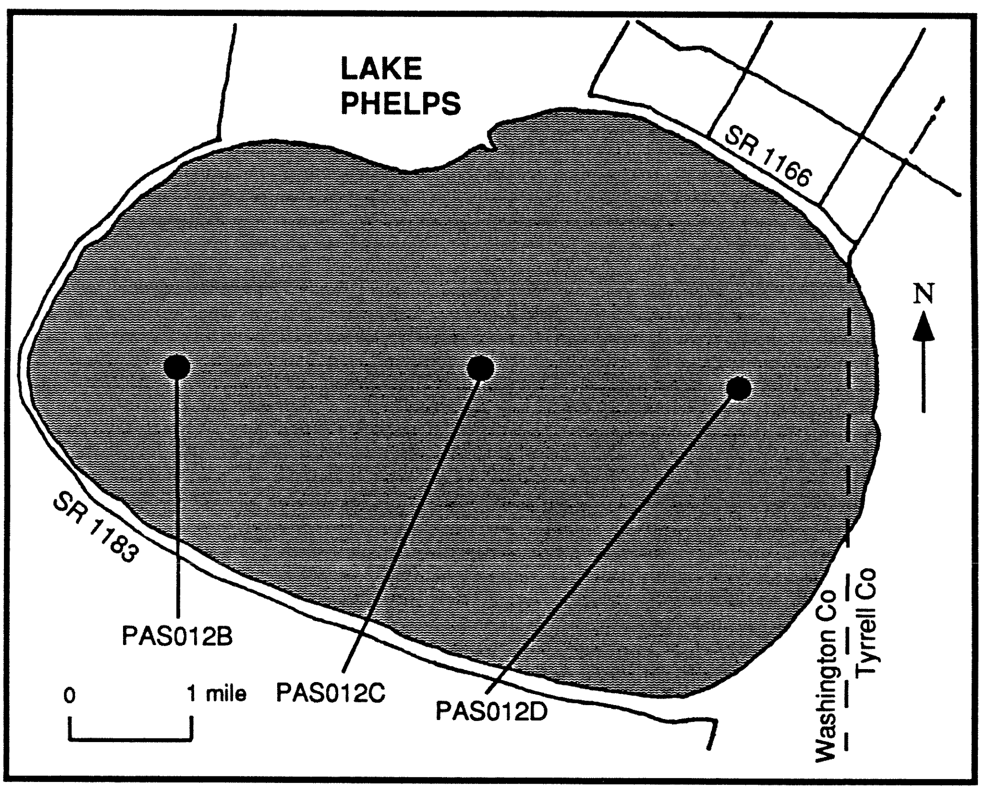




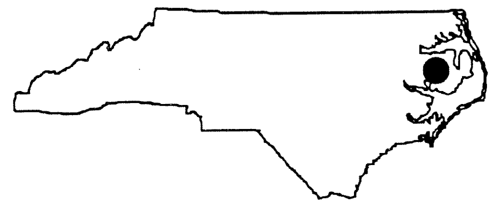



BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/m3 & units/ml
18000
15000
12000
9000
6000
3000
0
5
4
3
2
1
0
µg/l
PAS012B
PAS012C
PAS012D


% BIOVOLUME BY CLASS
100
90
80
70
60
50
40
30
20
10
0
PAS012B
PAS012C
PAS012D
OTHER
DIN
CHL
BAC


LAKE
PHELPS
SR 1166
N
SR 1183
PAS012B
PAS012C
PAS012D
0
1 mile
Washington Co
Tyrrell Co

ALLIGATOR LAKE



COUNTY:	Hyde	BASIN:	Pasquotank
SURFACE AREA:	2,226 hectares (5,500 acres)	USGS TOPO:	New Lake, N.C.
CLASS:	C - SW	LAKE TYPE:	Natural

LATEST NCTSI:	3.6	TROPHIC STATE:	Dystrophic
SAMPLING DATE:	August 23, 1989	ADDITIONAL COVERAGE:	Metals
SECCHI DEPTH:	0.3 m	CONDUCTIVITY:	98 - 99 µmhos/cm^2
TOTAL PHOSPHORUS:	0.1 mg/l	DISSOLVED OXYGEN:	7.0 mg/l
TOTAL ORGANIC NITROGEN:	0.625 mg/l	TEMPERATURE:	30.4 - 30.7 ^{o}C
CHLOROPHYLL-A:	7 µg/l	pH:	3.5 - 3.8 s.u.

Alligator Lake (also called New Lake) is located in the coastal plain of North Carolina near Lake Mattamuskeet. The lake resembles a giant puddle with an average depth of less than three feet and a surface area of over 2,000 hectares. Rich Farms owns most of the lake which is surrounded by agriculture and peat beds.

Some secondary recreation occurs at this lake which currently supports designated uses (NCDEM, 1990). Water from Alligator Lake is also used to combat forest/peat fires, such as those which burned in 1983.

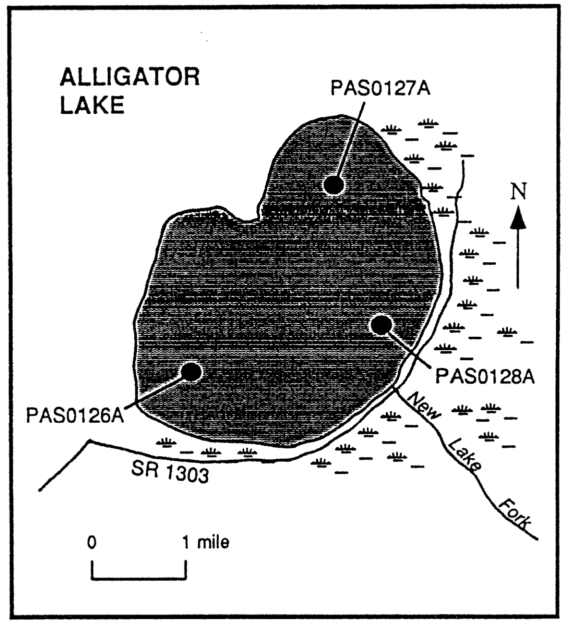
Two stations, PAS0126A and PAS1208A, were sampled on August 23, 1989. A third station, PAS0127B, was not sampled because low water level made the station inaccessible. Water in Alligator Lake warms easily as a result of the lake's shallow depth and highly colored water. Typical of other coastal bay lakes, Alligator Lake is acidic with a brownish tint. Waters were more turbid in the middle of the lake compared to the area near the shoreline, possibly a result of turbulence from the sampling boat. Nutrients were high in this lake, although chlorophyll-a values were not. Metals were not detected.

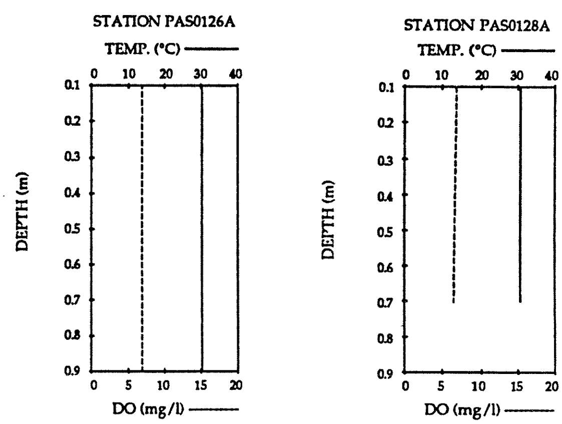
Compared to most Carolina Bay Lakes, algal biovolume was high in Alligator Lake. Phytoplanktonic growth in other bay lakes tends to be limited by low nutrients, low light availability, and low pH. However, phytoplanktonic growth in Alligator Lake was probably enhanced by warm water temperature and plentiful nutrients in the water column.

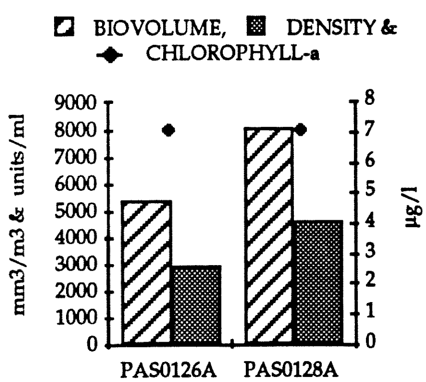
At PAS0126A, the biovolume was 5,350 mm^3/m^3, a value just at the threshold of a bloom. Algal biovolume reached 8,100 mm^3/m^3 at PAS0128A, but algal densities remained well below bloom levels at both stations (2,912 and 4,600 units/ml).

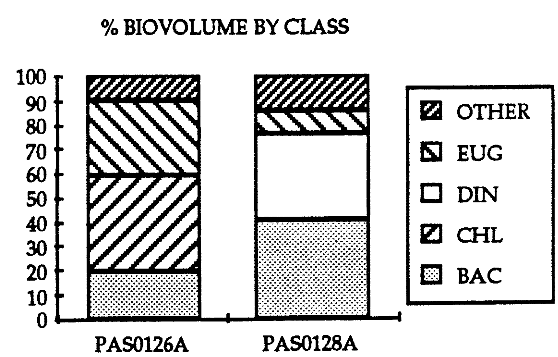
Staurastrum paradoxum cingulum, a huge, unicellular, green algae, comprised 40% of the phytoplanktonic biovolume at PAS0126A. This particular genus is typically found in acidic bodies of water such as Alligator Lake (Wetzel, 1975). Another 30% and 20% of the biovolume was dominated by euglenophytes and diatoms respectively. The biovolume at PAS0128A was dominated by a similar assemblage of diatoms as those at PAS0126A (Melosira granulata angustissima and M. granulata). The dinoflagellate Peridinium species 3 was codominant, constituting up to 35% of the algal biovolume at this station.

Alligator Lake is dystrophic, so a North Carolina TSI value is not useful in describing the water quality of this lake. Algal biovolume and average total phosphorus were higher in this lake than in the other two natural lakes in this basin, which suggests that Alligator Lake may be the most enriched of the three.

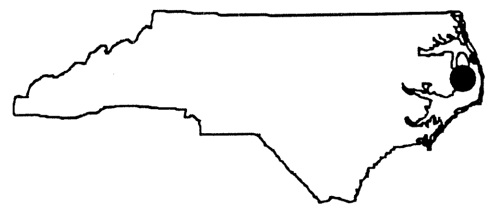








SWAN CREEK LAKE



COUNTY:	Hyde	BASIN:	Pasquotank
SURFACE AREA:	95 hectares (234 acres)	USGS TOPO:	Englehard NW, N.C.
CLASS:	C - SW, ORW	LAKE TYPE:	Natural

LATEST NCTSI:	0.7	TROPHIC STATE:	Dystrophic
SAMPLING DATE:	August 23, 1989	ADDITIONAL COVERAGE:	None
SECCHI DEPTH:	0.3 m	CONDUCTIVITY:	224 - 229 µmhos/cm^2
TOTAL PHOSPHORUS:	0.03 mg/l	DISSOLVED OXYGEN:	2.6 - 6.1 mg/l
TOTAL ORGANIC NITROGEN:	0.65 mg/l	TEMPERATURE:	28.0 - 28.9 ^{o}C
CHLOROPHYLL-A:	1 µg/l	pH:	3.2 - 4.5 s.u.

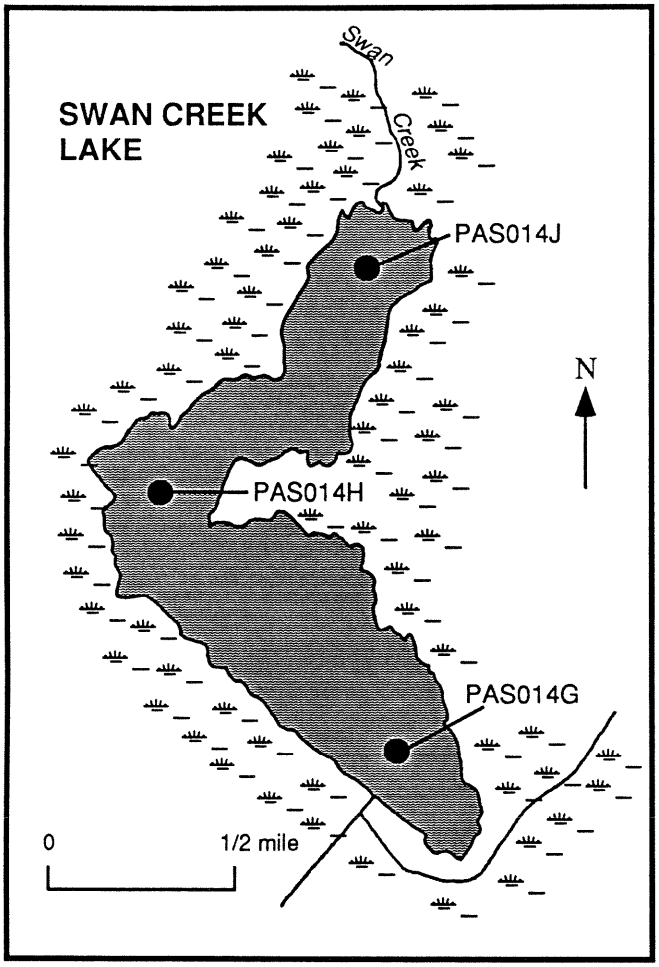
Swan Creek Lake is located in the protected Alligator River sub-basin. This natural, black-water lake is almost completely uninfluenced by human activities. Marsh and forested areas surround the lake, which is just south of the Dare County Bombing Range (USAF). Swan Creek Lake is recharged by precipitation and groundwater. No feeder stream is present, although some swamp water drains into the lake.

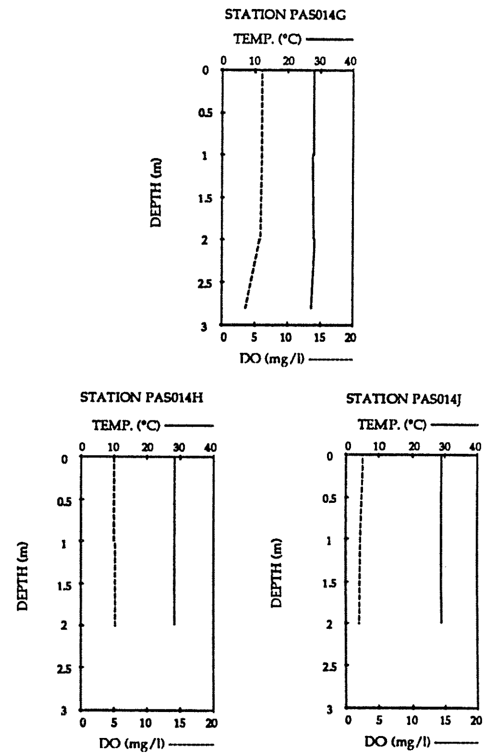
Georgia Timberlands and the U. S. Fish and Wildlife Service jointly own the lake. Access is difficult since entrance may only be gained through Swan Creek which drains the lake. Nevertheless, the lake is used by hunters and fishermen.

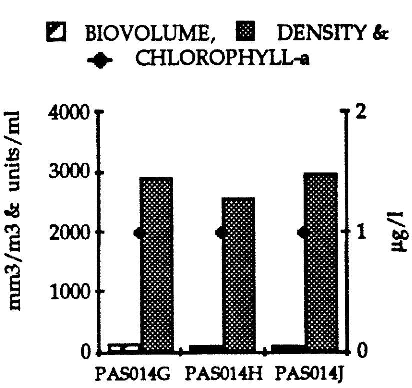
On August 23, 1989, Swan Creek Lake was sampled. The lake is so black that secchi disk readings were not comparable to non-tannic lakes. Maximum depth of the lake is approximately 3.5 meters. Despite the shallowness of the lake, some mild stratification was observed. Dissolved oxygen concentrations and pH levels were low. These data are probably a result of the deposition of organic matter from the surrounding swamps. Chlorophyll-a, solids, and turbidity were virtually not detected in this lake. Nitrogen and phosphorus levels were moderate.

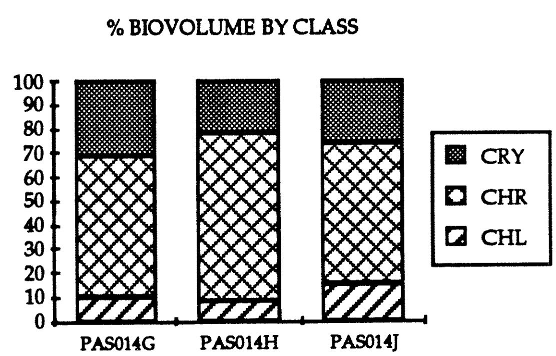
All three stations on Swan Creek Lake exhibited extremely low algal biovolumes and densities. Biovolumes ranged from only 97 to 135 mm^3/m^3 and densities reached a maximum of approximately 3,000 units/ml. Chrysophytes, golden-brown algae, and cryptophytes codominated the biovolume at each station. The same species of chrysophytes (Chrysococcus punctiformis, Mallomonas akrokomos, Ochromonas species, and Ophiocytium capitatum) were represented at all three sampling locations. Generally, chrysophytes are most prevalent in oligotrophic, clear-water lakes (Smith, 1950). The ubiquitous Chroomonas caudata was always the dominant cryptophyte.

Swan Creek Lake is considered dystrophic. The lake has only been sampled once by DEM, so it is unknown if the results from 1989 are typical. It should be noted that the lake level was high as a result of above average precipitation during the summer. All uses were being supported at the time of this assessment.









ROANOKE RIVER BASIN

DESCRIPTION OF REGION

The Roanoke River Basin stretches from the mountains of Virginia through the piedmont and coastal plain of North Carolina, draining a total of 21,700 km^2. About 9,300 km^2 of the watershed lies in North Carolina. Major land use in the basin consists of forestry and agriculture. The principal agricultural cash crops grown in the region are tobacco, corn, soybeans, and peanuts. Subsistence crops are corn, potatoes, and hay. Products of woodland areas include sawed lumber, poles, staves, and pulpwood. Recent trends throughout the basin are towards greater emphasis on livestock enterprises, particularly dairy products and beef cattle. Overall, the soil is erodable and vulnerable to land-disturbing activities. Nonpoint source runoff is, therefore, a major water quality problem in the basin.

In North Carolina, the basin can be divided into two main areas: the Dan River and the Roanoke River drainage areas. The Dan River originates in the western mountains of Virginia and meanders across the North Carolina/Virginia state line several times as it travels eastward. The Roanoke River also flows from Virginia into North Carolina and, together with the Dan River, forms the headwaters of John H. Kerr Reservoir. Kerr Reservoir then drains into Lake Gaston, which in turn drains into Roanoke Rapids Lake.

Below Roanoke Rapids Lake, the Roanoke River travels southeastward until it flows into Albemarle Sound. This section of the river is characterized by extreme seasonal fluctuations in flow and water level caused by varying discharge rates from upstream reservoirs. Low dissolved oxygen levels are commonly observed in the entire lower Roanoke River.

OVERVIEW OF WATER QUALITY

In North Carolina, the Mayo River, Smith River, and Hyco Creek are major tributaries to the Dan River. The lower sections of the Dan River are adversely affected by nonpoint source runoff and point source discharges. Urban runoff is suspected of contributing sediment to several streams near Belews Lake, including West Belews Creek, Reed Creek, and West Prong Beaver Island Creek. High concentrations of copper and nickel have been reported in the Dan River near Mayfield (NRCD 1985).

In the lower section of the Roanoke River Basin, many headwater streams have been altered by flood control projects. These projects have channelized streams, allowing rapid delivery of nutrients to the river.

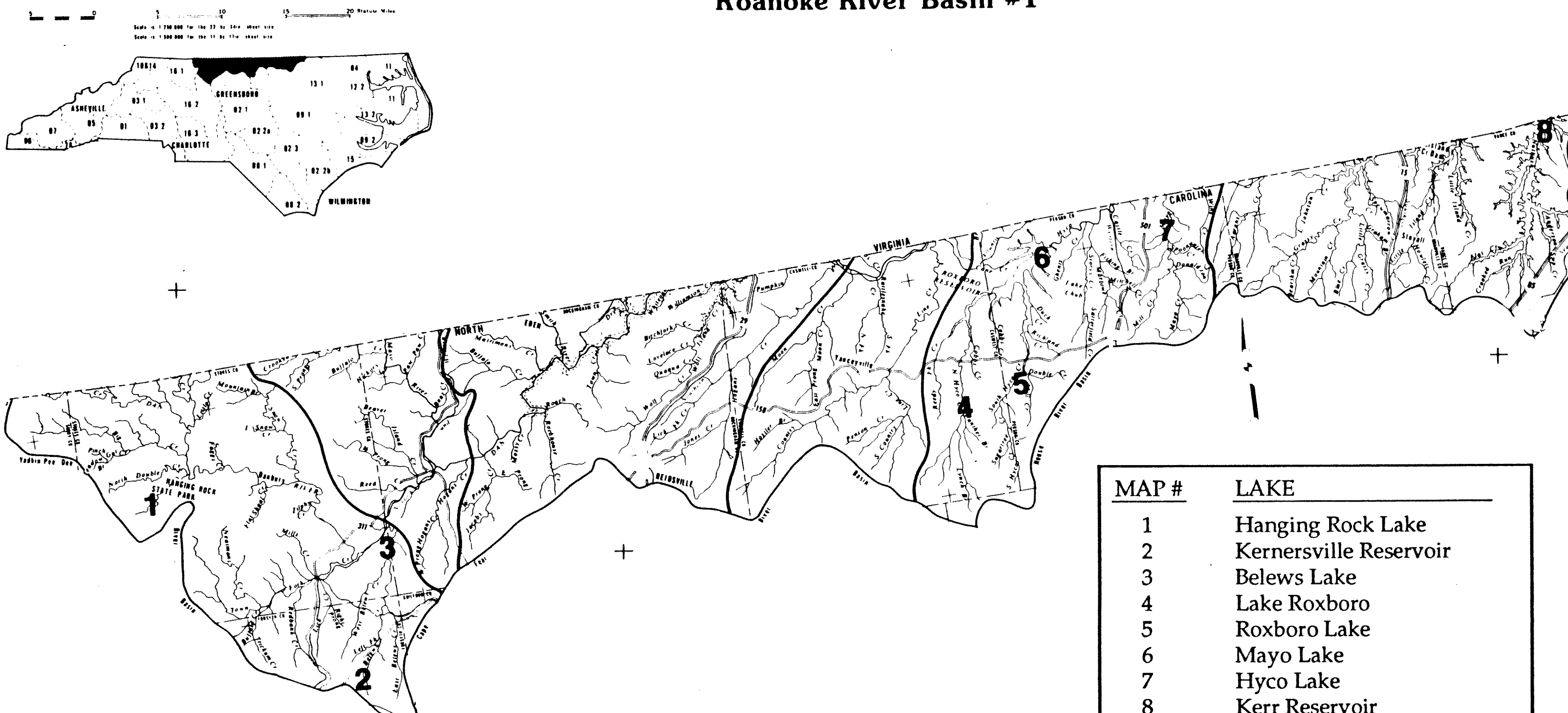
There are approximately 150 point source dischargers in the Roanoke River Basin. Of the streams and rivers known to be impacted by point sources, Marlowe Creek, Nutbush Creek, Welch Creek, and the Cashie River are the most severely affected. Elevated concentrations of chromium, copper, mercury, nickel, and zinc have been reported in the Roanoke River at Scotland Neck (NRCD 1985).

Eleven lakes are included in this section of the report. Belews Lake, Hyco Lake, and Mayo Lake are large reservoirs that provide cooling water for power plants. Hyco and Belews Lakes have been severely degraded by the heavy metal selenium which was discharged from waste ash ponds by the power companies. Hanging Rock Lake is located within a protected watershed northeast of Winston-Salem. It has a high level of water quality. Roxboro Lake and Kernersville Lake are water supply reservoirs. Lake Roxboro is a recreational lake located in Caswell and Person Counties. White Millpond is a hyper-eutrophic, aging millpond located in the coastal plain.

The remaining three lakes are impoundments of the Roanoke River: John H. Kerr Reservoir, Lake Gaston, and Roanoke Rapids Lake. All three reservoirs fully support designated uses. However, the Nutbush Creek arm of John H. Kerr Reservoir receives high phosphorus loads from the Henderson WWTP. The upper reaches of Lake Gaston have been infested with aquatic macrophytes, including elodea and hydrilla.

Roanoke #1

Roanoke River Basin #1

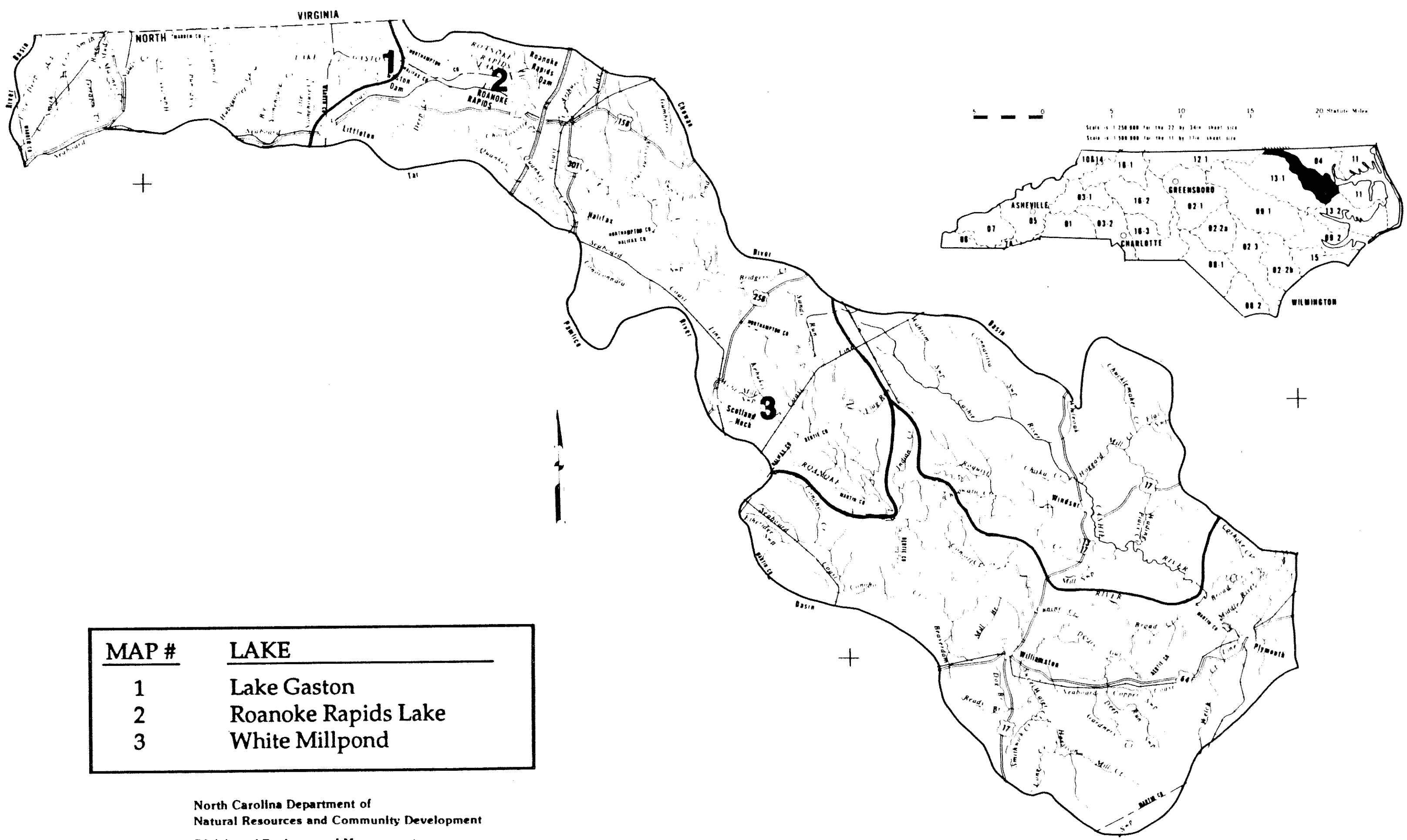


MAP #	LAKE
1	Hanging Rock Lake
2	Kernersville Reservoir
3	Belews Lake
4	Lake Roxboro
5	Roxboro Lake
6	Mayo Lake
7	Hyco Lake
8	Kerr Reservoir

North Carolina Department of
Natural Resources and Community Development
Division of Enviromental Management

Adapted from U.S.G.S.(A.M.S.) 1:250 000 U.S. Series

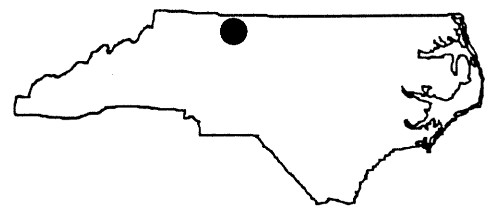
Roanoke River Basin #2



MAP #	LAKE
1	Lake Gaston
2	Roanoke Rapids Lake
3	White Millpond

North Carolina Department of
Natural Resources and Community Development
Division of Enviromental Management

HANGING ROCK LAKE



COUNTY:	Stokes	**BASIN:**	Roanoke
SURFACE AREA:	5 hectares (12 acres)	**USGS TOPO:**	Hanging Rock, N.C.
CLASS:	B	**LAKE TYPE:**	Reservoir

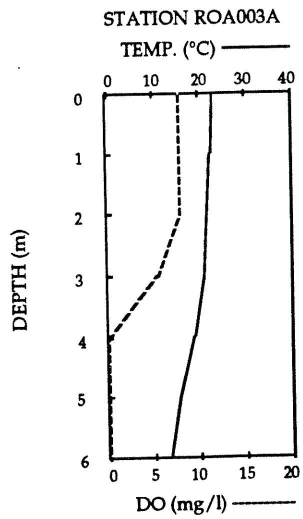
LATEST NCTSI:	- 2.1	**TROPHIC STATE:**	Oligotrophic
SAMPLING DATE:	August 16, 1989	**ADDITIONAL COVERAGE:**	Fecal
SECCHI DEPTH:	4.8 m	**CONDUCTIVITY:**	17 µmhos/cm^2
TOTAL PHOSPHORUS:	0.02 mg/l	**DISSOLVED OXYGEN:**	8.0 mg/l
TOTAL ORGANIC NITROGEN:	0.11 mg/l	**TEMPERATURE:**	23.1 °C
CHLOROPHYLL-A:	56 µg/l	**pH:**	6.7 s.u.

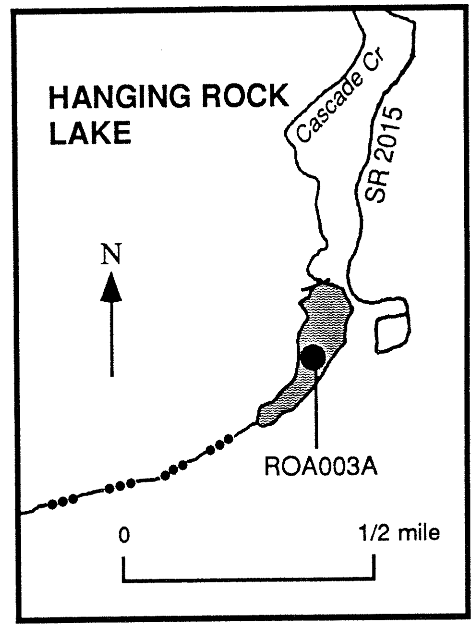
Hanging Rock Lake is a small impoundment located within Hanging Rock State Park, which has one of the highest rates of public use within the state system. The original earthen and concrete dam was built at this location in 1938 as a Civilian Conservation Corps project. Owned by the state of North Carolina, the 1.8 km^2 watershed is primarily forested. Hanging Rock Lake is classified B.

Hanging Rock Lake was sampled on August 16, 1989. Because it is small, the lake was assigned one sampling station located at its center. Physical measurements taken on this day showed that the lake was stratified. Nutrient concentrations were typical of lakes with minimal productivity. Levels of fecal coliform bacteria were below laboratory detection limits. A high concentration of chlorophyll-a was reported from Hanging Rock Lake. This value was not supported by other indicators of productivity; therefore, it must be assumed that this value represents an error in sampling or analysis.

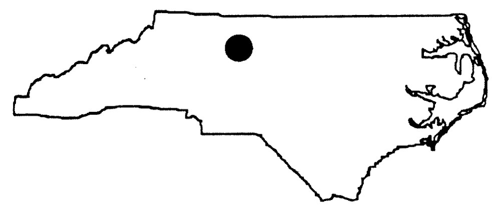
Phytoplankton were not analyzed in 1989. In August 1985, low estimates of algal biovolume and density reflected the oligotrophic state of this lake. Dinoflagellates and diatoms dominated density estimates, while dinoflagellates made up 80% of the biovolume. These two classes of algae are common in nutrient-poor waters.

The TSI in 1990 was -2.1. This value is greater than historical data as a result of the high chlorophyll-a concentration. Hanging Rock Lake Lake fully supported designated uses at the time of assessment.


STATION ROA003A
TEMP. (°C)
0 10 20 30 40
0 1 2 3 4 5 6
DEPTH (m)
0 5 10 15 20
DO (mg/l)


HANGING ROCK LAKE
Cascade Cr
SR 2015
N
ROA003A
0
1/2 mile

KERNERSVILLE RESERVOIR



COUNTY:	Forsyth	BASIN:	Roanoke
SURFACE AREA:	18 hectares (45 acres)	USGS TOPO:	Belews Creek, N.C.
CLASS:	WS	LAKE TYPE:	Reservoir

LATEST NCTSI:	0.4	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	August 17, 1988	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	0.9 m	CONDUCTIVITY:	94 µmhos/cm^2
TOTAL PHOSPHORUS:	0.03 mg/l	DISSOLVED OXYGEN:	7.5 mg/l
TOTAL ORGANIC NITROGEN:	0.35 mg/l	TEMPERATURE:	30.7 °C
CHLOROPHYLL-A:	9 µg/l	pH:	7.3 s.u.

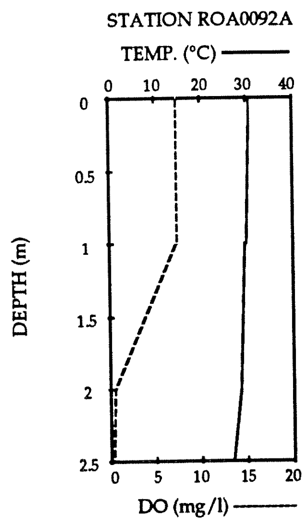
Kernersville Reservoir was built in 1952 as a water supply for the Town of Kernersville. The 18-hectare lake is fed by Belews Creek and springs. Maximum depth is 10 meters. Volume is 3.7×10^5 m^3 at normal pool (8.2×10^5 m^3 at full pool). Industrial land use is growing in the 8.5 km^2 drainage area.

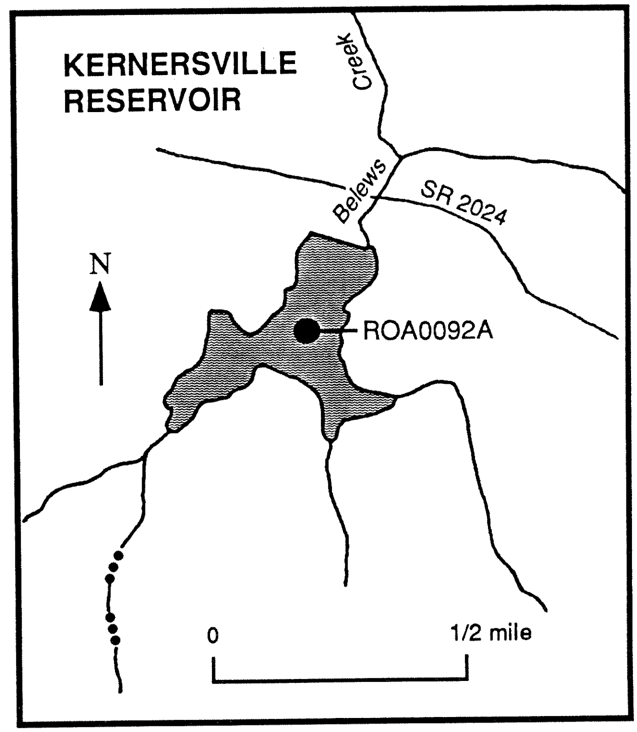
The lake was contaminated in June 1977 by vandals who opened chemical storage tanks at an upstream incineration plant. Water supply use was temporarily abandoned, but Kernersville Reservoir began supplying water again in March 1981. Since 1984, Kernersville has been buying potable water from the City of Winston-Salem. The reservoir will continue to be maintained as an emergency water supply. Public access is stringently prohibited, partially as a result of the chemical contamination incident.

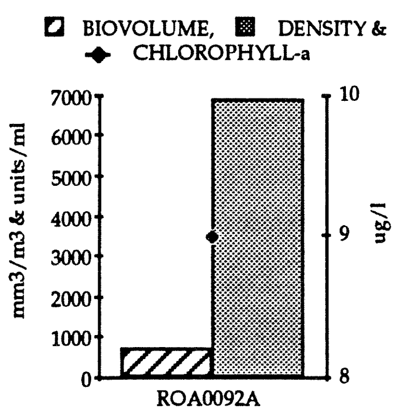
Kernersville Reservoir was sampled on August 17, 1988. The lake was not stratified, and dissolved oxygen reached 100% saturation at the water surface. Nutrient concentrations were moderate, but chlorophyll-a and phytoplanktonic estimates were low.

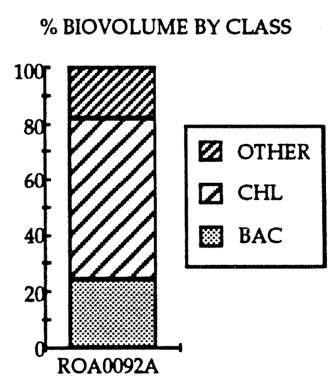
The short retention time of the lake probably contributed to the relatively low algal populations. The most abundant class of phytoplankton was Chlorophyceae (green algae), largely represented by several species of Chlamydomonas.

Kernersville Reservoir had a TSI of 0.4 in 1988, indicating it was mildly eutrophic. Uses were supported at the time of sampling, but anticipated industrialization upstream of the lake could potentially impact future water quality.

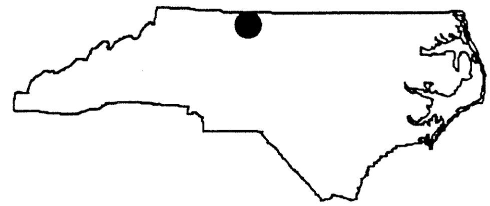

STATION ROA0092A
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0
0.5
1
1.5
2
2.5
0 5 10 15 20
DO (mg/l)


KERNERSVILLE
RESERVOIR
Belews
Creek
SR 2024
N
ROA0092A
0
1/2 mile


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/m3 & units/ml
7000
6000
5000
4000
3000
2000
1000
0
10
9
8
ug/l
ROA0092A


% BIOVOLUME BY CLASS
100
80
60
40
20
0
OTHER
CHL
BAC
ROA0092A

BELEWS LAKE



COUNTY:	Rockingham/Stokes	BASIN:	Roanoke
SURFACE AREA:	1,630 hectares (4,030 acres)	USGS TOPO:	Belews Lake, N.C.
CLASS:	B, C	LAKE TYPE:	Reservoir

LATEST NCTSI:	-5.0	TROPHIC STATE:	Oligotrophic
SAMPLING DATE:	August 15, 1990	ADDITIONAL COVERAGE:	Fecals
SECCHI DEPTH:	3.2 m	CONDUCTIVITY:	77 - 83 µmhos/cm^2
TOTAL PHOSPHORUS:	0.01 mg/l	DISSOLVED OXYGEN:	6.8 - 7.3 mg/l
TOTAL ORGANIC NITROGEN:	0.19 mg/l	TEMPERATURE:	28.8 - 30.5 °C
CHLOROPHYLL-A:	1 µg/l	pH:	6.8 - 7.4 s.u.

Belews Lake is situated on Belews Creek, a small tributary of the Dan River. Located in the Northern Piedmont of North Carolina, the lake lies in four counties: Rockingham, Stokes, Forsyth, and Guilford. Construction of the reservoir, owned by Duke Power Co., began in the spring of 1970 and was completed in April 1973. Belews Lake was built to provide a source of condenser cooling water for the Belews Creek Steam Station, the largest coal-fired electric generating station in the Duke Power system. The lake has a maximum depth of 44 meters, a mean depth of 15 meters and a volume of 228 x 10^6 m^3.

Belews Lake has a drainage basin covering 120 km^2 of land characterized as hilly. Most land is forested and agricultural with some urban areas. The large volume of the lake, the circulation of the water by the power plant, and the relatively small flow from the watershed have resulted in a retention time of approximately 1,500 days in the reservoir.

Belews Lake is designated Class B from the backwaters of Belews Lake to the Southern Railroad bridge and Class C from the Southern Railroad bridge to the Dan River. In 1970, the North Carolina Board of Water and Air Resources granted a variance on temperature standards for Belews Creek and its tributaries with stipulations for temperature monitoring. Elevated temperatures are inherent in most lakes used for cooling water.

Belews Lake has experienced elevated levels of selenium, a heavy metal toxic to fish and waterfowl in high concentrations, in the water column, sediment and in fish tissue. The selenium in Belews Lake originated from the coal ash disposal basin at the Belews

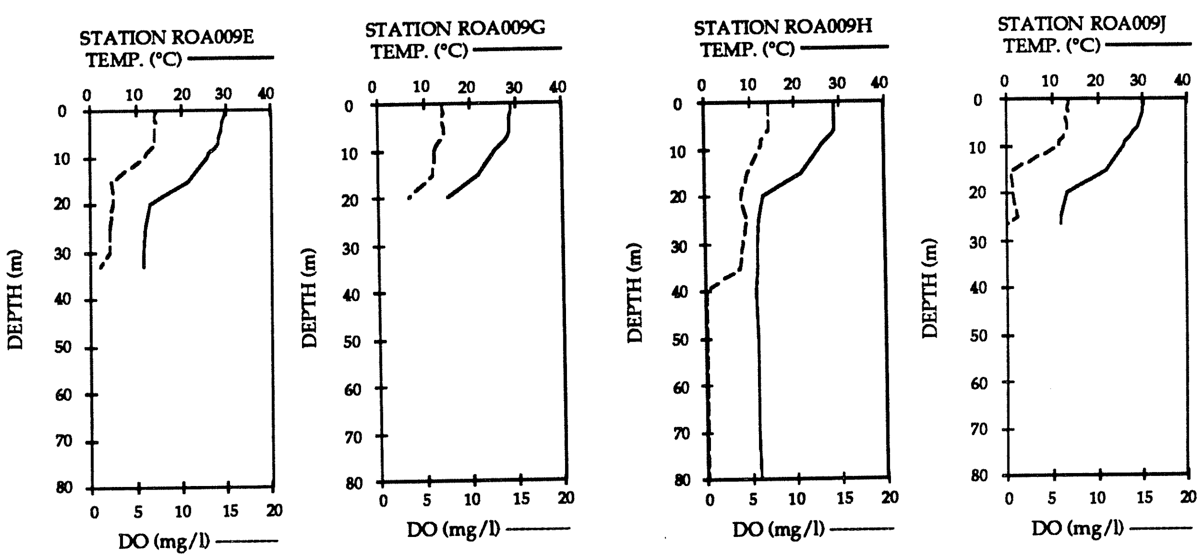
Creek Steam Station. Large-scale combustion of coal, primarily at steam-electric generating plants, can result in significant inputs of selenium to the aquatic ecosystem (Lemly 1985). After three years of plant operation, the selenium in Belews Lake had caused drastic alterations of species diversity and population densities in the fish communities of the lake. Of the 20 species of fish originally present in the reservoir, 16 were eliminated, two species were effectively unable to reproduce but persisted as adults, and populations of game fishes were virtually eliminated (Lemly 1985).

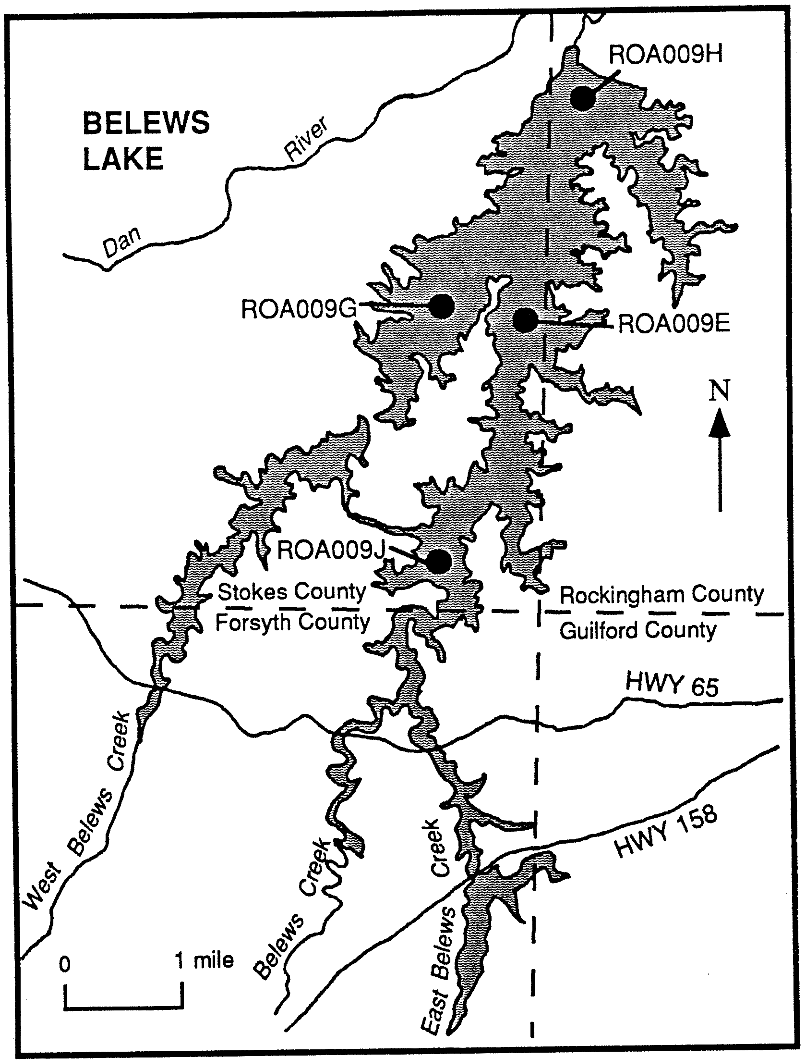
Duke Power Company switched to a dry fly ash system in December, 1985, which eliminated selenium discharges to the reservoir. Concentrations of selenium in the water column are currently below laboratory detection levels. Contaminants remain in the food chain and in the sediments, but the fish community is expected to recover as selenium levels decline.

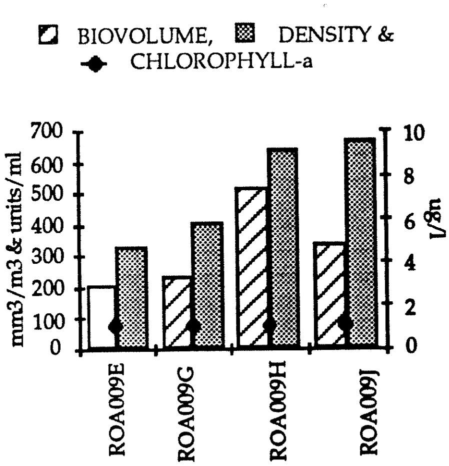
Belews Lake was sampled on August 15, 1990. Physical measurements indicated that the lake was stratified. Both nutrient and chlorophyll-a concentrations were low throughout the lake. The water was clear with an average secchi depth over three meters. Selenium was not detected in the water column in 1990. Analysis of sediment samples collected near the ash basin in 1987 found selenium at 17 mg/kg dry weight.

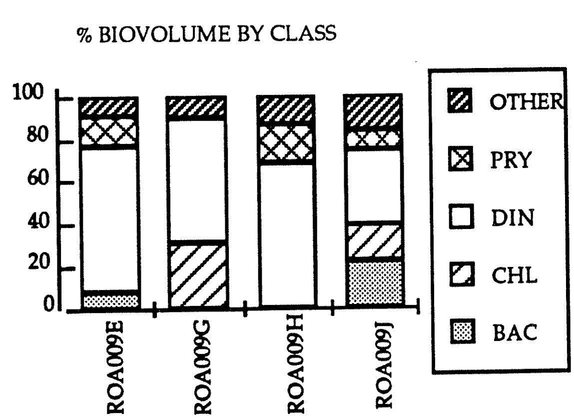
Phytoplankton populations were dominated by dinoflagellates and green algae. Highest densities were observed at the uppermost (ROA009J) and lowest (ROA009H) stations. Populations at these stations were dominated by dinoflagellates. Low nutrient levels have resulted in a low phytoplankton standing crop and low chlorophyll-a concentrations.

In 1990, the TSI was -5.0, which is consistent with past values, and indicates the reservoir is oligotrophic. At the time of assessment, no violations of state water quality standards were observed at Belews Lake. The reservoir does not support its designated use because the selenium contamination has not allowed the lake to support fish and wildlife propagation. The water quality and biological integrity of Belews Lake will continue to be monitored.

