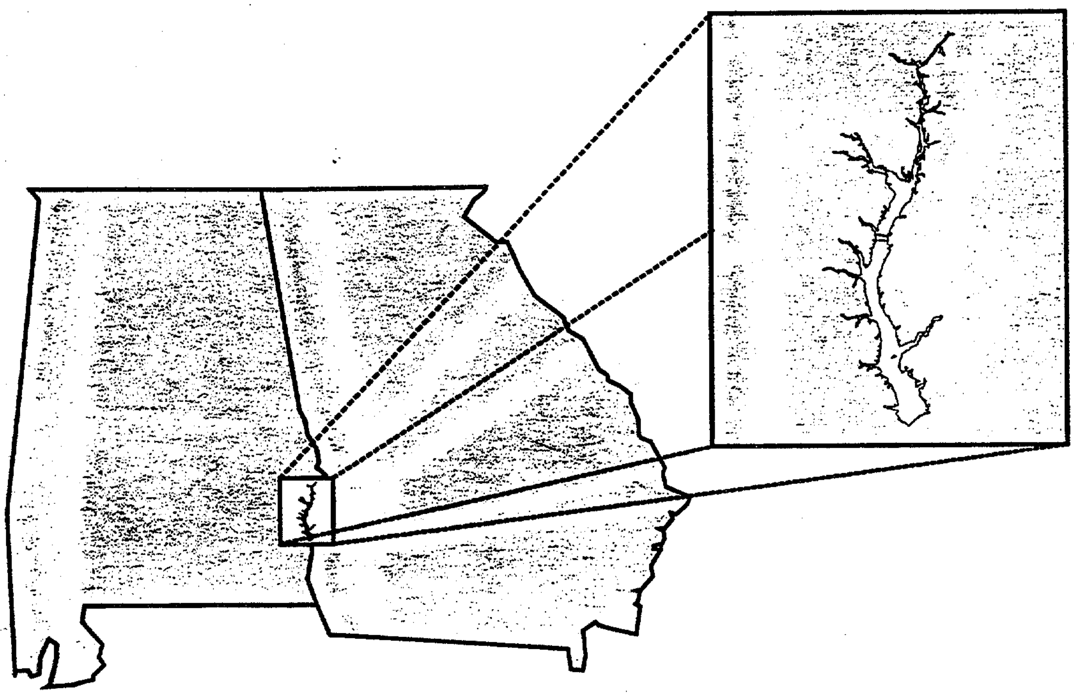
WALTER F. GEORGE RESERVOIR
PHASE I DIAGNOSTIC/FEASIBILITY STUDY
FINAL REPORT



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WALTER F. GEORGE RESERVOIR

Phase I Diagnostic/Feasibility Study

FINAL REPORT

Preface

Funding for this study was provided by 70% federal and 30% state matching grants to the states of Alabama and Georgia. These grants were made available through the Clean Water Act Section 314 Nationally Competitive Clean Lakes Program. Federal funding was administered through the United States Environmental Protection Agency.

This report includes results from a multi-year study. Comments or questions related to the content of this report should be addressed to:

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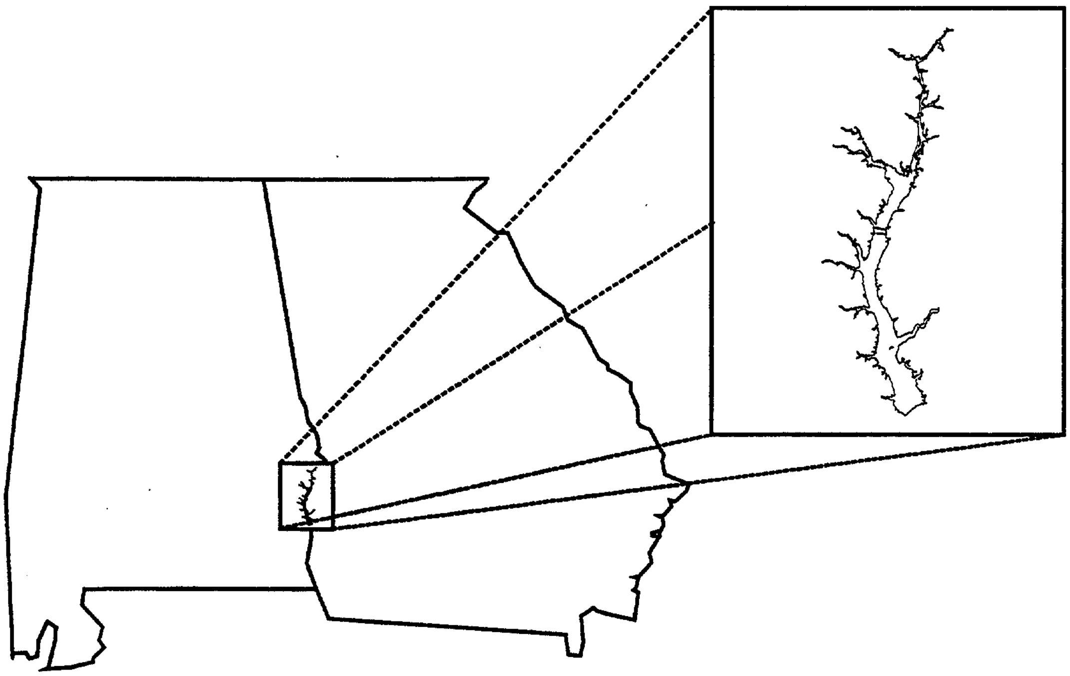
PART 1

WALTER F. GEORGE RESERVOIR

GEORGIA DIAGNOSTIC STUDY



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PART I - DIAGNOSTIC STUDY

1.0 INTRODUCTION

The Georgia Department of Natural Resources was awarded a Phase I Clean Lakes Grant for Walter F. George Reservoir in July 1990 under Section 314(a) of the Federal Water Quality Act of 1987. The purpose of this grant was to enable the Department of Natural Resources (DNR) to conduct a Phase I Diagnostic-Feasibility study of the reservoir. Study goals were to determine the reservoir's current water quality condition and to develop proposals for restoration and/or protection of the reservoir. Funding for the study was provided by a 70%-30% matching grant from the United States Environmental Protection Agency (EPA); $100,000 federal monies matched by $42,900 from Georgia DNR.

Walter F. George Reservoir was selected for study because of its size (third largest reservoir in the State), its location (on the Chattahoochee River downstream of major populated areas), and its value as a resource to the State. Due to the size of this reservoir and the limited resources available for the project, the study area was limited to the Georgia portion of the reservoir and watershed. The Alabama Department of Environmental Management was awarded a similar Phase I Clean Lakes study grant for Walter F. George Reservoir. The Alabama study was scheduled to follow the Georgia DNR study. The Alabama study area will include the Alabama portion of the lake and watershed not covered in this report. When both diagnostic reports are completed, Alabama and Georgia will work together to write the feasibility report.

The format of this report follows the outline suggested by the Clean Lakes Program Guidance Manual, prepared under contract for the U.S. Environmental Protection Agency by JACA Corporation, Fort Washington, Pennsylvania.

Figure 1.1 is a map of the Walter F. George Reservoir showing water quality sampling stations referenced in this report. In the station names LG stands for Lake George, CR for Chattahoochee River, HC for Hannahatchee Creek, PC for Pataula Creek, and DN for Drag Nasty Creek. These lake and tributary stations are described in detail in Chapter 6.

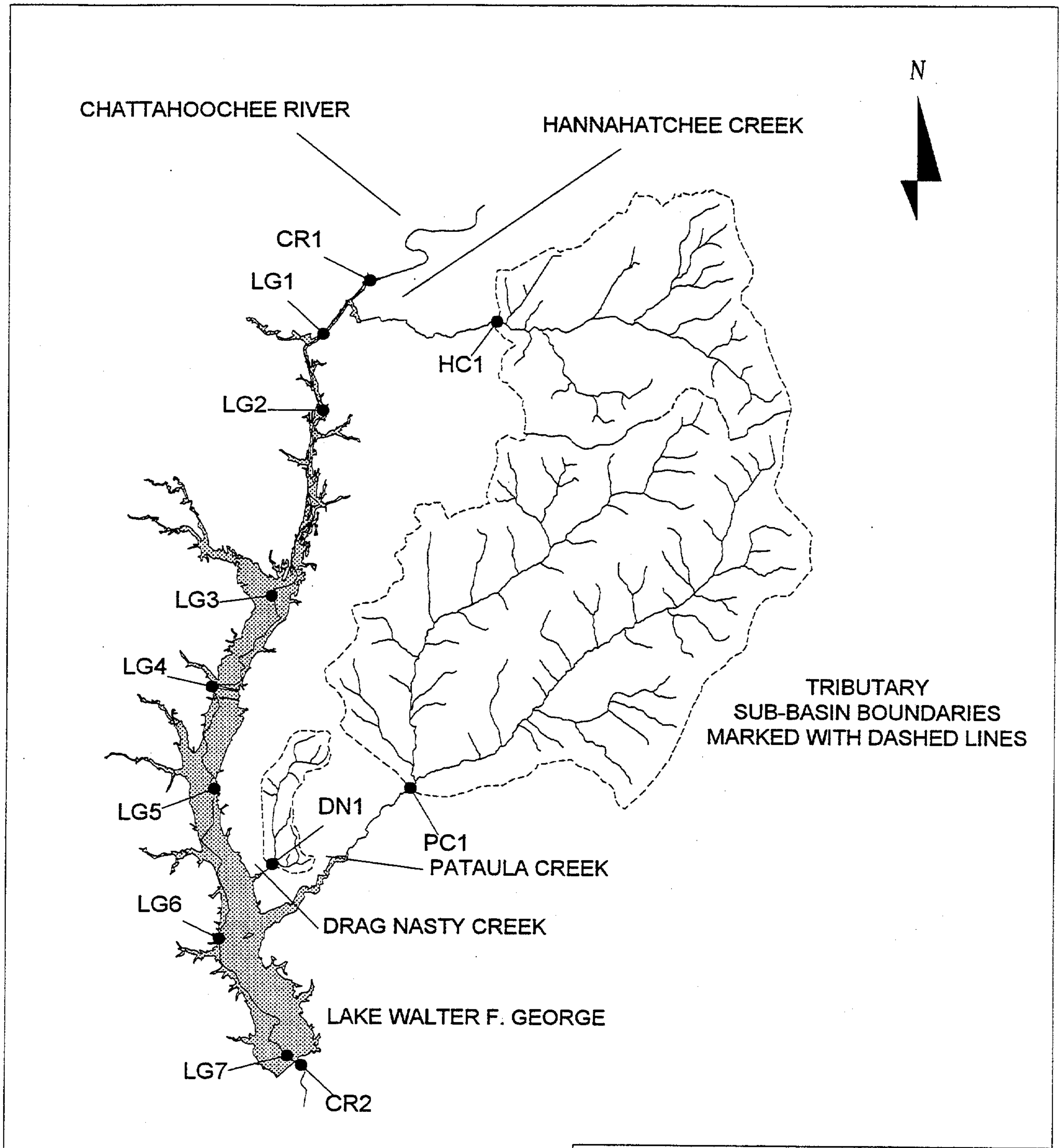


FIGURE 1.1
LAKE WALTER F. GEORGE
GEORGIA DNR PHASE I STUDY
STATION LOCATIONS

2.0 DESCRIPTION OF STUDY AREA

2.1 LAKE IDENTIFICATION AND LOCATION

The Walter F. George Reservoir project was authorized by the U.S. Congress in 1946 to provide hydroelectric power, regulate transportation, provide flood control, and promote recreation. Dam construction by the United States Army Corps of Engineers (COE) began in 1955. The project was completed and the reservoir was filled in 1963. The dam is located on the Chattahoochee River about one mile north of Fort Gaines, Georgia. Walter F. George Reservoir is the official designation of this lake, named after the U.S. Senator from Georgia who actively supported the project. It is also known by other names. In the early years of dam construction it was called the Fort Gaines Reservoir due to the location of the dam. In Alabama the reservoir is commonly known as Lake Eufaula, in honor of the City of Eufaula, Alabama, located approximately midway between the dam and the headwaters of the lake. In this report the reservoir will be referred to as Lake Walter F. George, Lake W.F. George, or simply as Walter F. George. When an abbreviation is needed, "WFG" will be used.

Lake Walter F. George lies along the Alabama-Georgia border as shown in Figure 2.1. The lock and dam are roughly 138 kilometers downstream of Columbus, Georgia. A transportation channel at least 100 feet wide and nine feet deep is maintained by the COE from the dam to Columbus Georgia and Phenix City Alabama. The dam pool area is up to five kilometers wide. The Chattahoochee River channel crosses the dam at 85°3'54" West, 31°37'26" North. The power plant has four 32.5 megawatt generators with an annual average production of 436 million kilowatt hours. The lake is managed by the COE under the supervision of the U.S. Army District Engineer at Mobile, Alabama.

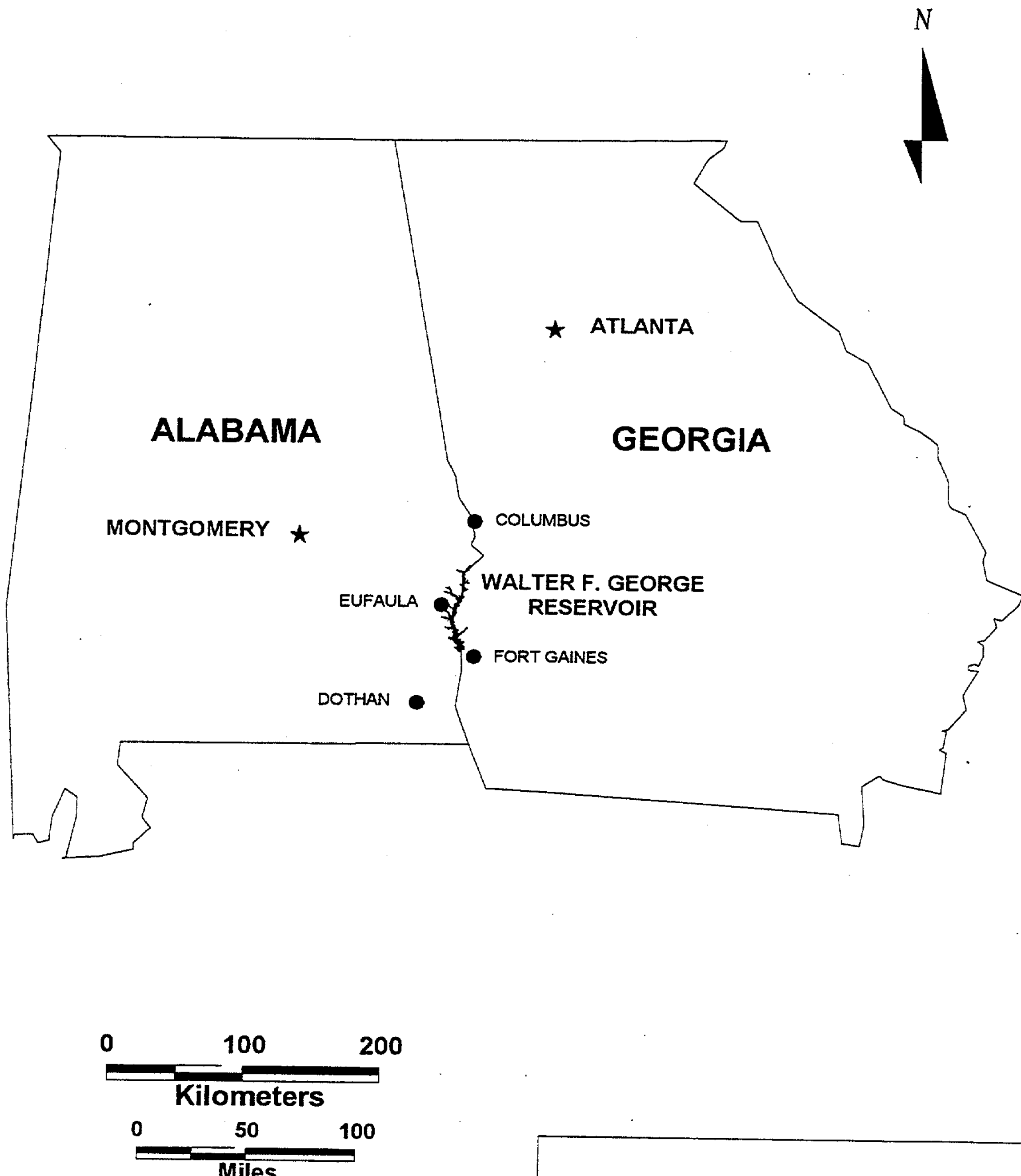


FIGURE 2.1
LAKE WALTER F. GEORGE
LAKE LOCATION MAP

2.2 LAKE MORPHOMETRY

The following data were taken from a number of sources including COE publications, the 1975 Region IV EPA National Eutrophication Survey report, and other DNR studies. Data are given for mean summer pool elevation unless otherwise noted.

LAKE ELEVATION	57.9 meters msl	190 feet msl
LAKE SURFACE AREA	18,284 hectares	45,180 acres
MEAN DEPTH	6.2 meters	20.3 feet
MAXIMUM DEPTH	29.3 meters	96.0 feet
LAKE VOLUME	1,154,378,000 meter^3	934,400 acre-feet
LAKE LENGTH	138 river km	85 river miles
SHORELINE LENGTH	1,022 km	640 miles
LAKE DRAINAGE AREA	19,321 km^2	7,460 mile^2
MEAN STREAM FLOW	284,000 liters/sec	10,000 cfs
MEAN HYDRAULIC RETENTION TIME	47 days	
MAX HYDRAULIC RETENTION TIME (min mean monthly flow)	111 days	
MIN HYDRAULIC RETENTION TIME (max mean monthly flow)	19 days	

MEAN FLOW DATA:

TRIBUTARY	MEAN FLOW (liters/sec)	PERCENT OF TOTAL
Chattahoochee River (upstream of Cowikee Creek)	241,700	85.1%
Cowikee Creek	13,300	4.7%
Pataula Creek	10,600	3.7%
Barbour Creek	3,500	1.2%
Cheneyhatchee Creek	1,300	0.46%
Holanna Creek	1,300	0.46%
White Oak Creek	400	0.14%
Tobannee Creek	400	0.14%
Drag Nasty Creek	400	0.14%
Sandy Creek (GA)	400	0.14%
Chewalla Creek	300	0.11%
Other Minor Tributaries & Drainage	10,400	3.7%
TOTAL	284,000	100%

2.3 BASIN DESCRIPTION

Lake W.F. George lies within the Chattahoochee River basin. This basin has a total drainage area of 8,770 square miles, 70 percent of which is in Georgia. The maximum width of the basin is 55 miles. The Georgia Chattahoochee River basin and local W.F. George sub-basin are shown in Figure 2.2. The Chattahoochee River begins in northeast Georgia in the Blue Ridge Mountains and flows 436 miles to the southwest corner of the State. At the Georgia-Florida border it joins the Flint river to form the Apalachicola River, which then flows south through Florida to the Gulf of Mexico. Below West Point, Georgia, the west bank of the Chattahoochee marks the Alabama-Georgia border. In the 26-mile section shared by Georgia and Florida the state line is mid-channel.

From its headwaters downstream to Columbus, Georgia, the Chattahoochee River passes through the impoundments of Lake Sidney Lanier, West Point Lake, Lake Harding, Goat Rock Lake, and Lake Oliver. These impoundments tend to mitigate the influence of activities in their watershed. The sub-basin above Columbus has an approximate drainage area of 4,670 square miles, 53 percent of the total drainage area. Due to the size of the Chattahoochee River basin and the moderating effect of these impoundments, this study will concentrate on the sub-basin from the Lake Oliver dam in Columbus to the Walter F. George Dam, with special emphasis on the Georgia side of this sub-basin. This watershed has an approximate drainage area of 2,790 square miles, with just over 50 percent of this area in Georgia (1,413 square miles).

The Georgia side of the local sub-basin includes all or part of these Georgia counties: Talbot, Muscogee, Marion, Chattahoochee, Stewart, Quitman, Randolph, and Clay. Muscogee, Chattahoochee, Stewart, Quitman, and Clay Counties are in direct contact with the Chattahoochee River or Lake W.F. George. Georgia cities and towns in this sub-basin include Columbus, Cusseta, Lumpkin, Georgetown, and Fort Gaines.

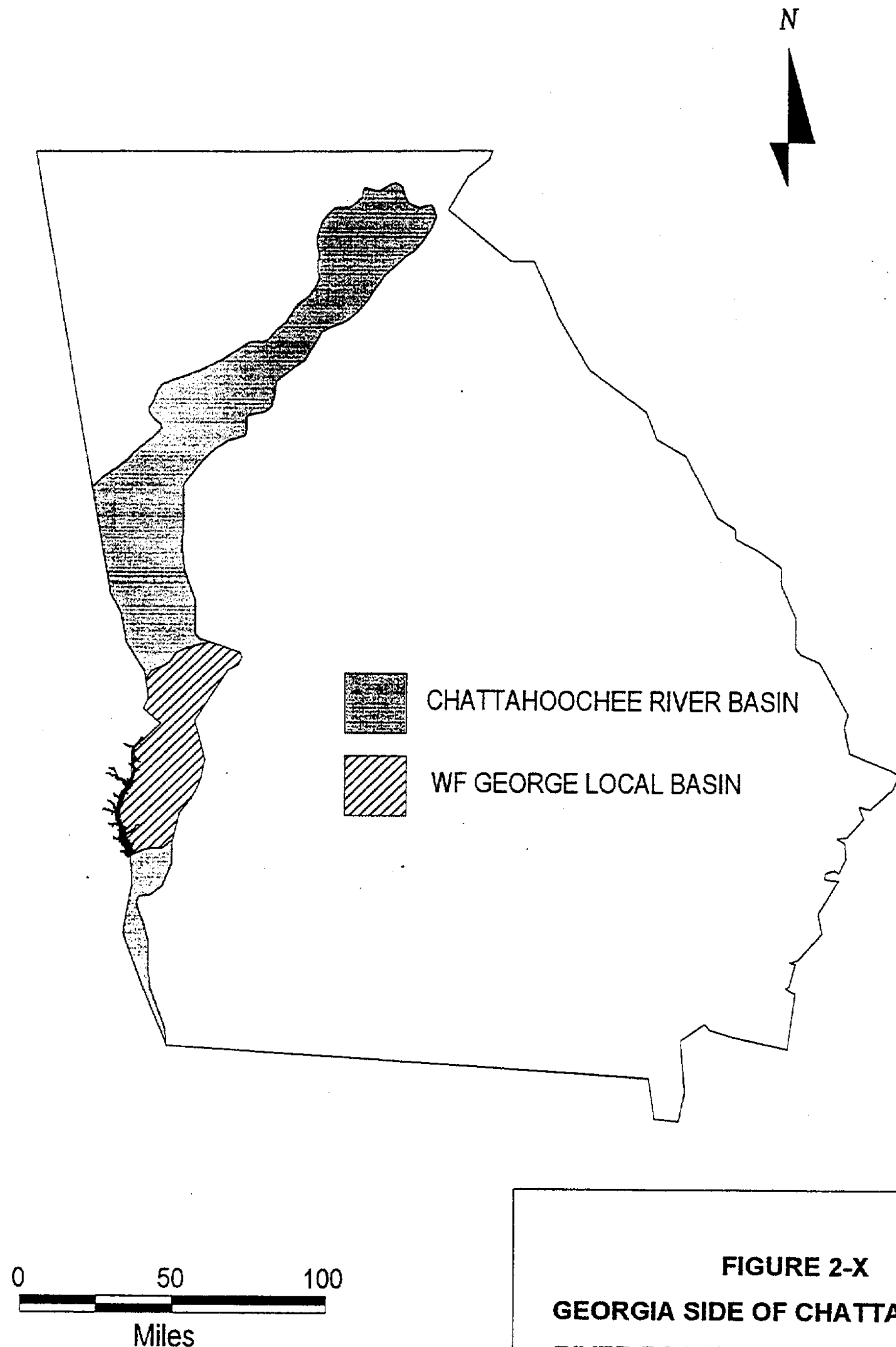


FIGURE 2-X
GEORGIA SIDE OF CHATTAHOOCHEE RIVER BASIN AND LAKE WF GEORGE LOCAL BASIN

2.4 WATER QUALITY STANDARDS

The Georgia Rules and Regulations for Water Quality Control, Chapter 391-3-6, set specific numerical water quality standards and associated use classifications for the State's surface waters. Appendix 1 summarizes these water quality standards. Some numerical standards vary according to the specified water use classification.

The Chattahoochee River from Oliver Dam to Columbus Highland Dam is classified Recreation and Drinking Water. The Chattahoochee River from Columbus Highland Dam to Cowikee Creek is classified Fishing. The Walter F. George Reservoir is classified Recreation from the Chattahoochee River-Cowikee Creek confluence downstream to the lock and dam. The Recreation classification extends up the lake's tributary embayments. The Georgia tributaries upstream of Cowikee Creek are classified Fishing. The Chattahoochee River downstream of the Walter F. George dam to the Great Southern Paper Mill is classified Recreation.

Both Recreation and Fishing classifications have a minimum dissolved oxygen standard of 4.0 mg/l, a daily average dissolved oxygen standard of 5.0 mg/l, a maximum temperature standard of 90 degrees Fahrenheit (32.2 degrees Celsius), a maximum pH standard of 8.5 units, and a minimum pH standard of 6.0 units.

The fecal coliform bacteria standard for the recreation classification is 200 MPN per 100 ml, determined as a geometric mean of four samples collected within a 30 day period. This same standard applies to fishing waters from May through October. For November through April, the fishing classification standard for fecal coliform bacteria is 1,000 MPN per 100 ml, geometric mean of four samples in a 30 day period, with a single sample maximum of 4,000 MPN per 100 ml. Refer to Appendix 1 for more details and information on other numerical standards.

3.0 DESCRIPTION OF PUBLIC USE

3.1 LAKE USE AND ACCESS

The Corps of Engineers operates this reservoir for electric power production, flood control, transportation, and recreation. Visitors use Lake W.F. George for many forms of recreation. The lake provides a transportation route from Columbus Georgia and Phenix City, Alabama down through Lake George W. Andrews and Lake Seminole to the Florida coast. Many large boats are docked at W.F. George.

Lake W.F. George is a prime fishing lake. Game fish include largemouth bass, white bass, hybrids, crappie, channel catfish, and bream. The COE, Georgia DNR, and the Alabama Department of Conservation and Natural Resources maintain a series of fish attractors to promote fishing in the lake. According to Georgia DNR Game and Fish Division creel boat survey records, the fish caught in 1991 were as follows: 109,319 largemouth bass, 9,064 hybrid bass, 13,374 whitebass, 131,018 black crappie, 171,396 bluegill, 74,065 channel catfish, 5,607 white catfish, and 22,399 other fish. These fish were caught in 118,057 fishing trips during a total of 579,575 angler hours.

Lake W.F. George is also used for boating, swimming, camping, picnicking, and nature observation. More than thirty parks and recreational facilities are located on the lake to provide public access. Table 3.1 describes some of the facilities and shows approximate visitation for 1991. Usage data are from COE estimates. Figure 3.1 shows the location of some of these facilities. The 1991 percentages of lake visitation by types were estimated by the COE as follows: 40% fishing, 30% boating, 13% swimming, 11% sightseeing, 10% camping, 7% water skiing, 6% picnicking, and 1% hunting (the total exceeds 100% since many visitors engage in more than one activity per visit). The total number of visits in 1991 was estimated at 6,792,436. A "visit" is defined as one person visiting the lake for one day or part of one day.

TABLE 3.1 1991 PUBLIC ACCESS AND USAGE				
AREA NAME AND PRIMARY USES	**AGENCY**	**NUMBER OF DEVELOPED ACRES**	**TOTAL ACRES**	**1991 VISITOR HOURS**
Barbour Creek - BP	Local	1	1	166,575
Bluff Creek - CBP	Corps	65	71	780,840
Briar Creek - B	Local	2	62	144,879
Cheneyhatchee Creek - B	Corps	3	55	131,436
Chewalla Creek Marina - B	Concess	7	47	102,456
Cool Branch - CBP	Corps	29	154	456,156
Cotton Hill - CBP	Corps	204	270	1,619,280
Damsite Lower Pool AL	Corps	35	100	435,798
Damsite Lower Pool GA	Corps	10	27	166,026
East Bank Damsite - BPS	Corps	55	68	616,648
Eufaula Yacht Club	Public	4	4	68,076
Florence Marina - CBFL	State	58	98	1,510,824
George T. Bagby - BPS	State	187	225	773,610
Hannahatchee	Corps	0	45	0
Hardridge Creek - BP	Corps	25	115	972,265
Hatchechubbee Creek - BP	Corps	10	238	220,653
Highland - BPS	Corps	70	100	137,358
Lakepoint - CBPSL	State	1200	1255	8,355,039
Old Creek Town - PS	Local	70	205	586,374
Pataula Creek - BP	State	45	289	586,374
River Bend	Corps	20	187	520,800
River Bluff - PF	Corps	7	212	226,890
Rood Creek - CP	Corps	10	142	291,240
Sandy Branch - BP	Local	10	43	36,378
Thomas Mill Creek - CBP	Federal	12	12	1,277,352
West Bank - PF	Corps	0	222	0
White Oak Creek - CBPS	Corps	140	170	5,178,648
TOTAL		2269	4179	25,361,975

C - Camping
B - Boat Ramp
P - Picknicing
S - Swimming Beach
F- Fishing Pier/Deck
L - Lodging

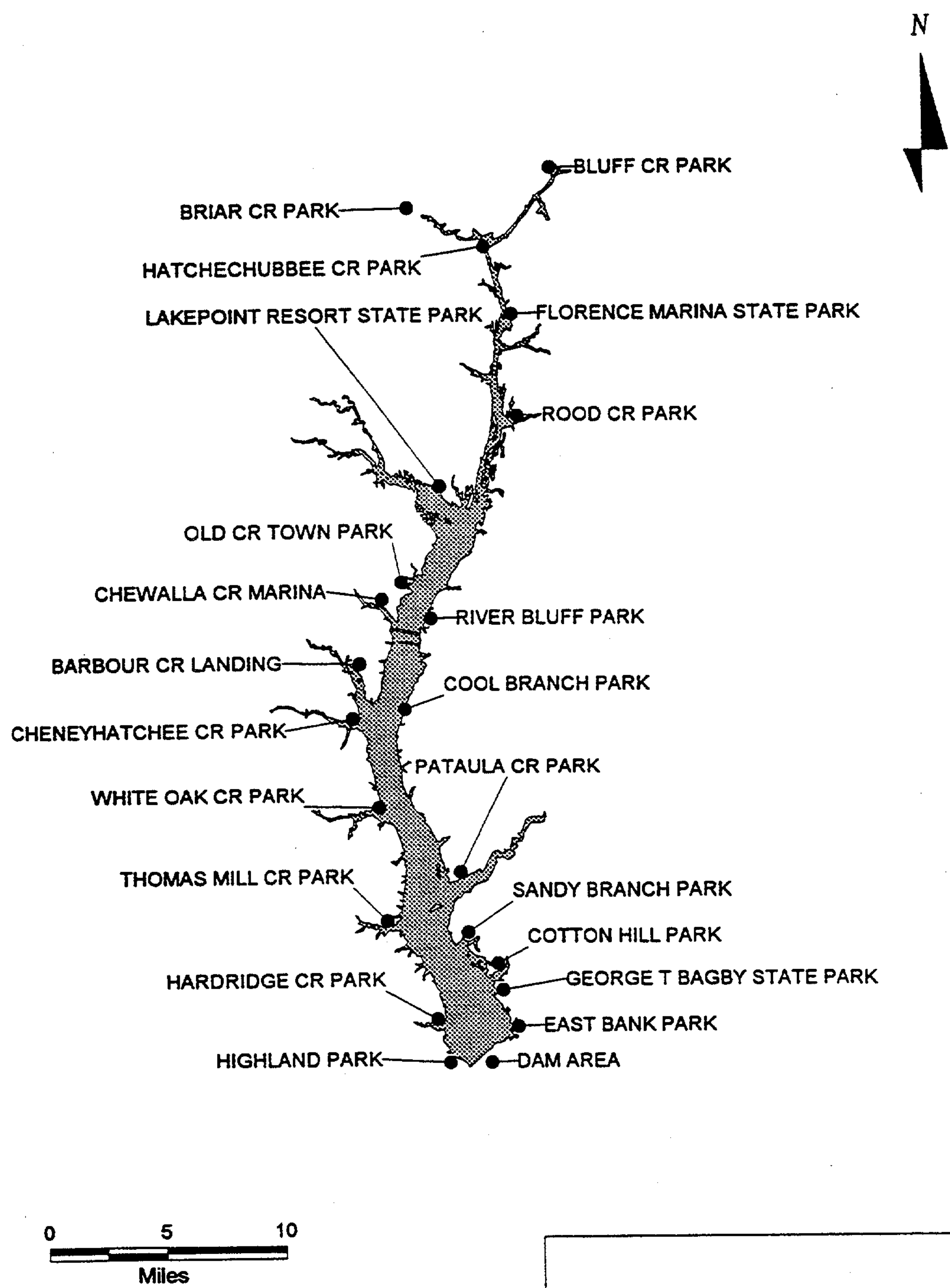


FIGURE 3-1
WALTER F. GEORGE RESERVOIR
PUBLIC ACCESS FACILITIES

Lake W.F. George and its surrounding forests provide a productive environment for the observation of wildlife. Local wild animals include waterfowl, deer, squirrels, rabbits, eagles, hawks, bobcats, snakes, turtles, alligators, fox, raccoons, opossum, and dozens of species of songbirds. The Eufaula National Wildlife Refuge is located seven miles north of Eufaula, Alabama. It was established in 1964 in cooperation with the COE as a feeding and resting habitat for migratory waterfowl. During the winter as many as sixteen species of ducks use the refuge along with four types of geese, including a resident flock of Canada geese. Animal populations are discussed in Chapter 9. The 11,160-acre refuge provides the public with an excellent site for observing these birds along with native wildlife. George T. Bagby State Park, located north of Fort Gaines, is another facility with miles of nature trails for walking and wildlife observation.

3.2 LOCAL POPULATION DATA

To describe the population local to Lake Walter F. George, demographic data were collected for five Georgia Counties in the local watershed: Muscogee, Chattahoochee, Stewart, Quitman, Randolph, and Clay (see Figure 3.2). This data is presented in Tables 3.2 through 3.7. Muscogee County, which includes Columbus, a major population center, has a population of almost five times that of the other four counties combined. Chattahoochee County is heavily influenced by the Fort Benning Army Reservation, which accounts for a large portion of the area and population. Stewart, Quitman, Randolph, and Clay are rural counties with individual populations below 10,000 each.

3.3 OTHER LAKES WITHIN 80 KILOMETERS

Nearby alternatives to Lake Walter F. George include Lake Harding, Goat Rock Lake, Lake Oliver, and Lake George W. Andrews. These lakes are located less than eighty kilometers (50 miles) from W.F. George as shown in Figure 3.3. West Point Lake, Lake Seminole, Lake Worth, and Lake Blackshear are other close by alternatives. Table 3.8 describes these impoundments.

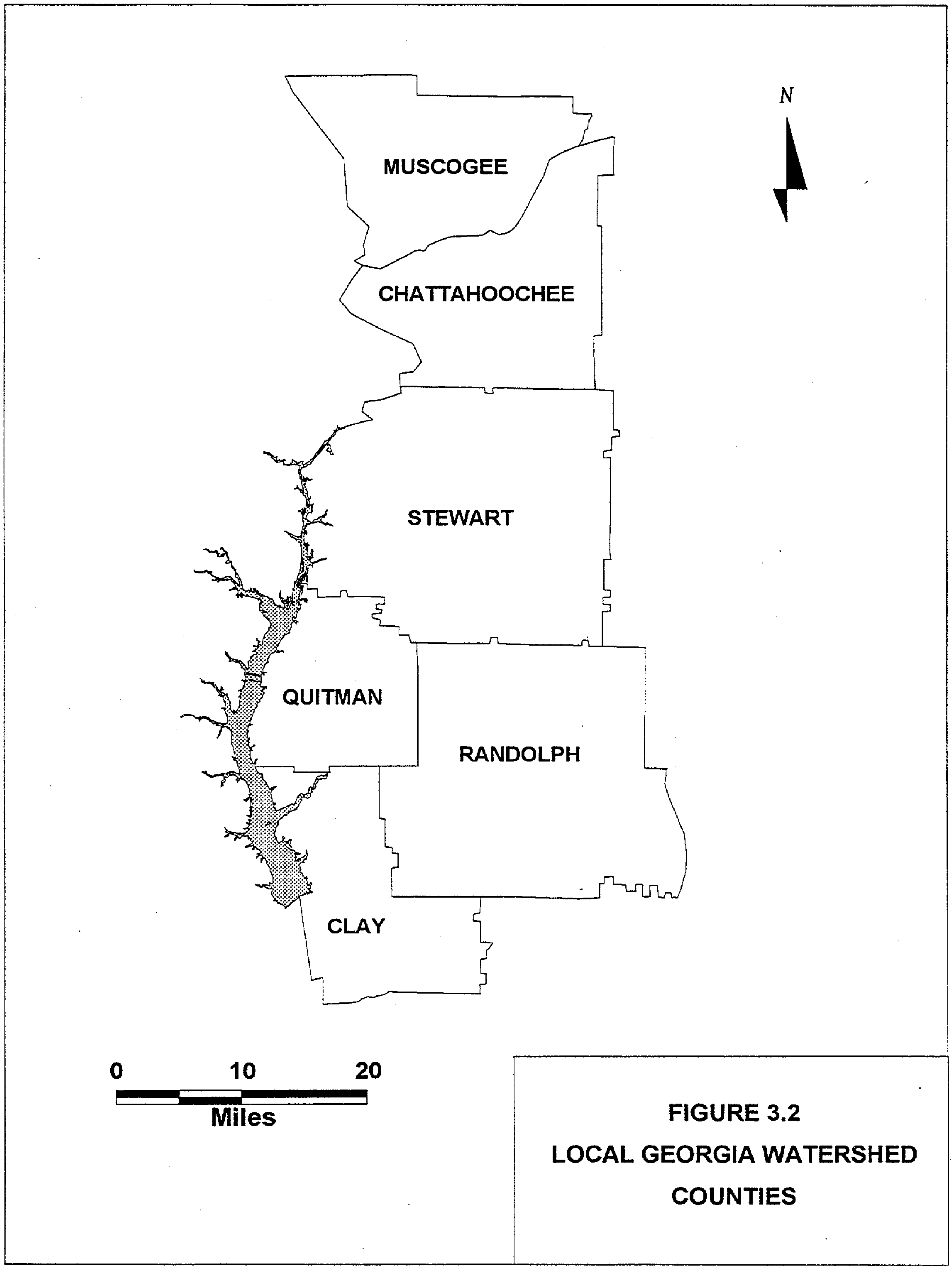


FIGURE 3.2
LOCAL GEORGIA WATERSHED
COUNTIES

TABLE 3.2

COUNTY POPULATION AND ECONOMIC ESTIMATES

COUNTY	POPULATION 1990 CENSUS	POPULATION PER SQ MILE 1990	PER CAPITA INCOME 1989	% CHANGE IN INCOME 1984-1989	% BELOW POVERTY LEVEL 1979
MUSCOGEE	179,278	811.6	$14,409	35.4	18 .0
CHATTAHOOCHEE	16,934	67.4	$11,007	52.0	11.8
STEWART	5,654	12.2	$9,959	24.8	38.8
QUITMAN	2,209	13.7	$11,239	33.4	40.7
RANDOLPH	8,023	18.6	$10,222	29.2	33.7
CLAY	3,364	15.5	$8,875	20.5	40.7

TABLE 3.3

POPULATION STATISTICS

COUNTY	HOUSING IN 1990		LABOR IN 1991			FOOD STAMPS IN 1991	
	% OWN	% RENT	% UNEMPLOYED	TOTAL EMPLOYED	TOTAL UNEMPLOYED	NUMBER OF PARTICIPANTS	% POPULATIO N
MUSCOGEE	53.9	33.6	4.6	70,426	3,400	22,281	12.43
CHATTAHOOCHEE	20.2	79.8	10.6	1,288	152	629	3.71
STEWART	70.8	29.2	8.4	1,669	154	1,299	22.97
QUITMAN	73.5	26.5	9 .0	578	57	551	24.94
RANDOLPH	66.7	33.3	5.2	3,421	186	2,207	27.51
CLAY	66.4	33.6	4.4	1,119	51	917	27.26

TABLE 3.4
WATER USAGE

COUNTY	1990 WATER AREA (SQ MILES)	WITHDRAWALS IN MILLION GALLONS PER DAY IN 1987				
		PUBLIC SUPPLY	DOMESTIC & COMMERCIAL	INDUSTRY & MINING	IRRIGATION	LIVESTOCK
MUSCOGEE	3.1	31.82	0.76	0.6	0.68	0.03
CHATTAHOOCHEE	1.1	6.69	0.01	0	0	0.01
STEWART	11	0.34	0.14	0	2.77	0.05
QUITMAN	15.1	0.12	0.08	0	0.37	0.03
RANDOLPH	0.5	0.64	0.3	0	12.07	0.13
CLAY	20.4	0.19	0.14	0	4.07	0.07

TABLE 3.5
MAJOR MANUFACTURED PRODUCTS OF 1991

COUNTY	NUMBER OF MANUFACTURING PLANTS	MAJOR MANUFACTURED PRODUCTS
MUSCOGEE	180	MACHINERY, TRANS EQUIP, BATTERIES, ELEC EQUIP, TEXTILES, PRINTING, CHEMICALS, RUBBER/PLASTIC, STONE/CLAY/GLASS/CONCRETE
CHATTAHOOCHEE	0	NA
STEWART	7	MOBILE HOMES
QUITMAN	1	NA
RANDOLPH	11	LUMBER, TEXTILES
CLAY	2	STONE/ CLAY/ GLASS/ CONCRETE

NA = NO DATA AVAILABLE

TABLE 3.6
AGRICULTURE PRODUCTION IN 1990

COUNTY	CORN X1000 BUSHELS	SOYBEANS X1000 BUSHELS	PEANUTS X1000 LBS	COTTON BALES	WHEAT X1000 BUSHELS	OATS X1000 BUSHELS	RYE X1000 BUSHELS	SORGHUM GRAIN X1000 BUSHELS
STEWART	193	24	7,806	1,410	210	NA	15	9
QUITMAN	40	4	2,456	850	14	5	10	NA
RANDOLPH	710	74	41,529	4,790	573	14	20	44
CLAY	170	5	13,595	2,030	193	16	17	78

NO DATA FOR MUSCOGEE AND CHATTAHOOCHEE COUNTIES

TABLE 3.7
LIVESTOCK AND POULTRY IN 1990

COUNTY	CATTLE AND CALVES	HOGS AND PIGS	COMMERCIAL LAYERS X 1000	COMMERCIAL BROILERS X 1000
MUSCOGEE	1,000	NA	0	0
CHATTAHOOCHEE	400	NA	0	0
STEWART	2,800	10,000	0	660
QUITMAN	1,600	1,400	0	0
RANDOLPH	8,000	5,300	0	0
CLAY	4,200	3,400	0	0

NA = NO DATA AVAILABLE

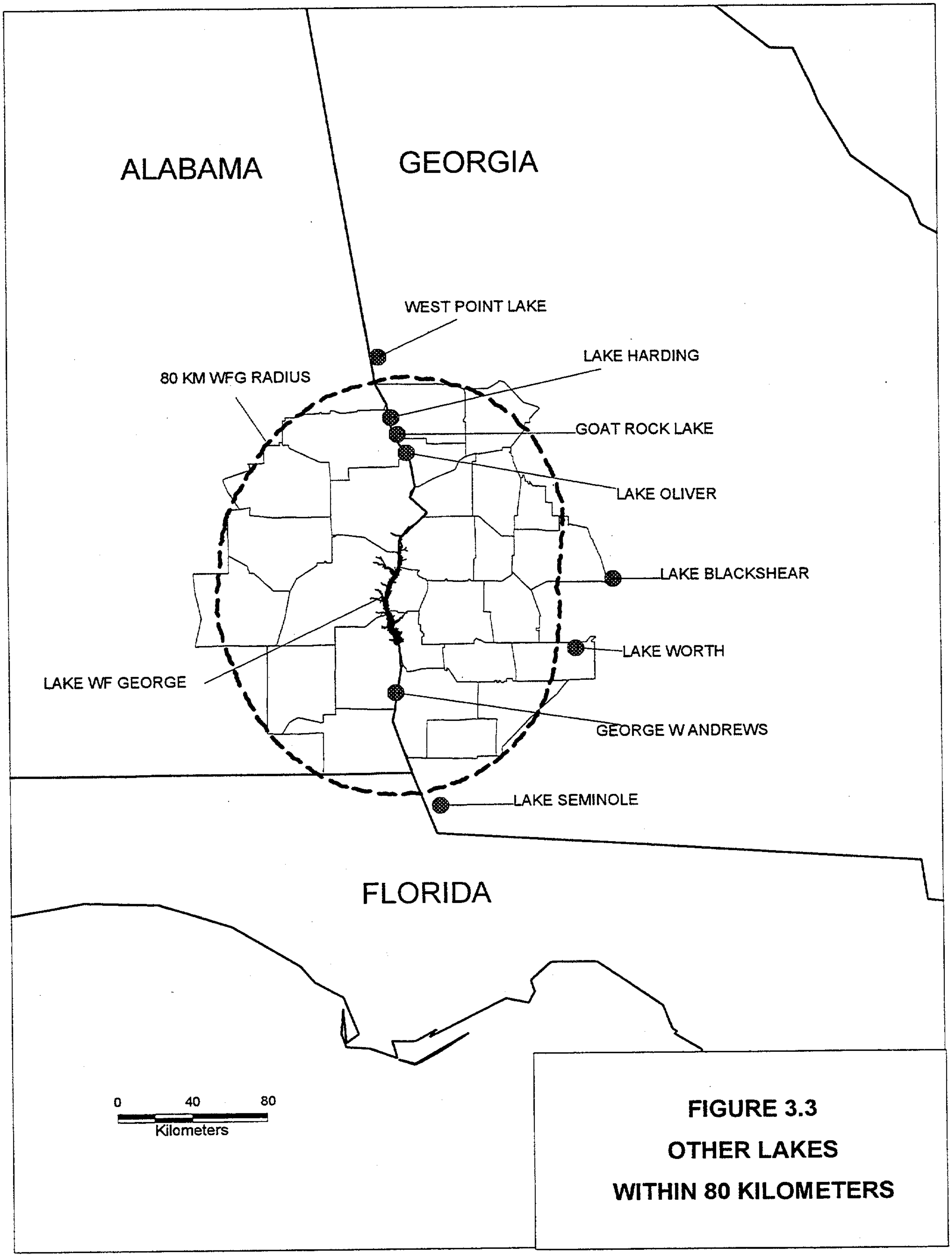


FIGURE 3.3
OTHER LAKES
WITHIN 80 KILOMETERS

TABLE 3.8

LAKES WITHIN OR NEAR AN 80 KM RADIUS

LAKE NAME	AREA hectares(acres)	PRIMARY TRIBUTARIES	LAKE USE CLASSIFICATION(S)
West Point Lake	10,081 (24,911)	Chattahoochee River	Recreation Fishing
Lake Harding	2,368 (5,851)	Chattahoochee River	Fishing Recreation Drinking Water
Goat Rock Lake	381 (941)	Chattahoochee River	Recreation Drinking Water
Lake Oliver	870 (2,150)	Chattahoochee River	Recreation Drinking Water
Lake George W. Andrews	635 (1,570)	Chattahoochee River	Recreation Fishing
Lake Seminole	15,182 (37,515)	Chattahoochee River and Flint River	Fishing Recreation
Lake Blackshear	3,447 (8,518)	Flint River	Recreation
Lake Worth	567 (1,400)	Flint River	Recreation

4.0 POINT AND NONPOINT DISCHARGE SOURCES

4.1 POINT SOURCE INVENTORY

Table 4.1 is a listing of Georgia point source dischargers in the Lake Walter F. George drainage basin downstream from and including the Lake Oliver Dam in Columbus. This list includes three water pollution control plants (WPCP), two in Columbus and one in Lumpkin. The Columbus South WPCP has the largest permitted flow of all listed point sources, 30.0 million gallons per day. Other water pollution control plants include two at the Fort Benning military reservation, one at Florence Marina State Park, and three other small facilities. Three of the point sources are industrial dischargers. Three others are cooling water discharges. Appendix 2 contains copies of NPDES permits issued to the Georgia WPCP dischargers and copies of available facility monitoring data for 1990 and 1991.

TABLE 4.1

GEORGIA POINT SOURCE DISCHARGERS INTO THE WALTER F. GEORGE DRAINAGE BASIN

FACILITY	PERMIT #-GA	WQMU #	COUNTY	FLOW (MGD)	RECEIVING WATERS
Columbus S. WPCP	0020516	1293	Muscogee	30.0	Chattahoochee
Fort Benning Infantry #1	0000973	1293	Chattahoochee	4.60	Chattahoochee
Fort Benning Infantry #2	0000973	1293	Chattahoochee	3.80	Chattahoochee
City of Lumpkin WPCP	0021032	1227	Stewart	0.20	Hodchodkee Ck.
Columbus WPCP Battle Forest	0020532	1225	Muscogee	0.15	Tiger Creek
DNR Florence Marina	0030147	1226	Stewart	.029	Lake W F George
Chattahoochee County	U020224	1225	Chattahoochee	.022	Lake W F George
Harris County High School	0049310	1225	Harris	.016	Chattahoochee
Acres of Shade MHP	0035912	1225	Harris	.002	Stribling Creek
Fieldcrest Mills	0001210	1293	Muscogee	monitor	Chattahoochee
Florida Rock Industries	0046477	1225	Muscogee	monitor	Chattahoochee
Cusseta Water Supply Wells	0048577	1226	Chattahoochee	monitor	Hichitee Creek
Martin Marietta Agg.	0046507	1225	Talbot	monitor	S. Fork Upatoi
Ga. Power, N Highlands	0001538	1293	Muscogee	cooling	Chattahoochee
Ga. Power Oliver Hydro	0001520	1293	Muscogee	cooling	Chattahoochee
Lummus Industries	0046965	1225	Muscogee	cooling	Weracoba Creek

4.2 PHOSPHORUS AND NITROGEN BUDGETS

Nutrient concentration and flow data from river and tributary stations were used to estimate phosphorus and nitrogen loadings to and from the lake (where loading equals concentration multiplied by flow). Concentration and flow were averaged for each month when more than one measurement was available. Monthly data were summed to produce annual loads in kilograms of total phosphorus and total nitrogen. Flow at the upstream river station, CR1, was estimated by adding the measured flow at the Columbus USGS gaging station to point source flows and estimated sub-basin drainage between Columbus and CR1. Nonpoint nutrient loadings from the Hannahatchee Creek, Pataula Creek, and Drag Nasty Creek sub-basins were used to estimate nonpoint nutrient loadings for areas with no data between station CR1 and the WF George Dam. Flows out of the lake, at station CR2, are from daily COE records. Tables 4.2 and 4.3 show tributary nutrient loading calculations for sampled stations.

Nutrient loadings from point sources were calculated in a similar manner. Total nitrogen concentration from water pollution control plants were assumed to be 40 milligrams per liter. Total phosphorus concentrations were estimated at four milligrams per liter for Georgia WPCP's (where phosphate detergents are banned) and eight milligrams per liter for Alabama WPCP's. These numbers were based on data from the Columbus South WPCP, information provided by DNR Municipal Engineering Program staff, and WASTEWATER ENGINEERING Treatment, Disposal, Reuse, *second edition, Metcalf and Eddy, Inc, 1979.* Real monthly average flow data were used when available. Permitted flows were used to estimate loadings from some of the minor point sources.

Table 4.4 summarizes the WF George nutrient budget. About half of the phosphorus loading is from nonpoint nutrient sources from the Chattahoochee River. The majority of point source loading is from the Columbus South WPCP. Half of the phosphorus and one third of the nitrogen is used or otherwise accumulated in the lake.

TABLE 4.2 TRIBUTARY TOTAL PHOSPHORUS LOADINGS					
WFG STATION[1]	FLOW (m^3/month)	TOT P (mg/l)	TOT P (kg/m^3)	P LOADING (kg/month)	P LOADING (kg/year)
HC1	5.46e+06	0.10	1.00e-04	5.46e+02	6.55e+03
PC1	2.01e+07	0.06	6.00e-05	1.21e+03	1.45e+04
DN1	9.00e+05	0.05	5.00e-05	4.50e+01	5.40e+02
CR1	6.33e+08	0.07	7.00e-05	4.43e+04	5.32e+05
CR2	6.84e+08	0.04	4.00e-05	2.74e+04	3.28e+05

TABLE 4.3 TRIBUTARY TOTAL NITROGEN LOADINGS					
WFG STATION	FLOW (m^3/month)	TOT N (mg/l)	TOT N (kg/m^3)	N LOADING (kg/month)	N LOADING (kg/year)
HC1	5.46e+06	0.34	3.40e-04	1.86e+03	2.23e+04
PC1	2.01e+07	0.35	3.50e-04	7.04e+03	8.44e+04
DN1	9.00e+05	0.58	5.80e-04	5.22e+02	6.26e+03
CR1	6.33e+08	0.77	7.70e-04	4.87e+05	5.85e+06
CR2	6.84e+08	0.54	5.40e-04	3.69e+05	4.43e+06

[1]See Table 6.1 for station descriptions; Stations are shown on Figure 1.1 and Figure 6.1

TABLE 4.4

TOTAL PHOSPHORUS AND TOTAL NITROGEN NUTRIENT BUDGET SUMMARY

NUTRIENT SOURCE	FLOW (m3/year)	TOT PHOS (kg/year)	TOT PHOS %	T NITROGEN (kg/year)	T NITROGEN %
POINT SOURCES					
Georgia WPCP's					
Columbus South	3.63e+07	1.45e+05	23.13%	1.45e+06	22.91%
Columbus Battle Forest	2.07e+05	8.29e+02	0.13%	8.29e+03	0.13%
Fort Benning #1	3.08e+06	1.23e+04	1.96%	1.23e+05	1.95%
Fort Benning #2	3.30e+06	1.32e+04	2.11%	1.32e+05	2.09%
Lumpkin	2.76e+05	1.11e+03	0.18%	1.11e+04	0.18%
Florence Marina SP	4.01e+04	1.60e+02	0.03%	1.60e+03	0.03%
Chattahoochee County	3.04e+04	1.22e+02	0.02%	1.22e+03	0.02%
Harris City High School	2.21e+04	8.84e+01	0.01%	8.84e+02	0.01%
Acres of Shade MHP	2.76e+03	1.10e+01	0.00%	1.10e+02	0.00%
Alabama WPCP's					
Phenix City	6.12e+06	4.90e+04	7.82%	2.45e+05	3.88%
Lakepoint Resort SP	4.71e+04	3.77e+02	0.06%	1.88e+03	0.03%
Eufaula	2.15e+06	1.72e+04	2.74%	8.59e+04	1.36%
POINT SOURCE SUB-TOTAL	5.16e+07	2.39e+05	**39.09%**	2.06e+06	**32.57%**
NONPOINT SOURCES					
Chattahoochee River upstream of Bluff Creek	7.59e+09	3.11e+05	49.63%	3.89e+06	61.59%
Other Tributaries and Local Lake Drainage	1.10e+09	6.23e+04	12.58%	3.77e+05	5.97%
NONPOINT SUB-TOTAL	8.69e+09	3.73e+05	**60.91%**	4.27e+06	**67.43%**
TOTAL INPUT	8.74e+09	6.12e+05	100.00%	6.33e+06	100.00%
OUTPUT AT WFG DAM	8.21e+09	3.28e+05	53.56%	4.43e+06	70.01%
NET ACCUMULATION		2.84e+05	**47.66%**	1.90e+06	**29.86%**

4.3 BASIN LAND USE, GEOLOGY, AND SOIL DATA

The Georgia Department of Natural Resources Wildlife Resource Division (WRD) analyzed the WF George Georgia sub-basin for land use, geology, and soils. ERDAS geographic information system (GIS) software was used to perform these analyses. This software used 1990 Landsat satellite imagery to produce raster plots of land usage in six classes: open water, clearcut/pine plantation, agricultural, urban, wetlands, and forest. Georgia geology and soil maps were digitized and integrated into the GIS sub-basin analysis. Digital slope data were also incorporated. Figures 4.1, 4.2, 4.3, and 4.4 are color thematic mappings of these data. The Hannahatchee Creek, Pataula Creek, and Drag Nasty Creek sub-basins were analyzed separately above sampling stations HC1, PC1, and DN1.

Land use data is summarized in Table 4.5. Land uses for the four sub-basins are graphed in Figure 4.5 by percentage. The land uses in the main sub-basin and the Hannahatchee Creek and Pataula Creek sub-basins are generally the same. Nearly three quarters of this land is forested. Agricultural lands and clearcut/pine plantation lands represent most of the remaining land use. The smaller Drag Nasty Creek sub-basin is about half forest and half agriculture or clearcut/pine plantation. Wetlands represent three to four percent of the Georgia sub-basin. The three tributary basins contain no significant urban areas.

Most of the WF George Georgia sub-basin (about 90%) is located in the Coastal Plains physiographic province. Much of this area was formed during the Cretaceous Period (65 to 136 million years ago) when sediments eroded from the Appalachian Mountains and the sea grew to extend to the present fall line. Other parts of this area were formed in the Tertiary and Quarternary Periods (during the last 70 million years). The geology in the Coastal Plains area is a combination of sands, clays, and limestones. Specific geologic regions include the Blufftown, Providence Sand, Tuscaloosa, Nanafalia-Porters Creek-Clayton, Cusseta Sand, and Ripley formations.

FIGURE 4-1
Landcover of the Lake George Watershed

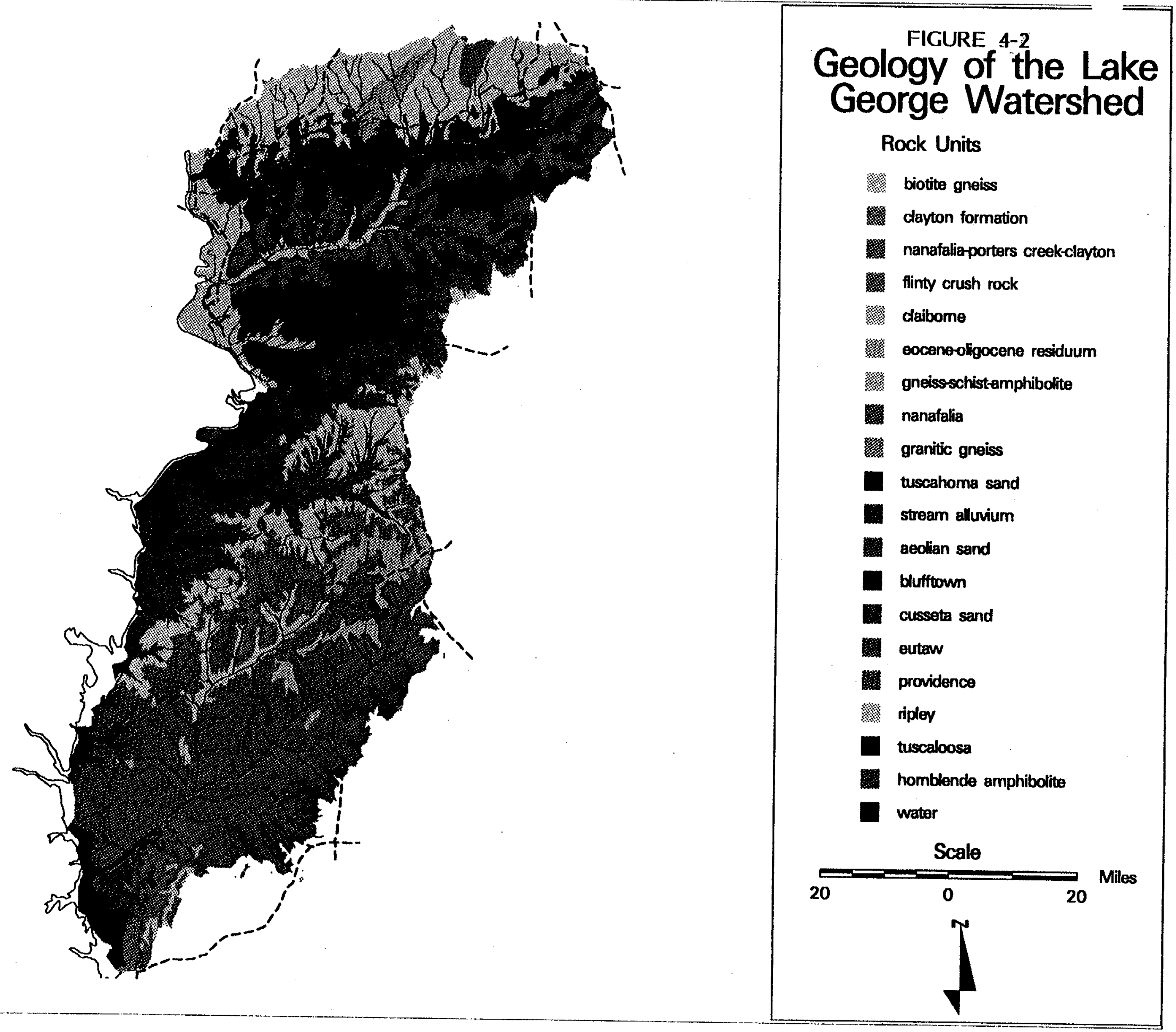


FIGURE 4-2
Geology of the Lake George Watershed
Rock Units
biotite gneiss
clayton formation
nanafalia-porters creek-clayton
flinty crush rock
claiborne
eocene-oligocene residuum
gneiss-schist-amphibolite
nanafalia
granitic gneiss
tuscahoma sand
stream alluvium
aeolian sand
blufftown
cusseta sand
eutaw
providence
ripley
tuscaloosa
hornblende amphibolite
water
Scale
20
0
20
Miles
N

FIGURE 4-3

Soil Associations of the Lake George Watershed

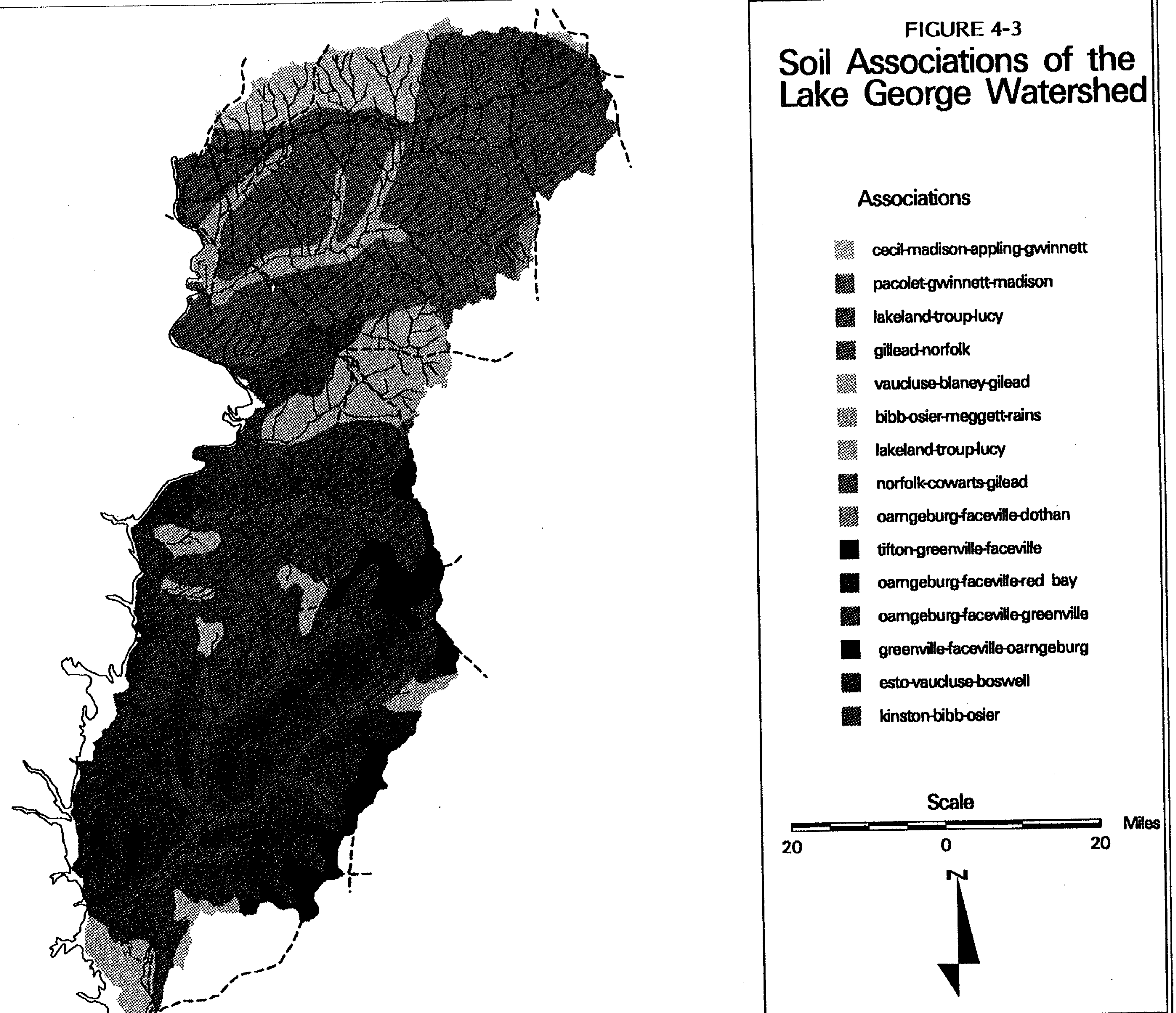


FIGURE 4-4

Slope Classes of the Lake George Watershed

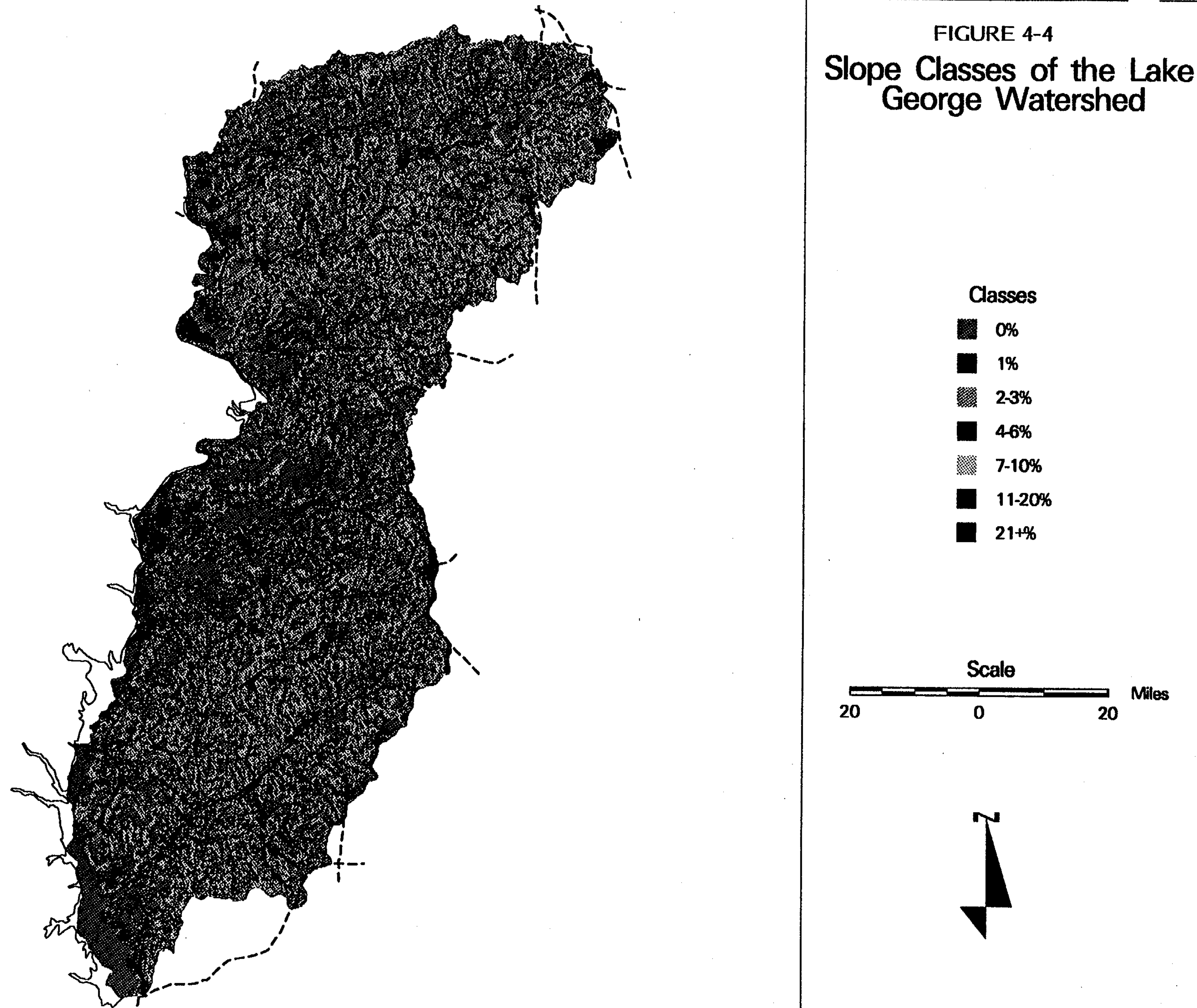


TABLE 4.5
GEORGIA SUB-BASIN LAND USE

MAIN SUB-BASIN

CLASS	ACRES	HECTARES	PERCENT
OPEN WATER	28,487.15	11,528.75	3.2%
CLEARCUT/PINE PLANTATION	95,815.88	38,776.69	10.6%
AGRICULTURAL	148,393.94	60,055.03	16.4%
URBAN	22,232.32	8,997.42	2.5%
WETLANDS	35,238.29	14,260.94	3.9%
FOREST	574,180.69	232,370.92	63.5%
TOTAL	**904,348.27**	365,989.74	100.0%

HANNAHATCHEE CREEK SUB-BASIN

CLASS	ACRES	HECTARES	PERCENT
OPEN WATER	193.53	78.32	0.3%
CLEARCUT/PINE PLANTATION	8,883.84	3,595.29	11.5%
AGRICULTURAL	8,992.65	3,639.33	11.6%
URBAN	246.56	99.78	0.3%
WETLANDS	2,557.39	1,034.98	3.3%
FOREST	56,371.21	22,813.43	73.0%
TOTAL	**77,245.18**	31,261.12	100.0%

PATAULA CREEK SUB-BASIN

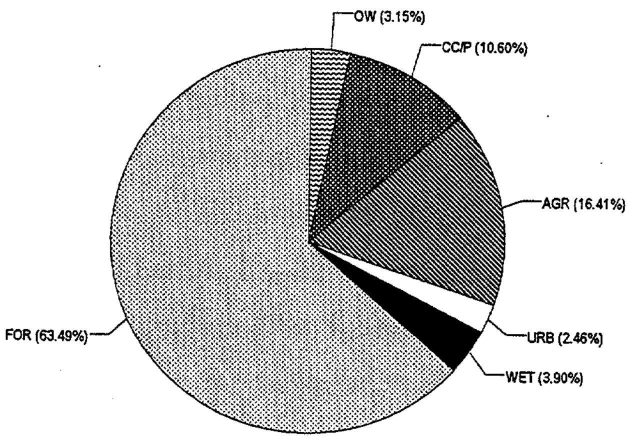
CLASS	ACRES	HECTARES	PERCENT
OPEN WATER	718.32	290.70	0.4%
CLEARCUT/PINE PLANTATION	19,838.84	8,028.78	10.5%
AGRICULTURAL	34,787.19	14,078.37	18.4%
URBAN	427.69	173.08	0.2%
WETLANDS	8,692.38	3,517.81	4.6%
FOREST	124,502.07	50,385.99	65.9%
TOTAL	**188,966.48**	76,474.73	100.0%

DRAG NASTY CREEK SUB-BASIN

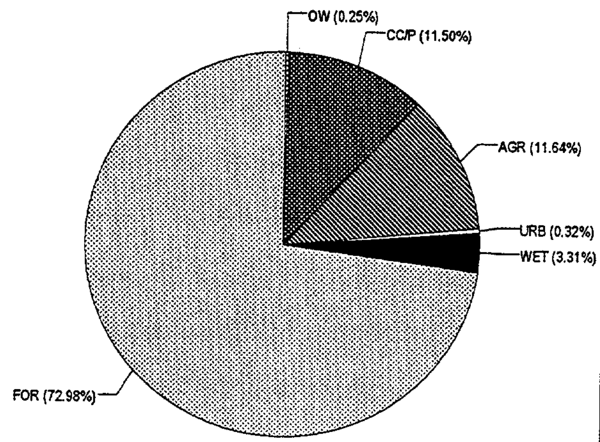
CLASS	ACRES	HECTARES	PERCENT
OPEN WATER	16.30	6.60	0.2%
CLEARCUT/PINE PLANTATION	922.87	373.48	11.3%
AGRICULTURAL	2,751.84	1,113.67	33.8%
URBAN	15.15	6.13	0.2%
WETLANDS	256.20	103.68	3.1%
FOREST	4,185.72	1,693.96	51.4%
TOTAL	**8,148.07**	3,297.52	100.0%

FIGURE 4.5
LAND USE BY CLASS AND SUB-BASIN

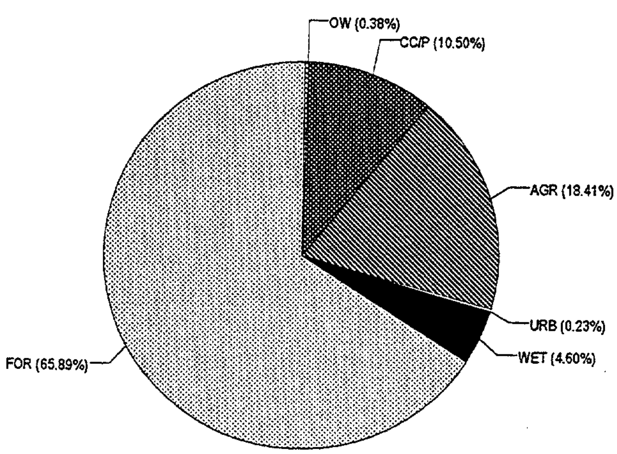
MAIN SUB-BASIN (904,348 ACRES)



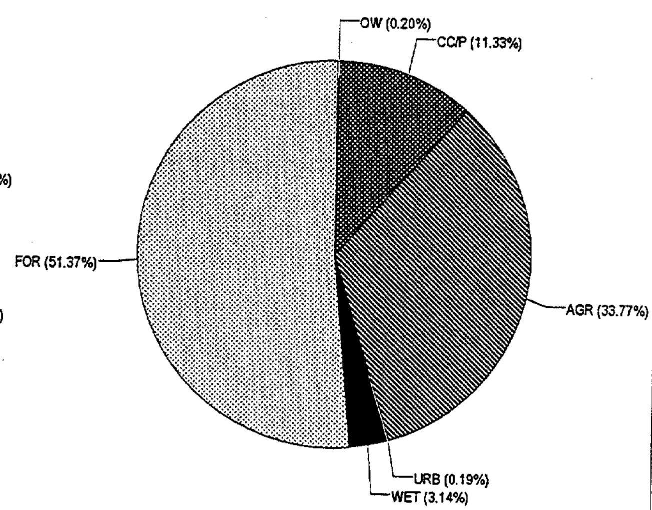
HANNAHATCHEE SUB-BASIN (77,245 ACRES)



PATAULA SUB-BASIN (188,966 ACRES)



DRAG NASTY SUB-BASIN (8,148 ACRES)



CLASSES

OW = OPEN WATER, CC/P = CLEARCUT/PINE PLANTATION, AGR = AGRICULTURAL
URB = URBAN, WET = WETLANDS, FOR = FOREST

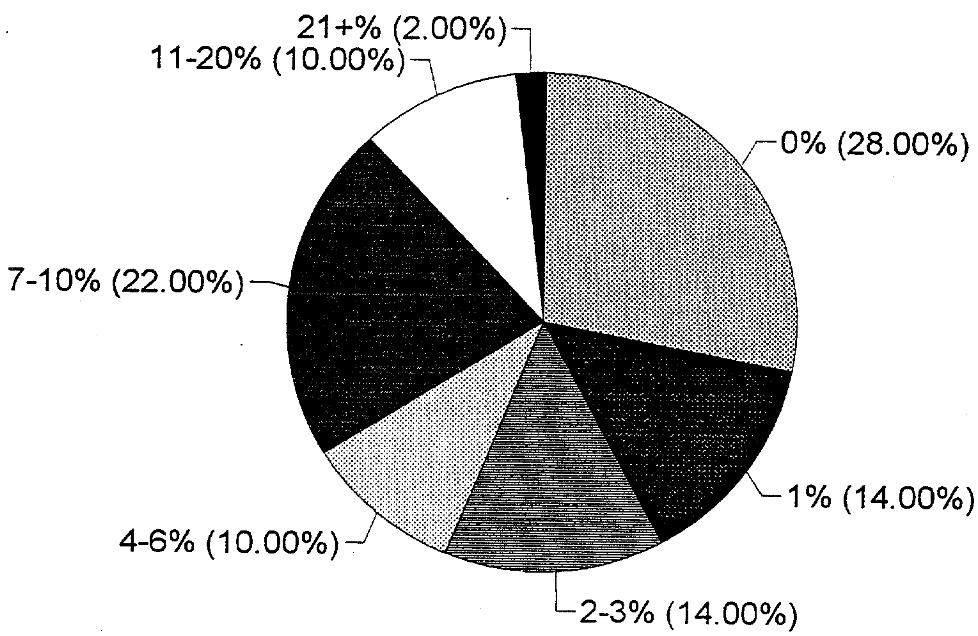
The northernmost section of the Georgia sub-basin is located in the Piedmont Plateau province. The geology in this area is mainly granite, granite gneiss, biotite gneiss, and schist, deposited during the Paleozoic and Precambrian eras (225 million to one billion year ago).

Fifteen soil associations were identified in the WF George Georgia sub-basin. Each association is a combination of two to four of 27 soil series. The northern part of the Georgia sub-basin is part of the Carolina and Georgia Sand Hills soil province. The Sand Hills province is a narrow belt of deep sandy soils that extends from Augusta to Columbus. The topography is rolling to hilly. Most soils in this province are infertile and droughty, best adapted to timber production and pasture grasses. The principal soil association found in this area is Lakeland-Troup-Lucy (26 percent of Georgia sub-basin).

The middle and southern areas of the Georgia sub-basin are in the Southern Coastal Plain soil province. The soils in this province are deep and have a loamy or sandy surface layer, and a loamy or clayey subsoil. These soils are suited for the production of a wide variety of crops including soybeans, corn, peanuts, cotton, tobacco, pecans, and vegetables. Pine timber production is also a major resource. The principal soil association in the this part of the sub-basin is Esto-Vaucluse-Boswell (32 percent of sub-basin).

Figure 4.6 is a graph of slope class distribution in the Georgia sub-basin. Twenty-eight percent of the sub-basin is flat. Only two percent has a slope in excess of 20 percent.

FIGURE 4.6
GEORGIA SUB-BASIN SLOPE DISTRIBUTION



5.0 HISTORICAL WATER QUALITY DATA

5.1 GEORGIA TREND STATION DATA

The Georgia DNR routinely collects water quality data from a network of stations throughout Georgia. These are called trend monitoring stations. Two of these trend monitoring stations are located in the Walter F. George headwaters in the Chattahoochee River; one just downstream of Columbus and one downstream of the Oswichee Creek Confluence (River Mile 137). Data is collected from these stations in cooperation with the City of Columbus. Another trend station coincides with the Phase I Study station LG1 at the Omaha railroad bridge. Field data and water quality samples are collected monthly at these sites. Appendix 3 contains 1990 and 1991 data from these stations.

5.2 GEORGIA DNR LAKE STUDIES

Georgia DNR Study of Nine Georgia Lakes

This study was conducted by the Georgia DNR Environmental Protection Division in the summer of 1979. The purpose of the study was to assess the usefulness of the Carlson Trophic State Index in gaging the trophic condition of Georgia lakes. Data collected was compared to the results of the 1973 National Eutrophication Survey. Samples were collected for chlorophyll *a* and total phosphorus. Water clarity was measured by Secchi disk. Carlson trophic state index data showed that Walter F. George ranked as the fourth most eutrophic lake of those studied, whereas in the 1973 survey it was the third highest for the same group of lakes.

Georgia DNR Major Lake Monitoring Project

Georgia DNR has performed a water quality assessment of twenty-seven publicly owned Georgia lakes during the late spring and summer each year since 1984. This Major Lake Monitoring Project (MLMP) was initiated following the 1980-1981 Georgia Clean Lakes Program Lake Classification Survey. The goal of the MLMP is to obtain water quality data for 27 public lakes with surface areas over 500 acres, and to document the trophic status of each lake using the Carlson trophic state index. Table 5.1 summarizes selected Lake Walter F. George data from the 1980-1981 Clean Lakes Classification Study and the 1984-1990 MLMP studies. The 1980 through 1989 data were collected from the dam pool (station LG7). In 1990 additional data were collected at an upstream station (station LG3).

Clean Lakes Water Quality Assessment Study

In 1989 Georgia DNR applied for and received a federal Clean Lakes Water Quality Assessment grant from the US EPA. This grant was used to gather more detailed information on the trophic status of 16 Georgia lakes including Lake Walter F. George. Carlson trophic state indices determined from Secchi disk transparency and chlorophyll *a* data averaged near 60. Total phosphorus indices were generally higher, averaging 65 to 70. These indices indcated Lake Walter F. George was eutrophic.

5.3 OTHER WATER QUALITY STUDIES

EPA National Eutrophication Survey

During 1973 and 1974 the Environmental Protection Agency (EPA) conducted a study of the Walter F. George Reservoir. The study was part of the National Eutrophication Survey. The national survey was to assess the trophic conditions of major lakes across the nation. The study on Walter F. George Reservoir included four lake stations and fourteen tributary sampling sites. Samples were collected for physical and chemical parameters, phytoplankton, chlorophyll *a*, and algal analysis. At each of the tributary stations, monthly nutrient samples were collected. The results of the study showed that Walter F. George ranked twelfth in total trophic quality when compared to fourteen Georgia lakes using a combination of six parameters. Eleven lakes had a lower mean total phosphorus concentration. The phosphorus loading rate for the year was calculated at 4.54 $g/m^3/yr$. This study recommended that all phosphorus inputs to Walter F. George be minimized to slow the aging process of this waterbody.

TABLE 5.1

MAJOR LAKES MONITORING PROJECT DATA SUMMARY (1980-1990)

	SAMPLE DATES										
PARAMETERS	7/80	7/81	7/84	6/85	5/86	6/87	5/88	7/89	Dam 5/90	US 5/90	Dam 8/90	US 8/90
Conductivity (umhos/cm)	50	69	39	80	71	60	88	71	85	66	82	94
Dissolved Oxygen (mg/l)	7.2	5.9	6.8	8.3	8.6	7.9	10.2	8.6	8.2	9.3	7.8	5.5
pH (std. units)	7.7	7.6	7.3	7.4	8.5	8.6	8.4	8.6	7.0	8.0	7.8	7.4
Turbidity (NTU)	2.7	2.0	3.0	5.0	4.0	5.0	5.0	3.0	5.0			
Alkalinity (mg/l)			19	21	18	24	20	15	16			
Sus. Solids (mg/l)			2	4	6	3	<1	7	4			
BOD 5 (mg/l)			1.7	2.0	1.5	1.0	1.2	2.1	0.6			
F. Coli (MPN/100ml)			20		<20	<3	<3		<3			
Chlorophyll a (ug/l)	18.9	17.2		11	15.5	4.39	21.2	25	4.5	13.7	2.1	3.2
Tot. Phosphorus (mg/l)	0.02	0.02	0.03	<0.02	0.03	<0.02	0.03	0.12	0.03	0.06	0.03	0.03
Diss. Phosphorus (mg/l)			0.02	<0.02	0.03	<0.02	<0.02	0.07	0.02			
TKN (mg/l)			0.3	0.3	0.4	0.7	0.4	1.0	0.2			
Total Ammonia (mg/l)			0.09	0.08	0.07	<0.02	<0.02	<0.03	0.04			
Nitrite + Nitrate (mg/l)			0.02	<0.02	<0.02	<0.02	0.07	<0.02	0.14			
TOC (mg/l)			3.9	4.3	9.9	9.1	3.4	5.4	3.8			
Hardness (mg/l)						33	76	19				
Avg Trophic State Index	53	54		<54	54	<47	56	64	48	61	48	51

Walter F. George Water Quality and Dye Tracer Study

This study was conducted by the Alabama Department of Environmental Management (ADEM) between August and November, 1987, to develop a water quality model of Walter F. George to establish the wasteload allocation for the Mead Paper Corporation Mill in Cottonton, Alabama. ADEM used nineteen stations in the lake and three tributary stations. The water sampling required twenty-four hour composite sampling at the Mead and Eufaula discharges. The other sampling stations were sampled three times a day by collecting a vertical dissolved oxygen and temperature profile. The EPA conducted sediment oxygen demand measurements at six of the stations. A time-of-travel survey was conducted using Rhodamine WT dye. The study was to be concluded before the lake destratified, however, the lake destratified September 22. This was three days after the water quality sampling began.

During 1990 Hydroqual, Incorporated, an environmental consultant, and ADEM co-developed a computer model for evaluating a flow-based permit for Mead's expanded mill. The calibrated model from the 1987 study demonstrated that the water quality standard of 5.0 mg/l would not be achieved even if Mead did not discharge into the river.

6.0 BASELINE LAKE AND TRIBUTARY WATER QUALITY MONITORING

6.1 DATA COLLECTION AND STATION LOCATIONS

A one-year study of current limnological conditions of Lake W.F. George was conducted from November 1990 through October 1991. Water quality samples were collected monthly during the months of November through April and October, and twice per month during the months of May through September. Twelve stations were sampled on each sample date. The sampling station locations are described in Table 6.1 and are shown in Figure 6.1. Stations LG1 through LG7 are lake stations; Stations HC1, PC1, and DN1 are minor tributary stations; and Stations CR1 and CR2 are Chattahoochee River stations upstream and downstream of the lake. Station CR1 is a transitional riverine/lacustrine station, heavily influenced by river flow and discharge from the Walter F. George dam.

Water samples were analyzed for laboratory parameters including nutrients, chlorophyll *a*, fecal coliform bacteria, pH, suspended solids, alkalinity, hardness, turbidity, and conductivity. These parameters are referenced in Table 6.1 as baseline water quality sampling. Lake samples were collected at evenly spaced intervals through the euphotic zone[1] and composited for analyses. Van Dorn samplers were used to collect lake water samples. A LICOR or Kahl Scientific underwater light meter was used to measure euphotic zone depth. Field parameters at lake stations included Secchi disk transparency and water column profile measurements of temperature, dissolved oxygen, pH, and conductivity. Profile measurements were made with Hydrolab multiparameter water quality monitoring instruments at approximate depths of 0.25 meters (subsurface), one-meter intervals from one to six meters, and at two meter intervals from eight meters to the station bottom.

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[1]The euphotic zone is defined as the depth at which 99 percent of the surface light has been absorbed or reflected back towards the surface. The euphotic zone has enough light to support algal growth.

Tributary samples were collected at the lesser of mid-depth or one meter. Samples were analyzed for all baseline water quality parameters except chlorophyll *a*. Stream flow and dissolved oxygen were measured at the tributary stations.

Water and sediment samples were collected from selected lake stations in April 1991 for metal and organic chemical analyses. Phytoplankton samples were collected from selected stations on four dates during the months of January, May, July, and September, 1991. See Table 6.1 for stations chosen for these parameters.

TABLE 6.1 WALTER F. GEORGE SAMPLING STATIONS				
STA NAME	COE RIVER MILE[1]	STATION LOCATION	STORET STA NO.	SAMPLE TYPES[2]
CR1	120.3	Chattahoochee River at Bluff Creek Park, Upstream of Lake	12218701	BWQ, AGP, PHT
LG1	117.3	Lake WF George d/s side of CSX Railway Bridge, Near Omaha, GA	12219001	BWQ, CHL, FSH, SED, OMW
LG2	112.7	Lake WF George off Florence Marina State Park, GA	12219021	BWQ, CHL, SOD, PHT, AGP, DDO
LG3	101.7	Lake WF George at Confluence with Cowikee Creek	12219051	BWQ, CHL, SED, OMW
LG4	94.9	Lake WF George at US Highway 82, Eufaula, AL	12219101	BWQ, CHL, FSH, SED, OMW, PHT, AGP, DDO
LG5	89.5	Lake WF George off Cheneyhatchee Creek Embayment	12219201	BWQ, CHL, SED, OMW, SOD, PHT, AGP, DDO
LG6	82.3	Lake WF George off Pataula Creek Embayment	12219401	BWQ, CHL
LG7	75.4	Lake WF George in Dam Forebay	12219501	BWQ, CHL, FSH, SOD, PHT
CR2	75.0	Chattahoochee River Downstream of WF George Lock and Dam	12219601	BWQ
HC1	Trib Sta	Hannahatchee Creek at Bridge 6 Miles East of Omaha, GA	12218901	BWQ, FLO
DN1	Trib Sta	Drag Nasty Creek at GA Highway 39 Bridge, Upstream Side	12219301	BWQ, FLO
PC1	Trib Sta	Pataula Creek at US Highway 82 Bridge, Upstream Side	12219351	BWQ, FLO

[1]Army Corps of Engineers navigational river miles; All lake stations centered over Chattahoochee River channel

[2]BWQ - baseline water quality, CHL - chlorophyll, SED - organics and metals in sediment, OMW - organics and metals in water, FLO - stream flow, FSH - contaminates in fish, SOD - sediment oxygen demand, PHT - phytoplankton, AGP - algal growth potential, DDO - diel dissolved oxygen

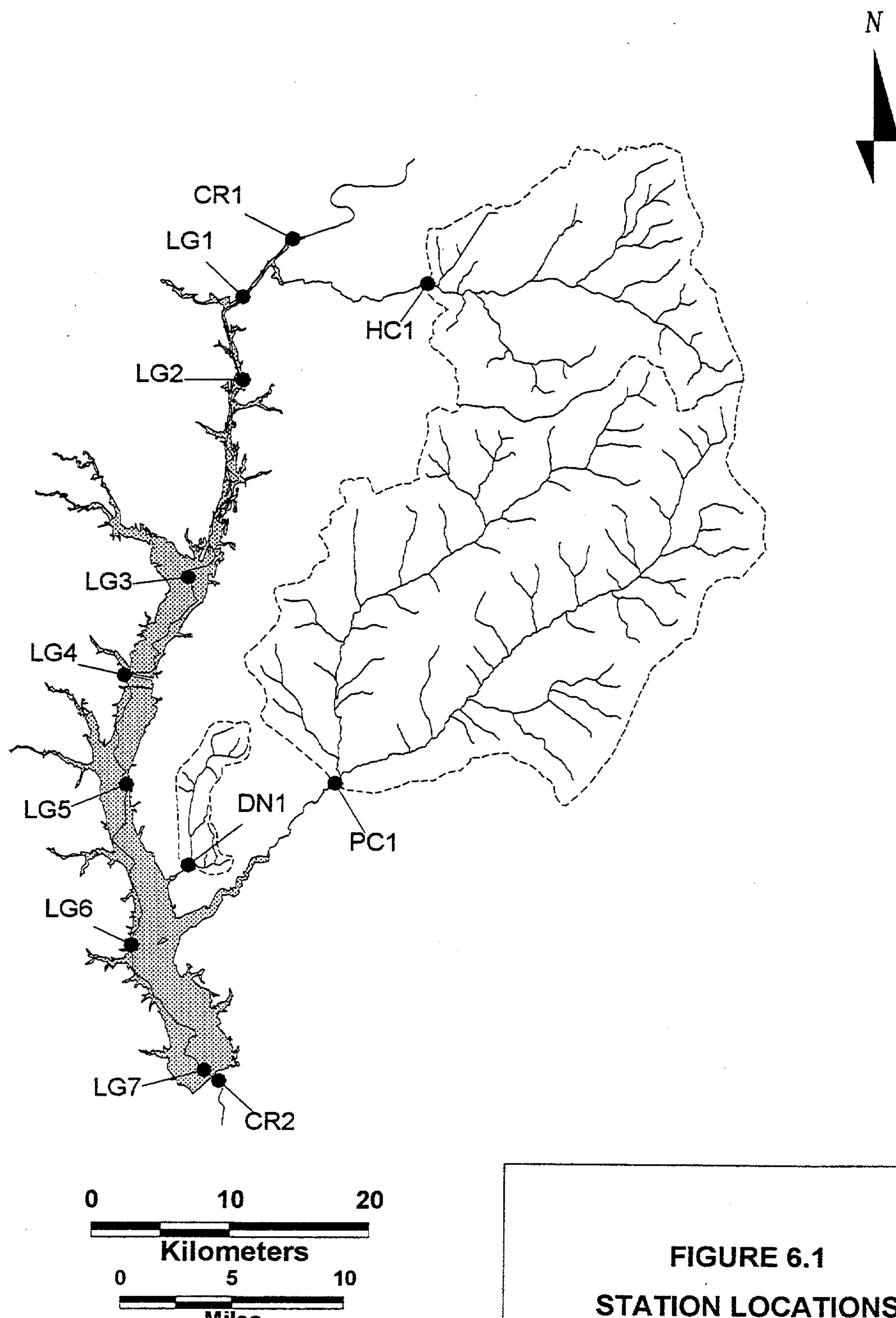


FIGURE 6.1
STATION LOCATIONS

6.2 LAKE ELEVATIONS AND RAINFALL DATA FOR SAMPLE DATES

Table 6.2 summarizes the rainfall and lake elevation data for the study sample dates. Rainfall data comes from three National Weather Service (NWS) stations - Columbus Georgia, Lumkin Georgia, and Eufaula National Wildlife Refuge. These NWS stations are shown with the local Georgia sub-basin and tributary sub-basins in Figure 6.2. Precipitation data in Table 6.2 is an average of data from the three NWS stations summed for the five day period before the sample dates (Table 6.3 shows precipitation data for each NWS station). Lake surface elevation data in Table 6.2 is from COE records of dam pool elevation recorded at 6:00 pm. The data in Table 6.2 indicate the 12 month sampling period represented essentially average rainfall and lake elevation conditions. The annual rainfall was 48.47 inches compared to a 1981-1990 annual average of 48.06 inches. (Table 6.4 summarizes annual rainfall for 1981 through 1990.)

Elevation ranged from a low of 185.89 ft msl on November 14, 1990, to a high of 190.35 ft msl on May 22, 1991. The normal summer pool elevation given by the COE is 190 ft msl. Figure 6.3 is a plot of dam pool elevation by date for the sample year.

TABLE 6.2

AREA PRECIPITATION AND LAKE ELEVATION DATA

SAMPLE DATE	PRECIPITATION[1] (INCHES)	LAKE ELEVATION (FT MSL)
11/14/90	1.33	185.89
12/05/90	0.58	186.04
01/16/91	1.20	188.67
02/13/91	0.01	187.69
03/20/91	0.62	188.35
04/10/91	0.93	189.90
05/08/91	0.72	189.27
05/22/91	0.16	190.35
06/05/91	1.37	190.26
06/19/91	0.09	188.90
07/10/91	1.07	190.27
07/24/91	0.77	190.06
08/07/91	1.08	190.04
08/21/91	0.28	190.10
09/11/91	0.00	187.82
09/25/91	0.37	186.41
10/23/91	0.00	186.72

TOTAL PRECIPITATION FOR SAMPLING YEAR (11/90-10/91) = **48.47 INCHES**
MEAN ANNUAL PRECIPITATION (1981-1990)[2] = **48.06 INCHES**

[1]Sum of the total daily precipitation for the 5 days prior to sampling date, averaged from three National Weather Service Stations: Columbus, Lumpkin, and Eufaula National Wildlife Refuge (See Tables 6.3 and 6.4).

[2]Data from NOAA publications: Georgia Climatological Data (1981-1986) and Hourly Percipitation Data (1987-1990).

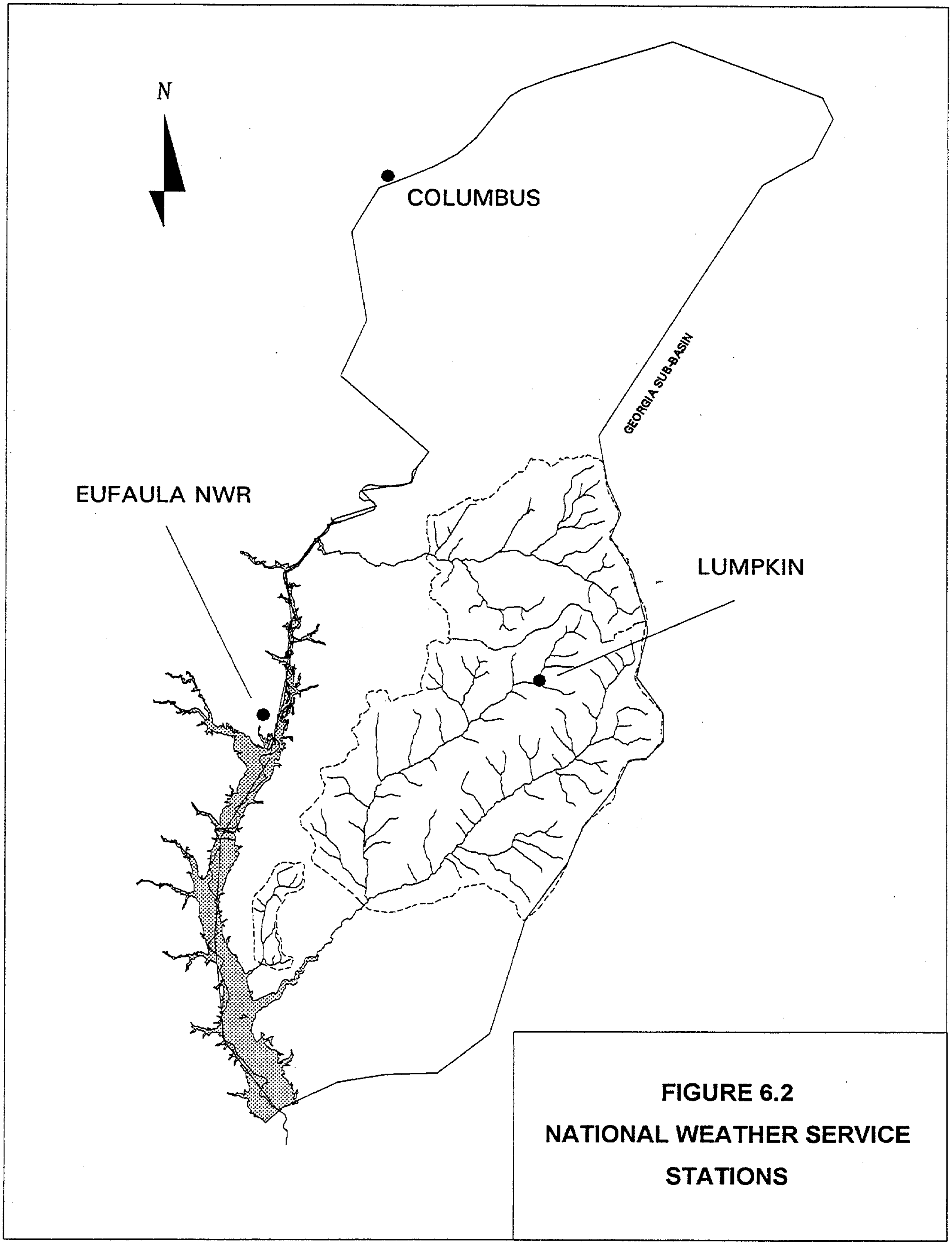


FIGURE 6.2
NATIONAL WEATHER SERVICE STATIONS

TABLE 6.3 RAINFALL FOR 5-DAY PERIOD PRECEEDING SAMPLING DATES LOCAL NATIONAL WEATHER SERVICE STATIONS				
SAMPLE DATE	EUFAULA	COLUMBUS	LUMPKIN	AVGERAGE
11/14/90	1.29[1]	1.40	1.30	1.33
12/05/90	0.45	0.87	0.43	0.58
01/16/91	1.02	1.07	1.50	1.20
02/13/91	0.02	0.00	0.00	0.01
03/20/91	0.81	0.34	0.70	0.62
04/10/91	0.97	0.93	0.90	0.93
05/08/91	0.86	0.79	0.50	0.72
05/22/91	0.30	0.01	N/R[2]	0.16
06/05/91	0.49	2.24	N/R	1.37
06/19/91	0.26	0.00	0.00	0.09
07/10/91	0.90	1.56	0.80	1.07
07/24/91	0.92	0.09	1.30	0.77
08/07/91	0.24	2.89	0.10	1.08
08/21/91	0.54	0.00	0.30	0.28
09/11/91	0.00	0.00	0.00	0.00
09/25/91	0.00	1.11	0.00	0.37
10/23/91	0.01	0.00	0.00	0.00

[1]Rainfall recorded in inches

[2]N/R designates information Not Reported for study period.

TABLE 6.4
TOTAL ANNUAL RAINFALL 1981-1990
LOCAL NATIONAL WEATHER SERVICE STATIONS

YEAR	EUFAULA	COLUMBUS	LUMPKIN	AVERAGE
1981	44.31[1]	47.54	46.58	46.14
1982	54.59	51.62	N/R[2]	53.11
1983	56.16	55.27	58.93	56.79
1984	43.74	38.12	38.37	40.08
1985	53.92	39.65	49.05	47.54
1986	41.92	44.96	43.44	43.44
1987	41.58	48.53	36.54	42.22
1988	46.13	38.32	47.74	44.06
1989	58.68	56.92	N/R	57.80
1990	50.46	48.44	N/R	49.45
TOTALS:	491.49	469.37	320.65	480.63

NATIONAL WEATHER SERVICE STATION DATA

STATION	COUNTY	LATITUDE	LONGITUDE	ELEVATION	YEARS[3]
COLUMBUS	MUSCOGEE	32°31' N	84°57' W	449 FT MSL	45
LUMPKIN	STEWART	32°02' N	84°47' W	570 FT MSL	71
EUFAULA	BARBOUR-AL	32°00' N	85°05' W	200 FT MSL	20

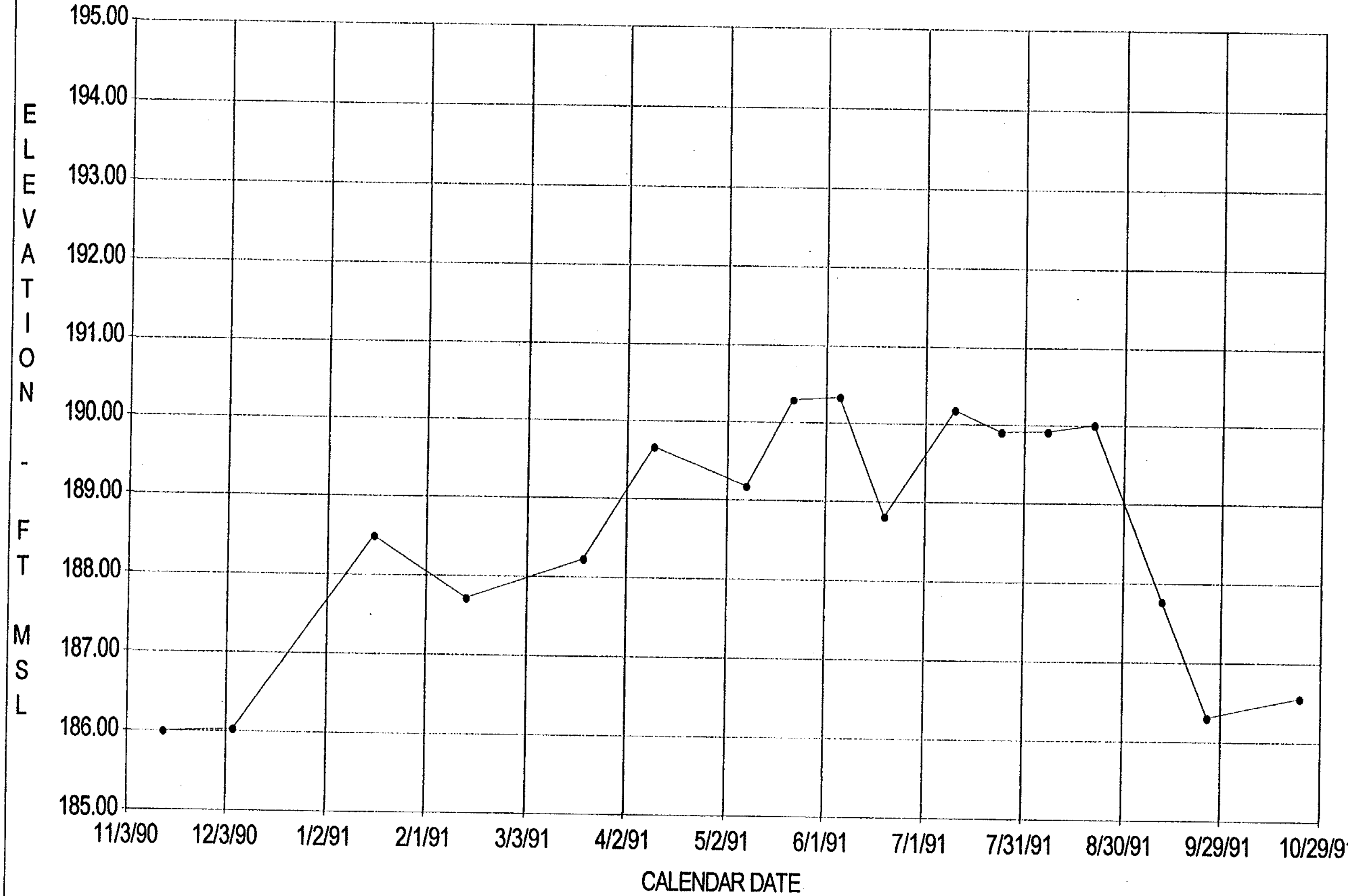
[1]Rainfall recorded in inches

[2]N/R designates information Not Reported for that year

[3]Years station has reported data

FIGURE 6.3

LAKE ELEVATION ON SAMPLE DATES



7.0 CURRENT LAKE WATER QUALITY DATA

Lake water quality data collected during the Phase I sampling is presented in this chapter. Analyses of some parameters are complicated when results were reported as less than the applicable laboratory detection limit. Generally a reported value of less than the detection limit implies a low value that does not cause concern. To simplify the computer processing of report data, "less than" values are treated here as equal to the detection limit, unless otherwise noted. *For example the average of <0.02 and 0.04 would be computed as 0.03.* Appendix 4 data summaries contain data as reported by the laboratory with less than detectable concentrations noted.

7.1 NUTRIENT DATA

Nitrogen and phosphorus are nutrients required to support plant growth. However, excess lake nutrient levels can drive algal growth to nuisance levels. The balance of phosphorus to nitrogen is an important determinant of how nutrients affect algal productivity. Nitrogen concentrations normally exceed phosphorus concentrations by a factor of ten or more. Algal growth is optimum when the ratio of nitrogen to phosphorus is in the range of 7 to 15. When the nitrogen to phosphorus ratio exceeds 15, phosphorus is in short supply, limiting algal growth. Increased phosphorus loading from point and nonpoint sources can alter this situation, making nitrogen the limiting nutrient. In general, phosphorus is the limiting nutrient in Georgia lakes.

Lake phosphorus concentrations were measured as total phosphorus and dissolved (reactive) phosphorus, both reported as mg/l elemental phosphorus. Dissolved phosphorus is the form most readily available for uptake by algae. Nitrogen concentrations were measured as ammonia *or ammonium* (NH_3), total Kjeldahl nitrogen (TKN), and nitrite/nitrate nitrogen (NO_3+NO_2), with concentrations of each parameter expressed as mg/l elemental nitrogen. Total nitrogen is calculated by summing TKN (organic and reduced nitrogen, including NH_3) and NO_3+NO_2.

Table 7.1 contains all lake total phosphorus data and Table 7.2 contains all lake total nitrogen data. These data are graphed by station average in Figure 7.1. Total phosphorus concentrations ranged from 0.02 to 0.15 mg/l, with a mean concentration of 0.06 and a standard deviation of 0.02 mg/l. *(Reminder: <0.02 data treated as 0.02)* Total nitrogen concentrations ranged from 0.13 to 1.96 mg/l, with a mean concentration of 0.67 and a standard deviation of 0.27 mg/l. Nutrients are generally higher in the upstream stations. Phosphorus decreases significantly in the mid-lake stations. Nitrogen is seen to decrease downstream at LG6 and LG7. Total nitrogen to total phosphorus ratios ranged from 8.54 to 49.0, with a mean ratio of 14.1 and a standard deviation of 8.54. (Nutrient ratios range in the transition area between co-limiting and phosphorus limiting. See section 7.5 algal growth potential test data.)

TABLE 7.1

TOTAL PHOSPHORUS (mg/l)

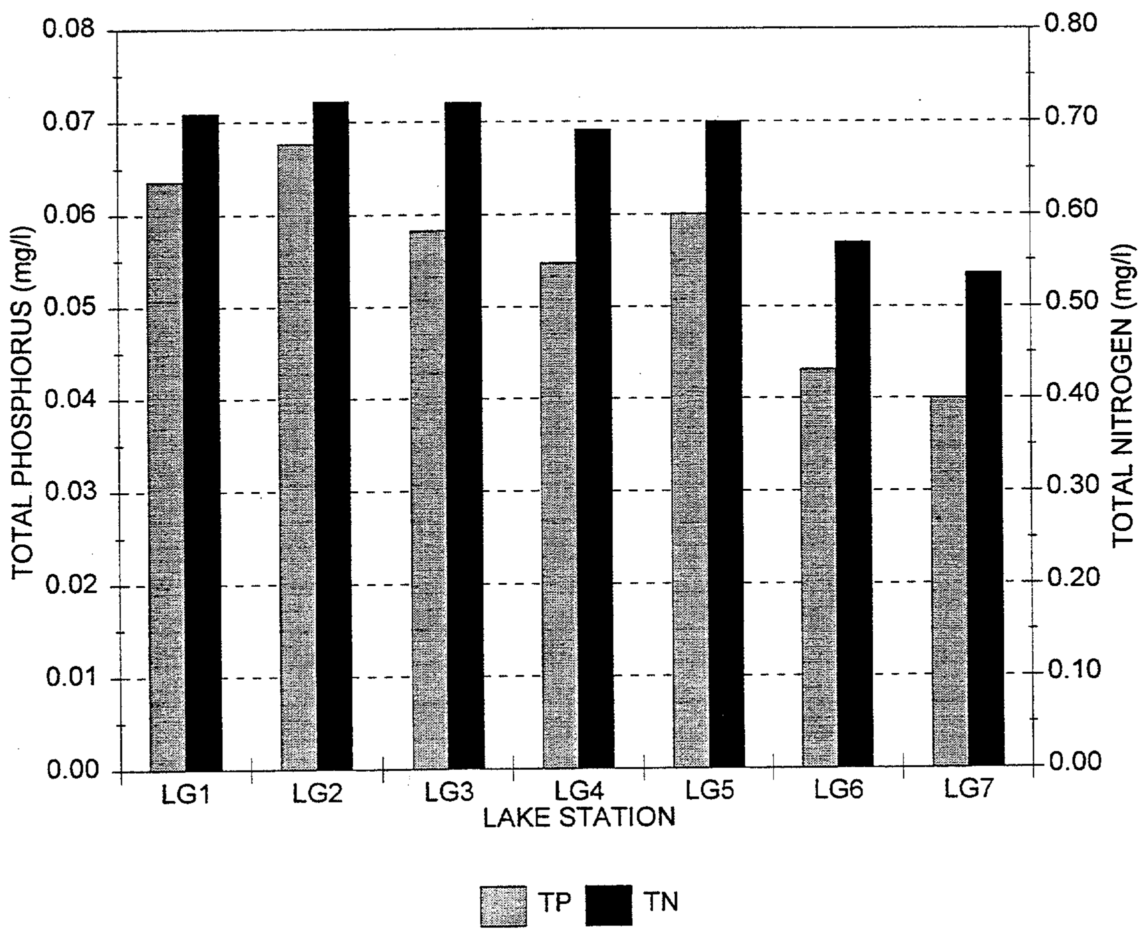
STATION	DATE	TOT PHOS	STATION	DATE	TOT PHOS	STATION	DATE	TOT PHOS
LG1	14-Nov-90	0.04	LG3	10-Apr-91	0.05	LG5	10-Jul-91	0.09
LG1	05-Dec-90	0.1	LG3	08-May-91	0.09	LG5	24-Jul-91	0.03
LG1	16-Jan-91	0.1	LG3	22-May-91	0.06	LG5	07-Aug-91	0.02
LG1	13-Feb-91	0.06	LG3	05-Jun-91	0.06	LG5	21-Aug-91	0.05
LG1	20-Mar-91	0.06	LG3	19-Jun-91	0.06	LG5	11-Sep-91	0.03
LG1	10-Apr-91	0.06	LG3	10-Jul-91	0.08	LG5	25-Sep-91	0.05
LG1	08-May-91	0.11	LG3	24-Jul-91	0.03	LG5	23-Oct-91	0.07
LG1	22-May-91	0.08	LG3	07-Aug-91	0.04	LG6	14-Nov-90	0.03
LG1	05-Jun-91	0.06	LG3	21-Aug-91	0.02	LG6	05-Dec-90	0.04
LG1	19-Jun-91	0.06	LG3	11-Sep-91	0.04	LG6	16-Jan-91	0.05
LG1	10-Jul-91	0.05	LG3	25-Sep-91	0.07	LG6	20-Mar-91	0.05
LG1	24-Jul-91	0.03	LG3	23-Oct-91	0.05	LG6	10-Apr-91	0.03
LG1	07-Aug-91	0.02	LG4	14-Nov-90	0.04	LG6	08-May-91	0.06
LG1	21-Aug-91	0.06	LG4	05-Dec-90	0.07	LG6	22-May-91	0.04
LG1	11-Sep-91	0.06	LG4	16-Jan-91	0.06	LG6	05-Jun-91	0.06
LG1	25-Sep-91	0.07	LG4	13-Feb-91	0.06	LG6	19-Jun-91	0.03
LG1	23-Oct-91	0.06	LG4	20-Mar-91	0.06	LG6	10-Jul-91	0.04
LG2	14-Nov-90	0.05	LG4	10-Apr-91	0.04	LG6	24-Jul-91	0.03
LG2	05-Dec-90	0.09	LG4	08-May-91	0.07	LG6	07-Aug-91	0.04
LG2	16-Jan-91	0.11	LG4	22-May-91	0.05	LG6	21-Aug-91	0.02
LG2	13-Feb-91	0.07	LG4	05-Jun-91	0.12	LG6	11-Sep-91	0.03
LG2	20-Mar-91	0.04	LG4	19-Jun-91	0.05	LG6	25-Sep-91	0.06
LG2	10-Apr-91	0.09	LG4	10-Jul-91	0.06	LG6	23-Oct-91	0.08
LG2	08-May-91	0.1	LG4	24-Jul-91	0.03	LG7	14-Nov-90	0.02
LG2	22-May-91	0.08	LG4	07-Aug-91	0.02	LG7	05-Dec-90	0.03
LG2	05-Jun-91	0.04	LG4	21-Aug-91	0.05	LG7	16-Jan-91	0.07
LG2	19-Jun-91	0.07	LG4	11-Sep-91	0.03	LG7	20-Mar-91	0.04
LG2	10-Jul-91	0.05	LG4	25-Sep-91	0.06	LG7	10-Apr-91	0.03
LG2	24-Jul-91	0.03	LG4	23-Oct-91	0.06	LG7	08-May-91	0.05
LG2	07-Aug-91	0.06	LG5	14-Nov-90	0.08	LG7	22-May-91	0.07
LG2	21-Aug-91	0.05	LG5	05-Dec-90	0.07	LG7	05-Jun-91	0.1
LG2	11-Sep-91	0.05	LG5	16-Jan-91	0.06	LG7	19-Jun-91	0.02
LG2	25-Sep-91	0.05	LG5	13-Feb-91	0.06	LG7	10-Jul-91	0.04
LG2	23-Oct-91	0.12	LG5	20-Mar-91	0.15	LG7	24-Jul-91	0.03
LG3	14-Nov-90	0.08	LG5	10-Apr-91	0.04	LG7	07-Aug-91	0.02
LG3	05-Dec-90	0.07	LG5	08-May-91	0.07	LG7	21-Aug-91	0.02
LG3	16-Jan-91	0.1	LG5	22-May-91	0.08	LG7	11-Sep-91	0.02
LG3	13-Feb-91	0.05	LG5	05-Jun-91	0.04	LG7	25-Sep-91	0.04
LG3	20-Mar-91	0.04	LG5	19-Jun-91	0.03	LG7	23-Oct-91	0.04

TABLE 7.2

TOTAL NITROGEN (mg/l)

STATION	DATE	TOTAL N	STATION	DATE	TOTAL N	STATION	DATE	TOTAL N
LG1	14-Nov-90	1.07	LG3	10-Apr-91	0.51	LG5	10-Jul-91	0.76
LG1	05-Dec-90	0.93	LG3	08-May-91	0.64	LG5	24-Jul-91	0.46
LG1	16-Jan-91	1.13	LG3	22-May-91	0.60	LG5	07-Aug-91	0.58
LG1	13-Feb-91	0.84	LG3	05-Jun-91	0.68	LG5	21-Aug-91	0.57
LG1	20-Mar-91	0.76	LG3	19-Jun-91	0.81	LG5	11-Sep-91	0.54
LG1	10-Apr-91	0.61	LG3	10-Jul-91	0.94	LG5	25-Sep-91	0.34
LG1	08-May-91	0.71	LG3	24-Jul-91	0.53	LG5	23-Oct-91	0.52
LG1	22-May-91	0.66	LG3	07-Aug-91	0.62	LG6	14-Nov-90	0.77
LG1	05-Jun-91	0.72	LG3	21-Aug-91	0.37	LG6	05-Dec-90	0.47
LG1	19-Jun-91	0.47	LG3	11-Sep-91	0.79	LG6	16-Jan-91	0.78
LG1	10-Jul-91	0.37	LG3	25-Sep-91	0.60	LG6	20-Mar-91	0.58
LG1	24-Jul-91	0.67	LG3	23-Oct-91	0.60	LG6	10-Apr-91	0.90
LG1	07-Aug-91	0.50	LG4	14-Nov-90	1.32	LG6	08-May-91	0.49
LG1	21-Aug-91	0.54	LG4	05-Dec-90	0.70	LG6	22-May-91	0.53
LG1	11-Sep-91	0.65	LG4	16-Jan-91	0.97	LG6	05-Jun-91	0.83
LG1	25-Sep-91	0.77	LG4	13-Feb-91	0.74	LG6	19-Jun-91	1.16
LG1	23-Oct-91	0.66	LG4	20-Mar-91	0.60	LG6	10-Jul-91	0.15
LG2	14-Nov-90	0.99	LG4	10-Apr-91	0.43	LG6	24-Jul-91	0.57
LG2	05-Dec-90	1.02	LG4	08-May-91	0.45	LG6	07-Aug-91	0.53
LG2	16-Jan-91	1.09	LG4	22-May-91	0.57	LG6	21-Aug-91	0.17
LG2	13-Feb-91	0.89	LG4	05-Jun-91	0.85	LG6	11-Sep-91	0.53
LG2	20-Mar-91	0.67	LG4	19-Jun-91	0.84	LG6	25-Sep-91	0.29
LG2	10-Apr-91	0.60	LG4	10-Jul-91	0.90	LG6	23-Oct-91	0.36
LG2	08-May-91	0.69	LG4	24-Jul-91	0.30	LG7	14-Nov-90	0.43
LG2	22-May-91	0.65	LG4	07-Aug-91	0.95	LG7	05-Dec-90	0.31
LG2	05-Jun-91	0.82	LG4	21-Aug-91	0.32	LG7	16-Jan-91	0.60
LG2	19-Jun-91	0.55	LG4	11-Sep-91	0.69	LG7	20-Mar-91	0.62
LG2	10-Jul-91	0.67	LG4	25-Sep-91	0.61	LG7	10-Apr-91	0.69
LG2	24-Jul-91	0.64	LG4	23-Oct-91	0.51	LG7	08-May-91	0.41
LG2	07-Aug-91	0.64	LG5	14-Nov-90	0.76	LG7	22-May-91	0.55
LG2	21-Aug-91	0.43	LG5	05-Dec-90	0.82	LG7	05-Jun-91	0.69
LG2	11-Sep-91	0.55	LG5	16-Jan-91	1.13	LG7	19-Jun-91	0.74
LG2	25-Sep-91	0.77	LG5	13-Feb-91	0.96	LG7	10-Jul-91	0.26
LG2	23-Oct-91	0.61	LG5	20-Mar-91	0.67	LG7	24-Jul-91	0.22
LG3	14-Nov-90	1.06	LG5	10-Apr-91	0.89	LG7	07-Aug-91	0.42
LG3	05-Dec-90	0.85	LG5	08-May-91	0.55	LG7	21-Aug-91	0.22
LG3	16-Jan-91	1.30	LG5	22-May-91	0.54	LG7	11-Sep-91	0.33
LG3	13-Feb-91	0.77	LG5	05-Jun-91	0.46	LG7	25-Sep-91	0.13
LG3	20-Mar-91	0.58	LG5	19-Jun-91	1.35	LG7	23-Oct-91	1.96

FIGURE 7.1
LAKE NUTRIENTS



7.2 CHLOROPHYLL DATA

Chlorophyll *a* is a pigment found in all green plants. As a water quality parameter it is used to measure algal productivity. Table 7.3 contains all chlorophyll *a* data in order of station and sample date.

Figure 7.2 is a graph of chlorophyll *a* data showing average, minimum, and maximum values for each lake station. Chlorophyll values are seen to increase from the upstream stations to Station LG4. LG4 is the first station after the lake widens into the mid-lake area. Suspended solids in the upstream stations have dropped out and the channel velocities have slowed, providing light and time for algal growth. The decrease from LG4 to LG5 is likely due to diminished nutrient levels.

Figure 7.3 is a bar graph of chlorophyll *a* data by month for Stations LG4 and LG7 (mid-lake and dam pool). Each datum represents one or two sample events for the given month. LG7 was not sampled in February 1991.

Note that chlorophyll *a* values decrease from November to February. In March a significant increase is noted with the coming of spring. Chlorophyll levels then rise and fall during the growing season. From November to April the mid-lake station data are significantly higher than the dam pool data. This may be due to deeper depths in the dam pool and the associated longer spring warming period.

TABLE 7.3

CHLOROPHYLL a (µg/l)

STATION	DATE	CHLOR a	STATION	DATE	CHLOR a	STATION	DATE	CHLOR a
LG1	14-Nov-90	1.8	LG3	08-May-91	7.1	LG5	23-Jul-91	10.0
LG1	05-Dec-90	3.7	LG3	22-May-91	5.3	LG5	07-Aug-91	16.9
LG1	13-Feb-91	2.4	LG3	05-Jun-91	14.3	LG5	21-Aug-91	12.5
LG1	20-Mar-91	5.7	LG3	19-Jun-91	13.1	LG5	11-Sep-91	13.9
LG1	10-Apr-91	6.2	LG3	10-Jul-91	17.8	LG5	24-Sep-91	15.0
LG1	08-May-91	2.8	LG3	23-Jul-91	16.7	LG5	23-Oct-91	16.0
LG1	22-May-91	3.2	LG3	07-Aug-91	0.3	LG6	14-Nov-90	8.3
LG1	05-Jun-91	4.4	LG3	21-Aug-91	17.5	LG6	05-Dec-90	7.5
LG1	19-Jun-91	13.4	LG3	11-Sep-91	13.6	LG6	16-Jan-91	3.1
LG1	23-Jul-91	9.4	LG3	24-Sep-91	7.8	LG6	20-Mar-91	18.7
LG1	07-Aug-91	10.0	LG3	23-Oct-91	6.5	LG6	10-Apr-91	6.2
LG1	21-Aug-91	10.3	LG4	14-Nov-90	26.3	LG6	08-May-91	25.0
LG1	11-Sep-91	9.0	LG4	05-Dec-90	12.2	LG6	22-May-91	4.2
LG1	24-Sep-91	6.3	LG4	16-Jan-91	6.0	LG6	05-Jun-91	5.9
LG1	23-Oct-91	3.7	LG4	13-Feb-91	4.2	LG6	19-Jun-91	13.4
LG2	14-Nov-90	2.6	LG4	20-Mar-91	18.0	LG6	10-Jul-91	19.3
LG2	05-Dec-90	3.9	LG4	10-Apr-91	14.1	LG6	23-Jul-91	14.1
LG2	16-Jan-91	1.5	LG4	08-May-91	12.9	LG6	07-Aug-91	19.0
LG2	13-Feb-91	1.9	LG4	22-May-91	13.5	LG6	21-Aug-91	12.8
LG2	20-Mar-91	4.5	LG4	05-Jun-91	13.7	LG6	11-Sep-91	14.2
LG2	10-Apr-91	5.7	LG4	19-Jun-91	18.3	LG6	24-Sep-91	13.5
LG2	08-May-91	3.4	LG4	10-Jul-91	19.7	LG6	23-Oct-91	13.3
LG2	22-May-91	5.2	LG4	23-Jul-91	15.0	LG7	14-Nov-90	9.1
LG2	05-Jun-91	4.6	LG4	07-Aug-91	14.7	LG7	05-Dec-90	7.4
LG2	19-Jun-91	12.3	LG4	21-Aug-91	9.9	LG7	16-Jan-91	1.5
LG2	10-Jul-91	8.4	LG4	11-Sep-91	14.2	LG7	20-Mar-91	12.0
LG2	23-Jul-91	10.7	LG4	24-Sep-91	18.0	LG7	10-Apr-91	8.1
LG2	07-Aug-91	7.0	LG4	23-Oct-91	18.1	LG7	08-May-91	13.6
LG2	21-Aug-91	12.6	LG5	14-Nov-90	10.5	LG7	22-May-91	13.5
LG2	11-Sep-91	12.3	LG5	05-Dec-90	11.4	LG7	05-Jun-91	8.0
LG2	24-Sep-91	8.8	LG5	16-Jan-91	7.1	LG7	19-Jun-91	15.2
LG2	23-Oct-91	3.9	LG5	20-Mar-91	14.7	LG7	10-Jul-91	20.0
LG3	14-Nov-90	4.4	LG5	10-Apr-91	11.0	LG7	23-Jul-91	15.1
LG3	05-Dec-90	10.2	LG5	08-May-91	8.8	LG7	07-Aug-91	13.7
LG3	16-Jan-91	1.8	LG5	22-May-91	3.2	LG7	21-Aug-91	13.1
LG3	13-Feb-91	5.8	LG5	05-Jun-91	7.9	LG7	11-Sep-91	19.1
LG3	20-Mar-91	9.1	LG5	19-Jun-91	11.5	LG7	24-Sep-91	17.8
LG3	10-Apr-91	15.0	LG5	10-Jul-91	11.2	LG7	23-Oct-91	17.6

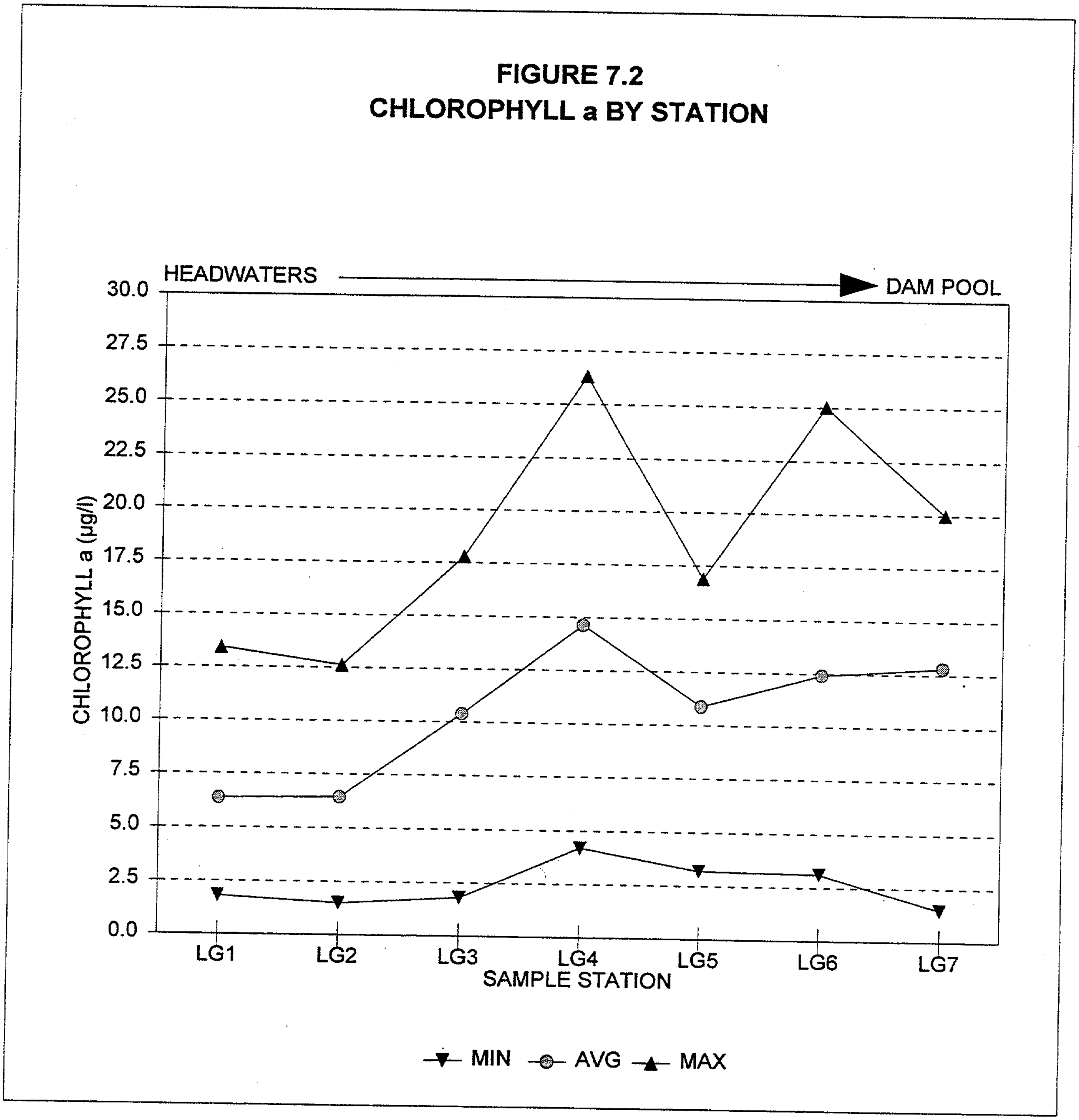
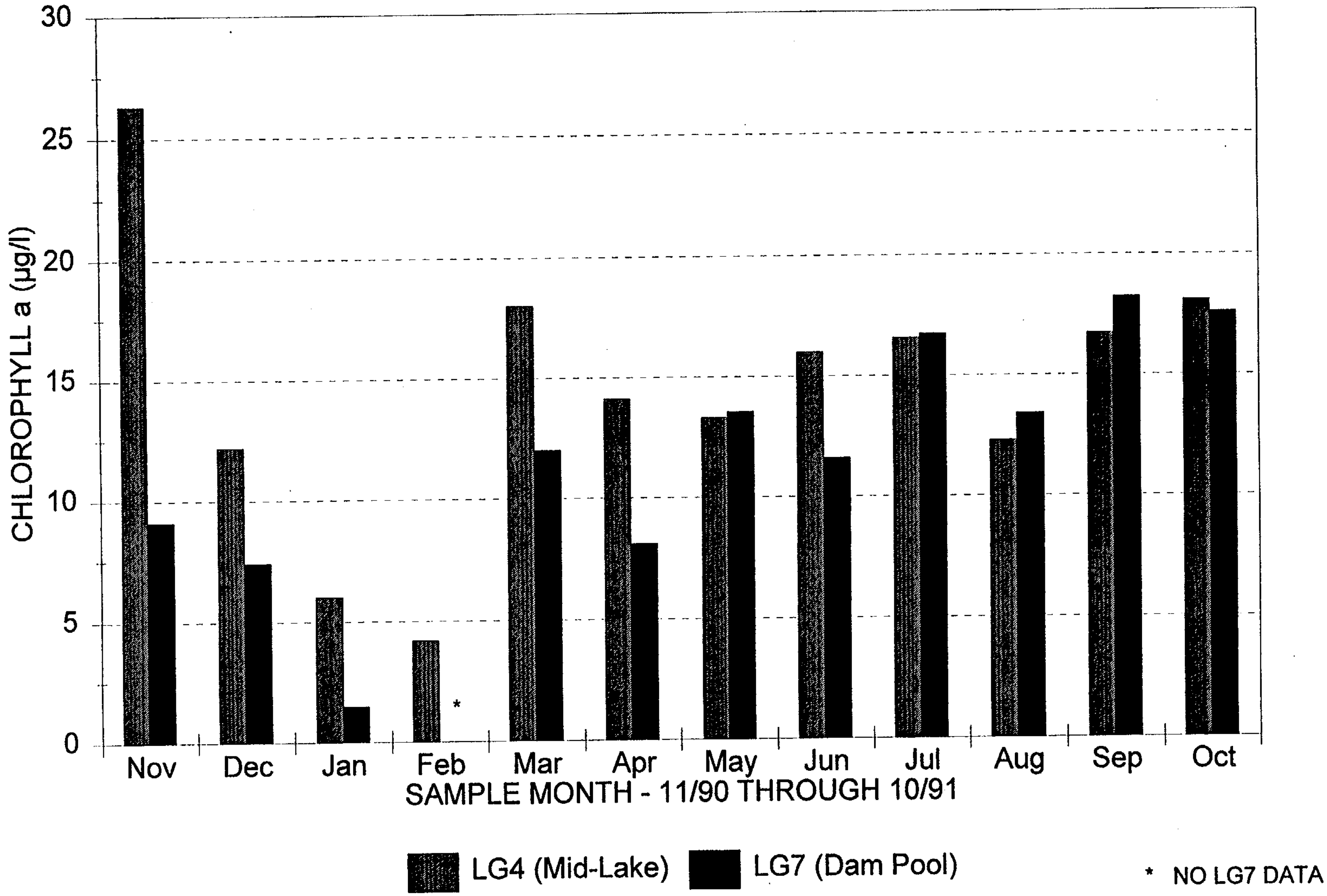


FIGURE 7.2
CHLOROPHYLL a BY STATION
HEADWATERS
DAM POOL
CHLOROPHYLL a (µg/l)
30.0
27.5
25.0
22.5
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
LG1
LG2
LG3
LG4
LG5
LG6
LG7
SAMPLE STATION
MIN
AVG
MAX

FIGURE 7.3
MONTHLY AVG CHLOROPHYLL a AT LG4 & LG7



7.3 SECCHI TRANSPARENCY DATA

Secchi disk transparency is a simple measurement of surface water clarity. The measurement is made by lowering a 20-cm diameter disk (colored in alternating black and white quadrants, attached to a calibrated chain) into the water until it can no longer be seen, then pulling the disk back up to the point it can just be distinguished from the background water. The depth, measured on the chain to the nearest tenth of a meter, is recorded as the Secchi disk transparency. Lake transparency is primarily reduced by the presence of suspended solids and algae. The combination of Secchi depth and water color can provide a quick analysis of water quality. Swimming and other water contact recreation can be impaired when Secchi transparencies fall below one meter.

The 117 lake Secchi disk transparency measurements made in this study are shown in Table 7.4. Measurements ranged between 0.5 and 2.2 meters, with a mean transparency of 1.1 and a standard deviation of 0.4 meters. Figure 7.4 is a graph of Secchi disk transparency data by station, showing minimum, average, and maximum depths for each station. Upstream transparencies tended to be lower with less variation. The maximum transparency was measured in the dam pool during June (in June the lake is stratified, reducing suspended sediments, and algal growth is not yet at its peak).