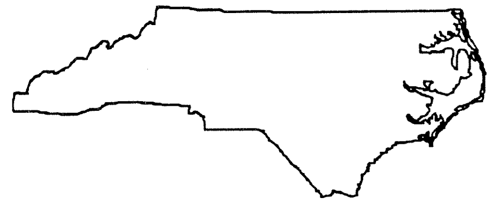



BELEWS LAKE
Dan River
ROA009H
ROA009G
ROA009E
ROA009J
N
Stokes County
Forsyth County
Rockingham County
Guilford County
HWY 65
HWY 158
West Belews Creek
Belews Creek
East Belews Creek
0
1 mile


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/m3 & units/ml
ug/l
700
600
500
400
300
200
100
0
10
8
6
4
2
0
ROA009E
ROA009G
ROA009H
ROA009J


% BIOVOLUME BY CLASS
100
80
60
40
20
0
ROA009E
ROA009G
ROA009H
ROA009J
OTHER
PRY
DIN
CHL
BAC

ROXBORO LAKE



COUNTY:	Person	BASIN:	Roanoke
SURFACE AREA:	86 hectares (212 acres)	USGS TOPO:	Olive Hill, N.C.
CLASS:	WS	LAKE TYPE:	Reservoir

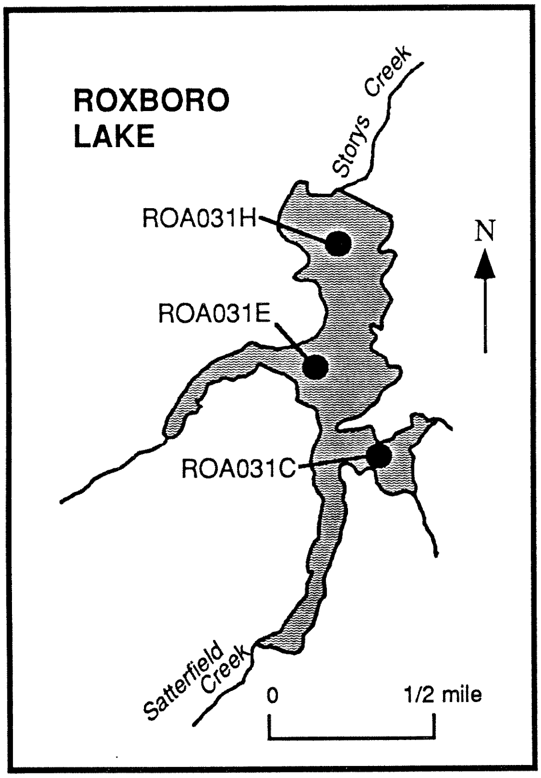
LATEST NCTSI:	1.4	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	July 28, 1988	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	1.2 m	CONDUCTIVITY:	72 - 84 µmhos/cm^2
TOTAL PHOSPHORUS:	0.04 mg/l	DISSOLVED OXYGEN:	7.6 - 8.2 mg/l
TOTAL ORGANIC NITROGEN:	0.32 mg/l	TEMPERATURE:	28.3 - 28.8 °C
CHLOROPHYLL-A:	34 µg/l	pH:	7.7 - 8.0 s.u.

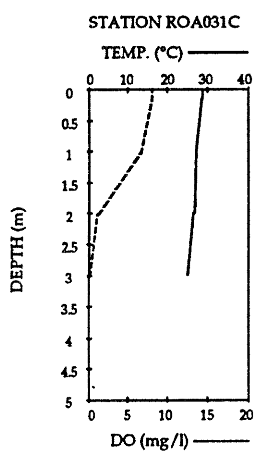
Roxboro Lake (also called Lake Isaac Walton) is located in Person County near the town of Roxboro and is the primary water supply for the town. The lake was built in the 1930's. Maximum depth is about seven meters, and mean depth is about three to four meters. Retention time is approximately 30 days. Satterfield and Storys Creeks are the main tributaries. The lake is used for recreation and is classified WS-III.

Roxboro Lake was sampled on July 28, 1988. The lake was stratified, and anoxic conditions were found near the bottom of the water column. Elevated levels of nitrogen and phosphorous were documented. Chlorophyll-a was elevated but did not exceed the state standard of 40 µg/l.

A mixture of chlorophytes dominated biovolume estimates at the upper end of the lake (ROA031C) with Lyngbya species, a filamentous blue-green algae, dominating the density estimates. At the other stations filamentous blue-green algae (Anabaenopsis raciborskii, Anabaena levanderi and A. subcylindrica) dominated biovolume and density estimates. These blue-green algae are common in eutrophic bodies of water throughout North Carolina. Overall biovolumes were moderate to low throughout the lake, but densities were above or approaching bloom levels. These findings support the elevated chlorophyll-a concentrations and the eutrophic status of the lake.

The TSI of 1.4 indicates the lake is eutrophic. Although the lake currently supports its use as a water supply, its eutrophic status is cause for future sampling.


ROXBORO
LAKE
Storys Creek
ROA031H
ROA031E
ROA031C
N
Satterfield Creek
0
1/2 mile


STATION ROA031C
TEMP. (°C)
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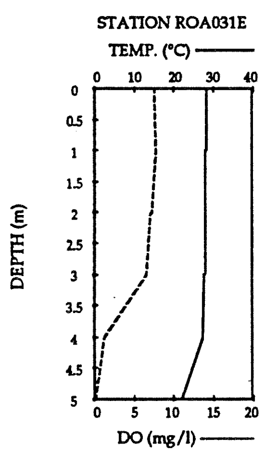
DEPTH (m)
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5
0 5 10 15 20
DO (mg/l)


STATION ROA031E
TEMP. (°C)
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DEPTH (m)
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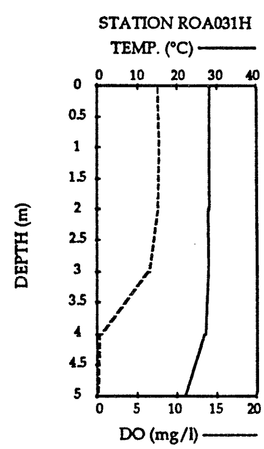
0 5 10 15 20
DO (mg/l)


STATION ROA031H
TEMP. (°C)
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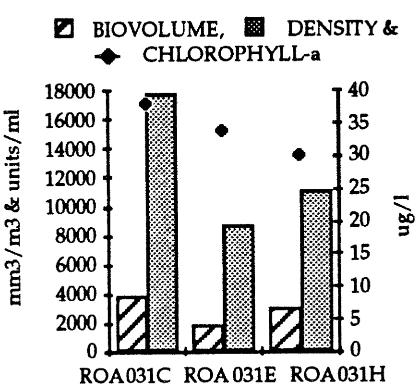
DEPTH (m)
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5
0 5 10 15 20
DO (mg/l)


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/m3 & units/ml
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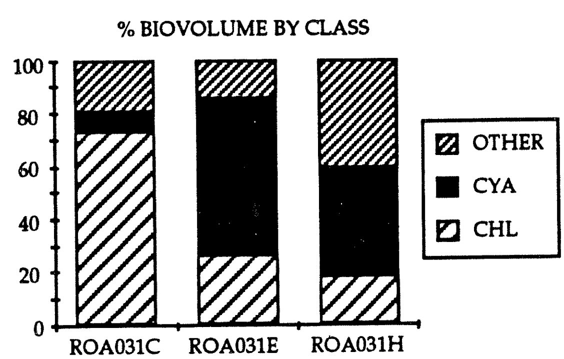
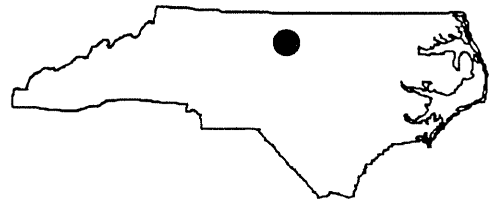
40 35 30 25 20 15 10 5 0
ug/l
ROA031C ROA031E ROA031H


% BIOVOLUME BY CLASS
100 80 60 40 20 0
ROA031C ROA031E ROA031H
OTHER
CYA
CHL

LAKE ROXBORO



COUNTY:	Caswell	BASIN:	Roanoke
SURFACE AREA:	79 hectares (195 acres)	USGS TOPO:	Ridgeville, N.C.
CLASS:	B	LAKE TYPE:	Reservoir

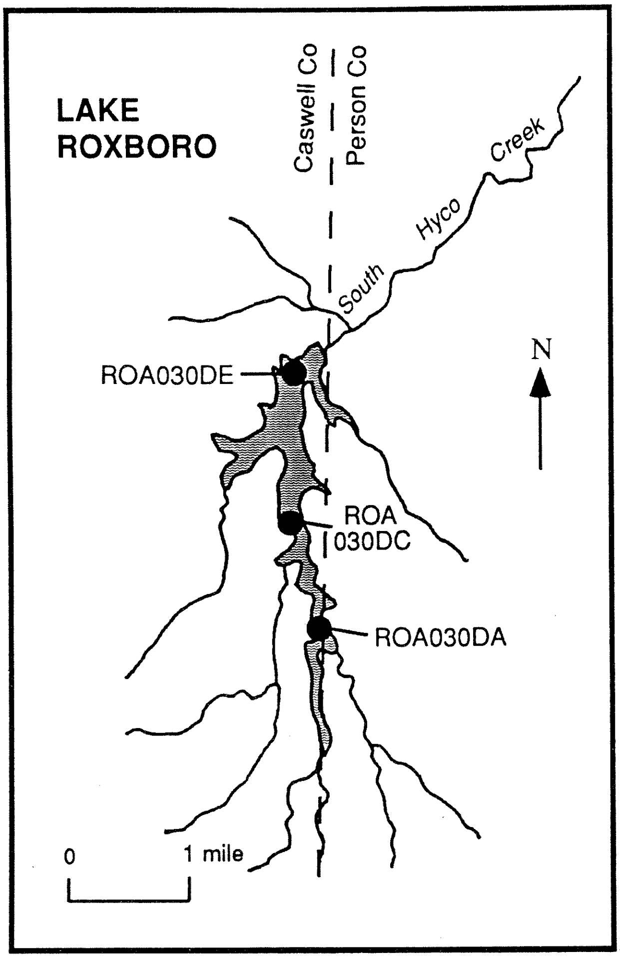
LATEST NCTSI:	- 0.2	TROPHIC STATE:	Mesotrophic
SAMPLING DATE:	August 23, 1988	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	1.9 m	CONDUCTIVITY:	34 - 92 µmhos/cm^2
TOTAL PHOSPHORUS:	0.03 mg/l	DISSOLVED OXYGEN:	6.7 - 13.3 mg/l
TOTAL ORGANIC NITROGEN:	0.3 mg/l	TEMPERATURE:	27.2 - 28.0 °C
CHLOROPHYLL-A:	15 µg/l	pH:	7.0 - 9.1 s.u.

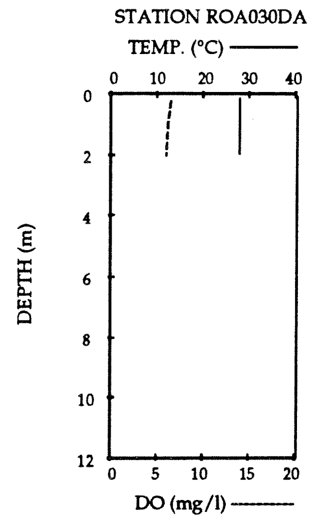
Lake Roxboro is located in Caswell and Person Counties near the Town of Roxboro. The lake was filled in 1978 and is owned by the Town of Roxboro. The volume of the lake is 10.8 x 10^6 m^3 with a maximum depth of 12.5 meters. The watershed covers 62 km^2. Land uses in the watershed include agriculture, forest, and residential areas. The main tributary to the lake is South Hyco Creek . The lake is classified B and is used for recreation.

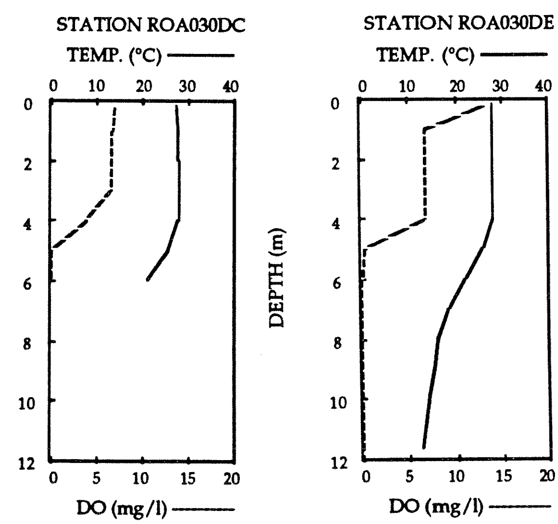
Lake Roxboro was sampled on August 23, 1988. The two downstream stations were stratified with anoxic conditions below four meters. A pH of 9.1 standard units, slightly above the state standard of 9.0 standard units, was recorded near the dam. The surface dissolved oxygen at this station was 13.3 mg/l. This supersaturated value, along with the greenish water color, indicated substantial algal productivity. Nitrogen was moderate and total phosphorous was slightly elevated.

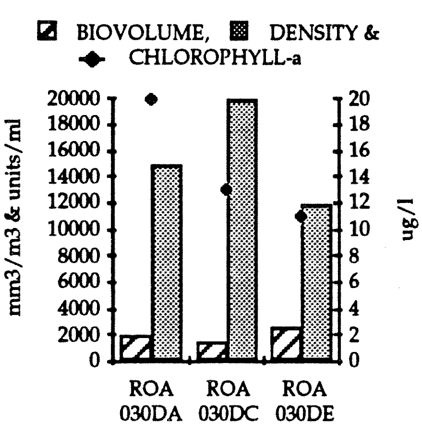
Small, filamentous, blue-green algae dominated phytoplanktonic density at bloom levels. However, moderate to low estimates of biovolume and low chlorophyll-a concentrations were also documented. Blue-green algae included Anabaenopsis raciborskii, Lyngbya species A, and Anabaena levanderi. These species are common in eutrophic waters throughout North Carolina. At the upper (ROA030DA) and lower (ROA030DE) stations Staurastrum tetracerum, a chlorophyte, codominated biovolume estimates along with the blue-green algae.

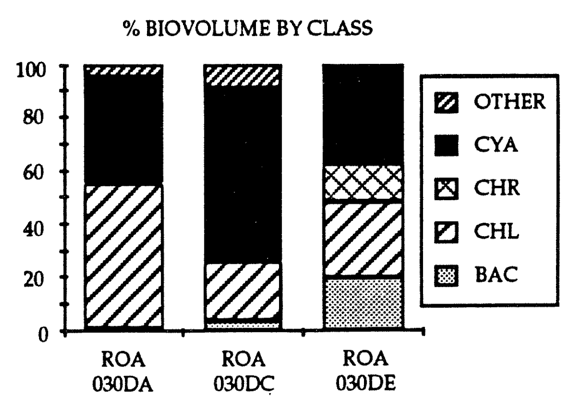
The TSI was -0.2 in 1988, indicating that Lake Roxboro is mesotrophic. The lake supported its uses although the algal activity and the elevated nutrient levels warrant future monitoring of the lake.



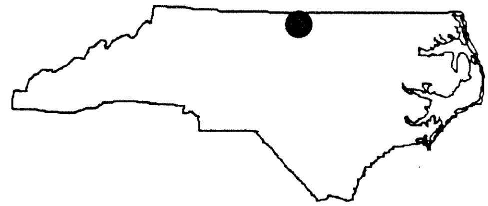








MAYO LAKE



COUNTY:	Person	BASIN:	Roanoke
SURFACE AREA:	1,133 hectares (2,800 acres)	USGS TOPO:	Virgilina, VA.
CLASS:	C	LAKE TYPE:	Reservoir

LATEST NCTSI:	-2.8	TROPHIC STATE:	Oligotrophic
SAMPLING DATE:	August 8, 1990	ADDITIONAL COVERAGE:	None
SECCHI DEPTH:	3.7 m	CONDUCTIVITY:	82 - 90 µmhos/cm^2
TOTAL PHOSPHORUS:	0.03 mg/l	DISSOLVED OXYGEN:	8.0 - 8.3 mg/l
TOTAL NITROGEN:	0.21 mg/l	TEMPERATURE:	27.4 - 28.3 °C
CHLOROPHYLL-A:	3 µg/l	pH:	7.6 s.u.

Mayo Lake is located on Mayo Creek in Person County just south of the Virginia border. Owned by Carolina Power and Light Company (CP&L), the reservoir was constructed in 1983 to provide cooling water for the Mayo Electric Generating Plant. Mayo Lake has a mean depth of nine meters and a volume of 105 x 10^6 m^3. The drainage area is 133 km^2, characterized by rolling hills with forests and agriculture. The reservoir is designated Class C.

As in other cooling water reservoirs of the Roanoke Basin (Hyco Lake and Belews Lake), the biota and sediments of Mayo Lake have been contaminated by selenium. Extensive monitoring by CP&L (1990b) found that selenium concentrations in both zooplankton and benthic organisms decreased in two of three stations in 1989. Selenium was introduced to the lake via ash pond discharges. Selenium concentrations in water samples have been below laboratory detection limits.

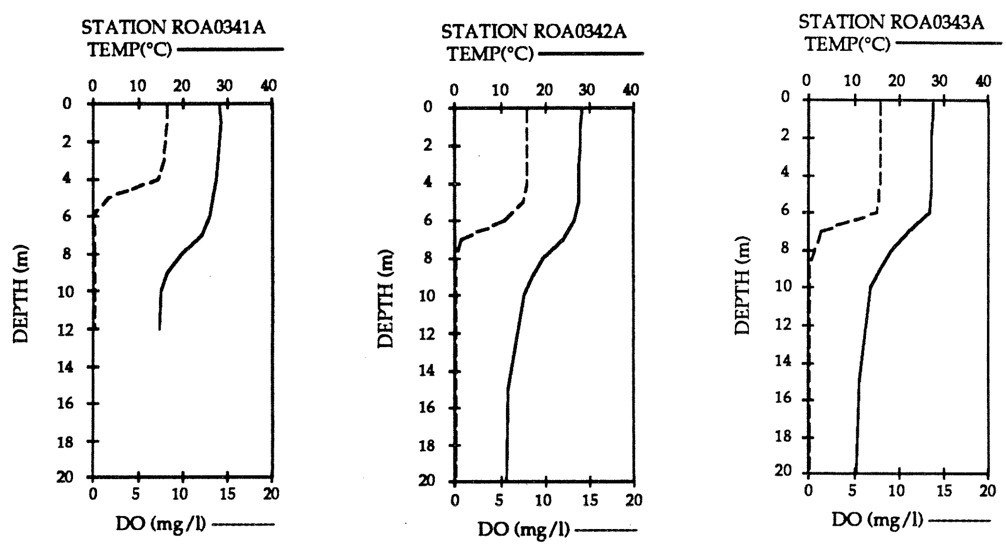
Mayo Lake was sampled on August 8, 1990. Physical measurements indicated that the lake was stratified. Total phosphorus concentrations were moderate. Nitrogen and chlorophyll-a concentrations were low, indicating minimal productivity in the lake.

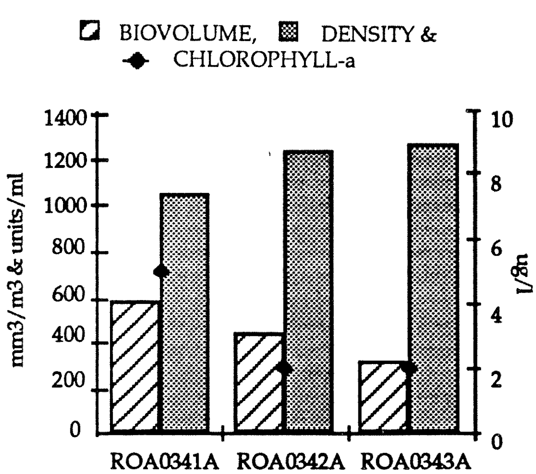
DEM and CP&L have monitored phytoplankton assemblages along with other parameters in Mayo Reservoir since 1983. Both sets of data indicate Mayo Lake to be a low to moderately productive system with green algae generally dominating both density and biovolume estimates. Since the lake was filled in 1983, no significant shifts in species have occurred, nor have algal blooms been reported (CP&L 1987; 1988).

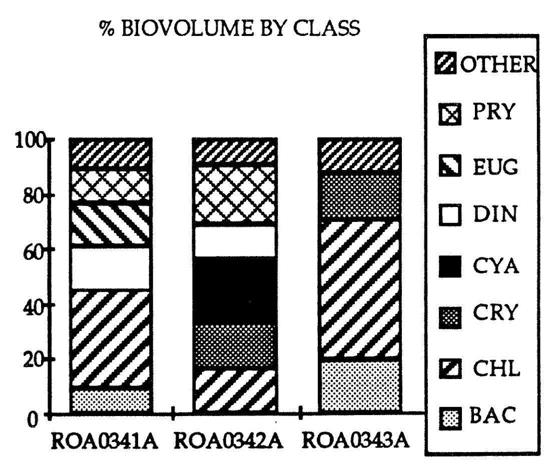
The headwaters have consistently experienced higher chlorophyll-a values than the middle and lower stations. However, these differences are not reflected in biovolume and density estimates, indicating that species composition may be responsible. Phytoplankton vary in the amount of chlorophyll-a relative to biovolume, and in diverse assemblages, this can result in a poor relationship between chlorophyll-a concentration and phytoplankton biovolume and density.

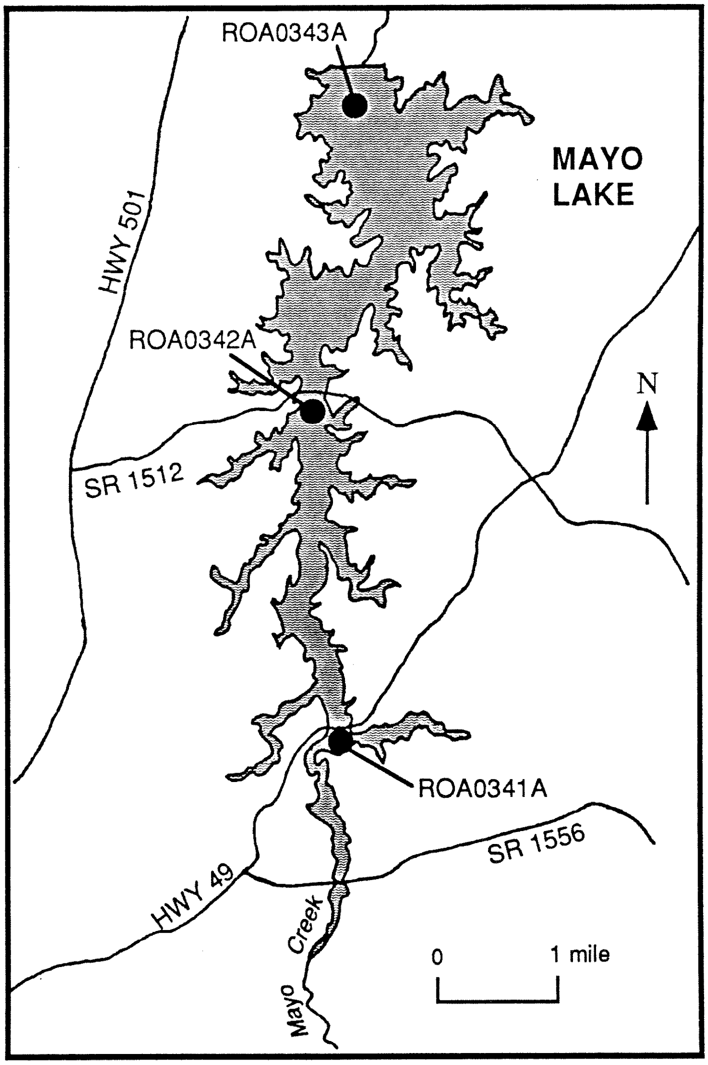
CP&L has monitored submersed aquatic vegetation in Mayo since 1983. Of the species present, Egeria densa and Potamogeton nodosus have spread at rates which warrant continued monitoring. In 1986, measures were taken to control egeria, but initial treatment with herbicide gave little or no control in the main body of the lake. In 1989, Hydrilla verticillata was discovered near a public boat ramp (CP&L 1990). Herbicides were applied in 1989 and 1990 in an attempt to control hydrilla, which grows rapidly with potential impact on power plant operation. Improved control is expected and CP&L is continuing monitoring efforts.

The TSI was -2.8 in 1990, which is similar to historical values. At the time of assessment, no violations of state water quality standards were observed at Mayo Lake, and water quality fully supported designated uses of the reservoir. Current levels of selenium in the biota and increasing infestation by aquatic macrophytes warrant continued monitoring of Mayo Lake.

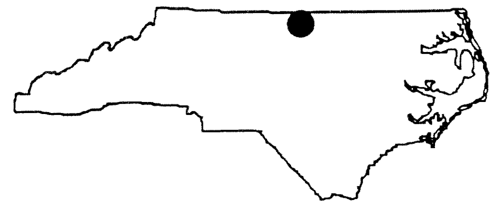







ROA0343A
MAYO
LAKE
HWY 501
ROA0342A
N
SR 1512
ROA0341A
SR 1556
HWY 49
Creek
Mayo
0
1 mile

HYCO LAKE



COUNTY:	Person	BASIN:	Roanoke
SURFACE AREA:	1,518 hectares (3,750 acres)	USGS TOPO:	Alton, VA.
CLASS:	WS, B	LAKE TYPE:	Reservoir

LATEST NCTSI:	-3.5	TROPHIC STATE:	Oligotrophic
SAMPLING DATE:	August 8, 1990	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	1.8 m	CONDUCTIVITY:	83 - 87 µmhos/cm^2
TOTAL PHOSPHORUS:	0.015 mg/l	DISSOLVED OXYGEN:	6.5 - 7.1 mg/l
TOTAL ORGANIC NITROGEN:	0.155 mg/l	TEMPERATURE:	29.7 - 31.1 °C
CHLOROPHYLL-A:	2.5 µg/l	pH:	6.8 - 7.1 s.u.

Hyco Lake is located on the Hyco River south of the Virginia State line in Person County. The reservoir was built in 1965 to provide cooling water for Carolina Power and Light Company's (CP&L) Roxboro Steam Plant. Coal-powered steam units were built on Hyco Lake in 1966, 1968, 1973, and 1980. There are four coal ash settling basins located in small arms of the lake.

Hyco Lake has a maximum depth of 15 meters, a mean depth of 6.1 meters, a volume of 99 x 10^6 m^3, and a mean hydraulic retention time of 180 days. The drainage area for Hyco Lake covers 487 km^2 of land which is characterized by rolling hills. Hyco Lake is classified C from the source of the Hyco River in Hyco Lake to the North Carolina-Virginia state line and WS-III from the source of South Hyco Creek to Hyco Lake.

Hyco Lake has experienced elevated levels of selenium, a heavy metal toxic to fish and waterfowl in high concentrations, in the water column, sediment and fish tissue. The selenium originated from the coal ash disposal basins at the Roxboro Steam Plant. It has been shown that large-scale combustion of coal, primarily at steam-electric generating plants, can result in significant inputs of selenium to aquatic ecosystems (Lemly 1985).

Health of the fishery began to decline in 1978. A large fish kill in 1980 was associated with a severe drought. Populations of larval fish also declined dramatically, falling 85% from 1979 to 1980 (NRCD 1986b). Selenium has been found in bluegill, largemouth bass, white catfish, and channel catfish collected from the lake.

Carolina Power and Light has converted its operations at the Roxboro Plant to a dry fly ash handling system. This should eliminate the discharge of selenium into the lake.

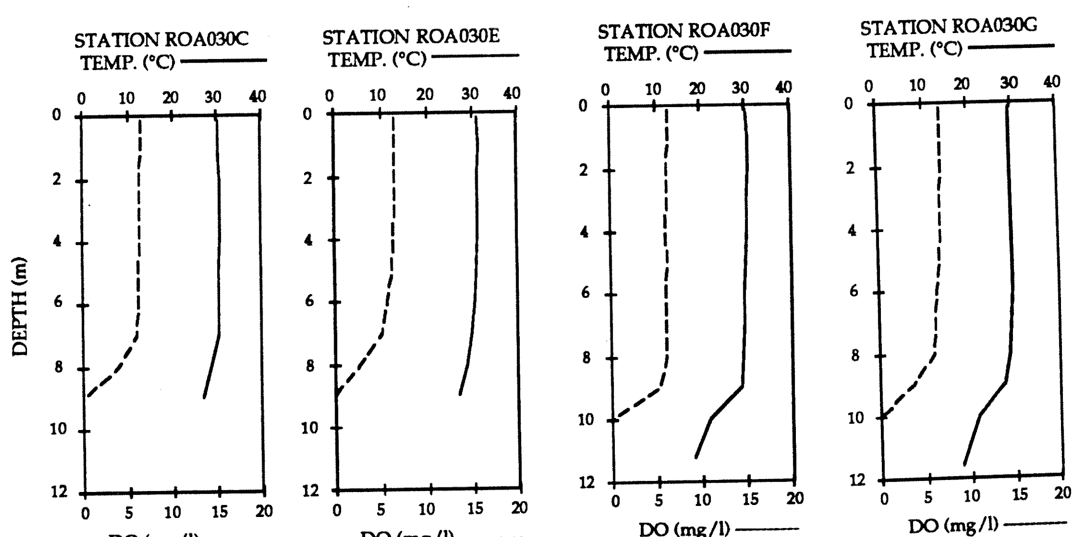
Hyco Lake formerly had nuisance infestations of macrophytes. Prior to 1985, the reservoir was clogged with extensive growths of elodea and hydrilla, but in early 1984, Tilapia zilli, a tropical herbaceous fish, was accidently introduced into the lake. In the absence of predaceous fish, the tilapia population increased rapidly. By 1986, the tilapia had eliminated the dense mats of aquatic vegetation and investigators were unable to find any submerged aquatic vegetation (CP&L 1986b).

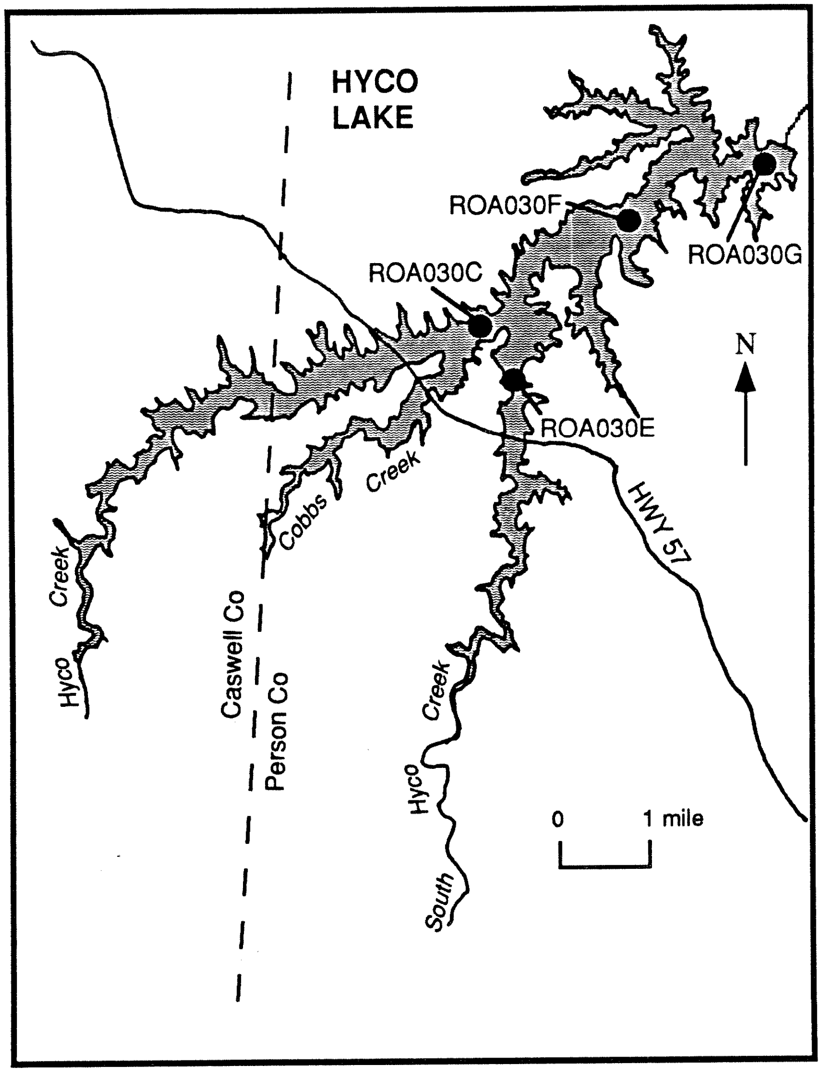
Hyco Lake was sampled on August 8, 1990. All sampling stations were stratified. Nutrient concentrations were low with higher concentrations found in bottom waters, a situation common in stratified lakes. Chlorophyll-a concentrations were also low. In 1990, selenium was not detected in surface water samples.

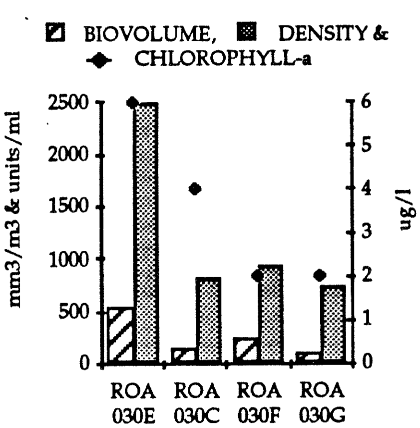
Algal biovolumes and densities were moderately low. Samples collected from 1986 through 1989 by DEM show that the South Hyco Creek arm (ROA030E) had slightly higher densities, biovolume and chlorophyll-a than the other stations on the lake. Since 1980, CP&L has reported similar findings at their station located further upstream. In 1990, algal densities and biovolumes were lower here than at other stations, however there was also a shift to greater dominance by cryptophytes and blue-greens. This shift was also apparent at the other three stations. Warmer temperatures allowed blue-green algae to proliferate.

Densities of phytoplankton at all stations were mainly composed of small filamentous blue-green algae, Lyngbya species A and Anabaenopsis raciborskii. These blue-green algae are common summer dominants in reservoirs throughout North Carolina.

In 1990, the TSI was -3.5 which is similar to previous values. This indicates the lake is oligotrophic. At the time of assessment, no North Carolina standards were violated. The lake does not support its designated use because selenium is still found in the food web. Although there are neither federal nor North Carolina standards for selenium in fish tissue, state officials have imposed a fish consumption advisory for Hyco Lake. Future monitoring of water quality and fish tissue is warranted.




HYCO
LAKE
ROA030F
ROA030G
ROA030C
ROA030E
N
Cobbs
Creek
HWY 57
Creek
Hyco
Caswell Co
Person Co
Creek
Hyco
South
0
1 mile


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/m3 & units/ml
ug/l
2500
2000
1500
1000
500
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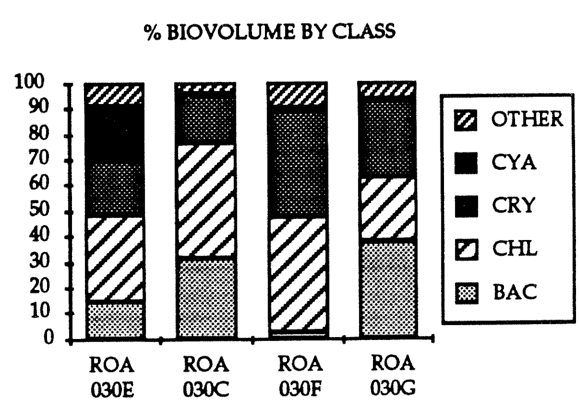
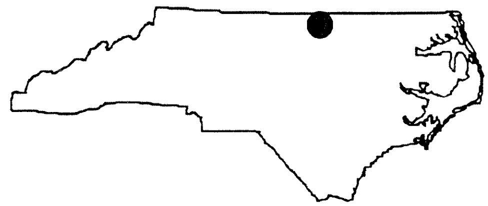
6
5
4
3
2
1
0
ROA 030E
ROA 030C
ROA 030F
ROA 030G


% BIOVOLUME BY CLASS
100
90
80
70
60
50
40
30
20
10
0
ROA 030E
ROA 030C
ROA 030F
ROA 030G
OTHER
CYA
CRY
CHL
BAC

JOHN H. KERR RESERVOIR



COUNTY:	Vance/Warren	BASIN:	Roanoke
SURFACE AREA:	19830 hectares (49000 acres)	USGS TOPO:	John H. Kerr Dam, N.C.
CLASS:	B, C, WS	LAKE TYPE:	Reservoir

LATEST NCTSI:	0.7	**TROPHIC STATE:**	Eutrophic
SAMPLING DATE:	September 14, 1988	**ADDITIONAL COVERAGE:**	Fecal
SECCHI DEPTH:	1.3 m	**CONDUCTIVITY:**	100 - 120 µmhos/cm^2
TOTAL PHOSPHORUS:	0.03 mg/l	**DISSOLVED OXYGEN:**	8.2 - 9.6 mg/l
TOTAL ORGANIC NITROGEN:	0.3 mg/l	**TEMPERATURE:**	25.4 - 25.8 °C
CHLOROPHYLL-A:	27 µg/l	**pH:**	6.0 - 8.7 s.u.

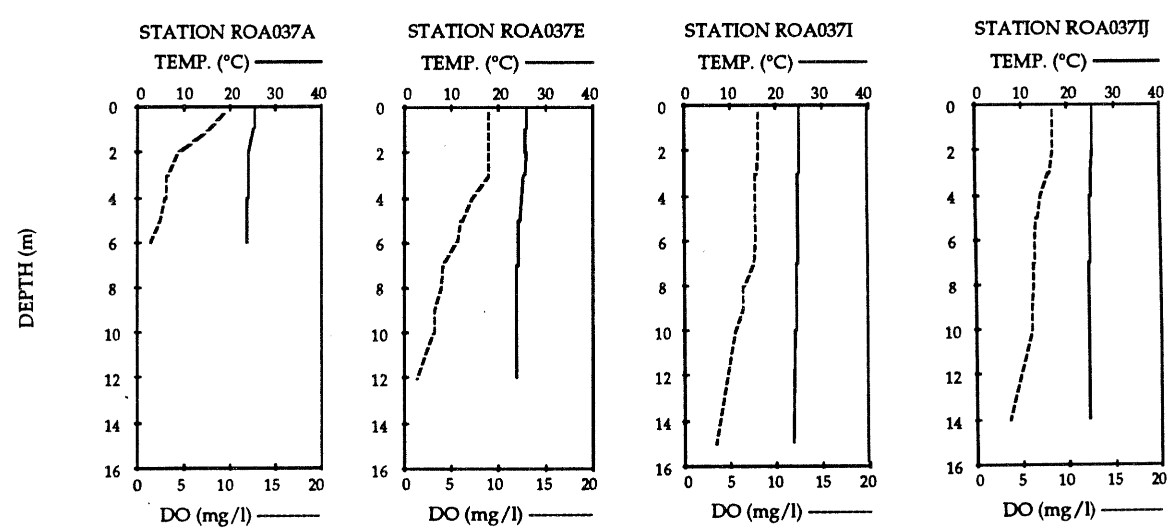
The John H. Kerr Reservoir (also called Kerr Lake) is a multi-purpose impoundment constructed and operated by the U. S. Army Corps of Engineers to provide flood control, water-based recreation and hydroelectric power. The reservoir crosses the North Carolina-Virginia state line with the majority of the lake located in Virginia. The reservoir has an average depth of 10.7 m, a volume of 448 x 10^6 m^3, and a mean hydraulic retention time of 124 days. Major tributaries to Kerr Lake include the Roanoke River, Hyco River, Nutbush Creek, and the Dan River. The lake has a drainage area covering 19,712 km^2 of land with forest and agriculture being the major land uses.

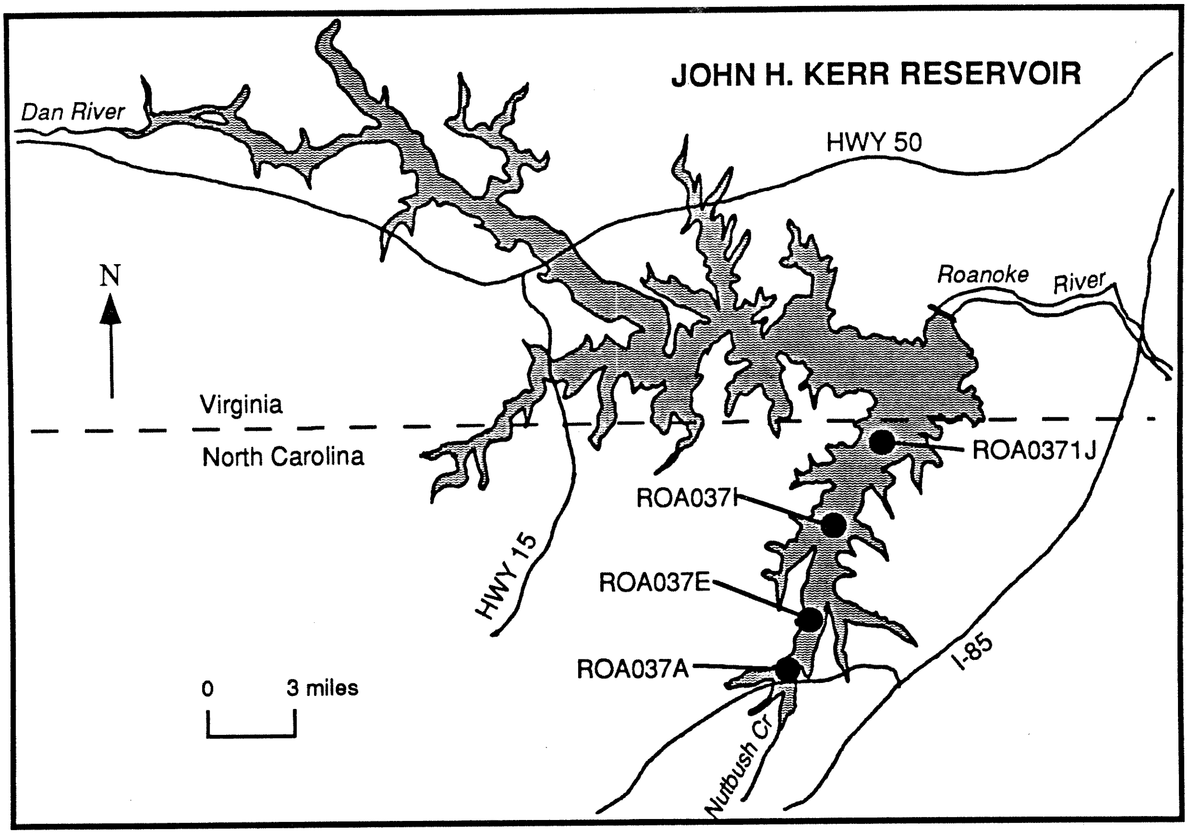
John H. Kerr Reservoir was sampled on September 14, 1988. Sampling was confined to the Nutbush Creek Arm of Kerr Lake because it is the only portion of the lake that lies in North Carolina. None of the stations exhibited thermal stratification; however, there was a marked dissolved oxygen gradient at the shallow, upstream station (ROA037A). Nutrients were elevated at this station, and chlorophyll-a (51 µg/l) exceeded the state standard of 40 µg/l. Chlorophyll-a and nutrients were moderate at the rest of the stations. This is consistent with other water quality data collected by DEM which show that nitrogen and phosphorus concentrations in reservoirs generally decrease in a downstream direction because sedimentation and assimilation by phytoplankton reduce the availability of nutrients in the water column.

The predominant source of nutrients into the Nutbush Creek Arm of Kerr Lake is the discharge from the Town of Henderson's wastewater treatment plant. During times of drought, the discharge into upper Nutbush Creek from the Henderson wastewater treatment plant constitutes 100% of the stream flow (DEM unpublished data 1988). Blue-green algal blooms have occurred at the uppermost station, downstream from the treatment plant. In 1988 DEM investigated the contribution of the Henderson facility to nutrient loading in the Nutbush Creek arm of Kerr Lake. Results of this study were used to limit total phosphorus levels in the discharge.

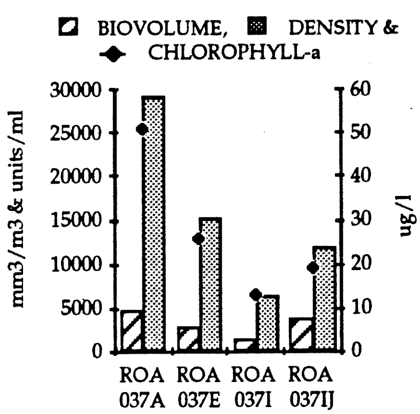
The spatial patterns observed for nutrient and chlorophyll-a concentrations in the Nutbush Creek Arm of Kerr Lake were also evident in the measured phytoplanktonic standing crops. Highest estimates of biovolume and density were seen at ROA037A near the mouth of Nutbush Creek. Algal populations in 1988 were similar to 1987 assemblages with small filamentous blue-greens (Oscillatoria geminata and Anabaenopsis raciborskii) dominating biovolume and density estimates at all stations. O. geminata was most prevalent at the two uppermost stations (ROA037A and ROA037E), while A. raciborskii dominated biovolume and density at ROA037I and ROA037IJ. Both of these blue-greens are usually associated with eutrophic conditions.

In 1988 the TSI was 0.7 which is similar to the TSI in 1987 (0.1). Historical TSI values have increased since 1981, which suggests that the reservoir is becoming enriched over time. The lake was classified as eutrophic in the 1988-1989 305b Report (EHNR 1990), but the data from Nutbush Creek suggests that hypereutrophic conditions exist in the headwaters of the Nutbush Creek arm. Conditions are expected to improve when the quality of the wastewater effluent is upgraded. Future monitoring will help evaluate the effects of these management efforts.

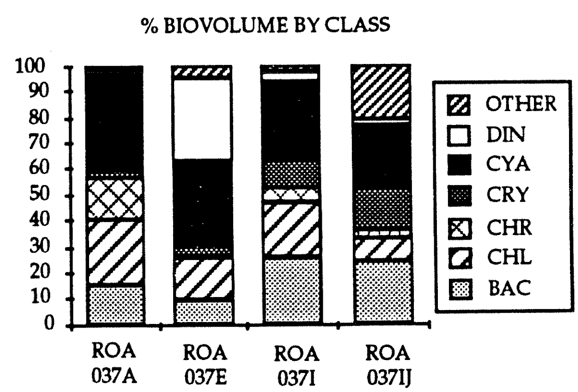




JOHN H. KERR RESERVOIR
Dan River
HWY 50
Roanoke River
N
Virginia
North Carolina
ROA0371J
ROA037I
ROA037E
ROA037A
HWY 15
I-85
Nutbush Cr
0 3 miles

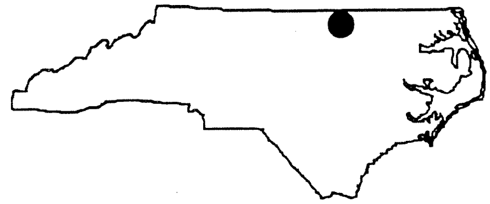


BIOVOLUME, DENSITY & CHLOROPHYLL-a
mm3/m3 & units/ml
ug/l
30000
25000
20000
15000
10000
5000
0
60
50
40
30
20
10
0
ROA 037A
ROA 037E
ROA 037I
ROA 037IJ



% BIOVOLUME BY CLASS
100
90
80
70
60
50
40
30
20
10
0
OTHER
DIN
CYA
CRY
CHR
CHL
BAC
ROA 037A
ROA 037E
ROA 037I
ROA 037IJ

LAKE GASTON



COUNTY:	Warren/Halifax/Northampton	BASIN:	Roanoke
SURFACE AREA:	8215 hectares (20300 acres)	USGS TOPO:	Valentines, VA. - N.C.
CLASS:	WS, B	LAKE TYPE:	Reservoir

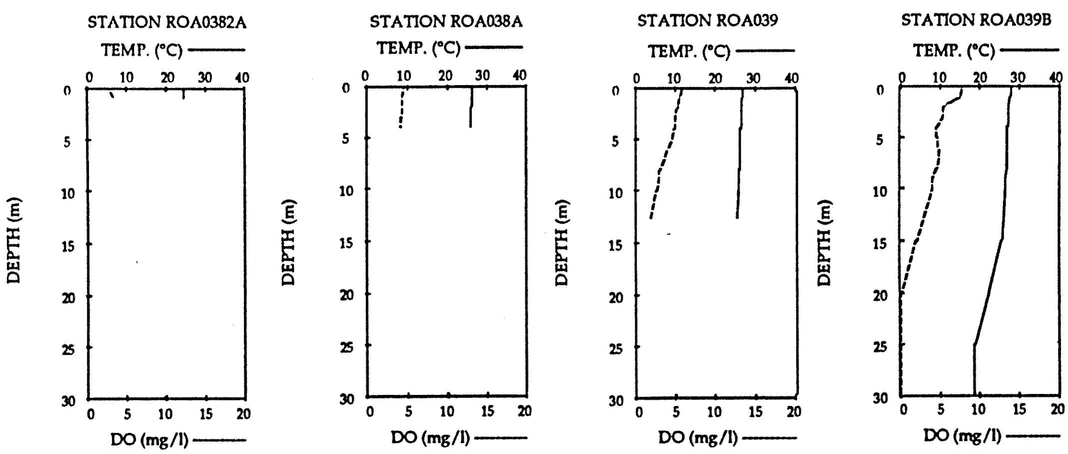
LATEST NCTSI:	- 1.1	TROPHIC STATE:	Mesotrophic
SAMPLING DATE:	August 8, 1989	ADDITIONAL COVERAGE:	Fecal, Water Supply Parameters
SECCHI DEPTH:	1.35 m	CONDUCTIVITY:	94 - 99 µmhos/cm^2
TOTAL PHOSPHORUS:	0.02 mg/l	DISSOLVED OXYGEN:	2.9-7.9 mg/l
TOTAL ORGANIC NITROGEN:	0.26 mg/l	TEMPERATURE:	24.6 - 28.1 ^oC
CHLOROPHYLL-A:	7.5 µg/l	pH:	6.4 - 7.0 s.u.