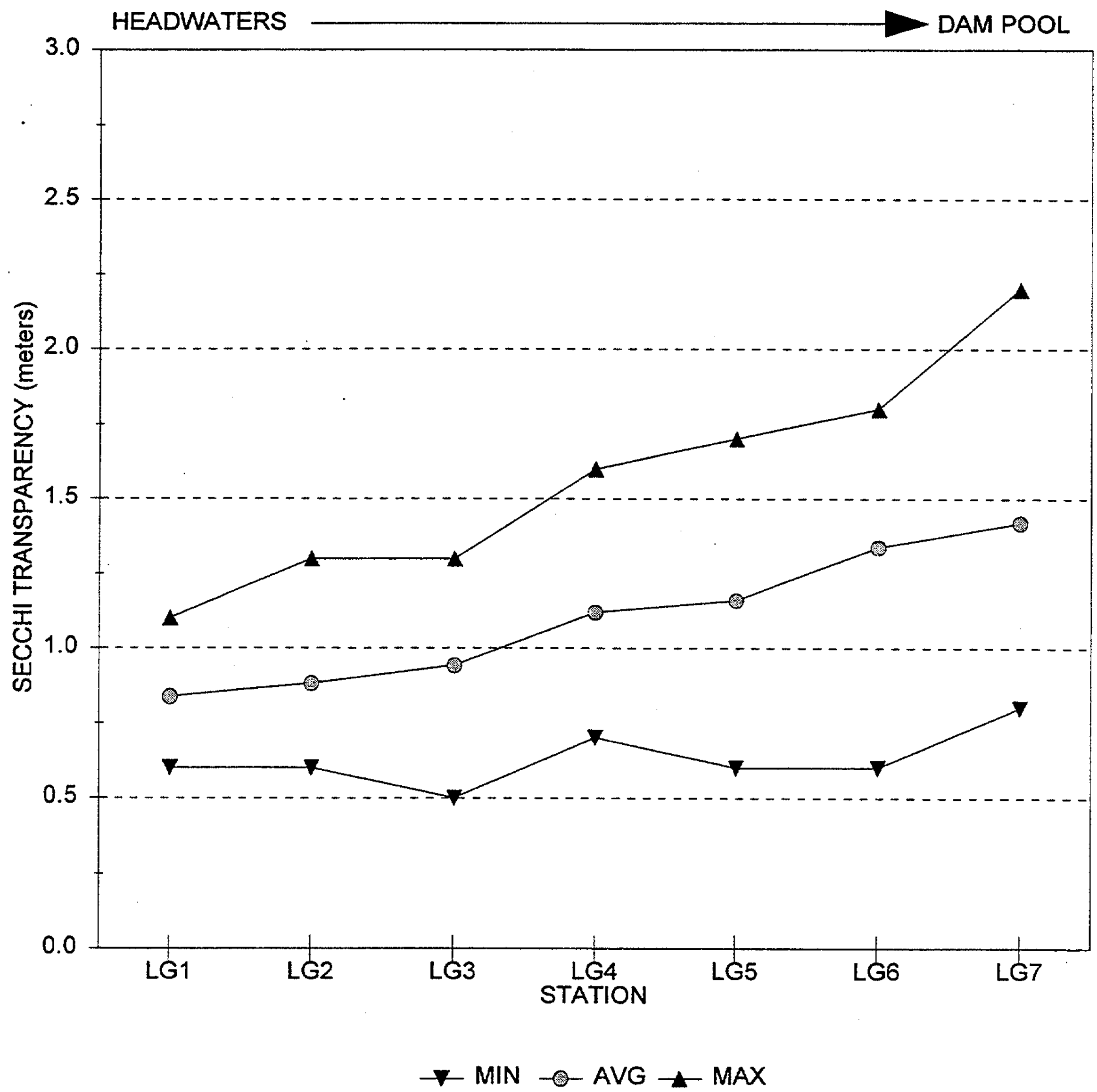
Secchi disk transparency is often used to estimate euphotic zone depth, the depth light penetration supports algal growth. During this study an underwater light meter was used to directly measure the euphotic zone 99 times. The ratio of euphotic zone to Secchi transparency depth ranged from 1.4 to 3.9 with an average ratio of 2.8.

TABLE 7.4

SECCHI DISK TRANSPARENCY (m)

STATION	DATE	SECCHI	STATION	DATE	SECCHI	STATION	DATE	SECCHI
LG1	14-Nov-90	0.8	LG3	08-May-91	0.9	LG5	23-Jul-91	1.0
LG1	05-Dec-90	1.0	LG3	22-May-91	0.7	LG5	07-Aug-91	1.7
LG1	16-Jan-91	1.1	LG3	05-Jun-91	1.0	LG5	21-Aug-91	1.1
LG1	13-Feb-91	0.8	LG3	19-Jun-91	1.3	LG5	11-Sep-91	1.2
LG1	20-Mar-91	0.7	LG3	10-Jul-91	1.0	LG5	24-Sep-91	1.0
LG1	10-Apr-91	0.6	LG3	23-Jul-91	0.9	LG5	23-Oct-91	1.4
LG1	08-May-91	0.7	LG3	07-Aug-91	1.3	LG6	14-Nov-90	1.0
LG1	22-May-91	0.6	LG3	21-Aug-91	0.9	LG6	05-Dec-90	1.2
LG1	05-Jun-91	0.7	LG3	11-Sep-91	1.0	LG6	16-Jan-91	1.0
LG1	19-Jun-91	0.9	LG3	24-Sep-91	0.9	LG6	20-Mar-91	0.6
LG1	23-Jul-91	1.0	LG3	23-Oct-91	1.3	LG6	10-Apr-91	1.7
LG1	07-Aug-91	0.9	LG4	14-Nov-90	1.0	LG6	08-May-91	1.4
LG1	21-Aug-91	0.7	LG4	05-Dec-90	0.9	LG6	22-May-91	1.8
LG1	11-Sep-91	1.0	LG4	16-Jan-91	1.1	LG6	05-Jun-91	1.7
LG1	24-Sep-91	0.7	LG4	13-Feb-91	0.7	LG6	19-Jun-91	1.5
LG1	23-Oct-91	0.9	LG4	20-Mar-91	0.7	LG6	10-Jul-91	1.6
LG2	14-Nov-90	0.9	LG4	10-Apr-91	0.9	LG6	23-Jul-91	1.2
LG2	05-Dec-90	1.3	LG4	08-May-91	1.0	LG6	07-Aug-91	1.4
LG2	16-Jan-91	0.9	LG4	21-May-91	1.6	LG6	21-Aug-91	1.4
LG2	13-Feb-91	0.8	LG4	22-May-91	0.8	LG6	11-Sep-91	1.5
LG2	20-Mar-91	0.8	LG4	05-Jun-91	1.3	LG6	24-Sep-91	1.2
LG2	10-Apr-91	0.7	LG4	19-Jun-91	1.4	LG6	23-Oct-91	1.4
LG2	08-May-91	0.6	LG4	10-Jul-91	1.3	LG7	14-Nov-90	1.1
LG2	21-May-91	0.6	LG4	23-Jul-91	1.4	LG7	05-Dec-90	1.2
LG2	22-May-91	0.8	LG4	07-Aug-91	1.6	LG7	16-Jan-91	1.1
LG2	05-Jun-91	0.8	LG4	21-Aug-91	1.3	LG7	20-Mar-91	0.8
LG2	19-Jun-91	0.9	LG4	11-Sep-91	1.1	LG7	10-Apr-91	1.6
LG2	10-Jul-91	1.0	LG4	24-Sep-91	1.0	LG7	08-May-91	1.5
LG2	23-Jul-91	0.8	LG4	23-Oct-91	1.2	LG7	21-May-91	1.5
LG2	07-Aug-91	1.1	LG5	14-Nov-90	0.9	LG7	22-May-91	1.6
LG2	21-Aug-91	0.7	LG5	05-Dec-90	1.0	LG7	05-Jun-91	1.9
LG2	11-Sep-91	0.9	LG5	16-Jan-91	1.0	LG7	19-Jun-91	2.2
LG2	24-Sep-91	0.9	LG5	20-Mar-91	0.6	LG7	10-Jul-91	1.8
LG2	23-Oct-91	1.2	LG5	10-Apr-91	1.0	LG7	23-Jul-91	1.4
LG3	14-Nov-90	1.0	LG5	08-May-91	1.4	LG7	07-Aug-91	1.8
LG3	05-Dec-90	0.8	LG5	21-May-91	1.5	LG7	21-Aug-91	1.2
LG3	16-Jan-91	1.2	LG5	22-May-91	1.1	LG7	11-Sep-91	1.2
LG3	13-Feb-91	0.7	LG5	05-Jun-91	1.4	LG7	24-Sep-91	1.3
LG3	20-Mar-91	0.7	LG5	19-Jun-91	1.6	LG7	23-Oct-91	1.3
LG3	10-Apr-91	0.5	LG5	10-Jul-91	1.3			

FIGURE 7.4
SECCHI TRANSPARENCY BY STATION



7.4 CARLSON TSI DATA

The trophic status is a measure of the potential productivity of aquatic plant life within a lake. A lake with moderate productivity allows the attainment of designated water uses and promotes the development of a desirable fishery. Algae and other water plants help provide the oxygen required by fish and other aquatic animal life and are a vital link in the food web. Excess algal productivity, however, can contribute to nuisance algal blooms, reduced dissolved oxygen at depth caused by algal decomposition, and taste and odor problems with drinking water. The natural process of eutrophication, where lakes slowly become more productive as they age, can be influenced by the introduction of nutrients, such as phosphorus and nitrogen compounds, which can stimulate algal growth. The trophic status can be an indicator of lake nutrient levels and other factors that affect algal productivity such as lake age, physical characteristics, location, and geology.

Trophic status was measured with indices calculated using Carlson's method[1]. These trophic state indices (TSI) are reported in terms of the parameters used in their calculation: Secchi disk, chlorophyll *a*, and total phosphorus (TSIs, TSIc, and TSIp). The average of these indices is abbreviated as TSIa. The formulae for the Carlson indices are:

$$TSIs = 10 [6 - (n\ SD / \ln 2)]$$

$$TSIc = 10 [6 - (2.04 - 0.68 \ln CHL) / \ln 2]$$

$$TSIp = 10 [6 - (n (48 / TP) / \ln 2)]$$

Here "SD" is Secchi transparency in meters, "CHL" is chlorophyll *a* in µg/l, and "TP" is total phosphorus in µg/l. Carlson based his scale on the assumption that Secchi transparency is inversely related to algal biomass, assuming that transparency depth is halved with each doubling of algal concentration. Carlson then related Secchi transparency to total phosphorus and chlorophyll *a* levels at equivalent trophic conditions, so that ideally all three water quality parameters yield the same index. The index was then artificially

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[1]Carlson, Robert E., 1977, *A Trophic State Index for Lakes*, Limnology and Oceanography 22(2):361-368

adjusted to a logarithmic scale of 0 to 100 where an increase by ten units indicates a doubling of algal biomass.

A TSI of less than 40 indicates an oligotrophic or poor nourishment state with Secchi transparency exceeding four meters, total phosphorus less than 0.012 mg/l, and chlorophyll *a* less than 2.6 µg/l. A TSI between 40 and 50 indicates a mesotrophic or moderate nourishment state with Secchi transparency between 2 and 4 meters, total phosphorus between 0.012 and 0.024 mg/l, and chlorophyll *a* between 2.6 and 7.2 µg/l. A TSI between 50 and 60 indicates a eutrophic or good nourishment state with Secchi transparency between 1 and 2 meters, total phosphorus between 0.024 and 0.048 mg/l, and chlorophyll *a* between 7.2 and 20 µg/l. A TSI above 60 indicates a hypereutrophic or excess nourishment state with Secchi transparency less than 1 meter, total phosphorus greater than 0.048 mg/l, and chlorophyll *a* above 20 µg/l.

Table 7.5 contains all lake TSI data organized by station and sample collection date. W.F. George TSI values are generally in the eutrophic range. Figure 7.5 is a graph of the Phase I TSI data averaged by lake station. Note Secchi disk and total phosphorus TSI's tend to be higher in the upstream stations. Nutrients and sediments are coming in from the Chattahoochee River and other headwater tributaries. The sediments reduce transparency and increase Secchi disk TSI. The sediments also prevent light from penetrating, restricting algal growth and chlorophyll TSI, despite high levels of phosphorus (high TSIp) and other nutrients. Further downstream in the mid-lake region sediments have settled out and water velocities have slowed, allowing algal growth to increase. This is seen by the peak of chlorophyll TSI at LG4. In the dam pool region, at LG7, most suspended solids have settled out. Excess nutrients begin to be depleted by lake phytoplankton. Secchi disk and total phosphorus TSI's are reduced and come into agreement with chlorophyll TSI.

TABLE 7.5 (3 PAGES)

CARLSON TROPHIC STATE INDICES

SECCHI - CHLOROPHYLL a - TOTAL PHOSPHORUS - AVERAGE

STATION	DATE	TSIs	TSIc	TSIp	TSIa
LG1	14-Nov-90	63	36	57	52
LG1	05-Dec-90	59	43	71	58
LG1	13-Feb-91	63	39	63	55
LG1	20-Mar-91	65	48	63	58
LG1	10-Apr-91	67	48	63	60
LG1	08-May-91	65	41	72	59
LG1	22-May-91	67	42	67	59
LG1	05-Jun-91	65	45	63	58
LG1	19-Jun-91	62	56	63	61
LG1	10-Jul-91	62	52	61	58
LG1	24-Jul-91	61	53	53	56
LG1	07-Aug-91	62	53	47	54
LG1	21-Aug-91	65	53	63	61
LG1	11-Sep-91	60	52	63	58
LG1	25-Sep-91	62	49	65	59
LG1	23-Oct-91	62	43	63	56
LG2	14-Nov-90	62	40	61	54
LG2	05-Dec-90	57	44	69	57
LG2	16-Jan-91	62	35	72	56
LG2	13-Feb-91	63	37	65	55
LG2	20-Mar-91	63	45	57	55
LG2	10-Apr-91	66	48	69	61
LG2	08-May-91	67	43	71	60
LG2	22-May-91	64	47	67	59
LG2	05-Jun-91	64	46	57	56
LG2	19-Jun-91	61	55	65	61
LG2	10-Jul-91	60	51	61	57
LG2	24-Jul-91	60	54	53	56
LG2	07-Aug-91	59	50	63	57
LG2	21-Aug-91	65	55	61	60
LG2	11-Sep-91	62	55	61	59
LG2	25-Sep-91	62	52	61	58
LG2	23-Oct-91	57	44	73	58
LG3	14-Nov-90	60	45	67	57
LG3	05-Dec-90	63	53	65	61
LG3	16-Jan-91	57	36	71	55
LG3	13-Feb-91	66	48	61	58
LG3	20-Mar-91	66	52	57	59
LG3	10-Apr-91	72	57	61	63
LG3	08-May-91	62	50	69	60

TABLE 7.5 (3 PAGES)
CARLSON TROPHIC STATE INDICES
SECCHI - CHLOROPHYLL a - TOTAL PHOSPHORUS - AVERAGE

STATION	DATE	TSIs	TSIc	TSIp	TSIa
LG3	22-May-91	65	47	63	58
LG3	05-Jun-91	60	57	63	60
LG3	19-Jun-91	56	56	63	58
LG3	10-Jul-91	60	59	67	62
LG3	24-Jul-91	62	58	53	58
LG3	07-Aug-91	56	19	57	44
LG3	21-Aug-91	62	59	47	56
LG3	11-Sep-91	60	56	57	58
LG3	25-Sep-91	62	51	65	59
LG3	23-Oct-91	56	49	61	55
LG4	14-Nov-90	61	63	57	60
LG4	05-Dec-90	62	55	65	61
LG4	16-Jan-91	59	48	63	57
LG4	13-Feb-91	66	45	63	58
LG4	20-Mar-91	65	59	63	62
LG4	10-Apr-91	62	57	57	59
LG4	08-May-91	60	56	65	60
LG4	22-May-91	62	56	61	60
LG4	05-Jun-91	56	56	73	62
LG4	19-Jun-91	55	59	61	58
LG4	10-Jul-91	56	60	63	60
LG4	24-Jul-91	59	57	53	56
LG4	07-Aug-91	53	57	47	53
LG4	21-Aug-91	57	53	61	57
LG4	11-Sep-91	59	57	53	56
LG4	25-Sep-91	60	59	63	61
LG4	23-Oct-91	57	59	63	60
LG5	14-Nov-90	62	54	67	61
LG5	05-Dec-90	60	54	65	60
LG5	16-Jan-91	60	50	63	58
LG5	13-Feb-91	67	42	63	58
LG5	20-Mar-91	66	57	76	67
LG5	10-Apr-91	61	54	57	57
LG5	08-May-91	55	52	65	57
LG5	22-May-91	59	42	67	56
LG5	05-Jun-91	55	51	57	54
LG5	19-Jun-91	53	55	53	54
LG5	10-Jul-91	56	54	69	60
LG5	24-Jul-91	57	53	53	55
LG5	07-Aug-91	52	58	47	53

TABLE 7.5 (3 PAGES) CARLSON TROPHIC STATE INDICES SECCHI - CHLOROPHYLL a - TOTAL PHOSPHORUS - AVERAGE					
STATION	DATE	TSIs	TSIc	TSIp	TSIa
LG5	21-Aug-91	59	55	61	58
LG5	11-Sep-91	57	56	53	56
LG5	25-Sep-91	57	57	61	58
LG5	23-Oct-91	55	58	65	59
LG6	14-Nov-90	60	51	53	55
LG6	05-Dec-90	58	50	57	55
LG6	16-Jan-91	60	42	61	54
LG6	20-Mar-91	68	59	61	62
LG6	10-Apr-91	52	48	53	51
LG6	08-May-91	55	62	63	60
LG6	22-May-91	52	45	57	51
LG6	05-Jun-91	52	48	63	55
LG6	19-Jun-91	54	56	53	54
LG6	10-Jul-91	53	60	57	57
LG6	24-Jul-91	57	57	53	56
LG6	07-Aug-91	55	59	57	57
LG6	21-Aug-91	55	56	47	53
LG6	11-Sep-91	54	57	53	55
LG6	25-Sep-91	57	56	63	59
LG6	23-Oct-91	55	56	67	59
LG7	14-Nov-90	59	52	47	53
LG7	05-Dec-90	58	50	53	54
LG7	16-Jan-91	59	35	65	53
LG7	20-Mar-91	63	55	57	59
LG7	10-Apr-91	53	51	53	53
LG7	08-May-91	54	56	61	57
LG7	22-May-91	53	56	65	58
LG7	05-Jun-91	51	51	71	57
LG7	19-Jun-91	49	57	47	51
LG7	10-Jul-91	52	60	57	56
LG7	24-Jul-91	55	57	53	55
LG7	07-Aug-91	52	56	47	52
LG7	21-Aug-91	57	56	47	54
LG7	11-Sep-91	57	60	47	55
LG7	25-Sep-91	59	59	57	58
LG7	23-Oct-91	56	59	57	57

FIGURE 7.5

TROPHIC STATE INDICES BY STATION

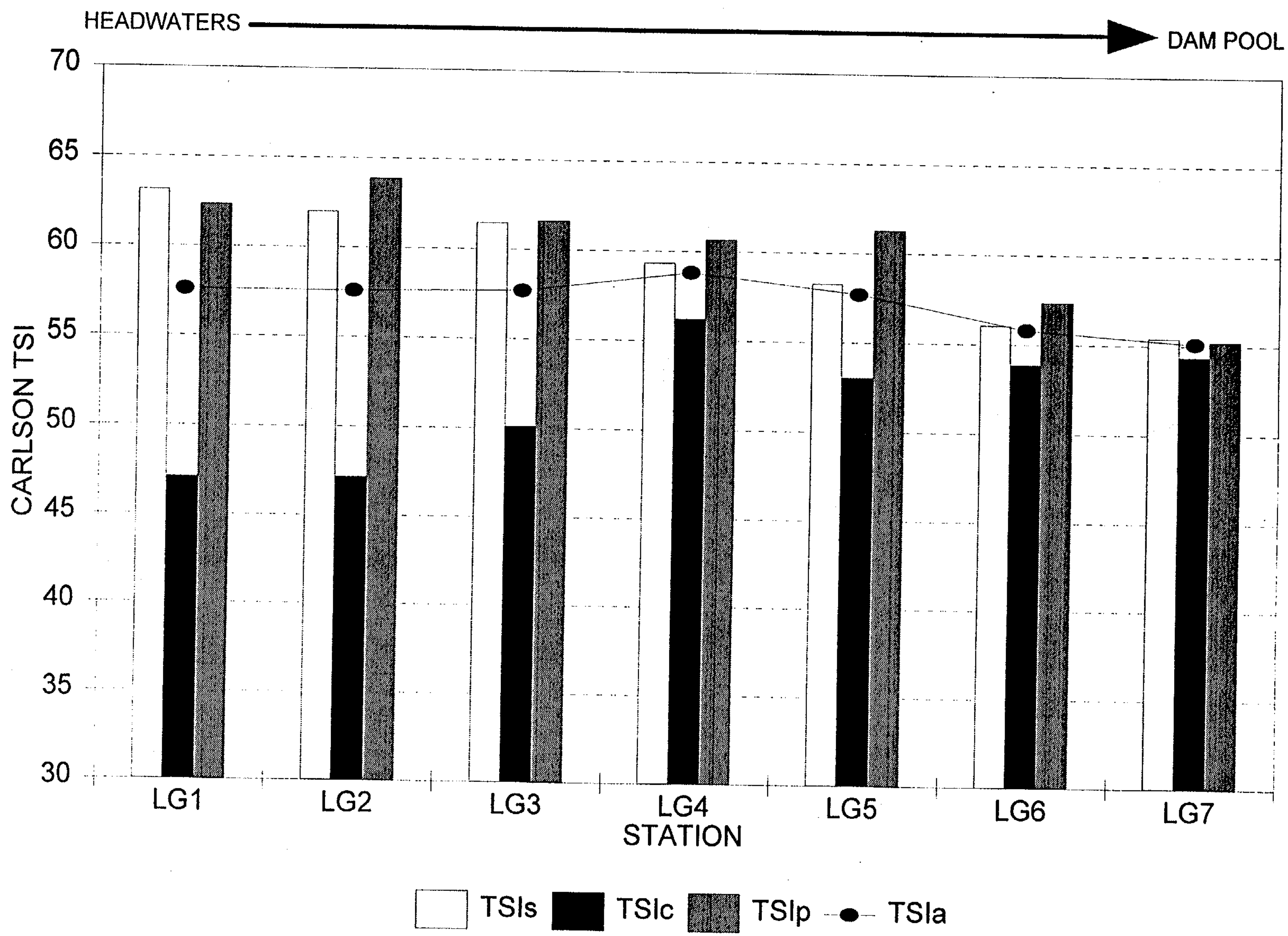


Figure 7.6 is a graph of TSI data for station LG4, averaged by the calendar months in which samples were collected. In the fall, TSIs and TSIp decrease due to less seasonal rainfall. TSIc decreases sharply due to the reduced nutrients, cooler temperatures, and the loss of stability inherent with summer thermal stratification. In the winter nutrient levels increase and transparency decreases due to increased rainfall and mixing of water from the benthic region following the loss of thermal stratification. This is evident in the January and February data. In March a peak in TSIa is seen when spring sunlight combined with elevated winter nutrient levels causes an increase in algal growth. In the summer months the trophic state indices are seen to merge following reestablishment of thermal stratification.

Figure 7.7 is a graph of TSI data for the W.F. George dam pool area (LG7) for the years 1980, 1981, and 1984 through 1992. 1980 and 1981 data are from the Georgia DNR Cleans Lakes Program. 1984 through 1992 data are from the Georgia DNR Major Lake Monitoring Project (MLMP). These data represent one or two sample dates in the late spring and early summer. It is apparent that the 1991 TSI data were above average compared to other years. 1987 had the lowest and 1989 had the highest trophic state index.

Figure 7.8 compares Lake W.F. George summer TSI data with TSI data from three other large Chattahoochee River impoundments. 1991 MLMP data are shown for average TSI. Lake Lanier, the first impoundment on the Chattahoochee River, represents a mesotrophic lake with significantly lower TSI's. West Point Lake and Lake Seminole are in the same eutrophic range as W.F. George.

FIGURE 7.6

MID-LAKE (LG4) TSI DATA BY MONTH

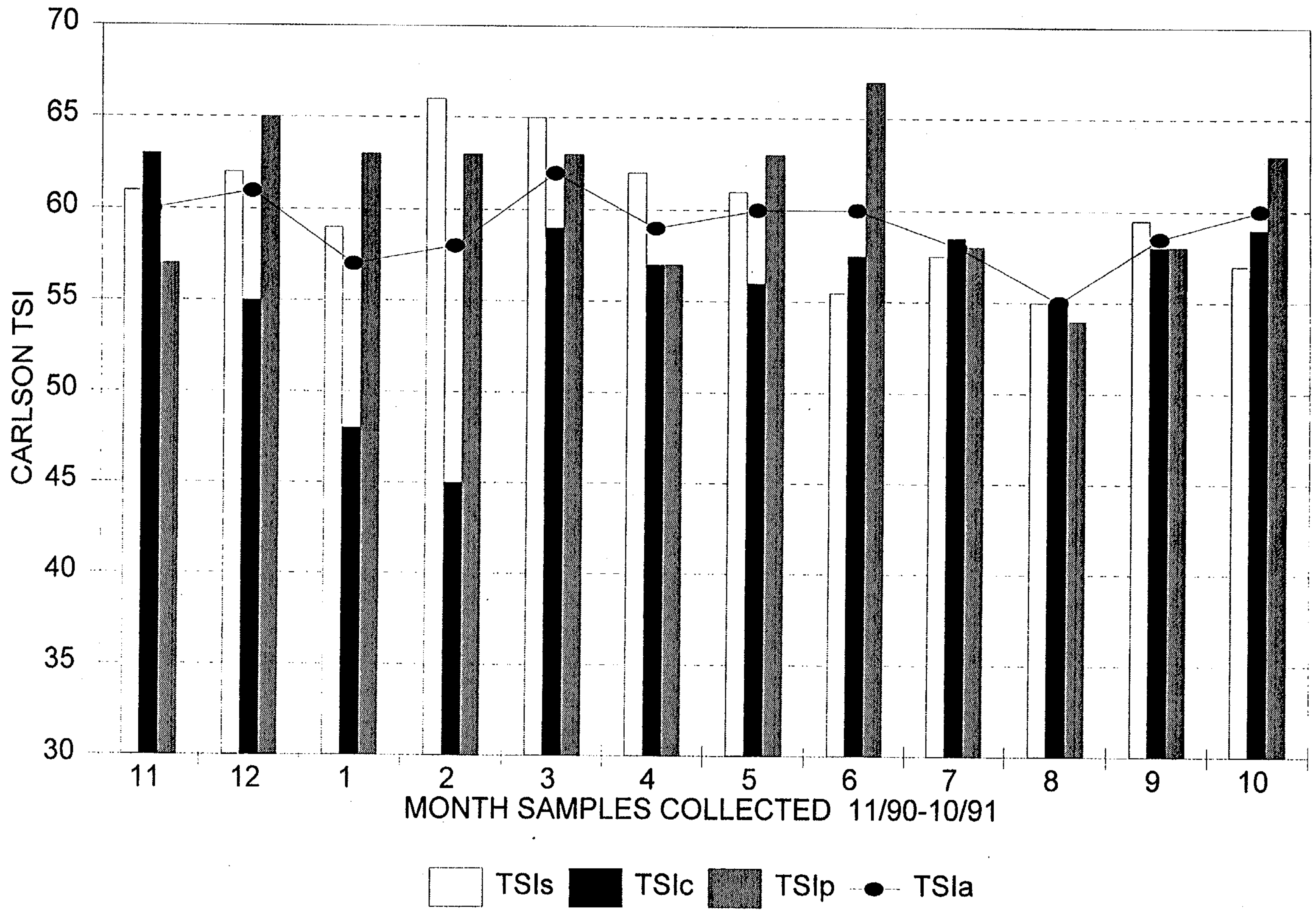


FIGURE 7.7

DAM POOL (LG7) TSI DATA 1980-1992

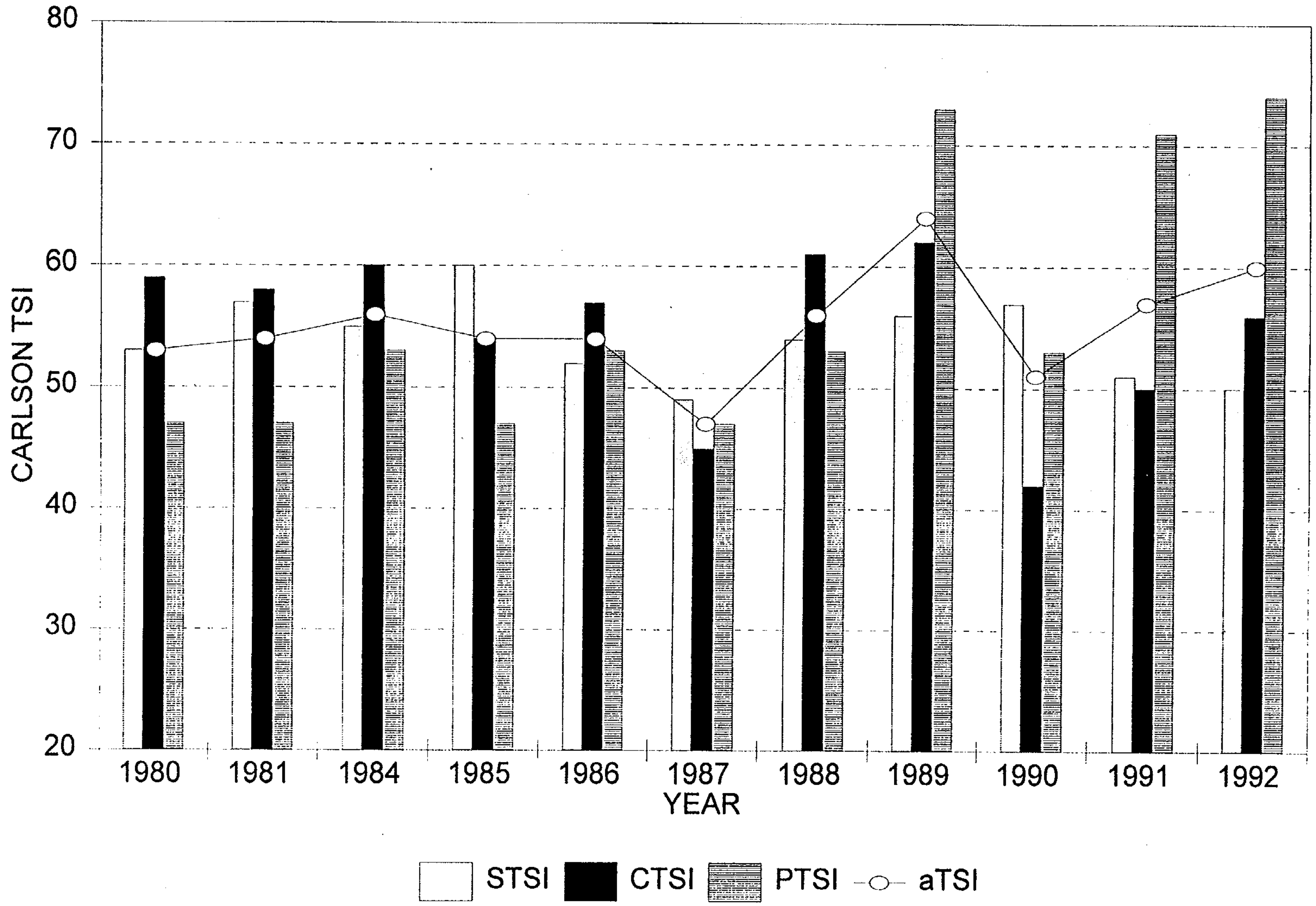
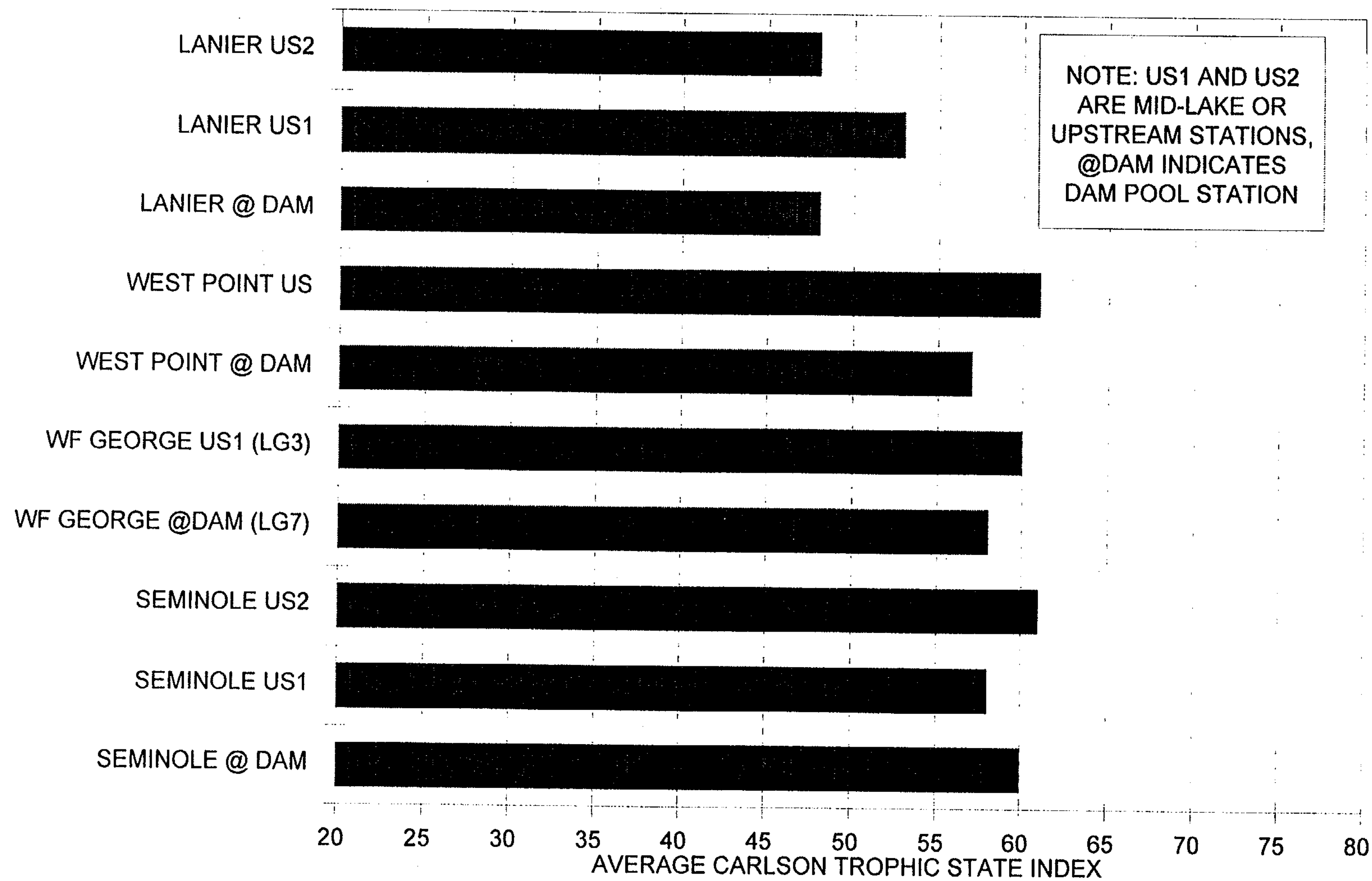


FIGURE 7.8

1991 TSI DATA - CHATTAHOOCHEE LAKES



7.5 ALGAL GROWTH POTENTIAL DATA

Algal growth potential was measured as part of this Phase I Study to decide if Lake Walter F. George is nitrogen, phosphorus, or co-limiting to algal growth, and to provide an estimate of the maximum algal biomass producible in the lake under optimal conditions.

The Georgia DNR-EPD requested the Environmental Services Division (ESD) of Region IV, EPA to conduct algal growth potential tests (AGPT) on water samples collected from W.F. George from stations CR1, LG2, LG4, and LG5. Samples were collected by EPD personnel during routine sample runs on May 21, July 23, and September 24, 1991. The ESD performed the algal growth potential tests using Selenastrum capricornutum according to the EPA standard operating procedure. Autoclaved and filtered samples were treated separately with nitrogen and phosphorus. A significant increase in mean maximum standing crop (MSC) in the nitrogen-spiked sample or the phosphorus-spiked sample showed that the water sample was nitrogen limited or phosphorus limited, respectively. However, if the addition of nitrogen or phosphorus to a sample did not increase the MSC over the untreated sample (control), the nutrients were already present in their optimum ratio for the growth of the test alga and the sample was considered co-limiting to algal growth.

Data from the AGPT is summarized in Table 7.6. All four stations were generally phosphorus limited in May. In July and September most locations were co-limited or marginally nitrogen limited except for station LG5, the most downstream station, which remained phosphorus limited. Mean standing crop levels were significantly higher in the two upstream stations, CR1 and LG2, than the mid-lake stations, LG4 and LG5. This difference is clearly paralleled by total nitrogen levels and somewhat paralleled by total phosphorus levels (total phosphorus data in the July samples were all below the lab detection limit of 0.02 mg/l). An adequate source of nutrients exists in the lake headwaters with phosphorus depletion tending to limit algal growth in the mid-lake area.

TABLE 7.6

SUMMARY OF ALGAL GROWTH POTENTIAL DATA

DATE	STATION	TOTAL NITROGEN (mg/l)	TOTAL PHOS (mg/l)	CONTROL AVG MSC (mg/L)	CON + N AVG MSC (mg/l)	CON + P AVG MSC (mg/l)	LIMITING NUTRIENT
5/21/91	CR1	0.76	0.03	16.38	16.48	19.43	PHOS
	LG2	0.90	0.03	14.65	14.85	23.54	PHOS
	LG4	0.67	0.03	6.35	6.59	11.73	PHOS
	LG5	0.60	<0.02	2.92	3.52	11.90	PHOS
7/23/91	CR1	0.63	<0.02	17.46	16.82	16.24	CO-LIMIT
	LG2	0.64	<0.02	16.76	20.05	14.05	NITROGEN
	LG4	0.42	<0.02	4.19	4.83	4.98	CO-LIMIT
	LG5	0.44	<0.02	3.70	3.53	8.56	PHOS
9/24/91	CR1	0.80	0.04	22.15	22.83	17.90	CO-LIMIT
	LG2	0.74	0.04	17.25	19.93	15.54	NITROGEN
	LG4	0.58	0.02	10.41	9.93	9.30	CO-LIMIT
	LG5	0.54	0.02	6.67	6.65	9.13	PHOS

MSC = MEAN STANDING CROP OF TEST ALGA

CON + N = CONTROL PLUS NITROGEN

CON + P = CONTROL PLUS PHOSPHORUS

7.6 PHYTOPLANKTON DATA

To characterize lake phytoplankton communities, water samples were collected from five stations, CR1, LG2, LG4, LG5, and LG7. Samples were collected on May 21, July 23, and September 24, 1991, to cover the beginning, middle, and end of the algal growing season. A fourth set was collected on January 16, 1991, as a winter comparison. Samples were collected with a Van Dorn sampler at evenly spaced intervals through the euphotic zone, composited, preserved in the field with Lugol's solution (approximately 1% by volume), and stored in amber bottles until counted.

Identification and enumeration of phytoplankton samples were performed by personnel from the University of Georgia Department of Zoology in Athens, Georgia. Counting was done with a Zeiss inverted microscope, using the settling chamber method first described by Untermoehl (1958). The total volume of each sample was measured with a graduated cylinder. Samples were firmly shaken for 60 seconds each, bubbles were allowed to elute off for 30 seconds, then samples were poured into 5 or 10 mL settling towers. Samples were settled for a minimum of 4 hours per 5 mLs (3 hours per 5 mLs is the minimum recommended time), then viewed for identification and enumeration.

Enumeration was done at 320X magnification by counting 1 or 2 transects the width of the Whipple disk across each settling chamber. A minimum of 500 cells were counted per site and sampling date (range= 693 to 5741). Cell counts were converted to cells per mL according to total area counted, volume settled, and dilution factor due to the Lugol's preservative.

The settling chambers were 25 mm in diameter. At 320X, the volume counted by one transect was 78.5 mm^3 (5 mL chamber) or 156.9 mm^3 (10 mL chamber), for a total of 1.57% of each subsample counted per transect. For each sampling date and site, at least 4 separate subsamples were counted (1 or 2 transects per subsample).

Twenty cells of most genera were measured for estimates of cell biovolume, using standard geometric shapes as models. Measurements were made with either a calibrated Whipple disk or the IBM-compatible OPTIMAS Bioscan image-analysis program. Colonial and filamentous organisms were counted as single units, but their average biovolumes were calculated using some measure of colony size. Cell volumes of less abundant genera were sometimes estimated with measurements of fewer than 20 cells, and cell volume estimates could not be obtained for a few exceedingly rare genera (Rhizosolenium, Characium, Quadrigula, Schroederia, and Rhabdoderma).

Algae that were not specifically identifiable were assigned a descriptive name and biovolumes were estimated for each group as described above for generic groups. These groups were as follows:

(i) green coccoids: single cells and colonies
(ii) blue-green coccoids
(iii) pennate diatoms: "regular," "large," and "thin"
(iv) centric diatoms.

Table 7.7 is a species list from Lake George phytoplankton samples. The approximate biovolume per cell type (in cubic micrometers) and the geometric formula used to estimate this value are listed for all algal groups enumerated, excepting those 5 groups listed above. Class or division names for all groups or genera were abbreviated as follows:

BAC= Bacillariophyceae
CHL= Chlorophyta
CPT= Cryptophyceae
CRY= Chrysophyta
DIN= Dinophyceae
EUG= Euglenophyta
MON= Chloromonadophyta
MXY= Myxophyceae

TABLE 7.7 (2 PAGES)
ESTIMATES OF ALGAL CELL BIOVOLUMES

CLASS	GENUS/GROUP	GEOMETRIC FORMULA	AVG SAMPLE BIOVOLUME (µm³/liter)
BAC	Diatoma		1,814
BAC	Fragilaria	(H*W*(1/2)*W)	6,015
BAC	Fragilaria--col'y	(H*W*(1/2)*W)*N	8,520
BAC	Gyrosigma	(H*W*(1/2)*W)	54,784
BAC	Melosira sp1	((PI*H*W*W)/4)*N	21,367
BAC	Melosira sp2	(PI*H*W*W)/4	2,207
BAC	Rhopalodia	(PI*H*W*W)/6	1,814
BAC	Synedra	(PI*H*W*W)/12	13,475
BAC	centrics	(PI*H*W*W)/4	8,093
BAC	pennates	(W*(0.5*W)*(H-W+(PI/4)*W))	1,814
BAC	pennates--large	(W*(0.5*W)*(H-W+(PI/4)*W))	45,583
BAC	pennates--thin	(W*(0.5*W)*(H-W+(PI/4)*W))	1,090
CHL	Actinastrum	((PI*H*W*W)/12)*N	2,745
CHL	Bitrichia	(PI*H*W*W)/6	1,644
CHL	Botryococcus	((PI*H*H*H)/6)*N	5,875
CHL	Chlamydomonas	(PI*H*W*W)/6	530
CHL	Closterium	(PI*H*W*W)/12	4,290
CHL	Coelastrum	((PI*H*H*H)/6)*N	4,636
CHL	Cosmarium	((PI*H*W*W)/6)*2	3,180
CHL	Crucigenia	((H*H*H)/4)*N	807
CHL	Dictyosphaerion	((PI*H*W*W)/6)*N	1,903
CHL	Elakatothrix	(PI*H*W*W)/12	348
CHL	Euastrum	(H*W*(1/3)*W)	6,713
CHL	Eudorina	(PI*H*W*W)/6	29,425
CHL	Gloeocystis	((PI*H*H*H)/6)*N	7,592
CHL	Kirchneriella	((PI*H*W*W)/12)*N	1,017
CHL	Lagerheimia	(PI*H*W*W)/6	1,947
CHL	Micrasterius	(H*H*(1/6)*H)	16,435
CHL	Micractinium	((PI*H*H*H)/6)*N	1,697
CHL	Oocystis	((PI*H*W*W)/6)*N	2,406
CHL	Pediastrum	((H*H*H)/4)*N	3,150
CHL	Scenedesmus	((PI*H*W*W)/6)*N	1,908
CHL	Sorastrum	((PI*H*H*H)/6)*N	3,559

TABLE 7.7 (2 PAGES) ESTIMATES OF ALGAL CELL BIOVOLUMES			
CLASS	GENUS/GROUP	GEOMETRIC FORMULA	AVG SAMPLE BIOVOLUME (μm^3/liter)
CHL	Staurastrum	(2*((1/3)*PI*H*((1/2)*W)*((1/2)*W))+ (4*PI*H*((1/2)*W)*((1/2)*W))	8,322
CHL	Tetraedron	(H*H*H)/4	675
CHL	Treubaria	(PI*(1/3)*W*W*W)/4	841
CHL	Ulothrix	((PI*H*W*W)/4)*N	2,872
CHL	Westella	((PI*H*H*H)/6)*N	490
CHL	green coccoids	(PI*H*H*H)/6	3,671
CHL	green coccoids-col'y	((PI*H*H*H)/6)*N	3,369
CPT	Cryptomonas	(PI*W*W(H+(W/2)))/12	6,237
CPT	Rhodomonas	(PI*W*W(H+(W/2)))/2	1,769
CRY	Dinobryon	((PI*H*W*W)/6)*N	1,534
CRY	Mallomonas	((PI*H*W*W)/6)	6,742
CRY	Ochromonas	(PI*W*W(H+(W/2)))/12	1,006
CRY	Synura	((PI*H*W*W)/6)*N	4,406
DIN	Ceratium	((PI*H*W*W)/6)+ (PI*64*(LH1+LH2+LH3+LH4))	386,822
DIN	Glenodinium	(PI*H*W*W)/6	24,194
DIN	Hemidinium	(PI*H*W*W)/6	2,806
EUG	Euglena	(PI*W*W(H+(W/2)))/12	14,361
EUG	Phacus	(PI*(H+W/2)*(H+W/2))*(1/6)*((H+W/2))	57,477
EUG	Trachelomonas	(PI*H*W*W)/6	20,239
MON	Gonyostomum	(PI*H*W*W)/6	15,061
MON	Gonyostomum--large	(PI*H*W*W)/6	125,705
MXY	Anabaena	(PI*H*W*W)/4	6,919
MXY	Chroococcus sp1	((PI*H*H*H)/6)*N	2,142
MXY	Chroococcus sp2	((PI*H*W*W)/6)*N	2,839
MXY	Cyanarcus	((PI*H*W*W)/4)*N	8,605
MXY	Dactylococcopsis	(PI*H*W*W)/12	112
MXY	Merismopedia	((PI*H*H*H)/6)*N	635
MXY	Microcystis	((PI*H*H*H)/6)*N	4,651
MXY	Oscillatoria	((PI*H*W*W/4)	958
MXY	bluegreen coccoids	(PI*H*H*H)/6	239

Results of total biovolume estimates (as shown in Figure 7.9) show that algal biomass increased throughout 1991 at all sites, and that the magnitude of this increase was greatest at the downstream sites (especially Site LG7). In general, Chlorophyta (green algae) and Cryptophyta (yellow-green algae) were the dominant groups by biovolume in January, but Bacillariophyta (diatoms) was the more usual dominant group at sites during May, August, and September. Myxophyta (bluegreen algae) was the dominant group at only one site and sampling date, LG7 on September 24, 1991. Bluegreen algae are indicators of increased eutrophic conditions. The dominance of any one group ranged from 29 to 82% of total algal biovolume per liter.

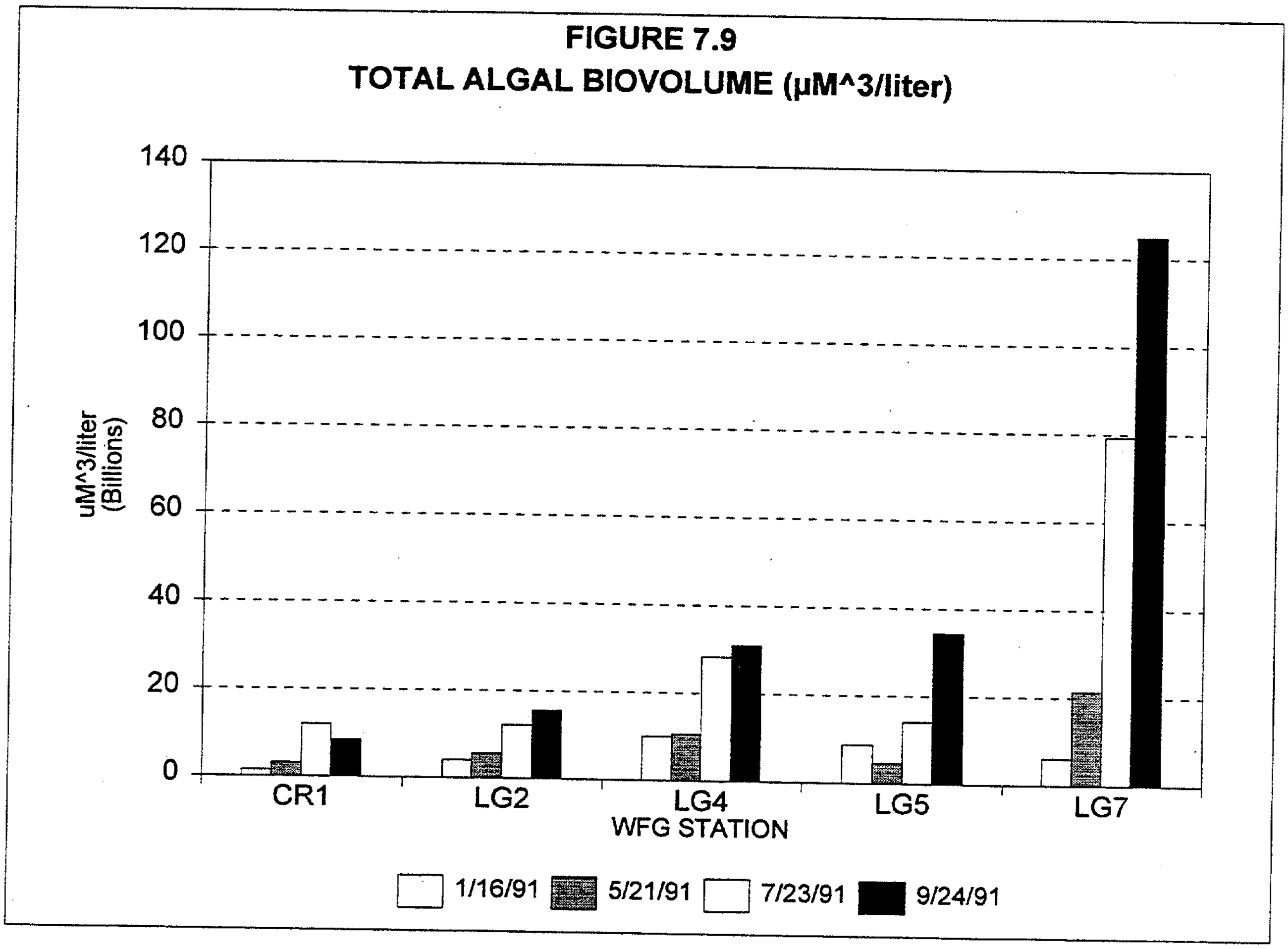


FIGURE 7.9
TOTAL ALGAL BIOVOLUME (µM^3/liter)
140
120
100
80
60
40
20
0
uM^3/liter
(Billions)
CR1
LG2
LG4
LG5
LG7
WFG STATION
1/16/91
5/21/91
7/23/91
9/24/91

7.7 DO AND TEMPERATURE PROFILE DATA

Dissolved oxygen and temperature levels control the habitat and viability of a lake's fish population. Inadequate dissolved oxygen can cause fish kills. Georgia piedmont lakes tend to stratify in the late spring and early summer into three thermal layers, the upper warm layer or epilimnion, the lower, cooler water or hypolimnion, and the transition layer or metalimnion. The top of the metalimnion, where the temperature gradient is most pronounced, is called the thermocline. This stratification is caused by the difference in density as the upper water is heated by increased summer sunlight. As lakes become thermally stratified they also become stratified with respect to dissolved oxygen. The algae in the upper layer generate oxygen during daytime photosynthesis. This combined with wind mixing causes elevated dissolved oxygen in the upper epilimnion. Water in the hypolimnion, isolated by the metalimnion, gradually becomes oxygen depleted from water biochemical oxygen demand and sediment oxygen demand. Decaying algal detritus accelerates this depletion.

Tables 7.8 and 7.9 contain lake DO data for lake stations at one-meter and ten-meter depths, respectively. DO ranged from 6.6 to 11.7 mg/l at one meter. The average was 8.7 and the standard deviation was 1.1 mg/l. DO ranged from 0.3 to 10.5 mg/l at ten meters. The average was 6.8 and the standard deviation was 2.2 mg/l. At ten meters, DO was found to be less than 4.0 mg /l thirteen times. These lower DO readings were all made between June 5 and September 11 at stations LG4, LG5, LG6, and LG7. Figure 7.10 is a graph of maximum, average, and minimum DO data at 10 meters by station. Note that DO generally decreases from upstream to downstream due to increased stratification. Figure 7.11 graphs maximum one-meter and ten-meter temperatures. Note that station LG6 had a maximum one-meter temperature in excess of 90 deg F.

TABLE 7.8

DISSOLVED OXYGEN AT ONE METER DEPTH (mg/l)

STATION	DATE	DO-1M	STATION	DATE	DO-1M	STATION	DATE	DO-1M
LG1	14-Nov-90	8.3	LG3	22-May-91	6.9	LG5	24-Sep-91	8.1
LG1	05-Dec-90	8.7	LG3	05-Jun-91	7.6	LG5	23-Oct-91	10.0
LG1	16-Jan-91	11.7	LG3	19-Jun-91	7.4	LG6	14-Nov-90	9.9
LG1	13-Feb-91	10.1	LG3	23-Jul-91	8.6	LG6	05-Dec-90	9.0
LG1	20-Mar-91	9.6	LG3	07-Aug-91	7.4	LG6	16-Jan-91	9.1
LG1	10-Apr-91	8.1	LG3	21-Aug-91	9.0	LG6	20-Mar-91	10.7
LG1	08-May-91	8.5	LG3	11-Sep-91	8.3	LG6	10-Apr-91	9.3
LG1	22-May-91	8.0	LG3	24-Sep-91	6.8	LG6	08-May-91	9.2
LG1	05-Jun-91	7.3	LG3	23-Oct-91	8.8	LG6	22-May-91	7.5
LG1	19-Jun-91	7.7	LG4	14-Nov-90	10.8	LG6	05-Jun-91	7.9
LG1	23-Jul-91	8.0	LG4	05-Dec-90	9.5	LG6	19-Jun-91	8.7
LG1	07-Aug-91	7.3	LG4	16-Jan-91	10.9	LG6	23-Jul-91	8.7
LG1	21-Aug-91	7.2	LG4	13-Feb-91	9.4	LG6	07-Aug-91	8.9
LG1	11-Sep-91	7.0	LG4	20-Mar-91	10.9	LG6	21-Aug-91	8.3
LG1	24-Sep-91	7.1	LG4	10-Apr-91	8.5	LG6	11-Sep-91	8.7
LG1	23-Oct-91	8.5	LG4	08-May-91	8.2	LG6	24-Sep-91	8.0
LG2	14-Nov-90	8.7	LG4	21-May-91	8.1	LG6	23-Oct-91	10.4
LG2	05-Dec-90	8.8	LG4	22-May-91	7.7	LG7	14-Nov-90	10.2
LG2	16-Jan-91	10.7	LG4	05-Jun-91	8.3	LG7	05-Dec-90	9.1
LG2	13-Feb-91	9.9	LG4	19-Jun-91	8.3	LG7	16-Jan-91	10.2
LG2	20-Mar-91	9.6	LG4	23-Jul-91	9.0	LG7	20-Mar-91	10.2
LG2	10-Apr-91	7.7	LG4	07-Aug-91	9.0	LG7	10-Apr-91	9.7
LG2	08-May-91	8.2	LG4	21-Aug-91	8.6	LG7	08-May-91	8.8
LG2	21-May-91	7.5	LG4	11-Sep-91	8.2	LG7	21-May-91	8.2
LG2	22-May-91	7.7	LG4	24-Sep-91	8.8	LG7	22-May-91	8.1
LG2	05-Jun-91	7.0	LG4	23-Oct-91	10.0	LG7	05-Jun-91	8.0
LG2	19-Jun-91	8.2	LG5	14-Nov-90	9.7	LG7	19-Jun-91	9.1
LG2	23-Jul-91	8.3	LG5	05-Dec-90	9.3	LG7	23-Jul-91	10.1
LG2	07-Aug-91	7.3	LG5	16-Jan-91	10.9	LG7	07-Aug-91	8.7
LG2	21-Aug-91	7.4	LG5	20-Mar-91	10.6	LG7	21-Aug-91	8.2
LG2	11-Sep-91	7.7	LG5	10-Apr-91	8.7	LG7	11-Sep-91	9.1
LG2	24-Sep-91	6.7	LG5	08-May-91	7.2	LG7	24-Sep-91	8.5
LG2	23-Oct-91	8.2	LG5	21-May-91	7.1	LG7	23-Oct-91	9.9
LG3	14-Nov-90	8.1	LG5	22-May-91	7.1			
LG3	05-Dec-90	9.3	LG5	05-Jun-91	6.6			
LG3	16-Jan-91	10.3	LG5	19-Jun-91	8.5			
LG3	13-Feb-91	9.9	LG5	23-Jul-91	7.6			
LG3	20-Mar-91	9.6	LG5	07-Aug-91	9.5			
LG3	10-Apr-91	8.0	LG5	21-Aug-91	8.9			
LG3	08-May-91	7.6	LG5	11-Sep-91	7.8			

TABLE 7.9

LAKE DISSOLVED OXYGEN AT TEN METER DEPTH (mg/l)

STATION	DATE	DO-10M	STATION	DATE	DO-10M	STATION	DATE	DO-10M
LG1	14-Nov-90	8.2	LG3	10-Apr-91	7.2	LG5	23-Jul-91	2.5
LG1	05-Dec-90	8.5	LG3	05-Jun-91	5.5	LG5	07-Aug-91	2.4
LG1	16-Jan-91	10.5	LG3	19-Jun-91	5.6	LG5	21-Aug-91	5.2
LG1	13-Feb-91	10	LG3	23-Jul-91	5.3	LG5	11-Sep-91	5.4
LG1	20-Mar-91	9.4	LG3	07-Aug-91	5.9	LG5	24-Sep-91	5.7
LG1	10-Apr-91	8	LG3	21-Aug-91	6.9	LG5	23-Oct-91	7.5
LG1	08-May-91	8.4	LG3	11-Sep-91	6.2	LG6	14-Nov-90	7.6
LG1	22-May-91	7.9	LG3	24-Sep-91	6.3	LG6	05-Dec-90	8.4
LG1	05-Jun-91	7.1	LG3	23-Oct-91	8	LG6	16-Jan-91	8.9
LG1	19-Jun-91	7.5	LG4	14-Nov-90	8.9	LG6	20-Mar-91	8.4
LG1	23-Jul-91	7.4	LG4	05-Dec-90	9.1	LG6	10-Apr-91	5.1
LG1	07-Aug-91	7	LG4	16-Jan-91	10.5	LG6	08-May-91	4.4
LG1	21-Aug-91	7	LG4	13-Feb-91	8.9	LG6	22-May-91	4.7
LG1	11-Sep-91	6.8	LG4	20-Mar-91	9.7	LG6	05-Jun-91	3.2
LG1	24-Sep-91	7	LG4	10-Apr-91	6.5	LG6	19-Jun-91	2.3
LG1	23-Oct-91	8.4	LG4	08-May-91	7.8	LG6	23-Jul-91	2.4
LG2	14-Nov-90	8.5	LG4	21-May-91	7.9	LG6	07-Aug-91	0.3
LG2	05-Dec-90	8.7	LG4	22-May-91	7.5	LG6	21-Aug-91	6.2
LG2	16-Jan-91	10	LG4	05-Jun-91	5	LG6	24-Sep-91	4.9
LG2	13-Feb-91	9.9	LG4	19-Jun-91	3.6	LG6	23-Oct-91	6.8
LG2	20-Mar-91	9.3	LG4	23-Jul-91	4.3	LG7	14-Nov-90	8.2
LG2	10-Apr-91	7.7	LG4	07-Aug-91	3.2	LG7	05-Dec-90	8.8
LG2	21-May-91	7.4	LG4	21-Aug-91	6.5	LG7	16-Jan-91	9.4
LG2	22-May-91	7.6	LG4	11-Sep-91	2.7	LG7	20-Mar-91	9.2
LG2	05-Jun-91	6.9	LG4	24-Sep-91	5.7	LG7	10-Apr-91	7.6
LG2	19-Jun-91	7.3	LG4	23-Oct-91	7.6	LG7	08-May-91	6.1
LG2	10-Jul-91	10.6	LG5	14-Nov-90	8.3	LG7	21-May-91	5.9
LG2	07-Aug-91	6.9	LG5	05-Dec-90	9	LG7	22-May-91	6.9
LG2	21-Aug-91	6.8	LG5	16-Jan-91	9.5	LG7	05-Jun-91	7.2
LG2	11-Sep-91	6.7	LG5	20-Mar-91	8.8	LG7	19-Jun-91	2.7
LG2	24-Sep-91	6.7	LG5	10-Apr-91	5.5	LG7	23-Jul-91	4.4
LG2	23-Oct-91	8.2	LG5	08-May-91	5.4	LG7	07-Aug-91	0.8
LG3	14-Nov-90	8.1	LG5	21-May-91	5.2	LG7	21-Aug-91	6.6
LG3	05-Dec-90	9.1	LG5	22-May-91	5.1	LG7	11-Sep-91	6.4
LG3	16-Jan-91	9.7	LG5	05-Jun-91	3.8	LG7	24-Sep-91	6.9
LG3	13-Feb-91	9.7	LG5	19-Jun-91	2.7	LG7	23-Oct-91	5.9
LG3	20-Mar-91	8.9						

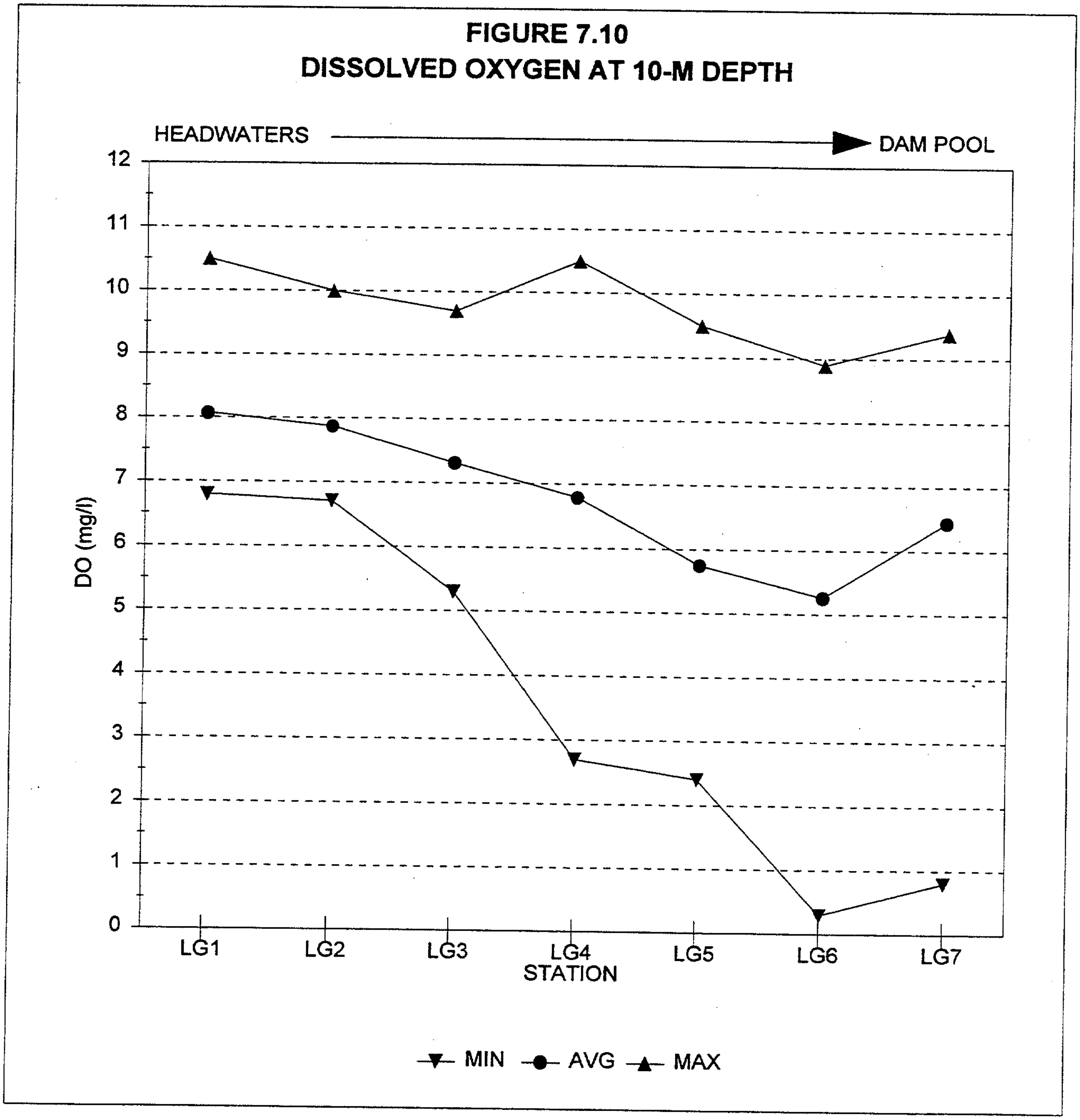
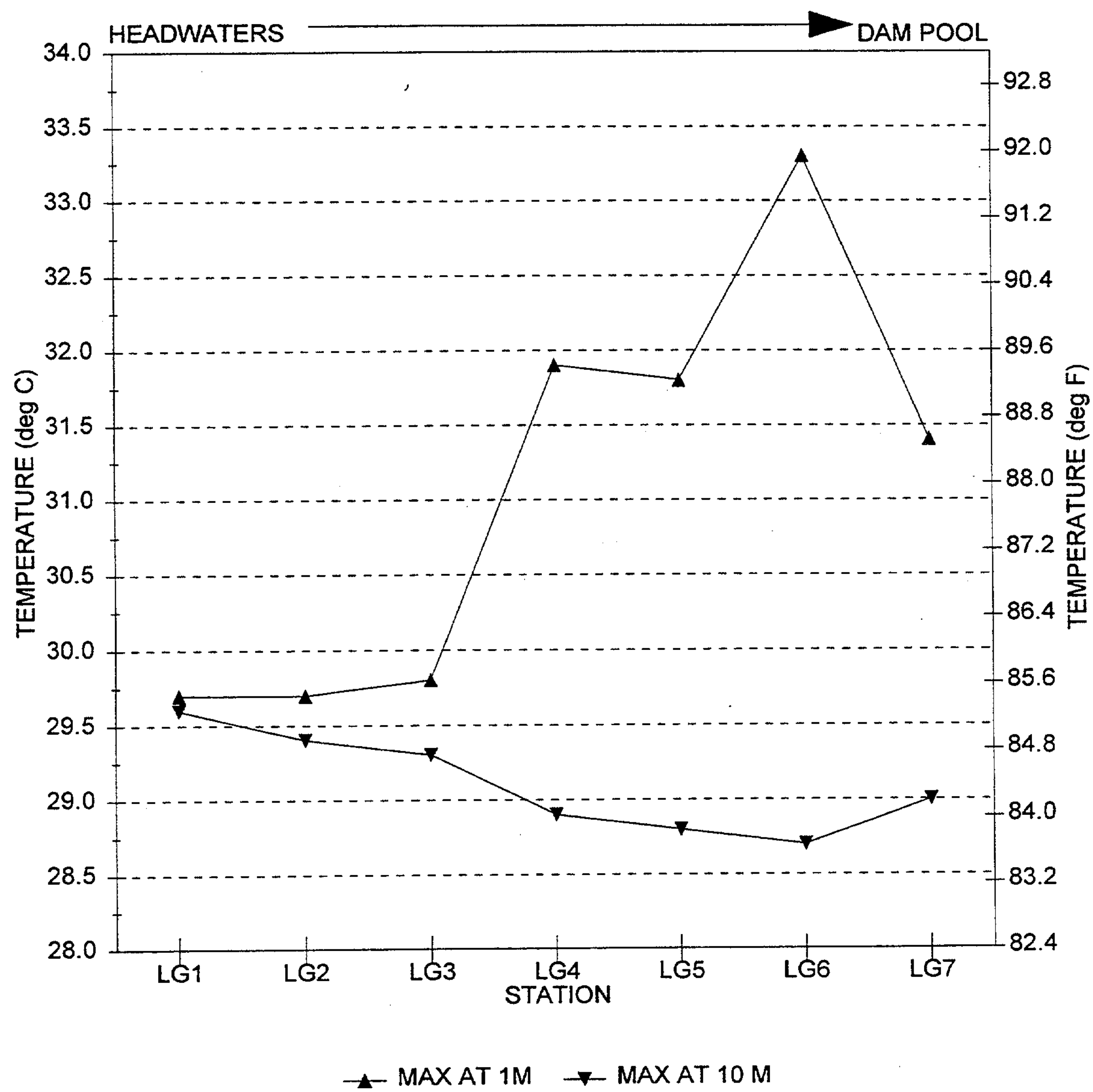


FIGURE 7.10
DISSOLVED OXYGEN AT 10-M DEPTH
HEADWATERS
DAM POOL
DO (mg/l)
0
1
2
3
4
5
6
7
8
9
10
11
12
LG1
LG2
LG3
LG4
LG5
LG6
LG7
STATION
MIN
AVG
MAX

FIGURE 7.11
MAXIMUM LAKE TEMPERATURES



Appendix 5 contains temperature and DO profile plots for stations LG3 and LG7 (mid-lake and dam pool stations). These plots indicate that the mid-lake area became stratified by June 6 and began to destratify by September 11. The dam pool began to stratify by April 10 and remained stratified till September 11. On August 7, dam pool DO was depleted at depths greater than 12 meters. This is typical for peak summer dam pool stratification.

Other lake profile data can be found on individual data sheets in Appendix 4.