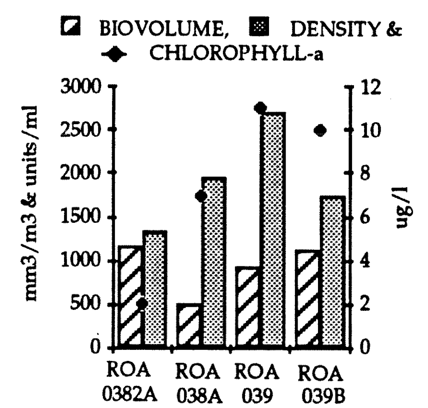
Lake Gaston is located on the North Carolina-Virginia border just downstream from the John H. Kerr Reservoir dam on the Roanoke River. The lake was built in 1962 by the Virginia Electric and Power Company for generating hydroelectric power. The lake is also used extensively for recreation with residential development, campgrounds, golf courses, marinas, beaches, etc. located along the shoreline. The maximum depth of the lake is 29 meters, mean depth is 6 meters, and volume is 512 x 10^6 m^3. Drainage area for the lake is 21,340 km^2 of mostly forested land with some agriculture. Lake Gaston is classified WS-III and B.

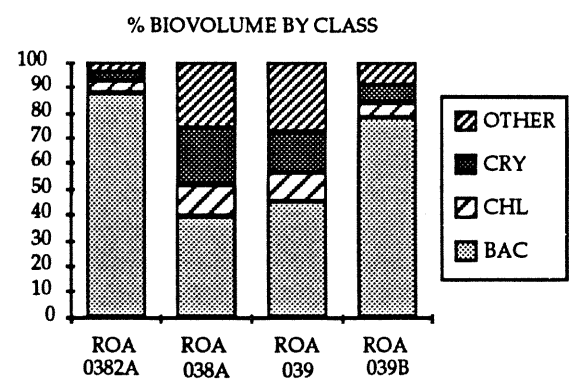
The most recent sampling of Lake Gaston was completed on August 8, 1989. Physical measurements indicated stratification at the deeper stations. Low dissolved oxygen and relatively low temperatures were found throughout the water column at the two upstream stations, probably as a result of upstream releases from the hypolimnion of Kerr Lake. Photic zone nutrient analyses revealed that ammonia levels were moderate, total Kjeldahl nitrogen was elevated only at station ROA038A, while nitrite-nitrate levels were elevated at all stations. Total phosphorus concentrations were moderate throughout the lake. Chlorophyll-a was low at all stations.

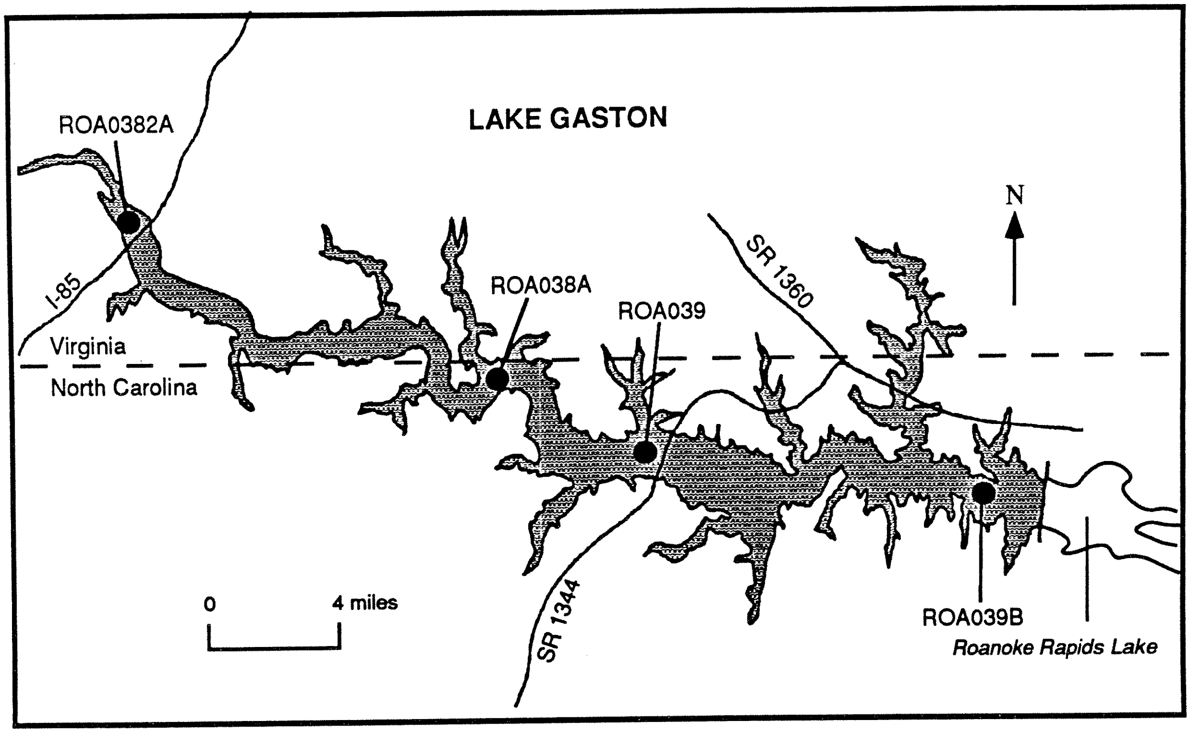
Lake Gaston was drawn down in the winter of 1987 - 1988 in an attempt to control Egeria densa and hydrilla infestations, primarily in the upstream end of the lake. The lake level was lowered three meters to expose the egeria to cold temperatures to kill the weed. Limited areas of hydrosoil were treated with Norosac to control the hydrilla growth. Observations after the treatment in 1988 revealed that the winter drawdown was effective in reducing the egeria; however, the herbicidal treatments were ineffective in controlling hydrilla. In fact, the hydrilla was found in greater abundance following the removal of egeria, its major competitor.

The TSI in 1989 was -1.1 indicating Lake Gaston is mesotrophic. Past TSI scores of -1.2, -1.4, and -1.4 are similar. Although the presence of hydrilla is a cause for concern, no violations of state water quality standards were exceeded at Lake Gaston in 1989, and the uses were fully supported.

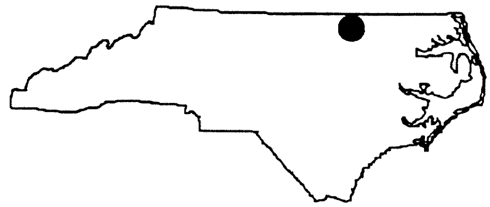







LAKE GASTON
ROA0382A
ROA038A
ROA039
ROA039B
N
I-85
SR 1360
SR 1344
Virginia
North Carolina
0
4 miles
Roanoke Rapids Lake

ROANOKE RAPIDS LAKE



COUNTY:	Northampton	BASIN:	Roanoke
SURFACE AREA:	1,980 hectares (4,893 acres)	USGS TOPO:	Roanoke Rapids, N.C.
CLASS:	WS, B	LAKE TYPE:	Reservoir

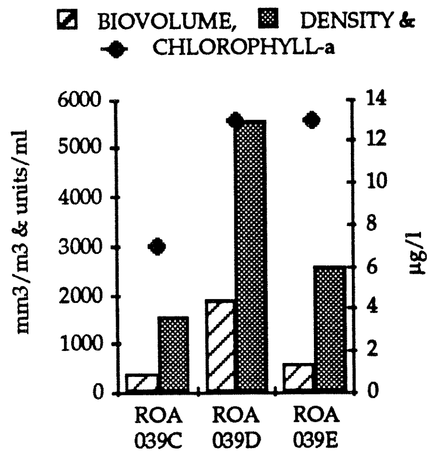
LATEST NCTSI:	- 0.7	TROPHIC STATE:	Mesotrophic
SAMPLING DATE:	July 30, 1987	ADDITIONAL COVERAGE:	None
SECCHI DEPTH:	1.3 m	CONDUCTIVITY:	100 - 103 µmhos/cm^2
TOTAL PHOSPHORUS:	0.02 mg/l	DISSOLVED OXYGEN:	3.8 - 8.1 mg/l
TOTAL ORGANIC NITROGEN:	0.28 mg/l	TEMPERATURE:	25.6 - 29.4 °C
CHLOROPHYLL-A:	11 µg/l	pH:	6.0 - 7.1 s.u.

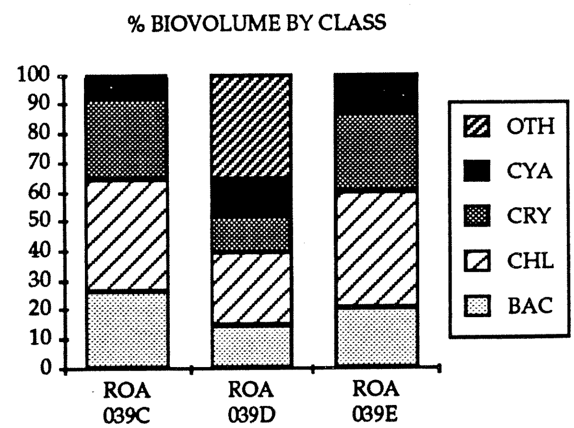
Roanoke Rapids Lake, located on the Roanoke River just downstream from Lake Gaston, is owned by the Virginia Electric and Power Company and used as a water supply and for recreation. Maximum depth is 27 meters, mean depth is five meters, and volume is 96 x 10^6 m^3. The Roanoke River is the major tributary to the reservoir and drains nearly all of its 21,482 km^2 watershed. The watershed is characterized by rolling hills where nearly three-fourths is forested and most of the remaining land is agricultural.

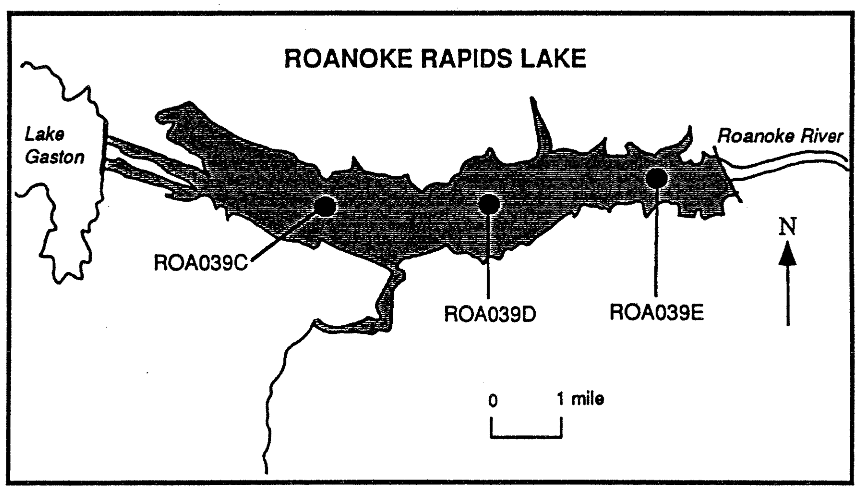
Roanoke Rapids Lake was sampled on July 30, 1987. Physical measurements indicated that the shallow, uppermost station was mixed while those closer to the dam were stratified. Nutrient and chlorophyll-a concentrations were moderate and relatively consistent between stations. At the stratified stations, nutrient concentrations were higher in the hypolimnion than the photic zone. Releases from Lake Gaston account for almost all of the inflow into Roanoke Rapids Lake; therefore, the water quality of these two reservoirs is very similar.

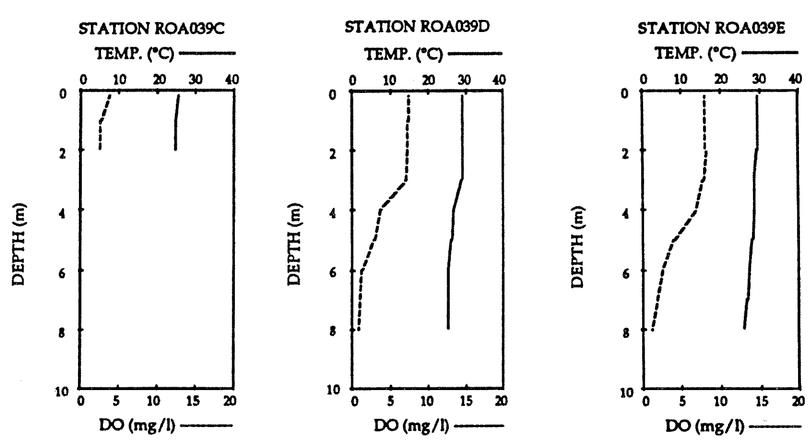
Populations of phytoplankton from Roanoke Rapids Lake indicated low to moderate productivity. No single class of algae was dominant. Chlorophytes (green algae), cyanophytes (blue-green algae), bacillariophytes (diatoms), chrysophytes and cryptophytes were all prevalent in algal samples from 1983 and 1987. Although estimates of algal biovolume and density were generally similar to those in 1983, chlorophyll-a values were slightly higher in 1987. The presence of Chrysochromulina breviturrita, a prymnesiophyte which contains a large amount of chlorophyll-a relative to its size, helps account for the higher chlorophyll-a. The higher density at the middle station (ROA039D) is attributed to the presence of Ochromonas species 3, a small chrysophyte which is common in North Carolina lakes.

Mesotrophic conditions were noted in 1987 by the TSI of -0.7, which is similar to historical values. At the time of assessment, no state water quality standards were violated at Roanoke Rapids Lake uses were fully supported.

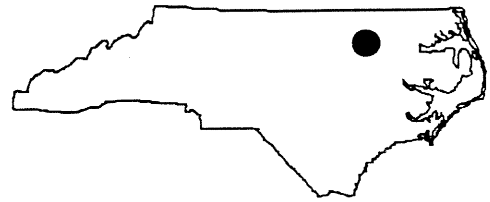








WHITE MILLPOND



COUNTY:	Halifax	BASIN:	Roanoke
SURFACE AREA:	61 hectares (150 acres)	USGS TOPO:	Palmyra, N.C.
CLASS:	C	LAKE TYPE:	Millpond

LATEST NCTSI:	6.8	TROPHIC STATE:	Hypereutrophic
SAMPLING DATE:	July 26, 1988	ADDITIONAL COVERAGE:	None
SECCHI DEPTH:	0.6 m	CONDUCTIVITY:	92 - 93 µmhos/cm^2
TOTAL PHOSPHORUS:	0.25 mg/l	DISSOLVED OXYGEN:	4.0 - 5.8 mg/l
TOTAL ORGANIC NITROGEN:	0.685 mg/l	TEMPERATURE:	25.2 - 25.4 °C
CHLOROPHYLL-A:	172.5 µg/l	pH:	6.5 - 6.8 s.u.

White Millpond is a 61-hectare millpond located in eastern Halifax County. The millpond is owned by several individuals. The Kehukee Swamp is the main tributary to the millpond. Maximum and average depths are approximately three meters and one and a half meters respectively.

The lake is used primarily for fishing. Land use in the watershed is agricultural and undeveloped swampland. There are some hog operations upstream which may contribute to algal blooms and duckweed in the millpond.

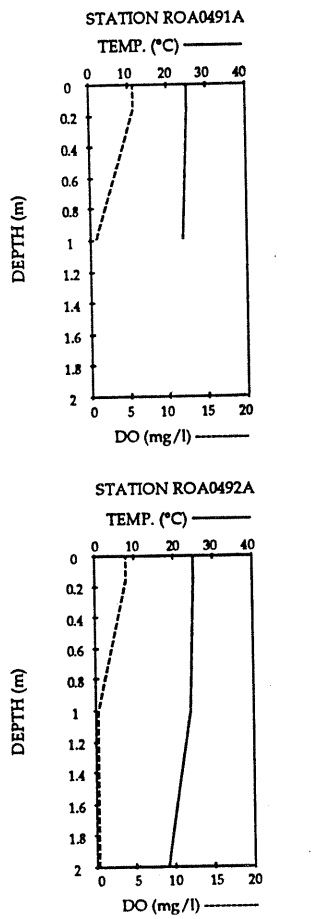
White Millpond was sampled on July 26, 1988. Both stations were stratified with anoxic conditions found below one meter. Surface dissolved oxygen at ROA0492A was 4.0 mg/l, which is at the state standard; however, the waters in this millpond are naturally low in dissolved oxygen as a result of the swampy conditions. Nutrients were elevated at ROA0491A where total phosphorus was 0.37 mg/l and orthophosphorous was 0.30 mg/l. Chlorophyll-a concentrations above the state standard were documented at both stations. Approximately half of the millpond was covered with duckweed. Low secchi disk measurements revealed poor water clarity.

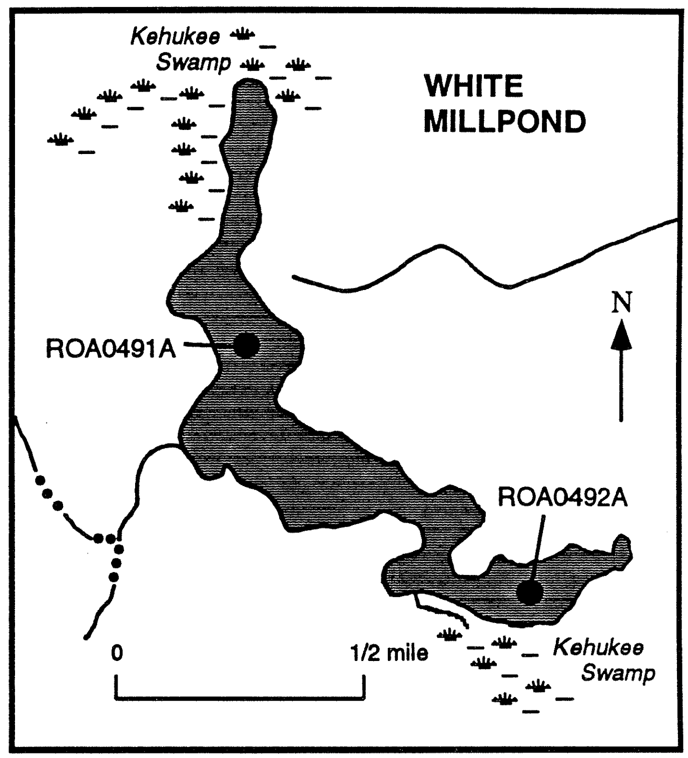
Estimates of phytoplanktonic biovolume and density were slightly elevated at both stations; however, they were not consistent with the extremely high chlorophyll-a concentrations. An abundance of species with high chlorophyll-a to biovolume ratios helps account for this discrepancy.

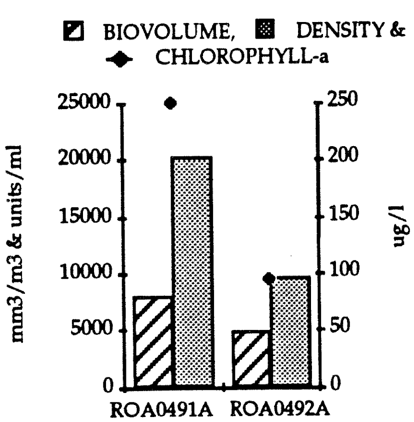
The dominant species at the upper station (ROA0491A) were chlorophytes and euglenophytes. Several chlorophytes of the genus

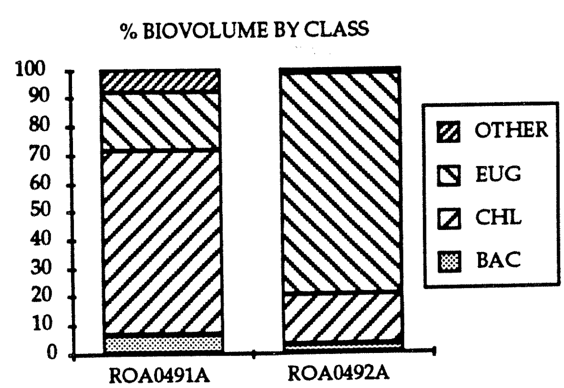
Chlamydomonas were present at this site. At ROA0492A euglenophytes were dominant by biovolume with Chlamydomonas species dominating density. Euglenophytes are commonly dominant in organically enriched waters, and Chlamydomonas occasionally reach bloom numbers in similar situations.

In 1988 the TSI was 6.8 for White Millpond, indicating it is hypereutrophic. Associated problems with algae, duckweed, and low dissolved oxygen are evidence that uses could be threatened. Additional monitoring is warranted to better assess the water quality of White Millpond.









TAR-PAMLICO RIVER BASIN

DESCRIPTION OF REGION

The Tar-Pamlico River Basin covers 14,000 km^2 in 16 counties in the eastern piedmont, and coastal plain of the state. The eastern piedmont region includes the headwaters of the Tar River, Swift Creek, and Fishing Creek. Rocky Mount, Oxford, Franklinton, Louisburg, Warrenton, and Scotland Neck are population centers in this part of the basin. Erosion rates for this region are moderate, but there are high rates of nutrient and pesticide application (NRCD 1985). Land use in this region is primarily forest and agriculture.

The inner coastal plain region includes the Tar River, Town Creek, Tranters Creek, and Grindle Creek. Agricultural erosion rates are low, but extensive channelization and intensive row cropping lead to above average loadings of nutrients and pesticides (NRCD 1985). Major cities in this region are Tarboro and Greenville.

The outer coastal plain region includes the Pamlico River, the Pungo River, and Pamlico Sound. The largest cities are Washington, Belhaven, Aurora, and Engelhard. Extensive deposits of phosphate are mined in the lower Pamlico River. The outer coastal plain has been developed for hundreds of years. Historical information has shown that much of the land along navigable streams had been developed by 1735. The Lake Mattamuskeet area was drained and farmed in the mid 1800's, and an attempt was made to drain the entire lake in the early 1900's. The high, sustainable fertility of drained swampland has spurred the extensive agricultural development of this region. Erosion rates are low, but pesticide application rates are the highest in North Carolina (NRCD 1985).

OVERVIEW OF WATER QUALITY

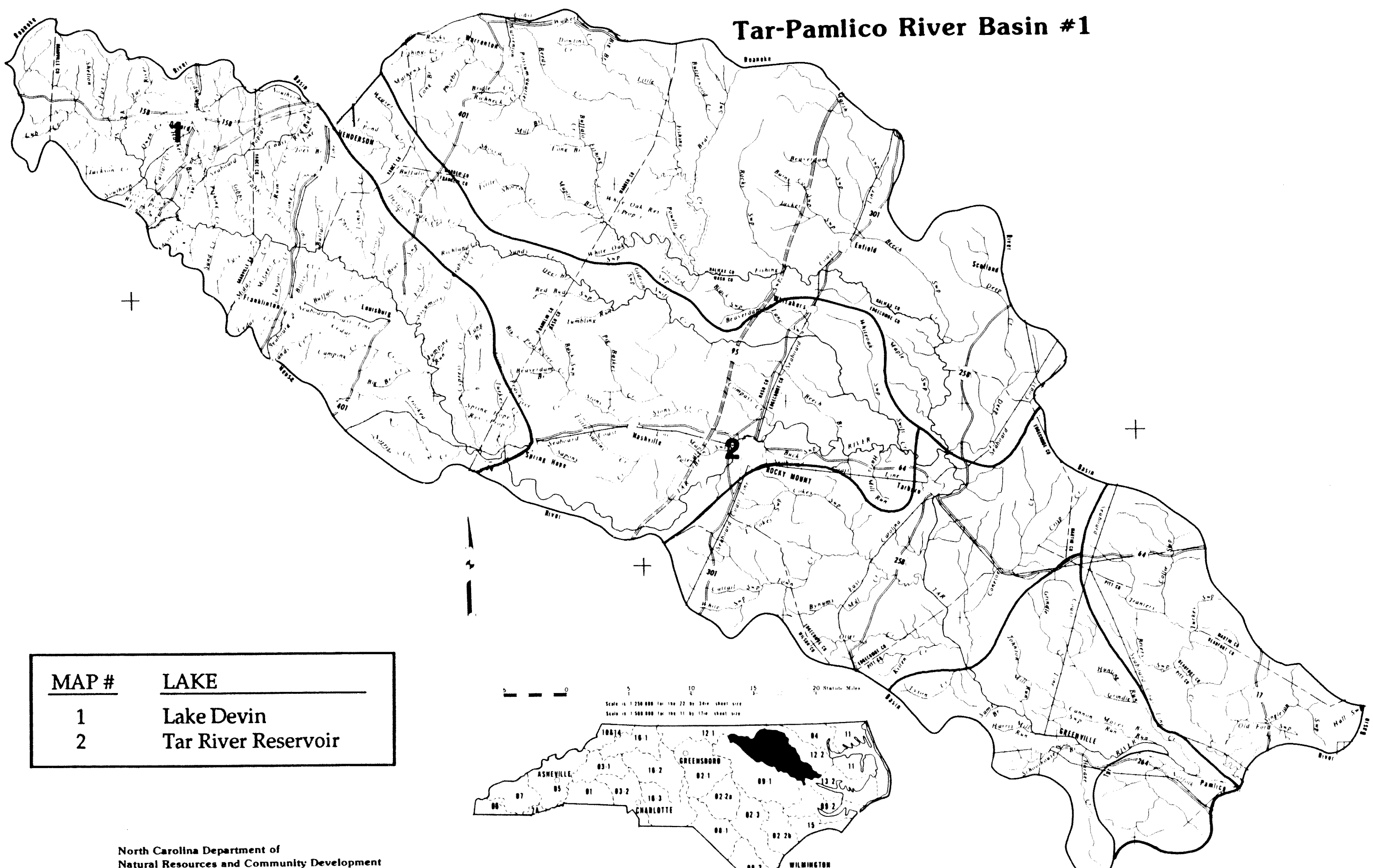
In the eastern piedmont region, water quality is adversely affected by both point and nonpoint source pollution. Stream degradation has been associated primarily with municipal wastewater operations. Nonpoint sources (especially agricultural runoff) have also contributed to widespread sedimentation of many streams and small tributaries.

In the inner coastal plain, the Tar River becomes deeper and more slow-moving. Streams in this area are swamp-like and characteristically have low dissolved oxygen levels, low velocity, and low pH. Many streams in this area were channelized prior to 1970, when "stream improvement" included dredging and straightening the channel with removal of most bordering vegetation. Nonpoint source problems (probably agriculturally related) are observed in many channelized streams in this region.

There are four lakes included in this section of the report: Lake Devin, Tar River Reservoir, Pungo Lake and Lake Mattamuskeet. Lake Devin is a water supply for the Town of Oxford located near the headwaters of the Tar River. Tar River Reservoir, an impoundment of the Tar River, provides potable water and recreation for the City of Rocky Mount and surrounding areas. Pungo Lake and Lake Mattamuskeet are natural bay lakes located on a peninsula between Albemarle Sound and the Pamlico River. Pungo Lake has acidic, turbid, and nutrient-rich waters. Lake Mattamuskeet is the largest natural lake in North Carolina. Since these lakes receive little overland inflow of water, they are not as affected by human activities as are many manmade reservoirs. At the time of assessment, all four lakes were fully supporting their designated uses.

Tar-Pamlico #1

Tar-Pamlico River Basin #1

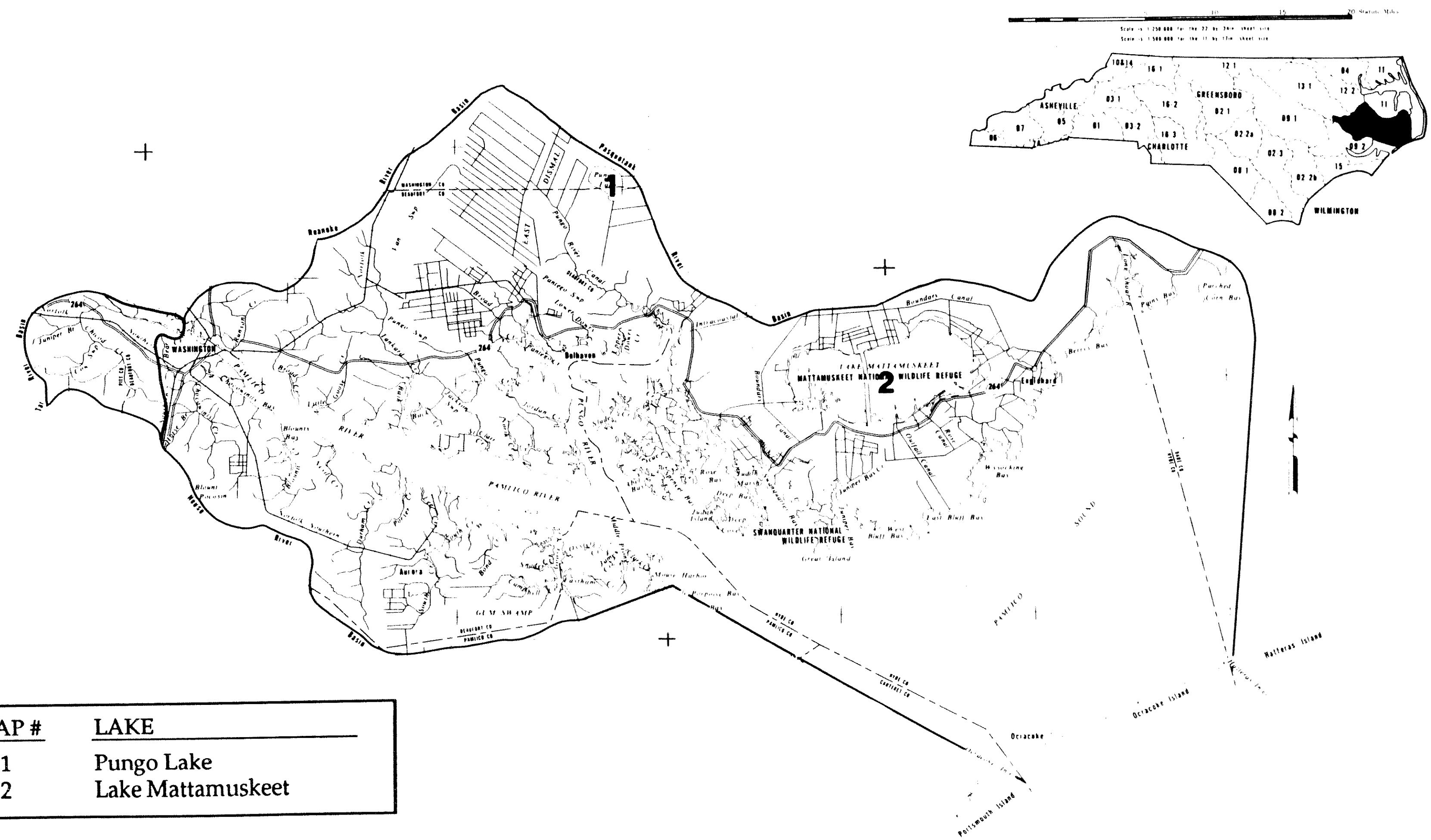


MAP #	LAKE
1	Lake Devin
2	Tar River Reservoir

North Carolina Department of
Natural Resources and Community Development
Division of Enviromental Management

Tar-Pamlico #2

Tar-Pamlico River Basin #2



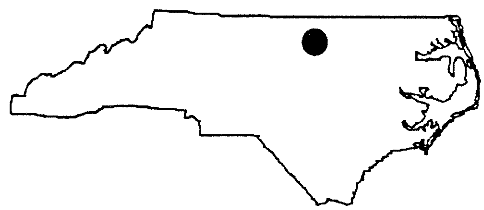
MAP #	LAKE
1	Pungo Lake
2	Lake Mattamuskeet

North Carolina Department of
Natural Resources and Community Development

Division of Enviromental Management

Adapted from U S G S (A M S) 1 250 000 U S Series

LAKE DEVIN



COUNTY:	Granville	**BASIN:**	Tar
SURFACE AREA:	51 hectares (125 acres)	**USGS TOPO:**	Oxford SE, N.C.
CLASS:	WS NSW	**LAKE TYPE:**	Reservoir

LATEST NCTSI:	2.5	**TROPHIC STATE:**	Eutrophic
SAMPLING DATE:	August 1, 1988	**ADDITIONAL COVERAGE:**	Water Supply Parameters
SECCHI DEPTH:	1.0 m	**CONDUCTIVITY:**	57 - 58 µmhos/cm^2
TOTAL PHOSPHORUS:	0.035 mg/l	**DISSOLVED OXYGEN:**	5.4 - 6.8 mg/l
TOTAL ORGANIC NITROGEN:	0.33 mg/l	**TEMPERATURE:**	27.5 - 27.9 °C
CHLOROPHYLL-A:	117 µg/l	**pH:**	6.2 s.u.

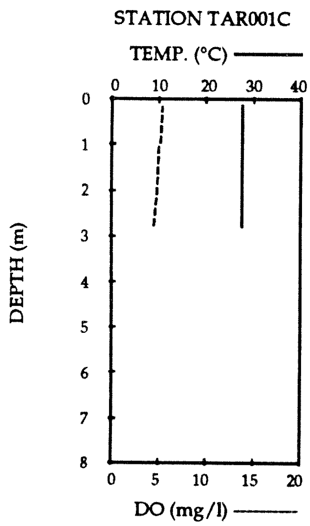
Lake Devin is a small water supply reservoir built in 1953 by the Town of Oxford. Volume of the lake is 1.6×10^6 m^3 with a maximum depth of nine meters. Hachers Run is the only stream feeding the lake. The small, rolling drainage area is mostly forested with some agriculture.

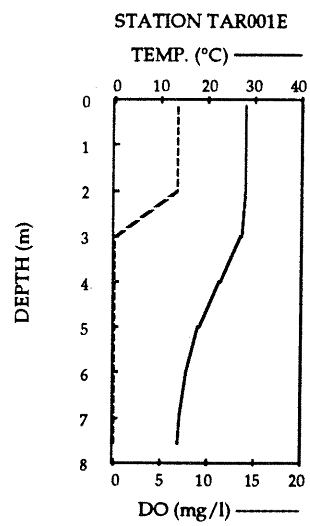
Lake Devin was sampled on August 1, 1988. The lake was stratified at the dam with oxygen levels approaching zero below three meters. Both nutrients and chlorophyll-a were elevated. Chlorophyll-a exceeded the state standard of 40 µg/l at both stations. Total phosphorus values were higher at the bottom of the lake than in the photic zone which is not unusual for a stratified lake.

Phytoplanktonic populations in Lake Devin were dominated by Gonyostomum semen, a member of the class Chloromonadophyceae. In Michigan and Wisconsin, this alga is common in swamps and acidic ponds. Whitford and Shumacher (1984) report that the species is widespread and, at times, abundant in North Carolina.

Estimates of phytoplanktonic biovolume and chlorophyll-a indicated algal blooms were present. As a result of the large size of the Gonyostomum, density estimates (which quantify the number of units and not the size of the organism) were less than 5,000 units/ml at both stations.

The TSI of 2.5 indicates the reservoir is eutrophic. Although uses were fully supported at the time of this assessment, future monitoring should continue to measure changes in phytoplanktonic assemblages and chlorophyll-a concentrations.


STATION TAR001C
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0 1 2 3 4 5 6 7 8
0 5 10 15 20
DO (mg/l)


STATION TAR001E
TEMP. (°C)
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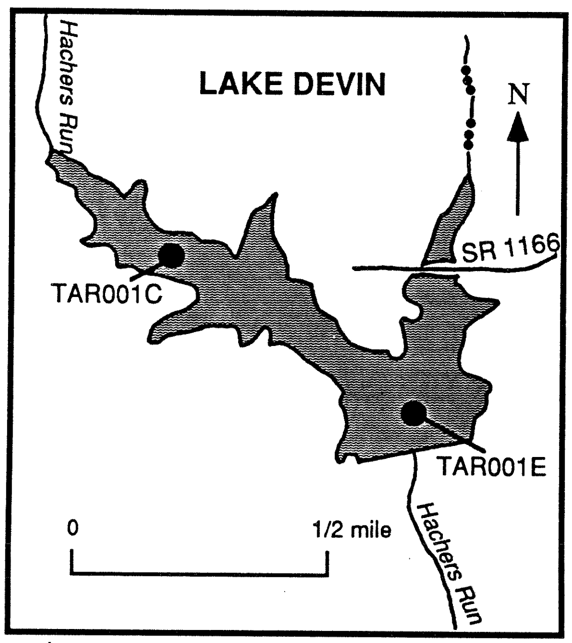
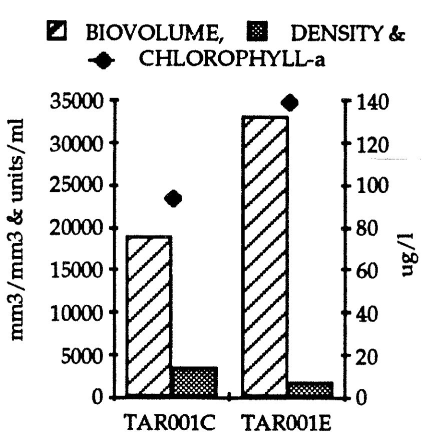
DEPTH (m)
0 1 2 3 4 5 6 7 8
0 5 10 15 20
DO (mg/l)


LAKE DEVIN
Hachers Run
N
SR 1166
TAR001C
TAR001E
0
1/2 mile
Hachers Run


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
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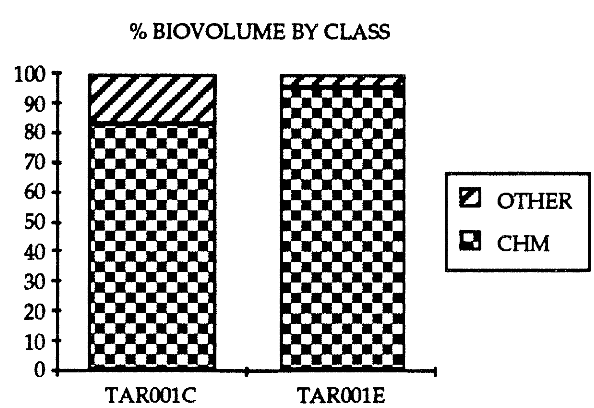
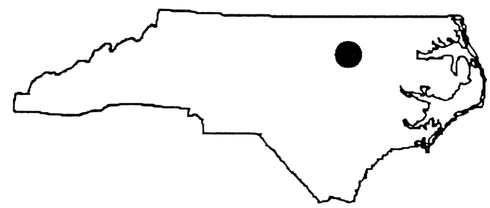
mm3/mm3 & units/ml
140 120 100 80 60 40 20 0
ug/l
TAR001C TAR001E


% BIOVOLUME BY CLASS
100 90 80 70 60 50 40 30 20 10 0
TAR001C TAR001E
OTHER
CHM

TAR RIVER RESERVOIR



COUNTY:	Nash	BASIN:	Tar - Pamlico
SURFACE AREA:	753 hectares (1,860 acres)	USGS TOPO:	Nashville, N.C.
CLASS:	WS, B NSW	LAKE TYPE:	Reservoir

LATEST NCTSI:	2.6	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	July 31, 1989	ADDITIONAL COVERAGE:	Fecal, Water Supply Parameters
SECCHI DEPTH:	0.8 m	CONDUCTIVITY:	63 - 75 µmhos/cm^2
TOTAL PHOSPHORUS:	0.07 mg/l	DISSOLVED OXYGEN:	6.6 - 7.8 mg/l
TOTAL ORGANIC NITROGEN:	0.315 mg/l	TEMPERATURE:	27.6 - 29.3 °C
CHLOROPHYLL-A:	41 µg/l	pH:	6.2 - 7.1 s.u.

In 1971, the City of Rocky Mount and the U.S. Army Corps of Engineers impounded the Tar River to form the Tar River Reservoir. Volume in the lake is 1.6×10^7 m^3 with a maximum depth of 12 meters. Although its primary use is to provide drinking water for the city, Tar River Reservoir is also used extensively for recreation.

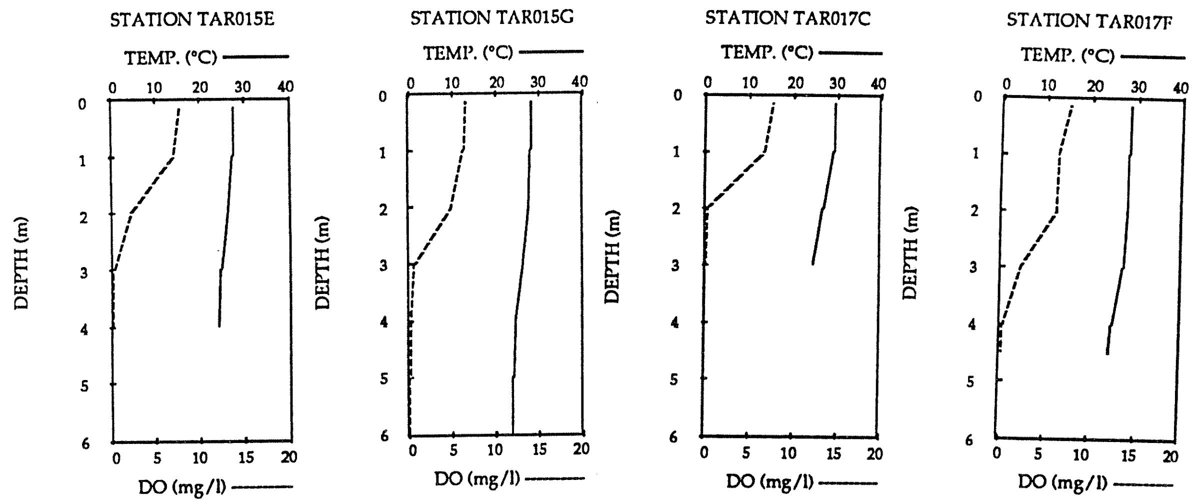
The Tar River dominates the flow into the lake, although Sapony Creek forms a large arm near the dam. Land in the watershed is flat with agriculture and forested areas as the dominant land uses.

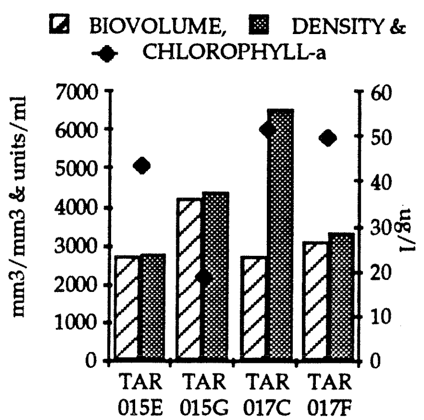
Tar River Reservoir was sampled on July 31, 1989. The lake was stratified with dissolved oxygen levels approaching zero below three meters. Nutrients were elevated with some accumulation of TP and TON in the hypolimnion. Chlorophyll-a concentrations exceeded the state standard of 40 µg/l at three of the four stations. Iron, aluminum, and manganese were detected in low levels in the surface water samples.

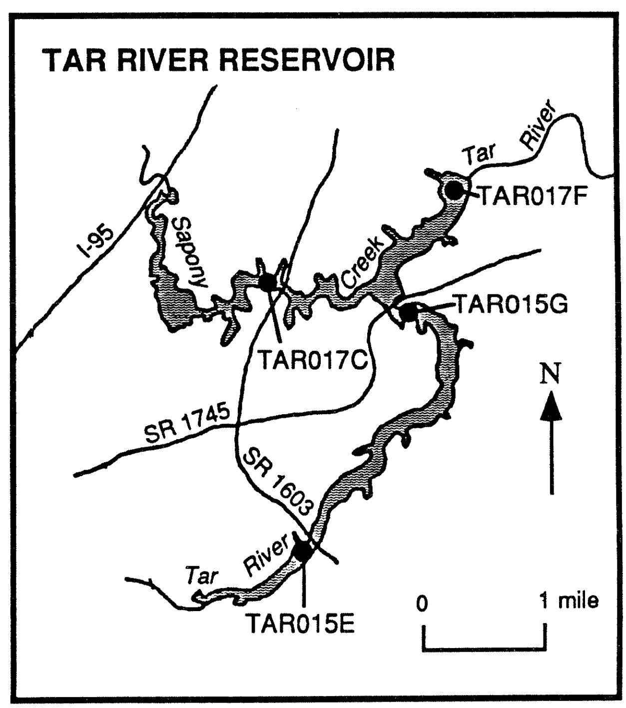
Although chlorophyll-a concentrations were high at three of the stations, algal biovolume and density estimates did not appear to confirm these findings. This discrepancy may be a result of algal species which contain large amounts of chlorophyll-a relative to their sizes.

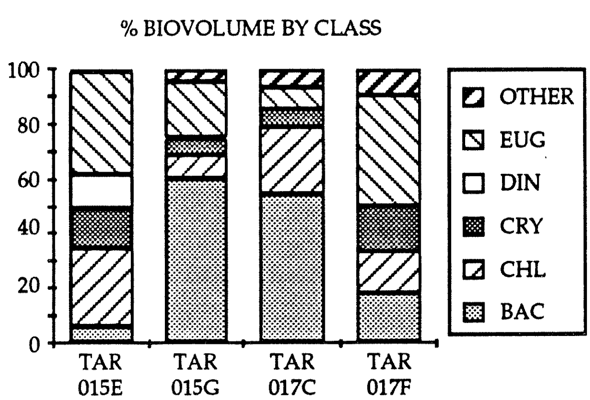
The diatoms, Cyclotella species and Cyclotella stelligera, dominated density estimates at all stations, while a variety of species dominated estimates of biovolume. The euglenophytes, Trachelomonas gibberosa and Phacus lemmermannii, dominated biovolume estimates at TAR015E. These species are commonly found in the coastal plain.

A TSI of 2.6 indicated that Tar River Reservoir was eutrophic. All uses of the lake were supported at the time of assessment.

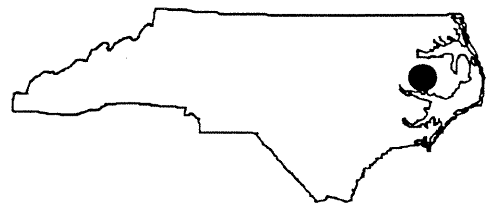








PUNGO LAKE



COUNTY:	Hyde	BASIN:	Tar
SURFACE AREA:	1,214 hectares (3,000 acres)	USGS TOPO:	Pungo Lake, N.C.
CLASS:	C - SW NSW	LAKE TYPE:	Natural

LATEST NCTSI:	8.7	TROPHIC STATE:	Dystrophic
SAMPLING DATE:	August 21, 1984	ADDITIONAL COVERAGE:	Fecal, Metals
SECCHI DEPTH:	0.05 m	CONDUCTIVITY:	93 - 95 µmhos/cm^2
TOTAL PHOSPHORUS:	0.365 mg/l	DISSOLVED OXYGEN:	7.6 mg/l
TOTAL ORGANIC NITROGEN:	2.2 mg/l	TEMPERATURE:	26.2 - 26.8 °C
CHLOROPHYLL-A:	5 µg/l	pH:	4.9 - 5.0 s.u.

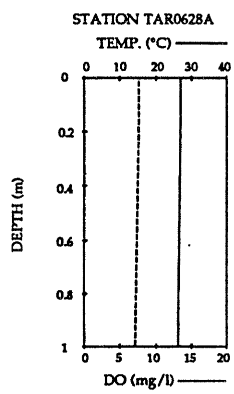
Pungo Lake is located on the outer coastal plain of North Carolina and lies within the Pungo National Wildlife Refuge. It is a shallow lake with a maximum depth of 1.5 meters and a mean depth of only 0.85 meters. Similar to other natural lakes in the area, Pungo Lake has no overland tributaries and is recharged solely from precipitation and groundwater.

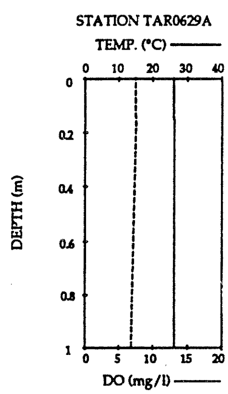
Pungo Lake was sampled on August 21, 1984. Physical measurements indicated that the lake was mixed with uniform values for dissolved oxygen and temperature throughout the water column. This is typical of shallow lakes where wind action thoroughly mixes the water column. Pungo Lake had a low secchi depth of 0.05 meters, resulting from the large amount of sediment suspended in the water column by wind mixing. Nutrient concentrations were elevated and were highest at station TAR0629A. Heavy metal concentrations were below laboratory detection limits. Fecal coliform bacteria levels were low (50/100 ml at TAR0628A and 20/100 ml at TAR0629A) and well below the state standard. Chlorophyll-a values were low, averaging only 5 µg/l.

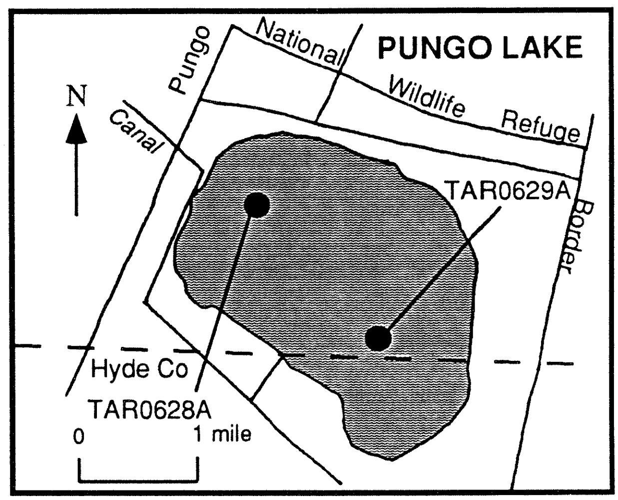
Pungo Lake is an example of a dystrophic lake. Nutrient levels in Pungo Lake were sufficient for algal growth; however, turbid conditions and extremely dark water reduced light availability and thus inhibited the use of the nutrients by the phytoplankton. There is also evidence that nutrients bind with organic material present in dystrophic lakes, reducing their bioavailability. In addition, low pH may also contribute to low algal growth.

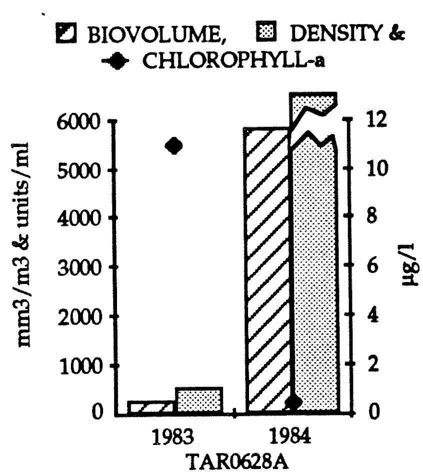
In 1984, phytoplanktonic populations were dominated by diatoms. Estimates of biovolume and density were 5,854 mm^3/m^3 and 7,907 units/ml. Diatoms composed 57% of the biovolume and 72% of the density. Cryptomonas ovata and C. erosa composed nearly 30% of the biovolume and 20% of the density. Nitzschia, Melosira, and Surirella are genera of diatoms that have been found to be capable of performing photosynthesis in reduced light conditions. These three genera made up two-thirds of the algal density. Flagellated cryptomonads are capable of locomotion which allows them to move freely within the photic zone. In 1983, estimates of algal populations were entirely composed of diatoms.

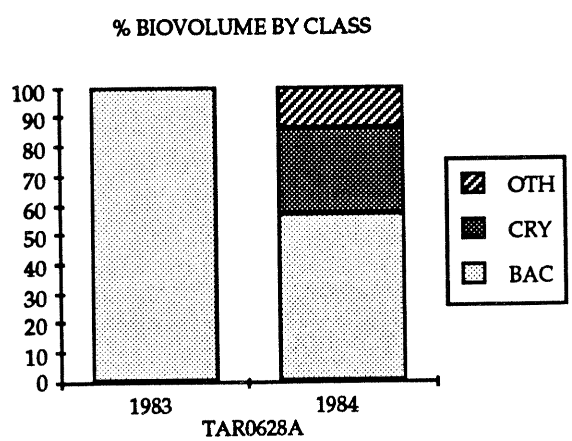
The TSI in 1984 was 8.7 which is consistent with historical values. The high TSI is the result of the turbid water rather than the result of enrichment by manmade discharges. At the time of assessment, no violations of state water quality standards were observed at Pungo Lake and the designated uses were fully supported.



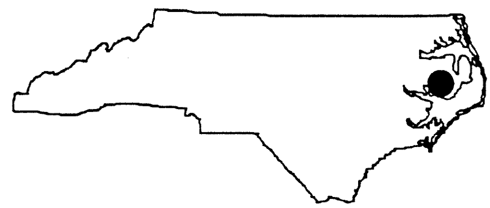








LAKE MATTAMUSKEET



COUNTY:	Hyde	BASIN:	Tar
SURFACE AREA: 17000 hectares (42000 acres)		USGS TOPO:	Fairfield, N.C.
CLASS:	SC NSW	LAKE TYPE:	Natural

LATEST NCTSI:	1.5	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	August 6, 1985	ADDITIONAL COVERAGE:	Fecal, Metals
SECCHI DEPTH:	0.6 m	CONDUCTIVITY:	1,754 - 1,890 µmhos/cm^2
TOTAL PHOSPHORUS:	0.03 mg/l	DISSOLVED OXYGEN:	4.9 - 8.0 mg/l
TOTAL ORGANIC NITROGEN:	0.71 mg/l	TEMPERATURE:	27.9 - 32.0 °C
CHLOROPHYLL-A:	5 µg/l	pH:	6.3 - 8.8 s.u.

Lake Mattamuskeet is located in the outer coastal plain of North Carolina. The 42,000 acre lake was formed on a vast peninsula lying between Albemarle Sound on the north and Pamlico River on the south. The lake is located within the Mattamuskeet National Wildlife Refuge and is the largest natural lake in North Carolina.

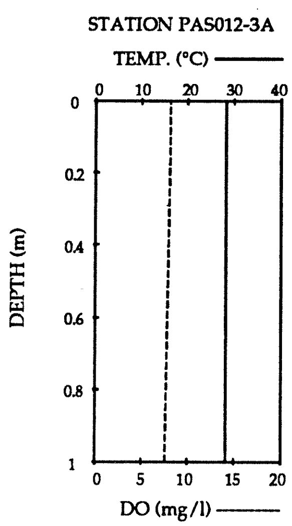
Lake Mattamuskeet is a shallow lake with no natural outlets and a maximum depth of only 1.2 meters. There are no overland tributaries into the lake and recharge is the result of precipitation and salt water intrusion from the manmade canal system. These canals were originally built to provide outlets from the lake to Pamlico Sound. The land surrounding the lake is primarily used for agriculture.

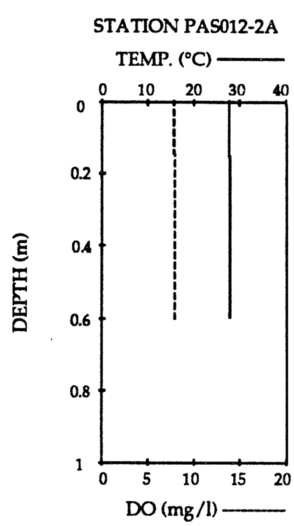
Lake Mattamuskeet was sampled on August 6, 1985. Physical measurements indicated that the lake was well mixed with similar dissolved oxygen and temperature values observed throughout the shallow water column. Nutrient concentrations were moderate with station PAS0124A having the highest concentrations. Chlorophyll-a was low and uniform among the sampling locations. Heavy metal concentrations at stations PAS0122A and PAS0123A were low with only zinc found above laboratory detection limits. At station PAS0124A, chromium, copper, and zinc were detected, but concentrations were within state water quality standards and action levels. Fecal coliform bacteria were detected at all stations. PAS0122A had a fecal coliform concentration of 10/100 ml, PAS0123A a concentration of 210/100 ml, and PAS0124A a concentration of 2,800/100 ml. As there are no known overland discharges into the lake, these observed levels may be the result of waterfowl or sample contamination. Water samples collected during 1984 and 1983 failed to detect fecal coliforms at all stations. High specific conductance levels reflected the presence of saltwater in the lake.

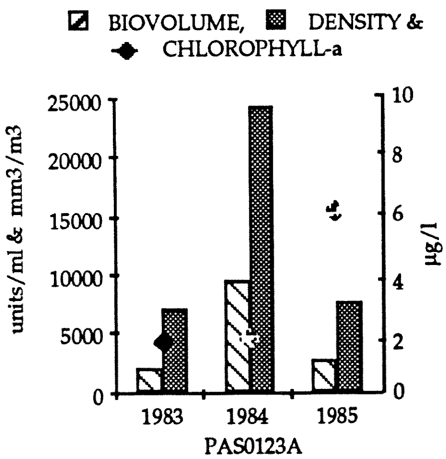
Low to moderate levels of phytoplankton characterized samples collected from Lake Mattamuskeet. Cyanophytes represented only 5% of the biovolume in 1983. Forty-eight and 89% of the biovolume were derived from this class of algae in 1984 and 1985 respectively. The highest concentrations of algal biovolume and density were measured in 1984 (24,282 units/ml and 9,572 mm^3/m^3) and were indicative of enriched waters. Samples from 1983 and 1985 contained relatively low amounts of phytoplankton. Algal density and biovolume may have been depressed by the shading effect of aquatic macrophytes.

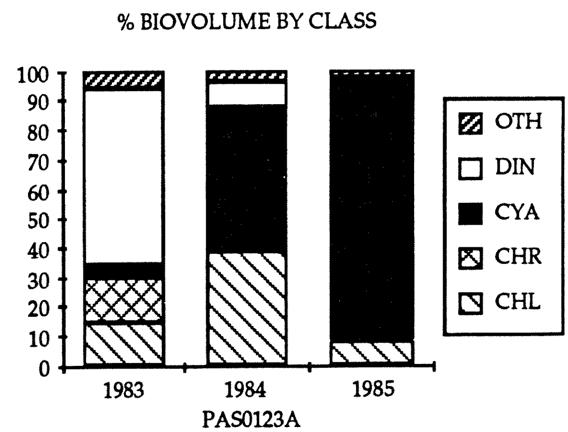
A wide variety of aquatic macrophytes are present in abundance within the lake. These plants take advantage of the shallow depth and utilize the available nutrients. Species present include Chara sp. (musk grass), Potamogeton perfoliatus (pondweed), Vallisneria americana (wild celery), and Myriophyllum sp. (water milfoil). Except for musk grass, all or part of these aquatic plants are consumed by waterfowl. At present, these aquatic weeds are not interfering with the designated uses of the lake.

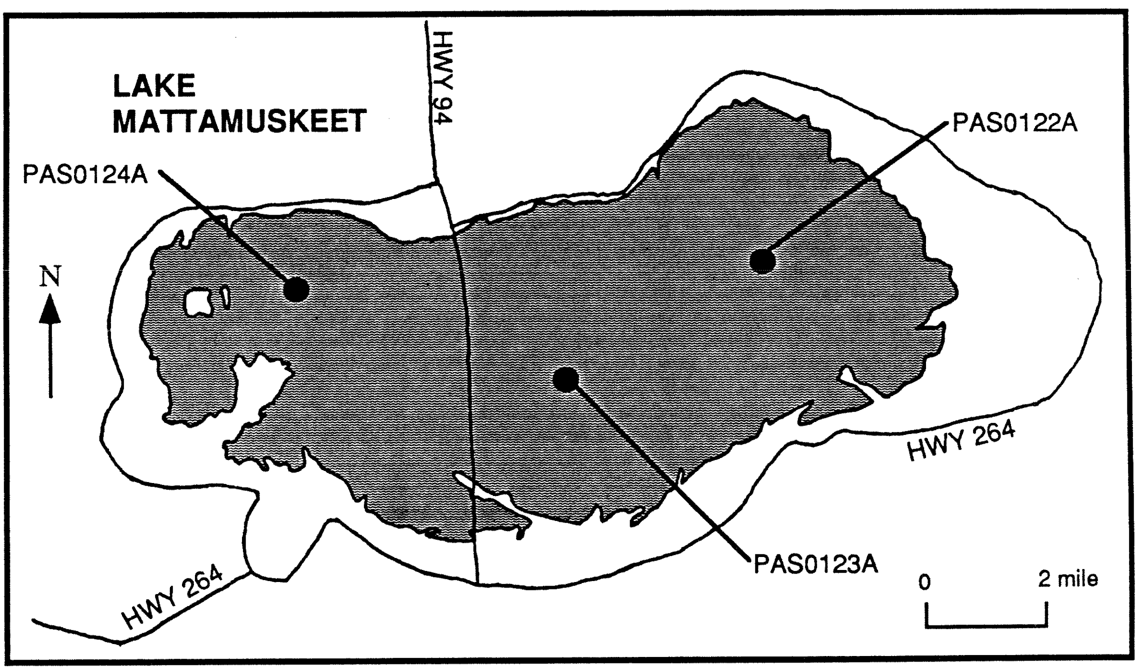
Lake Mattamuskeet has consistently been classified as a moderately productive lake. TSI values were 1.0 in 1981, 1.4 in 1983, 0.6 in 1984, and 1.5 in 1985. At the most recent assessment, no violations of water quality standards were observed, and Lake Mattamuskeet fully supported designated uses.






BIOVOLUME, DENSITY &
CHLOROPHYLL-a
units/ml & mm3/m3
µg/l
25000
20000
15000
10000
5000
0
10
8
6
4
2
0
1983
1984
1985
PAS0123A


% BIOVOLUME BY CLASS
100
90
80
70
60
50
40
30
20
10
0
OTH
DIN
CYA
CHR
CHL
1983
1984
1985
PAS0123A


LAKE
MATTAMUSKEET
HWY 94
PAS0124A
PAS0122A
PAS0123A
N
HWY 264
HWY 264
0
2 mile

WHITE OAK RIVER BASIN

DESCRIPTION OF REGION

The White Oak River Basin is located in the southern coastal plain, where 3,193 km^2 drains into the New, White Oak, Newport, and North Rivers. The basin also includes extensive estuarine areas, including 488 km^2 of shellfishing waters in Bogue and Core Sounds (NRCD 1988c).

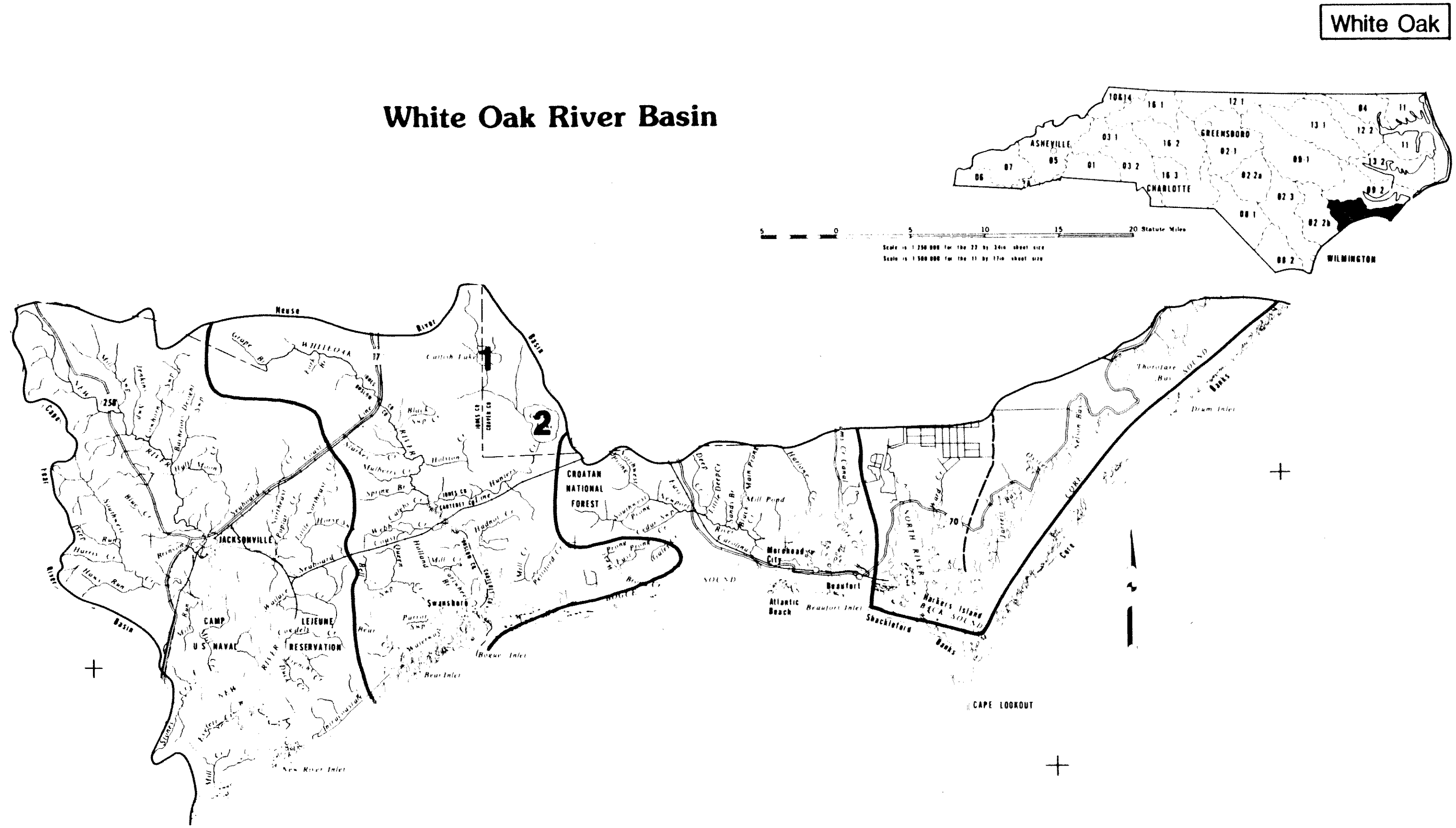
Many small streams, marshes, pocosins, and much publicly-owned land (Camp LeJeune, Cherry Point, Croatan National Forest, Hoffman Forest) are present within the basin. Most of the large point sources are located in the New River area. A network of channelized drainage canals in the North River watershed has allowed conversion of swamplands to agricultural use. Both erosion and application rates of nutrients and pesticides are low in this area.

OVERVIEW OF WATER QUALITY

Owing to the presence of large areas of protected watersheds (The Croatan National Forest and military lands), water quality in those areas of the White Oak basin is generally better than other North Carolina coastal areas.

Point sources cause isolated problems in this basin. Shellfish waters have been closed in the areas around the major cities as a result of the effects of population growth. Most severely affected is the New River below Jacksonville. Problems associated with nutrient and organic enrichment led to a "Nutrient Sensitive Waters" (NSW) classification for this river. Several streams have been channelized in the upper New River Basin as a result of small agricultural operations. Fresh water intrusion resulting from such activity has affected fish populations in the area (NRCD 1985).

Two Carolina bay lakes are included in this report. Catfish Lake and Great Lake are dystrophic, black-water lakes characterized by low pH and dark brown color. Both lakes fully support designated uses.

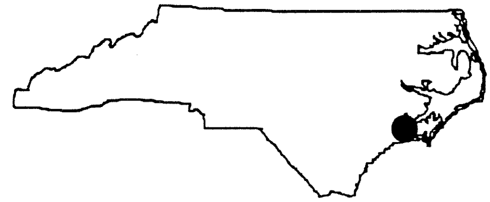


MAP #	LAKE
1	Catfish Lake
2	Great Lake

North Carolina Department of
Natural Resources and Community Development
Division of Enviromental Management

Adapted from U S G S (A M S) 1 250 000 U S Series

CATFISH LAKE



COUNTY:	Craven/Jones	BASIN:	White Oak
SURFACE AREA:	384 hectares (950 acres)	USGS TOPO:	Catfish Lake, N.C.
CLASS:	C	LAKE TYPE:	Natural

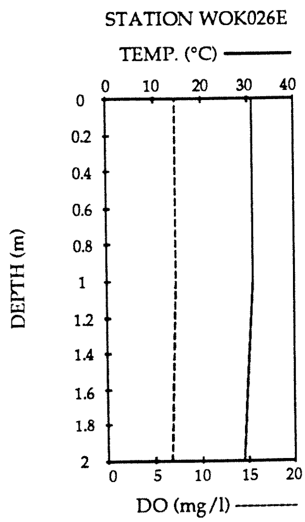
LATEST NCTSI:	0.2	TROPHIC STATE:	Dystrophic
SAMPLING DATE:	August 17, 1988	ADDITIONAL COVERAGE:	None
SECCHI DEPTH:	0.5 m	CONDUCTIVITY:	69 µmhos/cm^2
TOTAL PHOSPHORUS:	0.02 mg/l	DISSOLVED OXYGEN:	7.4 mg/l
TOTAL ORGANIC NITROGEN:	0.385 mg/l	TEMPERATURE:	31.2 °C
CHLOROPHYLL-A:	5 µg/l	pH:	3.8 s.u.

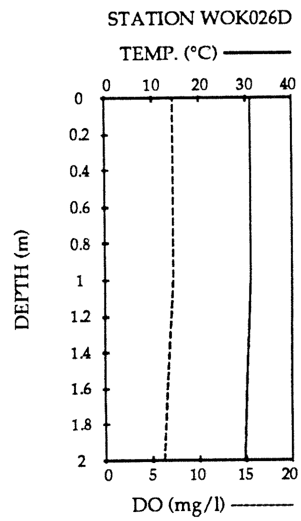
Catfish Lake is a natural black-water Carolina bay lake in the Croatan National Forest. Although the lake is fairly large (950 acres), it is uniformly shallow with a maximum depth of approximately two meters. Having no feeder stream, the lake level is maintained by rainfall and ground-water recharge. The land surrounding the lake is flat, swampy and forested.

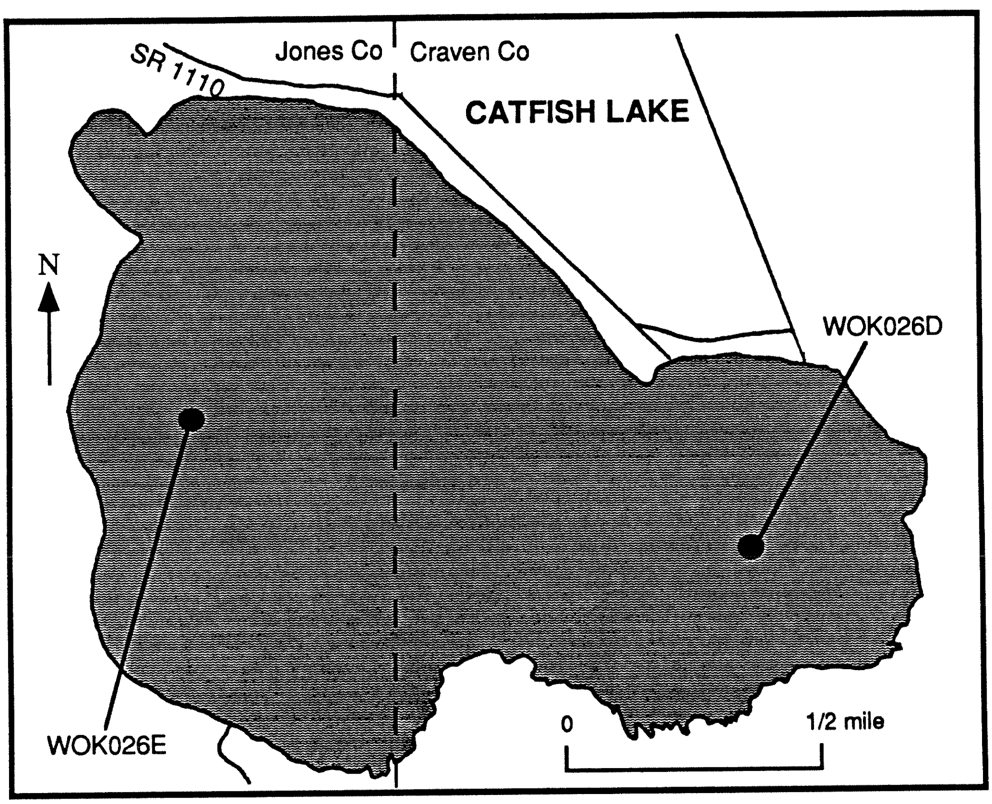
Catfish Lake was sampled on August 17, 1988. No stratification was evident in this shallow, wind-mixed system. As is typical of a dystrophic lake, acidic pH values were observed. Secchi depths were low as a result of the tea-colored water. Nutrients indicated a moderately enriched system.

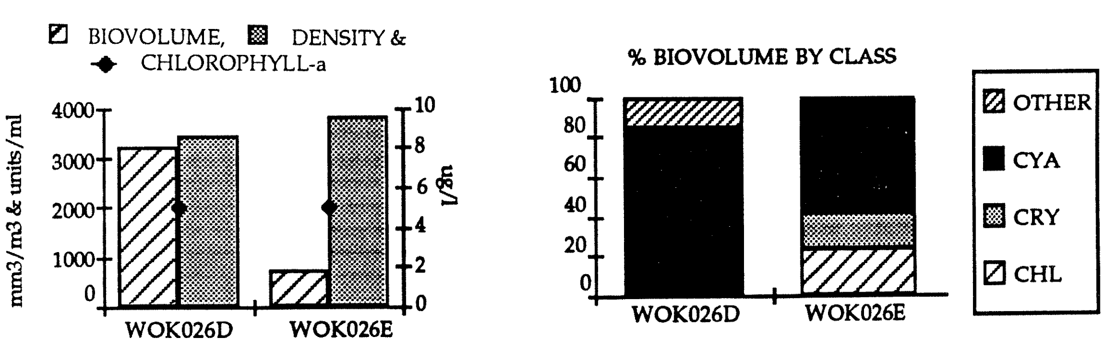
Estimates of algal biovolume and density were low averaging 1,964 mm^3/m^3 and 2,424 units/ml respectively. Gleocapsa species, a blue-green alga, made up 85% and 56% of the biovolume at WOK026D and WOK026E respectively.

A TSI of 0.2 normally indicates conditions bordering between mesotrophic and eutrophic. However, Catfish Lake is more appropriately classified as dystrophic. All uses were supported during the 1988 sampling and no water quality standards were violated.

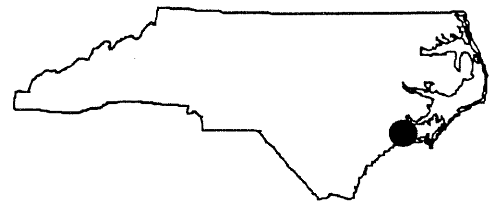

STATION WOK026E
TEMP. (°C)
DEPTH (m)
DO (mg/l)


STATION WOK026D
TEMP. (°C)
DEPTH (m)
DO (mg/l)


SR 1110
Jones Co
Craven Co
CATFISH LAKE
N
WOK026D
WOK026E
0
1/2 mile


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/m3 & units/ml
ug/l
WOK026D
WOK026E
% BIOVOLUME BY CLASS
OTHER
CYA
CRY
CHL

GREAT LAKE



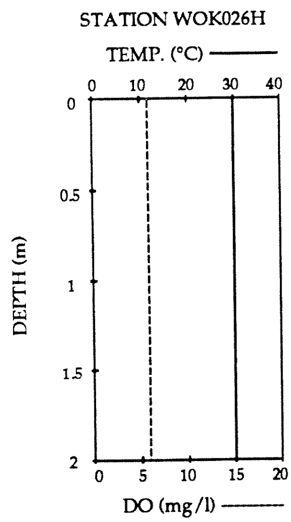
COUNTY:	Craven	**BASIN:**	White Oak
SURFACE AREA:	1,198 hectares (2,960 acres)	**USGS TOPO:**	Hadnot Creek, N.C.
CLASS:	C - SW	**LAKE TYPE:**	Natural

LATEST NCTSI:	1.3	**TROPHIC STATE:**	Dystrophic
SAMPLING DATE:	August 4, 1987	**ADDITIONAL COVERAGE:**	Metals
SECCHI DEPTH:	0.25 m	**CONDUCTIVITY:**	79 - 85 µmhos/cm^2
TOTAL PHOSPHORUS:	0.04 mg/l	**DISSOLVED OXYGEN:**	5.8 - 5.9 mg/l
TOTAL ORGANIC NITROGEN:	0.29 mg/l	**TEMPERATURE:**	30.0 - 30.1 °C
CHLOROPHYLL-A:	5.5 µg/l	**pH:**	3.0 - 3.1 s.u.

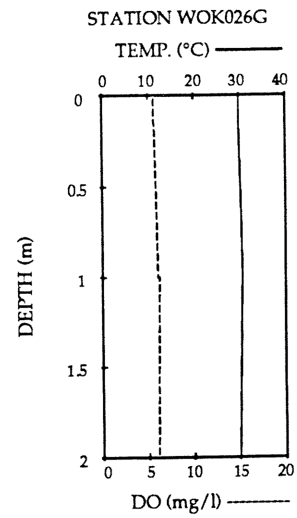
Great Lake is a natural freshwater lake located within the Croatan National Forest and owned by the United States Forest Service. Like other Carolina bay lakes it is large and shallow, with acidic, tannic water. Great Lake has no major tributaries and relies primarily on precipitation for recharge. The waters of the lake are classified C-Swamp and are used for recreation.

Great Lake was sampled on August 4, 1987. Physical measurements indicated that the lake was mixed with uniform temperature and dissolved oxygen values throughout the water column. Nutrient concentrations were low to moderate. Heavy metal levels at or below laboratory detection limits. Chlorophyll-a values were low with a mean of 5 µg/l. No phytoplankton analyses were performed on this date.

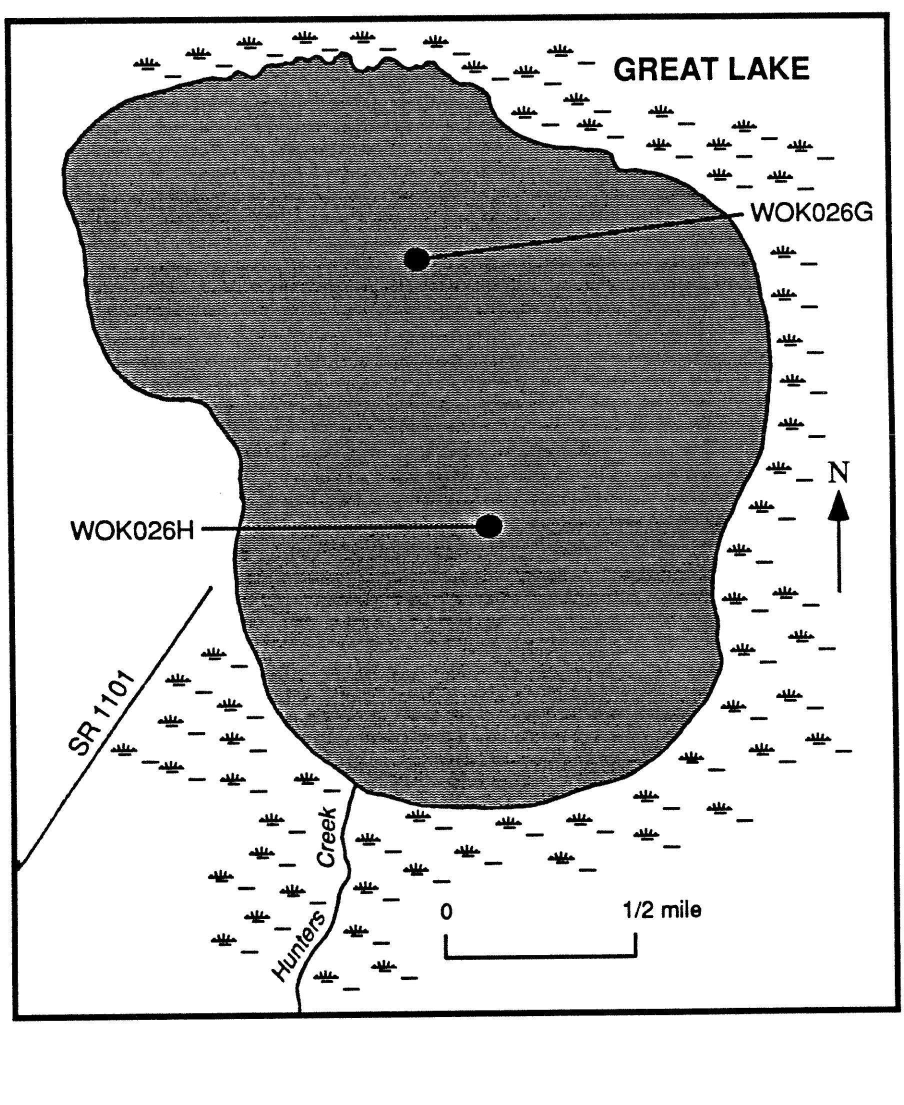
The TSI value was 1.3 in 1987. The dark, tannic waters of Great Lake resulted in a low secchi depth, thus increasing the TSI value. Highly colored water, acidic conditions, and low algal productivity support a dystrophic classification for this lake. At the time of assessment, no violations of state water quality standards were observed at Great Lake and it was fully supporting designated uses.



STATION WOK026H
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0
0.5
1
1.5
2
0 5 10 15 20
DO (mg/l)



STATION WOK026G
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0
0.5
1
1.5
2
0 5 10 15 20
DO (mg/l)



GREAT LAKE
WOK026G
WOK026H
N
SR 1101
Hunters Creek
0
1/2 mile

YADKIN-PEE DEE RIVER BASIN

DESCRIPTION OF REGION

The Yadkin-Pee Dee River Basin covers 18,700 km^2 throughout twenty-one counties and is the second largest basin in North Carolina. The basin drains a large section of North Carolina, including the upper piedmont, middle piedmont, lower piedmont and sandhill regions.

The Yadkin River originates on the eastern slopes of the Blue Ridge Mountains, flows northeastward approximately 100 miles, and then flows southeastward until it joins the Uwharrie River to form the Pee Dee River. The Pee Dee River continues flowing southeastward to the North Carolina-South Carolina border and through South Carolina to Winyah Bay. The Yadkin-Pee Dee River is impounded several times as it travels through North Carolina forming the Yadkin Chain Lakes. These reservoirs include W. Kerr Scott Reservoir, High Rock Lake, Tuckertown Reservoir, Badin Lake, Falls Lake, Lake Tillery, and Blewett Falls Lake.

Manufacturing is the single most important economic activity in the Yadkin-Pee Dee River basin. Textiles, furniture, tobacco products and communication equipment are major outputs. Agriculture, while declining in relative importance, still covers large areas in most rural watersheds (NCDNER 1977).

The Yadkin-Pee Dee River basin is divided into three drainage areas for the purposes of this report. The upper section (Basin Map #1) contains tributary flow from the Roaring, Mitchell, Fisher, and Ararat Rivers. Major towns within this drainage area are North Wilkesboro, Elkin and Mt. Airy. The middle section (Basin Map #2) contains tributary flow from the South Yadkin River, Muddy Creek, Abbotts Creek and the Uwharrie River. Major metropolitan areas within this drainage area include Winston-Salem, High Point, Thomasville, Lexington, Mocksville, Kannapolis, and Salisbury. The lower section (Basin Map #3) contains tributary flow from the Rocky and Little Rivers. Concord, Wadesboro, and Rockingham are the major towns within this section.

OVERVIEW OF WATER QUALITY

The upper section of the basin includes the protected watersheds in the Pisgah National Forest, Doughton Park and Stone Mountain State Park. The waterways in these areas all have high levels of water quality (NRCD 1985).

Outside of these protected watersheds, the upper Yadkin-Pee Dee River basin contains many point source discharges which have affected the water quality of their receiving waters. Point source dischargers have contributed to problems in the Yadkin River and the Ararat River below Mt. Airy. Fish kills have been common in the Yadkin River below Muddy Creek (NRCD 1985).

Nonpoint source pollution from agricultural lands has also caused water quality degradation in this region which has high erosion rates. Sedimentation is a problem in the Yadkin River below North Wilkesboro and in the Ararat River below Mt. Airy. In addition, agricultural runoff has degraded the Little Ararat River and Deep Creek (NRCD 1985).

The middle portion of the basin is affected by numerous point source discharges. Degraded water quality has been reported in Dye Branch, Irish Buffalo Creek, Long Creek, Richardson Creek, Negrohead Creek, and

Upper Rocky River (NRCD 1985). As in the upper section of the basin, agricultural runoff has caused sedimentation and turbidity problems. Good water quality conditions have been reported in the Uwharrie River which drains the Uwharrie National Forest.

The lower section of the basin has fewer point source dischargers than the upper sections and large areas are within the undeveloped Uwharrie National Forest. Many of the streams and rivers have shown good to excellent water quality. Point source discharges are generally municipal wastewater treatment plants and some locally degraded conditions have been observed in receiving waters (NRCD 1988c). Nonpoint source runoff from agricultural lands affects some streams in the southern portion of this region. Those streams include Brown Creek, Goulds Fork, Homer Creek, and both North and South Forks of Jones Creek (NRCD 1985).

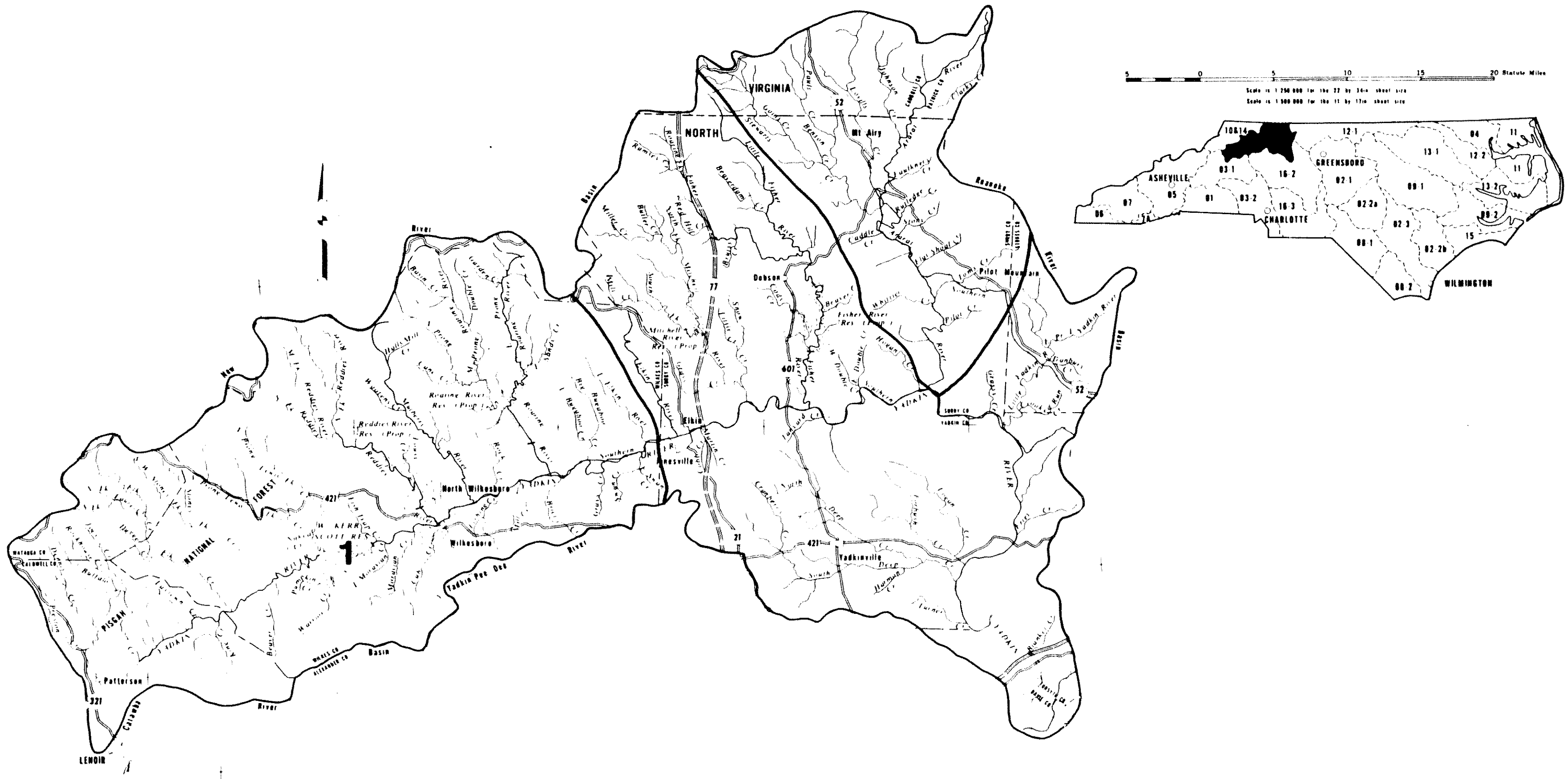
Of the 27 lakes included in this section of the report, seven are part of the Yadkin Chain Lakes system. W. Kerr Scott Reservoir is the first impoundment located on the Yadkin River. Its drainage area covers portions of the Pisgah National Forest and it has the highest water quality of all the Yadkin Chain Lakes. All of the other Yadkin Chain Lakes, with the exception of Lake Tillery and Falls Lake, are eutrophic. The degree of nutrient enrichment and productivity of these lakes is largely governed by upstream dam releases as well as conditions in the surrounding watershed.

The other 20 lakes are either primary or auxiliary water supply reservoirs and are all located near the municipalities which use them. Several of these lakes are eutrophic.

Two lakes in this basin are experiencing significant water quality problems and have been classified as "partially supporting" or "not supporting" their designated use. These lakes are High Rock Lake and Hamlet City Lake. High Rock Lake is one of the most eutrophic lakes in North Carolina and has the added problem of elevated mercury levels in its Abbotts Creek Arm. The mercury contamination has resulted in a fishing advisory for this arm of the lake. Hamlet City Lake has experienced sedimentation and is heavily infested with aquatic plants, primarily pondweed, water shield, water lily, and primrose. These problems have caused the lake to be classified as only "partially supporting" its designated use as a water supply.

Yadkin-Pee Dee #1

Yadkin-Pee Dee River Basin #1

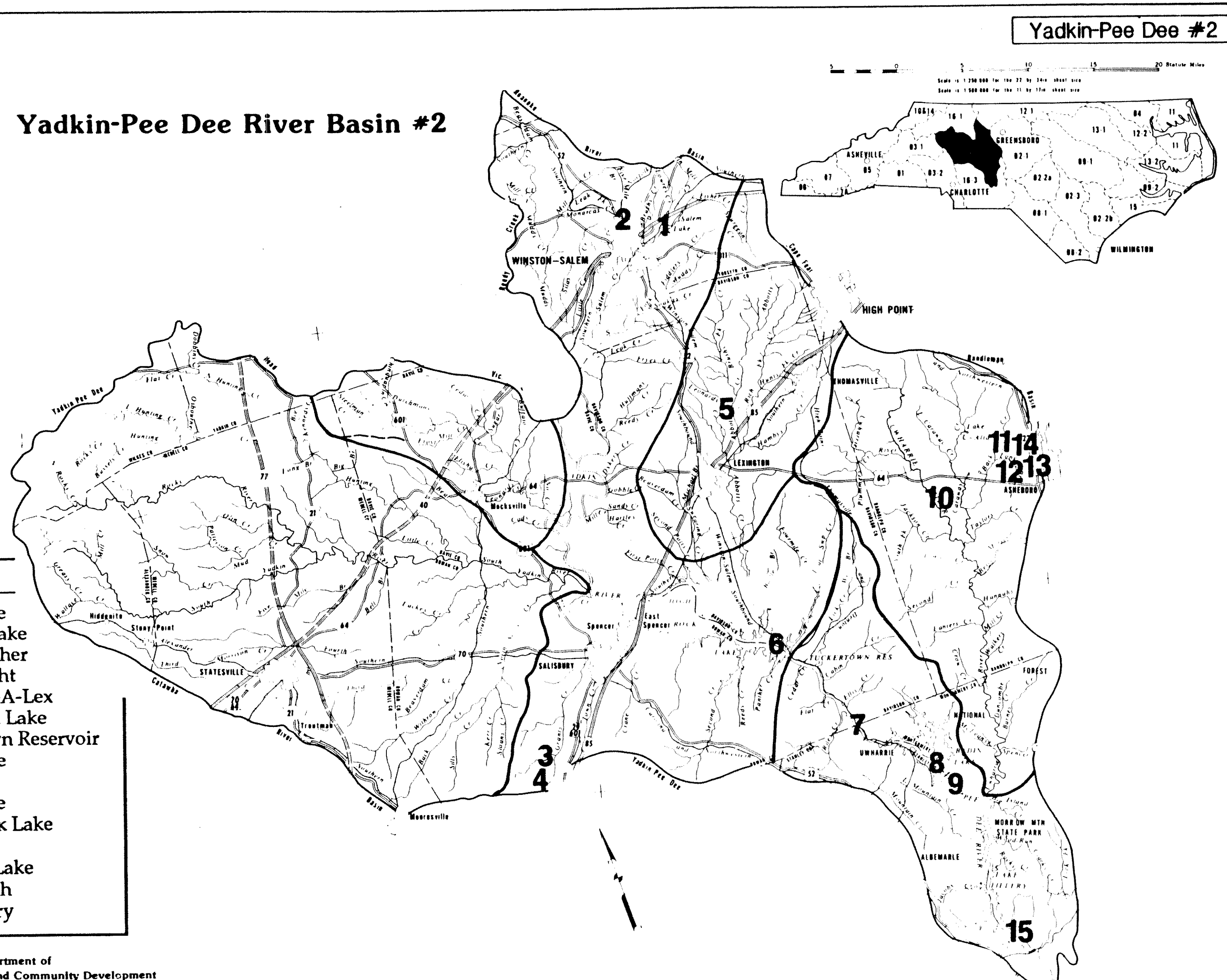


MAP #	LAKE
1	W. Kerr Scott Reservoir

North Carolina Department of
Natural Resources and Community Development
Division of Enviromental Management

Adapted from U.S.G.S. (A.M.S.) 1:250,000 U.S. Series

Yadkin-Pee Dee River Basin #2



MAP #	LAKE
1	Salem Lake
2	Winston Lake
3	Lake Corriher
4	Lake Wright
5	Lake Tom-A-Lex
6	High Rock Lake
7	Tuckertown Reservoir
8	Badin Lake
9	Falls Lake
10	Lake Reese
11	Back Creek Lake
12	Ross Lake
13	McCrary Lake
14	Lake Bunch
15	Lake Tillery

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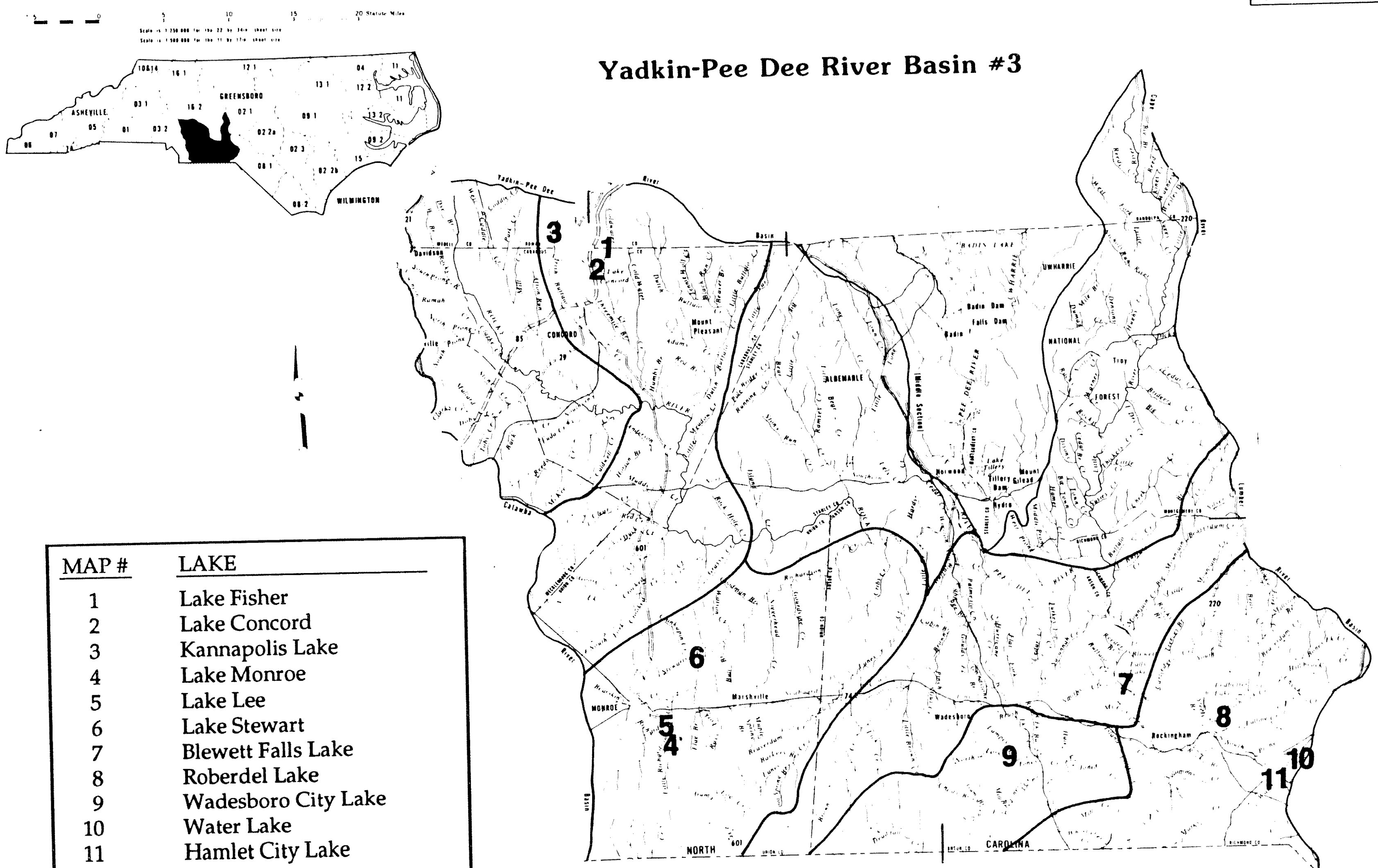
Division of Enviromental Management

Yadkin-Pee Dee River Basin #3

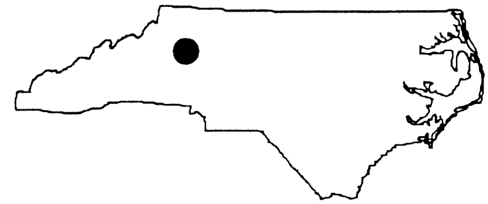


MAP #	LAKE
1	Lake Fisher
2	Lake Concord
3	Kannapolis Lake
4	Lake Monroe
5	Lake Lee
6	Lake Stewart
7	Blewett Falls Lake
8	Roberdel Lake
9	Wadesboro City Lake
10	Water Lake
11	Hamlet City Lake

North Carolina Department of
Natural Resources and Community Development
Division of Environmental Management

Adapted from U.S.G.S. (A.M.S.) 1:250,000 U.S. Series

W. KERR SCOTT RESERVOIR



COUNTY:	Wilkes	BASIN:	Yadkin
SURFACE AREA:	587 hectares (1,450 acres)	USGS TOPO:	Wilkesboro N.C.
CLASS:	B - TR	LAKE TYPE:	Reservoir

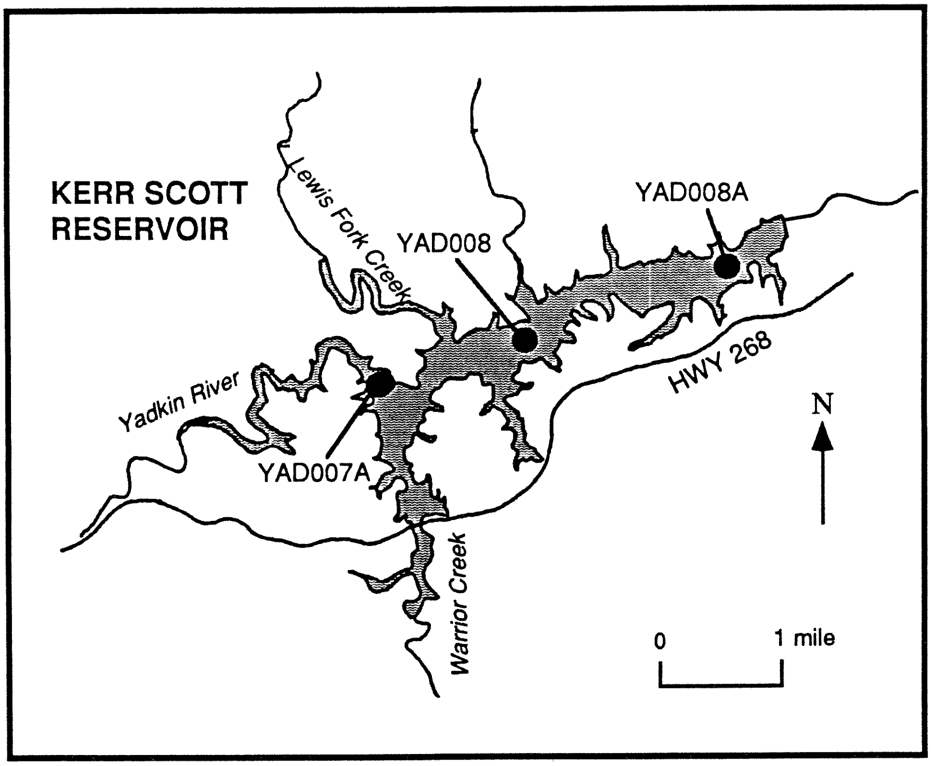
LATEST NCTSI:	- 1.9	TROPHIC STATE:	Mesotrophic
SAMPLING DATE:	August 10, 1989	ADDITIONAL COVERAGE:	Fecal
SECCHI DEPTH:	1.4 m	CONDUCTIVITY:	37 - 38 µmhos/cm^2
TOTAL PHOSPHORUS:	0.03 mg/l	DISSOLVED OXYGEN:	9.1 - 9.4 mg/l
TOTAL ORGANIC NITROGEN:	0.24 mg/l	TEMPERATURE:	26.4 - 26.7 °C
CHLOROPHYLL-A:	2 µg/l	pH:	6.8 - 8.3 s.u.