7.8 DIEL DO DATA

Diel dissolved oxygen measurements were made at Stations LG5, LG4, and LG2 to determine minimum DO levels in the lake epilimnion. Measurements were made with diver deployed multi-parameter water quality meters programmed to record at half-hour intervals over a period from early evening to the following afternoon (low DO was expected to occur between midnight and mid-morning). Meters were placed at different depths with at least one unit in the epilimnion (the upper stratum). The water quality meters were deployed at Station LG5 on July 8, 1991, moved to Station LG4 on July 9, and moved to Station LG2 on July 10. The meters were calibrated prior to each deployment.

Figures 7.12, 7.13, and 7.14 are graphs of these DO data sets. The DO at LG5 at 2.2 meters shows a clear diel sag with minimum DO occurring around 06:00 hours. Minimum DO remained above seven mg/l in the epilimnion. The LG5 data at depths from 5.6 to 12.7 meters show no noticeable diel pattern. DO at 5.6 meters remained around four mg/l.

At LG4 the meters were deployed between 1.6 and 6.1 meters to cover the range of the epilimnion. All four meters recorded a similar DO sag curve with minimum values occurring at around 08:00. The meter at 6.1 meters recorded a DO decline from 9.2 to 5.3 mg/l (the lowest level recorded).

Three meters were deployed at LG2 between 2.3 and 4.3 meters. As seen in Figure 7.14, DO increased slightly during the evening, then declined from midnight till noon. The lowest DO readings ranged around seven mg/l. The diel DO data from these three stations indicate no significant oxygen depletion in the lake epilimnion.

FIGURE 7-12
W.F. GEORGE DIEL DO DATA
STATION LG5, JUL 8–9, 1991

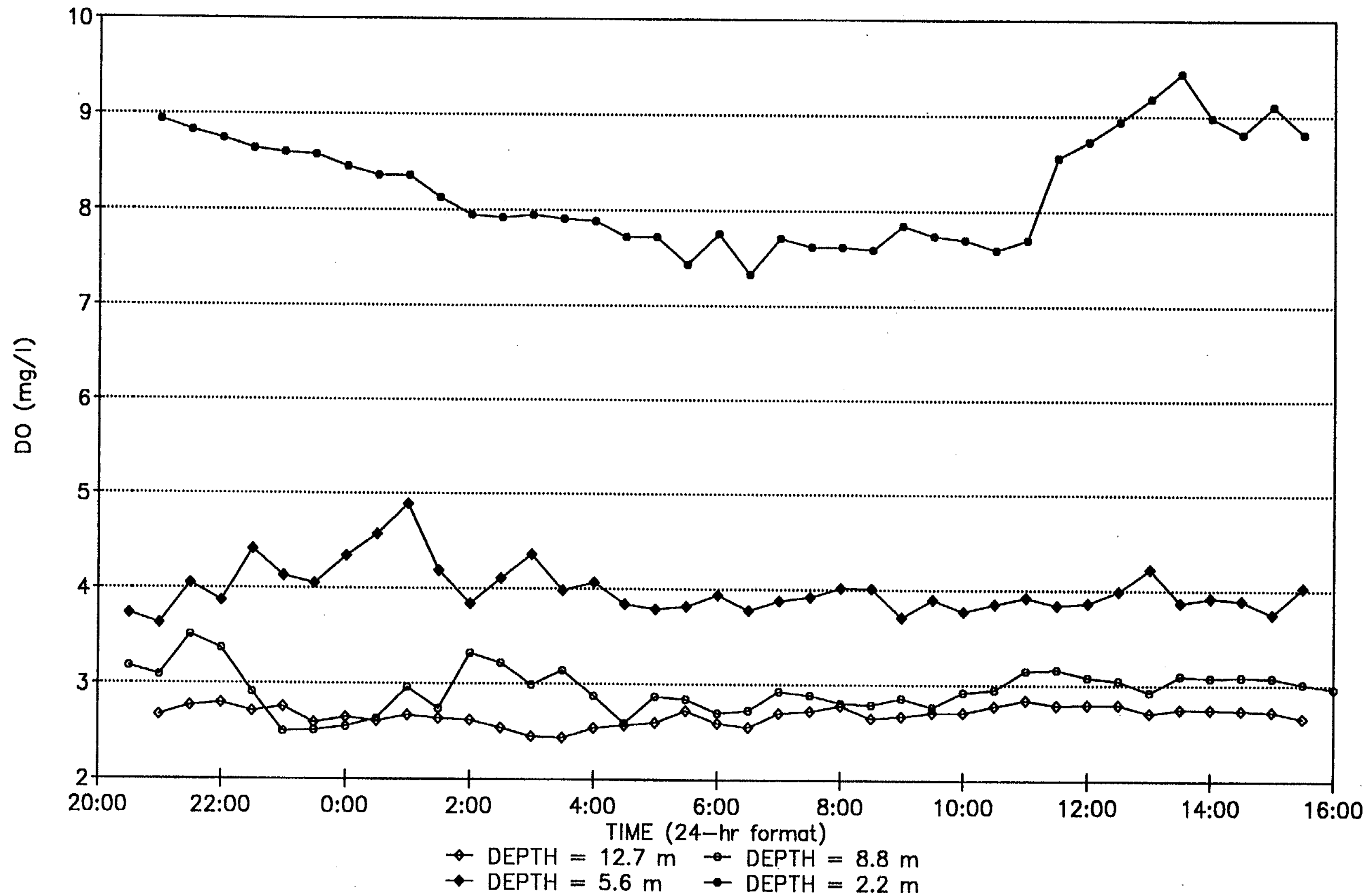


FIGURE 7-13
W.F. GEORGE DIEL DO DATA
STATION LG4, JUL 9–10, 1991

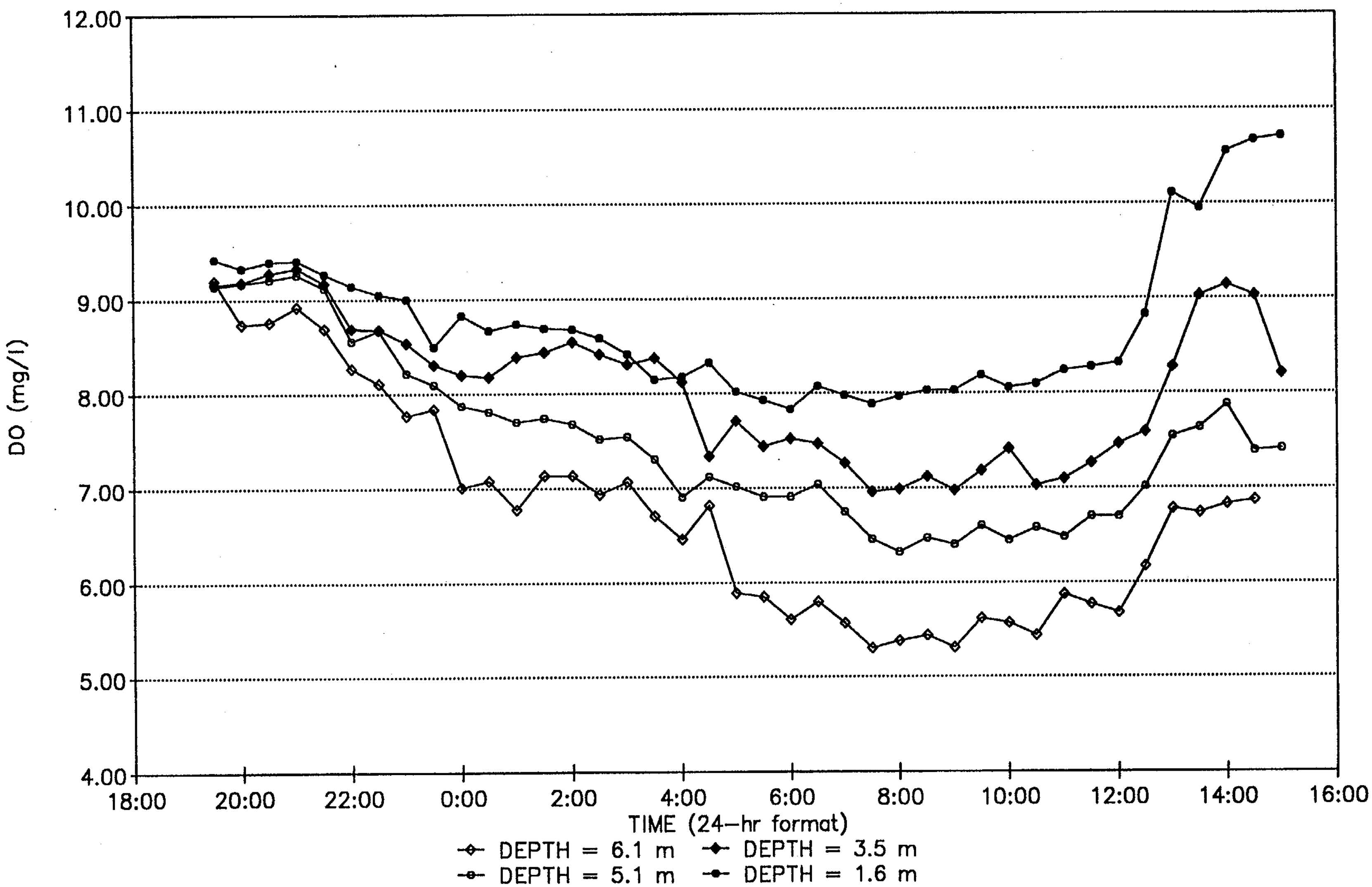
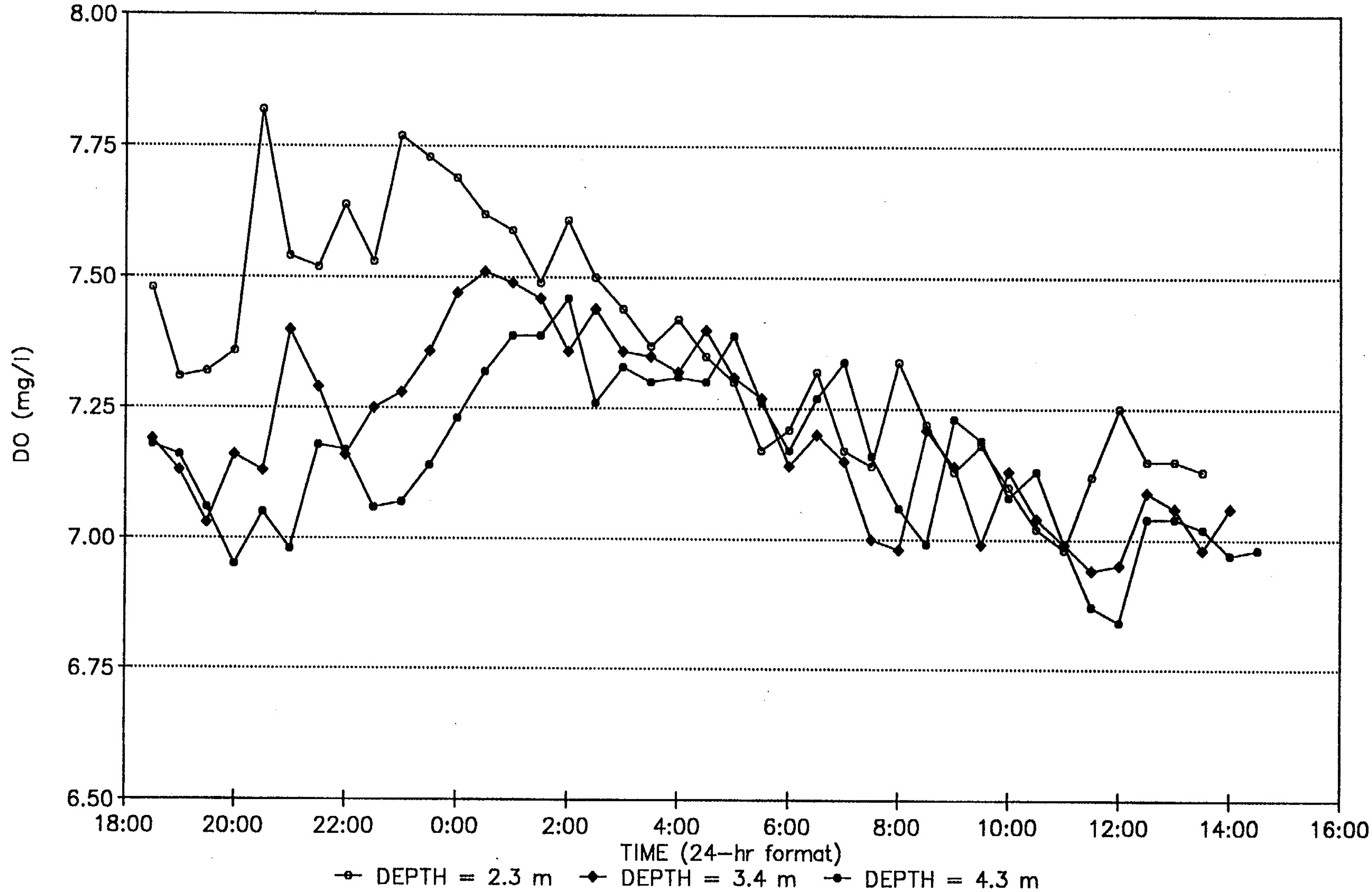


FIGURE 7-14
W.F. GEORGE DIEL DO DATA
STATION LG2, JUL 10–11, 1991



7.9 pH DATA

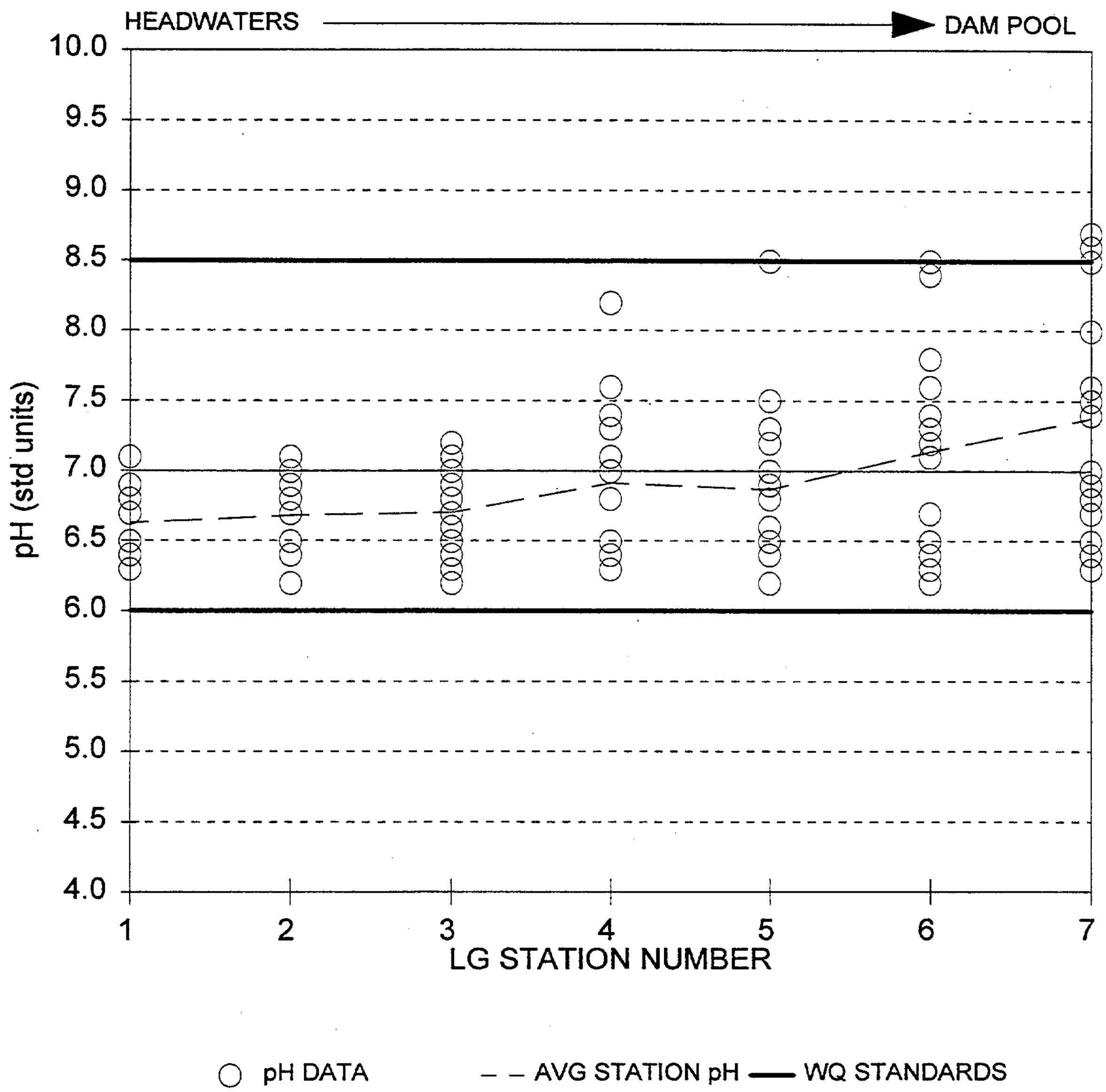
Table 7.10 shows laboratory pH data for all lake samples collected. Figure 7.15 is a scatter plot of this data by station with lines showing Georgia water quality standards and the average station pH. pH values are seen to increase from the headwaters to the dam pool, probably due to increased stability in water column stratification and and increased algal productivity. Note that three of the pH measurements at LG7 exceeded the 8.5 pH water quality standard. These three high pH measurements were made in July and August. Elevated pH is likely the result of algal activity that in turn is related to nutrient levels.

TABLE 7.10

LAB pH DATA (standard units)

STATION	DATE	pH	STATION	DATE	pH	STATION	DATE	pH
LG1	14-Nov-90	7.1	LG3	10-Apr-91	6.8	LG5	10-Jul-91	6.5
LG1	05-Dec-90	6.8	LG3	08-May-91	6.6	LG5	24-Jul-91	6.9
LG1	16-Jan-91	6.9	LG3	22-May-91	6.3	LG5	07-Aug-91	8.5
LG1	13-Feb-91	6.5	LG3	05-Jun-91	6.7	LG5	21-Aug-91	6.5
LG1	20-Mar-91	6.5	LG3	19-Jun-91	7.2	LG5	11-Sep-91	7.2
LG1	10-Apr-91	6.9	LG3	10-Jul-91	6.4	LG5	25-Sep-91	6.4
LG1	08-May-91	6.7	LG3	24-Jul-91	6.7	LG5	23-Oct-91	6.2
LG1	22-May-91	6.3	LG3	07-Aug-91	7.1	LG6	14-Nov-90	7.3
LG1	05-Jun-91	6.4	LG3	21-Aug-91	6.9	LG6	05-Dec-90	7.1
LG1	19-Jun-91	6.8	LG3	11-Sep-91	6.8	LG6	16-Jan-91	6.7
LG1	10-Jul-91	6.4	LG3	25-Sep-91	6.4	LG6	20-Mar-91	6.5
LG1	24-Jul-91	6.5	LG3	23-Oct-91	6.2	LG6	10-Apr-91	7.4
LG1	07-Aug-91	6.9	LG4	14-Nov-90	7.4	LG6	08-May-91	6.7
LG1	21-Aug-91	6.7	LG4	05-Dec-90	7.0	LG6	22-May-91	6.2
LG1	11-Sep-91	6.4	LG4	16-Jan-91	6.8	LG6	05-Jun-91	6.4
LG1	25-Sep-91	6.5	LG4	13-Feb-91	6.5	LG6	19-Jun-91	7.4
LG1	23-Oct-91	6.4	LG4	20-Mar-91	6.4	LG6	10-Jul-91	7.6
LG2	14-Nov-90	7.1	LG4	10-Apr-91	7.3	LG6	24-Jul-91	7.8
LG2	05-Dec-90	6.8	LG4	08-May-91	7.0	LG6	07-Aug-91	8.5
LG2	16-Jan-91	7.1	LG4	22-May-91	6.3	LG6	21-Aug-91	7.2
LG2	13-Feb-91	6.8	LG4	05-Jun-91	6.5	LG6	11-Sep-91	8.4
LG2	20-Mar-91	6.5	LG4	19-Jun-91	7.1	LG6	25-Sep-91	6.3
LG2	10-Apr-91	6.8	LG4	10-Jul-91	7.0	LG6	23-Oct-91	6.7
LG2	08-May-91	6.7	LG4	24-Jul-91	7.6	LG7	14-Nov-90	8.0
LG2	22-May-91	6.2	LG4	07-Aug-91	8.2	LG7	05-Dec-90	7.4
LG2	05-Jun-91	6.5	LG4	21-Aug-91	6.4	LG7	16-Jan-91	7.0
LG2	19-Jun-91	6.9	LG4	11-Sep-91	7.1	LG7	20-Mar-91	6.9
LG2	10-Jul-91	6.4	LG4	25-Sep-91	6.4	LG7	10-Apr-91	7.5
LG2	24-Jul-91	6.7	LG4	23-Oct-91	6.5	LG7	08-May-91	6.5
LG2	07-Aug-91	7.0	LG5	14-Nov-90	7.5	LG7	22-May-91	6.5
LG2	21-Aug-91	7.1	LG5	05-Dec-90	6.8	LG7	05-Jun-91	6.4
LG2	11-Sep-91	6.4	LG5	16-Jan-91	6.8	LG7	19-Jun-91	7.6
LG2	25-Sep-91	6.4	LG5	13-Feb-91	6.6	**LG7**	**10-Jul-91**	**8.6**
LG2	23-Oct-91	6.2	LG5	20-Mar-91	6.5	**LG7**	**24-Jul-91**	**8.7**
LG3	14-Nov-90	7.2	LG5	10-Apr-91	7.3	**LG7**	**07-Aug-91**	**8.6**
LG3	05-Dec-90	7.0	LG5	08-May-91	7.0	LG7	21-Aug-91	6.8
LG3	16-Jan-91	6.8	LG5	22-May-91	6.5	LG7	11-Sep-91	8.5
LG3	13-Feb-91	6.5	LG5	05-Jun-91	6.4	LG7	25-Sep-91	6.7
LG3	20-Mar-91	6.4	LG5	19-Jun-91	7.2	LG7	23-Oct-91	6.3

FIGURE 7.15
LAB pH SCATTER PLOT BY STATION



7.10 FECAL COLIFORM BACTERIA DATA

Fecal coliform bacteria are found in the intestines and feces of warm-blooded animals. This bacteria group is used as an indicator of water quality for various use categories. The unit of measure for fecal coliform is most probable number of bacterial colonies per 100 milliliters of water (MPN/100 ml). Fecal coliform data collected from lake stations are given in Table 7.11. A graph of the maximum and geometric mean station data is shown in Figure 7.16.

The fecal coliform bacteria standard for the recreation classification is 200 MPN per 100 ml, determined as a geometric mean of four samples collected within a 30 day period. This same standard applies to fishing waters from May through October. From November through April, the fishing classification criteria for fecal coliform is 1,000 MPN per 100 ml, geometric mean of four samples in a 30 day period, with a single sample maximum of 4,000 MPN per 100 ml. Stations LG1 and LG2 are classified as fishing. The other lake stations are classified recreation.

Fecal coliform levels are higher in the upstream stations and decrease downstream toward the dam. No sample measured above 4,000 MPN/100 ml. Seventeen samples exceeded 200 MPN/100 ml. These higher measurements are correlated to higher area rainfall data (see Table 6.2). The two September measurements at the upstream stations were clearly rainfall dependent. No rainfall was recorded from the three NWS stations 5-days prior to September 11, 1991. Fecal coliform bacteria measurements were low at all stations on that date. The Columbus NWS station recorded 1.1 inches of rain in the 5-day period prior to September 25, 1991, when elevated fecal coliform bacteria was measured at LG1 and LG2.

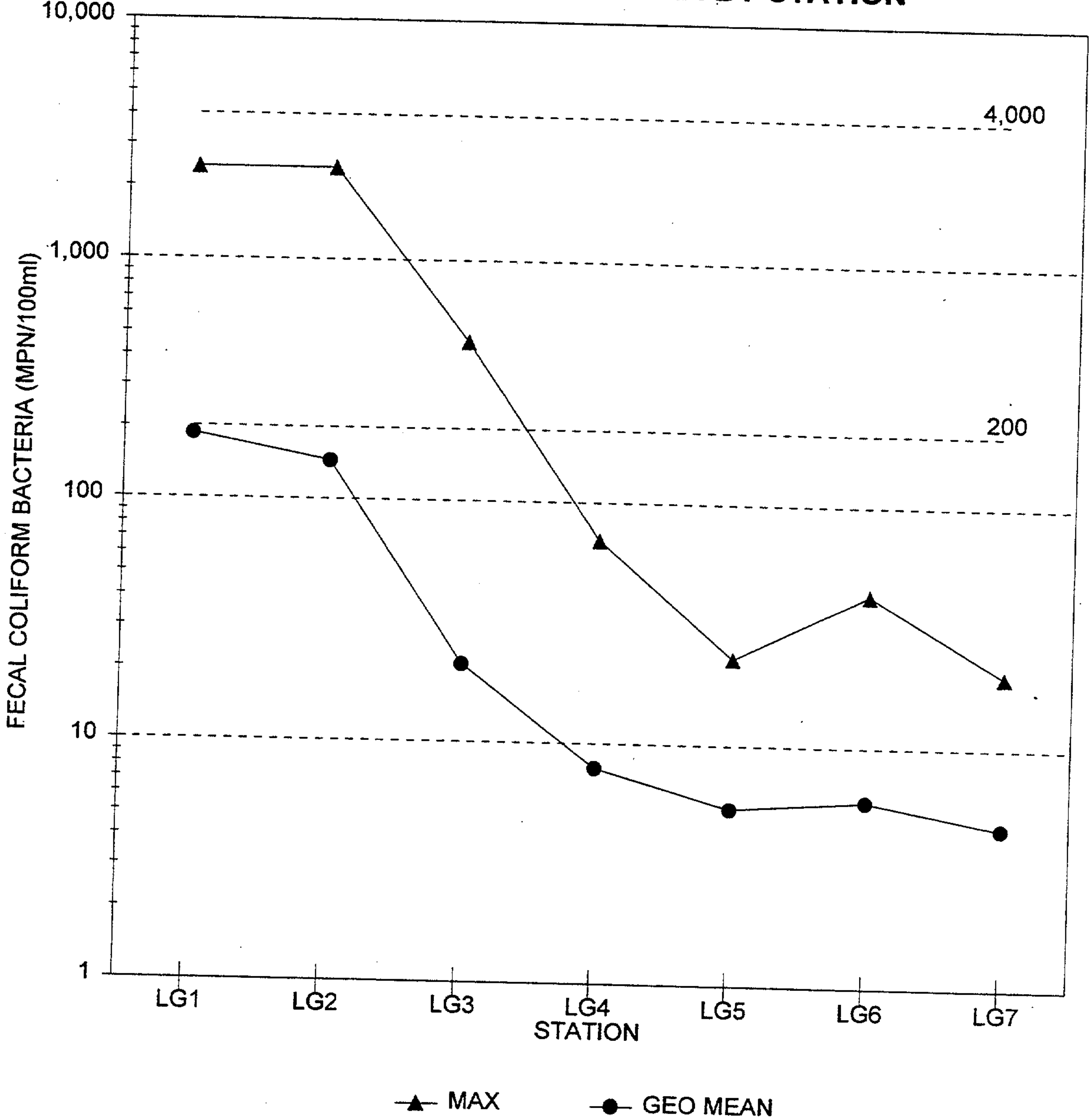
No four-sample, 30-day geometric means were determined since no more than two samples were collected in any 30-day period. The highest geometric mean of all data from any one station was 186 MPN/100 ml at station LG1.

TABLE 7.11

FECAL COLIFORM BACTERIA (MPN per 100 ml)

STATION	DATE	FC BAC	STATION	DATE	FC BACT	STATION	DATE	FC BACT
LG1	14-Nov-90	2400	LG3	10-Apr-91	20	LG5	10-Jul-91	9
LG1	05-Dec-90	23	LG3	08-May-91	460	LG5	24-Jul-91	3
LG1	16-Jan-91	2400	LG3	22-May-91	23	LG5	07-Aug-91	20
LG1	13-Feb-91	43	LG3	05-Jun-91	43	LG5	21-Aug-91	3
LG1	20-Mar-91	150	LG3	19-Jun-91	3	LG5	11-Sep-91	3
LG1	10-Apr-91	330	LG3	10-Jul-91	4	LG5	25-Sep-91	4
LG1	08-May-91	930	LG3	24-Jul-91	21	LG5	23-Oct-91	4
LG1	22-May-91	2400	LG3	07-Aug-91	20	LG6	14-Nov-90	3
LG1	05-Jun-91	1100	LG3	21-Aug-91	7	LG6	05-Dec-90	4
LG1	19-Jun-91	3	LG3	11-Sep-91	3	LG6	16-Jan-91	7
LG1	10-Jul-91	93	LG3	25-Sep-91	93	LG6	20-Mar-91	9
LG1	24-Jul-91	93	LG3	23-Oct-91	9	LG6	10-Apr-91	20
LG1	07-Aug-91	20	LG4	14-Nov-90	4	LG6	08-May-91	4
LG1	21-Aug-91	43	LG4	05-Dec-90	70	LG6	22-May-91	43
LG1	11-Sep-91	23	LG4	16-Jan-91	7	LG6	05-Jun-91	4
LG1	25-Sep-91	2400	LG4	13-Feb-91	9	LG6	19-Jun-91	3
LG1	23-Oct-91	460	LG4	20-Mar-91	4	LG6	10-Jul-91	3
LG2	14-Nov-90	460	LG4	10-Apr-91	20	LG6	24-Jul-91	9
LG2	05-Dec-90	23	LG4	08-May-91	7	LG6	07-Aug-91	20
LG2	16-Jan-91	2400	LG4	22-May-91	43	LG6	21-Aug-91	3
LG2	13-Feb-91	150	LG4	05-Jun-91	3	LG6	11-Sep-91	3
LG2	20-Mar-91	39	LG4	19-Jun-91	3	LG6	25-Sep-91	4
LG2	10-Apr-91	170	LG4	10-Jul-91	3	LG6	23-Oct-91	4
LG2	08-May-91	2400	LG4	24-Jul-91	4	LG7	14-Nov-90	3
LG2	22-May-91	1100	LG4	07-Aug-91	20	LG7	05-Dec-90	3
LG2	05-Jun-91	240	LG4	21-Aug-91	7	LG7	16-Jan-91	15
LG2	19-Jun-91	4	LG4	11-Sep-91	3	LG7	20-Mar-91	4
LG2	10-Jul-91	43	LG4	25-Sep-91	23	LG7	10-Apr-91	20
LG2	24-Jul-91	93	LG4	23-Oct-91	4	LG7	08-May-91	3
LG2	07-Aug-91	20	LG5	14-Nov-90	3	LG7	22-May-91	7
LG2	21-Aug-91	43	LG5	05-Dec-90	3	LG7	05-Jun-91	3
LG2	11-Sep-91	23	LG5	16-Jan-91	23	LG7	19-Jun-91	3
LG2	25-Sep-91	2400	LG5	13-Feb-91	3	LG7	10-Jul-91	3
LG2	23-Oct-91	460	LG5	20-Mar-91	4	LG7	24-Jul-91	3
LG3	14-Nov-90	93	LG5	10-Apr-91	20	LG7	07-Aug-91	20
LG3	05-Dec-90	43	LG5	08-May-91	3	LG7	21-Aug-91	3
LG3	16-Jan-91	230	LG5	22-May-91	23	LG7	25-Sep-91	3
LG3	13-Feb-91	14	LG5	05-Jun-91	4	LG7	23-Oct-91	3
LG3	20-Mar-91	3	LG5	19-Jun-91	3			

FIGURE 7.16
FECAL COLIFORM BACTERIA BY STATION



7.11 METALS AND ORGANIC COMPOUNDS IN WATER AND SEDIMENTS

Water and sediment samples were collected from stations LG1, LG3, LG4, and LG5 on April 10, 1991, for metals and organic compound analyses. The substances analyzed for and laboratory detection limits are listed in Appendix 6. Table 7.12 gives concentrations of substances detected in water samples. No substances were detected from the LG4 samples.

Lead was measured in the LG1 and LG3 samples in concentrations exceeding Georgia water quality criteria. Lead is a soft, gray natural element used in electroplating, metallurgy, manufacturing construction materials, radiation protective devices, plastics, and electronic equipment. Lead reaches water bodies through precipitation, fallout of lead dust, street runoff, and industrial and municipal wastewater discharges.

Mercury was found in the LG1 water sample. Mercury is a natural, silver-white, metallic element. Mercury has a very wide use for such things as electrical apparatus like lamps and mercury battery cells, for industrial and control instruments like switches, thermometers, and barometers, for antifouling and mildew proofing paint, and to control fungal disease of seeds, bulbs, plants, and vegetation. The detected concentration was 17 times higher than the Georgia water quality criteria.

Titanium was detected in the LG1, LG3, and LG5 samples. There are no water quality criteria for titanium. Titanium is a dark gray, almost silver metallic element. Titanium is very lustrous, hard, and corrosion-resistant which makes it a good element to toughen steel.

Phenol was detected in the LG3 and LG5 samples. The concentration measured was 2.6 percent of the Georgia water quality criteria. Phenol is a commonly used industrial chemical used primarily as an intermediate for the preparation of other chemicals. Phenol is also produced during the coking of coal, distillation of wood, operation of gas works and oil refineries, manufacture of livestock dips, in human and animal wastes, and microbiological decomposition of organic matter.

TABLE 7.12
METALS AND ORGANIC SUBSTANCES DETECTED AT STATIONS LG1, LG3, AND LG5 WITH RELATED WATER CHEMISTRY DATA

PARAMETER	LG1	LG3	LG5	DETECTION LIMIT	WATER QUALITY CRITERIA[1]
LEAD (μg/l)	25.0	34.0	ND[2]	25.0	1.3
MERCURY (μg/l)	0.2	ND	ND	0.1	0.012
TITANIUM (μg/l)	19.0	34.0	28.0	10.0	No Criteria
PHENOL (μg/l)	ND	8.0	8.0	5.0	300.0
pH	6.9	6.8	7.3		
HARDNESS (mg/l)	14.0	14.0	18.0		

Table 7.13 gives concentrations of substances detected in sediment samples. There are no regulatory criteria for sediment samples. Metals detected were arsenic, cadmium, chromium, copper, lead, magnesium, mercury, nickel, selenium, silver, titanium, and zinc. Arsenic is a gray, crystalline element found naturally and commonly referred to as a metal. Arsenic is used to manufacture glass, cloth, electrical semiconductors, fungicides, wood preservatives, growth stimulants for plants and animals, and veterinary applications. The

[1] Georgia Rules and Regulations for Water Quality Control

[2] Not detected

principal emission source for arsenic is coal-fuel power plants. However, arsenic is very wide-spread in its uses, and runoff could be another possibility.

TABLE 7.13
METALS AND ORGANIC SUBSTANCES DETECTED IN SEDIMENTS
STATIONS LG1, LG3, LG4, AND LG5

PARAMETER	LG1	LG3	LG4	LG5	DETECTION LIMIT
% Solids	78.3	34.0	46.7	25.5	
METALS (mg/kg)					
Arsenic	ND	13.0	6.2	ND	3.0
Cadmium	2.9	8.2	6.4	3.0	1.0
Chromium	18.0	42.0	34.0	4.9	1.0
Copper	ND	10.0	ND	3.5	1.0
Lead	12.0	49.0	32.0	8.8	3.0
Magnesium	ND	ND	ND	ND	1.0
Mercury	ND	0.2	ND	0.1	0.1
Nickel	4.1	11.0	ND	ND	1.0
Selenium	ND	ND	ND	ND	5.0
Silver	ND	7.0	5.2	ND	3.0
Titanium	220.0	390.0	500.0	8.0	1.0
Zinc	28.0	80.0	54.0	84.0	2.0
ORGANIC SUBSTANCES (µg/kg)					
[Bis(2-ethylhexyl) phthalate]	ND	740.0	206.0	ND	200.0
4,4'-DDE	ND	4.0	ND	10.0	1.0
PCB-1254	ND	13.0	ND	ND	6.0

Cadmium is a soft, silver-white metal used in electroplating, paint and pigment manufacture, and as a stabilizer in plastics manufacture. Cadmium reaches water as fallout from air, in effluent from pigments, plastics, alloys, and from municipal effluent.

Chromium is a metallic element, however, the salt form of chromium is used more often in manufacturing. For example, chromium salts are used in the metal finishing industry as electroplating, cleaning agents, as mordants in the textile industry, in cooling waters, in the leather tanning industry, in catalytic manufacture, in pigments and primer paints, and in fungicides and wood preservatives.

Copper is a soft but heavy metal present in the rocks and minerals of the earth's crust. Through weathering of these copper minerals, copper can be detected in small amounts in freshwater. Another sources of copper is through corrosion of brass and copper pipe by acidic waters, industrial effluent and fallout, sewage treatment plant effluent, and the use of copper compounds as algicides. However, it is the industrial usage of copper in smelting and refining industries, copper wire mills, coal burning industries, and iron and steel producing industries that emit the majority of the copper detected. This copper may enter water directly from the sources or by atmospheric fallout from pollution emitted by these industries.

Magnesium is a light, ductile, silver-white metallic element. Magnesium burns with a very bright dazzle and is commonly used in alloys, fireworks, and flashbulbs. Nickel is an element not commonly found in nature by itself. Nickel makes up a small percentage of the earth's crust and is commonly found as a component of minerals and rock. Selenium is a naturally occurring element used in photocopying, in the manufacturing of glass, electronic devices, pigments, dyes, insecticides, veterinary medicines, and antidandruff shampoos. The major source of selenium in the environment is the weathering of rocks and soils, however, human activities also contribute a significant amount. Silver is a naturally occurring white, ductile metal. Silver is primarily used in photographic materials, electroplating, for conductors, in dental alloys, in solder and brazing alloys, paints, jewelry, silverware, coinage, and mirror production. Zinc is a common metallic element used for galvanizing steel, for producing alloys, and as an ingredient in rubber and paints.

Organic substances found in sediments included DDE and PCB compounds. DDE is a pesticide that is a metabolic breakdown product of DDT. The use of DDT was banned in the United States in 1972. DDE was found in the LG3 and LG5 sediment samples. PCB's have been used as dielectric fluids in transformers, capacitors, and electromagnets. Prior to 1974, PCBs were also used as plasticizers, lubricants, ink carriers, and gasket seals. PCB production in the United States stopped after 1977. Uses since then have been limited to small, totally enclosed electrical systems in restricted access areas. PCBs can reach water bodies by runoff from PCB spills or electrical equipment fires, or runoff/seepage from disposal sites containing PCB-contaminated soils and equipment.

7.12 SEDIMENT OXYGEN DEMAND DATA

Sediment oxygen demand (SOD) is an expression of the rate of at which lake sediments consume oxygen from the overlying water column. Two processes, respiration of living organisms and decomposition of organic matter in the sediment, account for most of the oxygen consumption. SOD is an important component of water quality models that attempt to account for variations in lake dissolved oxygen. Field measurements of SOD were made at four sites near LG2 in November 1991 and at four other sites in the main body of the lake in May 1992. The locations of these sites are shown on Figure 7.17. A summary of the SOD data is given in Table 7.14.

SOD measurements were made according to methods given in the US EPA Standard Operation Procedures Manual, Section 2.12, Revision 1. SCUBA diver deployed chambers were used to isolate a specific volume of water over a specific area of sediment. Dissolved oxygen levels inside three test chambers were monitored for two to three hours. A fourth chamber was deployed with its bottom sealed from the sediment. This control chamber was used to measure oxygen uptake from the water BOD. SOD rates were calculated using the formula defined by Murphy and Hicks[1]:

$$SOD = 1.44\ V/A\ (b_1 - b_2)$$

where,

SOD	= sediment oxygen demand in g/m^2/day
b_1	= oxygen depletion inside test chamber in mg/l/min
b_2	= oxygen depletion inside control chamber in mg/l/min
V	= volume of water isolated by test chamber in liters = 65 liters
A	= area of sediment isolated by test chamber in square meters = 0.27 m^2
1.44	= unit conversion factor, converts mg/min to g/day

[1]Murphy, Philip J. and Delbert Hicks, 1986, *In-situ Method for Measuring Sediment Oxygen Demand*, in Sediment Oxygen Demand, ed. by Kathryn Hatcher, University of Georgia Press, Athens, Georgia

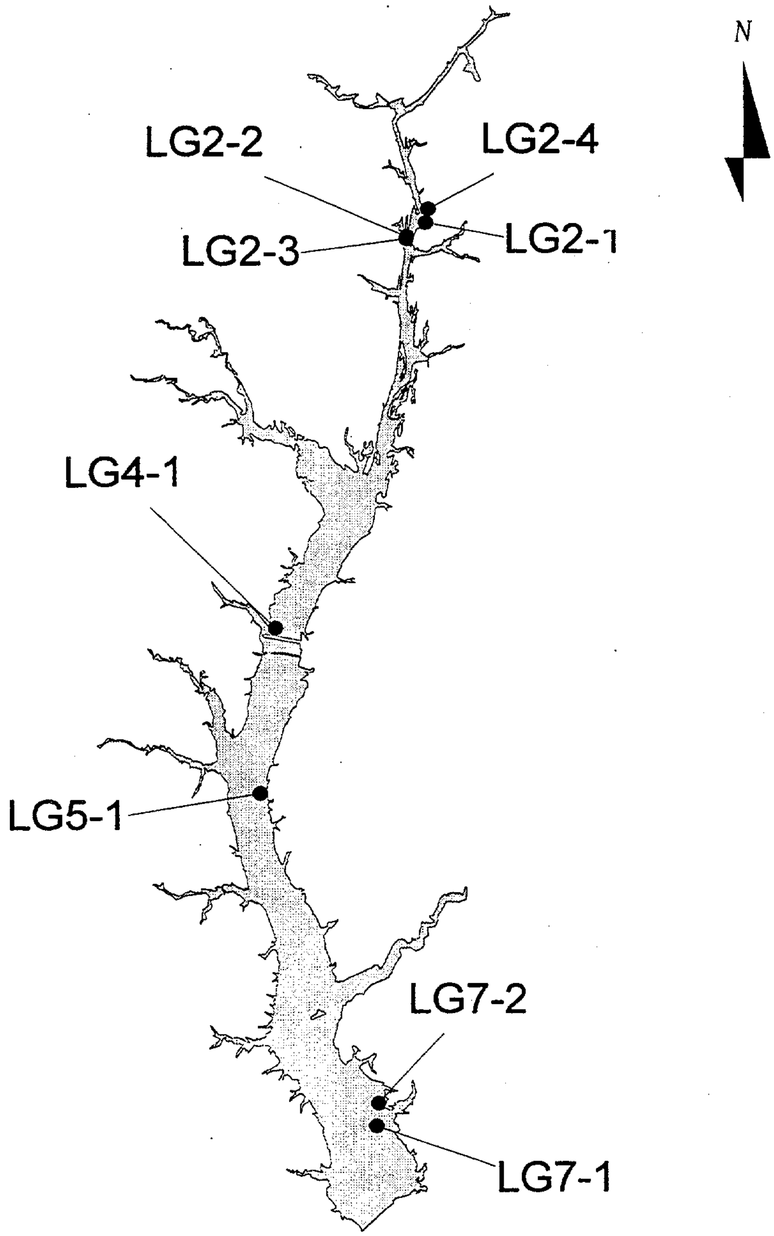


FIGURE 7.17
SEDIMENT OXYGEN DEMAND
TEST SITES

TABLE 7.14

SEDIMENT OXYGEN DEMAND DATA SUMMARY

SOD SITE	DATE	SOD CHAM 1 g/m²/day	SOD CHAM 2 g/m²/day	SOD CHAM 4 g/m²/day	AVG TEMP deg C	BOTTOM TYPE & DEPTH	AVG SOD g/m²/day
LG2-1	11/19/91	0.35	0.31	NOT USED	14.7	FIRM SAND	0.33
LG2-2	11/20/91	1.08	0.58	0.20	14.8	7" FINE SILT	0.62
LG2-3	11/20/91	1.81	1.19	NOT USED	14.8	7" FINE SILT	1.50
LG2-4	11/21/91	0.24	0.45	0.55	15.4	COURSE SAND	0.41
LG7-1	05/12/92	0.77	0.32	0.61	19.3	3" SOFT SEDIMENT	0.57
LG7-2	05/12/92	1.16	0.98	2.22	19.8	4" SED & SAND	1.45
LG5-1	05/13/92	0.55	0.75	0.60	18.8	6" FINE SEDIMENT	0.63
LG4-1	05/14/92	0.50	0.69	0.46	20.6	7" SOFT W DEBRIS	0.55
AVERAGE SOD FOR ALL SOD SITES (g/m²/day)							0.76

LAB DATA FOR SEDIMENT SAMPLES FROM SOD TESTS

SOD SITE	DATE		COD mg/kg dry	PERCENT SOLIDS	PERCENT VOLATILE SOLIDS
LG2-1	11/19/91		3,031	75.5	0.3
LG2-2	11/20/91		34,346	59.0	4.3
LG2-3	11/20/91		34,346	59.0	4.3
LG2-4	11/21/91		4,606	74.8	0.4
LG7-1	05/12/92		18,027	68.9	2.1
LG7-2	05/12/92		15,633	75.2	1.8
LG5-1	05/13/92		36,413	58.1	3.6
LG4-1	05/14/92		64,345	51.4	6.0

SOD rates for the seven sites tested ranged from 0.33 to 1.50 $g/m^2/day$ (mean = 0.76). The lowest SOD occurred at a site with a firm sandy bottom. The highest SOD occurred at a site where the bottom was described as five to ten inches of fine silt over clay with mixed-in tree debris. Mean water temperature ranged between 15.4 and 20.6 degrees Celsius and initial chamber dissolved oxygen concentrations ranged from 8.3 to 5.7 mg/l. Sediment chemical oxygen demand data ranged from 3,031 to 64,345 mg/kg.

SOD measurements made in November 1987 at six sites in W.F. George by the EPA for the Alabama Department of Environmental Management (see study reference in 5.3) ranged from 0.61 to 1.08 $g/m^2/day$ (mean = 0.79). These tests were made at stations distributed through the lake, near stations CR1, LG2, LG3, LG4, LG5, and LG6. The mean SOD rates calculated from the 1987 EPA study and the 1991 EPD study are comparable (0.79 and 0.76 $g/m^2/day$).

SOD measured in October 1992 at seven sites in West Point Lake, a comparable Chattahoochee River impoundment roughly 80 kilometers upstream of W.F. George, ranged from 0.75 to 1.49 $g/m^2/day$ (mean = 1.22). SOD measured between May and November 1990, at seven sites in Jackson Lake, a smaller, older impoundment in central Georgia, ranged from 0.8 to 1.5 $g/m^2/day$ (mean = 1.1). The measured mean W.F. George SOD is significantly lower than the measured mean SOD for these two lakes.

7.13 OTHER WATER QUALITY DATA

Other lake water quality parameters measured in this study include turbidity, suspended solids, total alkalinity, hardness, and specific conductivity. This data is given in Table 7.15, ordered by station and sample date. This data can be summarized as follows:

PARAMETER	MAXIMUM	MINIMUM	MEAN	STD DEV
TURBIDITY (NTU)	32	1	10	7
SUSPENDED SOLIDS (mg/l)	23	1	6	5
TOTAL ALKALINITY (mg/l)	50	9	23	7
HARDNESS (mg/l)	47	14	28	8
CONDUCTIVITY (μmho/cm^2)	122	50	80	14

TABLE 7.15 (3 PAGES)
OTHER WATER QUALITY DATA

STATION	DATE	TURBIDITY (NTU)	SUSPENDED SOLIDS (mg/l)	TOTAL ALKALINITY (mg/l)	HARDNESS (mg/l)	CONDUCTIVITY (µmho/cm²)
LG1	14-Nov-90	9	3	31	26	95
LG1	05-Dec-90	8	3	22	38	104
LG1	16-Jan-91	11	1	22	30	92
LG1	13-Feb-91	22	9	17	31	81
LG1	20-Mar-91	16	10	18	42	75
LG1	10-Apr-91	16	13	13	14	65
LG1	08-May-91	20	17	9	27	73
LG1	22-May-91	21	13	16	26	68
LG1	05-Jun-91	17	1	22	16	69
LG1	19-Jun-91	10	9	18	38	76
LG1	10-Jul-91	14	6	24	26	66
LG1	24-Jul-91	10	1	28	21	79
LG1	07-Aug-91	6	6	19	20	77
LG1	21-Aug-91	9	6	22	24	77
LG1	11-Sep-91	6	1	27	30	87
LG1	25-Sep-91	10	8	35	24	84
LG1	23-Oct-91	13	11	25	25	100
LG2	14-Nov-90	7	6	40	47	120
LG2	05-Dec-90	8	4	23	30	110
LG2	16-Jan-91	11	3	22	38	95
LG2	13-Feb-91	23	1	17	33	90
LG2	20-Mar-91	15	9	19	29	75
LG2	10-Apr-91	12	10	13	16	68
LG2	08-May-91	20	20	26	30	73
LG2	22-May-91	18	13	17	33	50
LG2	05-Jun-91	15	1	19	21	62
LG2	19-Jun-91	9	6	24	35	76
LG2	10-Jul-91	11	5	26	27	68
LG2	24-Jul-91	8	4	20	30	75
LG2	07-Aug-91	5	6	19	20	81
LG2	21-Aug-91	9	4	33	42	82
LG2	11-Sep-91	6	1	29	29	88
LG2	25-Sep-91	10	3	26	27	90
LG2	23-Oct-91	10	7	25	25	106
LG3	14-Nov-90	6	6	32	47	97
LG3	05-Dec-90	10	10	21	34	98
LG3	16-Jan-91	9	4	20	44	102
LG3	13-Feb-91	28	10	17	36	84
LG3	20-Mar-91	17	6	17	37	70

TABLE 7.15 (3 PAGES) OTHER WATER QUALITY DATA						
STATION	DATE	TURBIDITY (NTU)	SUSPENDED SOLIDS (mg/l)	TOTAL ALKALINITY (mg/l)	HARDNESS (mg/l)	CONDUCTIVITY (µmho/cm²)
LG3	10-Apr-91	32	11	11	14	59
LG3	08-May-91	15	23	22	27	74
LG3	22-May-91	16	11	21	28	72
LG3	05-Jun-91	10	1	27	17	75
LG3	19-Jun-91	11	8	22	39	75
LG3	10-Jul-91	10	6	22	42	71
LG3	24-Jul-91	10	2	21	22	72
LG3	07-Aug-91	5	5	20	20	78
LG3	21-Aug-91	6	2	28	31	76
LG3	11-Sep-91	6	1	28	45	82
LG3	25-Sep-91	10	2	25	24	91
LG3	23-Oct-91	10	6	19	36	104
LG4	14-Nov-90	6	5	45	32	122
LG4	05-Dec-90	8	8	22	31	98
LG4	16-Jan-91	9	1	25	42	97
LG4	13-Feb-91	32	15	17	28	82
LG4	20-Mar-91	17	13	14	21	68
LG4	10-Apr-91	17	8	14	16	65
LG4	08-May-91	14	11	23	32	72
LG4	22-May-91	15	9	21	27	70
LG4	05-Jun-91	6	1	31	19	68
LG4	19-Jun-91	8	5	19	24	72
LG4	10-Jul-91	7	6	27	32	68
LG4	24-Jul-91	8	1	32	24	73
LG4	07-Aug-91	4	4	19	20	77
LG4	21-Aug-91	5	9	28	28	80
LG4	11-Sep-91	5	1	32	36	80
LG4	25-Sep-91	12	4	30	23	90
LG4	23-Oct-91	6	5	29	28	100
LG5	14-Nov-90	6	4	30	25	116
LG5	05-Dec-90	10	7	26	28	95
LG5	16-Jan-91	8	3	22	24	97
LG5	13-Feb-91	30	14	16	24	85
LG5	20-Mar-91	20	10	14	29	64
LG5	10-Apr-91	7	6	15	18	73
LG5	08-May-91	12	19	20	28	74
LG5	22-May-91	14	8	23	31	65
LG5	05-Jun-91	10	1	30	24	68
LG5	19-Jun-91	5	1	19	30	72

TABLE 7.15 (3 PAGES) OTHER WATER QUALITY DATA						
STATION	DATE	TURBIDITY (NTU)	SUSPENDED SOLIDS (mg/l)	TOTAL ALKALINITY (mg/l)	HARDNESS (mg/l)	CONDUCTIVITY (µmho/cm²)
LG5	10-Jul-91	10	15	28	23	69
LG5	24-Jul-91	5	10	33	26	74
LG5	07-Aug-91	4	4	19	18	72
LG5	21-Aug-91	5	5	33	30	78
LG5	11-Sep-91	5	1	27	28	80
LG5	25-Sep-91	6	1	25	26	90
LG5	23-Oct-91	6	6	21	34	102
LG6	14-Nov-90	5	5	50	31	60
LG6	05-Dec-90	10	2	26	29	98
LG6	16-Jan-91	10	2	24	40	95
LG6	20-Mar-91	26	9	18	22	59
LG6	10-Apr-91	3	3	15	18	72
LG6	08-May-91	11	10	12	25	76
LG6	22-May-91	7	2	21	27	70
LG6	05-Jun-91	6	1	22	35	68
LG6	19-Jun-91	5	1	24	33	72
LG6	10-Jul-91	7	10	32	29	68
LG6	24-Jul-91	5	8	28	26	72
LG6	07-Aug-91	3	5	19	20	72
LG6	21-Aug-91	5	5	23	26	85
LG6	11-Sep-91	4	1	25	38	76
LG6	25-Sep-91	6	1	24	26	85
LG6	23-Oct-91	6	1	23	32	102
LG7	14-Nov-90	5	2	38	32	90
LG7	05-Dec-90	9	9	29	29	98
LG7	16-Jan-91	11	2	20	29	95
LG7	20-Mar-91	18	9	19	24	66
LG7	10-Apr-91	3	5	15	16	70
LG7	08-May-91	6	8	16	21	66
LG7	22-May-91	6	4	24	23	73
LG7	05-Jun-91	5	1	25	28	68
LG7	19-Jun-91	4	2	22	33	72
LG7	10-Jul-91	5	6	25	23	67
LG7	24-Jul-91	5	5	26	25	73
LG7	07-Aug-91	1	3	19	20	70
LG7	21-Aug-91	4	3	31	25	72
LG7	11-Sep-91	4	1	28	25	75
LG7	25-Sep-91	6	1	32	29	82
LG7	23-Oct-91	6	7	24	28	102

8.0 TRIBUTARY WATER QUALITY DATA

The only major tributary to WF George is the Chattahoochee River. The river was sampled upstream of the lake at CR1 adjacent to Bluff Creek Park at COE river mile 120.3. The river was also sampled downstream of the WF George dam (station CR2). Three other Georgia tributaries were included in this study: Hannahatchee Creek, Pataula Creek, and Drag Nasty Creek (stations HC1, PC1, and DN1). Refer to Figure 6.1 for station and sampled sub-basin locations. Selected water quality data from these tributaries are presented in this chapter.

8.1 NUTRIENT DATA

Table 8.1 contains total phosphorus data for tributary stations. Table 8.2 contains total nitrogen data. These data were used in nutrient budget calculations in chapter 4. Hannahatchee Creek had the highest average total phosphorus concentration. The Chattahoochee River upstream and Drag Nasty Creek had higher average total nitrogen concentrations.

TABLE 8.1

TOTAL PHOSPHOROUS (mg/l) - TRIBUTARY STATIONS

DATE	CR1	HC1	PC1	DN1	CR2
11/14/1990	0.09	0.03	0.02	0.03	0.03
12/05/1990	0.1	0.07	0.05	0.02	0.05
01/16/1991	0.04	0.1	0.02	0.03	0.02
02/13/1991	0.06	0.11	0.04	0.02	ND
03/20/1991	0.06	0.04	0.03	0.02	0.02
04/10/1991	0.07	0.15	0.04	0.11	0.04
05/08/1991	0.07	0.09	0.05	0.05	0.04
05/22/1991	0.12	0.17	0.14	0.06	0.07
06/05/1991	0.03	0.11	0.05	0.04	0.03
06/19/1991	0.15	0.22	0.14	0.15	0.05
07/10/1991	0.07	0.09	0.06	0.05	0.05
07/24/1991	0.03	0.07	0.03	0.03	0.03
08/07/1991	0.02	0.05	0.13	0.02	0.02
08/21/1991	0.08	0.09	0.04	0.04	0.02
09/11/1991	0.04	0.1	0.04	0.04	0.03
09/25/1991	0.07	0.1	0.04	0.03	0.02
10/23/1991	0.07	0.07	0.08	0.05	0.08
Avg	0.07	0.10	0.06	0.05	0.04
SD	0.03	0.05	0.04	0.03	0.02

TABLE 8.2 TOTAL NITROGEN (mg/l) - TRIBUTARY STATIONS					
DATE	CR1	HC1	PC1	DN1	CR2
11/14/1990	0.97	0.44	0.25	0.76	0.44
12/05/1990	0.94	0.53	0.03	0.42	1
01/16/1991	1.27	0.31	0.29	0.49	0.6
02/13/1991	1.04	0.19	0.61	0.78	ND
03/20/1991	0.75	0.63	0.19	0.38	0.59
04/10/1991	0.72	0.36	0.3	0.38	0.47
05/08/1991	0.72	0.21	0.32	0.56	0.46
05/22/1991	0.68	0.21	0.25	0.72	0.63
06/05/1991	0.63	0.32	1.05	ND	0.81
06/19/1991	0.66	0.22	0.37	0.76	0.94
07/10/1991	0.6	0.31	0.32	ND	0.26
07/24/1991	0.49	0.25	0.34	0.7	0.79
08/07/1991	0.8	0.42	0.56	0.64	0.28
08/21/1991	0.68	0.23	0.23	0.49	0.25
09/11/1991	0.86	0.21	0.44	0.72	0.44
09/25/1991	0.65	0.14	0.2	0.73	0.33
10/23/1991	0.66	0.72	0.12	0.69	0.37
Avg	0.77	0.34	0.35	0.61	0.54
SD	0.19	0.16	0.23	0.15	0.24

8.2 TURBIDITY AND SUSPENDED SOLIDS DATA

Turbidity and suspended solid data are shown in tables 8.3 and 8.4. These parameters are an indicator of relative soil loadings. Hannahatchee Creek had significantly higher average suspended solids concentrations and turbidity than the other tributary stations.

TABLE 8.3
TURBIDITY (NTU) - TRIBUTARY STATIONS

DATE	CR1	HC1	PC1	DN1	CR2
11/14/1990	10	15	11	9	6
12/05/1990	10	20	17	13	7
01/16/1991	12	160	26	30	12
02/13/1991	20	30	20	43	14
03/20/1991	16	31	18	18	7
04/10/1991	19	250	23	28	5
05/08/1991	20	38	30	21	10
05/22/1991	22	68	42	26	12
06/05/1991	18	56	31	132	10
06/19/1991	10	33	30	14	7
07/10/1991	13	45	39	26	7
07/24/1991	9	140	21	12	5
08/07/1991	7	28	20	10	3
08/21/1991	9	26	22	12	5
09/11/1991	9	33	16	13	5
09/25/1991	14	70	19	11	15
10/23/1991	11	19	18	11	7
Avg	13.47	62.47	23.71	25.24	8.06
SD	4.76	63.23	8.28	29.04	3.49

TABLE 8.4 SUSPENDED SOLIDS (mg/l) - TRIBUTARY STATIONS					
DATE	CR1	HC1	PC1	DN1	CR2
11/14/1990	7	4	1	2	7
12/05/1990	5	10	1	1	1
01/16/1991	2	148	6	10	1
02/13/1991	10	37	7	34	15
03/20/1991	8	32	8	4	1
04/10/1991	15	440	12	18	5
05/08/1991	13	32	10	9	7
05/22/1991	15	66	20	13	8
06/05/1991	4	44	10	48	1
06/19/1991	8	30	10	3	1
07/10/1991	9	36	24	15	5
07/24/1991	7	132	9	2	2
08/07/1991	7	30	12	5	3
08/21/1991	9	18	15	6	1
09/11/1991	4	36	1	53	1
09/25/1991	9	2	1	1	1
10/23/1991	11	9	8	5	6
Avg	8.41	65.06	9.12	13.47	3.88
SD	3.68	104.76	6.49	16.21	3.85

8.3 FLOW DATA

Stream flows at the three minor tributary stations were gaged using standard velocity meter integration methods. A staff gage was used at Hannahatchee and Drag Nasty Creeks. Pataula Creek was gaged with a bridge board device. Table 8.5 contains gaged flow data. Hannahatchee Creek had an average drainage of 0.23 cfs per km^2. Pataula Creek and Drag Nasty Creek both had an average drainage of 0.33 cfs per km^2.

TABLE 8.5

TRIBUTARY STATION FLOW (cfs)

DATE	HC1	PC1	DN1
11/14/1990	25	116	5
12/05/1990	32	224	6
01/16/1991	133	406	28
03/20/1991	ND	ND	15
04/10/1991	ND	339	29
05/22/1991	120	243	7
08/07/1991	52	211	5
08/21/1991	ND	349	ND
09/25/1991	73	145	5
10/23/1991	ND	ND	1
Avg	72.50	254.13	11.22
SD	45.24	102.22	10.47

9.0 BIOLOGICAL RESOURCES

9.1 MACROPHYTE INVENTORY DATA

During the week of August 20-24, 1991, the Alabama Department of Conservation and Natural Resources (ADCNR) conducted a survey to identify major aquatic plant communities in Lake Walter F. George. The survey was performed by Joe Zolczynski, Aquatic Plant Management Supervisor, and other personnel from the ADCNR Game and Fish Division. This macrophyte inventory was initiated by a request from the W.F. George Resource Manager.

Mr. Zolczynski and his team used an airboat and a 16-foot outboard motor boat to survey the entire shoreline and all shallow water areas of the lake. Shallow areas were also raked to check for submersed plants not visible from the surface. Submersed, emersed, floating, and marginal plants were identified and locations were marked on USGS 7.5-minute quadrangle maps. These maps were digitized to produce a lake map with the location of plant communities marked by key symbols. This map and Mr. Zolczynski's complete report are attached in Appendix 7.

The most common macrophytes identified in this survey included aligatorweed, water willow, maidencane, willows, and torpedo grass. Although not abundant, two other plants were specifically noted that caused concern; spinyleaf najas and giant cutgrass. A complete listing of all aquatic plants identified is included in the survey report, with their scientific and common names. Neither submersed nor emersed plants were found plentiful in the main body of the lake. However, broad beds of alligator weed, water willow, and maidencane were noted in the shallow shoreline areas between Florence Marina and the Cowikee Creek confluence. This includes the vicinity of the Eufaula National Wildlife Refuge. These same plants were noted in an oxbow section of the Chattahoochee River upstream of Bluff Creek in the area of River Bend Park. A comparison of these areas with aerial photographs from 1985 suggested no major increase in emersed plant populations.

Alligatorweed was the most abundant plant found. Alligatorweed flea beetles, Agasicles hygrophila, were observed on plants in most areas and damage from the flea beetles was heavy. No flea beetles were seen in the area between Florence Marina and Cowikee Creek. The ADCNR report recommends the redistribution of flea beetles from other parts of the lake to help control the aligatorweed in this area. Georgia DNR personnel observed an ADCNR boat crew attempting to collect beetles from the River Bend Park area in the summer of 1992 for this purpose.

Giant cutgrass was found in only a few locations that are all marked on the ADCNR map. Less than one acre was found throughout the lake. Walter F. George COE personnel have since treated these stands with herbicide to minimize growth of this plant.

Submersed plants were found scarce throughout the lake. The submersed plants found included chara, spineyleaf naiad, coontail, and slender spikerush. Spineyleaf naiad was the only plant that caused concern. This is an exotic submersed plant known to be a nuisance if too abundant. COE personnel have since treated the noted locations (1.25 acres total) with herbicide as recommended by the ADCNR report.

The Walter F. George Resource Manager's Office is very concerned about the introduction of new macrophytes and the increase in current nuisance plant populations. Lake Seminole, fifty miles to the south, is very unlike Walter F. George with respect to the aquatic plants that choke its waterways. According to a 1974 COE study, 70 noxious or potentially noxious plants were identified in Lake Seminole, with eurasian milfoil, giant cutgrass, and hydrilla causing the major problems.

9.2 FISH POPULATION DATA

The DNR Game and Fish Division (GFD) participates in managing fishery resources in Lake WF George. GFD personnel conduct cove rotenone surveys each year to estimate fish standing crop (the quantity of each species on a weight per area basis). Table 9.1 shows GFD cove rotenone standing crop data for 1975-1978, 1987-1990, and 1991.

Significant increases in standing crop population are seen from 75-78 to 87-90. Predatory game fish increased by 240 percent and non-predatory game fish increased by 170 percent. A decrease in predatory game fish was seen from 87-90 to 1991 (37 percent). A similar decrease is seen in forage fish and predatory and non-predatory food fish standing crop.

Table 9.2 compares 1983-1986 WF George standing crop data with three other lakes in the area, Lake Harding, Lake Seminole, and Lake Blackshear. During this period Lake Seminole had a 50 percent higher average concentration of predatory game fish than the other three lakes which all had about 20 kg/ha. The concentration of non-predatory game fish in WF George was about half that of the other lakes. Summing all fish standing crop, Lake Seminole had more than twice the concentration of Lake WF George, which in turn had twice the concentration of either Lake Harding or Lake Blackshear.

TABLE 9.1
STANDING CROPS OF FISH IN LAKE WALTER F. GEORGE
(kg/Ha)

SPECIES	1975-1978	1987-1990	1991
Predatory Game Fish			
Largemouth Bass	14.9	36.4	31.3
Black Crappie	3.9	25.7	8.8
Hybrid Bass	0.2	2.0	0.5
TOTAL	19.0	64.1	39.8
Non-predatory Game Fish			
Bluegill	25.9	61.8	75.2
Redbreast Sunfish	2.8	6.2	4.3
Green Sunfish	0.7	1.5	0.7
Warmouth	2.0	4.0	4.5
Redear Sunfish	1.9	6.4	8.6
Longear Sunfish	1.3	4.9	2.3
Yellow Perch	0.2	9.3	3.2
TOTAL	34.7	94.1	98.6
Non-predatory Food Fish			
Spotted Sucker	7.0	21.4	8.0
Bullhead	1.0	1.4	1.9
Carp	50.8	82.0	72.1
TOTAL	58.8	104.8	82.0
Predatory Food Fish			
Channel Catfish	6.6	8.9	7.7
White Catfish	2.1	26.7	3.7
TOTAL	8.7	35.6	11.4
Forage Fish			
Gizzard Shad	108.1	85.5	53.7
Threadfin Shad	17.6	52.2	31.4
Misc. Minnows	0.6	6.4	0.5
TOTAL	126.3	144.1	85.6
TOTAL ALL FISH	247.5	442.7	318.0

TABLE 9.2

SUMMARY OF TOTAL STANDING CROP BY SPECIES FROM COVE ROTENONE STUDIES FROM FOUR MAJOR RESERVOIRS IN SOUTHWEST GEORGIA, 1983-1986

(kg/Ha)

SPECIES	LAKE HARDING	LAKE W.F. GEORGE	LAKE SEMINOLE	LAKE BLACKSHEAR
Predatory Game Fish				
Largemouth Bass	18.7	18.3	24.1	16.3
Black Crappie	2.2	1.6	4.0	3.2
Hybrid Bass	0.0	1.0	2.3	0.0
TOTAL	20.8	20.8	30.4	19.5
Non-predatory Game Fish				
Bluegill	78.3	45.8	44.8	60.0
Redbreast Sunfish	1.3	2.3	3.2	2.7
Green Sunfish	0.1	1.8	0.0	0.2
Warmouth	2.6	1.9	41.7	18.5
Redear Sunfish	6.6	2.3	21.6	16.6
Longear Sunfish	0.9	1.2	0.0	0.0
Yellow Perch	7.3	1.8	0.0	3.4
TOTAL	97.0	57.1	111.3	101.3
Non-predatory Food Fish				
Spotted Sucker	1.4	21.0	35.9	63.5
Bullhead	0.5	116.0	1.2	1.4
Carp	46.7	0.8	1.8	0.0
TOTAL	48.5	137.8	38.9	64.9
Predatory Food Fish				
Channel Catfish	27.1	1.7	2.4	2.6
White Catfish	9.3	2.7	0.0	0.0
TOTAL	36.4	4.4	2.4	2.6
Forage Fish				
Gizzard Shad	66.5	185.1	506.3	34.4
Threadfin Shad	29.2	161.9	790.5	16.8
Misc. Minnows	0.4	2.0	2.3	1.7
TOTAL	96.1	349.0	1299.1	53.9
TOTAL ALL FISH				

9.3 METALS AND ORGANIC COMPOUNDS IN FISH

Fish from W.F. George were collected and analyzed for toxic contaminates in 1990 and 1991 during the W.F. George Phase I study. Table 9.3 lists the thirty organic compounds and the thirteen metals for which the samples were analyzed, with laboratory detection limits. In 1990 eighteen fish including carp, black crappie, and largemouth bass were analyzed. Table 9.4 presents the toxic substances detected in 1990. These were individual fish samples of edible flesh (fillets, skin off). Three of these samples were duplicated for a total of twenty-one samples. Only DDE, Dieldrin, PCB-1260, arsenic, copper, lead, mercury, and zinc were detected. No toxic substance was found above the Food and Drug Administration (FDA) action levels in the average concentration for each species.