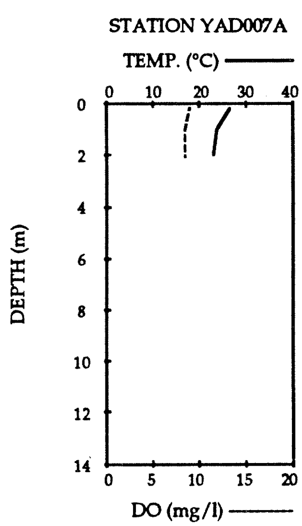
W. Kerr Scott Reservoir is the beginning of the Yadkin Chain Lakes. The dam was completed in 1962 by the U.S. Army Corps of Engineers. The lake is used for flood control, low-flow augmentation, and recreation. It has a mean depth of 12 meters and a volume of 189 x 10^6 m^3. The 900 km^2 drainage area is primarily forested.

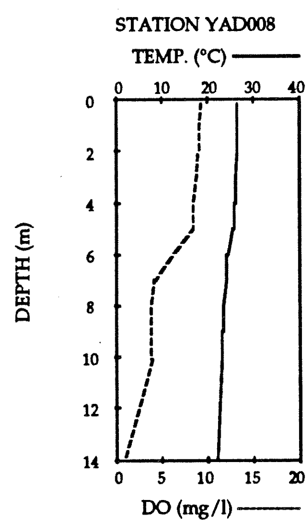
When sampled on August 10, 1989, the reservoir was stratified at all of the sampling stations. Nutrient concentrations were moderate, but chlorophyll-a concentrations were low. Fecal coliform bacteria were below laboratory detection limits except at YAD007A, where levels were well within state standards.

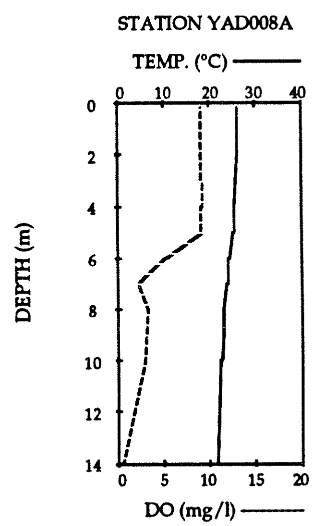
Similar to results from previous years, phytoplanktonic biovolume remained relatively low in 1989. Two species of Lyngbya dominated the algal density at all three sampling stations in both years. The predominance of these small, filamentous, blue-green algae accounts for the relatively high densities found at YAD008 and YAD008A in 1989. Lyngbya spp. are common components of algal populations during warmer summer months.

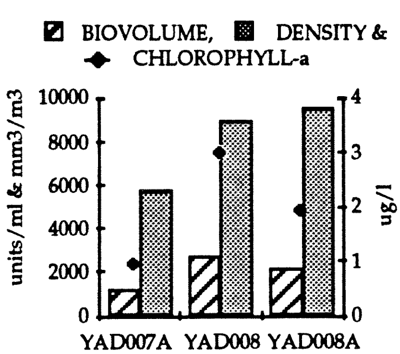
The TSI was -1.9 in 1989 which is similar to historical values for this lake. At the time of assessment, no violations of state water quality standards were observed at W. Kerr Scott Reservoir, and the lake fully supported designated uses.

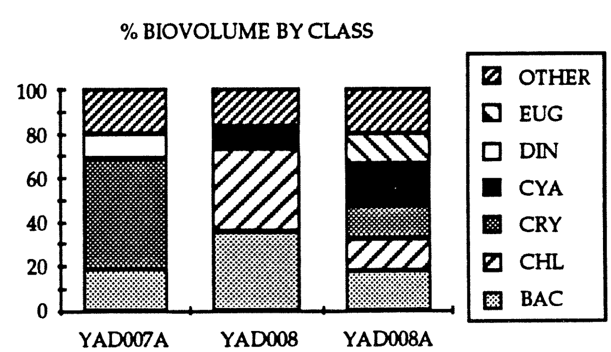

KERR SCOTT
RESERVOIR
Lewis Fork Creek
YAD008
YAD008A
Yadkin River
YAD007A
HWY 268
Warrior Creek
N
0
1 mile


STATION YAD007A
TEMP. (°C)
DEPTH (m)
DO (mg/l)

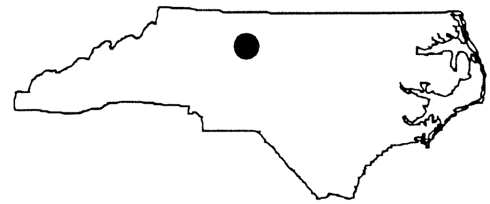

STATION YAD008
TEMP. (°C)
DEPTH (m)
DO (mg/l)


STATION YAD008A
TEMP. (°C)
DEPTH (m)
DO (mg/l)


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
units/ml & mm3/m3
ug/l
YAD007A YAD008 YAD008A


% BIOVOLUME BY CLASS
OTHER
EUG
DIN
CYA
CRY
CHL
BAC
YAD007A
YAD008
YAD008A

SALEM LAKE



COUNTY:	Forsyth	BASIN:	Yadkin
SURFACE AREA:	146 hectares (360 acres)	USGS TOPO:	Winston Salem East, N.C.
CLASS:	WS	LAKE TYPE:	Reservoir

LATEST NCTSI:	1.9	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	August 15, 1989	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	0.75 m	CONDUCTIVITY:	73 - 75 µmhos/cm^2
TOTAL PHOSPHORUS:	0.04 mg/l	DISSOLVED OXYGEN:	7.6 -8.4 mg/l
TOTAL ORGANIC NITROGEN:	0.23 mg/l	TEMPERATURE:	25.6 - 26.3 °C
CHLOROPHYLL-A:	65 µg/l	pH:	6.1 - 7.8 s.u.

Salem Lake is a water supply reservoir which provides approximately 40% of the drinking water for the City of Winston-Salem and Forsyth County. Located within the city of Winston-Salem, the lake has a long history of supplying water for growing communities in and around Winston-Salem.

The Town of Salem first began using Salem Creek as a water supply in 1877. Salem and the nearby town of Winston prospered and became interdependent, consolidating into the City of Winston-Salem in 1913. Subsequent growth in the area brought a demand for a larger water supply. In 1919, a dam was built on Salem Creek to create Salem Lake.

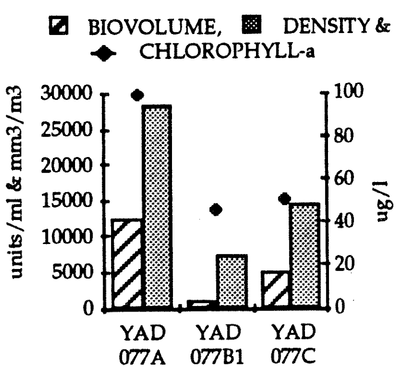
The watershed of Salem Lake covers approximately 66 km^2 of land and includes portions of the Towns of Kernersville and Walkertown. Feeding the lake are five major tributaries: Lowery, Martin Mill, Kerners Mill, Smith, and Fishers Branch Creeks, plus numerous smaller streams. Salem Lake floods 146 hectares, or 2% of the total land area of the watershed, and has a maximum depth of 11 meters. The lake has well defined north and south arms, 23 kilometers of shoreline, and is classified WS-III. Approximately half of the land in the watershed is forested. The remaining land use is split between agriculture and urban areas. The watershed is experiencing rapid development. Sedimentation and runoff from urban development and agriculture have sparked concerns about water quality in the lake.

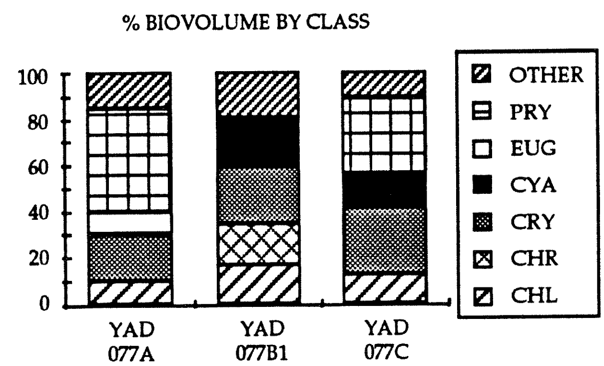
Salem Lake was sampled on August 15, 1989 by DEM. Physical data revealed that the shallow upper reaches of the impoundment were mixed while the dam station showed signs of mild stratification. A sub-surface diffuser pumped oxygen into the water column near the dam and may have helped prevent a stronger stratification. Analyses for heavy metals in the surface waters of the lake failed to document any high levels.

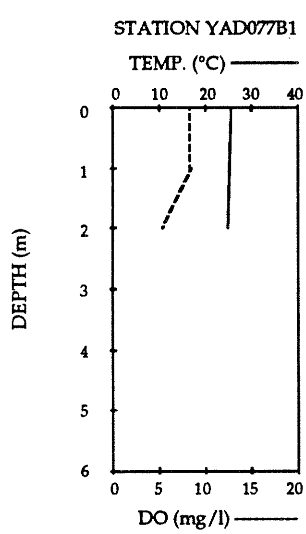
Total phosphorus was elevated throughout the lake. Organic nitrogen levels were low to moderate. Nitrate-nitrite was elevated at the two upstream stations, while ammonia was elevated near the dam. Chlorophyll-a exceeded the state standard of 40 µg/l at all three stations.

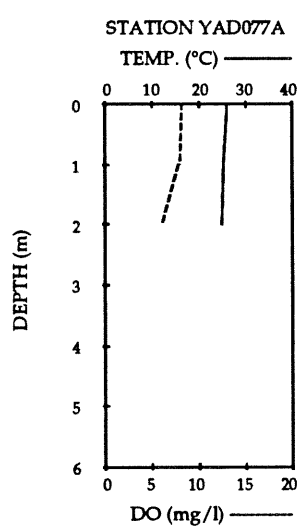
Sampling for phytoplankton in 1986 and 1989 revealed similar results. In both years, algal populations were dominated by Chrysochromulina breviturrita, a small golden flagellate that contains a large amount of chlorophyll-a relative to its size. The highest algal biovolume, density, and chlorophyll-a values were found at the uppermost station (YAD077A) located in the arm fed by Kerners Mill Creek. This portion of Salem Lake is shallow, allowing frequent mixing and circulation of nutrients. The other two stations exhibited lower levels of phytoplankton.

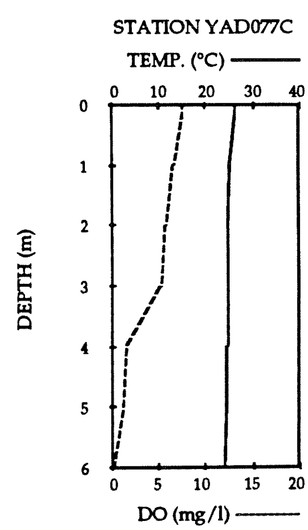
A TSI of 1.9 was calculated in 1989 which is between historical values of -0.4 and 3.5. Available data support a eutrophic classification for this lake. Salem Lake continues to experience problems associated with sedimentation and nutrient enrichment, and will continue to be monitored by DEM.

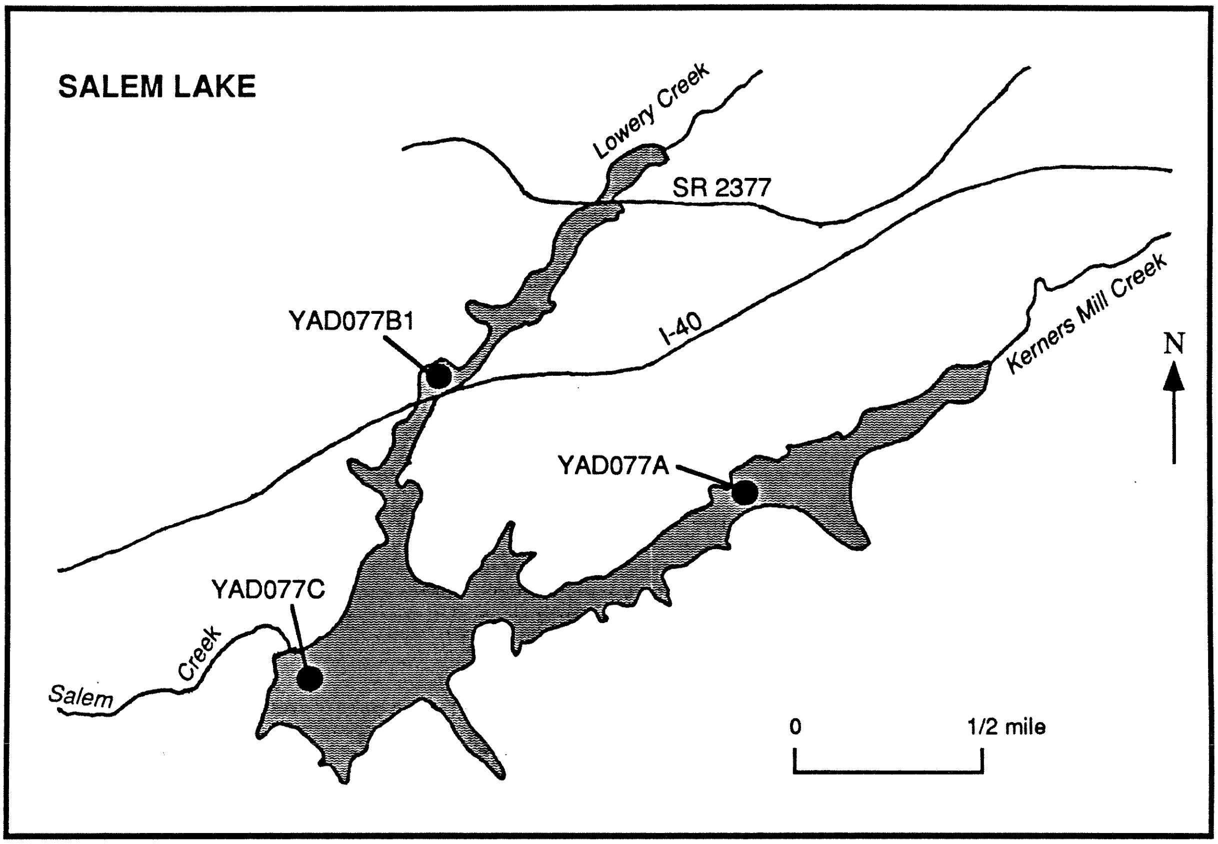




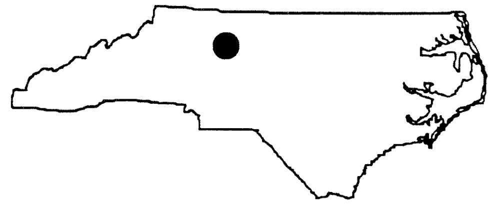







SALEM LAKE
Lowery Creek
SR 2377
YAD077B1
I-40
Kerners Mill Creek
N
YAD077A
YAD077C
Salem
Creek
0
1/2 mile

WINSTON LAKE



COUNTY:	Forsyth	**BASIN:**	Yadkin
SURFACE AREA:	10 hectares (25 acres)	**USGS TOPO:**	Winston-Salem, N.C.
CLASS:	C	**LAKE TYPE:**	Reservoir

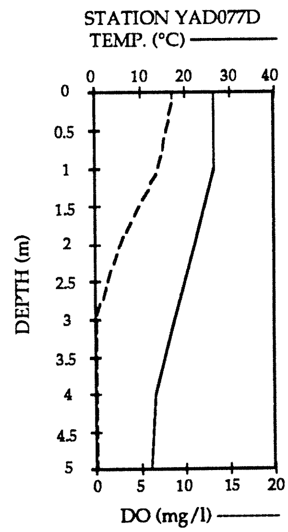
LATEST NCTSI:	-1.7	**TROPHIC STATE:**	Mesotrophic
SAMPLING DATE:	August 15, 1990	**ADDITIONAL COVERAGE:**	None
SECCHI DEPTH:	1.2 m	**CONDUCTIVITY:**	99 µmhos/cm^2
TOTAL PHOSPHORUS:	0.02 mg/l	**DISSOLVED OXYGEN:**	8.6mg/l
TOTAL ORGANIC NITROGEN:	0.15 mg/l	**TEMPERATURE:**	26.4 °C
CHLOROPHYLL-A:	10 µg/l	**pH:**	7.8 s.u.

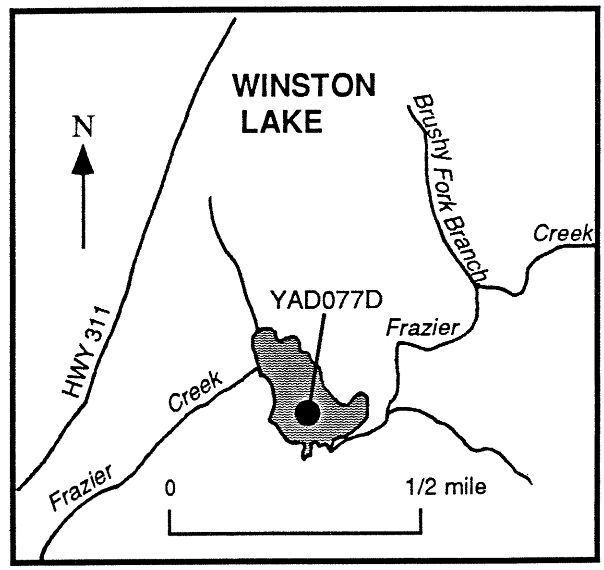
Around the turn of the century, the Town of Winston used Winston Lake as their primary water supply. After the Towns of Winston and Salem consolidated in 1913, Winston Lake became the primary water supply for the newly formed city. The existing dam was built in 1919 but the lake was eventually abandoned as a water supply. Fishing and boating are the main uses of the lake.

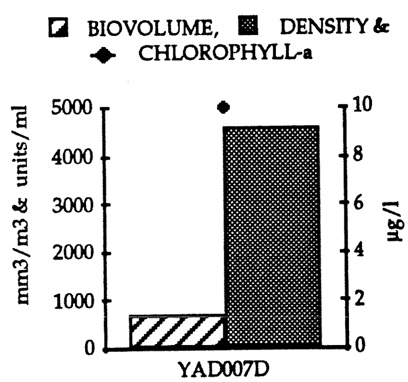
Volume of the lake is unknown, but maximum depth is approximately 5.5 meters. The major tributary is Frazier Creek. In 1986 the lake was drained and mechanically dredged. Spoil from this project was used to build a driving range at a nearby golf course.

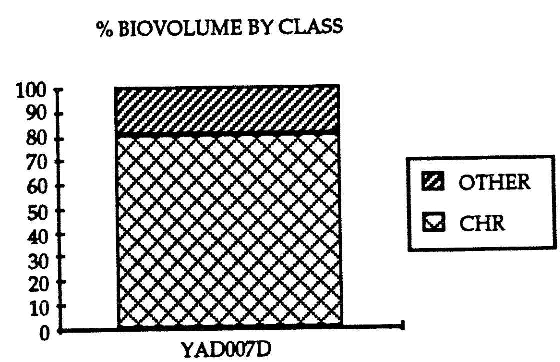
On August 15, 1990, Winston Lake was stratified and anoxic below three meters. Conductivity increased with depth to levels near 300 µmhos/cm^2. Nutrients and chlorophyll-a were low as were populations of phytoplankton. The predominant species was a colonial chrysophyte, Dinobryon sertularia, representing 80% of the phytoplanktonic biovolume. This particular genus of chrysophyte is commonly found in nutrient-poor waters (Wetzel, 1975).

Winston Lake is mesotrophic with a TSI of -1.7. All uses were fully supported at the time of this assessment.

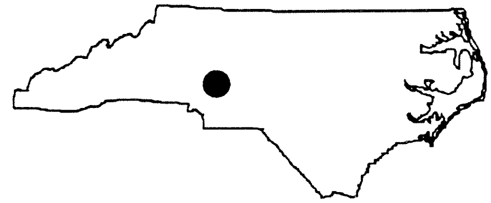

STATION YAD077D
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5
0 5 10 15 20
DO (mg/l)


WINSTON LAKE
N
Brushy Fork Branch
Creek
HWY 311
YAD077D
Frazier
Creek
Frazier
0
1/2 mile


BIOVOLUME, DENSITY & CHLOROPHYLL-a
mm3/m3 & units/ml
5000 4000 3000 2000 1000 0
10 8 6 4 2 0
µg/l
YAD007D


% BIOVOLUME BY CLASS
100 90 80 70 60 50 40 30 20 10 0
YAD007D
OTHER
CHR

LAKE CORRIHER



COUNTY:	Rowan	**BASIN:**	Yadkin
SURFACE AREA:	7 hectares (17 acres)	**USGS TOPO:**	China Grove, N.C.
CLASS:	WS	**LAKE TYPE:**	Reservoir

LATEST NCTSI:	1.1	**TROPHIC STATE:**	Eutrophic
SAMPLING DATE:	August 8, 1989	**ADDITIONAL COVERAGE:**	Water Supply Parameters
SECCHI DEPTH:	1.1 m	**CONDUCTIVITY:**	71 - 72 µmhos/cm^2
TOTAL PHOSPHORUS:	0.03 mg/l	**DISSOLVED OXYGEN:**	7.9 - 8.7 mg/l
TOTAL ORGANIC NITROGEN:	0.41 mg/l	**TEMPERATURE:**	27.5 - 27.6 °C
CHLOROPHYLL-A:	19.5 µg/l	**pH:**	7.6 - 7.7 s.u.

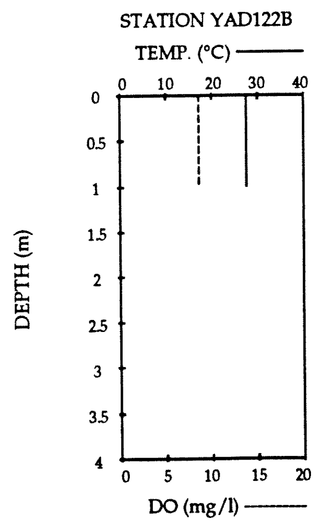
Lake Corriher is a small water supply built in 1953 by the Town of Landis. The lake is a holding pond adjacent to the water treatment plant. Maximum depth is five meters and volume is 1.8 x 10^5 m^3.

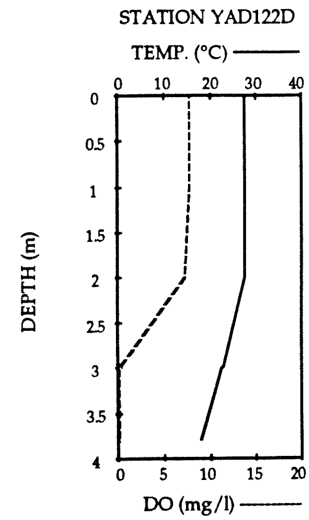
The 5.4 km^2 drainage area is primarily agricultural. Topography in the watershed is characterized by gently rolling hills. Grants Creek is the main tributary to this lake.

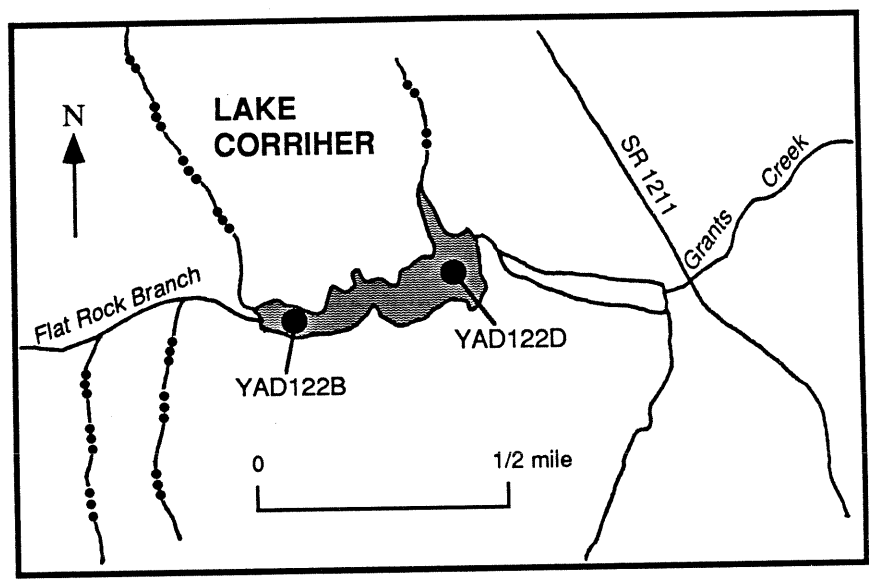
Lake Corriher was sampled on August 8, 1989. The downstream station was stratified with oxygen levels approaching zero towards the lake bed. Nutrients were extremely elevated in the hypolimnion, which is common for stratified systems. Chlorophyll-a and nutrients were high, but no water quality violations were documented. Toxic heavy metals were not detected. Iron was found, but within the state standard.

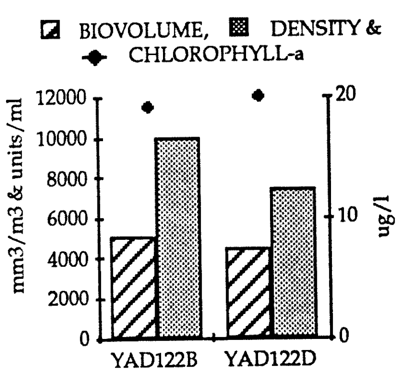
One sampling station on Lake Corriher (YAD122B) exceeded algal bloom thresholds with biovolume and density levels reaching 5,141 mm^3/m^3 and 10,057 units/ml, respectively. Diatoms (Rhizosolenia eriensis) dominated the algal biovolume at each station with chlorophytes, chrysophytes, and euglenophytes as codominant classes. Euglenophytes (Trachelomonas species 2) are generally considered indicators of organic enrichment.

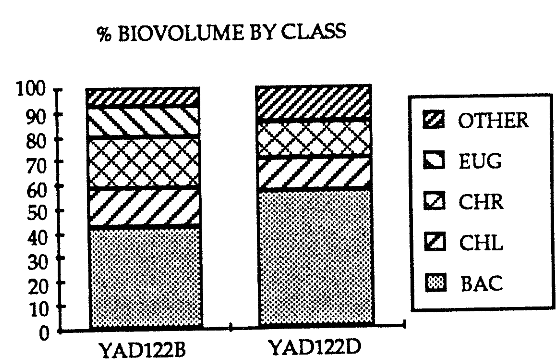
A TSI of 1.1 indicated that Lake Corriher was eutrophic. Treatment plant operators have reported problems with algae causing taste and odor problems, but all uses were supported at the time of this assessment.


STATION YAD122B
TEMP. (°C)
DEPTH (m)
DO (mg/l)

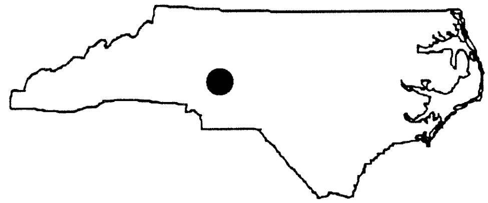

STATION YAD122D
TEMP. (°C)
DEPTH (m)
DO (mg/l)


N
LAKE
CORRIHER
SR 1211
Grants Creek
Flat Rock Branch
YAD122D
YAD122B
0
1/2 mile


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/m3 & units/ml
ug/l
YAD122B
YAD122D


% BIOVOLUME BY CLASS
OTHER
EUG
CHR
CHL
BAC
YAD122B
YAD122D

LAKE WRIGHT



COUNTY:	Rowan	BASIN:	Yadkin
SURFACE AREA:	12 hectares (29 acres)	USGS TOPO:	Enochville, N.C.
CLASS:	WS	LAKE TYPE:	Reservoir

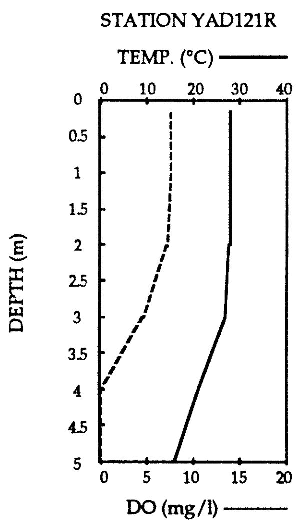
LATEST NCTSI:	- 0.9	TROPHIC STATE:	Mesotrophic
SAMPLING DATE:	August 8, 1989	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	2.2 m	CONDUCTIVITY:	61 µmhos/cm^2
TOTAL PHOSPHORUS:	0.03 mg/l	DISSOLVED OXYGEN:	7.7 mg/l
TOTAL ORGANIC NITROGEN:	0.13 mg/l	TEMPERATURE:	27.9 °C
CHLOROPHYLL-A:	40 µg/l	pH:	7.9 s.u.

Built in 1955, Lake Wright is located just north of Landis in Rowan County. The Town of Landis owns the lake which is used as a secondary water supply during times of low flow. Maximum depth of the lake is six meters and volume in the lake is 78.6 million gallons. Grants Creek is the major inflow to Lake Wright which has controlled access and no allowable recreational use.

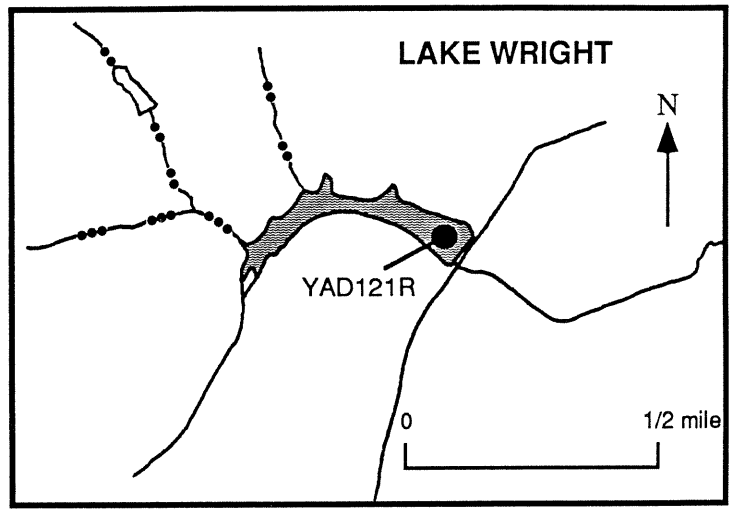
Lake Wright was sampled on August 8, 1989. The lake was stratified with oxygen levels approaching zero below three meters. Secchi readings were high, indicating good water clarity. Nitrogen levels were low in the photic zone, but phosphorus was moderate. Moreover, chlorophyll-a was 40 µg/l in the photic zone. Nitrogen levels were much higher at the bottom of the lake which is common in stratified lakes. Iron and copper were above laboratory detection levels, but neither were found at levels of concern.

Estimates of phytoplanktonic biovolume and density were relatively low in Lake Wright measuring 2,997 mm^3/m^3 and 3,249 units/ml respectively. A diverse assemblage of chlorophytes constituted almost 50% of the algal biovolume of this lake. Codominant classes of algae include euglenophytes and bacillariophytes. The low estimates of phytoplankton did not correspond to the chlorophyll-a value of 40 µg/l measured in this lake, a level at the threshold of an algal bloom.

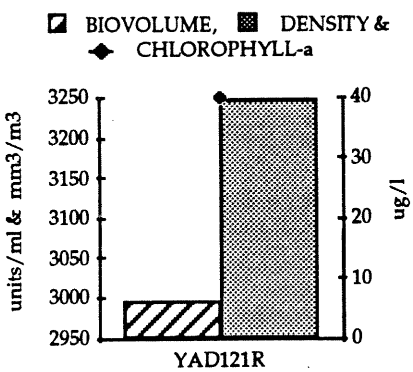
A TSI of -0.9 for Lake Wright indicated it is mesotrophic. All uses were supported at the time of this assessment.



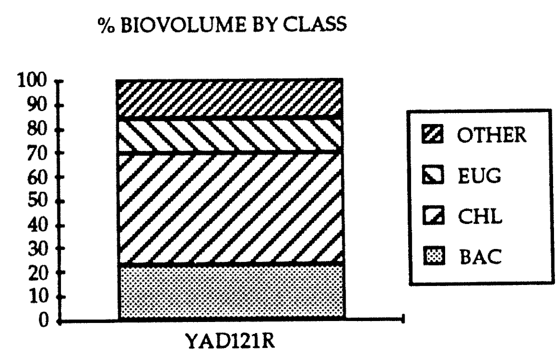
STATION YAD121R
TEMP. (°C)
0 10 20 30 40
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
DEPTH (m)
0 5 10 15 20
DO (mg/l)



LAKE WRIGHT
N
YAD121R
0
1/2 mile

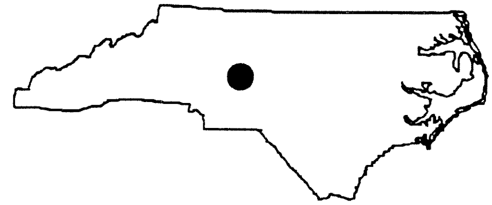


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
3250
3200
3150
3100
3050
3000
2950
units/ml & mm3/m3
40
30
20
10
0
ug/l
YAD121R



% BIOVOLUME BY CLASS
100
90
80
70
60
50
40
30
20
10
0
YAD121R
OTHER
EUG
CHL
BAC

LAKE TOM-A-LEX



COUNTY:	Davidson	BASIN:	Yadkin
SURFACE AREA:	263 hectares (650 acres)	USGS TOPO:	Lexington East, N.C.
CLASS:	WS	LAKE TYPE:	Reservoir

LATEST NCTSI:	2.2	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	August 16, 1989	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	0.9 m	CONDUCTIVITY:	90 - 92 µmhos/cm^2
TOTAL PHOSPHORUS:	0.045 mg/l	DISSOLVED OXYGEN:	9.0 - 10.7 mg/l
TOTAL ORGANIC NITROGEN:	0.35 mg/l	TEMPERATURE:	27.7 - 28.7 °C
CHLOROPHYLL-A:	32 µg/l	pH:	8.0 - 8.8 s.u.

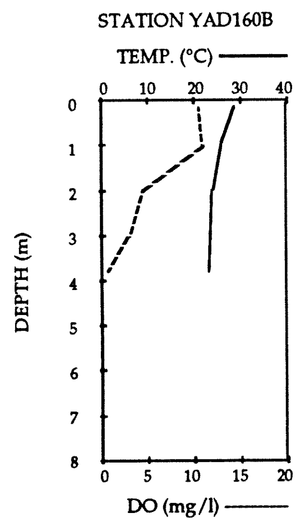
Lake Tom-A-Lex (also known as Lexington-Thomasville Reservoir) was constructed in 1957 as a water supply reservoir for the cities of Thomasville and Lexington. The lake has a maximum depth of eight meters and a volume of 7.8×10^6 m^3 and is a primary water supply and recreational lake. The drainage area for the lake is 102 km^2 and is characterized by rolling hills. The major tributary into the lake is Abbotts Creek.

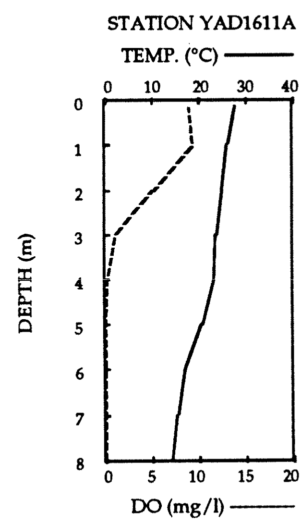
Lake Tom-A-Lex was sampled by DEM on August 16, 1989. On this date, physical measurements revealed stratified conditions at both stations with average surface temperatures of 28.2 °C and average bottom temperatures of 18.6 °C. Dissolved oxygen levels averaged 9.8 mg/l at the surface dropping to an average of 0.3 mg/l at the bottom. Nutrient concentrations on the bottom were greatly elevated compared to photic zone samples, which is typical of stratified impoundments.

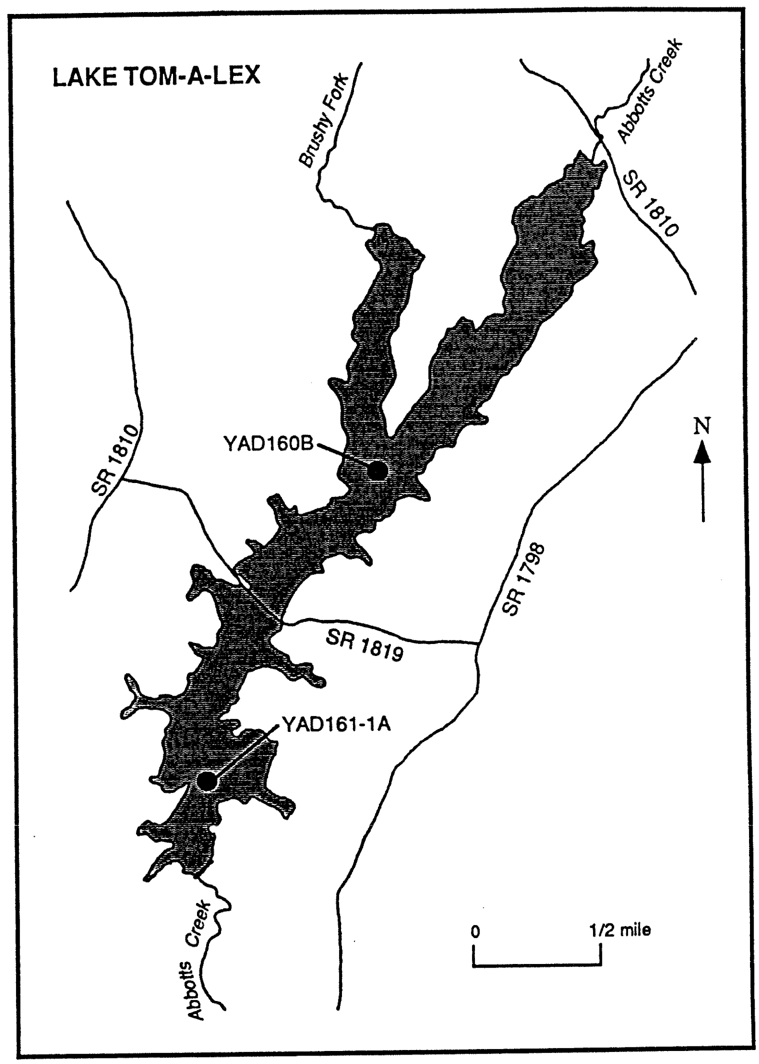
Similar to other North Carolina reservoirs, the upstream station had higher total phosphorus and ammonia concentrations than the station near the dam. In addition, station YAD160B had an elevated chlorophyll-a concentration of 44 µg/l, which exceeds the state standard of 40 µg/l. Concentrations of heavy metals were well within state standards.

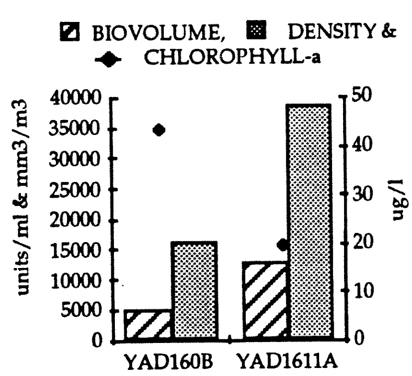
Similar to the sampling of Lake Tom-A-Lex in 1983 and 1985, estimates of algal biovolume and density in 1989 continue to be high and exceed the levels indicative of a bloom. Although cyanophytes (blue-green algae) comprised over 60% of the total algal biovolume in 1983, phytoplanktonic populations were dominated by euglenophytes as well as cyanophytes in 1985 and 1989. Other codominant algal classes in 1989 included chrysophytes and cryptophytes.

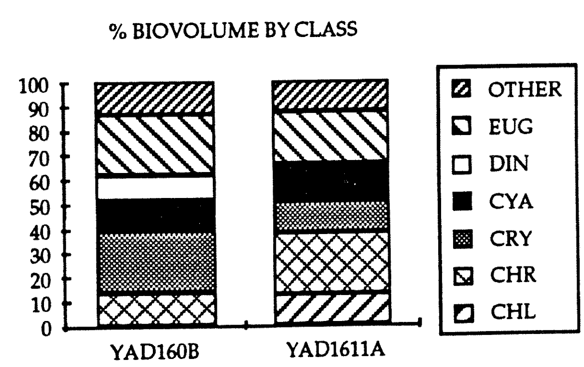
The TSI of 2.2 indicated that the lake is eutrophic. This is similar to historical TSI values for the reservoir. At the time of assessment, uses were fully supported at Lake Tom-A-Lex. However, the high TSI values suggests that the potential for water quality problems exists and that future monitoring is warranted. It is likely that future problems resulting from nutrient enrichment will first appear at the Thomasville intake, because it is located upstream of SR 1819 in the more eutrophic section of the lake.



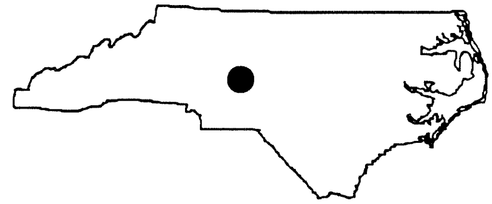








HIGH ROCK LAKE



COUNTY:	Rowan/Davidson	BASIN:	Yadkin
SURFACE AREA:	6374 hectares (15750 acres)	USGS TOPO:	High Rock, N.C.
CLASS:	WS, B	LAKE TYPE:	Reservoir

LATEST NCTSI:	3.3	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	August 14, 1990	ADDITIONAL COVERAGE:	Fecals, Water Supply Parameters
SECCHI DEPTH:	0.4 m	CONDUCTIVITY:	92-97 µmhos/cm^2
TOTAL PHOSPHORUS:	0.08 mg/l	DISSOLVED OXYGEN:	7.0 - 11.4 mg/l
TOTAL ORGANIC NITROGEN:	0.35 mg/l	TEMPERATURE:	28.2 - 29.1 °C
CHLOROPHYLL-A:	28 µg/l	pH:	7.5 - 9.6 s.u.

High Rock Lake is an impoundment of the Yadkin River situated downstream from W. Kerr Scott Reservoir. The dam that impounds High Rock Lake was originally built in 1927 by the Yadkin Corporation to provide hydroelectric power. With a maximum depth of 19 meters and a mean depth of five meters, High Rock Lake has a volume of 314×10^6 m^3. Because the water from the lake is used to generate hydroelectric power, the discharge rate from High Rock Lake remains fairly constant although the inflow varies. This variation causes considerable fluctuations in lake level and affects the hydraulic retention time. A two-year study conducted by the University of North Carolina (Weiss et. al. 1981) in 1977 and 1978 found residence times ranging from 3.6 days to 50.8 days depending on inflow to the impoundment.

The lake has a drainage area of 10,176 km^2 which is characterized by rolling hills. Half of the land is forested, over one quarter is agricultural, and the remainder is urbanized. The drainage basin includes several major urban areas of the Central Piedmont including Winston-Salem, Salisbury, Lexington and High Point. High Rock Lake is classified WS-III from its headwaters to and including Town and Swearing Creeks. From there to the dam, the lake is classified WS-III and B.

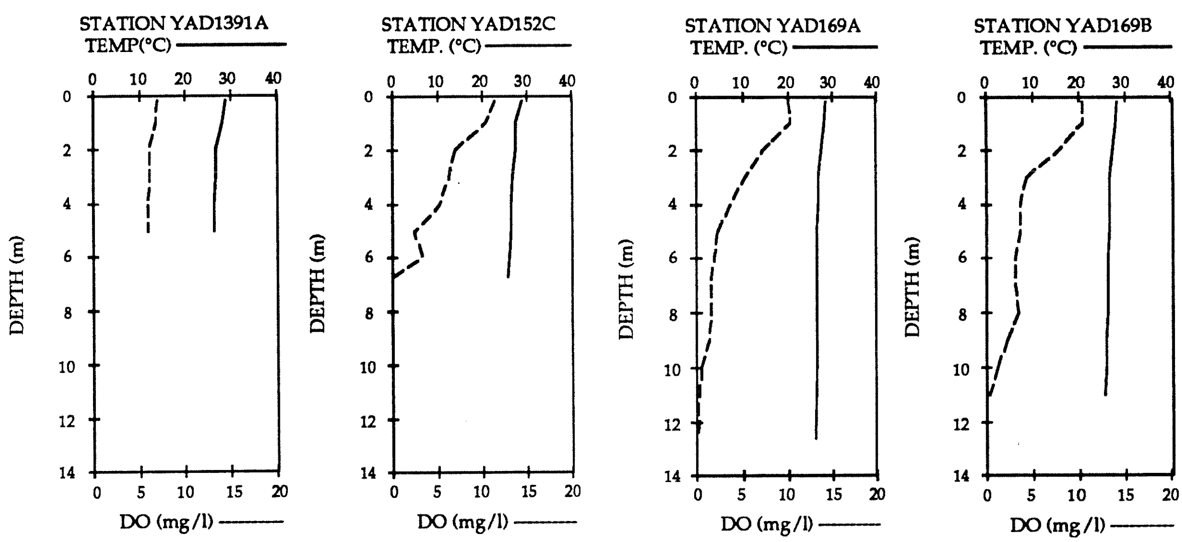
One major tributary is Abbotts Creek which gained the attention of DEM when mercury was discovered in the water and fish. Mercury entered the creek from a Duracell battery plant adjacent to the creek. Routine fish tissue analyses for mercury levels began in 1981. Although levels of mercury in fish tissue have declined overall, certain portions of the creek still contain high levels. Monitoring conducted in October of 1987 found that 18.5% of the fish collected had tissue concentrations of mercury above the FDA action level of 1.0 mg/kg. Largemouth bass is the species with the highest mercury levels. The State Health Director has issued an advisory limiting the consumption of fish taken from Abbotts Creek.

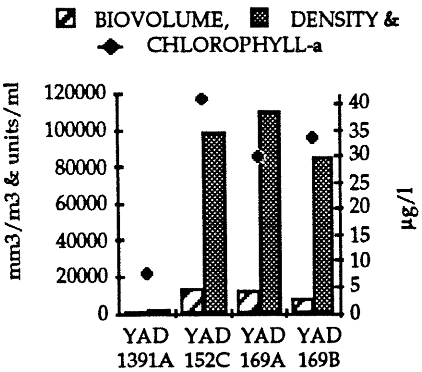
High Rock Lake was sampled by DEM on August 14, 1990. Oxygen levels were reduced towards the bottom of the water column except at YAD1391A where the lake is riverine. Nutrient and chlorophyll-a concentrations were elevated and water clarity was poor. A pronounced color gradation often exists near Potts Creek , a result of the incoming sediment load. Turbidity at the uppermost station (YAD1391A) was 32 NTU which is in violation of the state standard. Violations at this station are not unusual.

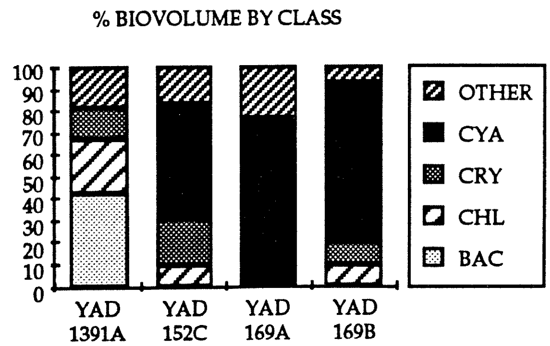
Populations of phytoplankton exceeding algal bloom levels were found at all stations sampled on High Rock Lake except YAD1391A, the station located furthest upstream. High flows and suspended solids inhibit the growth of phytoplankton at this station even in the presence of excessive levels of nutrients. The predominance of <u>Anabaenopsis raciborskii</u> and <u>Oscillatoria geminata</u>, small filamentous, blue-green algae, accounts for the particularly high estimates of phytoplanktonic density (85,596-110,053 units/ml) at three of the sampling stations. These species are commonly found in eutrophic waters throughout the state. Such elevated algal populations are cause for concern and could be reduced through watershed management.

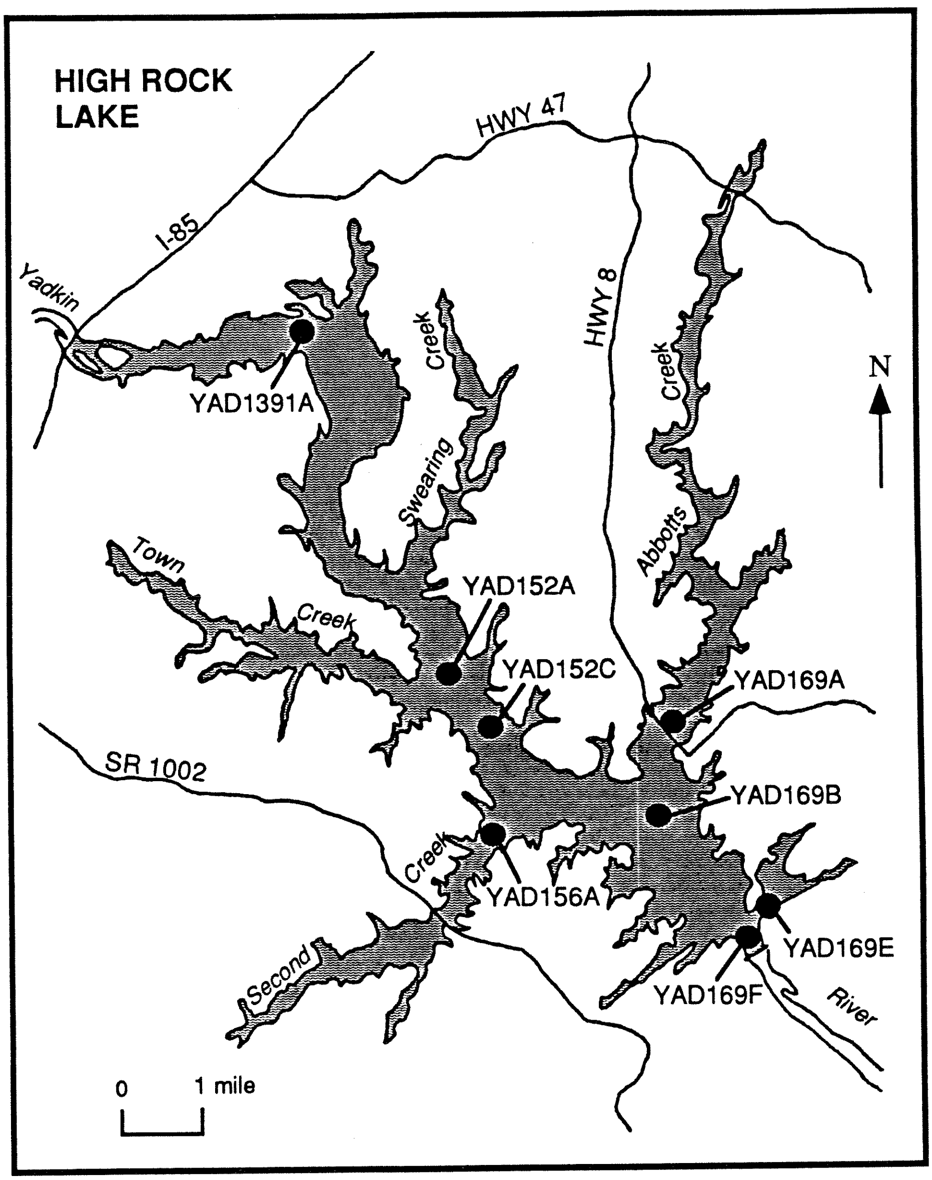
In 1990, the TSI was 3.3 which is indicative of a highly productive lake. This is similar to historical values.

High Rock Lake remains one of the most eutrophic lakes in North Carolina. The mercury contamination in the Abbotts Creek arm of the lake has caused it to be classified as not supporting its designated use. Chlorophyll-a values have consistently exceeded the state water quality standard of 40 µg/l, and blue-green algal blooms are common. Clearly, the situation at High Rock Lake warrants ongoing monitoring and management strategies to improve water quality.

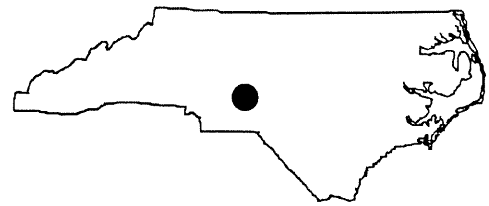



BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/m3 & units/ml
μg/l
120000
100000
80000
60000
40000
20000
0
40
35
30
25
20
15
10
5
0
YAD 1391A
YAD 152C
YAD 169A
YAD 169B


% BIOVOLUME BY CLASS
100
90
80
70
60
50
40
30
20
10
0
YAD 1391A
YAD 152C
YAD 169A
YAD 169B
OTHER
CYA
CRY
CHL
BAC


HIGH ROCK LAKE
HWY 47
I-85
Yadkin
HWY 8
Creek
Swearing
Creek
Abbotts
Town
Creek
YAD1391A
YAD152A
YAD152C
YAD169A
YAD169B
SR 1002
Creek
YAD156A
Second
YAD169E
YAD169F
River
N
0
1 mile

TUCKERTOWN RESERVOIR



COUNTY:	Stanly/Montgomery	BASIN:	Yadkin
SURFACE AREA:	1,032 hectares (2,550 acres)	USGS TOPO:	New London, N.C.
CLASS:	WS, B	LAKE TYPE:	Reservoir

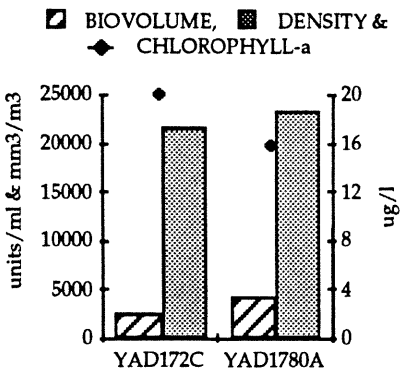
LATEST NCTSI:	2.0	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	August 9, 1989	ADDITIONAL COVERAGE:	Fecal, Water Supply Parameters
SECCHI DEPTH:	0.7 m	CONDUCTIVITY:	83 - 85 µmhos/cm^2
TOTAL PHOSPHORUS:	0.045 mg/l	DISSOLVED OXYGEN:	4.8 - 5.1 mg/l
TOTAL ORGANIC NITROGEN:	0.415 mg/l	TEMPERATURE:	26.1 - 27.0 °C
CHLOROPHYLL-A:	18 µg/l	pH:	6.1 -6.3 s.u.

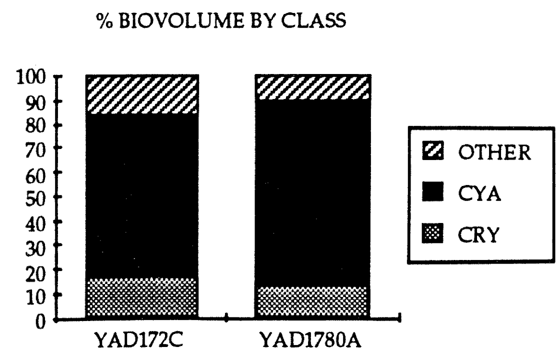
Located between High Rock Lake and Badin Lake on the Yadkin River, Tuckertown Reservoir is a run-of-the-river lake. Owned by the Yadkin Inc., the lake was filled in 1962 and is used to generate hydroelectric power and for recreation. It has a drainage area of 10,440 km^2. As with other impoundments in the Yadkin Chain Lake system, land use in the watershed is primarily forest and agriculture, with some urban development and pasture. The waters of the lake are classified WS-III and B.

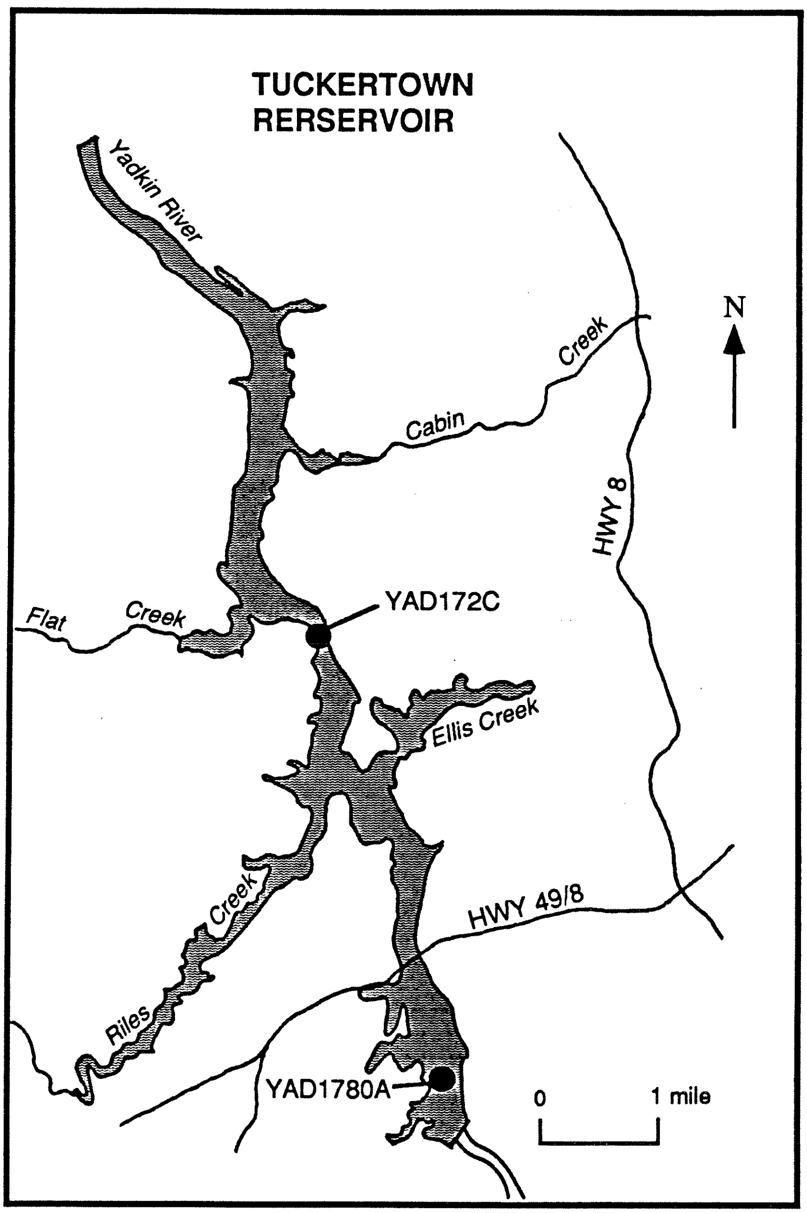
Tuckertown Reservoir was sampled on August 9, 1989. The water column was mixed with a slight decrease in dissolved oxygen as depth increased. Photic zone water samples contained elevated nutrient levels typical of enriched systems. Heavy metals were not found at levels of concern.

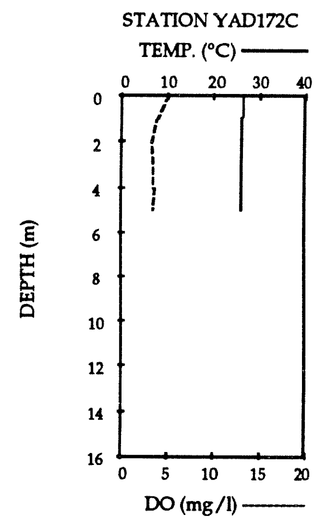
Similar to the sampling of Tuckertown Reservoir in 1986, the estimates of phytoplanktonic biovolume in 1989 remained moderate. The short retention time in this reservoir prevents excessive algal growth even in the presence of sufficient nutrients. Phytoplanktonic density, however, reached levels indicative of a bloom at both stations (21,749 and 23,322 units/ml) because of the predominance of Anabaenopsis raciborskii and Oscillatoria geminata, small filamentous, blue-green algae common in eutrophic waters during summer months.

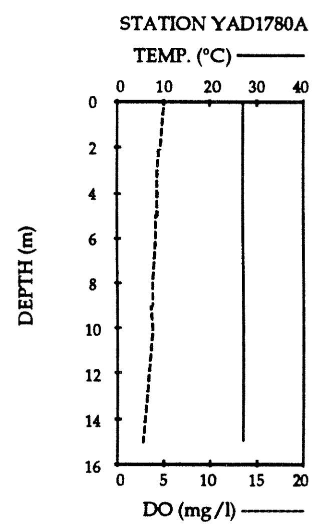
The TSI in 1989 was 2.0, indicative of eutrophication. At the time of assessment, no violations of state water quality standards were observed at Tuckertown Reservoir and designated uses were fully supported.


BIOVOLUME, DENSITY & CHLOROPHYLL-a
units/ml & mm3/m3
ug/l
25000
20000
15000
10000
5000
0
20
16
12
8
4
0
YAD172C
YAD1780A

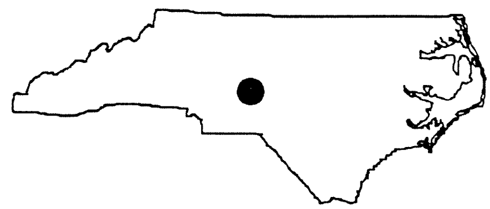

% BIOVOLUME BY CLASS
100
90
80
70
60
50
40
30
20
10
0
YAD172C
YAD1780A
OTHER
CYA
CRY


TUCKERTOWN RERSERVOIR
Yadkin River
Cabin Creek
Flat Creek
YAD172C
Ellis Creek
Riles Creek
HWY 8
HWY 49/8
N
YAD1780A
0
1 mile


STATION YAD172C
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0
2
4
6
8
10
12
14
16
0 5 10 15 20
DO (mg/l)


STATION YAD1780A
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0
2
4
6
8
10
12
14
16
0 5 10 15 20
DO (mg/l)

BADIN LAKE



COUNTY:	Stanly/Montgomery	BASIN:	Yadkin
SURFACE AREA:	2,165 hectares (5,350 acres)	USGS TOPO:	Badin, N.C.
CLASS:	WS, B	LAKE TYPE:	Reservoir

LATEST NCTSI:	-0.2	TROPHIC STATE:	Mesotrophic
SAMPLING DATE:	August 9, 1990	ADDITIONAL COVERAGE:	Fecal, Water Supply Parameters
SECCHI DEPTH:	1.4 m	CONDUCTIVITY:	74 - 81 µmhos/cm^2
TOTAL PHOSPHORUS:	0.025 mg/l	DISSOLVED OXYGEN:	5.2 - 7.3 mg/l
TOTAL ORGANIC NITROGEN:	0.27 mg/l	TEMPERATURE:	26.7 - 27.2 °C
CHLOROPHYLL-A:	17 µg/l	pH:	6.8 - 7.3 s.u.

Badin Lake is a chain lake on the Yadkin River, located downstream from Tuckertown Reservoir, High Rock Lake, and W. Kerr Scott Reservoir. The lake was filled in 1917 and is owned by Yadkin Inc., a subsidiary of ALCOA. It has a maximum depth of 53 meters, a mean depth of 14 meters, a volume of 344 x 10^6 m^3, and an average hydraulic retention time of 28 days (USEPA 1975a).

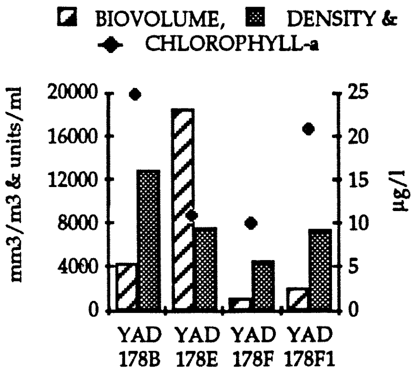
The drainage area for Badin Lake covers 10,660 km^2 characterized by rolling hills. Land use in the watershed is mainly forest with some agriculture. Badin Lake receives the majority of its inflow from the discharge of Tuckertown Reservoir and is classified WS-III and B.

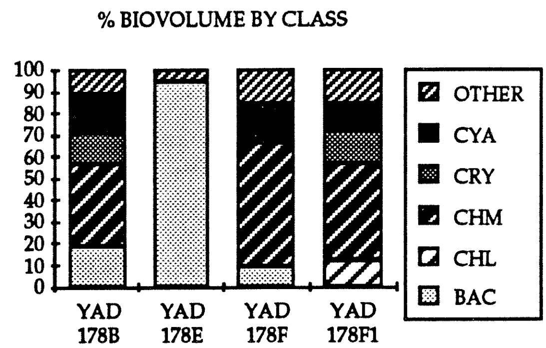
On August 9, 1990, the lake was stratified at all stations with dissolved oxygen levels approaching zero in the hypolimnion. Concentrations of nutrients and chlorophyll-a in the photic zone were moderate, consistent with the mesotrophic status of the lake. The average total organic nitrogen and total phosphorus values were lower than those for Tuckertown Reservoir and High Rock Lake which are located directly upstream of Badin Lake. Fecal coliform bacteria were found at or below detection levels.

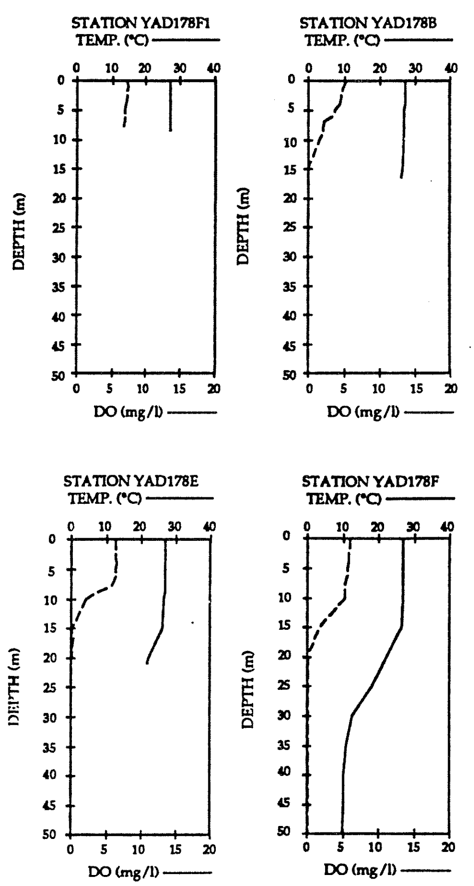
Four stations on Badin Lake were sampled for phytoplankton in 1990. Algal populations were moderate with biovolume and density ranging from 1122-18,527 mm3/m3 and 4581-12,927 units/ml respectively. Station YAD178B exhibited the highest algal density and chlorophyll-a, as was also the case in in 1987. Releases of nutrient-laden waters from impoundments located upstream supported these larger populations.

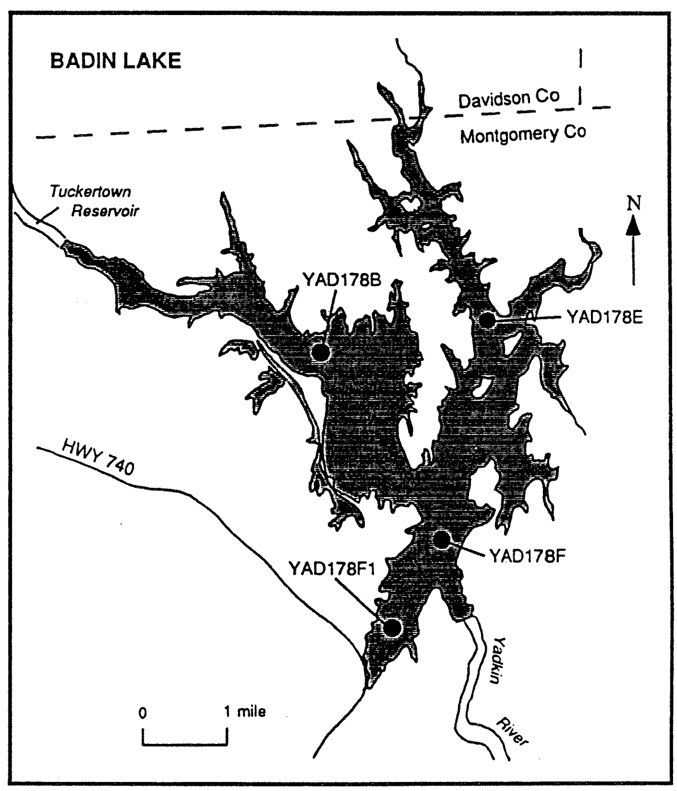
Anabaenopsis raciborskii and Oscillatoria geminata were present at all four stations, but unlike the results from 1987, they were not dominant throughout the lake. These species were responsible for the high estimates of algal density at YAD178B. The predominance of Rhizoselenia eriensis, a relatively large diatom, contributed to the elevated level of phytoplanktonic biovolume (18,527 mm^3/m^3) at YAD178E. This species, however, apparently contains low levels of chlorophyll-a since this parameter only reached 11 ug/l.

In 1990, the TSI was -0.2, which is similar to historical values, suggesting that the trophic status of the lake has changed little over the last ten years. At the time of assessment, no violations of state water quality standards were observed at Badin Lake and water quality in the reservoir fully supported designated uses.

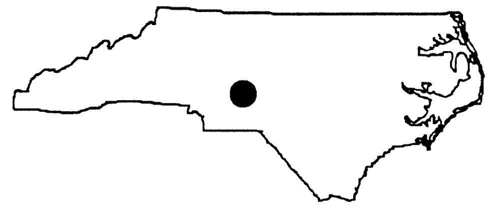








FALLS LAKE



COUNTY:	Stanly/Montgomery	BASIN:	Yadkin
SURFACE AREA:	82 hectares (203 acres)	USGS TOPO:	Badin, N.C.
CLASS:	WS,B	LAKE TYPE:	Reservoir

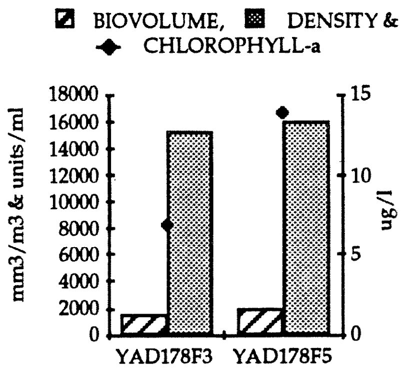
LATEST NCTSI:	- 0.7	TROPHIC STATE:	Mesotrophic
SAMPLING DATE:	August 9, 1989	ADDITIONAL COVERAGE:	Fecal, Water Supply Parameters
SECCHI DEPTH:	1.3 m	CONDUCTIVITY:	69 - 77 µmhos/cm^2
TOTAL PHOSPHORUS:	0.02 mg/l	DISSOLVED OXYGEN:	3.5 - 5.7 mg/l
TOTAL ORGANIC NITROGEN:	0.275 mg/l	TEMPERATURE:	26.2 °C
CHLOROPHYLL-A:	10.5 µg/l	pH:	6.2 - 7.5 s.u.

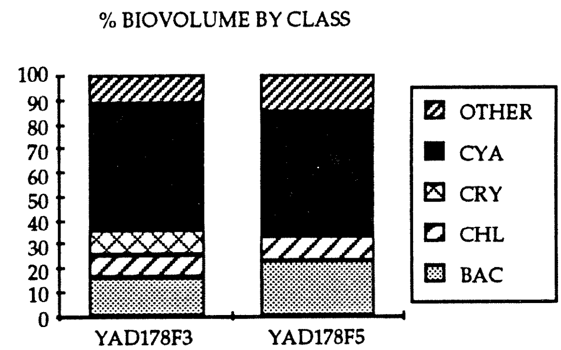
Falls Lake is a small, run-of-the-river impoundment located between Badin Lake and Lake Tillery on the Yadkin River. The lake is owned by the Carolina Aluminum Company which operates the Aluminum Company of America plant in the Town of Badin. Falls Lake has a drainage basin of 6,610 km^2 with the major inflow coming from the discharge of Badin Lake. The watershed is primarily forested with some agriculture. The lake is currently classified WS-III and B.

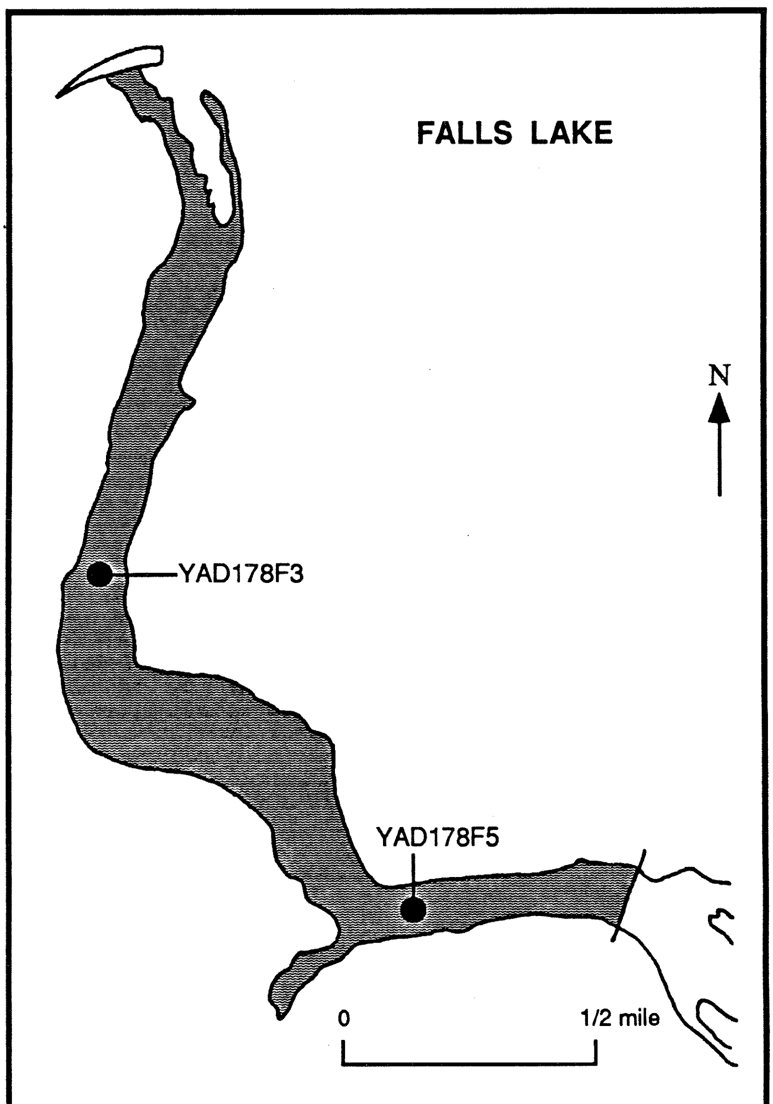
When sampled on August 9, 1989, the reservoir was not stratified. Dissolved oxygen concentrations were low, perhaps as a result of hypolimnetic releases from Badin Lake. Concentrations of nutrients in the photic zone and hypolimnion were similar, with low organic nitrogen and total phosphorus but elevated ammonia and nitrite-nitrate. Fecal coliform bacteria were at or below laboratory detection limits.

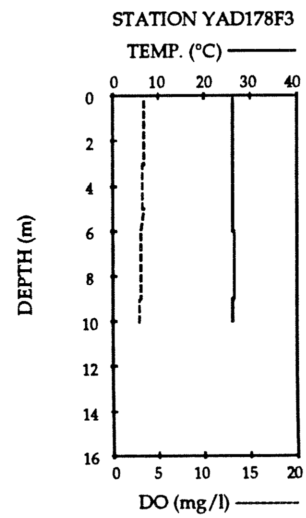
Levels of algal biovolume (1,512 and 2,045 mm^3/m^3) were low at both stations on Falls Lake, but densities reached bloom levels of 15,373 and 16,072 units/ml. Similar to communities found in 1986, bacillariophytes (diatoms), cyanophytes (blue-green algae), and chlorophytes (green algae) codominated the biovolume. Moreover, Oscillatoria geminata and Anabaenopsis raciborskii, small blue-green algae typically found in the chain lakes, were seen again in 1989. These species were responsible for the relatively high densities of algae observed in Falls Lake. They are commonly found in eutrophic bodies of water.

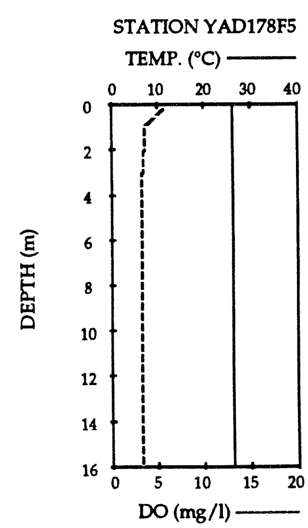
The TSI in 1989 was -0.7 which is similar to historical values. At the time of assessment, no violation of state water quality standards was observed, and water quality fully supported the designated uses of Falls Lake.



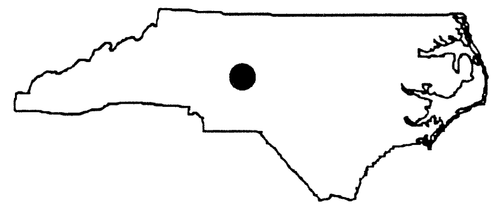








LAKE REESE



COUNTY:	Randolph	BASIN:	Yadkin
SURFACE AREA:	243 hectares (600 Acres)	USGS TOPO:	Farmer, N.C.
CLASS:	WS	LAKE TYPE:	Reservoir

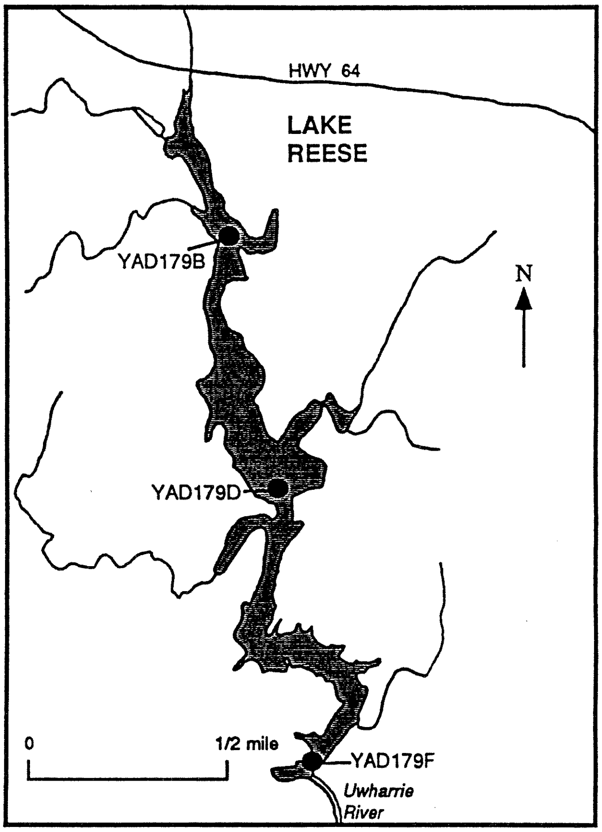
LATEST NCTSI:	- 1.1	TROPHIC STATE:	Mesotrophic
SAMPLING DATE:	July 27, 1989	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	1.8 m	CONDUCTIVITY:	71 - 87 µmhos/cm^2
TOTAL PHOSPHORUS:	0.02 mg/l	DISSOLVED OXYGEN:	8.2 - 8.5 mg/l
TOTAL ORGANIC NITROGEN:	0.17 mg/l	TEMPERATURE:	31.1 - 32.0 °C
CHLOROPHYLL-A:	26 µg/l	pH:	7.7 - 8.0 s.u.

In 1983, the City of Asheboro impounded the Uwharrie River and Caraway Creek to form Lake Reese, a water supply also used for recreation. Volume of the lake is 9.1 x 10^5 m^3 with a maximum depth of approximately ten meters. The wooded watershed is 259 km^2. Farms and residential areas also occupy the drainage area. Lake Reese is used only after Asheboro's primary water supply (Back Creek Lake) has a three-foot drop in level.

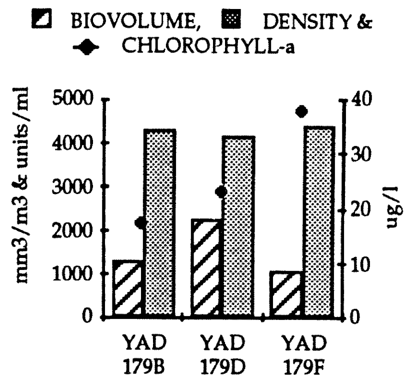
Lake Reese was sampled on July 27, 1989. The uppermost station was weakly stratified. The other two stations were distinctly stratified with anoxic conditions below three meters. Nutrient concentrations were moderate throughout the lake. Chlorophyll-a increased from moderate levels upstream to elevated levels near the dam (YAD179F).

Lake Reese contained a moderate yet diverse assemblage of phytoplankton. Dominant classes of algae included bacillariophytes (diatoms), chlorophytes (green algae), cryptophytes, cyanophytes (blue-green algae), and euglenophytes. Although phytoplanktonic biovolume (1,097 mm^3/m^3) and density (4,399 units/ml) at YAD179F were relatively low, chlorophyll-a peaked at 38 µg/l. A value this high generally indicates bloom conditions, but this was not corroborated by algal analysis or field observations.

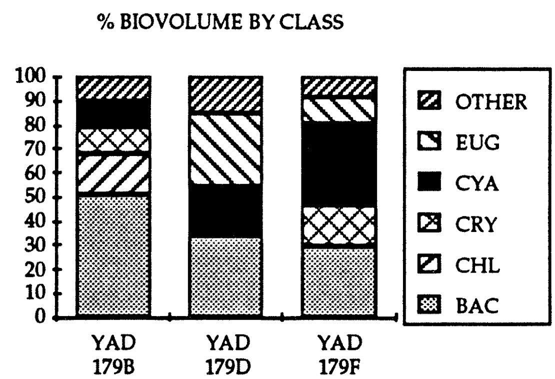
A TSI of -1.1 indicates Lake Reese is mesotrophic. All uses were supported at the time of this assessment, and no violations of water quality standards were noted.



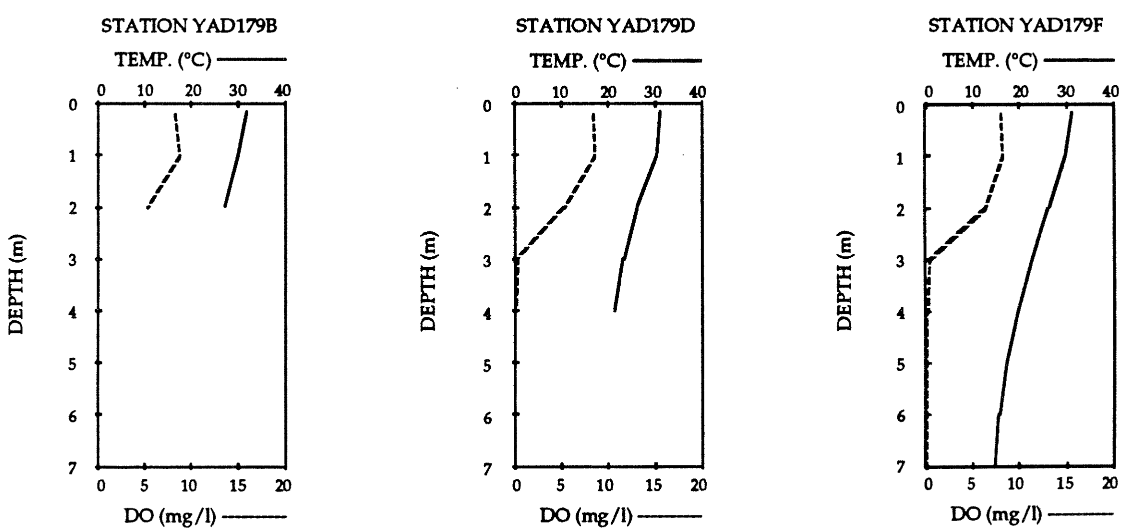
HWY 64
LAKE REESE
YAD179B
YAD179D
YAD179F
N
0
1/2 mile
Uwharrie River



BIOVOLUME, DENSITY & CHLOROPHYLL-a
mm3/m3 & units/ml
ug/l
YAD 179B
YAD 179D
YAD 179F

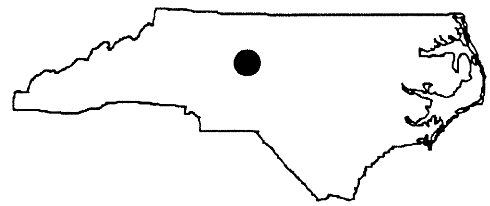


% BIOVOLUME BY CLASS
OTHER
EUG
CYA
CRY
CHL
BAC
YAD 179B
YAD 179D
YAD 179F



STATION YAD179B
TEMP. (°C)
DEPTH (m)
DO (mg/l)
STATION YAD179D
TEMP. (°C)
DEPTH (m)
DO (mg/l)
STATION YAD179F
TEMP. (°C)
DEPTH (m)
DO (mg/l)

BACK CREEK LAKE



COUNTY:	Randolph	BASIN:	Yadkin
SURFACE AREA:	101 hectares (250 acres)	USGS TOPO:	Farmer, N.C.
CLASS:	WS	LAKE TYPE:	Reservoir

LATEST NCTSI:	2.8	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	July 27, 1989	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	1.1 m	CONDUCTIVITY:	69 - 72 µmhos/cm^2
TOTAL PHOSPHORUS:	0.05 mg/l	DISSOLVED OXYGEN:	7.9 - 8.5 mg/l
TOTAL ORGANIC NITROGEN:	0.47 mg/l	TEMPERATURE:	28.4 - 28.6 °C
CHLOROPHYLL-A:	57 µg/l	pH:	7.0 - 7.2 s.u.

Built in 1946, Back Creek Lake (also called Lake Lucas) is the primary water supply for the City of Asheboro. The reservoir is part of a public park where fishing, boating, and swimming are common. The volume of the lake is 5 x 10^6 m^3, and it has a maximum depth of eight meters. The maximum water extraction rate is 19,000 m^3 per day. Hypolimnetic aerators have been installed near the intake structure to improve the quality of the water before it is withdrawn for treatment.

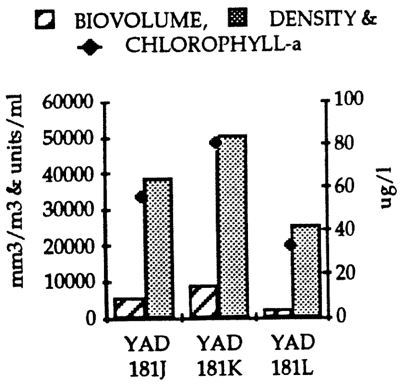
The rolling, 41 km^2- watershed is drained by Back Creek and Greenes Branch. Approximately half of the drainage area is wooded and most of the remainder is cultivated.

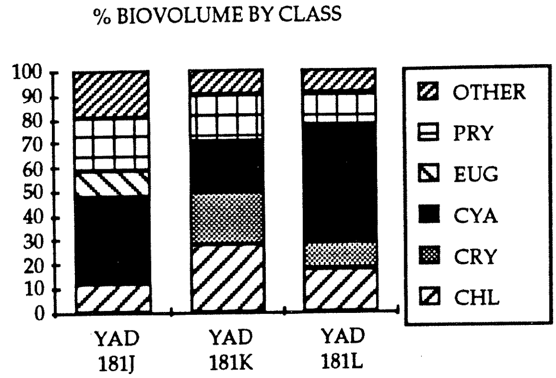
Back Creek Lake was sampled on July 27, 1989. Anoxic conditions were found below three meters at the two downstream stations, but the lake was only weakly stratified in terms of temperature. Nutrients were elevated, and chlorophyll-a values violated water quality standards at the two upstream stations. Aluminum and manganese were found at low levels, while iron was extremely elevated (11,000 µg/l). The source of this high amount of iron is not known.

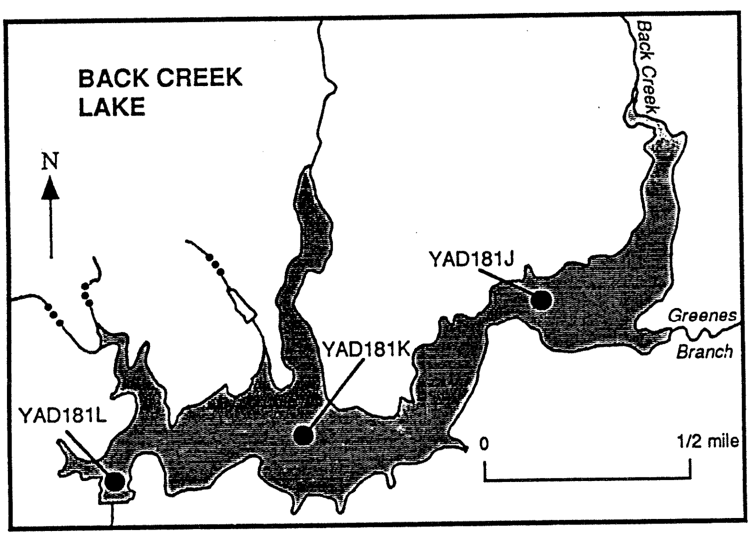
Algal bloom conditions were present at all three stations sampled on Back Creek Lake. At YAD181K (mid-lake), biovolume, density, and chlorophyll-a levels peaked, reaching 9180 mm^3/m^3, 50,399 units/ml, and 81 µg/l respectively. YAD181L, the station closest to the dam, exhibited the lowest amount of phytoplankton, presumably because nutrients were assimilated in the upstream reaches of the lake.

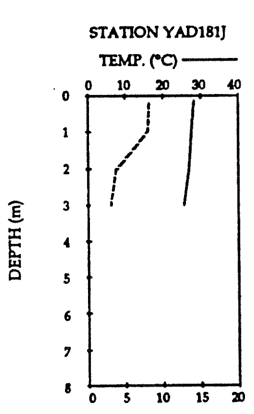
Anabaenopsis raciborskii, a cyanophyte, and Chrysochromulina breviturrita, a prymnesiophyte, codominated the algal biovolume at all three stations. A. raciborskii is a blue-green alga commonly found during the summer in eutrophic waters throughout the state. The prevalence of C. breviturrita helps explain the particularly high chlorophyll-a levels found in Back Creek Lake since this species contains a large amount of chlorophyll-a relative to its size.

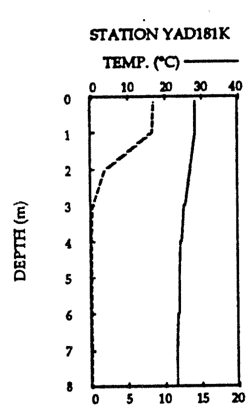
A TSI of 2.8 indicated Back Creek Lake was eutrophic. All uses were supported at the time of the last assessment, but continued nutrient enrichment could degrade water quality in the future. In addition, future assessments should include metals analysis.

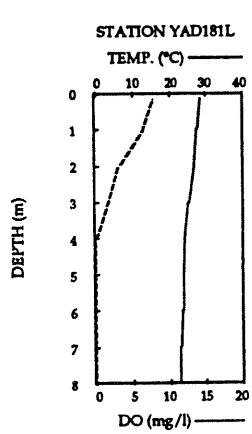




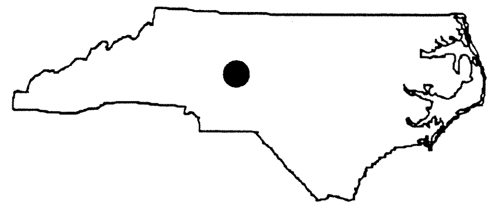








ROSS LAKE



COUNTY:	Randolph	BASIN:	Yadkin
SURFACE AREA:	2 hectares (5 acres)	USGS TOPO:	Asheboro, N.C.
CLASS:	WS	LAKE TYPE:	Reservoir

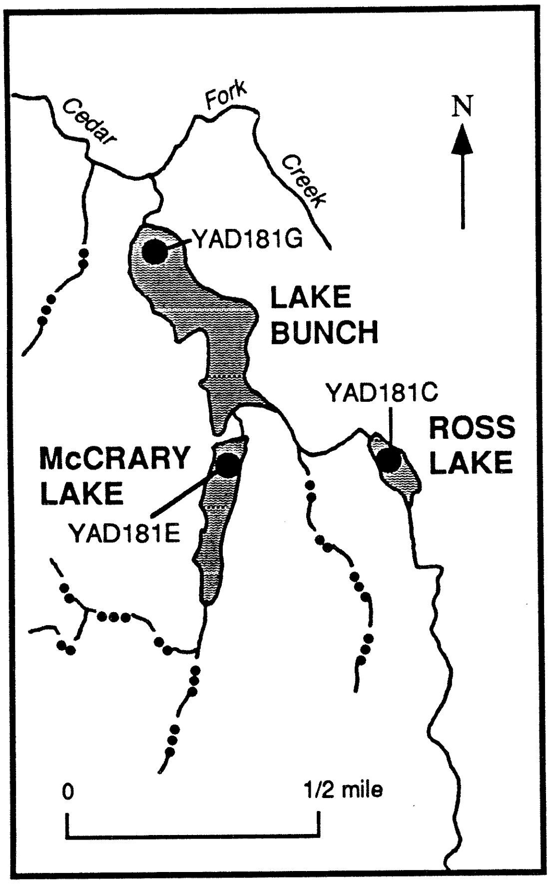
LATEST NCTSI:	3.9	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	July 27, 1989	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	0.3 m	CONDUCTIVITY:	32 μmhos/cm^2
TOTAL PHOSPHORUS:	0.07 mg/l	DISSOLVED OXYGEN:	6.4 mg/l
TOTAL ORGANIC NITROGEN:	0.58 mg/l	TEMPERATURE:	27.8 °C
CHLOROPHYLL-A:	18 μg/l	pH:	6.9 s.u.