In 1991 one hundred seventy-four fish were collected and grouped into thirty-one composite samples. Fish species were largemouth bass, hybrid bass, and channel catfish. Table 9.5 presents the toxic substances detected in the analyses of these composite samples. Table 9.6 lists the lengths and weights of the fish collected. The samples were edible flesh (fillets, skin-on except for catfish which were skin-off). Duplicates analyses were conducted on two metals samples and five pesticide/PCB samples Of the thirty pesticides/PCBs and thirteen metals analyzed for, only chlordane, DDE, dieldrin, PCB-1260, arsenic, mercury, selenium and zinc were detected.

In the 1991 W.F. George samples, no toxic substance was detected in concentrations above the FDA action levels in the average concentration for each species. However, although no advisory is warranted on Lake W. F. George at this time, there is one area where the toxics in fish data cause concern. This area is the Chattahoochee River downstream of Oswichee Creek. At the Chattahoochee River downstream of Oswichee Creek two of six channel catfish composite samples and one of six largemouth bass composite samples exceeded the 0.3 ppm FDA action level for chlordane. The six channel catfish in each of the composites of concern averaged 4.9 and 2.5 pounds respectively, and the six largemouth bass in the composite sample averaged 4.5 pounds. The average chlordane concentration of all six composite samples of each species did not exceed the FDA action level of 0.3ppm. The average chlordane concentration for channel catfish was 0.24 mg/kg and the average chlordane concentration for largemouth bass was 0.21 mg/kg.

TABLE 9.3

PARAMETERS AND DETECTION LIMITS FOR FISH SAMPLES*

PARAMETER	DETECTION LIMIT (mg/kg)
METALS	
Antimony	1
Arsenic	0.005
Beryllium	1
Cadmium	1
Chromium, Total	1
Copper	1
Lead	1
Mercury	0.01
Nickel	1
Selenium	0.01
Silver	1
Thallium	1
Zinc	1
PESTICIDES/PCB	
Aldrin	0.01
a-BHC	0.01
b-BHC	--
d-BHC	0.01
g-BHC (Lindane)	0.01
Chlordane	0.04
4,4-DDD	0.01
4,4-DDE	0.01
4,4-DDT	0.01
Dieldrin	0.01
Endosulfan I	0.02
Endosulfan II	0.03
Endosulfan Sulfate	0.05
Endrin	0.01
Endrin Aldehyde	--
Heptachlor	0.01
Heptachlor Epoxide	0.01
Toxaphene	0.01
PCB-1016	0.1
PCB-1221	0.1
PCB-1232	0.1
PCB-1242	0.1
PCB-1248	0.1
PCB-1254	0.1
PCB-1260	0.1
Methoxychlor	0.05
HCB	0.01
Mirex	0.1
Pentachloroanisole	0.01
Chlorpyrifos	0.05

*Analyses were conducted by the Cooperative Extension Service, University of Georgia.

TABLE 9.4

TOXIC SUBSTANCES DETECTED IN FISH IN 1990

SAMPLE DATA:						CONCENTRATIONS:			
LAKE STATION	FISH SAMPLE	FISH SPECIES	LENGTH (cm)	WEIGHT (gm)	DATE COLLECTED	DDE (ppm)	DIELDRIN (ppm)	PCB-1260 (ppm)	Hg (ppm)
LG1	LG1-1	Carp	53.4	2,057	11/14/90	0.031			0.39
LG1	LG1-3	Carp	52.2	1,703	11/14/90	0.037			0.36
LG1	LG1-3'	Carp	52.2	1,703	11/14/90	0.032			0.52
LG1	LG1-6	Carp	44.7	1,106	11/14/90		0.019		0.35
LG1	LG1-2	Largemouth bass	52.8	2,175	11/14/90	0.126	0.014	0.170	0.56
LG1	LG1-4	Largemouth bass	38.1	793	11/14/90				0.32
LG1	LG1-5	Largemouth bass	34.5	594	11/14/90	0.012			0.22
LG4	LG4-5	Black crappie	29.2	360	11/15/90				0.13
LG4	LG4-6	Black crappie	27.4	278	11/15/90				0.09
LG4	LG4-1	Carp	44.3	1,257	11/15/90	0.106	0.010		0.43
LG4	LG4-2	Carp	44.2	1,243	11/15/90	0.154	0.010		0.22
LG4	LG4-3	Carp	44.9	1,351	11/15/90	0.039			0.36
LG4	LG4-4	Largemouth bass	35.9	660	11/15/90	0.037			0.45
LG4	LG4-4'	Largemouth bass	35.9	660	11/15/90				0.46
LG7	LG7-1	Carp	49.5	1,489	11/15/90	0.090			0.23
LG7	LG7-2	Carp	51.8	1,470	11/15/90	0.025			0.30
LG7	LG7-3	Carp	48.4	1,598	11/15/90	0.043			0.13
LG7	LG7-4	Largemouth bass	30.4	337	11/15/90				0.13
LG7	LG7-5	Largemouth bass	31.9	391	11/15/90				0.12
LG7	LG7-6	Largemouth bass	41.2	948	11/15/90	0.043			0.29
LG7	LG7-6'	Largemouth bass	41.2	948	11/15/90	0.021			0.32

NOTES:

Samples were individual fish, edible flesh (fillets, skin off).

Samples LG1-3', LG4-4', and LG7-6' were duplicates of respective samples LG1-3, LG4-4, and LG7-6.

Station LG1 - Downstream of RR bridge near Omaha, Ga.

Station LG4 - Upstream of Hwy 82 near Eufaula Al.

Station LG7 - Walter F. George Reservoir dam pool

TABLE 9.5
TOXIC SUBSTANCES DETECTED IN FISH IN 1991

DIELDRIN (mg/kg)										
Composite	1st	1st Dup	2nd	3rd	3rd Dup	4th	5th	5th Dup	Range	Mean
D/S Oswichee Cr.										
Largemouth Bass	WQ443 <0.01	WQ443 <0.01	WQ444 <0.01	WQ445 <0.01	--	WQ446 <0.01	WQ447 <0.01	--	<0.01	0
Channel Catfish	WQ438 <0.01	--	WQ439 <0.01	WQ440 <0.01	WQ440 <0.01	WQ441 <0.01	WQ442 <0.01	--	<0.01	0
Chattahoochee Ri at US 82										
Hybrid Bass	WQ127 0.10	--	WQ128 0.01	WQ129 <0.01	--	WQ130 0.20	WQ131 0.02	WQ131 0.02	<0.01-0.20	0.06
Largemouth Bass	WQ132 <0.01	--	WQ133 <0.01	WQ134 <0.01	--	WQ135 <0.01	WQ136 <0.01	--	<0.01	0
Channel Catfish	WQ137 <0.01	--	WQ138 <0.01	WQ139 <0.01	WQ139 <0.01	WQ140 <0.01	WQ141 0.03	--	<0.01-0.03	0.005
Dam Pool										
Largemouth Bass	WQ402 0.01	WQ402 <0.01	WQ403 <0.01	WQ404 <0.01	--	--	--	--	<0.01	0
Channel Catfish	WQ399 <0.01	--	WQ400 <0.01	WQ401 <0.01	--	--	--	--	<0.01	0

PCB 1260 (mg/kg)										
Composite	1st	1st Dup	2nd	3rd	3rd Dup	4th	5th	5th Dup	Range	Mean
D/S Oswichee Cr.										
Largemouth Bass	WQ443 <0.10	WQ443 <0.10	WQ444 <0.35	WQ445 <0.10	--	WQ446 <0.10	WQ447 <0.10	--	<0.10-0.35	0.0583
Channel Catfish	WQ438 1.10	--	WQ439 <0.10	WQ440 <0.34	WQ440 0.21	WQ441 <0.10	WQ442 <0.10	--	<0.10-1.10	0.2925
Chattahoochee Ri at US 82										
Hybrid Bass	WQ127 <0.10	--	WQ128 0.13	WQ129 <0.10	--	WQ130 <0.10	WQ131 0.12	WQ131 0.17	<0.10-0.17	0.095
Largemouth Bass	WQ132 0.20	--	WQ133 <0.10	WQ134 <0.10	--	WQ135 <0.10	WQ136 <0.10	--	<0.10-0.20	0.04
Channel Catfish	WQ137 0.16	--	WQ138 <0.10	WQ139 <0.10	WQ139 0.04	WQ140 0.15	WQ141 0.61	--	<0.10-0.61	0.1767
Dam Pool										
Largemouth Bass	WQ402 <0.10	WQ402 <0.10	WQ403 <0.10	WQ404 <0.10	--	--	--	--	<0.10	0
Channel Catfish	WQ399 <0.10	--	WQ400 <0.10	WQ401 0.19	--	--	--	--	<0.10-0.19	0.0633

TABLE 9.5 CONTINUED

ZINC (mg/kg)									
Composite	1st	2nd	3rd	3rd Dup	4th	4th Dup	5th	Range	Mean
D/S Oswichee Cr.									
Largemouth Bass	WQ443 5.4	WQ444 8.1	WQ445 6.8	--	WQ446 6.2	--	WQ447 5.5	5.4-8.1	6.4
Channel Catfish	WQ438 5.3	WQ439 7.5	WQ440 7.2	--	WQ441 6.9	--	WQ442 6.4	5.3-7.5	6.7
Chattahoochee Ri at US 82									
Hybrid Bass	WQ127 7.2	WQ128 8.0	WQ129 6.1	WQ129 4.3	WQ130 6.7	--	WQ131 4.8	4.3-8.0	6.2
Largemouth Bass	WQ132 6.7	WQ133 6.7	WQ134 6.7	--	WQ135 7.3	--	WQ136 8.8	6.7-8.8	7.2
Channel Catfish	WQ137 8.0	WQ138 6.8	WQ139 8.4	--	WQ140 6.3	WQ140 7.2	WQ141 5.1	5.1-8.4	7
Dam Pool									
Largemouth Bass	WQ402 9.9	WQ403 7.8	WQ404 6.2	--	--	--	--	6.2-9.9	8
Channel Catfish	WQ399 9.0	WQ400 7.3	WQ401 6.5	--	--	--	--	6.5-9.0	7.6

ARSENIC (mg/kg)									
Composite	1st	2nd	3rd	3rd Dup	4th	4th Dup	5th	Range	Mean
D/S Oswichee Cr.									
Largemouth Bass	WQ443 0.022	WQ444 0.024	WQ445 0.015	--	WQ446 0.020	--	WQ447 0.019	0.015-0.024	0.02
Channel Catfish	WQ438 0.016	WQ439 <0.005	WQ440 <0.005	--	WQ441 <0.005	--	WQ442 0.005	<0.005-0.016	0.0042
Chattahoochee Ri at US 82									
Hybrid Bass	WQ127 0.051	WQ128 0.043	WQ129 0.046	--	WQ130 0.050	--	WQ131 0.030	0.030-0.051	0.044
Largemouth Bass	WQ132 0.035	WQ133 0.030	WQ134 0.026	--	WQ135 0.039	--	WQ136 0.019	0.019-0.039	0.0298
Channel Catfish	WQ137 0.012	WQ138 0.008	WQ139 <0.005	--	WQ140 0.017	--	WQ141 0.020	<0.005-0.020	0.0119
Dam Pool									
Largemouth Bass	WQ402 0.029	WQ403 0.032	WQ404 0.042	--	--	--	--	0.029-0.042	0.0343
Channel Catfish	WQ399 0.018	WQ400 0.13	WQ401 0.019	--	--	--	--	0.013-0.019	0.167

TABLE 9.5 CONTINUED

CHLORDANE (mg/kg)										
Composite	1st	1st Dup	2nd	3rd	3rd Dup	4th	5th	5th Dup	Range	Mean
D/S Oswichee Cr.										
Largemouth Bass	WQ443 <0.04	WQ443 <0.04	WQ444 0.90	WQ445 0.16	--	WQ446 0.14	WQ447 <0.04	--	<0.04- 0.90	0.21
Channel Catfish	WQ438 0.72	--	WQ439 0.53	WQ440 0.08	WQ440 0.06	WQ441 <0.04	WQ442 <0.04	--	<0.04- 0.72	0.2383
Chattahoochee Ri at US 82										
Hybrid Bass	WQ127 0.07	--	WQ128 0.10	WQ129 0.10	--	WQ130 <0.40	WQ131 0.14	WQ131 0.18	<0.04- 0.18	0.1017
Largemouth Bass	WQ132 <0.04	--	WQ133 <0.04	WQ134 <0.04	--	WQ135 <0.04	WQ136 <0.04	--	<0.04	0
Channel Catfish	WQ137 0.07	--	WQ138 0.08	WQ139 0.04	WQ139 0.04	WQ140 0.16	WQ141 0.26	--	<0.04- 0.26	0.0983
Dam Pool										
Largemouth Bass	WQ402 <0.04	WQ402 <0.04	WQ403 <0.04	WQ404 <0.04	--	--	--	--	<0.04	0
Channel Catfish	WQ399 <0.04	--	WQ400 <0.04	WQ401 0.06	--	--	--	--	<0.04- 0.06	0.02

DDE (mg/kg)										
Composite	1st	1st Dup	2nd	3rd	3rd Dup	4th	5th	5th Dup	Range	Mean
D/S Oswichee Cr.										
Largemouth Bass	WQ443 0.03	WQ443 <0.01	WQ444 0.06	WQ445 0.04	--	WQ446 0.03	WQ447 0.01	--	<0.01- 0.06	0.0292
Channel Catfish	WQ438 1.13	--	WQ439 0.79	WQ440 0.10	WQ440 0.12	WQ441 0.02	WQ442 0.03	--	0.02- 1.13	0.365
Chattahoochee Ri at US 82										
Hybrid Bass	WQ127 0.10	--	WQ128 0.17	WQ129 0.11	--	WQ130 0.20	WQ131 0.15	WQ131 0.17	0.10- 0.20	0.15
Largemouth Bass	WQ132 0.18	--	WQ133 <0.01	WQ134 0.06	--	WQ135 0.08	WQ136 <0.01	--	<0.01- 0.18	0.066
Channel Catfish	WQ137 0.11	--	WQ138 0.08	WQ139 <0.01	WQ139 0.03	WQ140 0.12	WQ141 0.47	--	<0.01- 0.47	0.1358
Dam Pool										
Largemouth Bass	WQ402 0.06	WQ402 0.07	WQ403 0.03	WQ404 0.04	--	--	--	--	0.03- 0.07	0.05
Channel Catfish	WQ399 0.02	--	WQ400 <0.01	WQ401 0.12	--	--	--	--	<0.01- 0.12	0.0483

TABLE 9.5 CONTINUED

MERCURY (mg/kg)									
Composite	1st	2nd	3rd	3rd Dup	4th	4th Dup	5th	Range	Mean
D/S Oswichee Cr.									
Largemouth Bass	WQ443 0.30	WQ444 0.40	WQ445 0.30	--	WQ446 0.40	--	WQ447 0.30	0.30-0.40	0.34
Channel Catfish	WQ438 0.10	WQ439 0.20	WQ440 0.10	--	WQ441 0.10	--	WQ442 0.20	0.10-0.20	0.14
Chattahoochee Ri at US 82									
Hybrid Bass	WQ127 0.10	WQ128 0.10	WQ129 0.10	WQ129 <0.10	WQ130 0.10	--	WQ131 0.10	<0.10-0.10	0.091
Largemouth Bass	WQ132 0.20	WQ133 0.20	WQ134 0.20	--	WQ135 0.20	--	WQ136 0.20	0.2	0.20
Channel Catfish	WQ137 <0.10	WQ138 <0.10	WQ139 <0.10	--	WQ140 <0.10	WQ140 <0.10	WQ141 0.10	<0.10-0.10	0.0167
Dam Pool									
Largemouth Bass	WQ402 0.30	WQ403 0.10	WQ404 0.10	--	--	--	--	0.10-0.30	0.17
Channel Catfish	WQ399 <0.10	WQ400 <0.10	WQ401 <0.10	--	--	--	--	<0.10	0

SELENIUM (mg/kg)									
Composite	1st	2nd	3rd	3rd Dup	4th	4th Dup	5th	Range	Mean
D/S Oswichee Cr.									
Largemouth Bass	WQ443 <1.0	WQ444 <1.0	WQ445 <1.0	--	WQ446 <1.0	--	WQ447 <1.0	<1.0	0
Channel Catfish	WQ438 <1.0	WQ439 <1.0	WQ440 <1.00	--	WQ441 <1.0	--	WQ442 <1.0	<1.0	0
Chattahoochee Ri at US 82									
Hybrid Bass	WQ127 <2.0	WQ128 <2.0	WQ129 <2.0	WQ129 <2.0	WQ130 <2.0	--	WQ131 <2.0	<2.0	0
Largemouth Bass	WQ132 <2.0	WQ133 <2.0	WQ134 <2.0	--	WQ135 <2.0	--	WQ136 <2.0	<2.0	0
Channel Catfish	WQ137 <2.0	WQ138 <2.0	WQ139 <2.0	--	WQ140 <2.0	WQ140 <2.0	WQ141 <2.0	<2.0	0
Dam Pool									
Largemouth Bass	WQ402 1.1	WQ403 <1.0	WQ404 <1.0	--	--	--	--	<1.0-1.1	0.367
Channel Catfish	WQ399 <1.0	WQ400 <1.0	WQ401 <1.0	--	--	--	--	<1.0	0

TABLE 9.6

LAB SAMPLE NUMBERS WITH LENGTHS (mm) AND WEIGHTS (gm) - 1991

SPECIES	SAMPLE	WATER BODY	LOCATION	L1	L2	L3	L4	L5	L6	W1	W2	W3	W4	W5	W6
Channel catfish	WQ0438	Chattahoochee R.	D/S of Oswichee Cr.	537	684	626	502	592	618	1197	2536	3009	1196	2142	3110
Channel catfish	WQ0439	Chattahoochee R.	D/S of Oswichee Cr.	532	522	531	484	534	471	1231	1229	1233	1000	1445	756
Channel catfish	WQ0440	Chattahoochee R.	D/S of Oswichee Cr.	450	468	438	435	446	463	676	758	583	568	571	695
Channel catfish	WQ0441	Chattahoochee R.	D/S of Oswichee Cr.	364	404	393	418	404	368	332	412	422	588	511	376
Channel catfish	WQ0442	Chattahoochee R.	D/S of Oswichee Cr.	308	317	323	275	320	346	207	192	223	125	211	312
Largemouth bass	WQ0443	Chattahoochee R.	D/S of Oswichee Cr.	375	365	349	324	314	361	759	559	543	430	402	627
Largemouth bass	WQ0444	Chattahoochee R.	D/S of Oswichee Cr.	544	595	481	506	494	475	2307	2769	1820	1946	1663	1649
Largemouth bass	WQ0445	Chattahoochee R.	D/S of Oswichee Cr.	431	388	400	398	404	406	1161	901	915	816	887	983
Largemouth bass	WQ0446	Chattahoochee R.	D/S of Oswichee Cr.	434	462	440	440	435	482	1119	1304	1100	1218	1120	1605
Hybrid bass	WQ0127	W. F. George	Chattahoochee R. At US 82	435						1206					
Hybrid bass	WQ0128	W. F. George	Chattahoochee R. At US 82	443	419	420	420	374	513	1022	804	890	888	556	1967
Hybrid bass	WQ0129	W. F. George	Chattahoochee R. At US 82	535	527	504	520	525	561	1505	1792	1852	2010	1939	2668
Hybrid bass	WQ0130	W. F. George	Chattahoochee R. At US 82	550	480	453	525	410	448	2224	1445	1238	1933	875	1148
Hybrid bass	WQ0131	W. F. George	Chattahoochee R. At US 82	492	561	525	415	435		1426	2370	1996	1160	911	
Largemouth bass	WQ0132	W. F. George	Chattahoochee R. At US 82	567	493	504	494	505	508	2722	2495	1930	1950	2033	2068
Largemouth bass	WQ0133	W. F. George	Chattahoochee R. At US 82	530	535	545	485	458	479	2468	2343	2249	1897	1416	1520
Largemouth bass	WQ0134	W. F. George	Chattahoochee R. At US 82	472	453	392	391	401	377	1483	1370	817	828	902	807
Largemouth bass	WQ0135	W. F. George	Chattahoochee R. At US 82	424	441	431	429	461	391	1120	1326	1149	1277	1562	898
Largemouth bass	WQ0136	W. F. George	Chattahoochee R. At US 82	355	374	336	340	351	333	560	692	451	455	636	430
Channel catfish	WQ0137	W. F. George	Chattahoochee R. At US 82	320	349	354	308	320	351	238	305	305	190	240	292
Channel catfish	WQ0138	W. F. George	Chattahoochee R. At US 82	285	304	339	346	298	294	170	174	314	295	159	175
Channel catfish	WQ0139	W. F. George	Chattahoochee R. At US 82	265	255	247	261	257	256	126	113	95	103	99	127
Channel catfish	WQ0140	W. F. George	Chattahoochee R. At US 82	417	368	473	458	398	363	624	398	1248	1028	548	335
Channel catfish	WQ0141	W. F. George	Chattahoochee R. At US 82	631	535	662	520	562	557	3220	1760	3740	1500	2340	2140
Channel catfish	WQ0399	W. F. George	Dam Pool	365	371	387	372	356	356	354	402	447	372	327	340
Channel catfish	WQ0400	W. F. George	Dam Pool	336	348	334	319	334	360	340	257	291	233	258	343
Channel catfish	WQ0401	W. F. George	Dam Pool	578	390	423	412	391	409	1608	432	615	640	450	555
Largemouth bass	WQ0402	W. F. George	Dam Pool	482	499	488	465	488	543	1478	1682	1923	1634	1690	2622
Largemouth bass	WQ0403	W. F. George	Dam Pool	406	437	431	424	424	444	986	1206	1017	1128	1065	1219
Largemouth bass	WQ0404	W. F. George	Dam Pool	384	326	332	382	375	343	796	381	484	756	745	477

For reference, Table 9.7 lists FDA action levels and the USEPA guidance criteria for toxic substances in fish. As of July 1993 all Georgia advisories regarding the consumption of fish are based on FDA action levels and the average concentration of a substance in a type of fish. This is also true for adjacent states.

TABLE 9.7
TOXIC SUBSTANCES AND NATIONAL GUIDANCE

TOXIC SUBSTANCES	FDA ACTION LEVEL (ppm)	EPA CRITERIA LEVELS (mg/kg)[a]			
		CARCINOGENS[b]			TOXICS[c]
		10^{-6}	10^{-5}	10^{-4}	
Arsenic	NA	0.0062	0.062	0.62	3.23
Selenium (Se)	NA	--	--	--	53.85
Zinc (Zn)	NA	--	--	--	3230.77
Mercury (Hg)	1.0	--	--	--	1.0
DDE	5	0.0449	0.449	4.49	5.38[d]
Dieldrin	0.3	0.00067	0.0067	0.067	0.54
Chlordane	0.3	0.0083	0.083	0.83	0.65
PCB 1260	2.0	0.0014	0.014	0.14	0.75[e]

[a]Milligrams per kilogram = parts per million (ppm)
[b]Values for carcinogens are derived using EPA cancer potency factors and assumptions of 6.5g fish consumption/day (approximately one meal per month) for 70 years. 10^{-6} = one additional cancer in one million, 10^{-5} = one additional cancer in one hundred thousand, and 10^{-4} = one additional cancer in ten thousand.
[c]Values for toxics are derived from EPA reference dose (RfD).
[d]DDT RfD utilized
[e]PCB 1016 RfD utilized

9.4 LAKE WATERFOWL AND OTHER BIOLOGICAL RESOURCES

Information for this section was taken from the Eufaula National Wildlife Refuge 1991 Annual Narrative Report, prepared by the U.S. Department of the Interior, Fish and Wildlife Service. The Eufaula National Wildlife Refuge (ENWR) has a variety of aquatic, wetland, and terrestrial habitats supporting a diversity of flora and fauna. Habitat management is focused on waterfowl. The refuge bird list includes 282 species. Thirty-six mammals have been recorded in the refuge and many others are suspected. The ENWR represents a concentration of biological resources, however, the data is indicative of the lake in general.

Migratory duck populations have steadily decreased since 1977 as seen in the population data shown in Table 9.8. This is largely due to a national trend of population decline in ducks. In the 1990-1991 winter inventory the most abundant ducks noted, in decreasing order, were mallards, ringnecks, and green-winged teal. Other migratory ducks inventoried during 1991 include widgeons, blue-winged teal, black ducks, gadwall, wood duck, and shovelers. The ENWR report estimated geese usage at 162,000 use days in 1991. This includes a resident flock of 500-800 Canada geese as well as migratory Canada, white-fronted, and snow geese.

Other common marsh and water birds include cattle egrets, common moorhens, little blue heron, great blue heron, green-backed heron, anhingas, and great egrets. Shorebirds and gulls include snipe, yellowlegs, killdeer, pectoral sandpipers, ringbill gulls, Forsters tern, Bonaparte's gulls, and herring gulls. Twelve species of raptors were observed in 1991: bald eagle, red tailed hawk, red shouldered hawk, American kestrel, marsh hawk, osprey, barn owl, barred owl, great horned owl, screech owl, turkey vulture, and black vulture.

TABLE 9.8 HISTORY OF WINTERING DUCK POPULATIONS EUFAULA NATIONAL WILDLIFE REFUGE 1977-1991		
Year	Peak Populations	Use Days
1977	47,000	4,743,000
1978	36,200	3,260,000
1979	30,300	2,210,000
1980	16,200	1,800,000
1981	17,000	1,640,000
1982	18,000	1,314,000
1983	11,000	991,000
1984	17,000	1,390,000
1985	9,000	1,065,750
1986	11,500	1,329,200
1987	11,800	1,091,100
1988	15,700	845,490
1989	5,000	450,000
1990	6,000	450,000
1991	9,700	727,500

Four animal species common to the ENWR were federally listed as endangered or threatened: American alligator, wood stork, bald eagle, and peregrine falcon. Alligators were reintroduced to the lake in 1971 and numbers have significatly increased in recent years. In 1991, the estimated refuge population was 600-800 alligators with 165,000 alligator use days. Wood storks are constantly seen on the refuge between June and October. During these months the water levels are low enough to create wading pools from which the wood storks fish. Bald eagles have not nested in the refuge since 1989. In 1991 no bald eagles were sited in refuge inventories,

10.0 DIAGNOSTIC STUDY SUMMARY

10.1 INTRODUCTION

Lake Walter F. George is a 45,180-acre US Army Corps of Engineers impoundment of the Chattahoochee River in southwest Georgia. It is located along the Georgia-Alabama border between Columbus and Fort Gaines. The impoundment project was authorized by the U.S. Congress in 1946 to provide hydroelectric power, regulate transportation, provide flood control, and promote recreation. Dam construction began in 1955 and the reservoir was filled in 1963. Past surveys by the Georgia Environmental Protection Division suggested eutrophic conditions. The Georgia Department of Natural Resources was awarded a Phase I Clean Lakes Grant in July 1990 to conduct a Phase I Diagnostic-Feasibility study of the reservoir.

10.2 METHODS

A one-year intensive study was conducted from November 1990 through October 1991. Water quality samples were collected monthly during the months of November through April and October, and twice per month during the months of May through September. Twelve stations were sampled - seven lake stations, three minor tributary stations, and an upstream and a downstream Chattahoochee River station. Water samples were analyzed for laboratory parameters including nutrients, chlorophyll *a*, fecal coliform bacteria, pH, suspended solids, alkalinity, hardness, turbidity, and conductivity. Lake samples were collected at intervals through the euphotic zone and composited for analyses. Field parameters at lake stations included Secchi disk transparency and water column profile measurements of temperature, dissolved oxygen, pH, and conductivity. Tributary samples were collected at one depth. Samples were analyzed for the same water quality parameters except chlorophyll *a*. Stream flow and dissolved oxygen were measured at the tributary stations. Water and sediment samples were collected from selected lake stations in April 1991 for metal and organic chemical analyses. Phytoplankton samples were collected from selected stations on four dates. Algal growth potential samples were collected from four stations on three dates. Other study efforts included fish contaminant sampling and sediment oxygen demand testing.

10.3 RESULTS

Total phosphorus and nitrogen nutrient loadings were estimated using nutrient measurements and flow data from the study. According to this budget, about 60 percent of the phosphorous and 70 percent of the nitrogen came from non-point sources. The Columbus South Water Pollution Control Plant was the primary point source of nutrients, contributing roughly half the point source phosphorus and nitrogen loading. Estimates of nutrients discharged from the Walter F. George dam indicated about half the phosphorus and one-third of the nitrogen loadings were used or otherwise accumulated in the lake.

Total phosphorus concentrations in the lake ranged from 0.02 to 0.15 mg/l, with a mean concentration of 0.06 and a standard deviation of 0.02 mg/l. Total nitrogen concentrations ranged from 0.13 to 1.96 mg/l, with a mean concentration of 0.67 and a standard deviation of 0.27 mg/l. Nutrient concentrations were generally higher in the upstream section of the lake. Phosphorus concentrations decreased significantly in the mid-lake area and nitrogen levels decreased in the lower end of the lake. Total nitrogen to total phosphorus ratios ranged from 8.54 to 49.0, with a mean ratio of 14.1 and a standard deviation of 8.54. These nutrient ratios show that algal productivity in the lake is limited by phosphorus or a combination of phosphorus and nitrogen levels.

Mean lake station chlorophyll *a* concentrations ranged between five and 15 µg/l. Only three chlorophyll *a* measurements equaled or exceeded 20 µg/l. In general, chlorophyll *a* concentrations were higher in the mid-lake and lower lake stations. Chlorophyll *a* levels were noted to be high in both mid-lake and the dam pool during the months of July, September, and October.

Lake Secchi disk transparency ranged between 0.5 and 2.2 meters, with a mean transparency of 1.1 and a standard deviation of 0.4 meters. Transparency generally increased from the headwaters to the dam pool. Transparency in the upper lake is limited by suspended sediments, while transparency measurements in the mid-lake and dam pool are more influenced by algal growth.

Carlson trophic state indices were calculated using total phosphorus, chlorophyll a, and Secchic transparency data. Average station trophic state indices ranged between 55 and 60, in the upper eutrophic zone. Carlson trophic state indices above 60 suggest hypereutrophic conditions. The total phosphorus and transparency indices were higher in the upstream part of the lake while the chlorophyll *a* indices were higher in the mid-lake and lower lake. The different indices converged in the lake dam pool, averaging about 55. A comparison of summer dam pool indices between 1980 and 1992 indicates the 1991 trophic index data was normal for the lake. A comparison with 1991 data from other Chattahoochee River impoundments shows that the Lake Walter F. George trophic condition is similar to that of West Point Lake and Lake Seminole.

Algal growth potential samples were collected in the months of May, July, and September. Algal growth in May at all stations was limited by phosphorus availability. In July and September the upper lake and mid-lake stations were co-limited or marginally nitrogen limited. The downstream part of the lake remained phosphorus limited. The upstream and mid-lake samples had a significantly higher potential for algal growth due to higher nutrient levels.

Phytoplankton samples were collected in the months of January, May, July, and September. Samples were identified to genus or group and counted to estimate algal bio-volume. Algal biomass generally increased at all sites from January to September with the highest biovolume being measured in the dam pool in September. Green and yellow-green algae were dominant in January. Diatoms were usually the dominant group during May, August, and September. Bluegreen algae were dominant in the September dam pool sample. Bluegreen algal dominance indicates increased eutrophic conditions.

Lake dissolved oxygen and temperature were measured at spaced intervals in the water column. The dissolved oxygen at one-meter depth ranged from 6.6 to 11.7 mg/l with a mean concentration of 8.7 and a standard deviation of 1.1 mg/l. At a ten-meter depth dissolved oxygen ranged from 0.3 to 10.5 mg/l with a mean concentration of 6.8 and a standard deviation of 2.2 mg/l. At ten-meters depth dissolved oxygen measured less than 4.0 mg/l thirteen times. These lower concentrations were in the mid-lake and dam pool area between June and September. Water temperature varied more in the mid-lake and dam pool stations due to thermal stratification. One temperature measurement at one-meter depth exceeded 90 degrees F. Thermal profiles showed the dam pool began to stratify in April, the mid-lake area began to stratify in early June, and both areas destratified in September. In early August the dam pool station was oxygen depleted at depths more than 12 meters.

Diel dissolved oxygen monitoring was performed at three stations during mid-July to determine if oxygen depletion occurred in the epilimnion. A mid-lake monitor at a six-meter depth recorded a diel dissolved oxygen decline from 9.2 to 5.3 mg/l. Lowest oxygen concentrations occurred in mid-lake stations between 6:00 and 8:00 a.m. Monitoring in an upper lake station showed no clear night related oxygen sag. No significant oxygen depletion was found in the lake epilimnion.

pH in the lake headwaters ranged from neutral to slightly acidic. pH increased with thermal stratification in the mid-lake and dam pool. Three pH measurements in the dam pool exceeded 8.5 units, the Georgia water quality standard. These alkaline pH data are related to increased algal productivity.

Fecal coliform bacteria levels were highest in the upper lake and decreased downstream toward the dam. Out of 116 lake fecal coliform samples, 17 exceeded 200 most probable number (MPN) per 100 ml. These higher concentrations correlated to higher area rainfall. The highest geometric mean of data by station, 186 MPN per 100 ml, occurred at the most upstream lake station. No sample measured above 4,000 MPN per 100 ml. No fecal coliform water quality standard violation was observed.

One set of water and sediment samples was collected in April 1991 at four stations and analyzed for a number of metals and organic compounds. Lead was measured in the upstream and upper mid-lake samples in concentrations exceeding Georgia water quality criteria. Mercury was detected in one of the four samples at a concentration higher than the Georgia water quality criteria. Titanium was detected in three of the four samples. There are no water quality criteria for titanium. Phenol was found in two of the samples at a concentration of 2.6 percent of the Georgia water quality criteria. No other metal or organic compound was found above lab detection limits. Metals detected in sediment samples were arsenic, cadmium, chromium, copper, lead, magnesium, mercury, nickel, selenium, silver, titanium, and zinc. Organic compounds found in sediments included DDE (a breakdown product of DDT) and PCB compounds. There are no water quality criteria for metals or organic compounds in sediments.

Sediment oxygen demand (SOD) testing was performed at four sites in November 1991 and at four sites in May 1992. SOD rates ranged from 0.33 to 1.50 grams of oxygen per square meter of sediment per day, with a mean of 0.76 $g/m^2/day$. These results were comparable to SOD data from Alabama Department of Environmental Management testing in 1987.

A macrophyte inventory was performed by the Alabama Department of Conservation and Natural Resources in the summer of 1991. This inventory identified the most common macrophytes as aligatorweed, water willow, maidencane, willows, and torpedo grass. Two other plants noted due to potential nuisance were spinyleaf najas and giant cutgrass. Neither submersed nor emersed plants were found plentiful in the main body of the lake. However, broad beds of alligator weed, water willow, and maidencane were noted in the shallow shoreline areas in the upstream part of the lake. A comparison of these areas with 1985 aerial photographs indicated no significant increase in emersed plant populations. Alligatorweed was the most abundant plant found.

Fish from Lake Walter F. George were collected and analyzed for toxic contaminants in 1990 and 1991. Edible fish fillet samples were analyzed for thirty organic compounds and thirteen metals. DDE, dieldrin, PCB-1260, arsenic, copper, mercury, and lead were detected in 1990 fish samples, however, no toxic substance was found above the Food and Drug Administration (FDA) action levels in the average concentration for each species.

Chlordane, DDE, dieldrin, PCB-1260, arsenic, mercury, selenium, and zinc were detected in the 1991 composite fish fillet samples. No toxic substance was found above the FDA action levels in the average concentration for each species of the 1991 samples. However, chlordane was found in some individual channel catfish and largemouth bass composite samples, from the Chattahoochee River headwaters, in concentrations exceeding the FDA action level of 0.3 ppm.

10.4 CONCLUSIONS

All of the major parameters used to assess the algal productivity of the lake (water clarity, chlorophyll concentration, phosphorus concentration, etc.) characterize Lake Walter F. George as eutrophic. Elevated pH and temperature in the lake dam pool during late summer are also symptoms of excess algal productivity. The increased dominance of bluegreen algae during the latter part of the growing season is another indicator of eutrophic conditions. Moderate eutrophic conditions may not be a detriment to current lake usage.

Both phosphorus and nitrogen are responsible for the abundance of algae within Lake Walter F. George. The Chattahoochee River is the major source of nutrients and sediment into the lake. This diagnostic study shows the need for a watershed management plan for the Lake Walter F. George headwaters if current water quality is to be maintained.

Other concerns suggested by this study include the presence of lead and mercury in water samples and the presence of chlordane[1] in fish samples. More monitoring is required to assess the degree of these concerns. The limited 1991 metals in water data suggest the need for additional sample collection using "clean lab" sampling techniques.

The Alabama Department of Environmental Management is preparing a separate Phase I diagnostic report for Lake Walter F. George. Georgia and Alabama will jointly prepare the Lake Walter F. George Phase I feasibility report.

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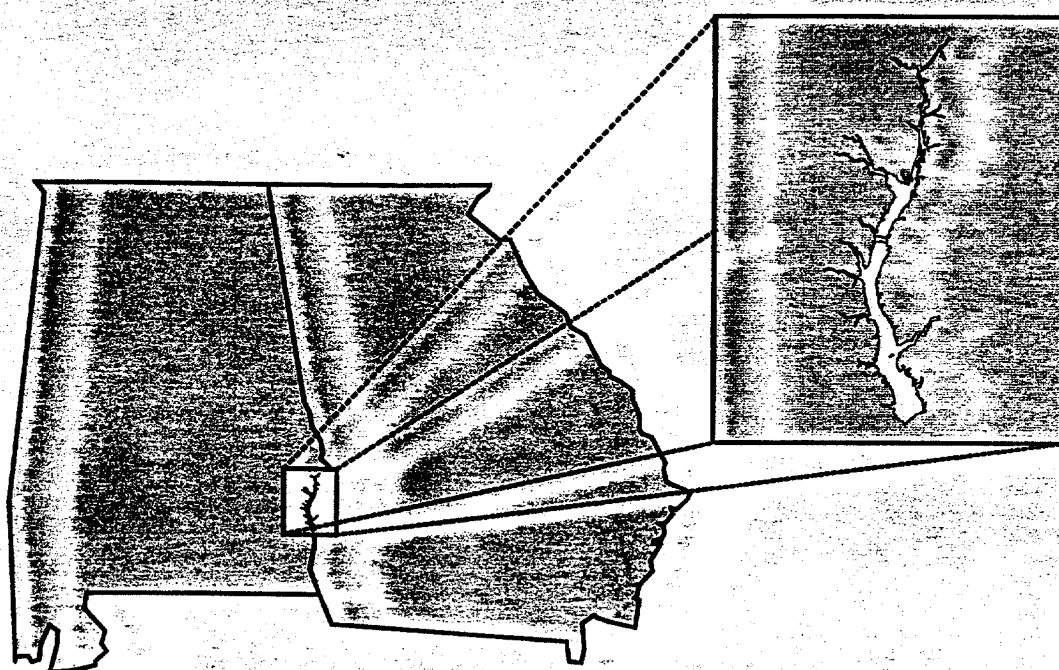
[1]Subsequent sampling found no detectable chlordane in 17 composite fish samples collected in the fall of 1993.

PART 2

WALTER F. GEORGE RESERVOIR

ALABAMA DIAGNOSTIC STUDY



LAKE W.F. GEORGE

PHASE I DIAGNOSTIC/FEASIBILITY STUDY

FINAL REPORT

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EXECUTIVE SUMMARY

Lake W.F. George is a large (18,300 ha) multiple-use impoundment of the Chattahoochee River located in Georgia and Alabama. The dam was constructed by the U.S. Army Corps of Engineers near the town of Ft. Gaines, Georgia and the lake first reached full pool in 1963. Lake George has been an important economic resource for east-central Alabama and west-central Georgia since its creation. Sport fishing and particularly the largemouth black bass fishery has been outstanding in this lake throughout its existence.

Historically, the lake has been relatively free of serious problems. As early as 1973-74 the U.S. E.P.A. found the lake to be eutrophic due to excessive nutrient loading. Subsequent studies have confirmed the eutrophic status of the lake and the resulting hypolimnial dissolved oxygen depletion has created some tailwater management problems. In 1971 some edible portions of largemouth bass collected in the lake near Cottonton, Alabama contained high levels of DDT (6.0 ppm) and PCB (13.0 ppm). In 1991, three of 12 composite samples of largemouth bass and channel catfish tested above the 0.3 mg/kg FDA action level for the insecticide chlordane. When all of the composite samples were averaged for each fish species the resulting means were lower than the FDA action level. In 1978, fecal coliform bacteria densities exceeded standards near some recreational areas of the lake. Of all aquatic plants inhabiting Lake George, alligator-weed (*Alternanthera philoxeroides*) has been the most serious threat to lake usage. It was usually found in shallow shoreline and inlet areas.

The large size and economic value of Lake George prompted both Georgia and Alabama to initiate two, Phase I, Clean Lakes, Diagnostic/Feasibility Studies on the lake. Georgia's study was conducted from November 1990 through October 1991 and Alabama's study was from November 1992 through October 1993. During the 1992 growing season (May-October 1992) the mainstem sampling stations were sampled with funding support from the U.S. Army Corps of Engineers, Mobile District. The objectives of these studies were to provide historic and current data on Lake George, identify water quality or other problems that exist and determine feasible solutions for problem correction.

Lake George is a warm monomictic reservoir that normally stratifies thermally from about June through September in the deeper lacustrine zone and especially in the area of the old river channel. During the growing seasons of 1992 and 1993 classical thermoclines ($\Delta T \geq 1.0$ °C per meter depth) were rarely encountered. Water column temperature gradients in deeper areas of the lake seldom exceeded 7.0 to 8.0 °C and frequently were 5.0 °C or less. Chemical stratification as evidenced by declining dissolved oxygen (D.O.) concentrations throughout the water column were pronounced especially in the lacustrine areas of the lake during the warmer months. D.O. concentrations frequently fell below 1.0 mg/L at or near the 8.0 m depth and continued to decline, sometimes to near 0.0 mg/L, at the bottom. Further upstream in the transition zone chemical stratification was less obvious although D.O. concentrations did decline with depth but never below 2.0 mg/L.

Specific conductance, a measure of the ionic content of water, ranged from a low of 51.2 µmhos/cm to a high of 115.2 µmhos/cm at mainstem sampling stations and from 26.0 µmhos/cm to 134.0 µhmos/cm in the tributary embayments. Total alkalinity, the concentration of bases in water (expressed as mg/L $CaCO_3$) primarily composed of bicarbonate (HCO_3^-) and carbonate (CO) ions, usually increases as basin soil fertility increases. Total alkalinity of Lake George varied from a low of 16.3 mg/L to a high of 31.5 mg/L. Specific conductance and total alkalinity of Lake George waters fall in the lower half of the range expected for Alabama lakes indicating limited fertility of basin soils. Since carbonate minerals function as a natural chemical buffer, waters of low alkalinity are subject to grater fluctuations in pH than more alkaline systems. pH measured at a depth of 2 m during the growing seasons of 1992 and 1993 ranged from a low of 6.7 to a high of 9.1.

Nitrogen and phosphorus are plant nutrients that are required in relatively high concentrations to support plant growth. Nitrogen concentrations normally exceed phosphorus concentrations by an order of magnitude or more. Of the macronutrients, phosphorus is usually in shortest supply in relation to plant needs and is therefore the element most often limiting to plant growth in freshwater ecosystems. Bioavailable nitrogen (NO_3^- and NH_4^+) was abundant in Lake George with mean concentrations in the headwaters ranging between 400 and 600 μg/L and lacustrine concentrations ranging from about 100 to 400 μg/L.

Phosphorus in water is routinely reported as total phosphorus (all forms of phosphorus expressed as P) and soluble reactive phosphorus which is an estimate of orthophosphate ($PO_4^=$ expressed as P), the most important and abundant form of phosphorus directly available to plants. Both forms of phosphorus demonstrated a strong longitudinal gradient in Lake George with higher concentrations occurring at upstream locations. Total phosphorus concentrations in the Chattahoochee River where it enters Lake George ranged between 45 and 72 μg/L. EPA has suggested a limit of 50 μg/L TP at the point where a stream enters a lake or reservoir in order to prevent excessive loading. PO_4-P, the readily bioavailable phosphorus, comprised a relatively small portion (<20%) of the TP in Lake George.

One explanation for elevated phosphorus concentrations at upstream locations relates to the proximity to point sources of nutrients in the Phenix

City, Alabama-Columbus/Fort Benning, Georgia area. Municipal wastewater treatment facilities are permitted to deliver about 58 MGD of treated effluent to the Chattahoochee River. In an effort to reduce phosphorus in surface waters, the Georgia General Assembly enacted a statewide ban on high phosphate laundry detergents that went into effect 1 January 1991. This has the potential to affect total phosphorus concentration in Lake George. Available data seem to indicate a decline in total phosphorus concentration at the mid-reservoir location during 1992 and 1993.

Using data collected by Georgia in 1991 on Georgia tributaries and Alabama data in 1993 on Alabama tributaries, efforts were made to estimate nutrient loading of Lake George. The lake received about 7.5 million kg/yr total nitrogen and 0.6 million kg/yr total phosphorus. About 90% of the nitrogen and 80% of the phosphorus entered the lake from the Chattahoochee River and relatively small tributaries entering the lake. The larger, monitored tributaries contributed about 10% of the nitrogen and 20% of the phosphorus. Permitted dischargers were responsible for about 33% of the nitrogen loading and 40% of the phosphorus loading. Most of the point source loading occurred in the upstream, riverine area of the lake.

Nutrient availability stimulated growth of plankton algae in Lake George. Fifty-eight algal taxa were identified during the study. Green algae were most numerous followed by blue-green algae and diatoms. On the mainstem of the reservoir phytoplankton density ranged from a low of 1,217 organisms/ml at station 6 in June of 1993 to a high of 7,037 organisms/ml at station 13 in July of 1993. The phytoplankton community of Lake George was indicative of a typical nutrient enriched southeastern reservoir.

During this study phytoplankton chlorophyll a concentrations ranged from a high of 20.3 μg/L at station 2 in September 1992 to a low of 1.7 μg/L in the Hatchechubbee Creek embayment in April 1993. Chlorophyll a concentrations were higher in 1992 than in 1993 even though rainfall and stream discharge were lower in 1993. In fact, there appears to be a trend of declining algal biomass in Lake George during the period 1989 through 1993. This could be a response to the apparent decline in TP caused by the phosphate detergent ban that went into effect in 1991. Chlorophyll a concentrations, even in 1993, remained within the eutrophic range.

Phytoplankton primary productivity of Lake George during the growing season of 1993 was indicative of a moderately eutrophic system with growing season mean production rates varying from a low of 980 $mgC/m^2 \cdot day$ in the transition zone to a high of 1,321 $mgC/m^2 \cdot day$ at the upstream lacustrine station. Based on the limited data available, Lake George productivity does not appear to be increasing.

The Algal Growth Potential Test (AGPT) determines the total quantity of algal biomass supportable by the test waters and provides a reliable estimate of the bioavailable and limiting nutrients. Algal growth potential was much higher at upstream riverine stations than at downstream locations probably because of the progressive decline in bioavailable phosphorus at downstream locations. With few exceptions phosphorus was the nutrient limiting phytoplankton growth throughout the lake. Nitrogen and phosphorus colimitation occurred at some upstream locations.

Fecal coliform densities in Lake George were low during the summer of 1992. Only five samples, all taken in October, exceeded a density of 20 fecal coliform colonies per 100 ml and, in those cases, densities were below the limits established to maintain water quality to support designated water uses of the lake.

Dominant macrophytes in 1993 included alligator-weed, water willow (*Justicia americana*), grasses (mainly *Panicum hemitomon* and *P. repens*) and *Sesbania* spp. (mainly *S. macrocarpa*). These plants usually grew in scattered colonies along the shoreline in water <1.0 m deep. Alligator-weed is an aggressive exotic weed species forming floating mats of vegetation. The plant has the potential to spread and increase coverage in quiescent waters of Lake George. In June 1993 Florida elodea, *Hydrilla verticillata*, was found growing near the boat ramp at the East Bank Recreational Area. In 1994 another stand of hydrilla was found in an embayment on the east side of the lake across the lake from the mouth of Cowikee Creek. Hydrilla has the potential to seriously disrupt normal usage of the lake.

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1.0 LAKE IDENTIFICATION

Lake W.F. George, located on the Chattahoochee River, was completed in 1963 by the United States Army Corps of Engineers. The lake is located in southeast Alabama along Henry, Barbour and Russell counties and southwest Georgia along Stewart, Quitman and Clay counties. It was formed for power generation, transportation, flood control and recreation. The largest municipality in the vicinity of Lake George is Eufaula, Alabama. Fort Gaines, Georgia is a small municipality near the location of the dam. Phenix City, Alabama and Columbus, Georgia are larger municipalities located upstream of the lake.

Morphometric characteristics of the lake appear in Table 1-1. W.F. George hydroelectric dam and turbine specifications appear in Table 1-2. Normal pool is maintained at 57.9 m msl from June through September. This constitutes a volume of 115,438 hectare-meters with an average depth of 6.2 m. Drawdown is maintained December through April at 57.3 m msl. Drawdown volume is 104,498 hectare-meters, which is only about a 9% decrease. Average depth at drawdown is 6.1 m.

The Alabama Department of Environmental Management water-use classifications for the Alabama portion of Lake George are as follows:

a.) From dam (at Fort Gaines, GA) to Cowikee Creek - Swimming, Fish and Wildlife

b.) Between Cowikee Creek upstream to 14th Street bridge at Phenix City, Alabama and Columbus, Georgia - Fish and Wildlife.

Table 1-1. Morphometric characteristics of Lake W.F. George.

Morphometric Characteristic	Values
Drainage area	19,321 square kilometers
Surface area	18,284 hectares
Shoreline length (at elev. 190)	1,022 kilometers
Full Reservoir length	136.8 kilometers
Maximum depth at dam	29.3 meters
Average depth	6.2 meters
Normal pool elevation	57.9 msl
Normal pool volume	115,437.8 heactare-meters
Drawdown pool elevation	57.3 msl
Drawdown pool volume	104,498.3 hectare-meters
Average depth at drawdown	6.1 meters
Hydraulic retention time	47 days

Table 1-2. Lake W.F. George hydroelectric dam and turbine specifications.

Location	
Town	Fort Gaines, Georgia
County	Clay
River	Chattahoochee
Construction started	September 1955
In-service date	March 1963
Total Investment at completion	$ 87,100,000
Dam	
Type	earthen filled dam
Maximum height	68 feet
Spillway gates	
Number	14
Size	42 feet X 29 feet
Capacity (each)	44,643 cfs
Hydraulic Turbines	
Number	4
Type	moveable blade - propeller
Water discharge (each)	6,500 cfs

2.0 BASIN DRAINAGE AND GEOLOGY

The Chattahoochee River flows southwest from Oliver Dam and forms the principal tributary to Lake George. Tributaries to Lake George from the Alabama side of the lake include Uchee Creek, Hatchechubbee Creek, Cowikee Creek, Chewalla Creek, Barbour Creek, Cheneyhatchee Creek, White Oak Creek, Thomas Mill Creek and Hardridge Creek.

The drainage area of Lake George includes both the Piedmont and Coastal Plain physiographic provinces. The subbasin from Oliver Dam to Fort Gaines, Georgia lies entirely within the Coastal Plain physiographic province. The Coastal Plain is generally an area of low relief with some gently rolling hills. Geological formations underlying the area are primarily sands and sandstone. Some clays and limestone are also present. Geological formations and their characteristics appear in Table 2-1. Soil series and their characteristics are found in Table 2-2. Soil suitabilities for the area are found in Table 2-3.

Table 2-1. Geological formations and their characteristics in the drainage area of Lake W.F. George, Russell, Barbour and Henry Counties, Alabama.

Geological Formation	County	Characteristics
Tuscaloosa undifferentiated	Russell	white, yellowish-orange and gray sand and gravel, varicolored and gray clay, sandstone.
<u>Selma Group</u>		
Blufftown Formation	Russell Barbour	dark grey sandy silty carbonaceous clay, fine to medium grained sand.
Ripley Formation	Russell Barbour	medium to coarse-grained sand, clay pebbles. Clayey fine grained micaceous sand and dark gray sandy silty carbonaceous clay. Calcareous sandstone, sandy fossiliferous limestone and calcareous sandstone.
Providence Sand	Russell Barbour	motled, varicolored, micaceous, carbonaceous clay and gray fine to coarse grained micaceous carbonaceous sand and clayey sand. Gray, calcareous and fossiliferous sands and clays. Calcareous sandstone, sandy clays.
Eutaw Formation	Russell	gray, sandy, calcareous fossiliferous clay, fossiliferous sandstone and limestone.
Nanafalia	Barbour Henry	basal sand, gray and white clay, white and yellow fine to coarse grained sand. Bauxite and bauxitic clay. Olive gray to yellowish gray very fine to coarse grained glauconitic micaceous calcareous fossiliferous sands and clayey sands, clay and claystone.
<u>Midway Group</u>		
Clayton Formation	Barbour Henry	medium-coarse grained sand, sandstone, silty, sandy limestone.
Tuscahoma Sand	Henry	greenish gray fine to coarse grained glauconitic sand containing some gravel and clay pebbles. Laminated and thin bedded carbonaceous micaceous silt, clay and very fine grained sand. Calcareous siltstone and sandstone.
Tallahattatta and Hatchetigbee Formations Undifferentiated	Henry	Greenish gray fine grained glauconitic sand. Light to gray clay, fine grained micaceous carbonaceous sand. Gravel, gray sand, fossiliferous limestone.
Residuum	Henry	white, yellow and red fine to coarse grained gravelly sand, white to gray mottled sandy silty clay, fossiliferous chert boulders, ferruginous sandstone, limonite concretions

Table 2-2. Properties of soil series in the Alabama portion of the Lake W.F. George watershed.

Property	Soil Series				
	Cahaba	Chewacla	Dothan	Luverne	Troup
Profile Characteristics	deep soil with brownish loamy surface over reddish loamy subsoil	deep soil with brownish loamy surface over brownish and grayish loamy subsoil	deep soil with brownish loamy surface and subsoil	moderately deep soil with brownish loamy surface over reddish clayey subsoil over stratified materials	deep soil with very thick brownish sandy surface over reddish loamy subsoil
Drainage Class	well	somewhat poorly	well	well	well
Permeability Class	moderate	moderate	moderately slow	moderately slow	moderate
Reaction	strongly acid	strongly acid	strongly acid	strongly acid	strongly acid
Depth to Bedrock:					
Hard, inches	>60	>60	>60	>60	>60
Rippable, inches	>60	>60	>60	>60	>60
High Water Table:					
Depth, feet	>6	1.0-1.5	3.5-4.5	>6	>6
Kind	--	apparent	perched	--	--
Months	--	Nov-Apr	Jan-Apr	--	--
Flooding:					
Frequency	none, occasional	frequent	none	none	none
Duration	brief	brief	--	--	--
Months	Nov-Feb	Feb-May	--	--	--
Shrink-swell potential (subsoil)	low	low	low	moderate	low
Slope range, percent	0-5	0-2	0-10	1-35	1-25

U.S. Army Corps of Engineers 1981.

Table 2-3. Soil suitability and major limitations in Alabama in the vicinity of Lake W.F. George.

Characteristic	Soil Association: Troup-Luverne-Dothan-Orangeburg	Soil Association: Cahaba-Chewacla-Myatt
Dominant Slope (%)	2-30	0-5
Suitability/Limitations:		
Cropland	poor: slope	good
Pasture	poor: slope	good
Woodland	good	good
Limitations for:		
Septic Tank Absorption Field	severe: slope	severe: floods
Local Roads & Streets	severe: slope	severs: floods
Small Commercial Bldgs.	severe: slope	severe: floods
Dwellings w/out Basements	severe: slope	severe: floods
Camp Areas	severe: slope	severe: floods
Picnic Areas	severe: slope	severe: floods
Play Grounds	severe: slope	severe: floods
Paths & Trails	severe: slope	severe: floods

3.0 PUBLIC ACCESS

Lake George is a heavily utilized reservoir with many lake side areas developed for multiple uses. Camping, fishing, site seeing, hunting and wildlife observation are among the many activities ongoing around the lake.

There are 34 on-water facilities including 29 boat ramps, 11 camp grounds, 19 COES parks, one Alabama state park and 2 Georgia state parks. At least 18 of the 29 boat ramps are launch sites operated by the states of Georgia, Alabama or the Corps of Engineers. These launch sites are available at no charge to the public.

4.0 SIZE AND ECONOMIC STRUCTURE OF POTENTIAL USER POPULATION

The watershed around Lake George consists primarily of three Alabama counties adjacent to the lake; Russell, Barbour and Henry. Two other counties in close proximity to the lake include Lee and Houston. Phenix City in Russell county, Auburn-Opelika in Lee County, Eufaula in Barbour County and Dothan in Houston County comprise the largest municipalities within these counties. Smaller municipalities within this area include Clayton, Abbeville, Ozark and Headland.

Population and income data for the counties in the vicinity of Lake George are presented in Table 4-1. Houston County had the highest population in the area and the highest per capita income. Barbour County had the highest percentage of families with incomes below the poverty level.

Business and employment data for the above mentioned counties appear in Tables 4-2 and 4-3. Service businesses and retail trade were the most numerous business establishments in this five county area. Manufacturing business employed the greatest number of people in all five counties, followed by retail trade, and in Houston County, service businesses.

Agricultural production data for each of the five counties in the vicinity of Lake George are presented in Table 4-4. Houston County had the greatest number of farms and the most acreage in production of the five counties; Russell County had the fewest number of farms and Lee County the least acreage in production. Houston County led in overall farm production. The only exception was cotton production which was greatest in Henry County.

Table 4-1. Total population and income characteristics of Alabama counties in the vicinity of Lake W.F. George.

County	Total Population	Per Capita Income	% Families with Income Below Poverty Level
Lee	87,146	11,409	13.2
Russell	46,860	9,675	16.8
Barbour	25,417	9,515	20.0
Henry	15,374	9,909	13.1
Houston	81,331	12,118	12.8

U.S. Bureau of the Census 1990.

Table 4-2. Number of business establishments of Alabama counties in the vicinity of Lake W.F. George.

County	Total	Agricultural Forestry Fishing	Mining	Construction	Manufacturing	Transportation, Public Utilities	Wholesale Trade	Retail Trade	Finance Insurance, Real Estate	Services	Unclassified Establishments
Lee	1,611	30	--	169	85	65	92	456	147	488	79
Russell	774	11	7	99	42	36	28	214	53	249	35
Barbour	515	8	2	29	54	23	36	169	42	132	20
Henry	308	9	1	20	36	21	27	86	21	75	12
Houston	2,403	14	2	192	108	96	232	716	204	762	77

U.S. Bureau of the Census 1990.

Table 4-3. Number of employees for business establishments of Alabama counties in the vicinity of Lake W.F. George.

County	Total	Agricultural Forestry Fishing	Mining	Construction	Manufacturing	Transportation, Public Utilities	Wholesale Trade	Retail Trade	Finance Insurance, Real Estate	Services	Unclassified Establishments
Lee		156	--	1566	9,456	1,090	2,955	6,357	1,136	4,900	67
Russell		51	54	540	3,250	331	220	2,438	436	1,668	33
Barbour		41	A	218	3,591	620	375	1,518	324	992	B
Henry	3,984	30	A	105	2,327	112	342	607	113	334	A
Houston	37,490	56	A	2,742	9,869	2,455	2,762	8,742	1,347	9,400	C

Note: Employment size classes are indicated as follows: A-0 to 19; B-20 to 99; C-100 to 249; E-250 to 499.

U.S. Bureau of the Census 1990.

Table 4-4. Agricultural production in Alabama counties in the vicinity of Lake W.F. George.

County	Total Farms	Farm Acreage	Total Cropland Acreage	Cattle Sold x 1000	Hogs Sold x 1000	Broilers Sold x 1000	Corn Bushels x 1000	Wheat Bushels x 1000	Soybeans Bushels x 1000	Cotton Bales
Lee	402	79,836	33,628	6.3	5.4	(D)[1]	18.9	2.2	1.9	2,623
Russell	276	143,568	50,775	5.7	4.5	---[2]	95.2	39.9	33.1	4,776
Barbour	498	207,906	78,654	12.5	23.2	1,407	272.1	26.3	9.3	4,858
Henry	421	171,444	101,098	8.5	24.3	---	624.8	180.8	73.0	6,044
Houston	862	207,817	141,755	14.3	27.7	(D)	699.4	216.5	294.3	1,122

[1] (D) Withheld to avoid disclosing data for individual farms.
[2] --- = zero.
U.S. Bureau of the Census 1987.

5.0 HISTORY OF LAKE USES

Lake George has been used for recreation, flood control, power generation and water supply for several industrial users on the lake.

Records on lake use have been maintained only since 1980, however since 1980, use in visitor days has remained greater than 4.5 million, with most years having in excess of 6.5 million visitor days.

Lake George continues to be heavily utilized for bass fishing in the spring with fishermen from all around the southeast visiting the lake (personal communication Ken Weathers, Alabama Department of Conservation, Game and Fish Division).

6.0 USER POPULATION AFFECTED BY LAKE DEGRADATION

Lake George is a large lake and an important economic resource for the states of Alabama and Georgia. Impaired uses of the reservoir, if any, have not been documented. The lake has not been placed under any fish consumption advisories, which was the case for some upstream reservoirs. Use of the lake has remained high in terms of number of visitor days (Table 6-1). Bass tournaments continue to bring in visitors from both Alabama and surrounding states (personal communication, Ken Weathers, ADCNR).

Table 6-1. Visitation at Lake W.F. George Reservoir 1990-1993.

Year	Visitor Days
1990	7,042,750
1991	7,136,587
1992	6,863,658
1993*	4,748,417

* 1993 data reflects new visitor surveys and a change in the method of calculating visitation. (U.S. Army Corps of Engineers 1994)

7.0 LAKE USE COMPARISON WITH NEARBY LAKES

Lake Harding and West Point Lake are two impoundments on the Chattahoochee River which are upstream of Lake George. Lake Harding, a 2,367 ha reservoir, was impounded in 1926 for electric power generation. It is much smaller than Lake George and is not heavily utilized for recreational purposes. West Point Lake, 10,467 ha, was impounded in 1974. Creation of this lake was for flood control, power generation, recreation, fish and wildlife enhancement and flow regulation for downstream navigation (EPD 1989a).

Lake George is larger in size than West Point Lake (18,284 vs 10,467 ha) but lake use appears lower on a per hectare basis. Proximity of West Point Lake to large metropolitan areas (i.e. Atlanta, Georgia) is one likely explanation. Visitor days to Lake George in 1992 were over 6.8 million. In 1993 the calculation method used by the corps changed and resulted in only a little over 4.7 million visitor days. It was not clear whether this was an actual decline in visitor days or a reflection of the change in survey and calculation method.

8.0 POINT SOURCE POLLUTION INVENTORY

A point source pollution inventory of actual and permitted discharges was compiled for industrial, municipal and mining discharges in Alabama flowing into Lake George from Phenix City, AL to the southern border of the Lake George watershed for November 1992 through October 1993 (Tables 8-1 and 8-2). Data were obtained from discharge monitoring reports from the Alabama Department of Environmental Management (ADEM). Annual point source loading estimates were calculated by expanding each monthly sampling value from a daily load to a monthly load by multiplying the sampling date daily loading estimate by the number of days in the month and summing up the 12 monthly loading estimates. Exceptions were nitrogen and phosphorus data from the Phenix City Wastewater Treatment Plant, which were based on ADEM annual compliance sampling inspection data. These data represent the only data available for nitrogen and phosphorus loading. In this case, a single value was expanded to an annual loading estimate, which yields a much less accurate estimate than those based on monthly monitoring reports.

A total of 15 permitted dischargers were identified; one industrial, seven municipal and seven mining dischargers (Tables 8-1 and 8-2). The total annual volume of wastewater effluent discharged into Lake George from the 15 dischargers was 10,586 million gallons. Of this total, the industrial facility of Mead Coated Board contributed 78.3% and the municipal discharge of Phenix City Wastewater Treatment Plant (WWTP) contributed 16.3%. The other 13 dischargers combined, produced the remaining 5.4% of the total wastewater.

Annual point source biochemical oxygen demand (BOD) loading was 1,584,369 lb. Again, the Mead facility and the Phenix City WWTP contributed almost all of this amount (72.5% and 22.1% respectively).

Table 8-1. Point source loading of permitted industrial (I), municipal (M) and mining (Mn) dischargers of biochemical oxygen demand (BOD), total suspended solids (TSS), total nitrogen (TN) and total phosphorus (TP) into Lake W.F. George, November 1992 - October 1993.

Facility	NPDES Number	FAC	Receiving Stream	Permitted Flow (MGD)	Actual Flow (MGD)	Total Flow (MG/yr)	BOD Loading (lb/yr)	TSS Loading (kg/yr)	TN Loading (kg/yr)	TP Loading (kg/yr)
					Chattahoochee River					
Mead Coated Board	AL0000817	I	Chattahoochee River	---	22.715	8,291.00	1,149,383	987,845	---	---
Blessed Trinity Retreat	AL0059251	M	Chattahoochee River	0.023	0.023	8.40	989	743	---	---
Phenix City WWTP	AL0022209	M	Chattahoochee River	7.750	4.718	1,721.90	349,929	149,578	142,624[1,2]	21,491[2]
Eufaula WWTP	AL0061671	M	Chattahoochee River	2.700	1.323	482.90	66,112	37,704	---	---
Blue Circle Aggregates Birckyard Rd #6	AL0057274	Mn	Abercumbie Mill Creek	---	---	---	---	---	---	---
SUBTOTALS				10.473	28.779	10,504.2	1,566,413	1,175,870	142,624	21,491
					Uchee Creek					
Bickerstaff Clay Products	AL0058629	Mn	Long Branch	---	---	---	---	---	---	---
Blue Circle Aggregates Uchee Plant #7	AL0057266	Mn	Uchee Creek	---	---	---	---	---	---	---
					Little Uchee Creek					
Smiths Station High School	AL0043681	M	Hospilika Creek	0.054	---	---	---	---	---	---
					Barbour Creek					
Eufaula Adolescent Center	AL0044563	M	Barbour Creek	0.021	0.023	8.33	1,264	521	---	---
					Cowikee Creek					
Lakepoint Resort	AL0023906	M	Cowikee Creek	0.150	0.068	24.82	7,797	8,344	---	---

Table 8-1. Continued.

Facility	NPDES Number	FAC	Receiving Stream	Permitted Flow (MGD)	Actual Flow (MGD)	Total Flow (MG/yr)	BOD Loading (lb/yr)	TSS Loading (kg/yr)	TN Loading (kg/yr)	TP Loading (kg/yr)
					North Fork Cowikee Creek					
Hurtsboro ACR Lagoon	AL0020699	M	Hurtsboro Creek	0.260	0.133	48.39	8,895	4,165	---	---
					Cheneyhatchee Creek					
Harbison-Walker Refractories Eufaula Plant	AL0001848	Mn	Tributary to Cheneyhatchee Creek	---	---	---	---	---	---	---
					White Oak Creek					
Harbison-Walker Refractories Bakerhill Plant	AL0050539	Mn	White Oak Creek	---	---	---	---	---	---	---
Harbison-Walker Refractories KACC17	AL0056944	Mn	White Oak Creek	---	---	---	---	---	---	---
					Barnes Mill Creek					
Mullite Co. of America	AL0048500	Mn	Tributary to Barnes Mill Creek	---	---	---	---	---	---	---
TOTALS				11	29	10,586	1,584,369	1,188,900	142,624	21,491

[1] Does not include nitrite-nitrogen.
[2] Loading based on utilizing actual flow (MGD) and concentration obtained from ADEM compliance sampling.
--- No information available.

Table 8-2. Potential point source loading of permitted industrial (I), municipal (M) and mining (Mn) dischargers of biochemical oxygen demand (BOD), total suspended solids (TSS), total nitrogen (TN) and total phosphorus (TP) into Lake W.F. George, November 1992 - October 1993.

Facility	NPDES Number	FAC	Permitted Flow (MGD)	Permitted BOD (mg/L)	Permitted BOD (lb/day)	Permitted BOD Load (lb/yr)	Permitted TSS (mg/L)	Permitted TSS (kg/day)	Permitted TSS Load (kg/yr)	Permitted[1] TN (mg/L)	Permitted TN Load (kg/yr)	Permitted TP (mg/L)	Permitted TP Load (kg/yr)
				Chattahoochee River									
Mead Coated Board	AL0000817	I	22.715[2]	---	19,600	7,154,000	---	23,401	8,541,497	---	---	---	---
Blessed Trinity Retreat	AL0059251	M	0.023	30.0	5.6	2,044	90.0	7.7	2,798	---	---	---	---
Phenix City WWTP	AL0022209	M	7.750	35.0	2,262	825,630	30.0	879	320,968	21.9[3]	234,479	3.3[3]	35,333
Blue Circle Aggregates Birckyard Rd #6	AL0057274	Mn	---	---	---	---	35.0	---	---	---	---	---	---
SUBTOTALS						7,981,674			8,865,263		234,479		35,333
				Uchee Creek									
Bickerstaff Clay Products	AL0058629	Mn	---	---	---	---	35.0	---	---	---	---	---	---
Blue Circle Aggregates Uchee Plant #7	AL0057266	Mn	---	---	---	---	35.0	---	---	---	---	---	---
				Little Uchee Creek									
Smiths Station High School	AL0043681	M	0.054	30.0	13.5	4,928	90.0	18.4	6,704	---	---	---	---
				Barbour Creek									
Eufaula Adolescent Center	AL0044563	M	0.021	30.0	5.3	1,935	30.0	2.4	878	---	---	---	---
Eufaula WWTP	AL0061671	M	2.700	30.0	675.5	246,558	30.0	306.3	111,818	---	---	---	---
				Cowikee Creek									
Lakepoint Resort	AL0023906	M	0.150	30.0	37.5	13,688	90.0	51.2	18,705	---	---	---	---

Table 8-2. Continued.

Facility	NPDES Number	FAC	Permitted Flow (MGD)	Permitted BOD (mg/L)	(lb/day)	Permitted BOD Load (lb/yr)	Permitted TSS (mg/L)	(kg/day)	Permitted TSS Load (kg/yr)	Permitted[1] TN (mg/L)	Permitted TN Load (kg/yr)	Permitted TP (mg/L)	Permitted TP Load (kg/yr)
North Fork Cowikee Creek													
Hurtsboro ACR Lagoon	AL0020699	M	0.260	30.0	65.1	23,762	90.0	88.5	32,312	---	---	---	---
Cheneyhatchee Creek													
Harbison-Walker Refractories Eufaula Plant	AL0001848	Mn	---	---	---	---	35.0	---	---	---	---	---	---
White Oak Creek													
Harbison-Walker Refractories Bakerhill Plant	AL0050539	Mn	---	---	---	---	35.0	---	---	---	---	---	---
Harbison-Walker Refractories KACC17	AL0056944	Mn	---	---	---	---	35.0	---	---	---	---	---	---
Barnes Mill Creek													
Mullite Co. of America	AL0048500	Mn	---	---	---	---	35.0	---	---	---	---	---	---
TOTALS						8,272,545			9,035,679		234,479		35,333

[1] Does not include nitrite-nitrogen.
[2] Actual flow.
[3] Facility not required to monitor total phosphorus and total nitrogen in their effluent, values were based on ADEM compliance sampling inspection (1991).
--- No information available.

Annual point source total suspended solids (TSS) loading was 1,188,900 kg; the Mead facility contributed 83.1% and Phenix City WWTP contributed 12.6%. Annual point source total nitrogen (TN) loading was 142,624 kg and annual point source total phosphorus (TP) loading was 21,491 kg, based on the limited ADEM compliance sampling data from the Phenix City WWTP.

Of the two major contributors of BOD, TSS, TN and TP to Lake George, the Mead facility discharged 16.1% of its permitted annual BOD load and 11.6% of its permitted annual TSS load. The Phenix City WWTP discharged 60.9% of its permitted annual wastewater discharge, 42.4% of its permitted annual BOD load, 46.6% of its permitted annual TSS load, 60.8% of its permitted TN load and 60.8% of its permitted TP load (based on a single water quality sample during the entire year).

9.0 NUTRIENT LOADING

Five tributary streams in addition to the Chattahoochee River (Table 9-1 and Figure 9-1) were sampled twenty times from November 1992 through October 1993. Stations were sampled once monthly in November, twice monthly from December through May, and then once monthly from June through October. Two additional samples were collected after significant rainfall events (February 12 and March 17, 1993). Water samples were collected just below the water's surface directly into 2 L Nalgene bottles or, when water was too deep to wade, water was collected using a van Dorn water sampler and then transferred into 2 L Nalgene bottles for transport to laboratory facilities at Auburn University. Water samples used to estimate the concentration of total suspended solids were collected with a depth-integrated, suspended-sediment sampler using methods describes by Glysson and Edwards (1988) except at station 21(Chattahoochee River at Ft. Benning Bridge), where a near-surface grab was the only feasible alternative. Water samples were analyzed for total phosphorus, soluble reactive phosphorus (orthophosphate), nitrate-nitrogen, nitrite-nitrogen, total ammonia nitrogen, organic nitrogen, alkalinity, specific conductance and total suspended solids utilizing methods described in Table 10-3. Stream discharge was measured _in situ_ on each sampling date at all ungaged stations (stations 16, 17 and 18). Discharge was determined by measuring stream depth and mean current velocity (velocity at 0.6 X depth) using a Marsh-McBirney, model 201D portable water current meter. Depth and mean current velocity were measured for each 1-3 m wide cell along a transect at the sampling site. Total stream discharge was then calculated by summing the product of depth X mean velocity X width of each cell along the transect.

Seasonal and annual mean concentrations of the water quality variables which were used to estimate total loading (point and nonpoint source) and

Table 9-1. Location of tributary sampling stations for assessment of nutrient loading into Lake W.F. George from November 1, 1992 through October 31, 1993.

Stream	Station Number	Station Description
Hatchechubbee Creek	16	Alabama Highway 431 Bridge 0.2 miles south of Pittsview, AL
North Fork Cowikee Creek	17	County Bridge 9.25 miles upstream from Lakepoint Resort State Park Boat Ramp
Middle Fork Cowikee Creek	18	County Bridge 8.25 miles upstream from Lakepoint Resort State Park Boat Ramp
South Fork Cowikee Creek	19	County Road 79 Bridge 0.5 miles north of Alabama Highway 82
Uchee Creek	20	Alabama Highway 165 Bridge at Fort Mitchell, AL
Chattahoochee River	21	Fort Benning Military Reservation Bridge
Chattahoochee River	22[a]	Columbus, Georgia City water intake

[a] Sampled by Georgia Environmental Protection Division.

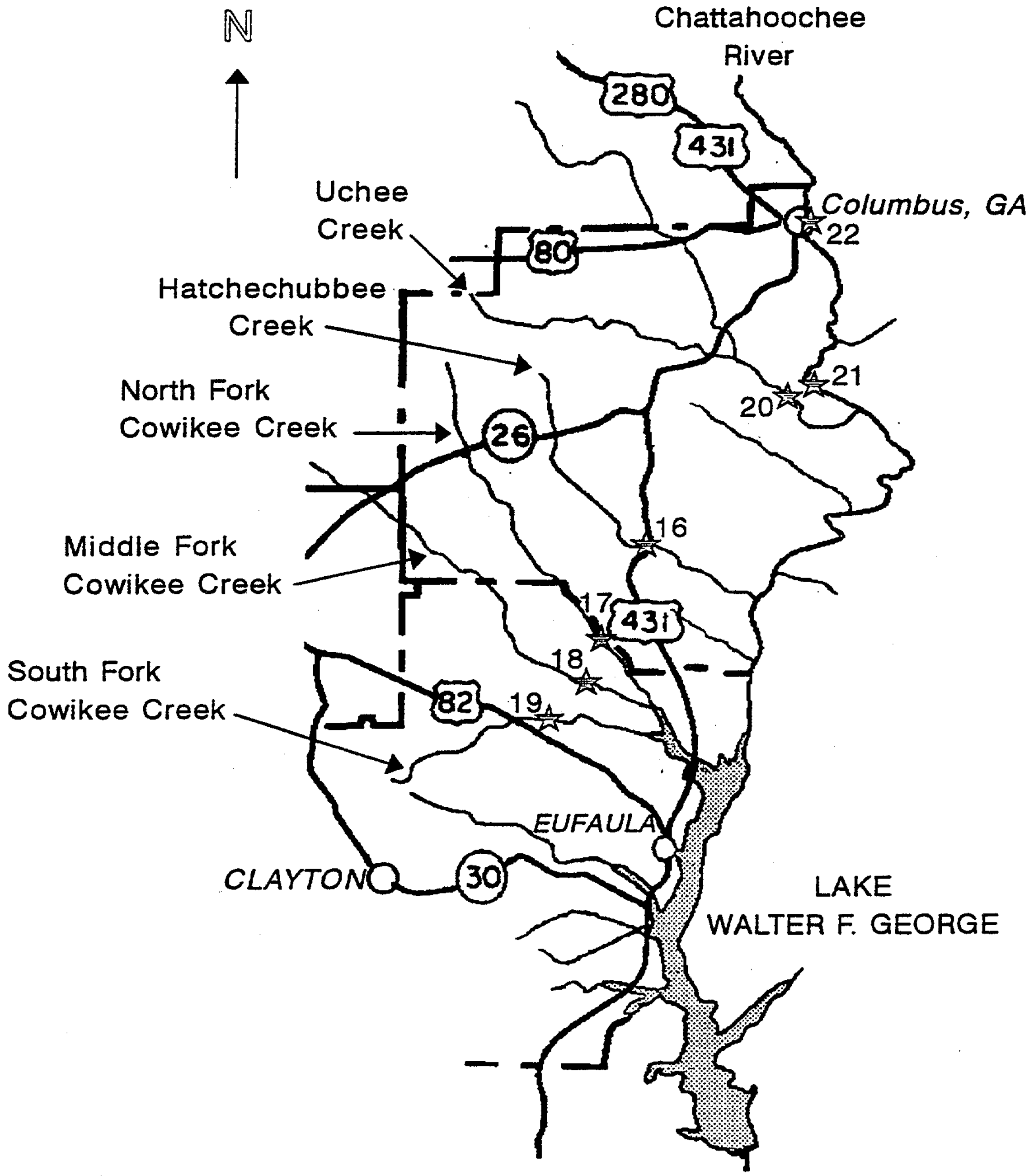


Figure 9-1. Location of tributary sampling stations 16 (Hatchechubbee Creek), 17 (South Fork Cowikee Creek), 18 (Middle Fork Cowikee Creek), 19 (South Fork Cowikee Creek), 20 (Uchee Creek), 21 (Chattahoochee River at Fort Benning Bridge) and 22 (Georgia EPD sampling station at Columbus, Georgia).

seasonal and annual means of mean daily discharge appear in Table 9-2, 9-3 and 9-4. The wet season (December through May) included the months when two or more samples were taken each month, and the dry season (June through November) included months when only one sample was taken. November, considered a dry month, was unusually wet in 1992 (+21.8 cm deviation from normal monthly rainfall at Columbus, GA). Overall dry season deviation from normal rainfall was +6.1 cm, and overall wet season deviation was -12.3 cm (Table 10-4).

Annual means were for the 365 days from November 1, 1992 through October 31, 1993. Mean daily discharge in cubic feet per second (cfs) of the South Fork of Cowikee Creek, Uchee Creek and the Chattahoochee River at Columbus, Georgia (stations 19, 20 and 22) was obtained from USGS gage data. The 20 measured and calculated discharges from the 20 sampled dates for Hatchechubbee, North Fork of Cowikee and Middle Fork of Cowikee Creeks (stations 16, 17 and 18) were regressed against 20 concurrent gaged discharge values of the South Fork of Cowikee and 20 concurrent gaged discharge values of Uchee Creek (Thomas 1967). Regressions using the discharge of Uchee Creek gave the best fit (highest r^2) for all three ungaged streams. Log-Log linear regressions ($\log_{10}y = a + b(\log x)$) were determined to estimate mean daily discharge for stations 16, 17 and 18 (r^2 = 0.87, 0.84, 0.85, respectively). Mean daily discharge estimations for stations 16, 17 and 18 above the range of the 20 regressed data points (mean daily discharge values of Uchee Creek greater than 2,355 cfs) were greatly overestimated, therefore these estimations were calculated using linear regressions ($y = a + bx$) of the 20 discharge values of stations 16, 17 and 18 and the 20 concurrent discharge values of Uchee Creek (r^2 = 0.89, 0.88, 0.91, respectively). Mean daily discharge of Uchee Creek exceeded 2,355 cfs seven of the 365 days from November 1, 1992 through October 31, 1993.

Table 9-2. Mean (range) daily discharge in cfs and mean (range) concentration of total suspended solids in mg/L for wet (December-May) and dry (June-November) seasons, and annual mean and r^2 (square of correlation coefficient) of correlation between total suspended solids and instantaneous stream discharge (n = 20 for stations 16-21), for tributary streams (stations 16-20) and the Chattahoochee River at Columbus, GA (station 22) and at Fort Benning Bridge (station 21) from November 1992 through October 1993.

	Mean Daily Discharge (cfs)			Total Suspended Solids (mg/L)			
Stations	Wet	Dry	Annual	Wet	Dry	Annual	r^2
16	84^{a} (4.8-1,075)	60^{a} (0.3-5,877)	72^{a} (0.3-5,877)	57.1 (6-323)	7.9 (3-20)	28.8 (3-323)	0.86
17	154^{a} (2.4-2,025)	112^{a} (0.05-11,089)	133^{a} (0.05-11,089)	69.1 (7-442)	5.7 (1-14)	32.3 (1-442)	0.68
18	226^{a} (11.9-2,809)	158^{a} (0.7-15,305)	192^{a} (0.7-15,305)	73.1 (10-422)	7.7 (2-13)	35.7 (2-422)	0.85
19	193^{b} (23-3,280)	48^{b} (0.6-2,190)	120^{b} (0.6-3,280)	59.8 (6-357)	5.2 (2-9)	29.3 (2-357)	0.89
20	661^{b} (84-3,600)	281^{b} (10-18,500)	470^{b} (10-18,500)	41.7 (5-146)	11.5 (2-46)	25.7 (2-146)	0.71
21	$14,749^{c}$ (1,975-51,623)	$7,020^{c}$ (1,475-86,557)	$10,874^{c}$ (1,475-86,557)	12.2 (5-37)	8.0 (4-23)	9.8 (4-37)	0.46
22	$13,616^{b}$ (1,550-47,700)	$6,532^{b}$ (1,320-73,100)	$10,064^{b}$ (1,320-73,100)	--	--	--	--

[a] Means estimated from mean daily discharge values estimated from regression based on USGS gaged discharge of Uchee Creek.

[b] Means of mean daily discharge values from USGS gages.

[c] Means estimated from mean daily discharge values estimated from USGS gaged discharges of Uchee and Upatoi Creeks and the Chattahoochee River at Columbus, GA.

Table 9-3. Mean (range) concentration of total nitrogen and total inorganic nitrogen in µg/L for wet (December-May) and dry (June-November) seasons, and annual mean and r^2 (square of correlation coefficient) of correlation between total nitrogen and instantaneous stream discharge and between total inorganic nitrogen and instantaneous stream discharge (n = 20 for stations 16-21, n = 9 for station 22), for tributary streams (stations 16-20) and the Chattahoochee River at Columbus, GA (station 22) and at Fort Benning Bridge (station 21) from November 1992 through October 1993.

Stations	Total Nitrogen (µg/L)				Total Inorganic Nitrogen (µg/L)			
	Wet	Dry	Annual	r^2	Wet	Dry	Annual	r^2
16	504 (342-821)	477 (378-849)	485 (342-849)	0.45	128 (31-223)	171 (95-357)	152 (31-357)	0.20
17	593 (313-1,017)	481 (317-706)	530 (313-1,017)	0.67	156 (61-242)	92 (0-221)	128 (0-242)	0.10
18	604 (402-1,325)	381 (250-523)	482 (250-1,325)	0.75	132 (22-243)	104 (26-192)	122 (22-243)	0.29
19	571 (305-1,330)	407 (313-483)	486 (305-1,330)	0.73	146 (31-300)	134 (68-184)	146 (31-300)	0.18
20	402 (275-749)	312 (177-658)	356 (177-749)	0.49	116 (62-175)	41 (3-119)	80 (3-175)	0.07
21	833 (707-992)	901 (397-1,261)	869 (397-1,261)	0.03	556 (444-706)	562 (289-827)	562 (289-827)	0.06
22	--	--	--	--	483[a] (450-530)	494[a] (340-770)	489[a] (340-770)	0.004

[a] Data from Georgia Environmental Protection Division.

Table 9-4. Mean (range) concentration of total phosphorus and orthophosphate in μg/L for wet (December-May) and dry (June-November) seasons, and annual mean and r^2 (square of correlation coefficient) of correlation between total phosphorus and instantaneous stream discharge ($n = 20$ for stations 16-21, $n = 9$ for station 22), for tributary streams (stations 16-20) and the Chattahoochee River at Columbus, GA (station 22) and at Fort Benning Bridge (station 21) from November 1992 through October 1993.

	Total Phosphorus (μg/L)				Orthophosphate (μg/L)		
Stations	Wet	Dry	Annual	r^2	Wet	Dry	Annual
16	57 (12-165)	27 (19-47)	41 (12-165)	0.78	3.4 (1-12)	3.5 (1-8)	3.4 (1-12)
17	77 (17-258)	40 (15-72)	56 (15-258)	0.76	5.5 (2-11)	4.0 (1-7)	4.7 (1-11)
18	97 (16-351)	51 (34-80)	71 (16-351)	0.80	7.3 (3-16)	8.3 (3-10)	7.9 (3-16)
19	86 (10-325)	36 (30-47)	58 (10-325)	0.81	6.9 (4-16)	8.2 (4-11)	7.6 (4-16)
20	57 (11-180)	35 (19-91)	45 (11-180)	0.67	5.1 (2-19)	3.0 (1-7)	4.0 (1-19)
21	62 (27-90)	57 (33-88)	60 (27-90)	0.10	16.8 (8-31)	25.2 (8-50)	21.1 (8-50)
22	75[a] (60-90)	60[a] (50-70)	67[a] (50-90)	0.41	--	--	--

[a] Data from Georgia Environmental Protection Division.

Mean daily discharge for the Chattahoochee River at Fort Benning Bridge (station 21) was estimated from USGS discharge data obtained at the gage on the Chattahoochee River at Columbus, Georgia (station 22) and gages on Uchee Creek (station 19) and Upatoi Creek in Georgia. Mean daily discharge for the Chattahoochee River watershed area between Columbus, Georgia and the Fort Benning Bridge (area = 560 mi^2) was estimated from mean daily discharge of Uchee and Upatoi Creeks. Upatoi Creek watershed occupies 342 mi^2 of this watershed and occupies 67.3% of the portion of this watershed lying in Georgia (area = 508 mi^2), therefore the mean daily discharge of the Georgia portion of this watershed was determined by multiplying Upatoi Creek mean daily discharge by 1/0.673 (or 1.485). The portion of the above-mentioned Chattahoochee River watershed in Alabama covers an area of 52 mi^2. Uchee Creek, with an area of 322 mi^2, was used to estimate the discharge from the Alabama portion of the watershed by multiplying the mean daily discharge of Uchee Creek by 52/322 (or 0.1615). The total mean daily discharge of the Chattahoochee River at Fort Benning Bridge for the 365 days from November 1, 1992 through October 31, 1993 was estimated by summing the mean daily discharge of the Chattahoochee River at Columbus plus the estimated mean daily discharges of the Georgia portion and Alabama portion of the Chattahoochee River watershed between Columbus and Fort Benning Bridge.

Annual mean daily discharge for the five tributary streams ranged from 72 cfs for Hatchechubbee Creek to 470 cfs for Uchee Creek (Table 9-2). The annual mean daily discharge for the Chattahoochee River was 10,064 cfs at Columbus, Georgia and 10,874 cfs 15 river-miles downstream at the Fort Benning Bridge. Wet season mean daily discharge ranged from 1.4 to 4.0 times greater than dry season discharge. Total monthly discharge ($m^3 \times 10^6$) was calculated and plotted from November 1992 through October 1993 for stations 16-22 (Figures 9-2, 9-3, 9-4, 9-5, 9-6, 9-7 and 9-8). Hatchechubbee, North Fork of Cowikee, Middle Fork of Cowikee and Uchee Creeks had peak total monthly discharge in November, typically one of the driest months of the year, and a lesser (about half the magnitude of November) peak in March. All four streams were at base flow from June through October. The South Fork of Cowikee Creek had peak discharge in March and a lesser peak in November and December. The Chattahoochee River discharge showed very similar patterns at Columbus, Georgia and Fort Benning Bridge: high flows November through March, with peak discharge in December, followed by a gradual decline in flow from March to September.

Annual mean concentrations of water quality variables were calculated by first calculating monthly mean concentrations and then calculating annual mean concentrations of the 12 months (Tables 9-2, 9-3 and 9-4). The number of samples for wet season means was 14 and the number of samples for dry season means was 6 for stations 16-21. The Georgia Environmental Protection Division (EPD) supplied monthly water quality data for the Chattahoocheee River at Columbus, Georgia (station 22). Samples were not taken by EPD in November and December of 1992 and in February of 1993, therefore the number of samples for the wet season means was four and the number of samples for the dry season means was five. Also, total suspended solids, total nitrogen and orthophosphate were not measured by EPD. Correlations were run between stream discharge and concentrations of total suspended solids, total nitrogen, total inorganic nitrogen and total phosphorus measured on the 20 sampling dates for stations 16-22 to determine correlation coefficents (r) and probabilities (p) (SAS 1990).

Total suspended solids (TSS) concentrations were much higher in tributary streams (mean annual concentrations from 25.7-35.7 mg/L) than in the

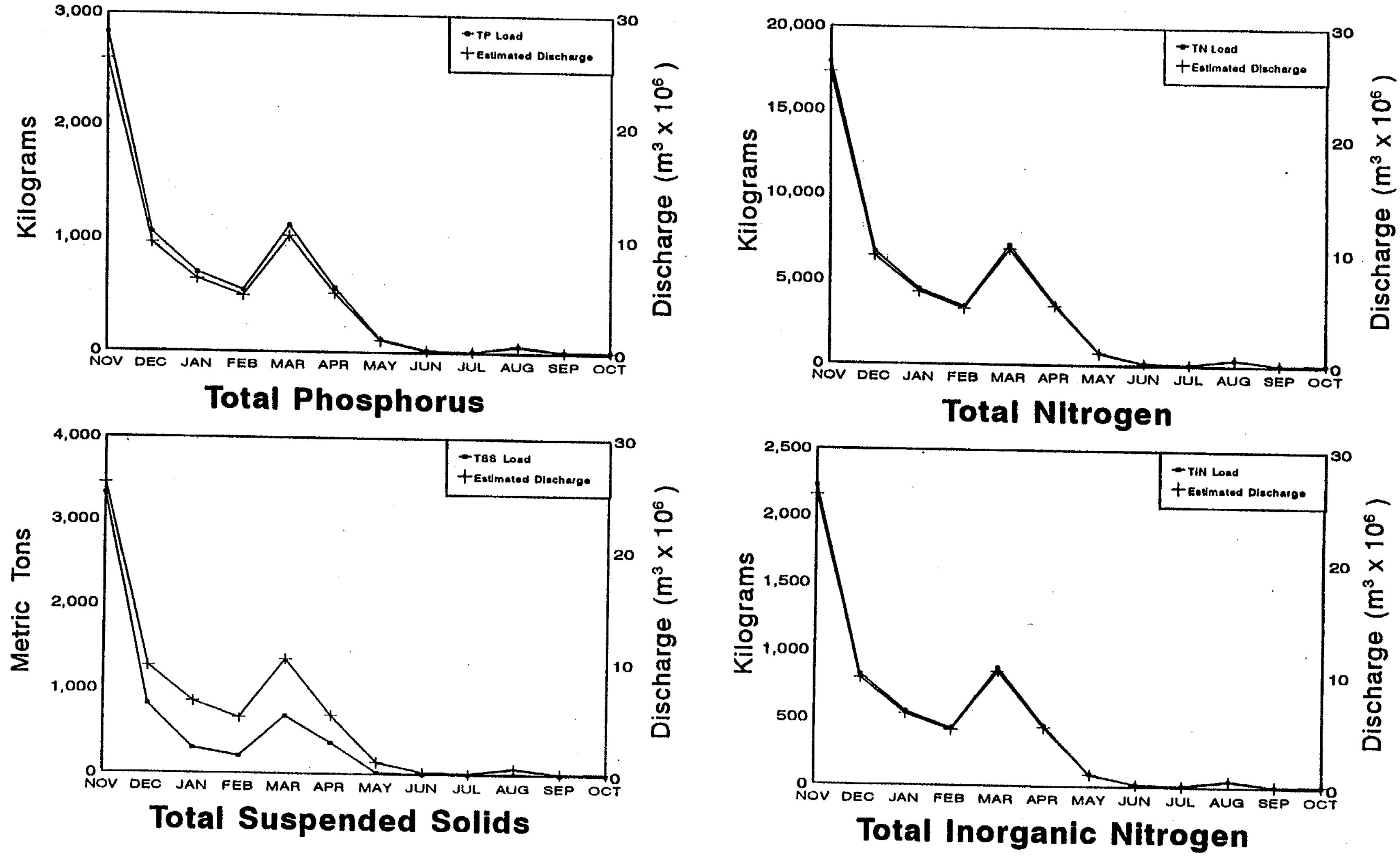


Figure 9-2. Total monthly loading (point and nonpoint source) at station 16, Hatchechubbee Creek, in kilograms for total phosphorus, total nitrogen and total inorganic nitrogen and in metric tons for total suspended solids, determined by FLUX, plotted with estimates of total monthly discharge ($m^3 \times 10^6$) during the diagnostic study of Lake W. F. George, November 1992 through October 1993.

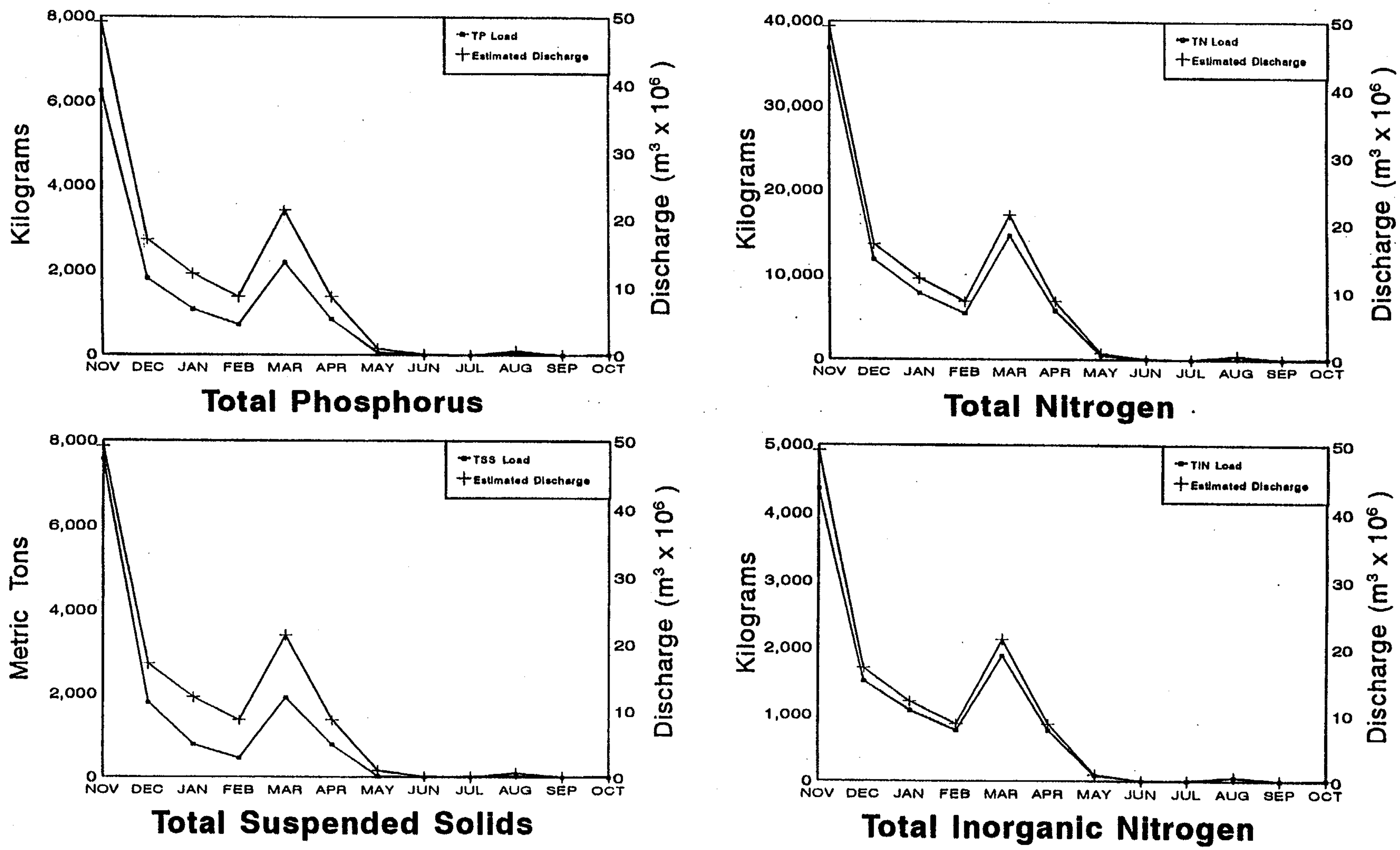


Figure 9-3. Total monthly loading (point and nonpoint source) at station 17, North Fork Cowikee Creek, in kilograms for total phosphorus, total nitrogen and total inorganic nitrogen and in metric tons for total suspended solids, determined by FLUX, plotted with estimates of total monthly discharge ($m^3 \times 10^6$) during the diagnostic study fo Lake W. F. George, November 1992 through October 1993.

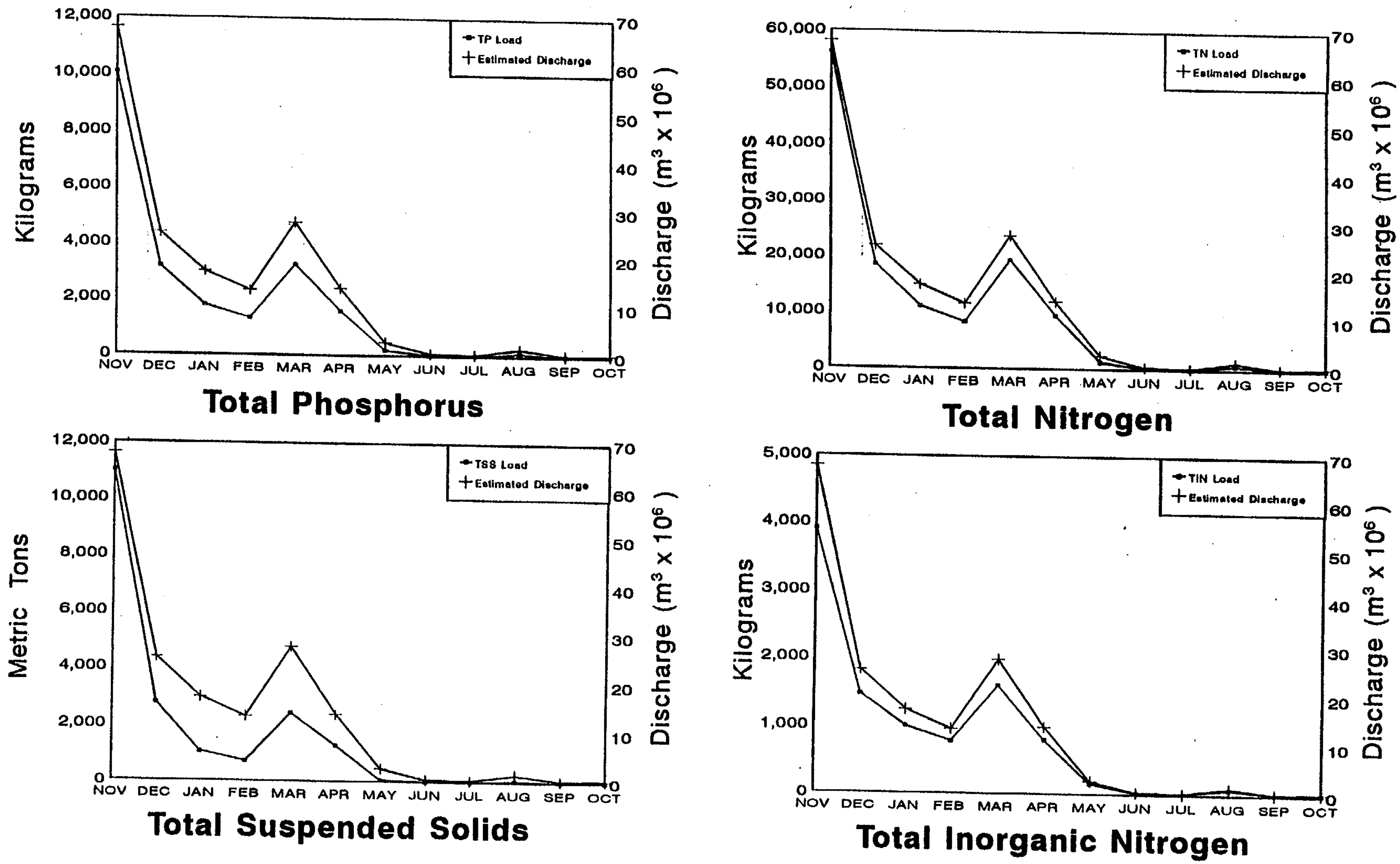


Figure 9-4. Total monthly loading (point and nonpoint source) at station 18, Middle Fork Cowikee Creek, in kilograms for total phosphorus, total nitrogen and total inorganic nitrogen and in metric tons for total suspended solids, determined by FLUX, plotted with estimates of total monthly discharge ($m^3 \times 10^6$) during the diagnostic study of Lake W. F. George, November 1992 through October 1993.

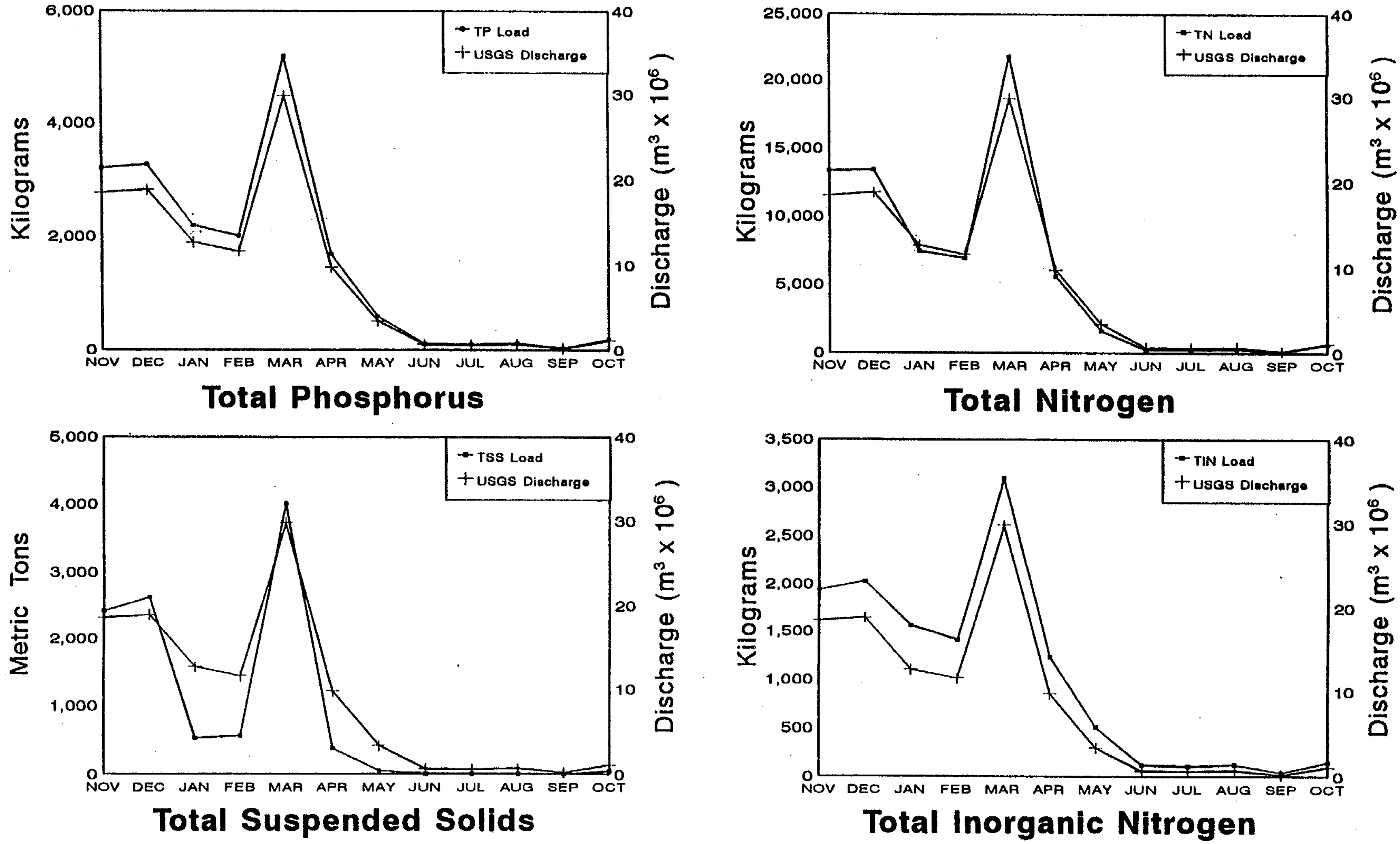


Figure 9-5. Total monthly loading (point and nonpoint source) at station 19, South Fork Cowikee Creek, in kilograms for total phosphorus, total nitrogen and total inorganic nitrogen and in metric tons for total suspended solids, determined by FLUX, plotted with USGS total monthly discharge ($m^3 \times 10^6$) during the diagnostic study of Lake W. F. George, November 1992 through October 1993.

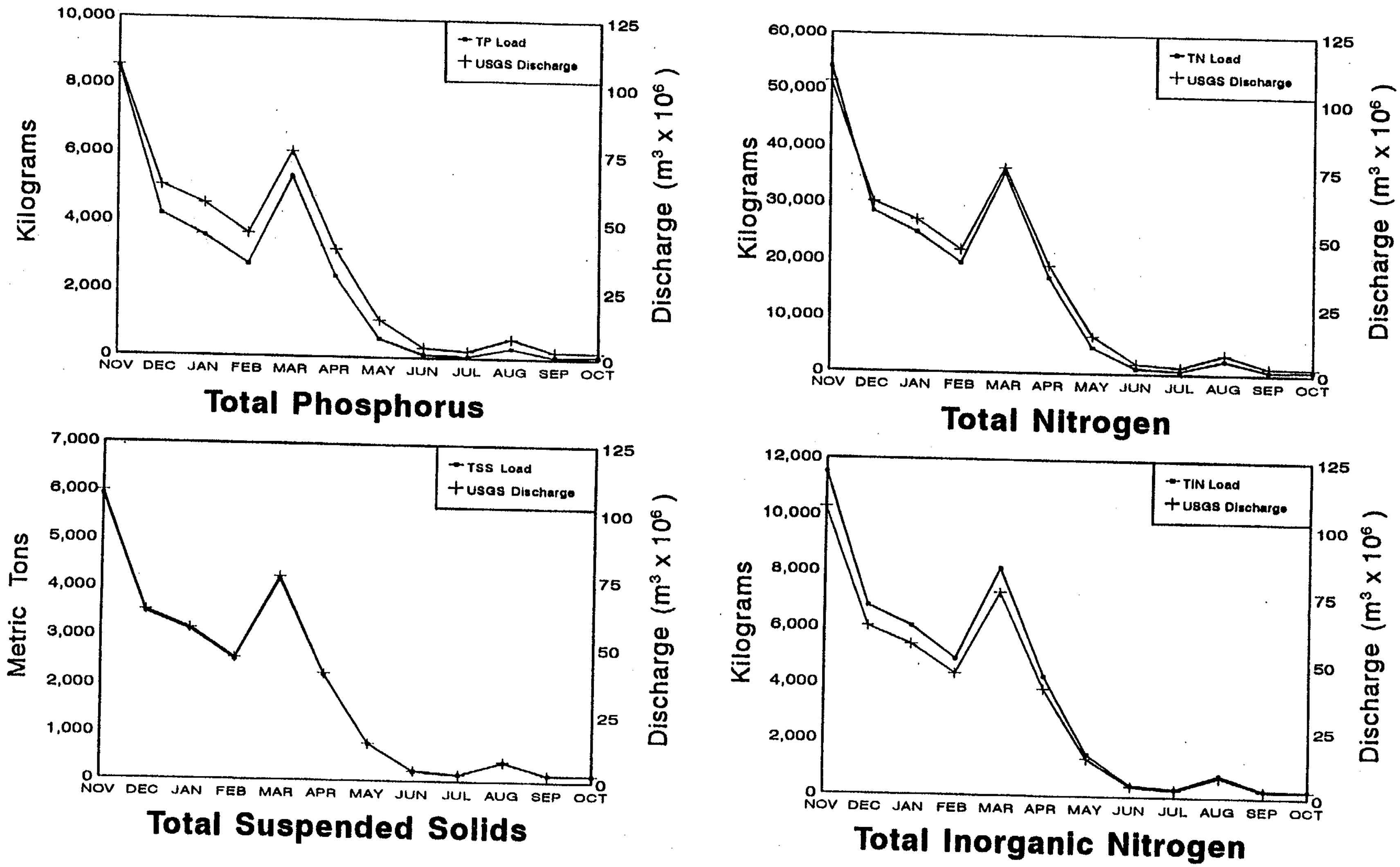


Figure 9-6. Total monthly loading (point and nonpoint source) at station 20, Uchee Creek, in kilograms for total phosphorus, total nitrogen and total inorganic nitrogen and in metric tons for total suspended solids, determined by FLUX, plotted with USGS total monthly discharge ($m^3 \times 10^6$) during the diagnostic study of Lake W. F. George, November 1992 through October 1993.

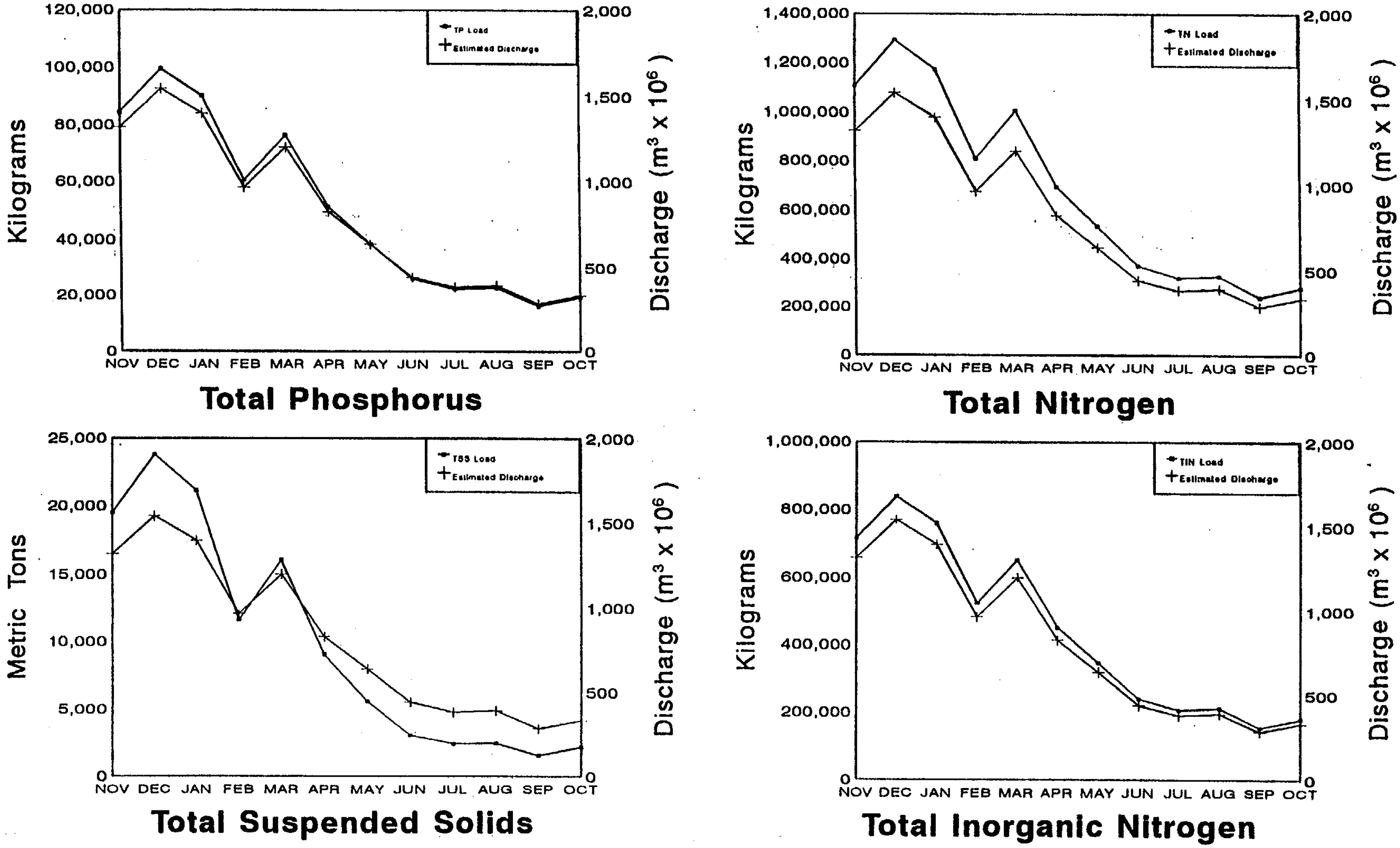
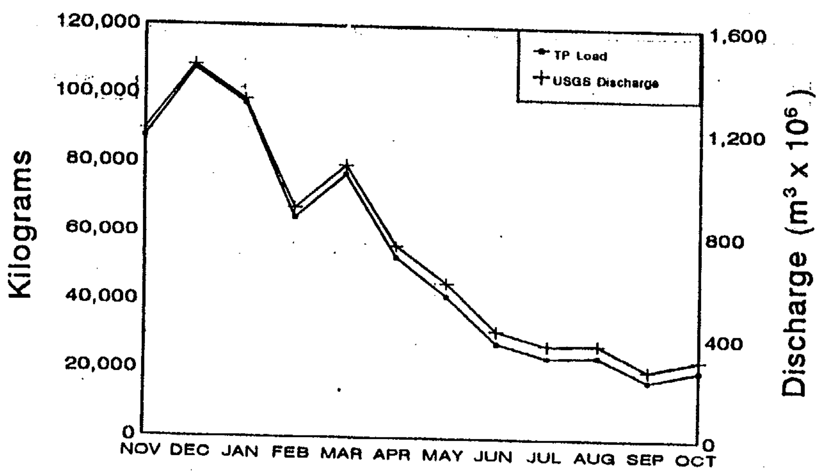
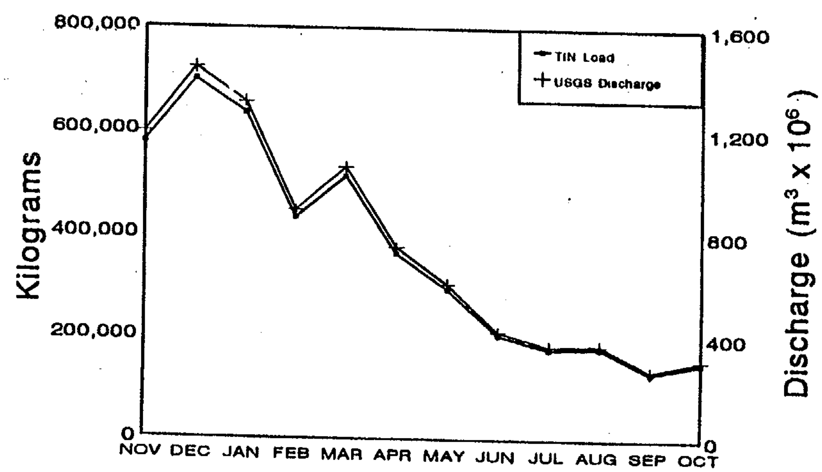


Figure 9-7. Total monthly loading (point and nonpoint source) at station 21, Chattahoochee River at Fort Benning Bridge, in kilograms for total phosphorus, total nitrogen and total inorganic nitrogen and in metric tons for total suspended solids, determined by FLUX, plotted with estimates of total monthly discharge ($m^3 \times 10^6$) during the diagnostic study of Lake W. F. George, November 1992 through October 1993.



Total Phosphorus



Total Inorganic Nitrogen

Figure 9-8. Total monthly loading (point and nonpoint source) at station 22, Chattahoochee River at Columbus, Georgia, in kilograms for total phosphorus and total inorganic nitrogen determined by FLUX, plotted with USGS total monthly discharge ($m^3 \times 10^6$) during the diagnostic study of Lake W. F. George, November 1992 through October 1993.

Chattahoochee River at Fort Benning Bridge (mean annual concentration = 9.8 mg/L, Table 9-2). Wet season TSS concentrations were from 3.6 to 12.1 times higher than dry season TSS concentrations in the tributary streams. The seasonal variation in TSS concentration was small in the Chattahoochee River. TSS concentrations were highly positively correlated ($p < 0.01$) to instantaneous stream flow in all five tributary streams (r^2 ranged from 0.68 to 0.89). The correlation of TSS and instantaneous flow for the Chattahoochee River was much weaker ($r^2 = 0.46$, $p < 0.01$).

Total nitrogen (TN) concentrations were about twice as high in the Chattahoochee River as they were in the five tributary streams (mean annual concentration of 869 μg/L versus 356-530 μg/L, Table 9-3). There were only slight differences in seasonal TN concentrations. TN concentrations were highly positively correlated ($p < 0.01$) to instantaneous stream flow in all five tributary streams (r^2 ranged from 0.45 to 0.75) and not significantly correlated ($p = 0.47$) to instantaneous stream flow in the Chattahoochee River ($r^2 = 0.03$).

Total inorganic nitrogen (TIN) concentrations in the Chattahoochee River were three to seven times higher than TIN concentrations in the five tributary streams (mean annual concentration of 489-562 μg/L verses 80-152 μg/L, Table 9-3). TIN accounted for 22-31% of TN in the five tributary streams and 63% of the TN in the Chattahoochee River at Fort Benning Bridge. TIN concentrations were weakly negatively correlated ($p < 0.05$) at stations 16 and 18 and not correlated at all ($p > 0.05$) at stations 17 and 19-22 to instantaneous discharge (r^2 ranged from 0.004 to 0.29). Annual and seasonal mean TIN concentrations were about 70 μg/L higher in the Chattahoochee River at Fort Benning Bridge than at Columbus, Georgia.

Total phosphorus (TP) concentrations were comparable among the five tributary streams and the Chattahoochee River (Table 9-4). Mean annual TP concentrations ranged from 41 to 71 μg/L. TP concentrations were highly correlated ($p < 0.01$) with instantaneous stream discharge in all five tributary streams ($r^2 = 0.67$-0.81) but only weakly correlated ($p < 0.06$) in the Chattahoochee River at Columbus, Georgia ($r^2 = 0.41$). There was no significant correlation ($p > 0.19$) between TP concentration and instantaneous stream discharge in the Chattahoochee River at Fort Benning Bridge ($r^2 = 0.10$), probably because of the influence of point source TP contributed by the municipal wastewater treatment plants of Columbus, Georgia, Phenix City, Alabama and Fort Benning, Georgia. The limited data suggest that TP concentrations were slightly lower downstream at the Fort Benning Bridge. Orthophosphate (OP) concentrations were 2.7-6.2 times higher in the Chattahoochee River at Fort Benning Bridge (no OP data were collected at Columbus, GA) than OP concentrations in the five tributary streams. The major point source inflows from Columbus, Phenix City and Fort Benning were probably influential in these higher OP levels.

Total loading (point and nonpoint source) from the five tributary streams (stations 16-20) and from the Chattahoochee River (stations 21-22) for TP, TN, TIN and TSS was estimated using FLUX (Table 9-5). FLUX is an interactive data reduction program for estimating nutrient loading from grab sample nutrient concentration data, with associated instantaneous flow measurements, and continuous flow (mean daily discharge) data (Walker 1986). Continuous flow records were obtained from USGS for stations 19, 20 and 22. Continuous flow was estimated for stations 16, 17, 18 and 21 as mentioned previously. Water quality data for stations 16-21 were from the 20 sampled dates from November 1992 through October 1993. Water quality data for station 22 were obtained from EPD and

Table 9-5. Estimated total loading (point and nonpoint) using FLUX for TP, TN, TIN, and TSS from tributary streams (stations 16-20) and from the Chattahoochee River (stations 21 and 22) into Lake W.F. George from November 1, 1992 through October 31, 1993.

Stream	Station Number	Watershed Area ($miles^2$)	Mean Daily Discharge (cfs)	TP Loading (kg/yr)	TN Loading (kg/yr)	TIN Loading (kg/yr)	TSS Loading (mt/yr)[f]
Hatchechubbee	16	53[ab]	72.2[c]	7,051	44,571	5,546	5,743
North Fork Cowikee	17	113[ab]	132.7[c]	12,970	83,294	10,502	13,314
Middle Fork Cowikee	18	166[ab]	191.7[c]	21,439	125,202	9,859	19,299
South Fork Cowikee	19	112[a]	120.4[d]	18,669	71,677	12,313	10,625
Uchee	20	322[a]	470.3[d]	27,882	189,336	45,185	23,230
Chattahoochee at Fort Benning	21	5,230	10,873.6[e]	605,748	8,155,191	5,285,027	118,234
Chattahoochee at Columbus	22	4,670	10,064.1[d]	640,397	---	4,348,337	---
Total Stream Load (from stations 16-20)				88,011	514,080	83,405	72,211
Total Stream and River Load (from stations 16-21)				693,759	8,669,271	5,368,432	190,445

[a] Watershed area in square miles above the point of sampling.
[b] Watershed area determined by planimeter.
[c] Mean daily discharge estimated from regressions based on USGS gaged discharge of Uchee Creek.
[d] Mean daily discharge from USGS gage data.
[e] Mean daily discharge estimated from gaged discharges of Uchee and Upatoi Creeks and the Chattahoochee River at Columbus, GA.
[f] mt/yr = metric tons/yr.

contained nine monthly sampling dates. Total loading of TP, TN, TIN (kg/yr) and TSS (metric tons/yr) was estimated for the period of November 1, 1992 through October 31, 1993.

In the five tributary streams (stations 16-20) total loading of TP, TN, TIN and TSS generally increased with increasing tributary watershed area and tributary discharge; Hatchechubbee Creek yielded the lowest loading and Uchee Creek yielded the highest loading (Table 9-5). Nonpoint source loading was evidently the predominant contributor, since loading appeared to be a function of watershed area. Total loading of TP, TN, TIN and TSS from all five tributary streams and the Chattahoochee River (stations 16-21) into Lake George was 693,759 kg/yr, 8,669,271 kg/yr, 5,368,432 kg/yr and 190,445 metric tons/yr, respectively. Of these total amounts, the Chattahoochee River was the major contributor (Figure 9-9), accounting for 87.3% of the TP, 94.1% of the TN, 98.4% of the TIN and 62.1% of the TSS. The five tributary streams (stations 16-20) were significant contributors of TP (12.7%), but minor contributors of TN and especially TIN. The five tributary streams appeared to contribute a major portion of TSS loading (37.9%). These data may have erred in estimating TSS concentrations in the Chattahoochee River, since depth-integrated suspended-sediment sampling was not possible at that site (TSS samples were near-surface grabs).

Loading of total phosphorus (TP) was estimated for Lake George by Georgia Department of Natural Resources (EPD 1993b) for 1990 and 1991, which represented pre- and post phosphate detergent ban loading. Estimated TP loading declined from 861,678 kg/yr in 1990 to 612,000 kg/yr in 1991, an apparent 29% reduction in TP loading resulting from the phosphate detergent ban. Estimated TP loading in 1993 was 693,759 kg/yr, an apparent 19% reduction in TP loading relative to

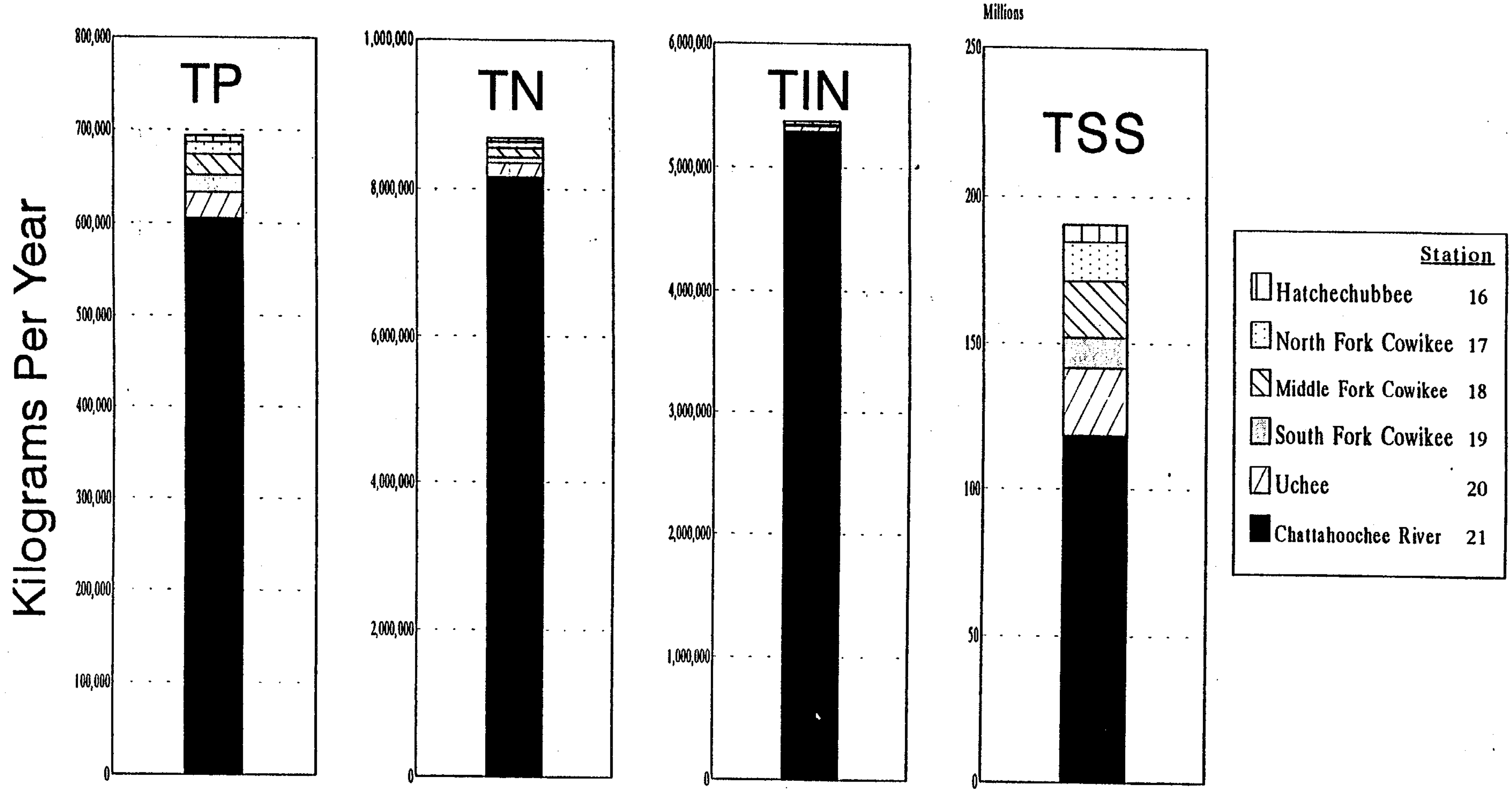


Figure 9-9. Total annual loading (point and nonpoint source) of total phosphorus (TP), total nitrogen (TN), total inorganic nitrogen (TIN) and total suspended solids (TSS) into Lake W. F. George in kg/year from stations 16-21, determined by FLUX, during the diagnostic study of Lake W. F. George, November 1992 through October 1993.

the 1990 estimate. Estimated annual discharge via the Chattahoochee River into Lake George was 8,917 $m^3 \times 10^6$ in 1990, 6,791 $m^3 \times 10^6$ in 1991 and 9,718 $m^3 \times 10^6$ in 1993. Total discharge was down by 24% in 1991 and up by 9% in 1993 relative to 1990 discharge. Therefore, if TP loading is directly correlated to total discharge of the Chattahoochee River (as implied by the FLUX-generated monthly trends of TP loading and total monthly discharge, Figure 9-7), then the actual reduction in TP loading appears to be discharge dependant. Given an annual total discharge of equal magnitude relative to that of 1990, a more accurate estimate in the reduction in TP loading would be obtained by regressing TP loading and total annual discharge of 1991 and 1993, which assumes a linear relationship between increased flow and increased discharge. Without more data points, a more accurate mathematical model cannot be determined. The linear regression is:

$$\text{TP load} = 422{,}500 + 27.9 \times \text{Total Discharge}$$

where TP is expressed in kg/yr and Total Discharge into Lake George is expressed in $m^3 \times 10^6$/yr. For an annual discharge equivalent to 1990 pre-ban level (8,917 $m^3 \times 10^6$), the predicted TP load would be 671,284 kg/yr or a decrease of 22% (190,394 kg). Of course, actual reduction of TP from year to year, appears dependant on discharge.

Total monthly loading of TP, TN, TIN and TSS was also estimated using FLUX (Figures 9-2 through 9-8). All loading estimates closely followed the magnitude of total monthly discharge. Total loading of TP, TN, TIN and TSS was therefore highest for stations 16, 17, 18 and 20 in November, highest for station 19 during March, and highest for stations 21 and 22 during December.

10.0 LAKE W.F. GEORGE LIMNOLOGY

10.1 LAKE W.F. GEORGE LIMNOLOGICAL HISTORY

The most recent study completed on Lake W.F. George was conducted by the Environmental Protection Division (EPD), Georgia Department of Natural Resources (DNR). It was a Clean Lakes, Phase I, Diagnostic/Feasibility Study that spanned a 12 month period from November 1990 through October 1991. It included an assessment of the limnological condition of the lake, measurement of fecal coliform bacteria densities, toxic contaminants in water and sediment, sediment oxygen demand and a macrophyte survey. Three Georgia tributaries to the lake were sampled to estimate sediment and nutrient loading. Results of their diagnostic study will be considered along with results of our diagnostic study prior to preparation of a single feasibility report for Lake George.

In the EPD (1993b) report, a history of Lake George water quality was discussed. Water quality information collected by Georgia DNR included Georgia trend station data, lake studies conducted in 1979 and 1989 and a lake monitoring project spanning the period, 1980 through 1990. The U.S. E.P.A. included Lake George in its National Eutrophication Survey conducted in 1973 and 1974. Generally, these studies revealed the lake to be eutrophic as a result of excess nutrient (primarily phosphorus) loading. Additionally EPD (1993b) cited a waste load allocation study conducted by the Alabama Department of Environmental Management in 1987. The study was conducted to predict the impact of planned expansion of the Mead Paper Corporation Mill at Cottonton, Alabama. The water quality model applied using the 1987 data revealed that the dissolved oxygen standard of 5.0 mg/L could not be maintained even if the Mead Mill ceased to discharge wastewater.

To better understand the fate of soluble contaminants entering Lake George, a dye (Rhodamine WT) study was conducted during August and September 1966 (Bayne 1967). Water movements in the upper reaches of the reservoir between the Fort Benning bridge at mile 141 and Florence Landing at mile 113 were distinctly riverine, moving at a rather constant rate of about 0.3 miles per hour. Bottom waters confined to the old river channel in the lacustrine zone of the lake moved downstream more slowly (0.1 mph) and on one occasion a dye cloud moved upstream along the bottom for a total distance of about 2.5 miles.

Lawrence (1968) conducted a study of Lake George from May 1965 through November 1967. During the first two growing seasons of the study he emphasized water chemistry and later investigated the fate of eleven chemical elements entering the lake. He reported thermal and chemical stratification of the lacustrine portions of the lake and frequent dissolved oxygen depletion at depths greater than 6.0 - 7.0 m. Yearly variation in strength of thermal stratification and dissolved oxygen (D.O.) concentration of hypolimnial waters was noted. Using data gathered in this study, Lawrence (1970) compared nutrient dynamics in rather open, flow-through aquatic systems (river reservoirs) with simpler more closed systems (watershed ponds). Increased hydraulic retention time resulted in more efficient utilization of available nutrients. In Lake George about 75% of the input phosphorus was deposited in bottom sediments.

A fish management plan for Lake George was prepared for the Corps of Engineers by a team of workers from Auburn University's Agricultural Experiment Station (Auburn University 1974). This report contains much general information about the lake as well as limnological conditions related to fish management. A survey of aquatic weeds was presented and problems associated with weed species and their management were discussed.

An early record of pesticide (and PCB) residues in water, sediment and fish was reported by the Alabama Pesticide Laboratory Division (1971). Edible portions of largemouth bass collected from Lake George in the vicinity of Cottonton, Alabama contained high levels of DDT (6.0 ppm) and PCB's (13.0 ppm). Other fish species (carp, shad and catfish) and bass collected at one other location in the lake had varying but generally not excessive residue levels. Other more recent toxic contaminant studies have been conducted. In 1990 the Eufaula National Wildlife Refuge examined water, sediment and fish samples for heavy metals, organochlorine pesticides (including PCB's) and aromatic hydrocarbons. Samples were collected on and around the refuge. In general, toxicant levels were low and no significant problems were identified. In 1991, as part of their Lake Assessment Project the Georgia DNR analyzed largemouth bass and channel catfish composite fillet samples for an array of metals and organic chemical compounds (EPD 1993a). At that time mean chlordane concentrations in bass (0.21 mg/kg) and catfish (0.24 mg/kg) collected at the upstream (near Oswichee Creek) site were below the FDA action level of 0.3 mg/kg. A subsequent study conducted at this location revealed chlordane concentrations in two of six channel catfish composite samples and one of six largemouth bass composite samples exceeded the 0.3 mg/kg FDA action level for chlordane. Average concentrations for all channel catfish and all largemouth bass samples were 0.24 mg/kg and 0.21 mg/kg, respectively (EPD 1993b).

The U.S. Army Corps of Engineers, Mobile District contracted Harmon Engineering and Testing of Auburn, Alabama to conduct a Water Quality Management Study of Lake George during 1978 and 1979 (Harmon Engineering 1984). The study included physico-chemical water quality data as well as biological variables such as fecal bacteria, phytoplankton, zooplankton, macroinvertebrates and aquatic macrophytes. Physical and chemical stratification occurred with low D.O. concentrations of hypolimnial waters resulting in frequent D.O. deficiencies of lake tailwaters. Concern was also expressed over continued nutrient enrichment of Lake George and the effects this would have on algal and macrophytic vegetation. Fecal coliform bacteria densities exceeded standards near some recreation areas during the summer of 1978 but not in 1979.

A history of low D.O. concentrations in Lake George tailwaters coupled with a major tailwater fish kill (about 100,000 fish) in July 1985 prompted the Corps of Engineers to initiate a study of the problem in 1986 (Findley and Day 1987). Variations in operation of generating units and floodgates were evaluated relative to changes in tailwater D.O. concentrations. Operational regimes resulting in the highest possible D.O. levels were identified.

Lake George was one of four large river impoundments studied by Auburn University limnologists and fisheries biologists in an effort to identify limnological variables which influence fish communities and sport fisheries (Bayne and Maceina 1992). The lake was sampled in January and then monthly from March through September for a 2-year period (1989-1991). Variables measured included physico-chemical water quality, phytoplankton and zooplankton. Growing season mean chlorophyll a (uncorrected) concentrations (15 μg/L) and phytoplankton primary productivity (1,361 mgC/m^2•day) indicated Lake George was moderately eutrophic with a mean Carlson Trophic State Index (based on chlorophyll a) of 57 (Carlson 1977). Sport fish production and yield was similar or superior to production in lakes of higher trophic status.

10.2 CURRENT LIMNOLOGICAL CONDITION

Lake George was sampled from May through October 1992 and from April through October 1993 (Table 10-1). Tributary streams were sampled from November 1992 through October 1993. The U.S. Army, Corps of Engineers (COE), Mobile District funded work done May through October 1992. From November 1992 through October 1993 a Phase I, Clean Lakes, Diagnostic/Feasibility Study was conducted under contract with the Alabama Department of Environmental Management (ADEM). The Phase I grant of $70,000 was matched by Auburn University with $30,000. Others providing data used in this lake assessment included ADEM, COE and the U.S. Geological Survey (USGS).

Table 10-1. Schedule of activities for the diagnostic study of Lake W.F. George, May 1992-October 1993.

Variable	Year 1992 May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	1993 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Water Quality	X	X	X	X	X	X						X	X	X	X	X	X	X
Phytoplankton	X	X	X	X	X	X						X	X	X	X	X	X	X
Chlorophyll a	X	X	X	X	X	X						X	X	X	X	X	X	X
Algal Growth Potential Test													X	X	X	X	X	
Primary Productivity													X	X	X	X	X	
Fecal Coliform		X	X	X	X	X												
Tributary Sampling							X	XX	XX	XX*	XX*	XX	XX	X	X	X	X	X
Macrophyte Survey																		X

* One additional sample during rain event.