Ross Lake was built in 1916 as a back-up water supply for the City of Asheboro. The lake is small, shallow, and does not have much storage capacity; therefore, the city is considering draining the lake.

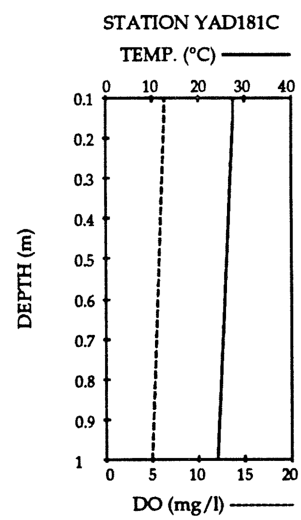
The lake was sampled on July 27, 1989. Physical measurements were not unusual for a lake of this type, but chemical parameters indicated over enrichment. Phosphorus, nitrogen, and chlorophyll-a were elevated. The lake appeared muddy, and turbidity levels exceeded water quality standards. Metals values were also elevated which might be a consequence of the abundant colloidal material in the water column.

Estimates of phytoplanktonic biovolume and density in Ross Lake were low (1,817 mm^3/m^3 and 2,284 units/ml). Approximately 50% of the algal biovolume consisted of cyanophytes including Anabaena sphaerica and Oscillatoria acuminata. Blue-green algae are common constituents of phytoplanktonic populations during warm summer months in more eutrophic waters. Dominant algal classes include cryptophytes and euglenophytes. These two algal classes contain large amounts of chlorophyll-a accounting for the moderately high level of chlorophyll-a (18 μg/l) in this lake.

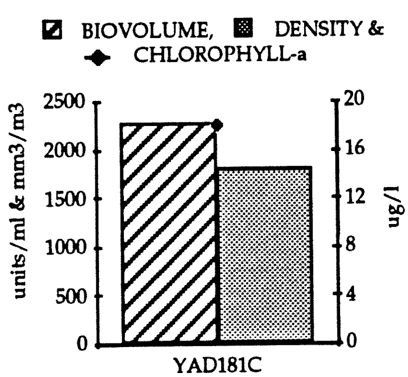
The TSI of 3.9 for Ross Lake indicates eutrophic conditions. Uses are currently supported; however, continued turbidity violations and nutrient enrichment threaten water quality.



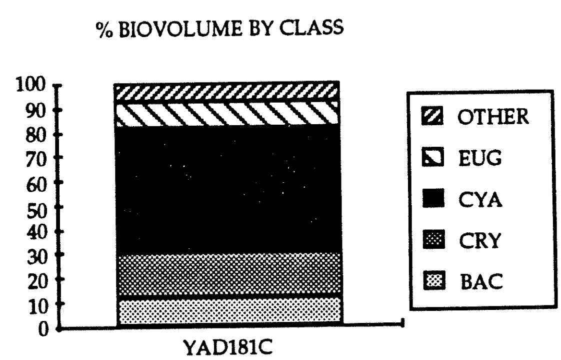
Cedar
Fork
Creek
N
YAD181G
LAKE BUNCH
YAD181C
ROSS LAKE
McCRARY LAKE
YAD181E
0
1/2 mile



STATION YAD181C
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0 5 10 15 20
DO (mg/l)

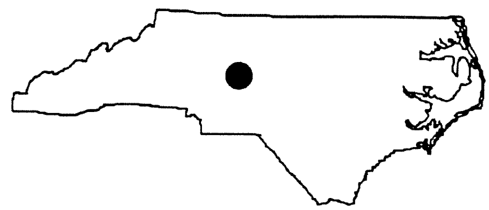


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
units/ml & mm3/m3
2500
2000
1500
1000
500
0
20
16
12
8
4
0
ug/l
YAD181C



% BIOVOLUME BY CLASS
100
90
80
70
60
50
40
30
20
10
0
YAD181C
OTHER
EUG
CYA
CRY
BAC

MCCRARY LAKE



COUNTY:	Randolph	BASIN:	Yadkin
SURFACE AREA:	6 hectares (15 acres)	USGS TOPO:	Asheboro, N.C.
CLASS:	WS	LAKE TYPE:	Reservoir

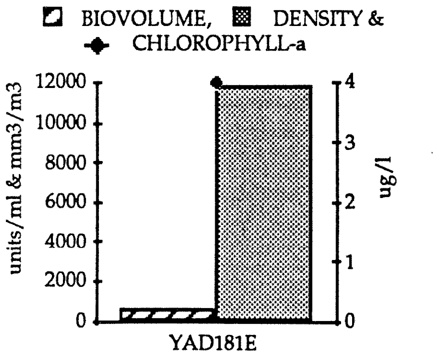
LATEST NCTSI:	- 4.0	TROPHIC STATE:	Oligotrophic
SAMPLING DATE:	July 27, 1989	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	3.2 m	CONDUCTIVITY:	81 µmhos/cm^2
TOTAL PHOSPHORUS:	0.01 mg/l	DISSOLVED OXYGEN:	8.4 mg/l
TOTAL ORGANIC NITROGEN:	0.17 mg/l	TEMPERATURE:	29.3 °C
CHLOROPHYLL-A:	4 µg/l	pH:	8.7 s.u.

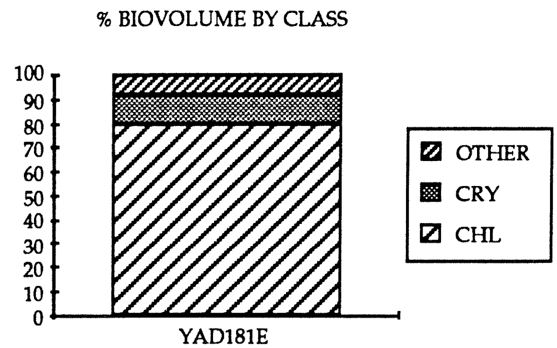
McCrary Lake was built in 1924 by the City of Asheboro for use as a water supply. The dam was rebuilt in 1984 for safety reasons. Volume in the lake is 8.5 x 10^5 m^3, and maximum depth is approximately five meters. An unnamed tributary to Cedar Fork Creek is the major inflow to the creek. The drainage area of 2 km^2 is almost completely wooded. McCrary Lake is primarily used to regulate flow upstream of Lake Bunch.

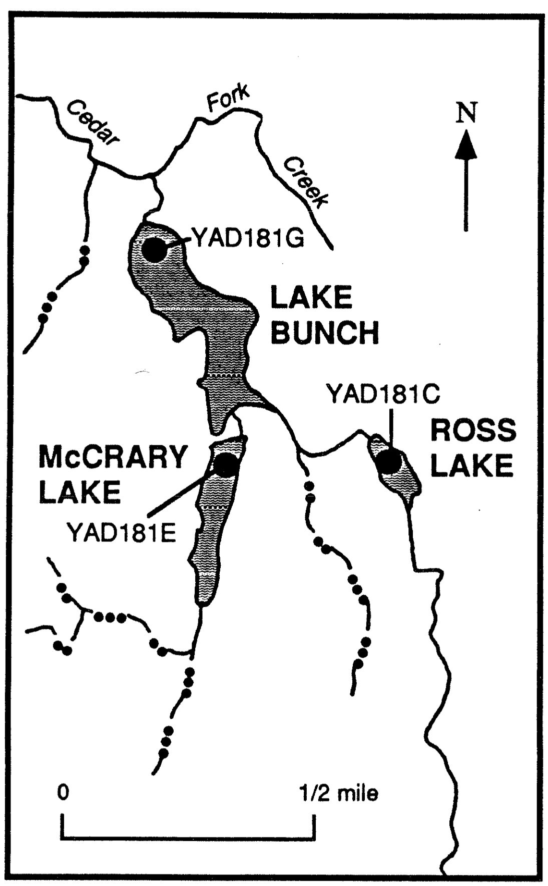
McCrary Lake was sampled on July 27, 1989. The stratified lake had high pH values. Chemical samples were indicative of an oligotrophic lake, including high water clarity, low nutrients, and low chlorophyll-a. Of the metals sampled, only iron was found above laboratory detection limits.

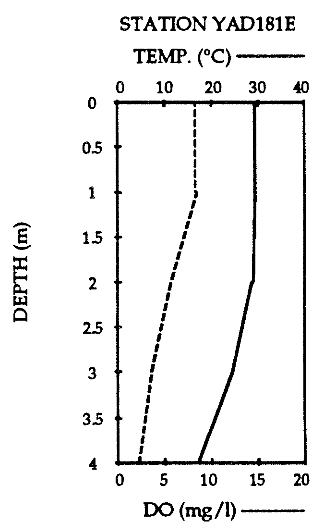
Phytoplanktonic biovolume was low (669 mm^3/m^3) in McCrary Lake with chlorophytes representing over 80% of this estimated level. Algal density, however, reached 11,879 units/ml, a level usually indicating an algal bloom. The predominance of Dictyosphaerium pulchellum, a small colonial, green algae, accounts for this high estimate of phytoplanktonic density.

The TSI of -4.0 indicates that McCrary Lake is oligotrophic. No water quality standards were violated at this sampling, and water quality of the lake fully supported designated uses.

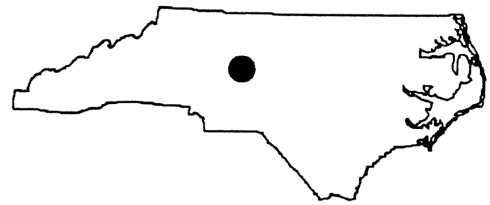

BIOVOLUME, DENSITY & CHLOROPHYLL-a
units/ml & mm3/m3
ug/l
12000
10000
8000
6000
4000
2000
0
4
3
2
1
0
YAD181E


% BIOVOLUME BY CLASS
100
90
80
70
60
50
40
30
20
10
0
YAD181E
OTHER
CRY
CHL


Cedar
Fork
Creek
N
YAD181G
LAKE BUNCH
YAD181C
ROSS LAKE
McCRARY LAKE
YAD181E
0
1/2 mile


STATION YAD181E
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0
0.5
1
1.5
2
2.5
3
3.5
4
0 5 10 15 20
DO (mg/l)

LAKE BUNCH



COUNTY:	Randolph	BASIN:	Yadkin
SURFACE AREA:	12 hectares (30 acres)	USGS TOPO:	Asheboro, N.C.
CLASS:	WS	LAKE TYPE:	Reservoir

LATEST NCTSI:	- 4.0	TROPHIC STATE:	Oligotrophic
SAMPLING DATE:	July 27, 1989	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	3.0 m	CONDUCTIVITY:	68 µmhos/cm^2
TOTAL PHOSPHORUS:	0.01 mg/l	DISSOLVED OXYGEN:	11.1 mg/l
TOTAL ORGANIC NITROGEN:	0.19 mg/l	TEMPERATURE:	30.4 °C
CHLOROPHYLL-A:	3 µg/l	pH:	9.6 s.u.

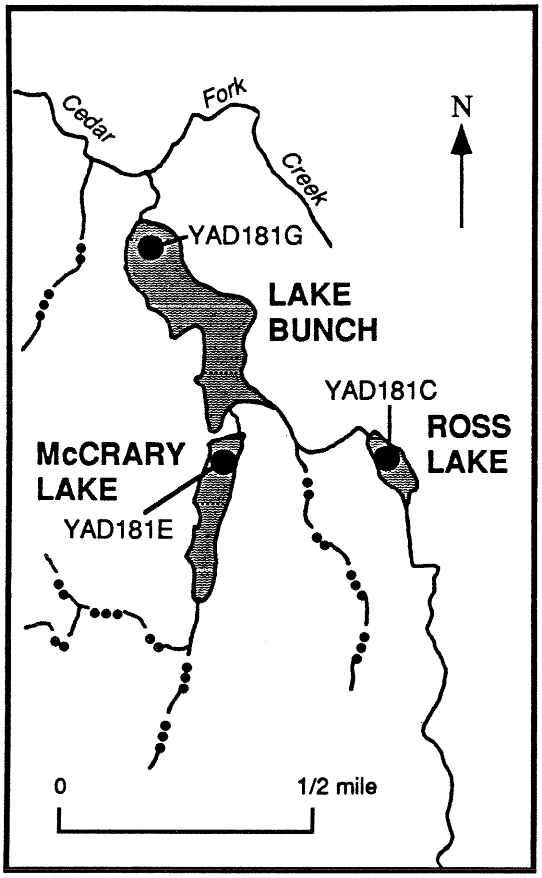
Lake Bunch was built in 1932 on an unnamed tributary to Cedar Fork, which eventually flows into Back Creek Lake. The height of the dam was increased in 1942, but storms washed out the spillway in 1946 so it was rebuilt. The spillway was refurbished again in 1990-1991 for cosmetic and safety reasons.

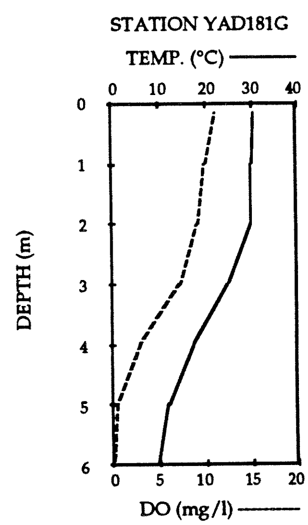
Land in the small drainage area is mostly wooded. Topography in this area of the piedmont is characterized by rolling hills.

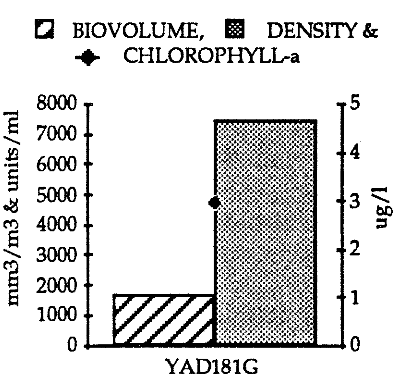
Lake Bunch was sampled on July 27, 1989. The reservoir was stratified, and pH was elevated throughout the top four meters of the water column. Although this usually indicates high algal activity, chlorophyll-a and nutrient concentrations were low. Overall, physical/chemical parameters indicated good water quality. Iron was found in low concentration, but no other metals were detected.

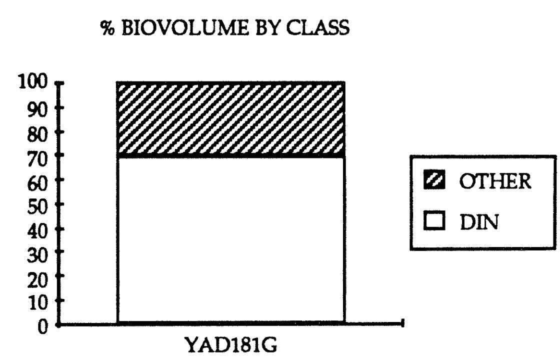
Phytoplanktonic analyses from Lake Bunch support its oligotrophic classification since algal biovolume (1,700 mm^3/m^3) and density (7,512 units/ml) were both relatively low. Peridinium wisconsinense, a large dinoflagellate, made up 70% of the algal biovolume. P. wisconsinense is widespread and sometimes abundant in piedmont and coastal plain streams (Whitford and Shumacher, 1984).

Lake Bunch is oligotrophic with a TSI of -4.0. This TSI was the lowest recorded east of the mountains in 1989. All uses are fully supported.

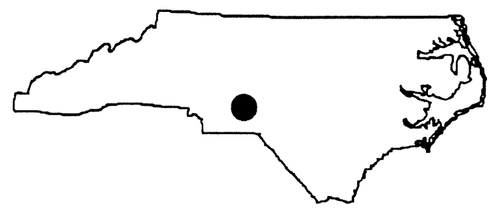

Cedar
Fork
Creek
N
YAD181G
LAKE
BUNCH
YAD181C
ROSS
LAKE
McCRARY
LAKE
YAD181E
0
1/2 mile


STATION YAD181G
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0 1 2 3 4 5 6
0 5 10 15 20
DO (mg/l)


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/m3 & units/ml
8000 7000 6000 5000 4000 3000 2000 1000 0
5 4 3 2 1 0
ug/l
YAD181G


% BIOVOLUME BY CLASS
100 90 80 70 60 50 40 30 20 10 0
OTHER
DIN
YAD181G

LAKE TILLERY



COUNTY:	Stanly/Montgomery	**BASIN:**	Yadkin
SURFACE AREA:	2,130 hectares (5,264 acres)	**USGS TOPO:**	Mount Gilead West, N.C.
CLASS:	WS,B	**LAKE TYPE:**	Reservoir

LATEST NCTSI:	- 0.6	**TROPHIC STATE:**	Mesotrophic
SAMPLING DATE:	August 16, 1989	**ADDITIONAL COVERAGE:**	Fecal, Water Supply Parameters
SECCHI DEPTH:	1.7 m	**CONDUCTIVITY:**	23 - 78 µmhos/cm^2
TOTAL PHOSPHORUS:	0.025 mg/l	**DISSOLVED OXYGEN:**	3.7 - 8.8 mg/l
TOTAL ORGANIC NITROGEN:	0.24 mg/l	**TEMPERATURE:**	26.1 - 29.7 °C
CHLOROPHYLL-A:	17 µg/l	**pH:**	6.4 - 7.9 s.u.

Lake Tillery is in the Yadkin Chain Lake series, located between Falls Lake and Blewett Falls Lake. The dam for Lake Tillery was built in 1928, and the lake is owned by Carolina Power and Light Company. With a maximum depth of 21 meters and a mean depth of 10 meters, Lake Tillery has a volume of 207 x 10^6 m^3 and an average hydraulic retention time of 15 days. The major inflows into the lake are the Yadkin River, Uwharrie River, Mountain Creek, and Little Mountain Creek. Lake Tillery has a drainage basin of 12,520 km^2 characterized by rolling hills. Most of the watershed is forested, though agriculture is another major land use. The waters of the lake are classified WS-III and B.

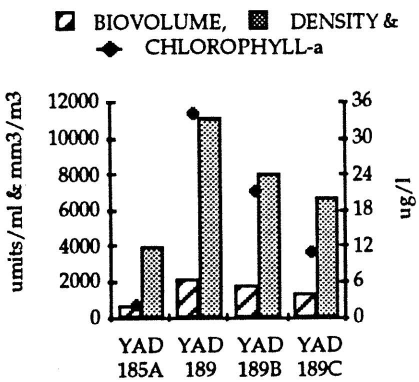
In 1989, Lake Tillery exhibited water quality characteristics representative of a moderately productive lake. Nutrient concentrations were consistent throughout the lake, typical of a run-of-the-river reservoir. Dissolved oxygen levels decreased slightly with increasing depth. :ale Tillery was thermally mixed as a result of the relatively small size of the impoundment and the high rate of flow discharged through the dam. Heavy metal concentrations were low, except for one lead value at YAD189B which was near the state standard of 25 µg/l. Sources of the lead are not known. Fecal coliform bacteria were not detected.

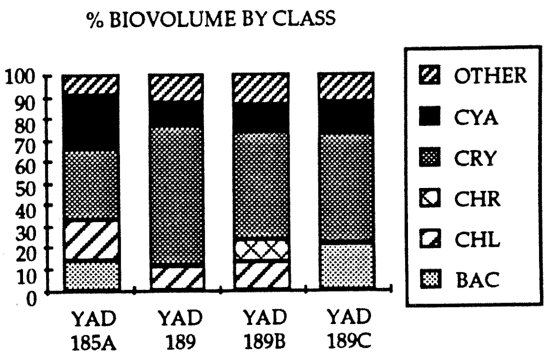
Similar to results from 1986, estimates of phytoplanktonic biovolume and density in 1989 remained moderate. The short residence time of this lake prevents excessive algal growth even when sufficient nutrients are present.

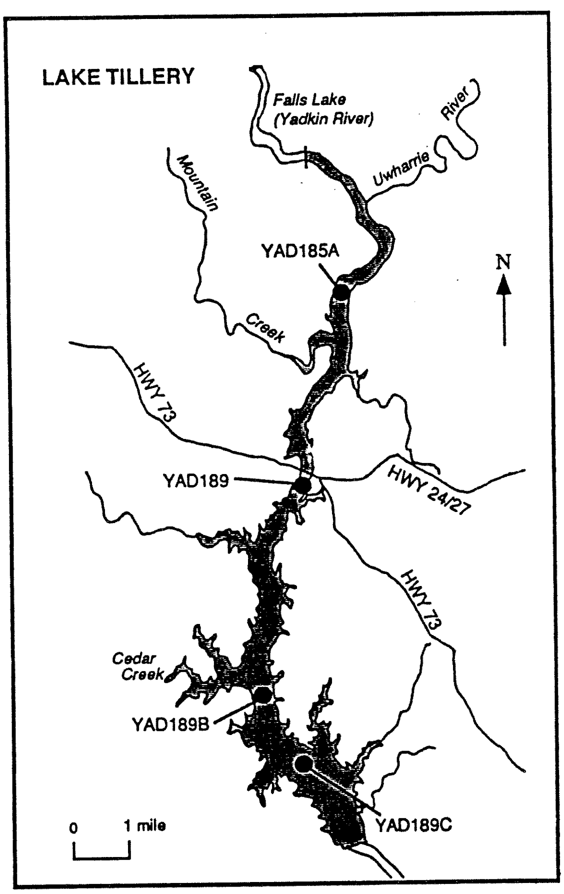
In contrast to 1986 when cyanophytes were the dominant algal class, cryptophytes dominated biovolume in 1989. Chroomonas minuta, C. caudata, and Cryptomonas erosa, among the most ubiquitous phytoplanktonic species in North Carolina, were present at all four stations. The peak in chlorophyll-a of 34 ug/l at YAD189 corresponded to the predominance of cryptophytes at this station. These species contain relatively large amounts of chlorophyll-a.

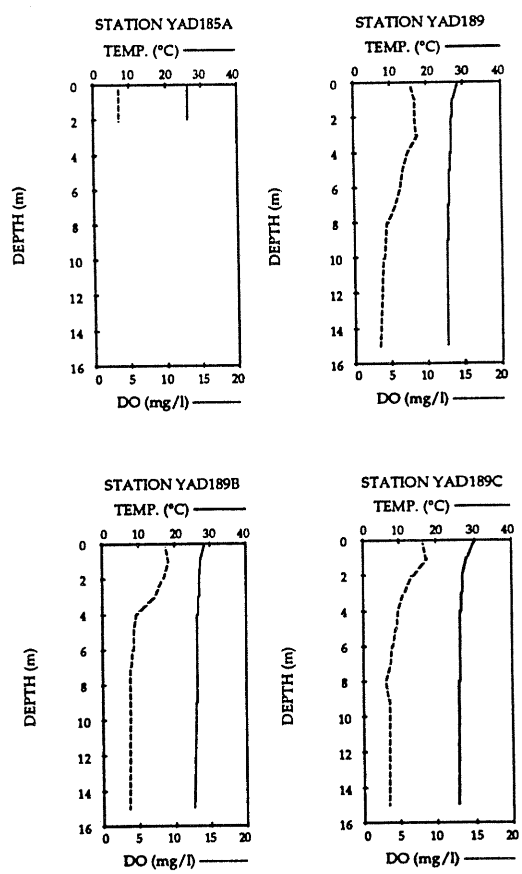
Cyanophytes codominated phytoplanktonic biovolume at each station. Oscillatoria geminata, Anabaenopsis raciborskii, and Lyngbya species, common filamentous, blue-green algae, were represented at each station.

The TSI was -0.6 which is higher than the 1983 value (-1.3) and the 1981 value (-2.2). At the time of assessment, no violations of state water quality standards were observed at Lake Tillery, and the reservoir fully supported designated uses.

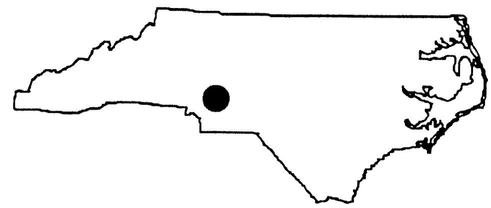








LAKE FISHER



COUNTY:	Cabarrus	BASIN:	Yadkin
SURFACE AREA:	112 hectares (277 acres)	USGS TOPO:	Concord, N.C.
CLASS:	WS	LAKE TYPE:	Reservoir

LATEST NCTSI:	4.7	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	August 8, 1989	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	0.6 m	CONDUCTIVITY:	92 - 102 µmhos/cm^2
TOTAL PHOSPHORUS:	0.04 mg/l	DISSOLVED OXYGEN:	6.7 - 13.0 mg/l
TOTAL ORGANIC NITROGEN:	1.37 mg/l	TEMPERATURE:	26.5 - 27.3 °C
CHLOROPHYLL-A:	43 µg/l	pH:	7.5 - 10.0 s.u.

Cold Water Creek was impounded in 1948 to form Lake Fisher, a water supply for the City of Concord. The reservoir has a volume of 4,180 m^3 with a maximum depth of 11 meters. Access to the lake is strictly controlled.

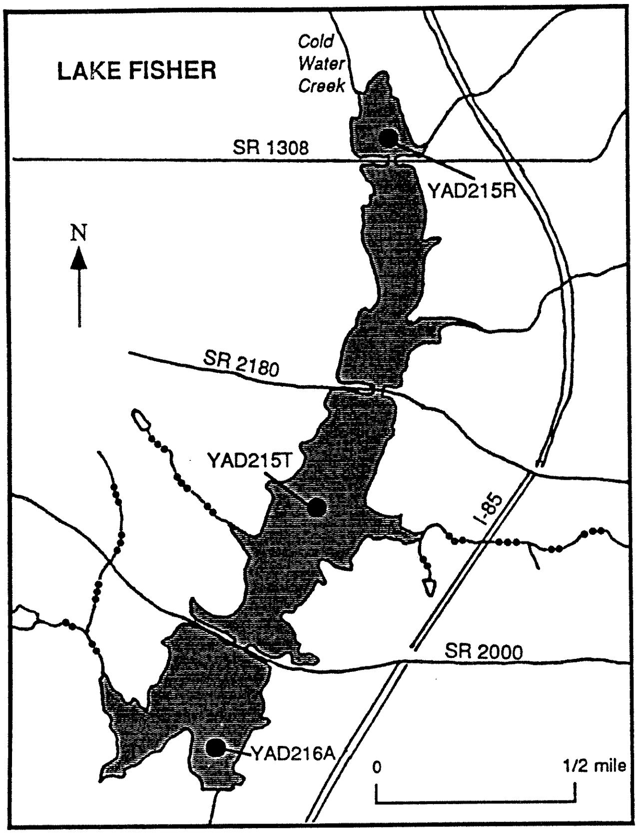
Lake Fisher drains 203 km^2 of rolling hills in the western piedmont. Although the majority of this watershed is forested, some residential land use also exists.

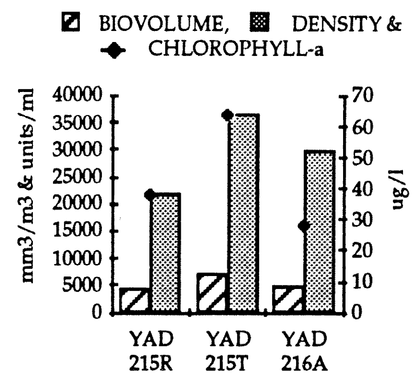
Lake Fisher was sampled on August 8, 1989. Physical measurements indicated high algal activity near the dam. Dissolved oxygen and pH were elevated on the surface. The lake was stratified with anoxic conditions below four meters. Nitrogen and phosphorus were elevated at the uppermost station. Concentrations were more moderate at the two downstream stations. Chlorophyll-a was also elevated throughout the lake, reaching a maximum of 64 µg/l at YAD215T. This represents a violation of the state standard for chlorophyll-a of 40 µg/l.

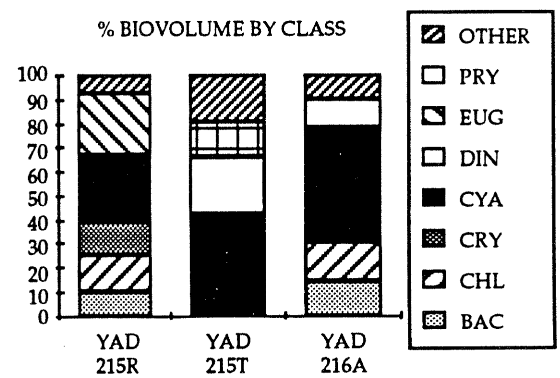
Levels of phytoplankton reached bloom proportions at all three sampling stations on Lake Fisher. Algal densities were particularly high because small, filamentous blue-green algae (Anabaenopsis raciborskii and Anabaenopsis phillipinensis) were predominant. These species are commonly found in eutrophic waters throughout the state.

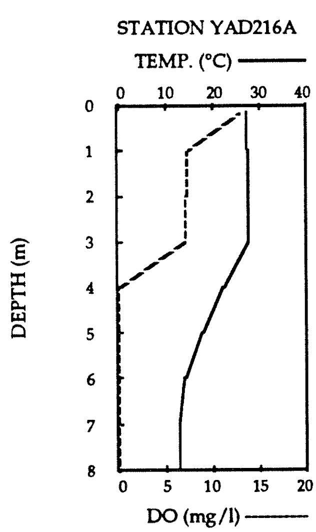
Along with declining biovolume and density values, the chlorophyll-a level dropped considerably from 64 µg/l at YAD215T (mid-lake) to 28 µg/l at YAD216A, the station closest to the outlet of the lake. The lower standing crop of phytoplankton near the dam probably resulted from upstream settling and assimilation of nutrients.

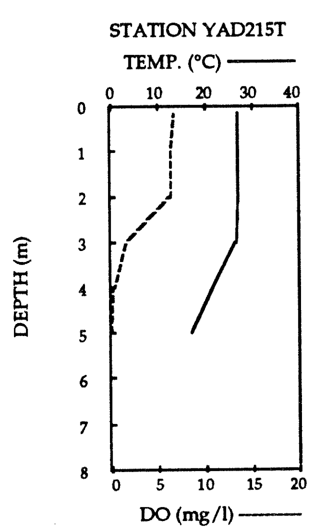
The overall TSI of 4.7 is skewed by the hypereutrophic conditions found at station YAD215R. Results from the other two stations show that downstream portions of the lake are also eutrophic, but not atypical of small impoundments in the piedmont. Sources of elevated nutrients and suspended solids to the headwaters are not known but warrant study. Designated uses of Lake Fisher are fully supported, but could be threatened if enrichment continues.

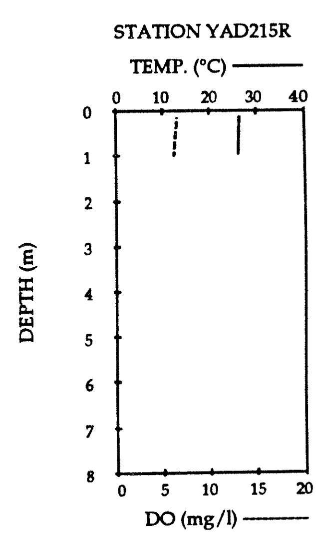




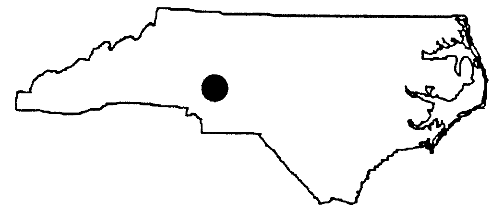








LAKE CONCORD



COUNTY:	Cabarrus	BASIN:	Yadkin
SURFACE AREA:	40 hectares (100 acres)	USGS TOPO:	Concord, N.C.
CLASS:	WS	LAKE TYPE:	Reservoir

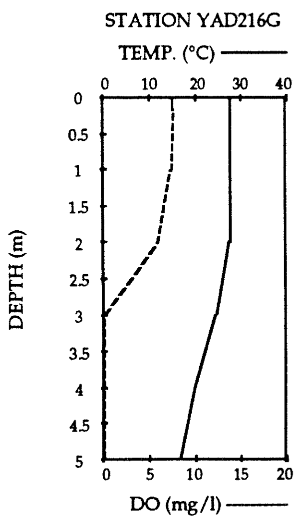
LATEST NCTSI:	3.6	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	August 8, 1989	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	0.6 m	CONDUCTIVITY:	83 - 84 µmhos/cm^2
TOTAL PHOSPHORUS:	0.05 mg/l	DISSOLVED OXYGEN:	7.6 - 8.3 mg/l
TOTAL ORGANIC NITROGEN:	0.57 mg/l	TEMPERATURE:	27.7 - 28.0 °C
CHLOROPHYLL-A:	49 µg/l	pH:	7.6 - 8.1 s.u.

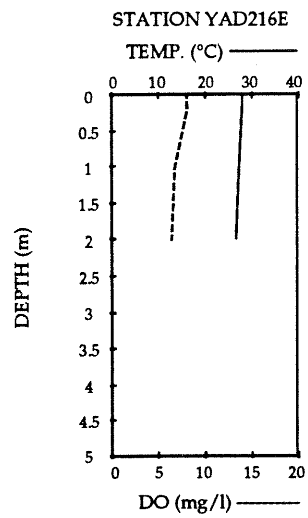
In the 1930's, Chambers Branch was impounded to form Lake Concord. The lake is used as a back-up water supply for the City of Concord. Maximum depth of the lake is six meters. The watershed is primarily urban although there is a forested buffer around the shore of the lake.

Lake Concord was sampled on August 8, 1989. The lake was stratified near the dam and well mixed at the other two stations. Nutrients were elevated throughout the lake, and chlorophyll-a violations were observed at all three stations. Four metals were above laboratory detection levels (copper, aluminum, iron and manganese), but none violated water quality standards.

The algal bloom threshold was exceeded at all stations. Algal biovolumes were large (5,095-6,710 mm^3/m^3), and density levels were particularly high, ranging from 38,782 to 47,788 units/ml. The predominance of Anabaenopsis phillipinensis, Anabaenopsis raciborskii, and Lyngbya species A, all small, filamentous blue-green algae, accounts for high densities. These species are indicators of over-enrichment in bodies of water throughout the state.

A TSI of 3.6 indicates Lake Concord is eutrophic. Because nuisance levels of chlorophyll-a and phytoplankton were documented, Lake Concord should continue to be monitored in the future to assure that uses remain supported.


STATION YAD216G
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5
0 5 10 15 20
DO (mg/l)


STATION YAD216E
TEMP. (°C)
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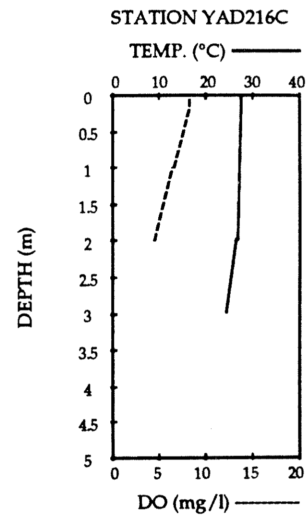
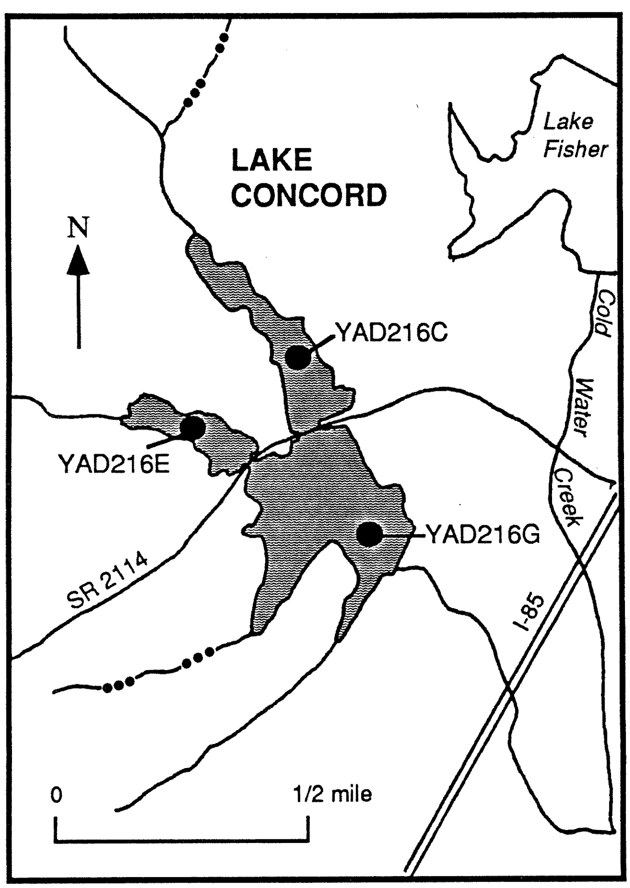
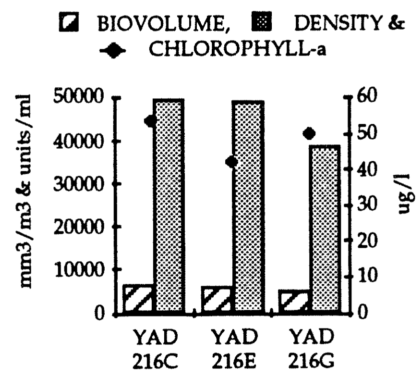
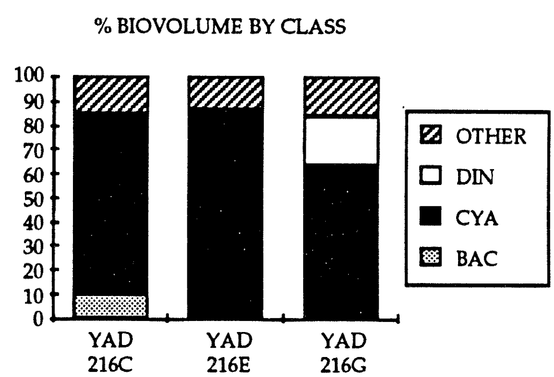
DEPTH (m)
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5
0 5 10 15 20
DO (mg/l)

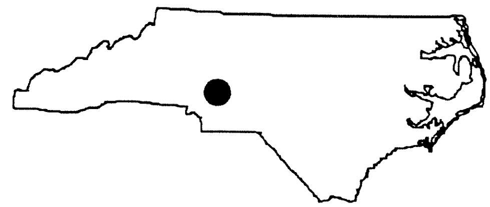

STATION YAD216C
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5
0 5 10 15 20
DO (mg/l)


LAKE CONCORD
Lake Fisher
N
YAD216C
YAD216E
YAD216G
Cold Water Creek
SR 2114
I-85
0
1/2 mile


BIOVOLUME, DENSITY & CHLOROPHYLL-a
mm3/m3 & units/ml
50000 40000 30000 20000 10000 0
60 50 40 30 20 10 0
ug/l
YAD 216C
YAD 216E
YAD 216G


% BIOVOLUME BY CLASS
100 90 80 70 60 50 40 30 20 10 0
YAD 216C
YAD 216E
YAD 216G
OTHER
DIN
CYA
BAC

KANNAPOLIS LAKE



COUNTY:	Rowan	BASIN:	Yadkin
SURFACE AREA:	117 hectares (289 acres)	USGS TOPO:	Enochville, N.C.
CLASS:	WS	LAKE TYPE:	Reservoir

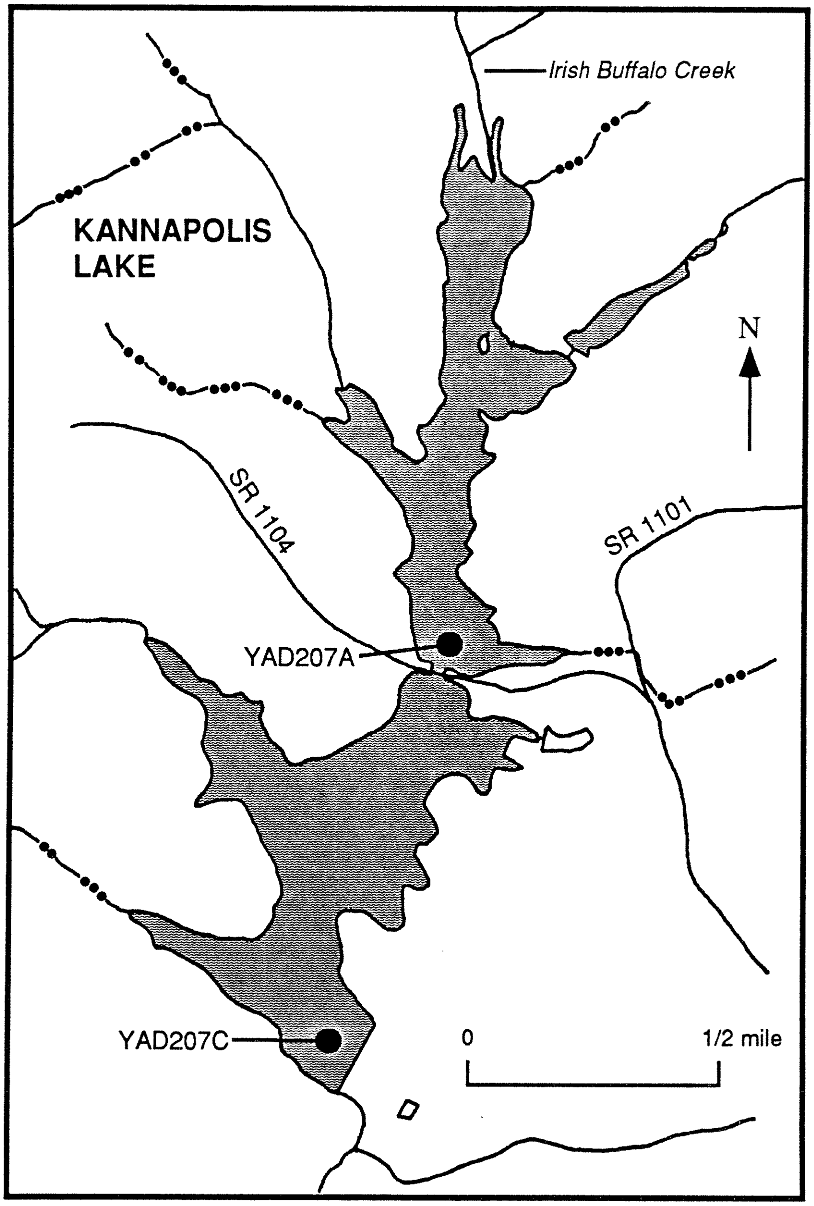
LATEST NCTSI:	1.2	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	August 8, 1989	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	1.05 m	CONDUCTIVITY:	78 - 79 µmhos/cm^2
TOTAL PHOSPHORUS:	0.02 mg/l	DISSOLVED OXYGEN:	7.5 - 7.8 mg/l
TOTAL ORGANIC NITROGEN:	0.52 mg/l	TEMPERATURE:	28.2 °C
CHLOROPHYLL-A:	22.5 µg/l	pH:	7.8 - 8.2 s.u.

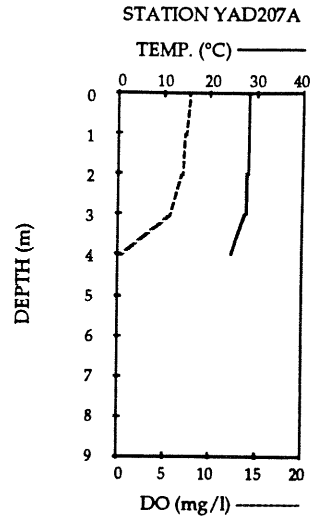
Kannapolis Lake was built in 1938. The City of Kannapolis uses the lake as a water supply, although it is owned by Atlantic American Properties. Access to the lake is strictly controlled. Maximum depth is ten meters with a volume of 5.2 x 10^6 m^3. Buffalo Creek drains the 28 km^2 watershed. The drainage area includes residential, agricultural, and forested land uses.

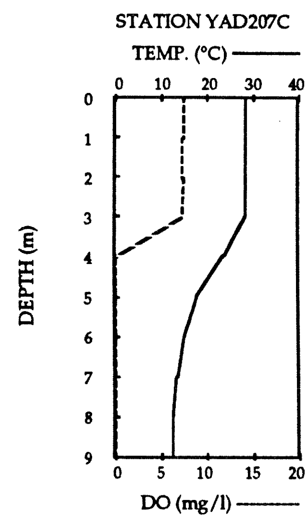
Kannapolis Lake was sampled on August 8, 1989. The reservoir was thermally stratified with anoxic conditions below four meters. Chlorophyll-a and pH were high at both stations, indicating algal activity. Nitrogen concentrations were also elevated.

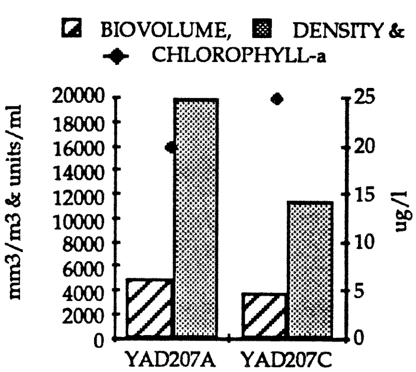
Phytoplanktonic density was relatively high in Kannapolis Lake exceeding the bloom threshold at each station. Algal biovolume was dominated by Chrysochromulina breviturrita, a prymnesiophyte, and a diverse assemblage of chlorophytes. The predominance of C. breviturrita accounts for the relatively high chlorophyll-a levels observed (20 and 25 µg/l) since this species contains a large amount of chlorophyll-a in comparison to its size.

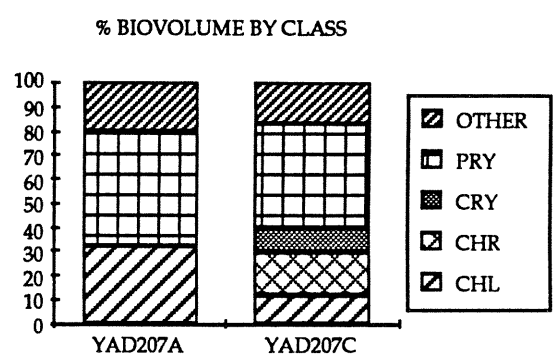
A TSI of 1.2 indicates that Kannapolis Lake is eutrophic. Although there were elevated levels of phytoplankton and nutrients, no water quality standards were violated. All uses were supported at the time of this assessment.


Irish Buffalo Creek
KANNAPOLIS LAKE
N
SR 1104
SR 1101
YAD207A
YAD207C
0
1/2 mile

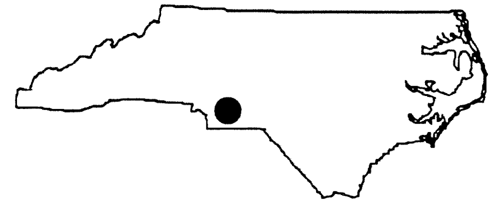

STATION YAD207A
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0 1 2 3 4 5 6 7 8 9
0 5 10 15 20
DO (mg/l)


STATION YAD207C
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0 1 2 3 4 5 6 7 8 9
0 5 10 15 20
DO (mg/l)


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/m3 & units/ml
20000 18000 16000 14000 12000 10000 8000 6000 4000 2000 0
ug/l
25 20 15 10 5 0
YAD207A YAD207C


% BIOVOLUME BY CLASS
100 90 80 70 60 50 40 30 20 10 0
YAD207A YAD207C
OTHER
PRY
CRY
CHR
CHL

LAKE MONROE



COUNTY:	Union	BASIN:	Yadkin
SURFACE AREA:	57 hectares (140 acres)	USGS TOPO:	Monroe, N.C.
CLASS:	WS	LAKE TYPE:	Reservoir

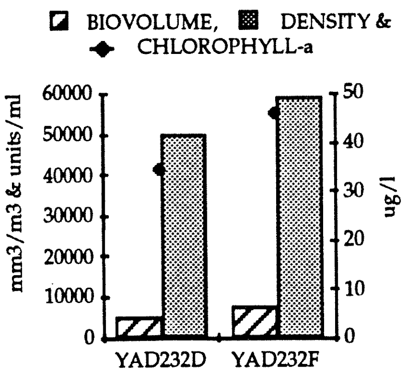
LATEST NCTSI:	3.3	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	August 9, 1989	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	1.0 m	CONDUCTIVITY:	103 - 109 µmhos/cm^2
TOTAL PHOSPHORUS:	0.04 mg/l	DISSOLVED OXYGEN:	5.2 - 6.0 mg/l
TOTAL ORGANIC NITROGEN:	0.835 mg/l	TEMPERATURE:	25.2 - 26.2 °C
CHLOROPHYLL-A:	40.5 µg/l	pH:	6.8 - 6.9 s.u.

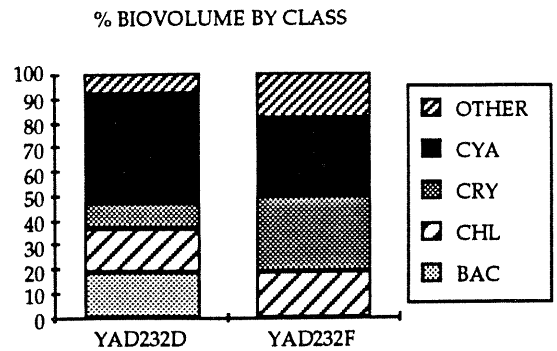
Lake Monroe is a secondary water supply for the City of Monroe in Union County and is also used for recreation. This reservoir was built in 1955. It has a volume of 1.8×10^6 m^3 and a maximum depth of eleven meters. Richardson Creek is the main tributary to the lake. The drainage area has rolling hills with forested and cultivated land uses.