10.2.1 LAKE WATER QUALITY

Lake and embayment sampling stations (Table 10-2 and Figure 10-1) were visited monthly May through October 1992 and April through October 1993 (Table 10-1). At each sampling station (except tailwater station 0) in situ measurements of temperature, pH, dissolved oxygen (D.O.) and specific conductance were made throughout the water column with a Hydrolab® Surveyor II (Table 10-3). Sampling was usually conducted from mid-morning to mid-afternoon. Secchi disk visibility was measured and the 1% incident light depth was determined with a submarine photometer. In the tailwater sampled during 1993 water was collected at a depth of 0.3 m near mid-channel.

Previous studies of a Chattahoochee River impoundment have revealed marked seasonal changes in water quality caused by variations in temperature, precipitation and solar radiation (Bayne *et al.* 1983 and Bayne *et al.* 1990). During the Lake George study, the 1992 growing season (May through October) was cooler (monthly mean -0.1°C) and wetter (monthly mean +1.0 cm) than normal and the 1993 season was warmer (monthly mean +1.3°C) and drier (monthly mean -3.6 cm) than normal (Table 10-4). Mean daily discharge through W.F. George Dam was 5,674 cfs during the 1992 growing season and 4,347 cfs in 1993.

Lake George is a warm monomictic reservoir that normally stratifies thermally from about June through September in the deeper lacustrine zone and especially in the area of the old river channel (Bayne 1967, Lawrence 1968 and Harmon Engineering 1984). During the growing seasons of 1992 and 1993 classical thermoclines ($\Delta T \geq 1.0$°C per meter depth) were rarely encountered (Figures 10-2 and 10-3). Water column temperature gradients in deeper areas of the lake seldom exceeded 7.0 to 8.0°C and frequently were 5.0°C or less. The strongest thermal

Table 10-2. Sampling station number (Georgia DNR number and Auburn University number), description and sample type collected during the diagnostic study of Lake W.F. George, 1992-1993.

Station Number DNR No.	Auburn No.	Station Description	Sample/Analysis* 1992	1993
Mainstem				
CR2	0	Chattahoochee River downstream W.F. George Lock and Dam, mile 75.0	---	WQ
LG7	1	Dam Forebay, mile 75.4	WQ,Phy,Chl,FC	WQ,Phy,Chl,PP,AGP
LG6	2	Off mouth of Pataula Creek, mile 82.3	WQ,Phy,Chl,FC	WQ,Phy,Chl,PP,AGP
LG5	3	Off mouth of Cheneyhatchee Creek, mile 89.5	WQ,Phy,Chl,FC	WQ,Phy,Chl
LG4	4	At U.S. Highway 82, mile 94.9	WQ,Phy,Chl,FC	WQ,Phy,Chl,PP,AGP
LG3	5	Off mouth of Cowikee Creek, mile 101.7	WQ,Phy,Chl,FC	WQ,Phy,Chl
LG2	6	Off Florence Marina, mile 112.7	WQ,Phy,Chl,FC	WQ,Phy,Chl,PP,AGP
LG1	7	Downstream Omaha RR, mile 117.3	WQ,Phy,Chl,FC	WQ,Phy,Chl
CR1	8	Bluff Creek park, mile 120.3	WQ,Phy,Chl,FC	WQ,Phy,Chl,AGP
Embayments				
---	9	Hatchechubee	---	WQ,Phy,Chl
---	10	Cowikee	---	WQ,Phy,Chl
---	11	Chewalla	---	WQ,Phy,Chl
---	12	Barbour	---	WQ,Phy,Chl
---	13	Cheneyhatchee	---	WQ,Phy,Chl
---	14	White Oak	---	WQ,Phy,Chl
---	15	Thomas Mill	---	WQ,Phy,Chl
Tributary				
---	16	Hatchechubee	---	WQ,Flw
---	17	Cowikee (N. Fork)	---	WQ,Flw
---	18	Cowikee (Middle Fork)	---	WQ,Flw
---	19	Cowikee (S. Fork)	---	WQ
---	20	Uchee	---	WQ
---	21	Chattahoochee (Fort Benning bridge)	---	WQ

* WQ = water quality, Phy = phytoplankton, Chl = chlorophyll a, PP = primary productivity, AGP = algal growth potential test, Flw = stream flow and FC = fecal coliform.

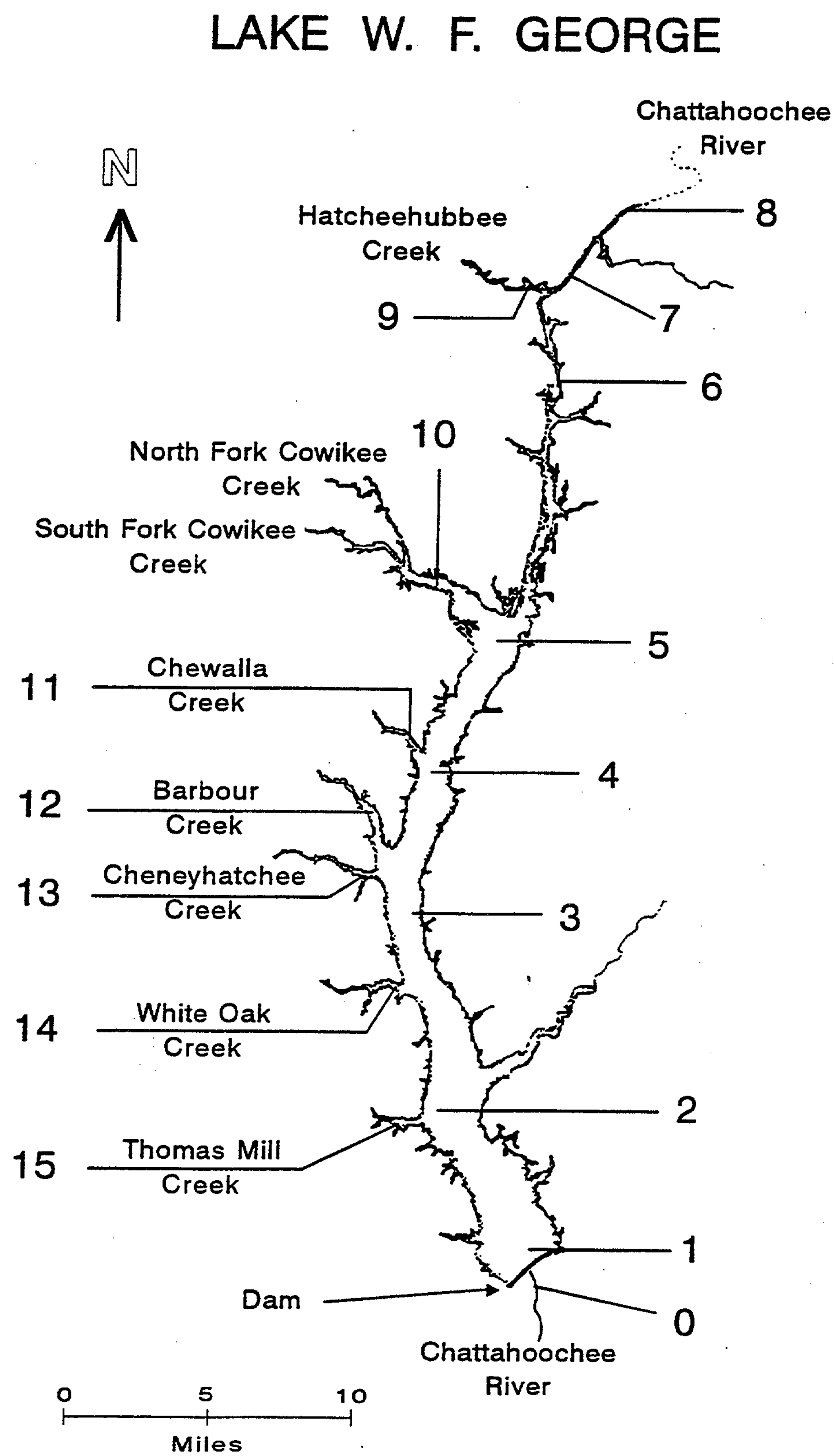


Figure 10-1. Location of main stem sampling stations (stations 0-8) and embayment sampling stations (stations 9-15) during the diagnostic study of Lake W. F. George, April 1992 through October 1993.

Table 10-3. Analytical methods used in measuring water quality during the diagnostic study of Lake W.F. George, 1992-1993.

Variable	Method	Reference
In Situ		
Temperature	thermistor	APHA, 1992
Dissolved oxygen	membrane electrode	APHA, 1992
pH	glass electrode	APHA, 1992
Specific conductance	conductivity cell	APHA, 1992
Visibility	Secchi disk	Lind, 1985
Euphotic zone determination	submarine photometer	Lind, 1985
Laboratory Analyses		
Total suspended solids	vacuum filtration	APHA, 1992
Turbidity	HACH turbidimeter	APHA, 1992
Alkalinity	potentiometric titration	APHA, 1992
Total ammonia (NH_3-N)	phenate method	APHA, 1992
Nitrite (NO_2-N)	diazotizing method	APHA, 1992
Nitrate (NO_3-N)	cadmium reduction	APHA, 1992
Total phosphorus	persulfate digestion, ascorbic acid	APHA, 1992
Organic nitrogen	macro Kjeldahl	APHA, 1992
Soluble reactive phosphorus	ascorbic acid	APHA, 1992
Hardness	EDTA titrimetric	Boyd, 1979

Table 10-4. Meteorological conditions and river and lake discharge measured during the 18 month study of Lake W.F. George, 1992-1993.

Year	Month	Temp[1] (°C)	DFN[2] (°C)	Rainfall[3] (cm)	DFN[2] (cm)	Mean Daily Solar Radiation[4] (Langleys)	Columbus Mean Daily Discharge[5] (CFS)	W.F. George Dam Mean Daily Discharge (CFS)
1992	MAY	21.8	-0.39	2.0	-9.3	552	4264	5909
	JUN	25.7	-0.17	6.9	-3.7	514	4126	4149
	JUL	28.2	+0.95	21.2	+7.2	518	5975	5568
	AUG	26.1	-0.95	23.2	+13.0	467	5854	5210
	SEP	24.6	+0.22	7.1	-2.0	397	5951	7248
	OCT	18.2	-0.22	6.2	+1.0	358	6285	5958
	NOV	13.7	+1.0	29.5	+21.8	236	16250	19273
	DEC	9.9	+0.9	10.3	-1.8	185	19050	22843
1993	JAN	11.2	+3.4	10.5	-1.0	192	17300	19602
	FEB	9.4	+0.1	8.8	-2.6	293	13040	14149
	MAR	12.3	-1.0	20.3	+5.2	382	13950	20343
	APR	16.4	-1.8	5.5	-5.9	529	10210	13694
	MAY	22.1	-0.1	5.1	-6.2	540	7977	9723
	JUN	27.5	+1.7	1.8	-8.8	586	5726	5281
	JUL	29.9	+2.6	8.7	-5.2	599	4806	4920
	AUG	28.1	+1.1	11.0	+0.8	503	4862	5824
	SEP	26.1	+1.7	2.5	-6.7	461	3656	4344
	OCT	19.4	+1.0	9.4	+4.2	329	4087	4738

[1] Air temperature measured at Columbus, GA.
[2] DFN = deviation from normal.
[3] Columbus, GA airport.
[4] Auburn, AL.
[5] Chattahoochee River at Columbus, GA.

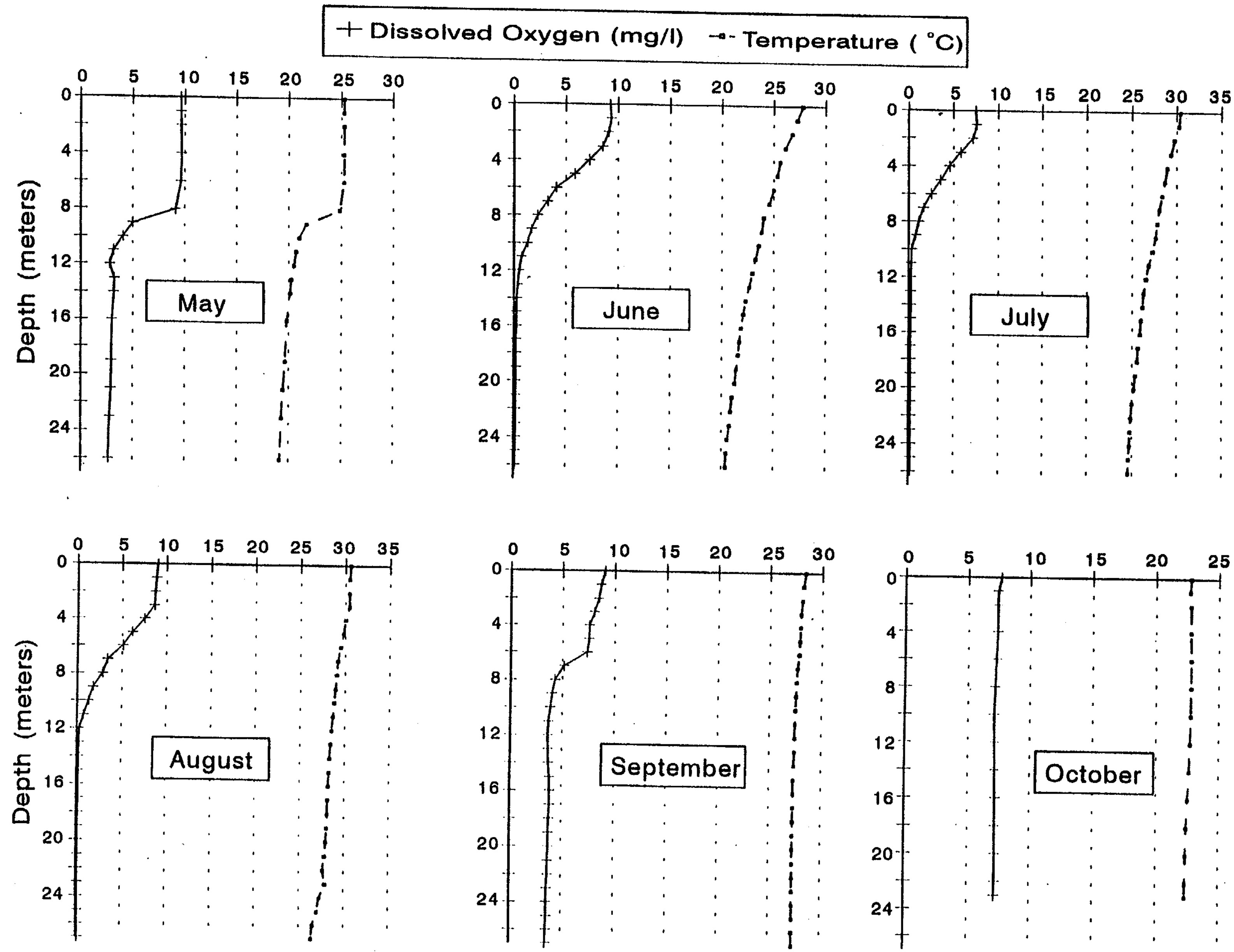


Figure 10-2. Dissolved oxygen (mg/l) and temperature (°C) profiles at station 1 (dam forebay) on Lake W. F. George May through October, 1992.

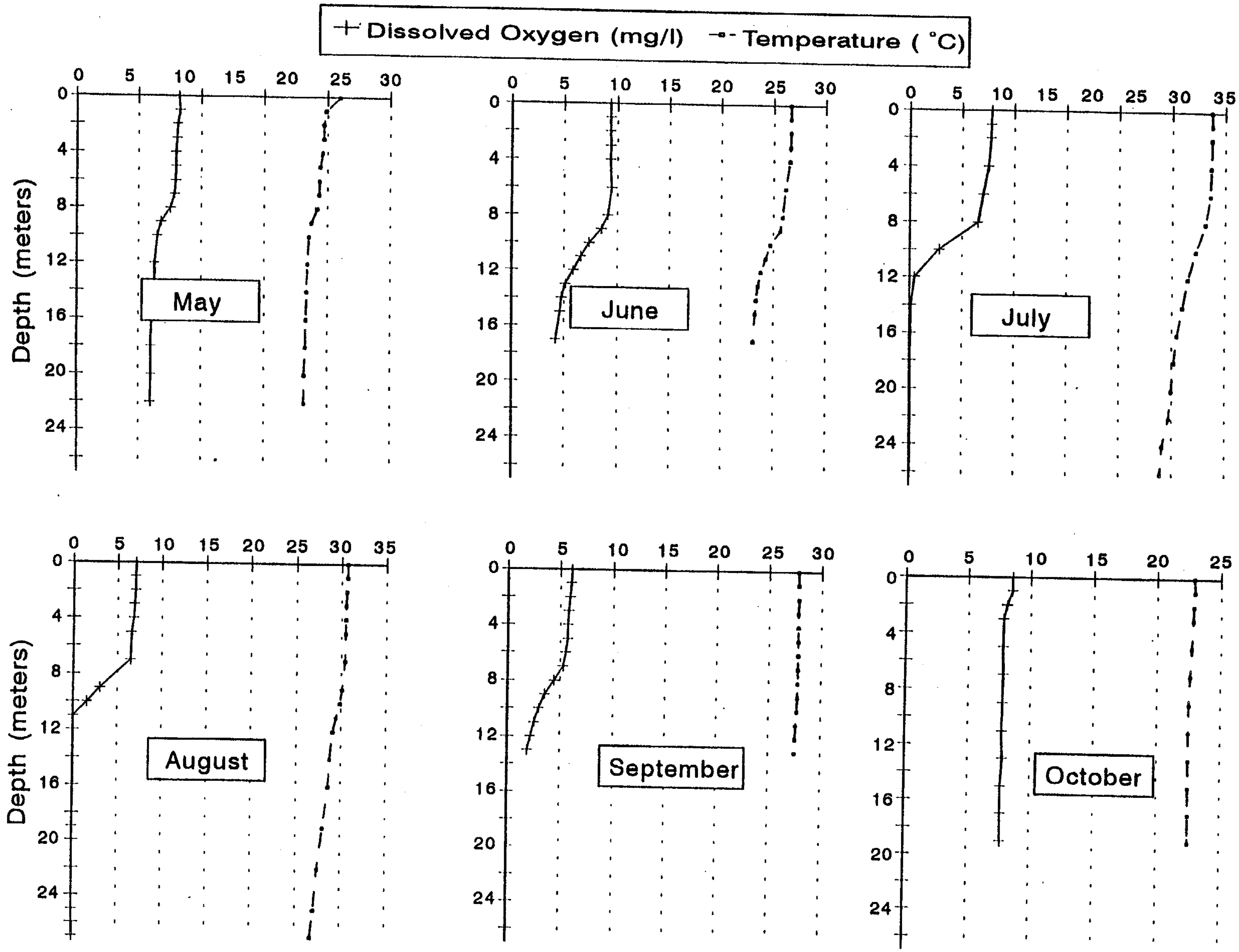


Figure 10-3. Dissolved oxygen (mg/l) and temperature (°C) profiles at station 1 (dam forebay) on Lake W. F. George May through October, 1992.

stratification measured in Lake George occurred in May 1992 but disappeared by the June 1992 sample (Figure 10-2).

Chemical stratification as evidenced by declining dissolved oxygen (D.O.) concentrations throughout the water column were pronounced especially in the lacustrine (stations 1,2,3,4 and 5) areas of the lake during the warmer months (Figures 10-2 and 10-3). D.O. concentrations frequently fell below 1.0 mg/L at or near the 8.0 m depth and continued to decline, sometimes to near 0.0 mg/L, at the bottom. Further upstream in the transition zone (stations 6 and 7) chemical stratification was less obvious although D.O. concentrations did decline with depth. D.O. levels in the deeper waters of the transition zone never declined below 2.0 mg/L and were usually > 4.0 mg/L.

Thermal and chemical stratification of tributary embayments was similar to the mainstem of the reservoir, however; the embayments were shallower than most of the mainstem stations. The lowest surface D.O. concentrations were measured in Hatchechubbee Creek (3.76 mg/L) and Cowikee Creek (4.38 mg/L) embayments in August 1993. The lowest mainstem D.O. concentration measured at the surface was at station 2 (4.81 mg/L) in August 1993.

Water temperature measured at the 2 m depth ranged from a low of 13.8°C in April 1993 to a high of 30.7°C in July 1992 (Table 10-5). D.O. concentrations measured at the 2 m depth varied from a low of 3.3 mg/L in Hatchechubbee Creek in August 1993 to a high of 10.6 mg/L in Thomas Mill Creek in April 1993 (Table 10-6). D.O. concentrations varied inversely with water temperature resulting in highest mean D.O. levels in April and May and lowest levels in August 1993.

Specific conductance, a measure of the ionic content of water, ranged from a low of 51.2 μmhos/cm to a high of 115.2 μmhos/cm at mainstem sampling stations and from 26.0 μmhos/cm to 134.8 μmhos/cm in the tributary embayments (Table 10-7).

Table 10-5. Mean (range) water temperature (°C) measured at a depth of 2 m at fifteen sampling stations on Lake W.F. George during the growing seasons of 1992 and 1993.

Stations	April-May		June-August		Sept-October		Growing Season[2]	
	1992[1]	1993	1992	1993	1992	1993	1992	1993
Mainstem								
0	---	---	---	---	---	---	---	---
1	25.3	17.5 (15.3-19.7)	29.0 (26.8-30.4)	28.6 (26.7-30.6)	25.4 (22.8-28.1)	25.3 (22.9-27.8)	27.2 (22.8-30.4)	24.5 (15.3-30.6)
2	25.2	18.1 (16.0-20.2)	28.9 (26.4-30.2)	28.5 (26.0-30.1)	25.2 (22.2-28.1)	25.7 (22.9-28.5)	27.0 (22.2-30.2)	24.7 (16.0-30.1)
3	24.2	---	29.4 (27.8-30.7)	---	25.2 (22.0-28.5)	---	27.1 (22.0-30.7)	---
4	25.5	17.9 (15.2-20.6)	29.1 (26.6-30.4)	28.6 (26.6-30.6)	25.0 (21.6-28.5)	25.5 (22.7-28.3)	27.1 (21.6-30.4)	24.6 (15.2-30.6)
5	24.2	---	29.0 (26.9-30.0)	---	24.7 (21.7-27.7)	---	26.8 (21.7-30.0)	---
6	24.1	16.7 (13.8-19.7)	28.6 (26.4-29.9)	27.6 (24.4-30.3)	24.6 (22.0-27.2)	25.6 (23.1-28.1)	26.5 (22.0-29.8)	23.9 (13.8-30.3)
7	24.8	---	28.7 (26.5-29.9)	---	24.4 (21.9-26.9)	---	26.6 (21.9-29.9)	---
8	24.3	16.7 (13.8-19.6)	28.4 (26.2-29.7)	27.3 (24.3-30.0)	24.4 (21.9-27.0)	25.3 (23.1-27.6)	26.4 (21.9-29.7)	23.7 (13.8-30.0)
Embayment								
9	---	17.6 (14.9-20.2)	---	27.7 (24.5-30.1)	---	25.3 (22.5-28.1)	---	24.1 (14.9-30.1)
10	---	18.7 (16.1-21.4)	---	28.7 (27.4-29.9)	---	25.2 (22.3-28.1)	---	24.9 (16.1-29.9)
11	---	18.2 (15.5-20.9)	---	28.6 (26.7-30.4)	---	25.7 (22.8-28.7)	---	24.8 (15.5-30.4)
12	---	18.7 (15.9-21.5)	---	27.9 (25.3-29.7)	---	25.9 (22.7-29.0)	---	24.7 (15.9-29.7)
13	---	18.1 (15.4-20.9)	---	29.2 (27.9-29.9)	---	25.7 (22.8-28.7)	---	25.0 (15.4-29.9)
14	---	18.3 (15.8-20.7)	---	28.7 (26.8-30.3)	---	25.6 (23.1-28.1)	---	24.8 (15.8-30.3)
15	---	18.7 (16.6-20.8)	---	28.5 (26.8-30.3)	---	26.0 (23.0-29.1)	---	25.0 (16.6-30.3)

[1] Data for May 1992.
[2] Includes data from May through October, yearly.

Table 10-6. Mean (range) dissolved oxygen concentration (mg/L) measured at a depth of 2 m at fifteen sampling stations on Lake W.F. George during the growing seasons of 1992 and 1993.

Stations	April-May		June-August		Sept-October		Growing Season[2]	
	1992[1]	1993	1992	1993	1992	1993	1992	1993
Mainstem								
0	---	---	---	---	---	---	---	---
1	9.7	8.7 (8.1-9.3)	8.3 (7.2-9.1)	8.0 (7.0-9.3)	7.9 (7.4-8.5)	7.0 (5.9-8.1)	8.4 (7.2-9.7)	7.9 (5.9-9.3)
2	8.9	8.7 (8.3-9.1)	8.4 (7.8-8.9)	7.6 (4.5-9.7)	7.9 (7.3-8.4)	7.6 (7.2-8.0)	8.3 (7.3-8.9)	7.9 (4.5-9.7)
3	8.7	---	7.7 (6.4-9.2)	---	8.2 (7.3-9.1)	---	8.1 (6.4-9.2)	---
4	9.1	8.5 (8.2-8.8)	7.8 (6.5-8.6)	7.0 (5.5-9.0)	8.8 (7.4-10.2)	6.8 (6.6-7.1)	8.3 (6.5-10.2)	7.4 (5.5-9.0)
5	8.4	---	7.5 (7.3-7.7)	---	7.6 (7.1-8.0)	---	7.7 (7.1-8.4)	---
6	8.1	9.0 (8.2-9.9)	7.3 (7.0-7.5)	7.0 (5.6-8.3)	7.0 (6.7-7.4)	6.5 (6.4-6.7)	7.3 (6.7-8.1)	7.5 (5.6-9.9)
7	9.3	---	7.9 (7.2-8.4)	---	6.9 (6.9-6.9)	---	7.8 (6.9-9.3)	---
8	7.4	9.2 (8.4-10.0)	7.9 (7.5-8.0)	7.4 (6.5-8.4)	7.2 (7.1-7.4)	7.3 (7.1-7.6)	7.6 (7.1-8.0)	7.9 (6.5-10.0)
Embayment								
9	---	7.6 (7.5-7.7)	---	6.0 (3.3-8.0)	---	7.2 (6.6-7.8)	---	6.8 (3.3-8.0)
10	---	7.1 (6.8-7.4)	---	6.4 (3.9-8.1)	---	7.2 (6.9-7.5)	---	6.9 (3.9-8.1)
11	---	8.2 (8.0-8.4)	---	7.5 (6.3-8.9)	---	7.7 (7.5-8.0)	---	7.7 (6.3-8.9)
12	---	8.2 (7.5-8.9)	---	6.5 (4.6-8.0)	---	8.3 (7.8-8.7)	---	7.5 (4.6-8.9)
13	---	8.3 (8.2-8.3)	---	6.1 (2.0-8.7)	---	8.3 (7.8-8.9)	---	7.3 (2.0-8.9)
14	---	8.9 (8.8-8.9)	---	7.8 (5.7-9.3)	---	7.4 (7.0-7.7)	---	8.0 (5.7-9.3)
15	---	9.4 (8.3-10.6)	---	7.4 (5.7-9.2)	---	8.4 (8.0-8.7)	---	8.2 (5.7-10.6)

[1] Data for May 1992.
[2] Includes data from May through October, yearly.

Table 10-7. Mean (range) specific conductance (μ mhos/cm) measured throughout the water column at fifteen sampling stations on Lake W.F. George during the growing seasons of 1992 and 1993.

Stations	April-May 1992[1]	April-May 1993	June-August 1992	June-August 1993	Sept-October 1992	Sept-October 1993	Growing Season[2] 1992	Growing Season[2] 1993
Mainstem								
0	---	61.1 (58.8-63.4)	---	79.0 (69.2-88.2)	---	99.2 (96.2-102.2)	---	79.7 (58.8-102.2)
1	79.1 (77.8-80.4)	60.7 (58.0-63.8)	89.4 (79.2-109.4)	79.9 (68.8-104.2)	86.7 (82.8-89.4)	95.0 (93.6-98.0)	87.3 (77.8-109.4)	78.1 (58.0-104.2)
2	79.3 (77.2-81.8)	62.7 (57.8-68.2)	91.0 (81.4-110.0)	80.4 (70.8-101.8)	87.1 (82.0-91.4)	95.8 (86.0-99.2)	88.2 (77.2-110.0)	79.6 (57.8-101.8)
3	81.8 (80.8-85.4)	---	92.0 (76.4-104.0)	---	88.7 (86.2-92.8)	---	89.5 (76.4-104.0)	---
4	83.4 (82.0-84.2)	61.0 (51.2-75.2)	93.6 (86.6-102.4)	85.9 (77.2-99.6)	86.3 (80.4-94.8)	106.9 (103.8-109.4)	89.1 (80.4-102.4)	84.3 (51.2-109.4)
5	92.0 (89.0-98.6)	---	92.8 (88.4-101.0)	---	86.2 (75.0-91.4)	---	89.9 (75.0-101.0)	---
6	119.6 (92.8-173.2)	66.4 (58.2-75.4)	100.1 (94.0-112.4)	86.2 (74.2-101.4)	85.6 (72.2-97.2)	113.9 (112.8-115.2)	97.1 (72.2-173.2)	88.1 (58.2-115.2)
7	128.9 (83.2-207.0)	---	104.5 (82.2-164.4)	---	85.9 (74.0-128.2)	---	100.7 (74.0-207.0)	---
8	82.6 (81.6-85.2)	60.1 (54.2-68.6)	85.9 (79.8-89.4)	78.2 (73.4-82.6)	81.1 (73.6-85.8)	98.3 (93.2-104.8)	83.5 (73.6-89.4)	77.7 (54.2-104.8)
Embayment								
9	---	81.0 (66.0-109.2)	---	89.3 (79.6-96.8)	---	105.4 (96.4-111.4)	---	91.1 (66.0-111.4)
10	---	68.6 (51.0-92.6)	---	89.9 (82.8-106.0)	---	107.2 (104.4-114.2)	---	86.9 (51.0-114.2)
11	---	63.3 (52.4-71.2)	---	84.4 (77.4-90.2)	---	104.9 (101.2-107.4)	---	85.1 (52.4-107.4)
12	---	58.7 (48.2-66.0)	---	85.5 (74.0-112.4)	---	102.3 (98.2-105.2)	---	84.4 (48.2-112.4)
13	---	43.7 (26.0-61.2)	---	70.9 (42.4-84.8)	---	97.0 (80.4-101.4)	---	69.3 (26.0-101.4)
14	---	67.3 (58.4-95.4)	---	89.5 (73.4-117.2)	---	101.9 (96.6-105.0)	---	86.0 (58.4-117.2)
15	---	76.3 (65.8-121.4)	---	99.1 (79.8-128.2)	---	108.9 (97.8-134.8)	---	96.7 (65.8-134.8)

[1] Data for May 1992.
[2] Includes data from May through October, yearly.

Specific conductance is a crude indicator of natural fertility since increases in ionic content are usually accompanied by increases of plant nutrients. Mainstream Alabama reservoirs were found to have specific conductance values ranging from 27 μmhos/cm to 200 μmhos/cm (Bayne *et al.* 1989). Lake George would rank in the lower half of this Alabama range indicating only moderate natural fertility. Conductance was usually relatively low at the upstream most station 8 (Bluff Creek Park) and highest just downstream at station 7 (Omaha Georgia railroad bridge) the nearest station downstream of the effluent from the Mead Corporation Paper Mill near Cottonton, Alabama. From station 7, mean specific conductance declined progressively downstream to the dam (Figure 10-4).

Secchi disk visibility and photic zone depth (1% of incident surface light) varied seasonally and along the longitudinal gradient within seasons (Tables 10-8 and 10-9). Upstream stations 6, 7 and 8 usually had the lowest Secchi visibility and shallowest photic zones caused primarily by higher abiogenic turbidity at these locations. Visibility and light penetration were usually highest each season at downstream stations 1, 2 and 3. Light penetration in the lacustrine zone is influenced more by biogenic (phytoplankton) turbidity than by abiogenic turbidity. Mid-reservoir zone stations 4 and 5 were influenced by both biogenic and abiogenic turbidity depending on seasonal conditions and water flow. As the relatively fertile waters of the Chattahoochee River reach the more lentic transition zone of the lake, abiogenic turbidity declines (particles settle) and as light penetration increases biogenic turbidity (phytoplankton) increases in response to more favorable light conditions. Light penetration in the transition zone is controlled by the interaction of biotic and abiotic variables. Mean Secchi visibility and photic zone depth were highest at embayment stations 15 (Thomas Mill Creek) and 14 (White Oak Creek). These tributaries were located

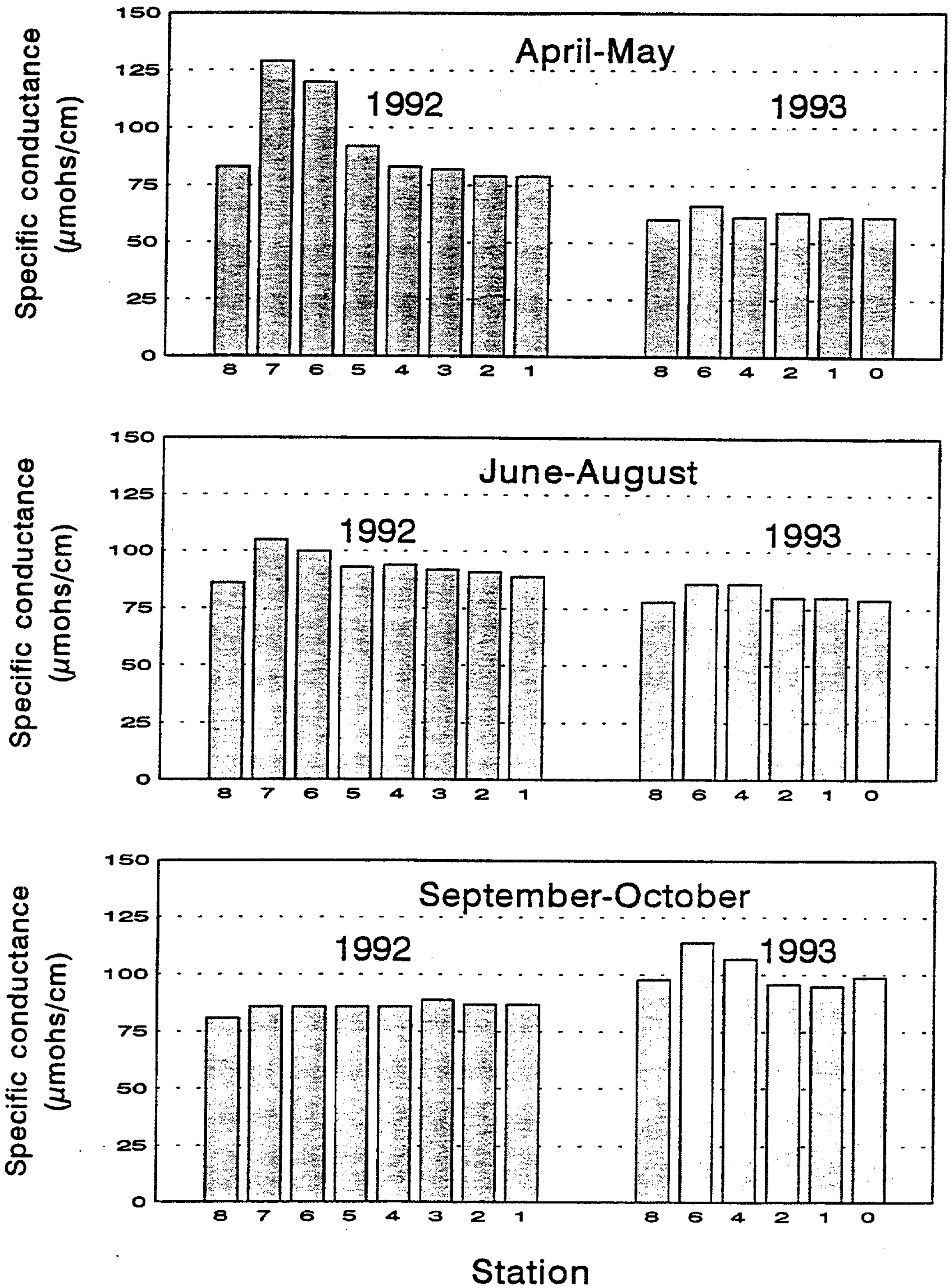


Figure 10-4. Mean specific conductance of the entire water column at main stem sampling stations (headwaters at station 8 and dam at station 1) during the diagnostic study of Lake W. F. George, April 1992 through October 1993. In 1992 no April sample was taken.

Table 10-8. Mean (range) Secchi disk visibility (cm) measured at fifteen sampling stations on Lake W.F. George during the growing seasons of 1992 and 1993.

Stations	April-May		June-August		Sept-October		Growing Season[2]	
	1992[1]	1993	1992	1993	1992	1993	1992	1993
Mainstem								
0	---	---	---	---	---	---	---	---
1	238.0	101.0 (96.0-106.0)	183.0 (176.0-196.0)	192.0 (170.0-221.0)	155.5 (147.0-164.0)	145.0	183.0 (147.0-238.0)	160.3 (96.0-221.0)
2	222.0	72.5 (64.0-81.0)	174.7 (157.0-198.0)	183.7 (159.0-206.0)	138.0 (131.0-145.0)	146.5 (138.0-155.0)	170.3 (131.0-222.0)	154.2 (81.0-206.0)
3	157.0	---	165.0 (159.0-170.0)	---	150.0 (146.0-154.0)	---	158.7 (146.0-170.0)	---
4	128.0	85.5 (49.0-122.0)	120.0 (106.0-133.0)	145.0 (131.0-154.0)	130.0 (117.0-143.0)	150.5 (120.0-181.0)	124.7 (106.0-143.0)	143.0 (120.0-181.0)
5	115.0	---	102.3 (88.0-116.0)	---	116.0 (108.0-124.0)	---	109.0 (88.0-124.0)	---
6	112.0	83.5 (71.0-96.0)	98.0 (78.0-116.0)	117.7 (110.0-128.0)	78.5 (69.0-88.0)	107.0 (97.0-117.0)	93.8 (69.0-116.0)	110.5 (96.0-128.0)
7	103.0	---	104.7 (95.0-113.0)	---	74.0 (64.0-84.0)	---	94.2 (64.0-113.0)	---
8	88.0	91.0 (80.0-102.0)	105.7 (84.0-125.0)	146.7 (128.0-159.0)	79.0 (76.0-82.0)	123.5 (113.0-134.0)	93.8 (76.0-125.0)	131.5 (102.0-159.0)
Embayment								
9	---	76.5 (46.0-107.0)	---	121.0 (105.0-136.0)	---	110.0 (97.0-123.0)	---	115.0 (97.0-136.0)
10	---	61.0 (41.0-81.0)	---	122.0 (104.0-135.0)	---	103.5 (93.0-114.0)	---	109.0 (81.0-135.0)
11	---	71.5 (43.0-100.0)	---	139.3 (133.0-150.0)	---	123.5 (94.0-153.0)	---	127.5 (94.0-153.0)
12	---	47.0 (21.0-73.0)	---	124.3 (106.0-149.0)	---	101.0 (94.0-108.0)	---	108.0 (73.0-149.0)
13	---	73.0	---	119.0 (109.0-134.0)	---	108.0 (93.0-123.0)	---	107.7 (73.0-134.0)
14	---	86.5 (60.0-113.0)	---	155.0 (150.0-162.0)	---	109.0 (101.0-117.0)	---	132.7 (101.0-162.0)
15	---	76.0 (63.0-89.0)	---	152.7 (130.0-171.0)	---	128.0	---	133.8 (89.0-171.0)

[1] Data for May 1992.
[2] Includes data from May through October, yearly.

Table 10-9. Mean (range) photic zone depth (cm) measured with a submarine photometer at fifteen sampling stations on Lake W.F. George during the growing seasons of 1992 and 1993.

Stations	April-May		June-August		Sept-October		Growing Season[2]	
	1992[1]	1993	1992	1993	1992	1993	1992	1993
Mainstem								
0	---	---	---	---	---	---	---	---
1	638.0	290.0 (285.0-295.0)	520.3 (486.0-538.0)	609.3 (532.0-694.0)	469.5 (359.0-580.0)	450.5 (397.0-504.0)	523.0 (359.0-638.0)	504.0 (295.0-694.0)
2	615.0	227.5 (199.0-256.0)	458.0 (439.0-475.0)	560.3 (559.0-561.0)	366.5 (288.0-445.0)	386.5 (380.0-393.0)	453.7 (288.0-615.0)	451.7 (256.0-561.0)
3	509.0	---	426.7 (422.0-434.0)	---	388.0 (329.0-447.0)	---	427.5 (329.0-509.0)	---
4	357.0	236.0 (157.0-315.0)	346.7 (302.0-376.0)	373.7 (332.0-441.0)	369.5 (325.0-414.0)	355.5 (310.0-401.0)	356.0 (302.0-414.0)	357.8 (310.0-441.0)
5	315.0	---	293.3 (271.0-326.0)	---	341.0 (317.0-365.0)	---	312.8 (271.0-365.0)	---
6	447.0	213.0 (184.0-242.0)	289.3 (236.0-341.0)	280.0 (233.0-307.0)	228.5 (207.0-250.0)	243.0 (239.0-247.0)	295.3 (207.0-447.0)	261.3 (233.0-307.0)
7	454.0	---	294.3 (262.0-317.0)	---	242.0 (209.0-275.0)	---	303.5 (209.0-454.0)	---
8	450.0	242.0 (217.0-267.0)	307.0 (264.0-336.0)	339.0 (298.0-364.0)	252.5 (232.0-273.0)	266.0 (248.0-284.0)	312.7 (232.0-450.0)	302.7 (248.0-364.0)
Embayments								
9	---	170.0 (100.0-240.0)	---	295.3 (281.0-320.0)	---	255.0 (253.0-257.0)	---	272.7 (240.0-320.0)
10	---	132.5 (90.0-175.0)	---	272.7 (220.0-301.0)	---	258.0 (235.0-281.0)	---	251.5 (175.0-301.0)
11	---	195.5 (124.0-267.0)	---	352.7 (328.0-382.0)	---	348.0 (271.0-425.0)	---	336.8 (267.0-425.0)
12	---	143 (59.0-227.0)	---	356.7 (323.0-375.0)	---	298.0 (281.0-315.0)	---	315.5 (227.0-375.0)
13	---	165.5 (100.0-231.0)	---	323.7 (216.0-380.0)	---	310.5 (274.0-347.0)	---	303.8 (216.0-380.0)
14	---	245.5 (188.0-303.0)	---	407.0 (363.0-447.0)	---	327.5 (309.0-346.0)	---	363.2 (303.0-447.0)
15	---	217.5 (174.0-261.0)	---	489.7 (432.0-557.0)	---	402.0 (373.0-431.0)	---	422.3 (261.0-557.0)

[1] Data for May 1992.
[2] Includes data from May through October, yearly.

nearest the dam. The tributaries located further upstream had variable but usually lower Secchi visibility and light penetration depths compared to stations 14 and 15.

A composite water sample was collected from the photic zone of the water column at each sampling station (Figure 10-1) for additional water quality analyses. In order to maintain consistency with previous studies on Lake George (Bayne and Maceina 1992) the photic zone depth was defined as four times the Secchi disk visibility (Taylor 1971). This depth usually exceeded the 1% incident light depth. A submersible electric pump and hose apparatus was raised and lowered throughout the photic zone and the water was collected in a plastic container on-board boat. Aliquots from this composite sample were poured into Nalgene containers and stored on ice in coolers prior to transport to laboratory facilities at Auburn University. Samples to be held for later analysis (total phosphorus and Kjeldahl nitrogen) were preserved in the field (APHA *et al.* 1992). All analyses were conducted within the recommended holding times (APHA *et al.* 1992). Monthly samples were collected during the two growing seasons (Table 10-1). Water quality variables measured and methods used appear in Table 10-3.

Turbidity, an indirect measure of suspended particles, and total suspended solids (TSS), a gravimetric measure of suspended particles, both illustrate the effects of longitudinal changes in water quality expected from headwaters downstream to the dam (Tables 10-10 and 10-11). Concentrations of suspended particles were usually highest at upstream stations 6, 7 and 8 and lowest in the lacustrine zone (stations 1, 2, 3, 4 and 5). Rainfall and runoff influenced suspended particle concentrations during the two growing seasons (Table 10-4). Downstream embayments (stations 13, 14 and 15) had lower concentrations of

Table 10-10. Mean (range) turbidity (NTU) measured in photic zone composite samples collected at fifteen sampling stations on Lake W.F. George during the growing seasons of 1992 and 1993.

Stations	April-May		June-August		Sept-October		Growing Season[2]	
	1992[1]	1993	1992	1993	1992	1993	1992	1993
Mainstem								
0	---	13.1 (11.0-15.2)	---	3.7 (2.0-5.1)	---	4.2 (4.1-4.3)	---	5.8 (2.0-15.2)
1	2.5	10.9 (10.8-11.0)	2.8 (2.5-3.2)	3.6 (2.6-4.7)	3.8 (2.4-5.1)	3.9 (3.3-4.5)	3.1 (2.4-5.1)	4.9 (2.6-10.8)
2	3.0	16.6 (12.2-21.0)	3.8 (3.2-4.3)	3.3 (2.7-4.0)	4.7 (3.5-5.8)	4.5 (4.1-4.8)	4.0 (3.0-5.8)	5.2 (2.7-12.2)
3	5.1	---	4.6 (3.7-5.1)	---	4.5 (3.2-5.8)	---	4.7 (3.2-5.8)	---
4	5.2	22.1 (9.1-35.0)	7.1 (5.3-8.9)	6.9 (5.2-9.8)	6.1 (4.5-7.7)	9.0 (7.4-10.5)	6.5 (4.5-8.9)	7.9 (5.2-10.5)
5	7.1	---	7.4 (5.8-8.9)	---	7.2 (4.9-9.5)	---	7.3 (4.9-9.5)	---
6	8.8	18.6 (15.2-22.0)	8.9 (6.8-10.9)	11.1 (9.3-14.4)	14.3 (12.4-16.3)	8.5 (5.7-11.2)	10.7 (6.8-16.3)	10.9 (5.7-15.2)
7	8.1	---	8.3 (7.6-8.6)	---	14.1 (12.2-15.9)	---	10.2 (7.6-15.9)	---
8	10.7	15.9 (11.7-20.0)	8.9 (7.0-10.4)	7.6 (7.0-8.6)	12.4 (12.3-12.5)	7.4 (5.2-9.6)	10.4 (7.0-12.5)	8.2 (5.2-11.7)
Embayment								
9	---	23.0 (10.9-35.0)	---	8.2 (7.2-9.5)	---	8.5 (7.2-9.8)	---	8.8 (7.2-10.9)
10	---	31.3 (15.5-47.0)	---	8.9 (6.4-11.7)	---	9.4 (8.2-10.5)	---	10.1 (6.4-15.5)
11	---	28.1 (11.1-45.0)	---	7.3 (6.9-8.1)	---	7.4 (4.7-10.1)	---	8.0 (4.7-11.1)
12	---	50.0 (15.0-85.0)	---	5.6 (5.0-6.1)	---	7.0 (6.6-7.4)	---	7.6 (5.0-15.0)
13	---	34.6 (17.1-52.0)	---	6.7 (5.7-8.4)	---	7.0 (6.6-7.4)	---	8.5 (5.7-17.1)
14	---	16.7 (10.4-23.0)	---	5.7 (4.6-6.7)	---	6.1 (5.0-7.1)	---	6.6 (4.6-10.4)
15	---	16.0 (13.9-18.0)	---	5.2 (4.9-5.5)	---	5.5 (5.2-5.7)	---	6.8 (4.9-13.9)

[1] Data for May 1992.
[2] Includes data from May through October, yearly.

Table 10-11. Mean (range) total suspended solids concentrations (mg/L) measured at fifteen sampling stations on Lake W.F. George during the growing seasons of 1992 and 1993.

Stations	April-May		June-August		Sept-October		Growing Season[2]	
	1992[1]	1993	1992	1993	1992	1993	1992	1993
Mainstem								
0	---	8.3 (7.7-9.0)	---	4.7 (4.1-5.2)	---	6.0 (4.6-7.3)	---	5.6 (4.1-7.7)
1	2.0	6.0 (5.0-7.0)	3.2 (3.1-3.2)	3.5 (2.6-4.1)	4.3 (3.0-5.6)	7.0 (6.3-7.7)	3.3 (2.0-5.6)	4.9 (2.6-7.7)
2	2.7	7.7 (7.6-7.8)	4.3 (3.9-5.0)	4.3 (3.6-4.8)	5.1 (4.0-6.1)	9.5 (5.6-13.3)	4.3 (2.7-6.1)	6.6 (3.6-13.3)
3	3.9	---	4.4 (3.7-4.9)	---	4.6 (3.3-5.9)	---	4.4 (3.3-5.9)	---
4	4.6	16.5 (7.0-26.0)	7.0 (5.6-8.0)	7.6 (6.6-8.8)	6.3 (4.6-8.0)	7.5 (5.7-9.4)	6.4 (4.6-8.0)	7.5 (5.7-9.4)
5	5.5	---	7.0 (5.8-8.4)	---	5.6 (4.1-7.0)	---	6.3 (4.1-8.4)	---
6	7.3	19.9 (8.7-31.0)	6.5 (4.3-8.6)	10.7 (8.2-15.1)	10.0 (9.6-10.5)	9.7 (9.3-10.0)	7.8 (4.3-10.5)	10.0 (8.2-15.1)
7	8.7	---	6.4 (4.8-7.7)	---	10.1 (9.6-10.6)	---	8.0 (4.8-10.6)	---
8	8.7	11.0 (7.4-14.5)	7.8 (6.1-9.0)	10.1 (7.1-15.1)	10.6 (10.0-11.2)	9.7 (8.4-11.0)	8.9 (6.1-11.2)	9.5 (7.1-15.1)
Embayment								
9	---	14.5 (8.4-20.5)	---	10.3 (8.6-13.3)	---	8.0 (5.0-11.0)	---	9.2 (5.0-13.3)
10	---	19.4 (10.2-28.5)	---	9.0 (7.2-10.4)	---	11.9 (10.7-13.1)	---	10.2 (7.2-13.1)
11	---	15.8 (9.7-21.9)	---	8.3 (8.0-8.8)	---	7.6 (3.3-11.8)	---	8.3 (3.3-11.8)
12	---	22.6 (12.1-33.2)	---	6.2 (5.7-6.6)	---	12.4 (9.5-15.3)	---	9.3 (5.7-15.3)
13	---	14.8 (9.1-20.5)	---	6.1 (5.2-6.6)	---	5.5 (3.0-8.0)	---	6.4 (3.0-9.1)
14	---	5.7 (5.4-6.1)	---	5.8 (5.3-6.5)	---	7.3 (6.0-8.5)	---	6.3 (5.3-8.5)
15	---	9.4 (6.9-12.0)	---	4.8 (4.6-5.0)	---	5.8 (4.7-7.0)	---	5.5 (4.6-7.0)

[1] Data for May 1992.
[2] Includes data from May through October, yearly.

suspended particles than embayments located further upstream (stations 9, 10, 11 and 12). Embayment concentrations were similar to but usually higher than concentrations measured at the nearest mainstem sampling station.

Total alkalinity, the concentration of bases in water (expressed as mg/L $CaCO_3$) primarily composed of bicarbonate (HCO_3^-) and carbonate ($CO_3^{=}$) ions, usually increases as basin soil fertility increases. Total hardness (expressed as mg/L $CaCO_3$) is a measure of the divalent, alkaline earth metal content of water. Calcium (Ca^{++}) and magnesium (Mg^{++}) are normally the most abundant divalent metals in soils of the eastern United States and they are generally associated with the carbonate minerals responsible for alkalinity of water. Therefore, total alkalinity and total hardness are usually similar and tend to vary together. In a recent study (Bayne *et al.* 1989), total alkalinity of large mainstream impoundments of Alabama varied from a low of 7 mg/L (as $CaCO_3$) to a high of 67 mg/L (as $CaCO_3$). Total alkalinity of Lake George varied from a low of 16.3 mg/L to a high of 31.5 mg/L (Table 10-12). Total hardness ranged from a low of 15.0 mg/L to a high of 43.3 mg/L (Table 10-13). As in the case of specific conductance, total alkalinity of Lake George waters falls in the lower half of the range expected for Alabama lakes indicating limited fertility of basin soils. Since carbonate minerals function as a natural chemical buffer, waters of low alkalinity are subject to greater fluctuations in pH than more alkaline systems. pH measured at a depth of 2 m during the growing seasons of 1992 and 1993 ranged from a low of 6.7 to a high of 9.1 (Table 10-14).

Nitrogen and phosphorus are plant nutrients that are required in relatively high concentrations to support plant growth. Nitrogen concentrations normally exceed phosphorus concentrations by an order of magnitude or more (Wetzel 1983). Of the macronutrients, phosphorus is usually in shortest supply in relation to plant needs and is therefore the element most often limiting to plant growth in

Table 10-12. Mean (range) total alkalinity (mg/L as $CaCO_3$) measured at fifteen sampling stations on Lake W.F. George during the growing seasons of 1992 and 1993.

Stations	April-May		June-August		Sept-October		Growing Season[2]	
	1992[1]	1993	1992	1993	1992	1993	1992	1993
Mainstem								
0	---	20.9 (20.0-21.8)	---	22.9 (17.5-26.5)	---	29.6 (28.3-31.0)	---	25.0 (17.5-31.0)
1	18.3	18.3 (17.5-19.0)	22.2 (21.5-23.0)	21.6 (18.8-23.8)	27.5 (26.5-28.5)	24.8 (23.3-26.3)	24.3 (18.3-28.5)	22.2 (18.8-26.3)
2	19.5	16.6 (15.8-17.5)	22.8 (20.8-25.3)	22.3 (20.0-23.8)	29.1 (26.8-31.5)	24.3 (22.8-25.8)	24.4 (19.5-31.5)	22.1 (17.5-25.8)
3	19.0	---	22.2 (21.3-23.3)	---	24.3 (22.5-26.0)	---	22.3 (19.0-26.0)	---
4	18.5	13.8 (11.3-16.3)	22.6 (20.5-24.8)	20.4 (16.5-22.5)	22.8 (20.5-25.0)	22.9 (22.0-23.8)	22.0 (18.5-25.0)	20.5 (16.3-23.8)
5	20.8	---	22.8 (21.8-24.3)	---	22.8 (20.3-25.5)	---	22.5 (20.3-25.5)	---
6	20.0	15.0 (13.8-16.3)	23.9 (22.5-25.3)	20.3 (16.3-23.0)	21.8 (21.0-22.5)	22.3 (21.5-23.0)	22.5 (20.0-25.3)	20.3 (16.3-23.0)
7	18.5	---	23.2 (21.0-24.8)	---	21.1 (19.8-22.5)	---	21.7 (18.5-24.8)	---
8	21.0	14.5 (13.5-15.5)	20.7 (19.8-22.3)	18.9 (16.3-20.5)	21.0 (20.0-22.0)	20.0 (20.0-20.0)	20.8 (19.8-22.3)	18.7 (15.5-20.5)
Embayment								
9	---	18.8 (16.3-21.3)	---	22.6 (17.5-25.8)	---	23.1 (22.8-23.5)	---	22.5 (17.5-25.8)
10	---	18.1 (13.8-22.5)	---	22.6 (22.3-23.3)	---	27.0 (25.8-28.3)	---	24.0 (22.3-28.3)
11	---	14.4 (11.3-17.5)	---	21.8 (16.3-25.3)	---	23.3 (22.5-23.8)	---	21.5 (16.3-25.3)
12	---	17.4 (16.0-18.8)	---	25.0 (22.3-29.3)	---	26.9 (26.3-27.5)	---	24.6 (18.8-29.3)
13	---	14.5 (12.8-16.3)	---	22.9 (19.0-26.3)	---	22.4 (22.3-22.5)	---	21.6 (16.3-26.3)
14	---	20.3 (19.3-21.3)	---	26.4 (26.0-26.8)	---	25.9 (25.5-26.3)	---	25.0 (19.3-26.8)
15	---	22.3 (19.5-25.0)	---	28.9 (28.3-29.3)	---	27.6 (26.5-28.8)	---	27.8 (25.0-29.3)

[1] Data for May 1992.
[2] Includes data from May through October, yearly.

Table 10-13. Mean (range) total hardness ($\mu g/L$ as $CaCO_3$) measured at fifteen sampling stations on Lake W.F. George during the growing seasons of 1992 and 1993.

Stations	April-May		June-August		Sept-October		Growing Season[2]	
	1992[1]	1993	1992	1993	1992	1993	1992	1993
Mainstem								
0	---	17.1 (15.3-19.0)	---	22.8 (19.6-24.8)	---	23.4 (21.0-25.8)	---	22.4 (19.0-25.8)
1	20.5	16.4 (16.3-16.6)	23.1 (21.0-27.3)	19.5 (17.5-20.8)	21.7 (21.0-22.3)	20.0 (19.4-20.7)	22.2 (20.5-27.3)	19.2 (16.6-20.8)
2	20.5	16.9 (16.2-17.7)	21.1 (20.0-22.1)	20.6 (19.6-21.0)	21.6 (21.1-21.9)	20.0 (19.8-20.3)	21.1 (20.0-22.1)	19.9 (17.7-21.0)
3	20.5	---	21.4 (20.0-23.1)	---	20.1 (18.9-21.2)	---	20.8 (18.9-23.1)	---
4	19.3	17.4 (16.0-18.7)	21.7 (19.8-25.2)	20.5 (19.8-21.0)	21.6 (21.0-22.1)	19.9 (19.4-20.3)	21.3 (19.3-25.2)	20.0 (18.7-21.0)
5	21.7	---	20.8 (19.3-22.1)	---	21.4 (20.9-21.9)	---	21.1 (19.3-22.1)	---
6	20.5	18.9 (18.1-19.6)	21.2 (20.6-22.1)	20.4 (19.8-20.8)	21.8 (19.3-24.2)	32.1 (21.0-43.2)	21.3 (19.3-24.2)	23.9 (18.1-43.2)
7	20.5	---	20.9 (19.4-22.1)	---	19.2 (19.0-19.4)	---	20.3 (19.0-22.1)	---
8	18.9	15.7 (14.8-16.7)	20.7 (19.3-22.8)	20.6 (19.8-21.7)	20.5 (20.2-20.8)	22.2 (19.4-25.0)	20.3 (18.9-22.8)	20.5 (16.7-25.0)
Embayment								
9	---	26.6 (25.5-27.6)	---	23.9 (21.3-25.2)	---	25.1 (22.1-28.2)	---	24.6 (21.3-28.2)
10	---	26.5 (22.9-30.1)	---	25.5 (24.1-28.4)	---	22.8 (19.9-25.8)	---	25.4 (19.9-30.1)
11	---	18.7 (18.2-19.2)	---	22.0 (21.3-22.4)	---	21.1 (20.2-22.1)	---	21.2 (19.2-22.4)
12	---	18.3 (17.1-19.6)	---	20.4 (18.3-22.2)	---	29.0 (20.8-37.3)	---	23.1 (18.3-37.3)
13	---	13.6 (12.2-15.0)	---	20.3 (18.6-21.9)	---	19.9 (19.4-20.3)	---	19.3 (15.0-21.9)
14	---	18.2 (17.7-18.7)	---	24.0 (22.9-25.9)	---	22.2 (21.0-23.4)	---	22.5 (18.7-25.9)
15	---	22.3 (21.1-23.4)	---	26.6 (24.1-28.8)	---	22.6 (21.9-23.2)	---	24.7 (21.9-28.8)

[1] Data for May 1992.
[2] Includes data from May through October, yearly.

Table 10-14. Mean (range) pH measured at a depth of 2 m at fifteen sampling stations on Lake W.F. George during the growing seasons of 1992 and 1993.

Stations	April-May		June-August		Sept-October		Growing Season[2]	
	1992[1]	1993	1992	1993	1992	1993	1992	1993
Mainstem								
0	---	---	---	---	---	---	---	---
1	9.1	7.1 (7.0-7.2)	8.8 (8.5-9.0)	8.6 (8.2-9.0)	7.6 (7.3-8.8)	7.6 (7.5-7.7)	8.0 (7.3-9.1)	7.7 (7.2-9.0)
2	8.4	7.1 (6.9-7.2)	8.7 (8.5-9.0)	7.4 (7.0-8.9)	7.6 (7.3-8.8)	7.3 (7.1-7.5)	8.0 (7.3-9.0)	7.3 (7.0-8.9)
3	8.2	---	8.3 (7.9-9.0)	---	7.5 (7.2-9.0)	---	7.8 (7.2-9.0)	---
4	8.9	7.1 (6.9-7.3)	7.9 (7.9-8.6)	7.5 (7.3-8.7)	7.5 (7.2-8.9)	7.4 (7.3-7.5)	7.8 (7.2-8.9)	7.4 (7.3-8.7)
5	7.6	---	7.6 (7.5-7.8)	---	7.1 (7.0-7.3)	---	7.4 (7.0-7.8)	---
6	7.2	6.9 (6.9-6.9)	7.1 (7.1-7.2)	7.0 (7.0-7.2)	6.9 (6.8-7.1)	7.0 (6.9- 7.0)	7.1 (6.8-7.2)	7.0 (6.9-7.2)
7	7.8	---	7.2 (7.1-7.3)	---	6.9 (6.8-6.9)	---	7.1 (6.8-7.8)	---
8	7.1	7.2 (7.1-7.3)	7.3 (7.3-7.4)	7.2 (7.1-7.3)	7.0 (6.9-7.0)	7.3 (7.2-7.3)	7.1 (6.9-7.4)	7.2 (7.1-7.3)
Embayment								
9	---	6.9 (6.7-7.1)	---	7.1 (6.8-7.4)	---	7.2 (7.1-7.4)	---	7.1 (6.8-7.4)
10	---	6.8 (6.7-7.1)	---	7.4 (7.1-8.0)	---	7.5 (7.4-7.6)	---	7.3 (7.1-8.0)
11	---	6.9 (6.7-7.2)	---	7.6 (7.4-8.7)	---	7.6 (7.4-8.1)	---	7.5 (7.2-8.7)
12	---	6.9 (6.7-7.4)	---	7.4 (7.0-7.7)	---	7.6 (7.5-7.6)	---	7.4 (7.0-7.7)
13	---	6.9 (6.7-7.4)	---	7.2 (6.7-8.4)	---	7.8 (7.7-7.9)	---	7.3 (6.7-8.4)
14	---	7.1 (6.9-7.4)	---	7.6 (7.2-8.6)	---	6.9 (6.7-7.6)	---	7.3 (6.7-8.6)
15	---	7.5 (7.5-7.6)	---	7.6 (7.3-8.4)	---	7.5 (7.3-8.0)	---	7.6 (7.3-8.4)

[1] Data for May 1992.
[2] Includes data from May through October, yearly.

freshwater ecosystems. On occasions, phosphorus levels can rise high enough that nitrogen availability becomes limiting to plant growth. This usually occurs at total nitrogen to total phosphorus ratios < 16:1 (Porcella *et al.* 1981).

Nitrogen is available to plants as nitrates ($NO_3^=$) or as the ammonium ion (NH_4^+). Bioavailable nitrogen was abundant in Lake George with mean concentrations in the headwaters ranging between 400 and 600 μg/L and lacustrine concentrations ranging from about 100 to 400 μg/L (Tables 10-15, 10-16 and Figure 10-5). These concentrations were about one-half those measured in West Point Lake, an upstream impoundment of the Chattahoochee River, receiving large quantities of nutrients from watershed runoff and treated wastewater discharged in the Atlanta, Georgia metropolitan area (Bayne *et al.* 1993). Total organic nitrogen concentrations (Table 10-17 and Figure 10-5) also averaged about one-half those concentrations measured in West Point Lake during the growing season. In general, embayment nitrogen concentrations were similar to concentrations measured at nearby mainstem sampling stations, however, station 10 (Cowikee Creek) had unusually low inorganic nitrogen levels but the highest growing season mean total organic nitrogen concentration measured at any location.

Phosphorus in water is routinely reported as total phosphorus (all forms of phosphorus expressed as P) and soluble reactive phosphorus which is an estimate of orthophosphate ($PO_4^=$ expressed as P), the most important and abundant form of phosphorus directly available to plants. Both forms of phosphorus demonstrated a strong longitudinal gradient in Lake George with higher concentrations occurring at upstream locations (Tables 10-18, 10-19 and Figure 10-6). Concentrations of orthophosphate (PO_4-P) at upstream station 8 ranged between 2 and 26 μg/L and total phosphorus (TP) concentrations at station 8 ranged from 45 to 72 μg/L. These concentrations are an order of magnitude lower

Table 10-15. Mean (range) nitrate-nitrite (μg/L) measured at fifteen sampling stations on Lake W.F. George during the growing seasons of 1992 and 1993.

Stations	April-May 1992[1]	April-May 1993	June-August 1992	June-August 1993	Sept-October 1992	Sept-October 1993	Growing Season[2] 1992	Growing Season[2] 1993
Mainstem								
0	---	273.0 (244.0-302.0)	---	82.0 (21.0-178.0)	---	53.5 (19.0-88.0)	---	99.5 (19.0-244.0)
1	74.0	285.0 (223.0-347.0)	29.3 (2.0-78.0)	39.7 (4.0-99.0)	47.5 (1.0-94.0)	33.0 (8.0-58.0)	42.8 (1.0-94.0)	68.0 (4.0-223.0)
2	150.0	317.5 (295.0-340.0)	17.3 (4.0-40.0)	88.3 (9.0-233.0)	70.0 (51.0-89.0)	30.5 (29.0-32.0)	57.0 (4.0-150.0)	103.5 (9.0-295.0)
3	177.0	---	107.7 (75.0-145.0)	---	162.5 (84.0-241.0)	---	137.5 (75.0-241.0)	---
4	135.0	313.5 (290.0-337.0)	90.0 (59.0-111.0)	217.3 (177.0-253.0)	235.0 (92.0-378.0)	238.0 (236.0-240.0)	145.8 (59.0-378.0)	244.2 (177.0-337.0)
5	206.0	---	171.3 (164.0-184.0)	---	336.0 (284.0-388.0)	---	232.0 (164.0-388.0)	---
6	376.0	336.0 (334.0-338.0)	378.0 (279.0-561.0)	379.3 (323.0-414.0)	250.0 (112.0-388.0)	403.0 (395.0-411.0)	335.0 (112.0-561.0)	379.7 (323.0-414.0)
7	351.0	---	392.7 (287.0-599.0)	---	257.0 (129.0-385.0)	---	340.5 (129.0-599.0)	---
8	358.0	386.0 (380.0-392.0)	369.0 (264.0-555.0)	419.7 (395.0-455.0)	266.5 (156.0-377.0)	409.5 (400.0-419.0)	333.0 (156.0-555.0)	411.7 (392.0-455.0)
Embayment								
9	---	183.0 (78.0-288.0)	---	246.3 (179.0-347.0)	---	255.0 (236.0-274.0)	---	256.2 (179.0-347.0)
10	---	58.5 (40.0-77.0)	---	45.3 (38.0-56.0)	---	24.5 (22.0-27.0)	---	43.7 (22.0-77.0)
11	---	247.0 (207.0-287.0)	---	186.0 (96.0-251.0)	---	179.0 (165.0-193.0)	---	200.5 (96.0-287.0)
12	---	218.0 (156.0-280.0)	---	142.0 (34.0-237.0)	---	66.5 (32.0-101.0)	---	139.8 (32.0-280.0)
13	---	246.0 (245.0-247.0)	---	122.3 (66.0-215.0)	---	62.0 (26.0-98.0)	---	123.0 (26.0-247.0)
14	---	238.5 (192.0-285.0)	---	101.0 (7.0-206.0)	---	61.0 (58.0-64.0)	---	118.3 (7.0-285.0)
15	---	267.5 (253.0-282.0)	---	69.7 (10.0-128.0)	---	5.0 (3.0-7.0)	---	78.7 (3.0-253.0)

[1] Data for May 1992.
[2] Includes data from May through October, yearly.

Table 10-16. Mean (range) total ammonia ($\mu g/L$) measured at fifteen sampling stations on Lake W.F. George during the growing seasons of 1992 and 1993.