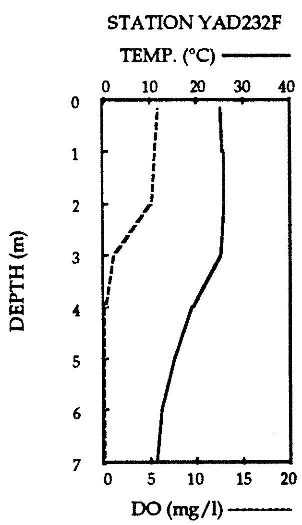
Lake Monroe was sampled on August 9, 1989. Thermal stratification was especially evident at the dam, where hypolimnetic oxygen levels approached zero. Chlorophyll-a violated the state standard of 40 µg/l at YAD232F. Total phosphorus and nitrogen were elevated throughout the lake which may be indicative of significant nonpoint sources upstream. Heavy metals, chloride, and hardness were within state standards.

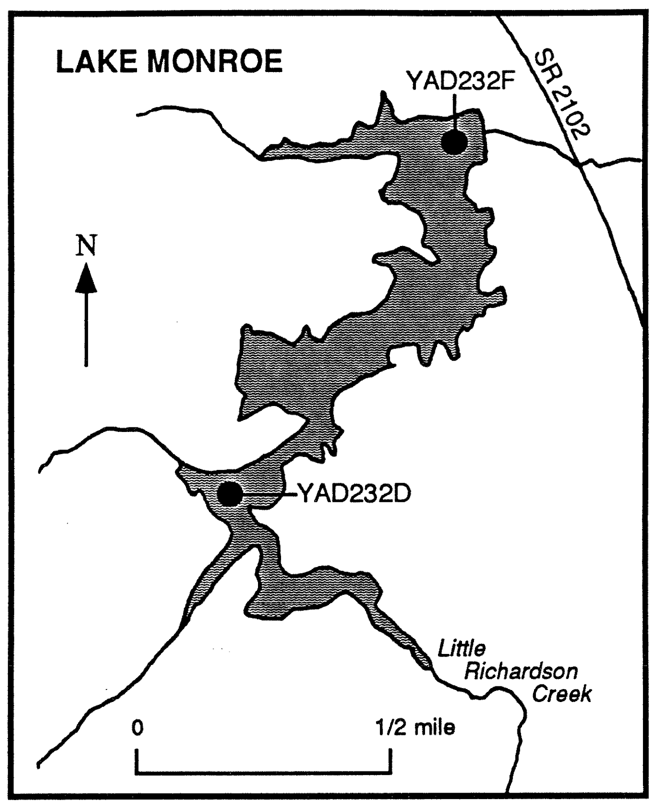
Anabaenopsis raciborskii, a small, filamentous blue-green alga, dominated the phytoplanktonic biovolume and accounted for the particularly high densities (50,137 and 59,396 units/ml) measured in this lake. The predominance and abundance of this species, a common component of summertime blooms, coupled with relatively high chlorophyll-a levels (35 and 46 µg/l) support a eutrophic classification for Lake Monroe.

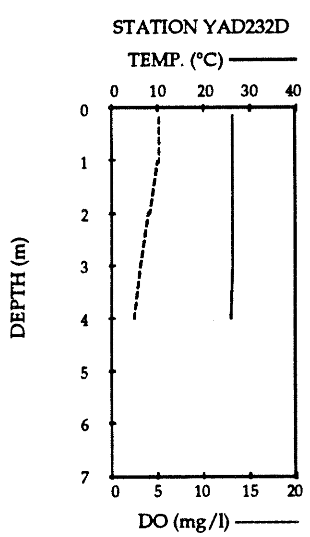
A TSI of 3.3 also indicates that Lake Monroe is eutrophic. Designated uses were supported at the time of this assessment, but continued enrichment of the lake could threaten uses in the future.


BIOVOLUME, DENSITY & CHLOROPHYLL-a
mm3/m3 & units/ml
ug/l
YAD232D
YAD232F

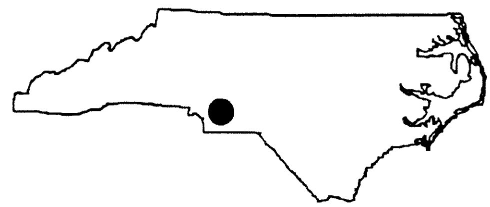

% BIOVOLUME BY CLASS
OTHER
CYA
CRY
CHL
BAC
YAD232D
YAD232F


STATION YAD232F
TEMP. (°C)
DEPTH (m)
DO (mg/l)


LAKE MONROE
YAD232F
SR 2102
N
YAD232D
Little Richardson Creek
0
1/2 mile


STATION YAD232D
TEMP. (°C)
DEPTH (m)
DO (mg/l)

LAKE LEE



COUNTY:	Union	**BASIN:**	Yadkin
SURFACE AREA:	51 hectares (125 acres)	**USGS TOPO:**	Monroe, N.C.
CLASS:	WS	**LAKE TYPE:**	Reservoir

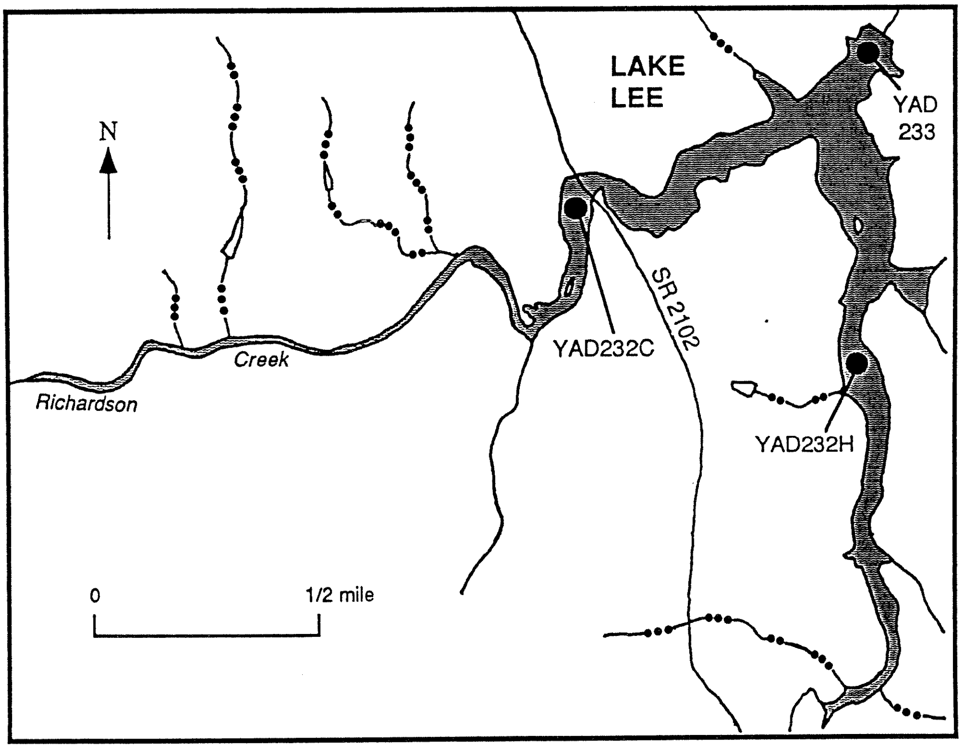
LATEST NCTSI:	6.1	**TROPHIC STATE:**	Hypereutrophic
SAMPLING DATE:	August 9, 1989	**ADDITIONAL COVERAGE:**	Water Supply Parameters
SECCHI DEPTH:	0.4 m	**CONDUCTIVITY:**	114 -121 µmhos/cm^2
TOTAL PHOSPHORUS:	0.15 mg/l	**DISSOLVED OXYGEN:**	5.8 -5.9 mg/l
TOTAL ORGANIC NITROGEN:	0.93 mg/l	**TEMPERATURE:**	24.7 - 25.6 °C
CHLOROPHYLL-A:	51 µg/l	**pH:**	6.7 - 7.8 s.u.

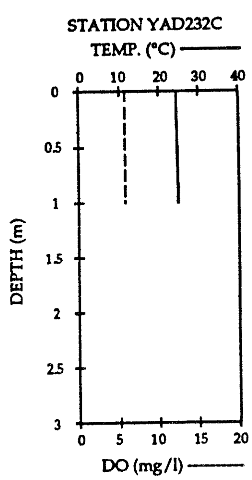
Built in 1927, Lake Lee is a secondary water supply for the City of Monroe. Maximum depth in the lake is approximately three meters and volume is 9.5×10^5 m^3. Land use in the flat drainage area is approximately half forested. The remainder is mostly agricultural with some urban/residential areas. Richardson Creek is the major inflow to Lake Lee.

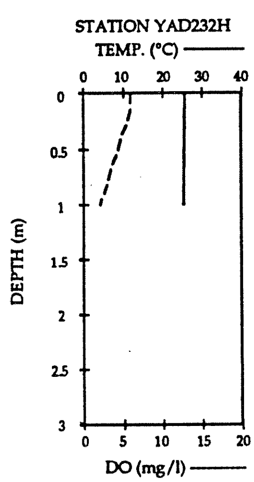
Lake Lee was sampled on August 9, 1989. Surface scum, high suspended solids, low secchi values and a greenish water color indicated that water quality was poor. Nutrient concentrations were high, and chlorophyll-a exceeded the state standard of 40 µg/l at two of the three stations. Lake Lee is an extremely enriched lake with documented water quality problems.

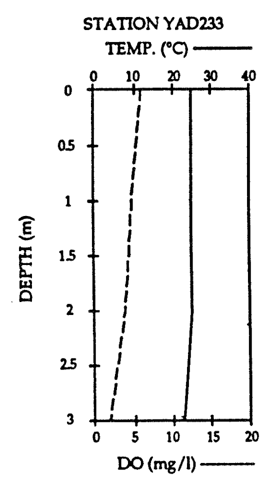
The high levels of algal biovolume (9,883-13,695 mm^3/m^3) and density (59,571-96,780 units/ml) at Lake Lee support a hypereutrophic classification. At each station, cyanophytes were the dominant algal class, composed primarily of Oscillatoria geminata and Anabaenopsis raciborskii. These two species of blue-green algae commonly form blooms during the summer in nutrient-enriched bodies of water.

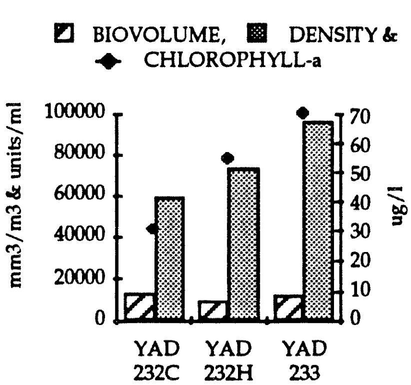
A TSI of 6.1 was among the highest ever recorded in North Carolina, indicating Lake Lee is hypereutrophic. Future monitoring is needed to better assess sources of enrichment.

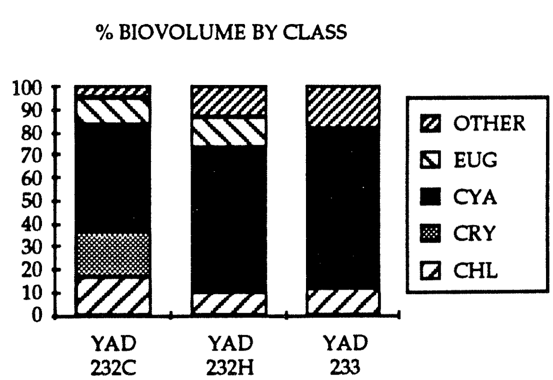

LAKE
LEE
N
YAD
233
YAD232C
SR 2102
YAD232H
Creek
Richardson
0
1/2 mile


STATION YAD232C
TEMP. (°C)
DEPTH (m)
DO (mg/l)

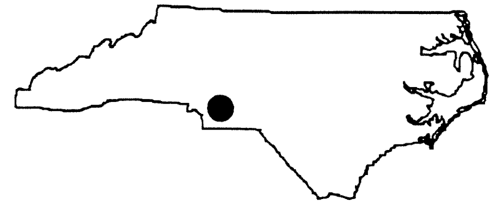

STATION YAD232H
TEMP. (°C)
DEPTH (m)
DO (mg/l)


STATION YAD233
TEMP. (°C)
DEPTH (m)
DO (mg/l)


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
mm3/m3 & units/ml
ug/l
YAD 232C
YAD 232H
YAD 233


% BIOVOLUME BY CLASS
OTHER
EUG
CYA
CRY
CHL
YAD 232C
YAD 232H
YAD 233

LAKE TWITTY



COUNTY:	Union	BASIN:	Yadkin
SURFACE AREA:	33 hectares (82 acres)	USGS TOPO:	Watson, N.C.
CLASS:	WS	LAKE TYPE:	Reservoir

LATEST NCTSI:	3.2	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	August 9, 1989	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	0.85 m	CONDUCTIVITY:	105 - 118 µmhos/cm^2
TOTAL PHOSPHORUS:	0.06 mg/l	DISSOLVED OXYGEN:	5.2 - 5.9 mg/l
TOTAL ORGANIC NITROGEN:	0.61 mg/l	TEMPERATURE:	24.9 - 26.1 °C
CHLOROPHYLL-A:	30 µg/l	pH:	6.8 - 8.0 s.u.

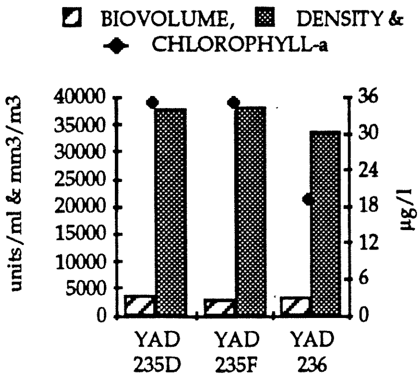
Lake Twitty (also called Lake Stewart) was impounded in 1972. It is owned and operated by the City of Monroe where it is used as the primary water supply. The reservoir is also used for recreational purposes.

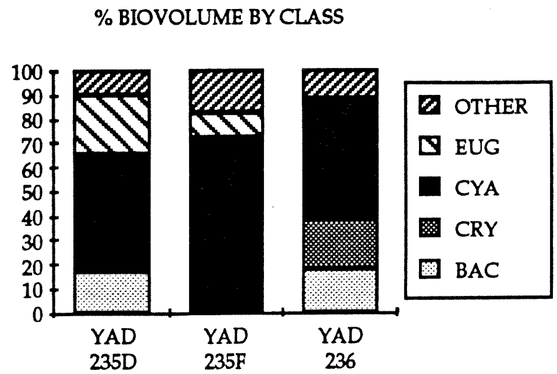
Maximum volume of the lake is 7.6×10^6 m^3, and maximum depth at full pool is 20 meters. Stewart Creek and Chinkapin Creek are the main tributaries to Lake Twitty. Land in the mainly flat drainage area is forested and agricultural.

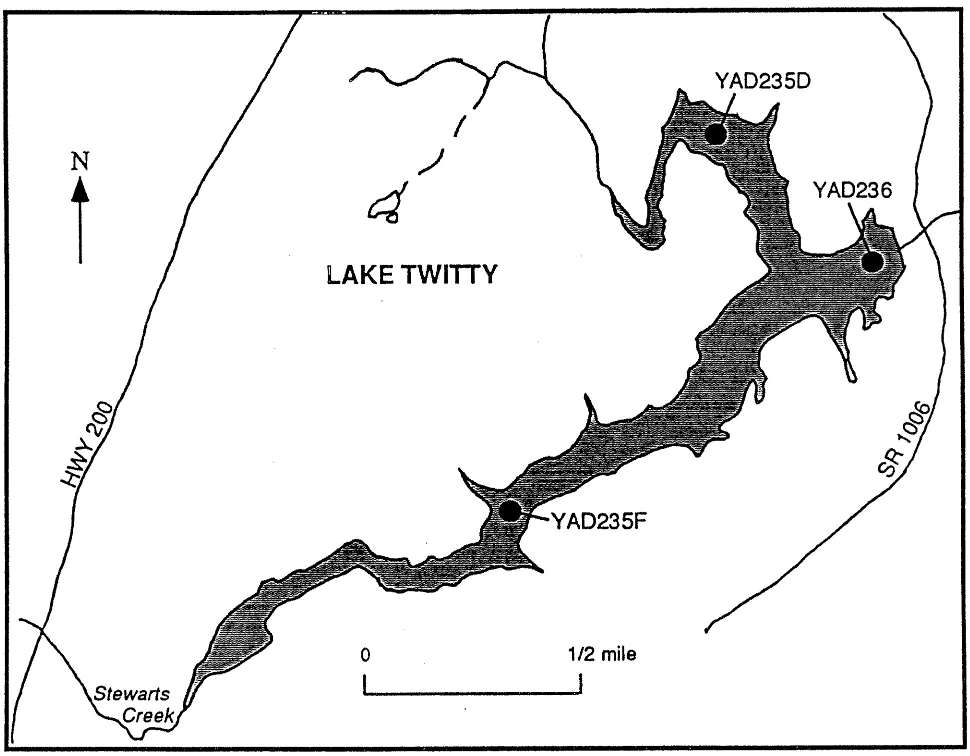
Lake Twitty exhibited pronounced stratification at all three sampling stations with an average difference of 13.4 °C between surface and bottom temperatures. Anoxic conditions were found at each station with dissolved oxygen levels less than one mg/l at depths below three meters. Nutrient and chlorophyll-a concentrations were elevated, indicating high productivity in the reservoir. Metals were below laboratory detection levels with the exception of aluminum, iron, and manganese. None of these results violated state water quality standards.

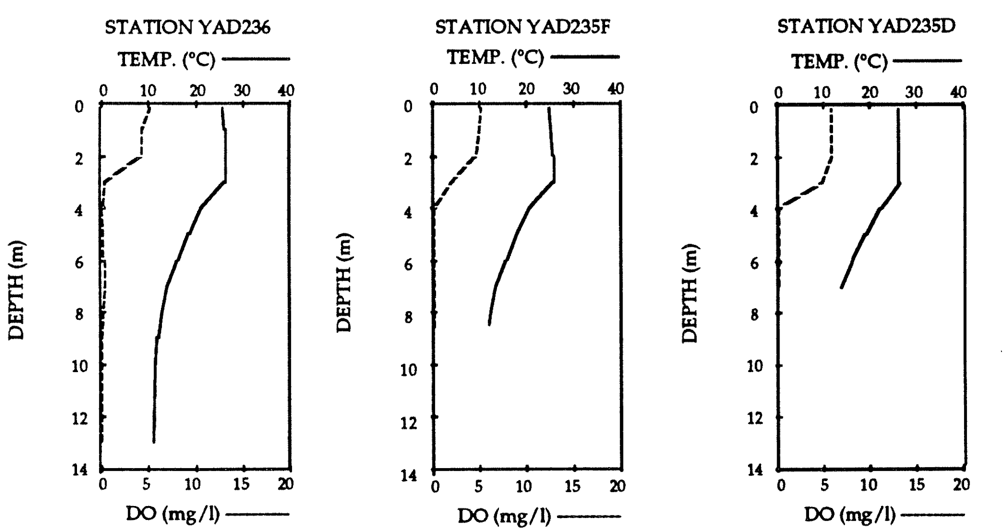
Estimates of phytoplanktonic density indicated blooms at all three stations and ranged from 33,803 to 38,258 units/ml. Anabaenopsis raciborskii and Oscillatoria geminata, small, blue-green algae, dominated the algal biovolume and contributed to the particularly high densities of phytoplankton. These two species of algae are commonly found during the summertime in eutrophic waters throughout North Carolina.

A TSI of 3.2 indicates that Lake Twitty is eutrophic. No violations of water quality standards were documented and uses were fully supported.

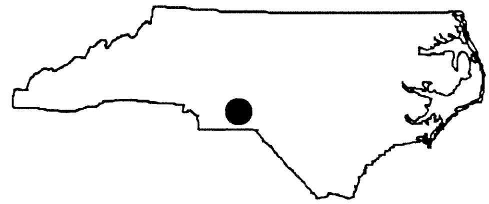

BIOVOLUME, DENSITY &
CHLOROPHYLL-a
units/ml & mm3/m3
µg/l
YAD 235D
YAD 235F
YAD 236


% BIOVOLUME BY CLASS
OTHER
EUG
CYA
CRY
BAC
YAD 235D
YAD 235F
YAD 236


YAD235D
YAD236
N
LAKE TWITTY
HWY 200
SR 1006
YAD235F
0
1/2 mile
Stewarts Creek


STATION YAD236
TEMP. (°C)
DEPTH (m)
DO (mg/l)
STATION YAD235F
TEMP. (°C)
DEPTH (m)
DO (mg/l)
STATION YAD235D
TEMP. (°C)
DEPTH (m)
DO (mg/l)

BLEWETT FALLS LAKE



COUNTY:	Richmond/Anson	BASIN:	Yadkin
SURFACE AREA:	1,040 hectares (2,570 acres)	USGS TOPO:	Lilesville, N.C.
CLASS:	WS, B	LAKE TYPE:	Reservoir

LATEST NCTSI:	2.8	TROPHIC STATE:	Eutrophic
SAMPLING DATE:	August 13, 1986	ADDITIONAL COVERAGE:	Fecal, Metals
SECCHI DEPTH:	0.9 m	CONDUCTIVITY:	110 µmhos/cm^2
TOTAL PHOSPHORUS:	0.07 mg/l	DISSOLVED OXYGEN:	8.2 mg/l
TOTAL ORGANIC NITROGEN:	0.36 mg/l	TEMPERATURE:	28 °C
CHLOROPHYLL-A:	46 µg/l	pH:	7.2 s.u.

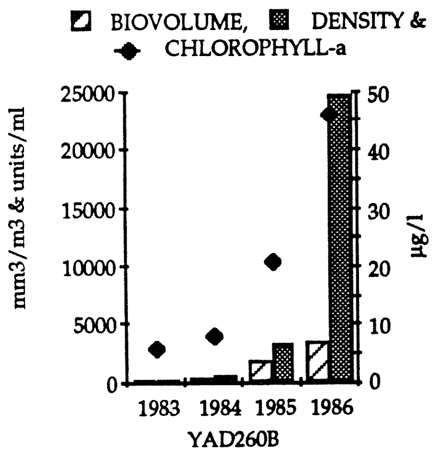
Blewett Falls Lake is the most downstream Yadkin Chain Lake in North Carolina. This narrow, run-of-the-river reservoir was filled in 1912 and is owned by Carolina Power and Light. It has a surface area of 1,040 hectares, a maximum depth of 12 meters, a mean depth of 11 meters, a volume of 8.3 x 10^6 m^3, and a mean hydraulic retention time of seven days. The lake is classified WS-III and B. The 17,570 km^2 watershed is characterized by rolling hills. Land use is mostly forested, with some agriculture and a small amount of urban development. As is true of the other Yadkin Chain Lakes, Blewett Falls receives inflow mostly from the discharge of the reservoir upstream - Lake Tillery.

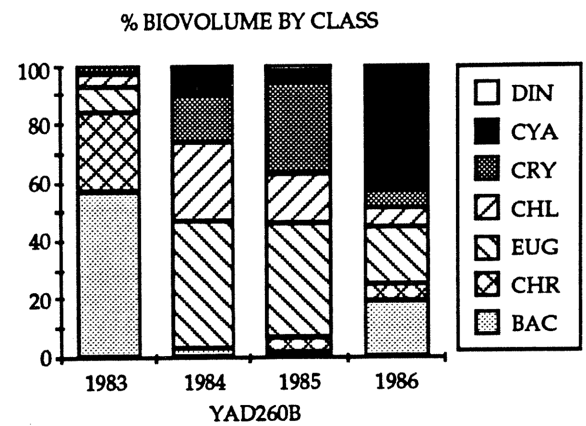
When sampled on August 13, 1986, Blewett Falls Lake was not stratified. Dissolved oxygen concentrations on the surface and in the hypolimnion differed by only 1.8 mg/l, while temperature remained constant throughout the water column. Nutrients were elevated, and chlorophyll-a (46 µg/l) violated the North Carolina standard of 40 µg/l. Heavy metals and fecal coliform bacteria were below laboratory detection limits.

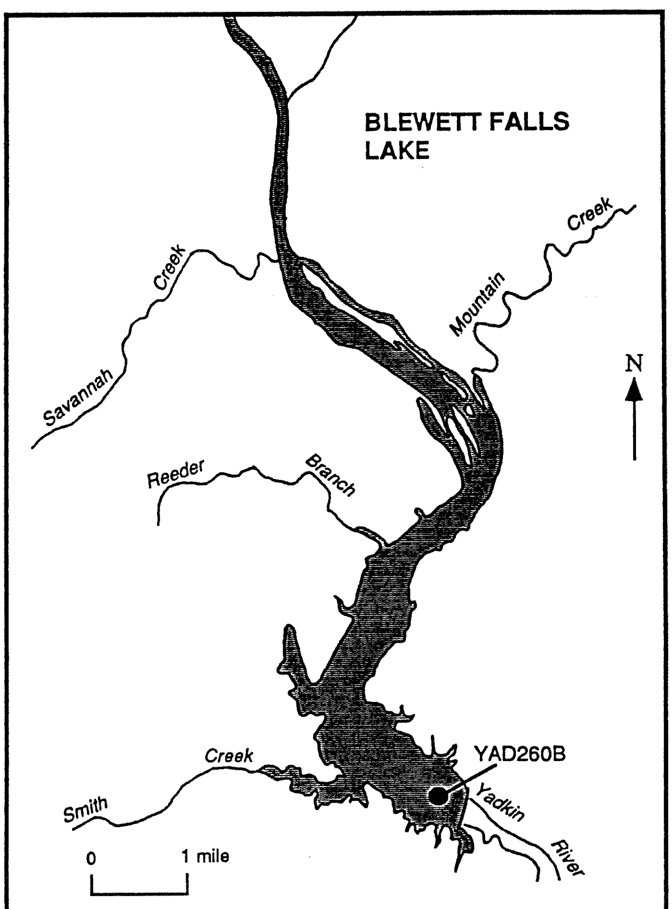
Estimates of algal biovolume and density in 1986 were higher than those measured in previous years. Standing crop was low in 1983 and 1984, moderate in 1985, and higher in 1986. Chlorophyll-a values correlated well with the abundance of phytoplankton.

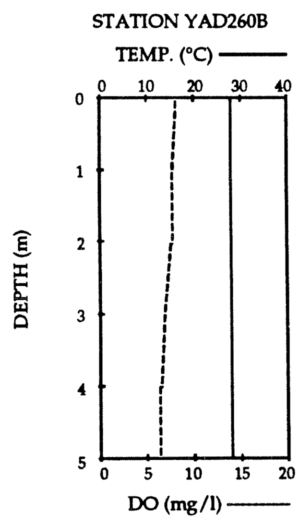
The dominant classes of algae varied from year to year. Phytoplanktonic densities were particularly high in 1986 when Oscillatoria geminata and Anabaenopsis raciborskii, small filamentous blue-greens, were dominant.

The TSI of 2.7 in 1986 was much higher than in 1983 (-0.5) but lower than in 1981 (3.5). The fluctuations in TSI values may be a result of highly variable retention times. Under normal flow regimes this reservoir behaves like a slow- moving river rather than a lake, and the brief retention time prevents optimal growth of phytoplankton. In low-flow years, the reservoir does not flush as rapidly, and algae are able to utilize available nutrients for growth and reproduction. Overall, results indicate that the potential for water quality problems exists at Blewett Falls Lake. Although water quality in the reservoir fully supported designated uses, future sampling of the lake is clearly warranted.

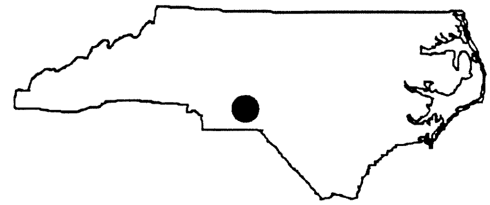








ROBERDEL LAKE



COUNTY:	Richmond	BASIN:	Yadkin
SURFACE AREA:	40 hectares (100 acres)	USGS TOPO:	Hamlet, N.C.
CLASS:	WS	LAKE TYPE:	Millpond

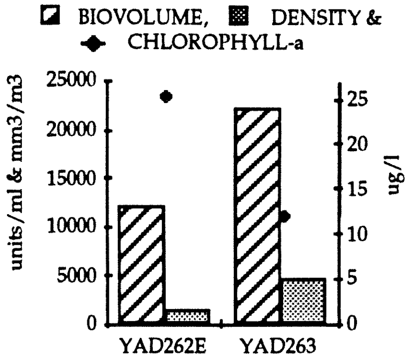
LATEST NCTSI:	1.1	TROPHIC STATE:	Dystrophic
SAMPLING DATE:	August 9, 1989	ADDITIONAL COVERAGE:	Water Supply Parameters
SECCHI DEPTH:	0.7 m	CONDUCTIVITY:	21 - 23 µmhos/cm^2
TOTAL PHOSPHORUS:	0.03 mg/l	DISSOLVED OXYGEN:	5.6 - 5.9 mg/l
TOTAL ORGANIC NITROGEN:	0.32 mg/l	TEMPERATURE:	25.2 - 26.3 °C
CHLOROPHYLL-A:	18.5 µg/l	pH:	5.3 - 6.1 s.u.

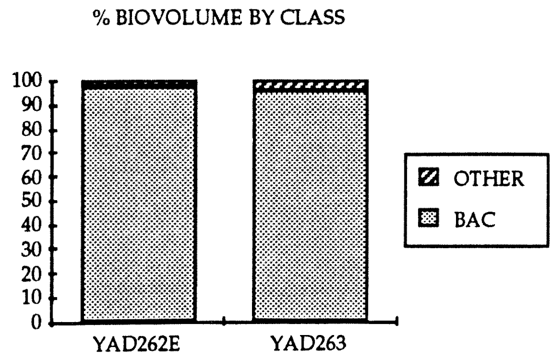
Roberdel Lake is a water supply for the Town of Roberdel which was created for use as a millpond in the 1930's. The reservoir is located in the sandhills of North Carolina, and it is the westernmost blackwater/cypress swamp lake sampled by DEM. Volume of Roberdel Lake is 95,000 m^3 with a maximum depth of five meters. Hitchcock Creek is the main tributary to the lake. Land use in this drainage area is mostly forested with some residential land close to the lake.

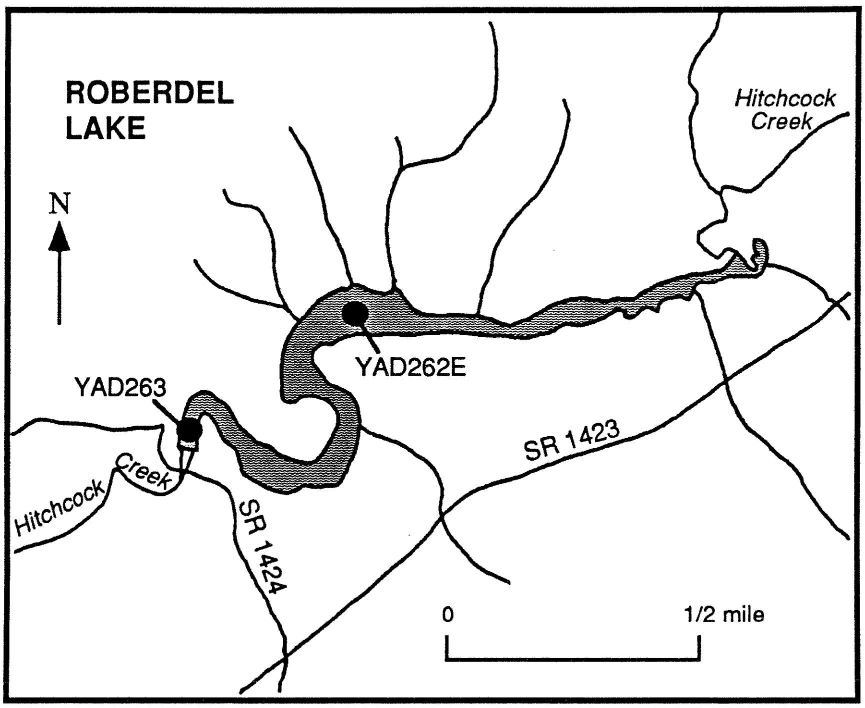
Sample results from August 9, 1989 were indicative of a dystrophic lake. Dissolved oxygen and conductivity were low. Acidic pH values were present and water clarity was low, partly as a result of the tea-colored water. Chlorophyll-a and nutrient concentrations were moderate.

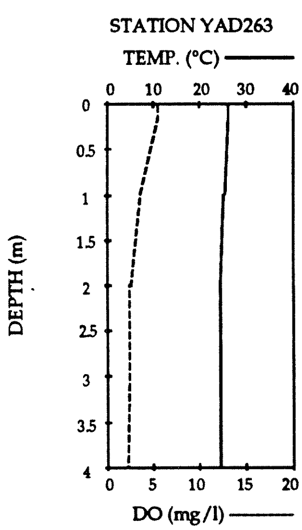
Although algal densities remained low, biovolumes reached levels indicative of a bloom (12,034 and 22,378 mm^3/m^3) at both stations on Roberdel Lake. The predominance of Tabellaria fenestrata, a relatively large, colonial diatom, accounts for these high estimates of biovolume. Tabellaria is a common diatom in nutrient-poor ponds and lakes throughout North Carolina (Wetzel, 1975).

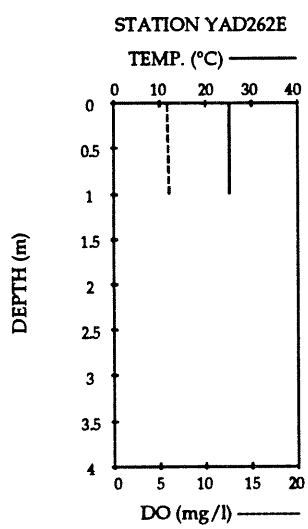
A TSI of 1.1 was calculated for Roberdel Lake, reflecting the moderately productive conditions at this dystrophic lake. All uses were supported at the time of sampling.


BIOVOLUME, DENSITY &
CHLOROPHYLL-a
units/ml & mm3/m3
25000
20000
15000
10000
5000
0
25
20
15
10
5
0
ug/l
YAD262E
YAD263

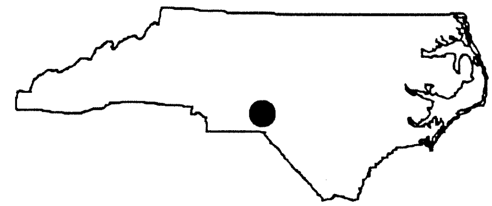

% BIOVOLUME BY CLASS
100
90
80
70
60
50
40
30
20
10
0
YAD262E
YAD263
OTHER
BAC


ROBERDEL
LAKE
N
Hitchcock
Creek
YAD262E
YAD263
Hitchcock Creek
SR 1423
SR 1424
0
1/2 mile


STATION YAD263
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0
0.5
1
1.5
2
2.5
3
3.5
4
0 5 10 15 20
DO (mg/l)


STATION YAD262E
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0
0.5
1
1.5
2
2.5
3
3.5
4
0 5 10 15 20
DO (mg/l)

WATER LAKE



COUNTY:	Richmond	**BASIN:**	Yadkin
SURFACE AREA:	19 hectares (48 acres)	**USGS TOPO:**	Hamlet, N.C.
CLASS:	WS	**LAKE TYPE:**	Reservoir

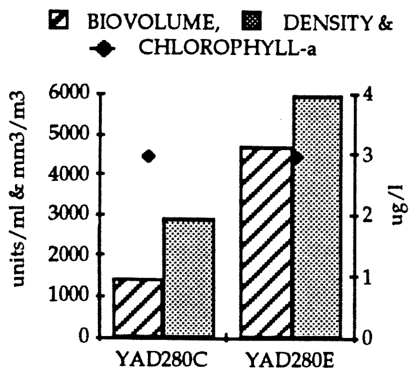
LATEST NCTSI:	- 3.0	**TROPHIC STATE:**	Oligotrophic
SAMPLING DATE:	August 9, 1989	**ADDITIONAL COVERAGE:**	Water Supply Parameters
SECCHI DEPTH:	1.2 m	**CONDUCTIVITY:**	37 - 49 µmhos/cm^2
TOTAL PHOSPHORUS:	0.015 mg/l	**DISSOLVED OXYGEN:**	4.8 - 10.9 mg/l
TOTAL ORGANIC NITROGEN:	0.155 mg/l	**TEMPERATURE:**	24.6 - 25.5 °C
CHLOROPHYLL-A:	3 µg/l	**pH:**	5.5 - 8.1 s.u.

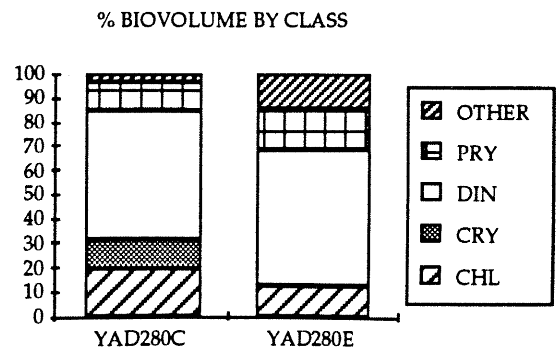
Water Lake is the primary water supply for the City of Hamlet, located in the sandhills of North Carolina. The impoundment has a sandy substrate and a small, undisturbed, watershed. Marks Creek is the main tributary to the lake, and public access to the lake is prohibited.

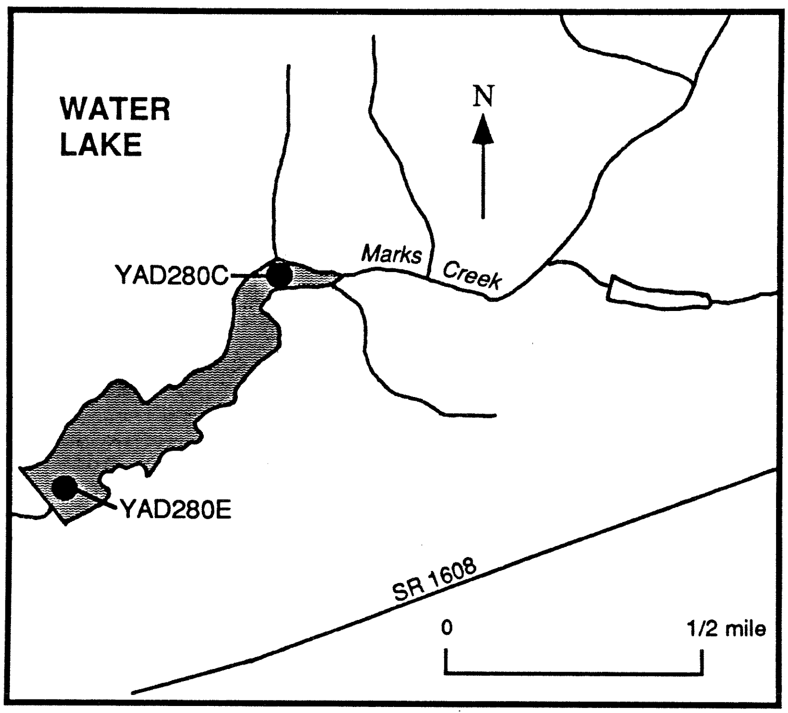
Water Lake was sampled on August 9, 1989. The water column was stratified at the dam. Nutrient and chlorophyll-a concentrations indicated low productivity. Turbidity was less than 1.5 NTU at both stations, indicating good water clarity. The few metals that were detected were below state action levels.

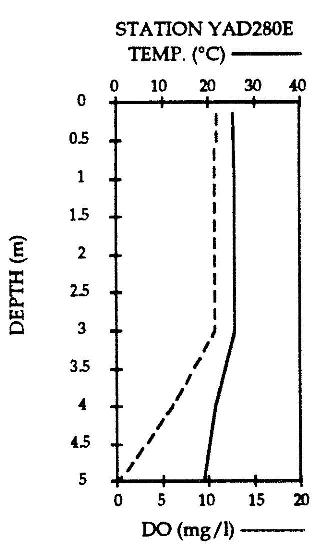
In accordance with the oligotrophic classification, levels of phytoplanktonic biovolume and density in Water Lake were both relatively low. Codominant classes of algae included chlorophytes, dinoflagellates, and prymnesiophytes. An assemblage of Peridinium species (dinoflagellates) composed over 50% of the algal biovolume at each station. Peridinium is commonly present in more oligotrophic bodies of water.

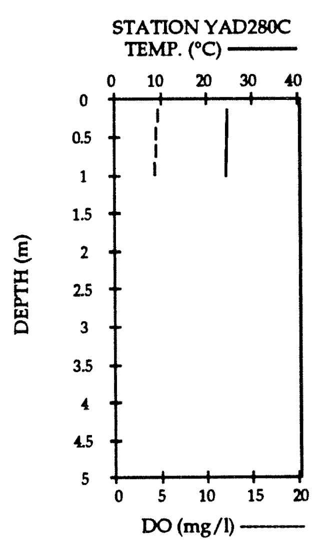
A TSI of -3.0 was calculated for Water Lake, indicating that it is oligotrophic. Water quality in Water Lake fully supported its use as a water supply.


BIOVOLUME, DENSITY & CHLOROPHYLL-a
units/ml & mm3/m3
ug/l
6000
5000
4000
3000
2000
1000
0
4
3
2
1
0
YAD280C
YAD280E

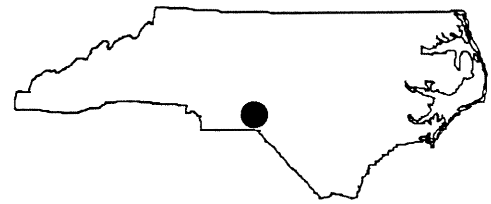

% BIOVOLUME BY CLASS
100
90
80
70
60
50
40
30
20
10
0
YAD280C
YAD280E
OTHER
PRY
DIN
CRY
CHL


WATER LAKE
N
Marks Creek
YAD280C
YAD280E
SR 1608
0
1/2 mile


STATION YAD280E
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0 5 10 15 20
DO (mg/l)


STATION YAD280C
TEMP. (°C)
0 10 20 30 40
DEPTH (m)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0 5 10 15 20
DO (mg/l)

HAMLET CITY LAKE



COUNTY:	Richmond	BASIN:	Yadkin
SURFACE AREA:	40 hectares (100 acres)	USGS TOPO:	Hamlet, N.C.
CLASS:	WS	LAKE TYPE:	Reservoir

LATEST NCTSI:	- 1.8	TROPHIC STATE:	Mesotrophic
SAMPLING DATE:	July 26, 1990	ADDITIONAL COVERAGE:	None
SECCHI DEPTH:	1.55 m	CONDUCTIVITY:	52 μmhos/cm^2
TOTAL PHOSPHORUS:	0.015 mg/l	DISSOLVED OXYGEN:	4.3 - 5.0 mg/l
TOTAL ORGANIC NITROGEN:	0.27 mg/l	TEMPERATURE:	29.4 - 29.6 °C
CHLOROPHYLL-A:	5.5 μg/l	pH:	6.4 - 6.9 s.u.

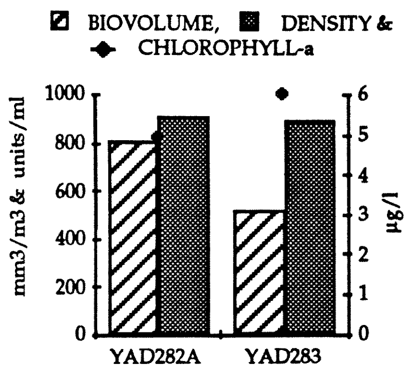
Hamlet City Lake is a small, shallow lake located in the town of Hamlet, North Carolina. The drainage basin for the lake is five square kilometers and is mostly undeveloped. However, the area immediately around the lake drains urban sections of the City. Prior to the mid-1950's, drainage from a large railroad switching and repair yard also entered the lake. The lake has historically suffered water quality problems related to sedimentation and aquatic macrophyte infestation and has recently received restoration funding through the Civil Works Program of the U.S. Army Corps of Engineers. Plans have been submitted to drain and dredge the lake to alleviate the aforementioned problems. Hamlet City Lake is classified WS-III.

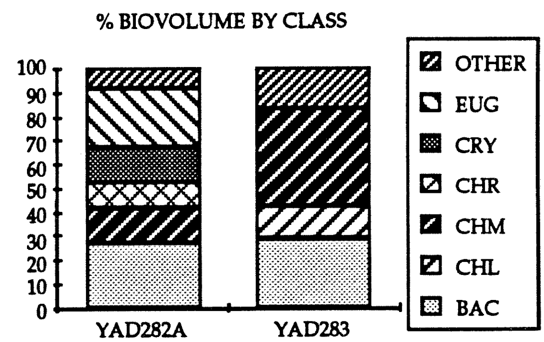
When sampled on July 26, 1990, the lake was well mixed with consistent dissolved oxygen, temperature and nutrient levels observed throughout the water column. The lake exhibited moderate nutrient and chlorophyll-a values, consistent with the mesotrophic status of the lake.

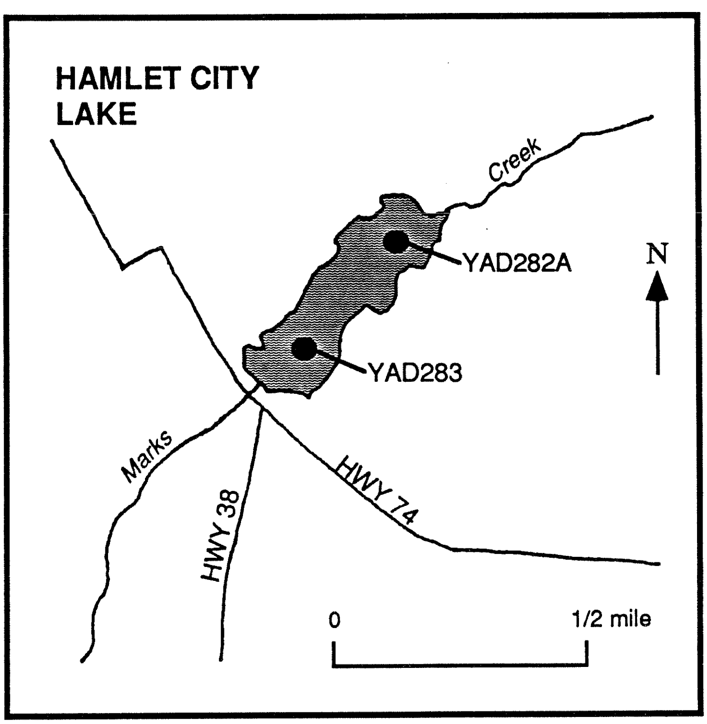
In Hamlet City Lake, aquatic macrophytes probably play a more important role in productivity and nutrient regulation than phytoplankton. The shallow water in the reservoir allows light to penetrate to the bottom of the lake resulting in a large and diverse assemblage of aquatic plants. Field observations in 1990 found that 90% of the lake was infested with aquatic plants. Most of the species collected from Hamlet City Lake are tolerant of low pH: Brasenia schreberi (water shield); Nymphaea odorata (fragrant water-lily); Potamogeton diversifolius (variable-leaf pondweed); Utricularia vulgaris (bladderwort); and Myriophyllum pinnatum (green parrot's-feather).

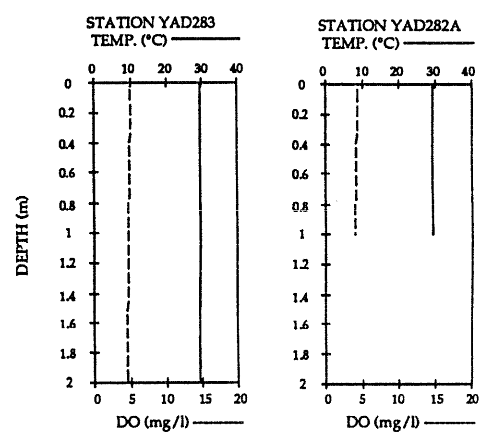
As in 1987, shading and utilization of nutrients by aquatic macrophytes limited the growth of phytoplankton in Hamlet City Lake. Both stations sampled exhibited low estimates of phytoplanktonic biovolume and density ranging from 520-808 mm^3/m^3 and 897-908 units/ml. In contrast to 1987, blue-green algae did not dominate the biovolume at YAD282A in 1990. Instead, a diverse assemblage of algal classes including euglenophytes, cryptophytes, chrysophytes, chloromonadophytes, and bacillariophytes were documented. At YAD283, Vacuolaria virescens, a relatively large chloromonadophyte, comprised almost half of the algal biovolume, and bacillariophytes and chlorophytes codominated.

The TSI in 1990 was -1.8 which is similar to historical values. At the time of assessment, Hamlet City Lake was categorized as partially supporting its designated use because aquatic macrophytes and sedimentation prevented its use as a water supply.









LAKE INDEX