Stations	April-May		June-August		Sept-October		Growing Season[2]	
	1992[1]	1993	1992	1993	1992	1993	1992	1993
Mainstem								
0	---	103.5 (42.0-165.0)	---	169.0 (101.0-299.0)	---	99.5 (52.0-147.0)	---	145.2 (52.0-299.0)
1	14.0	95.5 (74.0-117.0)	63.3 (13.0-126.0)	47.7 (36.0-55.0)	17.0 (0.0-34.0)	57.0 (11.0-103.0)	39.7 (0.0-126.0)	62.3 (11.0-117.0)
2	43.0	90.0 (67.0-113.0)	25.3 (13.0-43.0)	71.7 (19.0-118.0)	20.0 (0.0-40.0)	50.5 (34.0-67.0)	26.5 (0.0-43.0)	63.8 (19.0-118.0)
3	57.0	---	67.3 (54.0-76.0)	---	31.5 (0.0-63.0)	---	53.7 (0.0-76.0)	---
4	86.0	83.0 (81.0-85.0)	83.0 (59.0-107.0)	94.7 (50.0-134.0)	17.0 (0.0-34.0)	79.5 (61.0-98.0)	61.5 (0.0-107.0)	87.3 (50.0-134.0)
5	42.0	---	60.3 (25.0-93.0)	---	71.5 (43.0-100.0)	---	61.0 (25.0-100.0)	---
6	212.0	138.5 (104.0-173.0)	121.7 (81.0-150.0)	155.3 (81.0-294.0)	127.5 (33.0-222.0)	201.5 (194.0-209.0)	138.7 (33.0-222.0)	173.7 (81.0-294.0)
7	39.0	---	163.0 (61.0-287.0)	---	181.5 (143.0-220.0)	---	148.5 (39.0-287.0)	---
8	90.0	119.5 (73.0-166.0)	160.0 (129.0-215.0)	133.7 (89.0-187.0)	160.0 (132.0-188.0)	120.5 (110.0-131.0)	148.3 (90.0-215.0)	134.7 (89.0-187.0)
Embayment								
9	---	81.0 (63.0-99.0)	---	115.7 (65.0-210.0)	---	85.5 (49.0-122.0)	---	96.8 (49.0-210.0)
10	---	77.5 (50.0-105.0)	---	87.0 (32.0-164.0)	---	34.0 (4.0-64.0)	---	63.2 (4.0-164.0)
11	---	112.0 (104.0-120.0)	---	88.0 (39.0-163.0)	---	31.5 (29.0-34.0)	---	71.8 (29.0-163.0)
12	---	124.0 (56.0-192.0)	---	95.7 (44.0-156.0)	---	66.5 (61.0-72.0)	---	79.3 (44.0-156.0)
13	---	103.5 (83.0-124.0)	---	112.7 (20.0-248.0)	---	37.5 (37.0-38.0)	---	82.7 (20.0-248.0)
14	---	71.0 (61.0-81.0)	---	71.7 (62.0-88.0)	---	50.0 (31.0-69.0)	---	66.0 (31.0-88.0)
15	---	67.5 (62.0-73.0)	---	94.7 (46.0-189.0)	---	23.5 (22.0-25.0)	---	67.3 (22.0-189.0)

[1] Data for May 1992.
[2] Includes data from May through October, yearly.

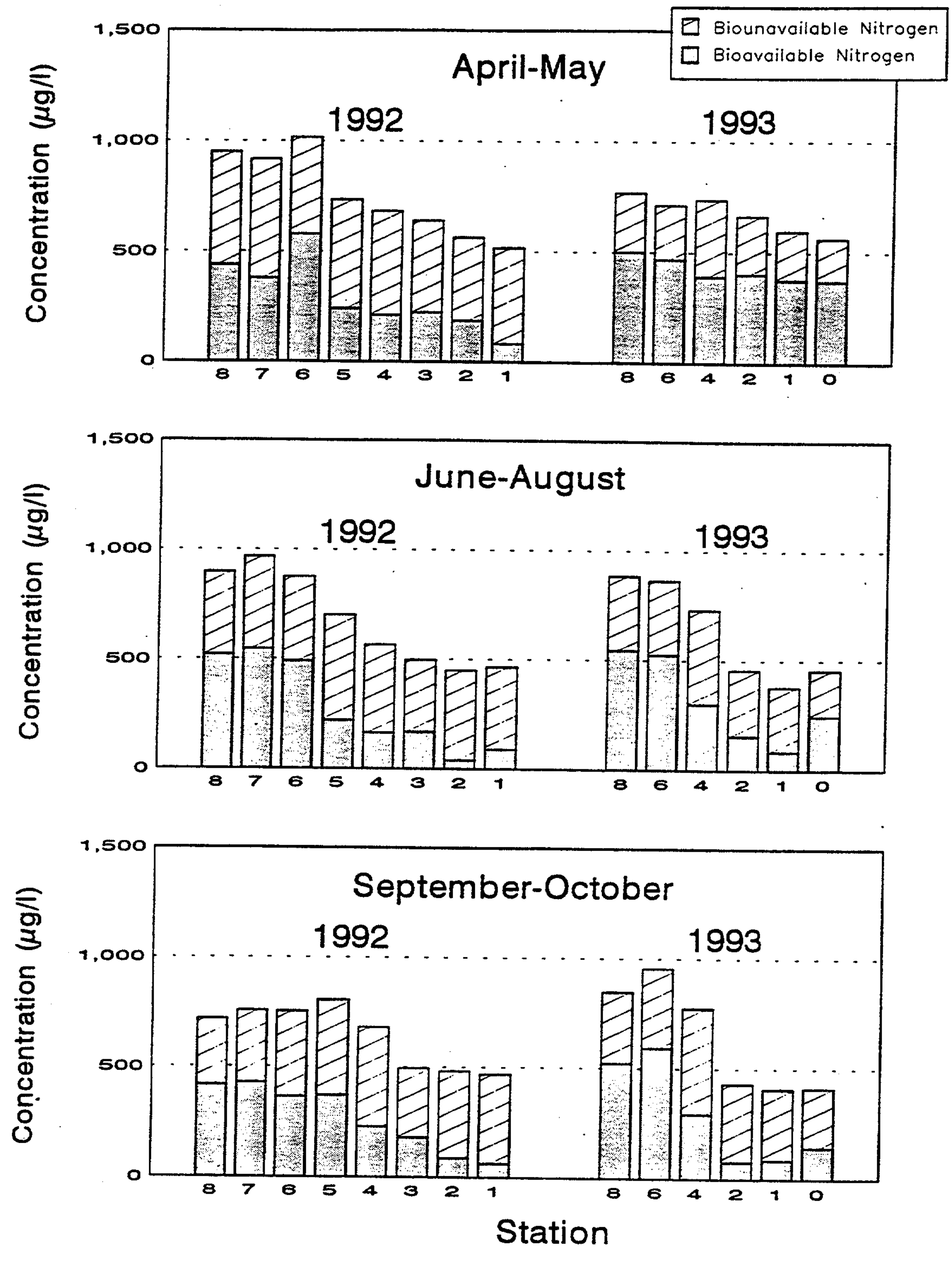


Figure 10-5. Mean bioavailable nitrogen and biounavailable nitrogen concentrations at main stem sampling stations (headwaters at station 8 and dam at station 1) during the diagnostic study of Lake W. F. George, April 1992 through October 1993. In 1992 no April sample was taken.

Table 10-17. Mean (range) total organic nitrogen ($\mu g/L$) measured at fifteen sampling stations on Lake W.F. George during the growing seasons of 1992 and 1993.

Stations	April-May		June-August		Sept-October		Growing Season[2]	
	1992[1]	1993	1992	1993	1992	1993	1992	1993
Mainstem								
0	---	186.5 (178.0-195.0)	---	205.3 (161.0-250.0)	---	259.0 (196.0-322.0)	---	218.7 (161.0-322.0)
1	428.0	216.0 (200.0-232.0)	373.0 (337.0-426.0)	292.3 (231.0-345.0)	404.5 (381.0-428.0)	318.5 (260.0-377.0)	392.8 (337.0-428.0)	285.7 (200.0-377.0)
2	371.0	257.0 (250.0-264.0)	407.7 (386.0-437.0)	297.7 (213.0-341.0)	391.5 (390.0-393.0)	349.5 (330.0-369.0)	396.2 (371.0-437.0)	307.0 (213.0-369.0)
3	406.0	---	323.7 (303.0-360.0)	---	301.0 (282.0-320.0)	---	329.8 (282.0-406.0)	---
4	463.0	340.0 (305.0-375.0)	394.0 (328.0-474.0)	421.3 (394.0-447.0)	426.5 (367.0-486.0)	456.0 (430.0-482.0)	416.3 (328.0-486.0)	413.5 (305.0-482.0)
5	486.0	---	474.0 (423.0-508.0)	---	394.5 (364.0-425.0)	---	449.5 (364.0-508.0)	---
6	428.0	237.5 (213.0-262.0)	378.0 (320.0-431.0)	331.3 (252.0-406.0)	373.0 (277.0-469.0)	349.5 (294.0-405.0)	384.7 (277.0-469.0)	317.7 (213.0-406.0)
7	528.0	---	413.0 (368.0-457.0)	---	316.0 (221.0-411.0)	---	399.8 (221.0-528.0)	---
8	503.0	261.5 (228.0-295.0)	369.3 (314.0-414.0)	331.7 (265.0-384.0)	289.5 (221.0-358.0)	315.0 (247.0-383.0)	365.0 (221.0-503.0)	308.8 (228.0-384.0)
Embayment								
9	---	367.5 (328.0-407.0)	---	313.7 (202.0-375.0)	---	461.5 (441.0-482.0)	---	365.3 (202.0-482.0)
10	---	551.0 (490.0-612.0)	---	450.0 (434.0-475.0)	---	524.0 (487.0-561.0)	---	481.3 (434.0-561.0)
11	---	362.0 (357.0-367.0)	---	418.7 (392.0-437.0)	---	410.0 (392.0-428.0)	---	407.2 (367.0-437.0)
12	---	299.0 (287.0-316.0)	---	260.3 (230.0-293.0)	---	450.5 (439.0-462.0)	---	328.2 (230.0-462.0)
13	---	240.5 (236.0-245.0)	---	257.7 (204.0-317.0)	---	408.0 (397.0-419.0)	---	305.7 (204.0-419.0)
14	---	296.0 (250.0-342.0)	---	289.3 (261.0-312.0)	---	364.0 (359.0-369.0)	---	307.7 (250.0-369.0)
15	---	329.5 (250.0-409.0)	---	269.0 (245.0-294.0)	---	397.5 (392.0-403.0)	---	308.7 (245.0-403.0)

[1] Data for May 1992.
[2] Includes data from May through October, yearly.

Table 10-18. Mean (range) orthophosphorus ($\mu g/L$) measured at fifteen sampling stations on Lake W.F. George during the growing seasons of 1992 and 1993.

Stations	April-May		June-August		Sept-October		Growing Season[2]	
	1992[1]	1993	1992	1993	1992	1993	1992	1993
Mainstem								
0	---	4.5 (4.0-5.0)	---	0.3 (0.0-1.0)	---	0.5 (0.0-1.0)	---	1.2 (0.0-5.0)
1	0	2.0	1.0 (0.0-2.0)	0.3 (0.0-1.0)	0	1.0 (0.0-2.0)	0.5 (0.0-2.0)	0.8 (0.0-2.0)
2	0	3.5 (2.0-5.0)	1.7 (1.0-3.0)	0.7 (0.0-2.0)	0.5 (0.0-1.0)	1.5 (1.0-2.0)	1.0 (0.0-3.0)	1.2 (0.0-2.0)
3	1.0	---	1.7 (1.0-2.0)	---	0.5 (0.0-1.0)	---	1.2 (0.0-2.0)	---
4	2.0	4.5 (2.0-7.0)	2.3 (1.0-3.0)	0.7 (0.0-2.0)	1.0	1.5 (1.0-2.0)	1.8 (1.0-3.0)	1.2 (0.0-2.0)
5	1.0	---	2.0 (1.0-3.0)	---	4.0 (0.0-8.0)	---	2.5 (0.0-8.0)	---
6	7.0	8.5 (7.0-10.0)	2.0 (1.0-3.0)	4.7 (2.0-9.0)	10.0 (1.0-19.0)	10.0 (5.0-15.0)	5.5 (1.0-19.0)	7.3 (2.0-15.0)
7	3.0	---	6.0 (2.0-13.0)	---	13.5 (7.0-20.0)	---	8.0 (2.0-20.0)	---
8	4.0	8.5 (6.0-11.0)	3.7 (2.0-5.0)	6.3 (6.0-7.0)	14.5 (3.0-26.0)	10.5 (8.0-13.0)	7.3 (2.0-26.0)	8.5 (6.0-13.0)
Embayment								
9	---	2.5 (2.0-3.0)	---	0.7 (0.0-1.0)	---	3.0	---	1.7 (0.0-3.0)
10	---	6.0 (3.0-9.0)	---	1.0	---	1.5 (1.0-2.0)	---	1.5 (1.0-3.0)
11	---	3.5 (1.0-6.0)	---	0.3 (0.0-1.0)	---	2.0	---	1.0 (0.0-2.0)
12	---	2.0 (0.0-4.0)	---	0.7 (0.0-2.0)	---	0.5 (0.0-1.0)	---	0.5 (0.0-2.0)
13	---	1.5 (0.0-3.0)	---	2.0 (0.0-6.0)	---	0.5 (0.0-1.0)	---	1.2 (0.0-6.0)
14	---	1.5 (0.0-3.0)	---	5.7 (0.0-17.0)	---	0.5 (0.0-1.0)	---	3.0 (0.0-17.0)
15	---	2.0 (1.0-3.0)	---	0.7 (0.0-2.0)	---	0.5 (0.0-1.0)	---	0.7 (0.0-2.0)

[1] Data for May 1992.
[2] Includes data from May through October, yearly.

Table 10-19. Mean (range) total phosphorus (µg/L) measured at fifteen sampling stations on Lake W.F. George during the growing seasons of 1992 and 1993.

Stations	April-May		June-August		Sept-October		Growing Season[2]	
	1992[1]	1993	1992	1993	1992	1993	1992	1993
Mainstem								
0	---	39.0 (37.0-41.0)	---	23.0 (18.0-28.0)	---	26.5 (25.0-28.0)	---	27.2 (18.0-41.0)
1	16.0	35.0 (33.0-37.0)	23.0 (19.0-26.0)	19.0 (18.0-21.0)	26.0 (22.0-30.0)	28.0 (25.0-31.0)	22.8 (16.0-30.0)	24.3 (18.0-33.0)
2	18.0	41.0 (36.0-46.0)	26.7 (23.0-31.0)	21.0 (20.0-22.0)	29.5 (27.0-32.0)	30.5 (29.0-32.0)	26.2 (18.0-32.0)	26.7 (20.0-36.0)
3	27.0	---	31.0 (28.0-34.0)	---	34.0 (31.0-37.0)	---	31.3 (27.0-37.0)	---
4	32.0	52.0 (38.0-66.0)	38.7 (34.0-42.0)	34.7 (30.0-39.0)	42.0 (37.0-47.0)	38.0 (34.0-42.0)	38.7 (32.0-47.0)	36.3 (30.0-42.0)
5	35.0	---	44.0 (40.0-50.0)	---	45.0 (38.0-52.0)	---	42.8 (35.0-52.0)	---
6	56.0	55.0 (52.0-58.0)	50.3 (46.0-55.0)	50.3 (48.0-54.0)	57.5 (53.0-62.0)	64.0 (57.0-71.0)	53.7 (46.0-62.0)	55.2 (48.0-71.0)
7	66.0	---	53.0 (46.0-59.0)	---	57.5 (55.0-60.0)	---	56.7 (46.0-66.0)	---
8	66.0	53.0 (52.0-54.0)	57.7 (49.0-72.0)	47.3 (45.0-52.0)	59.5 (53.0-66.0)	54.5 (47.0-62.0)	59.7 (49.0-72.0)	50.5 (45.0-62.0)
Embayment								
9	---	45.5 (40.0-51.0)	---	39.7 (33.0-45.0)	---	46.0 (42.0-50.0)	---	41.8 (33.0-50.0)
10	---	70.0 (52.0-88.0)	---	44.3 (37.0-48.0)	---	49.5 (44.0-55.0)	---	47.3 (37.0-55.0)
11	---	63.5 (50.0-77.0)	---	42.0 (36.0-47.0)	---	40.5 (33.0-48.0)	---	42.8 (33.0-50.0)
12	---	68.5 (41.0-96.0)	---	29.3 (29.0-30.0)	---	38.0	---	34.2 (29.0-41.0)
13	---	51.0 (36.0-66.0)	---	25.7 (24.0-28.0)	---	31.0	---	29.2 (24.0-36.0)
14	---	40.5 (34.0-47.0)	---	25.3 (24.0-27.0)	---	30.5 (30.0-31.0)	---	28.5 (24.0-34.0)
15	---	40.5 (38.0-43.0)	---	24.3 (22.0-26.0)	---	32.0 (31.0-33.0)	---	29.2 (22.0-38.0)

[1] Data for May 1992.
[2] Includes data from May through October, yearly.

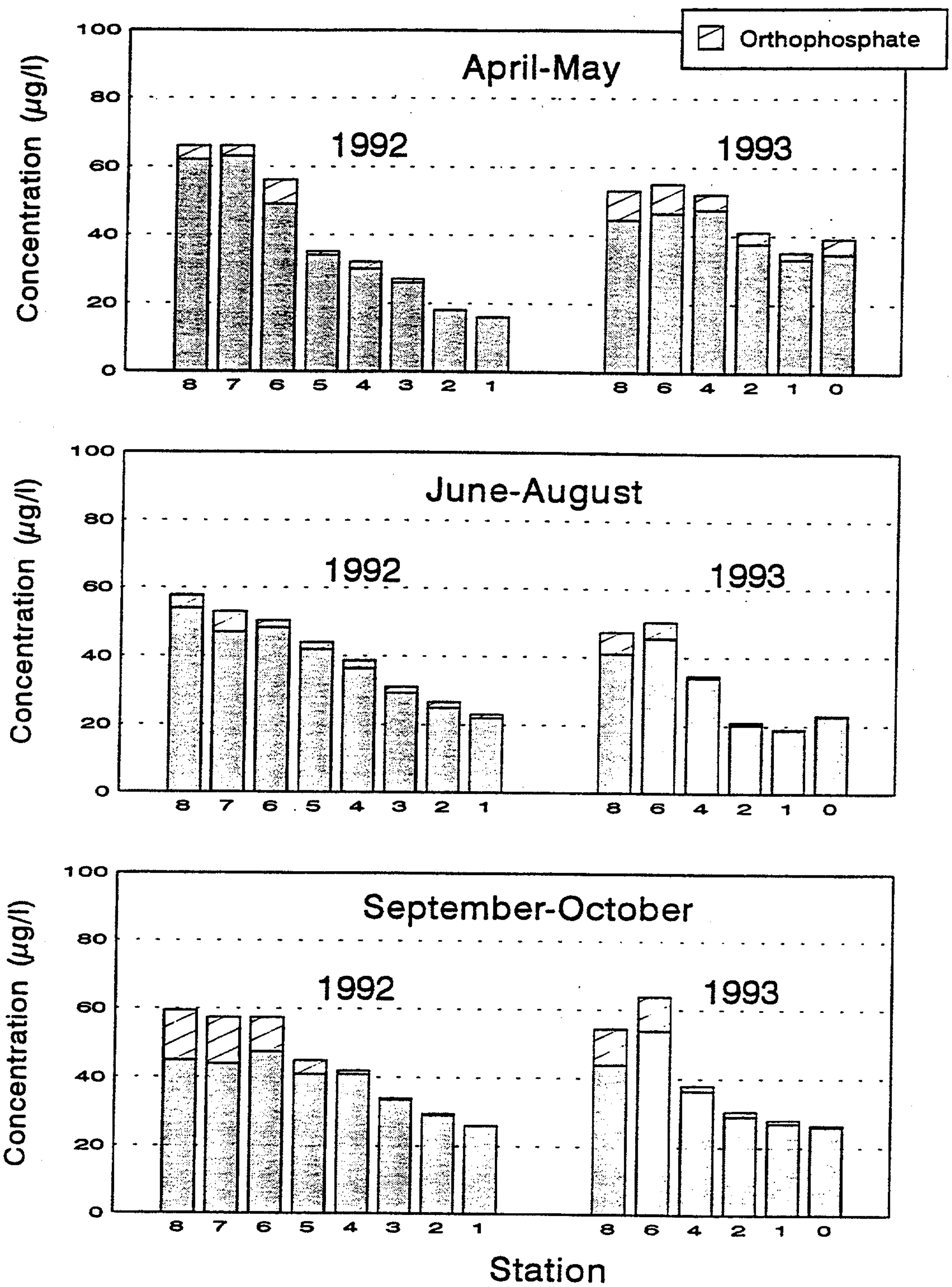


Figure 10-6. Mean total phosphorus and orthophosphate concentrations at main stem sampling stations (headwaters at station 8 and dam at station 1) during the diagnostic study of Lake W. F. George, April 1992 through October 1993. In 1992 no April sample was taken.

than levels reported for West Point Lake during comparable seasons of the year (Bayne *et al.* 1993) but are still considered near the upper limit allowable. EPA (1986) suggested a limit of 50 $\mu g/L$ TP at the point where a stream enters a lake or reservoir in order to prevent excessive loading. PO_4-P, the readily available phosphorus, comprised a relatively small portion (< 20%) of the TP in Lake George (Figure 10-6).

Phosphorus tends to adsorb onto surfaces of suspended inorganic particles, and therefore, increases in abiogenic turbidity are frequently accompanied by increased phosphorus concentration. That is one explanation for the elevated phosphorus concentrations at upstream locations, where greater water movement maintains particles in suspension. Further downstream, water movement subsides and particles settle to the bottom removing much of the incoming sediment and associated phosphorus. This phosphorus is deposited in bottom sediments and may remain there indefinitely. Mainstream reservoirs are known to trap large quantities of incoming phosphorus. Lawrence (1970) reported phosphorus losses of 61% and 75% in lakes Seminole and George, respectively. Lake Seminole is located on the Chattahoochee River downstream from Lake George. Bayne *et al.* 1993 estimated 80% phosphorus retention in West Point Lake. Under some circumstances some of the accumulated phosphorus can reenter the water column and reach the photic zone, a process known as internal loading of phosphorus. Lakes with anaerobic hypolimnia are more prone to internal loading since reducing conditions mobilize phosphorus in the sediments and release soluble phosphorus to the overlying water column.

Another explanation for elevated phosphorus concentrations at upstream locations relates to the proximity to point sources of nutrients in the Phenix City, Alabama-Columbus/Fort Benning, Georgia area. Municipal wastewater treatment facilities are permitted to deliver about 58 MGD of treated effluent to the Chattahoochee River upstream of station 8. In an effort to reduce phosphorus in surface waters, the Georgia General Assembly enacted a statewide ban on high phosphate laundry detergents that went into effect 1 January 1991 (EPD 1990). This has the potential to affect total phosphorus concentration in Lake George. Available data seem to indicate a decline in total phosphorus concentration at the mid-reservoir (station 4) location during 1992 and 1993 (Table 10-20).

During the months (June, July and August) when Lake George was chemically stratified (Figures 10-2 and 10-3), total nitrogen and total phosphorus concentrations generally declined along the mainstem from headwaters (station 8) to the dam forebay (station 1) (Table 10-21). The optimum ratio of total nitrogen to total phosphorus (TN:TP) for phytoplankton growth is in the range of 11 to 16 (Porcella and Cleave 1981). Values < 11 indicate nitrogen limitation of algal growth and values > 16 indicate phosphorus limitation. Waters receiving excessive amounts of treated municipal effluent often have relatively low (2 to 5) TN:TP (Raschke and Schultz 1987). In Lake George, TN:TP ratios ranged from a low of 12.7 to a high of 27.3 (Table 10-21). Downstream lacustrine areas were phosphorus limited and upstream areas were co-limited. Results of Algal Growth Potential Tests were used to further define nutrient limitation in Lake George (Section 10.2.2).

Table 10-20. Trends in nitrogen and phosphorus concentrations in Lake George from 1989 through 1993. Values represent mean photic zone concentrations measured during the months of May through September.

Station	1989[1]	1990[1]	1991[2]	1992	1993
	NO_3+NO_2 (µg/L)				
1	36	67	97	33	120
4	173	163	208	99	245
	TP (µg/L)				
1	29	26	41	21	27
4	60	46	54	37	35

[1] Bayne and Maceina 1992.
[2] EPD 1993.

Table 10-21. Seasonal mean total nitrogen (μg/L), total phosphorus (μg/L) and the ratio of TN to TP at mainstem stations on Lake George during the summer (June, July and August) seasons of 1992 and 1993.

Mainstem Stations	1992			1993		
	TN	TP	TN:TP	TN	TP	TN:TP
8	898	58	15.5	599	47	12.7
7	696	53	13.1	--	--	--
6	877	50	17.5	642	50	12.8
5	705	44	16.0	--	--	--
4	567	39	14.5	611	35	17.5
3	498	31	16.1	--	--	--
2	450	27	16.7	441	21	21.0
1	466	23	20.3	519	19	27.3

10.2.2 PHYTOPLANKTON

The photic zone composite water sample collected at each sampling station (Table 10-2) was the source of water used for analyses of the phytoplankton-related variables. Aliquots of the composite sample were separated for total organic carbon (TOC) analyses, phytoplankton identification and enumeration, chlorophyll a analyses and the Algal Growth Potential Test (AGPT) (Table 10-22). Phytoplankton counts, chlorophyll a analyses and TOC analyses were conducted monthly at all stations during both years. Algal growth potential and phytoplankton primary productivity were measured monthly from May through September 1993 (Table 10-1). Primary productivity and AGPT were done at stations 1, 2, 4 and 6 and in addition, AGPT was done at station 8 (Table 10-2). Productivity was measured using the carbon-14 method. Duplicate light and dark bottles were incubated for 3 h at midday at each of three depths within the euphotic zone: the lower limit of the euphotic zone, midway between the lower limit and the surface and about 0.3 m below the water surface. The lower limit of the euphotic zone was determined by multiplying the Secchi disk visibility by a factor of four (Taylor 1971). Productivity measured during the 3-h exposure was expanded to total daily productivity (mgC/m^2•day) using solar radiation data obtained during the exposure period and for the entire day (Boyd 1979). Continuous solar radiation was measured at the National Oceanic and Atmospheric Administration's (NOAA) National Weather Station, Auburn, Alabama (Table 10-4).

On the mainstem of the reservoir phytoplankton density ranged from a low of 1,217 organisms/ml at station 6 in June of 1993 to a high of 7,037 organisms/ml at station 13 in July of 1993 (Table 10-23). From June through October densities were usually higher downstream in the lacustrine zone (stations 1-5) than in the transition (stations 6 and 7) and riverine (stations 8) zones

Table 10-22. Analytical methods used in measuring microbiological variables during the diagnostic study of Lake W.F. George, 1992-1993.

Variable	Method	Reference
Chlorophyll a	Spectrophotometric	APHA *et al.* 1992
Total Organic Carbon	Persulfate digestion, with Dohrman DC-80	APHA *et al.* 1992
Phytoplankton Enumeration	Sedimentation chamber	APHA *et al.* 1992
Algal Growth Potential Test	U.S.E.P.A. Methodology	Athens, GA Lab.
Phytoplankton Primary Productivity	Carbon 14 Method	APHA *et al.* 1992
Fecal Coliforms	Membrane Filter Procedure	APHA *et al.* 1992

Table 10-23. Mean (range) phytoplankton densities (organisms/L) measured at fifteen sampling stations on Lake W.F. George during the growing seasons of 1992 and 1993.

Stations	April-May		June-August		Sept-October		Growing Season[2]	
	1992[1]	1993	1992	1993	1992	1993	1992	1993
Mainstem								
0	---	1743.0 (1647.0-1839.0)	---	2359.3 (1526.0-2938.0)	---	3489.5 (3079.0-3900.0)	---	2617.3 (1526.0-3900.0)
1	1457.0	1495.0 (1443.0-1547.0)	3029.3 (1454.0-4583.0)	3860.0 (1870.0-5077.0)	3352.5 (3061.0-3644.0)	4545.0 (4463.0-4628.0)	2965.0 (1454.0-4583.0)	3703.0 (1547.0-5077.0)
2	1689.0	1974.5 (1932.0-2017.0)	3039.7 (1787.0-3914.0)	4509.0 (2785.0-7006.0)	3673.0 (3637.0-3709.0)	3352.5 (3064.0-3641.0)	3025.7 (1689.0-3914.0)	3694.0 (1932.0-7006.0)
3	2323.0	---	3028.7 (2263.0-3720.0)	---	2675.0 (2639.0-2711.0)	---	2793.2 (2263.0-3720.0)	---
4	1996.0	1517.5 (1355.0-1680.0)	2295.0 (1673.0-2975.0)	3026.0 (2853.0-3115.0)	2588.5 (2034.0-3143.0)	2625.5 (2347.0-2904.0)	2343.0 (1673.0-3143.0)	2668.2 (1680.0-3115.0)
5	2080.0	---	2290.0 (1945.0-2793.0)	---	2065.0 (1895.0-2236.0)	---	2180.2 (1895.0-2793.0)	---
6	1637.0	1524.5 (1432.0-1617.0)	2352.7 (1978.0-2651.0)	1662.0 (1217.0-1979.0)	2022.0 (1812.0-2232.0)	1760.5 (1736.0-1785.0)	2123.2 (1637.0-2651.0)	1687.3 (1217.0-1979.0)
7	1426.0	---	1738.7 (1432.0-1982.0)	---	1661.0 (1492.0-1830.0)	---	1660.7 (1426.0-1982.0)	---
8	2014.0	1669.0 (1442.0-1896.0)	1904.0 (1621.0-2353.0)	1909.3 (1609.0-2416.0)	1538.0 (1229.0-1847.0)	2014.0 (1834.0-2194.0)	1800.3 (1229.0-2353.0)	1942.0 (1609.0-2416.0)
Embayment								
9	---	1840.0 (1306.0-2374.0)	---	2260.3 (1867.0-2542.0)	---	3314.5 (2505.0-4124.0)	---	2630.7 (1867.0-4124.0)
10	---	1693.0 (1245.0-2141.0)	---	3560.7 (3179.0-3936.0)	---	5055.5 (4901.0-5210.0)	---	3822.3 (2141.0-5210.0)
11	---	1976.0 (1317.0-2635.0)	---	3804.3 (1955.0-5264.0)	---	3440.5 (3145.0-3736.0)	---	3488.2 (1955.0-5264.0)
12	---	1931.5 (1522.0-2341.0)	---	3203.3 (2397.0-4371.0)	---	4016.5 (3852.0-4181.0)	---	3330.7 (2341.0-4371.0)
13	---	1877.0 (1404.0-2350.0)	---	3882.0 (1906.0-7037.0)	---	4324.0 (3664.0-4984.0)	---	3774.0 (1906.0-7037.0)
14	---	1803.0 (1494.0-2112.0)	---	3866.7 (2284.0-6024.0)	---	5035.5 (4736.0-5335.0)	---	3963.8 (2112.0-6024.0)
15	---	2684.5 (1827.0-3542.0)	---	2713.7 (2275.0-3230.0)	---	3253.0 (2753.0-3753.0)	---	3031.5 (2275.0-3753.0)

[1] Data for May 1992.
[2] Includes data from May through October, yearly.

upstream (Figure 10-7). Embayment densities were usually higher, sometimes much higher, than nearby mainstem station densities (Table 10-23).

Green algae (Division Chlorophyta) and yellow green algae (Division Chrysophyta) shared dominance in Lake George during the two growing seasons. Green algae were more prevalent in 1992 and yellow green algae (primarily diatoms) more abundant in 1993 (Figure 10-8). No other algal Division approached dominant status. The euglenoids (Division Euglenophyta) were the third most abundant group followed by the bluegreen algae (Division Cyanobacteria) and the dinoflagellates (Division Pyrrhophyta). Phytoplankton community structure was similar in 1989 and 1990 (Bayne and Maceina 1992).

Fifty-eight algal taxa were identified during the study (Table 10-24). Virtually all of the organisms have been previously reported from Georgia reservoirs (Morris *et al.* 1977). Green algal taxa were most numerous followed by blue-green algae and diatoms (Table 10-24).

Pennate diatoms were common and abundant throughout the reservoir and, in aggregate, were numerically dominant on most sampling occasions (Table 10-25). The most commonly encountered pennate diatoms that could be identified without special preparation were *Tabellaria* sp., *Asterionella formosa* and *Fragilaria* sp. The centric diatoms, *Melosira distans* and *M. granulata* were abundant and frequently ranked among the top three dominant organisms (Table 10-25). Dominant green algae included *Ankistrodesmus convolutus*, *Chlamydomonas* sp., *Scenedesmus quadricauda*, *A. nannoselene* and *Gloeocystis* sp. *Trachelomonas* sp. was the only euglenoid and *Peridinium* sp. the only dinoflagellate among the dominant taxa in the lake. No blue-green algae were ever dominant.

Among the dominant phytoplankton genera, all occur with great frequency in reservoirs of the southeastern United States (Taylor *et al.* 1979). Palmer (1969) Figure 10-7.

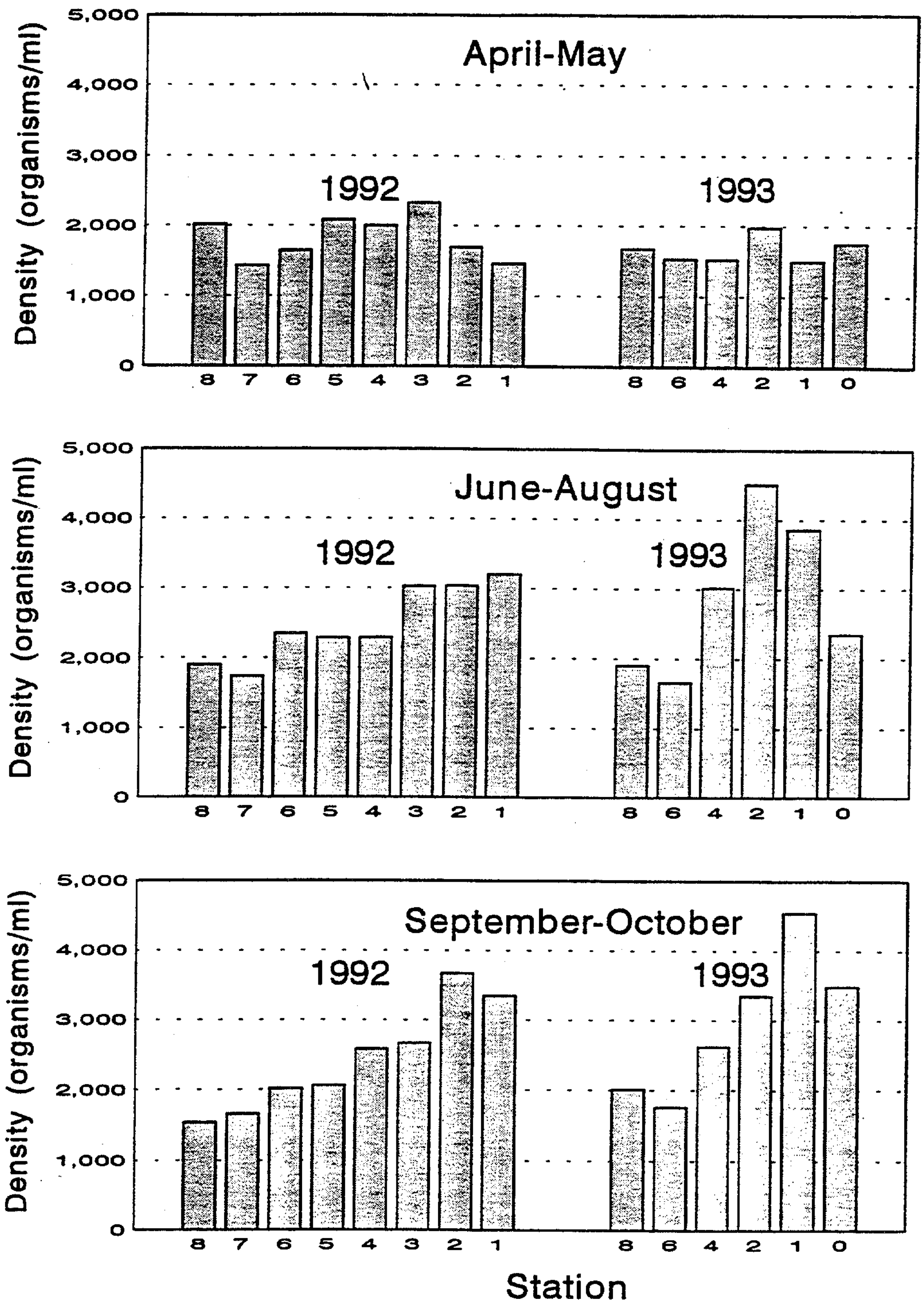


Figure 10-7. Mean phytoplankton densities at main stem sampling stations (headwaters at station 8 and dam at station 1) during the diagnostic study of Lake W. F. George, April 1992 through October 1993. In 1992 no April sample was taken.

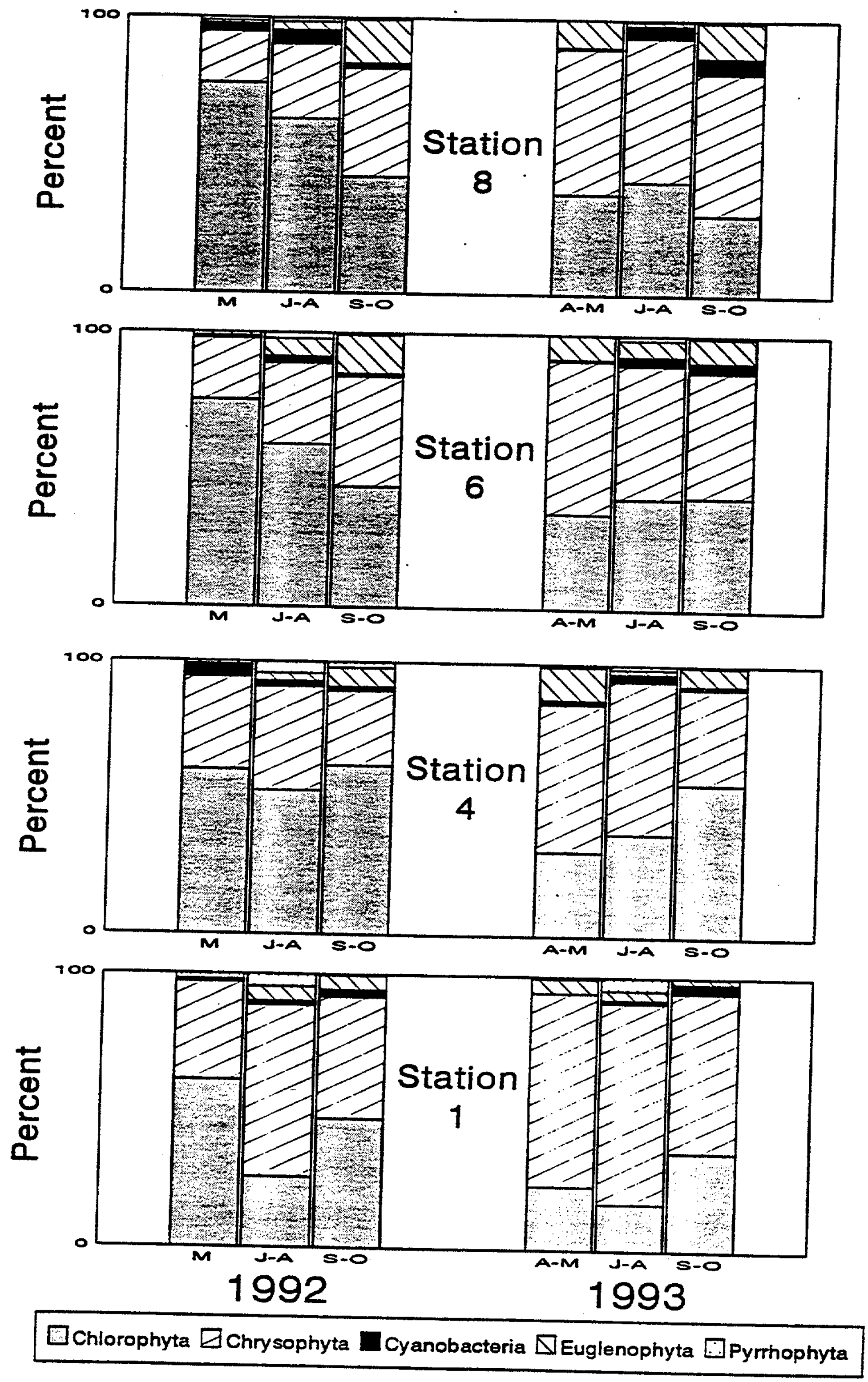


Figure 10-8. Percent composition of mean phytoplankton densitites by algal Division at stations 8, 6, 4 and 1 (dam forebay) during the diagnostic study of Lake W. F. George, April 1992 through October 1993 (A-M=April-May, M=May, J-A=June-August, S-O=September-October). In 1992 no April sample was taken.

Table 10-24. Taxa list of plankton algae identified in Lake W.F. George during the growing seasons of 1992 and 1993.

Chlorophyta
- *Actinastrum* sp.
- *Ankistrodesmus convolutus*
- *A. falcatus*
- *A. nannoselene*
- *Chlamydomonas* sp.
- *Chodatella* sp.
- *Closteriopsis* sp.
- *Closterium* sp.
- *Coelastrum* sp.
- *Cosmarium* sp.
- *Crucigenia* sp.
- *Dictyosphaerium* sp.
- *Euastrum* sp.
- *Franceia* sp.
- *Gloeocystis* sp.
- *Golenkinia* sp.
- *Kirchneriella* sp.
- *Micrasterias* sp.
- *Oocystis* sp.
- *Pachycladon* sp.
- *Pandorina* sp.
- *Pediastrum* sp.
- *Scenedesmus* sp.
- *S. abundans*
- *S. acuminatus*
- *S. armatus*
- *S. denticulatus*
- *S. quadricauda*
- *Schroederia* sp.
- *Selenastrum* sp.
- *Sphaerocystis* sp.
- *Staurastrum* sp.
- *Tetraedron* sp.
- *T. gracile*
- *T. minimum*
- *Tetrastrum* sp.
- *Treubaria* sp.

Chrysophyta
- *Asterionella* sp.
- *Dinobryon* sp.
- *Fragilaria* sp.
- *Melosira distans*
- *M. granulata*
- *Tabellaria* sp.
- Centric diatom
- Pennate diatom

Table 10-24 continued.

Cyanobacteria
Aphanocapsa sp.
Chroococcus sp.
Coelosphaerium sp.
Gomphosphaeria sp.
Merismopedia sp.
Oscillatoria sp.
Rhaphidiopsis sp.
Spirulina sp.
Euglenophyta
Euglena sp.
Phacus sp.
Trachelomonas sp.
Pyrrophyta
Ceratium sp.
Peridinium sp.

Table 10-25. Dominant algal taxa encountered at representative mainstem sampling stations on Lake W.F. George during the 1992 and 1993 growing seasons.

Year	Stations 1	2	4	6	8
1992					
May	1. Gloeocystis sp. 2. Pennate diatom 3. Chlamydomonas sp. 3. Asterionella sp. 3. Melosira granulata	1. Gloeocystis sp. 1. Melosira granulata 2. Pennate diatom 3. Chlamydomonas sp.	1. Pennate diatom 2. Ankistrodesmus convolutus 3. Ankistrodesmus nannoselene	1. Ankistrodesmus convolutus 2. Pennate diatom 3. Scenedesmus quadricauda	1. Ankistrodesmus convolutus 2. Pennate diatom 3. Chlamydomonas sp.
June-Aug	1. Pennate diatom 2. Melosira granulata 3. Chlamydomonas sp.	1. Pennate diatom 2. Ankistrodesmus convolutus 3. Chlamydomonas sp.	1. Pennate diatom 2. Chlamydomonas sp. 3. Ankistrodesmus convolutus	1. Pennate diatom 2. Chlamydomonas sp. 3. Ankistrodesmus convolutus	1. Chlamydomonas sp. 2. Pennate diatom 3. Scenedesmus quadricauda
Sept-Oct	1. Pennate diatom 2. Ankistrodesmus convolutus 3. Melosira granulata	1. Pennate diatom 2. Ankistrodesmus convolutus 3. Scenedesmus sp.	1. Chlamydomonas sp. 2. Pennate diatom 3. Scenedesmus sp.	1. Pennate diatom 2. Chlamydomonas sp. 3. Trachelomonas sp.	1. Pennate diatom 2. Chlamydomonas sp. 3. Trachelomonas sp.
1993					
April-May	1. Melosira distans 2. Pennate diatom 3. Centric diatom	1. Melosira distans 2. Pennate diatom 3. Melosira granulata	1. Pennate diatom 2. Melosira distans 3. Trachelomonas sp.	1. Pennate diatom 2. Chlamydomonas sp. 3. Melosira distans	1. Pennate diatom 2. Chlamydomonas sp. 3. Trachelomonas sp.
June-Aug	1. Pennate diatom 2. Chlamydomonas sp. 3. Peridinium sp.	1. Pennate diatom 2. Chlamydomonas sp. 3. Melosira granulata	1. Pennate diatom 2. Chlamydomonas sp. 3. Ankistrodesmus convolutus	1. Pennate diatom 2. Chlamydomonas sp. 3. Melosira distans	1. Pennate diatom 2. Chlamydomonas sp. 3. Melosira granulata
Sept-Oct	1. Pennate diatom 2. Ankistrodesmus convolutus 3. Melosira granulata	1. Pennate diatom 2. Ankistrodesmus convolutus 3. Scenedesmus sp.	1. Pennate diatom 2. Chlamydomonas sp. 2. Melosira distans 3. Ankistrodesmus convolutus	1. Melosira distans 2. Pennate diatom 3. Chlamydomonas sp.	1. Pennate diatom 2. Melosira distans 3. Trachelomonas sp.

listed *Ankistrodesmus*, *Chlamydomonas*, *Melosira* and *Scenedesmus* as genera of algae tolerant of organic pollution. In addition, practically all of the genera listed in Table 10-25 were found to occur most frequently at mean total phosphorus concentrations ranging from 100 to 200 µg/L and mean NO_2^- + NO_3^- concentrations of from 350 to 700 µg/L (Lambou *et al.* 1981). The phytoplankton community of Lake George is indicative of a typical nutrient enriched southeastern reservoir.

Phaeophytin-corrected, chlorophyll a concentration is an indicator of phytoplankton biomass and is a variable often used to determine the trophic status of lakes in the absence of macrophytes (Carlson 1977, EPA 1990). It is a variable that integrates the physical, chemical and biological environmental components into one expression of biotic response and is, therefore, superior to simple physical (water transparency) or chemical (nutrients) variables used to characterize trophic status (Hern *et al.* 1981). Corrected chlorophyll a concentrations from about 6.4 to 56.0 µg/L are indicative of eutrophic water (Carlson 1977). Waters having concentrations >56.0 µg/L are considered hypereutrophic. Maximum chlorophyll a concentrations reported for Lake George have been in the range of 20-25 µg/L (Bayne and Maceina 1992, EPD 1993b).

During this study chlorophyll a concentrations ranged from a high of 20.3 µg/L at station 2 in September 1992 to a low of 1.7 µg/L in the Hatchechubbee Creek embayment in April 1993 (Table 10-26). With the exception of May 1992, mean chlorophyll a concentrations were usually highest in the lacustrine zone between stations 1 and 4 (Figure 10-9). Chlorophyll a concentrations measured in tributary embayments were generally higher than concentrations measured at the nearest mainstem sampling station (Table 10-26).

Chlorophyll a concentrations were higher in 1992 than in 1993 even though rainfall and stream discharge were lower in 1993 (Table 10-4). In fact, there

Table 10-26. Mean (range) chlorophyll a concentrations ($\mu g/L$) measured at fifteen sampling stations on Lake W.F. George during the growing seasons of 1992 and 1993.

Stations	April-May		June-August		Sept-October		Growing Season[2]	
	1992[1]	1993	1992	1993	1992[3]	1993	1992	1993
Mainstem								
0	---	5.1 (2.0-8.1)	---	6.1 (4.4-8.7)	---	5.6	---	5.7 (2.0-8.7)
1	9.4	4.9 (2.4-7.5)	10.7 (9.8-11.6)	7.9 (6.3-9.6)	18.7	13.4 (9.2-17.5)	12.0 (9.4-18.7)	8.6 (2.4-17.5)
2	5.3	5.0 (3.5-6.5)	14.1 (10.0-19.6)	8.1 (4.4-11.5)	20.3	12.4 (11.8-13.0)	13.6 (5.3-20.3)	8.4 (3.5-13.0)
3	8.2	---	10.2 (8.0-12.0)	---	12.7	---	10.3 (8.0-12.7)	---
4	8.2	4.6 (2.9-6.3)	13.6 (9.8-15.6)	8.3 (7.9-9.2)	17.4	8.9 (7.9-9.9)	13.7 (8.2-17.4)	7.4 (2.9-9.9)
5	11.1	---	13.6 (12.7-14.7)	---	17.1	---	13.8 (11.1-17.1)	---
6	9.6	3.0 (2.9-3.1)	10.5 (8.0-13.4)	6.2 (3.9-7.7)	14.9	7.9 (7.8-8.0)	11.2 (8.0-14.9)	5.8 (2.9-8.0)
7	19.6	---	10.3 (6.9-16.0)	---	8.9	---	11.9 (6.9-19.6)	---
8	14.7	2.9 (2.7-3.1)	9.6 (5.8-15.4)	5.3 (2.8-7.1)	10.9	6.4	10.9 (5.8-15.4)	4.9 (2.7-7.1)
Embayment								
9	---	4.5 (1.7-7.2)	---	9.3 (5.5-13.4)	---	11.4 (10.0-12.8)	---	8.5 (1.7-13.4)
10	---	5.3 (2.5-8.0)	---	12.2 (9.1-18.3)	---	15.4 (13.0-17.8)	---	11.1 (2.5-18.3)
11	---	6.3	---	11.4 (11.2-11.6)	---	11.5 (9.8-13.2)	---	10.6 (6.3-13.2)
12	---	4.6 (3.3-5.9)	---	9.1 (8.3-10.2)	---	16.5 (14.2-18.8)	---	9.9 (3.3-18.8)
13	---	3.7 (3.1-4.3)	---	8.0 (7.2-9.2)	---	14.0 (13.1-14.8)	---	8.5 (3.1-14.8)
14	---	5.1 (3.9-6.3)	---	8.6 (7.3-10.6)	---	14.1 (14.0-14.2)	---	9.2 (3.9-14.2)
15	---	9.2 (4.0-14.4)	---	7.6 (5.7-8.8)	---	13.8 (13.0-14.6)	---	9.8 (4.0-14.6)

[1] Data for May 1992.
[2] Includes data from May through October, yearly.
[3] October samples were lost.

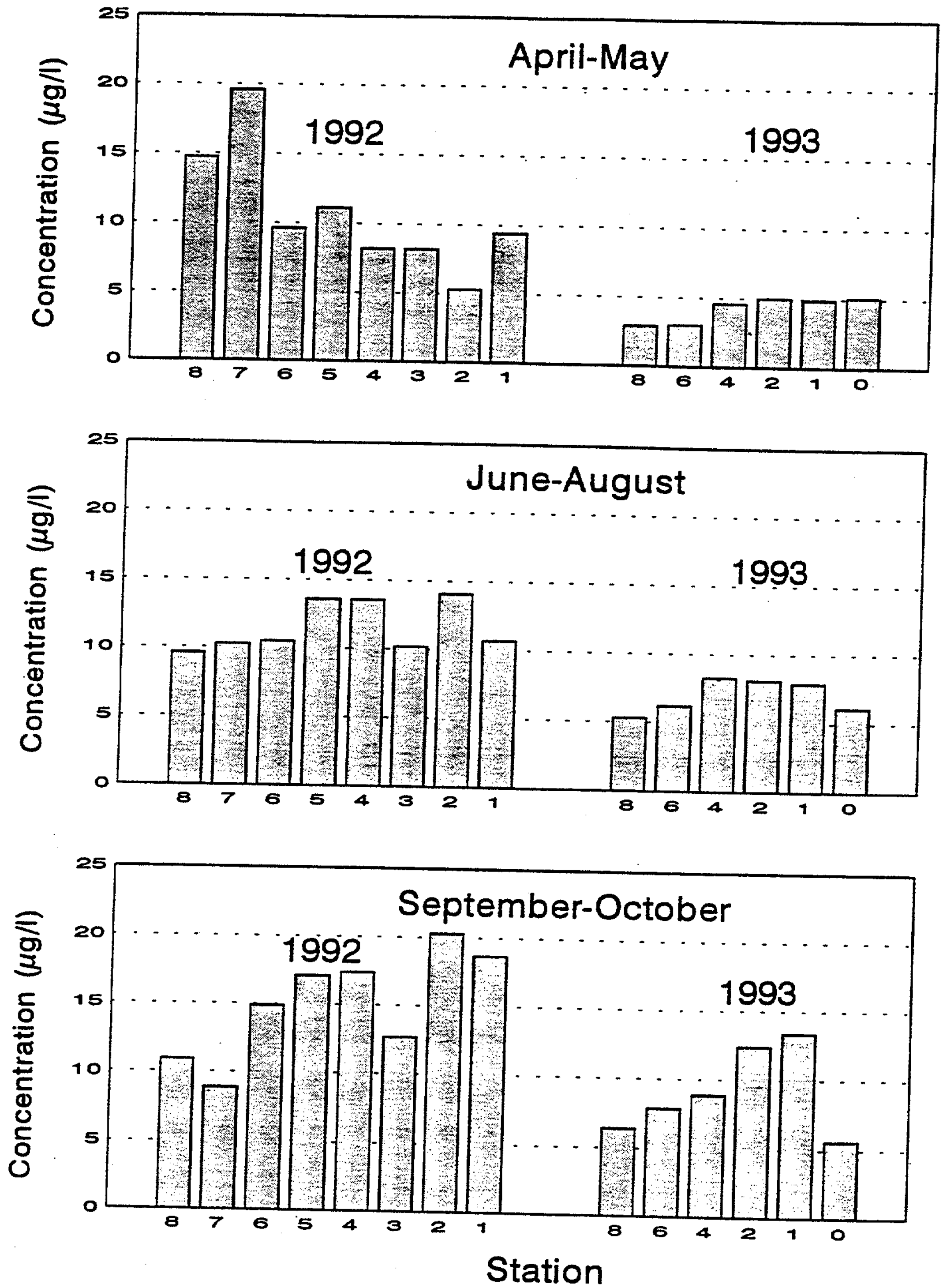


Figure 10-9. Mean chlorophyll a concentrations at main stem sampling stations (headwaters at station 8 and dam at station 1) during the diagnostic study of Lake W. F. George, April 1992 through October 1993. In 1992 no April sample was taken.

appears to be a trend of declining algal biomass in Lake George during the period 1989 through 1993 (Table 10-27). This could be a response to the apparent decline in TP caused by the phosphate detergent ban that went into effect in 1991 (Table 10-20).

Phytoplankton primary productivity is the rate of formation of organic matter over a specified time period (Wetzel 1983). The C-14 method of measuring productivity approximates net productivity, which is the gross accumulation of new organic matter minus any losses (e.g. respiration) that occur during the specified time interval. Phytoplankton biomass is an important variable influencing primary productivity although the efficiency with which a unit of phytoplankton biomass produces a unit of organic matter (photosynthetic efficiency) is quite variable (Fogg 1965). Efficiency can be affected by such physicochemical variables as light, temperature, degree of turbulence and nutrients. Species composition, size structure of the plankton algae and predation are examples of biotic influences on efficiency. Bayne *et al.* (1990) reported photosynthetic efficiencies (mgC fixed per mg chlorophyll a • hour) of West Point Lake phytoplankton communities ranging from 0.2 to 4.9. Phytoplankton primary productivity integrates a number of environmental variables in addition to algal biomass into an expression of system productivity. Productivity rates have also been used to trophically categorize lakes. Lakes with productivities ranging from 250-1000 mgC/m^2•day are considered mesotrophic and values >1000 mgC/m^2•day are eutrophic (Wetzel 1983).

Primary productivity of Lake George during the growing season of 1993 was indicative of a moderately eutrophic system with growing season mean production rates varying from a low of 980 mgC/m^2•day at transition station 6 to a high of 1,321 mgC/m^2•day at the upstream lacustrine station 4 (Table 10-28 and Figure 10-10).

Table 10-27. Trends in growing season chlorophyll *a* (phaeophytin corrected) and phytoplankton primary productivity in Lake W.F. George from 1989 through 1993.

Station	1989[1]	1990[1]	1991[2]	1992	1993
	Chlorophyll *a* µg/l				
1	16.1	10.6	14.5	12.0	8.6
4	20.1	15.4	15.3	13.7	7.4
	Primary Productivity (mgC/m²•day)				
1	1,269	1,035	--	--	1,045
4	1,354	1,789	--	--	1,321

[1] Bayne and Maceina 1992.
[2] EPD 1993.

Table 10-28. Mean phytoplankton primary productivity measured at four mainstem sampling stations on Lake W.F. George during the 1993 growing season.

Mainstem Stations	May		June		July		August		September		Growing Season	
	$mgC/m^3 \cdot day$	$mgC/m^2 \cdot day$	$mgC/m^3 \cdot day$	$mgC/m^2 \cdot day$	$mgC/m^3 \cdot day$	$mgC/m^2 \cdot day$	$mgC/m^3 \cdot day$	$mgC/m^2 \cdot day$	$mgC/m^3 \cdot day$	$mgC/m^2 \cdot day$	$mgC/m^3 \cdot day$	$mgC/m^2 \cdot day$
1	10.3	499.7	16.7	1091.7	14.9	1293.4	16.6	1480.2	22.3	857.9	16.1 (10.3-22.7)	1044.6 (499.7-1480.2)
2	7.6	295.7	17.9	1173.9	31.5	2065.7	11.5	679.0	27.3	886.7	19.2 (7.6-31.5)	1020.2 (295.7-2065.7)
4	11.5	485.4	32.7	1351.1	36.3	1854.0	19.6	1502.8	37.4	1410.6	27.5 (11.5-37.4)	1320.8 (485.4-1854.0)
6	9.6	345.2	45.3	1167.6	53.0	2086.1	10.5	456.3	42.0	844.8	32.1 (9.6-53.0)	980.0 (345.2-2086.1)

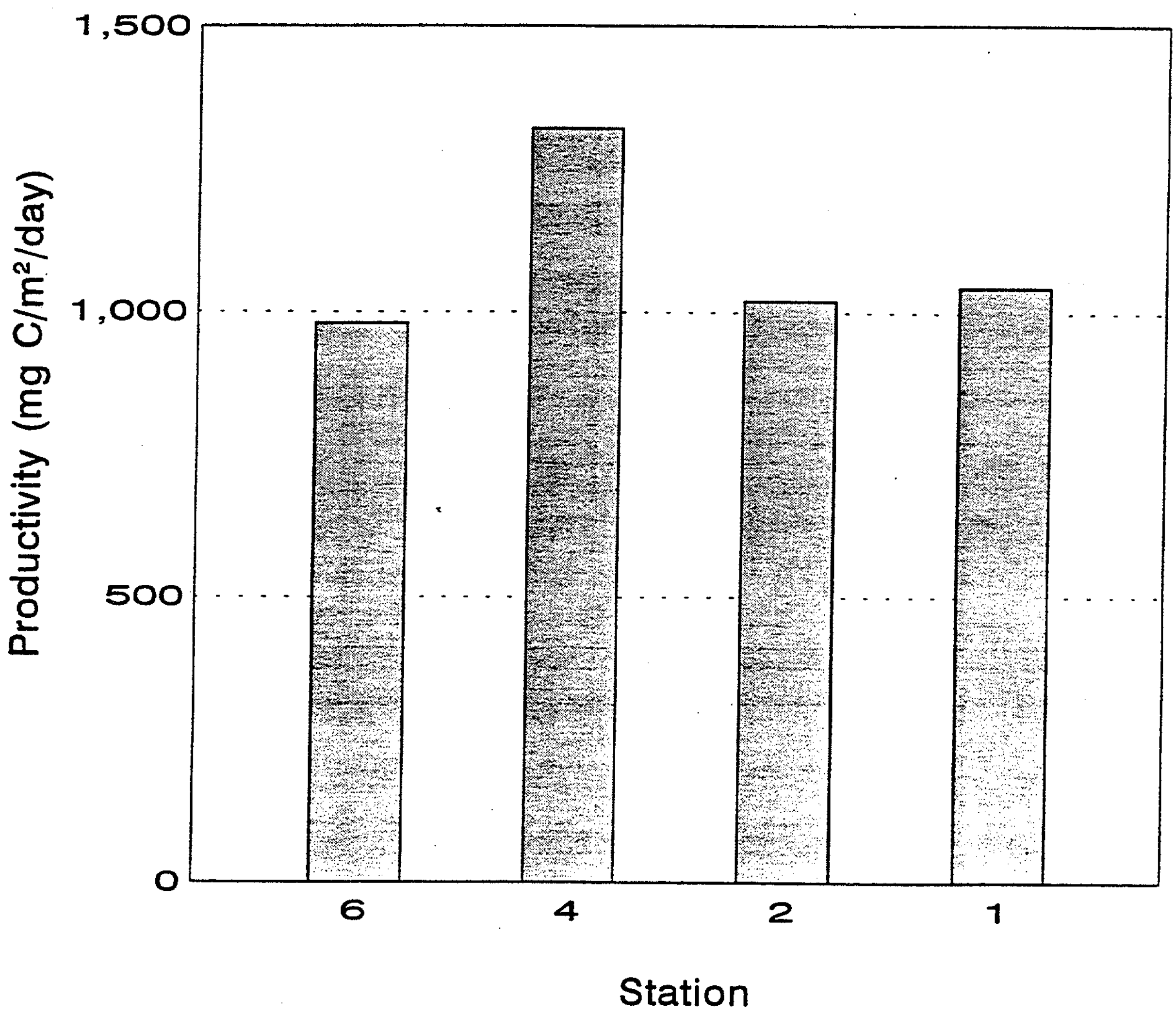


Figure 10-10. Mean primary productivity (mg $C/m^2/day$) at stations 1 (dam forebay), 2, 4 and 6 during May through September, 1993.

Based on the limited data available, Lake George productivity does not appear to be increasing (Table 10-27).

The Algal Growth Potential Test (AGPT) determines the total quantity of algal biomass supportable by the test waters and provides a reliable estimate of the bioavailable and limiting nutrients (Raschke and Schultz 1987). Algal growth potential was much higher at upstream stations 6 and 8 than at downstream locations (Table 10-29). Station 6 concentrations were about an order of magnitude higher than dam forebay (station 1) concentrations each month and the seasonal mean for this station was the highest of all stations. The increase in algal biomass from station 8 to station 6 was partially caused by the nutrient enrichment resulting from the discharge of treated effluent by the Mead Corporation Paper Mill located between stations 8 and 6. Also, Hannahatchee Creek, entering the lake between stations 8 and 6, maintained the highest mean TP concentration (94 μg/L) during the growing season of all monitored tributaries (EPD 1993b).

With the exception of May, mean algal biomass at downstream stations 1 and 2 remained below 5.0 mg/L, the threshold concentration thought to afford protection from nuisance algal blooms and fish-kills in southeastern lakes, excluding Florida (Raschke and Schultz 1987). Concentrations exceeding 10 mg/L are indicative of eutrophic conditions likely to result in nuisance algal blooms. Stations 4, 6 and 8 had seasonal mean biomass concentrations in excess of 10 mg/L and station 6 had a mean of 20.1 mg/L (Table 10-29).

In most freshwater lakes, phosphorus is the essential plant nutrient that limits growth and productivity of plankton algae (Wetzel 1983). Nitrogen usually becomes the limiting nutrient when bioavailable phosphorus increases relative to nitrogen, as in the case of waters receiving quantities of treated municipal

Table 10-29. Mean maximum dry weight (mg/L) of Selenastrum capricornutum cultured in Lake George waters from May through September 1993.

Mainstem Stations	Mean Maximum Dry Weight (mg/L) Month					
	May	June	July	August	September	Season Mean
1	8.1	4.4	2.2	2.7	2.2	3.9
2	8.7	3.2	2.3	3.7	2.9	4.2
4	15.5	11.4	21.8	11.5	3.8	12.8
6	24.4	21.0	16.0	15.6	23.5	20.1
8	21.3	19.7	18.0	6.5	7.7	14.6

[1] Results of Algal Growth Potential Tests conducted by the Ecological Support Branch, U.S.E.P.A. Region IV, Athens, Georgia.

waste (Raschke and Schultz 1987). The AGPT is helpful in identifying these common growth limiting nutrients. With the exception of station 4 in July 1993 and station 6 in June, August and September 1993 all stations were phosphorus limited during the 1993 growing season (Table 10-30). The co-limitation (N and P) at station 6 likely resulted from an increase in bioavailable phosphorus released into the lake between stations 8 and 6. EPD (1993b) reported similar findings (Table 10-30).

Total organic carbon (TOC) concentrations are composed of dissolved and particulate fractions and the ratio of dissolved to particulate ranges from 6:1 to 10:1 in most unpolluted lakes (Wetzel 1983). Most of the particulate fraction is composed of dead organic matter with living plankton contributing a small amount to the total (Wetzel 1983). Dissolved organic carbon, most of which is contributed from the watershed, tends to stabilize TOC concentrations and prevents wide fluctuations in concentration both spatially and temporally. TOC concentrations in Lake George ranged from a low of 2.5 mg/L at station 8 in May 1993 to a high of 14.6 mg/L at station 1 in July 1993. Mean growing season concentrations ranged from 3.5 to 5.5 mg/L at mainstem stations and 4.3 to 5.5 mg/L at the tributary embayment stations (Table 10-31).

Table 10-30. Temporal and spacial variation in nutrient limitation based on results of Algal Growth Potential Tests conducted during the growing seasons of 1991 and 1993.

Date	Limiting Nutrient Mainstem Station 1	2	3	4	6	8
1991[1]						
May	--	--	P	P	P	P
July	--	--	P	N/P	N	N/P
September	--	--	P	N/P	N	N/P
1993						
May	P	P	--	P	P	P
June	P	P	--	P	N/P	P
July	P	P	--	N	P	P
August	P	P	--	P	N/P	P
September	P	P	--	P	N/P	P

[1] EPD 1993b.

Table 10-31. Mean (range) total organic carbon concentration (mg/L) measured at fifteen sampling stations on Lake W.F. George during the growing seasons of 1992 and 1993.

Stations	April-May		June-August		Sept-October		Growing Season[2]	
	1992[1]	1993	1992	1993	1992	1993	1992	1993
Mainstem								
0	---	3.8 (3.4-4.3)	---	4.6 (3.3-6.7)	---	3.2 (3.1-3.3)	---	3.9 (3.1-6.7)
1	4.3	3.4 (3.2-3.5)	4.0 (3.8-4.1)	7.7 (4.2-14.6)	3.8 (3.8-3.9)	3.9 (3.8-3.9)	4.0 (3.8-4.3)	5.7 (3.2-14.6)
2	3.8	3.8 (3.4-4.2)	4.1 (3.8-4.3)	4.7 (3.6-6.7)	3.8 (3.8-3.8)	3.6 (3.3-3.9)	3.9 (3.8-4.3)	4.1 (3.3-6.7)
3	3.7	---	4.0 (3.7-4.1)	---	3.8 (3.7-4.0)	---	3.9 (3.7-4.1)	---
4	3.9	4.3 (3.0-5.5)	3.7 (3.4-4.0)	4.3 (3.4-5.7)	4.0 (3.5-4.4)	3.7 (3.7-3.8)	3.8 (3.4-4.4)	3.9 (3.0-5.7)
5	4.0	---	3.7 (3.3-4.1)	---	3.9 (3.3-4.5)	---	3.8 (3.3-4.5)	---
6	3.3	3.2 (2.8-3.5)	3.4 (3.2-3.5)	5.0 (2.7-8.5)	4.2 (4.0-4.3)	6.9 (6.9-6.9)	3.6 (3.2-4.3)	5.3 (2.7-8.5)
7	3.3	---	3.2 (2.9-3.5)	---	4.1 (3.6-4.6)	---	3.5 (2.9-4.6)	---
8	3.3	2.8 (2.5-3.1)	3.3 (3.1-3.6)	6.4 (3.0-12.5)	3.8 (3.6-4.0)	5.5 (3.1-7.9)	3.5 (3.1-4.0)	5.5 (2.5-12.5)
Embayment								
9	---	6.9 (4.0-9.7)	---	4.5 (2.9-7.6)	---	3.8 (3.7-4.0)	---	4.3 (2.9-7.6)
10	---	9.1 (6.6-11.6)	---	6.0 (5.4-6.4)	---	4.3 (4.0-4.5)	---	5.5 (4.0-6.6)
11	---	5.3 (4.0-6.5)	---	5.4 (2.9-9.5)	---	3.7 (3.4-4.0)	---	4.6 (2.9-9.5)
12	---	6.1 (3.9-8.3)	---	4.9 (3.1-7.7)	---	7.3 (4.5-10.0)	---	5.5 (3.1-10.0)
13	---	4.2 (3.6-4.8)	---	5.3 (3.5-8.7)	---	4.3 (4.2-4.3)	---	4.7 (3.5-8.7)
14	---	3.7 (3.3-4.1)	---	5.7 (3.8-8.0)	---	3.9 (3.5-4.3)	---	4.7 (3.3-8.0)
15	---	3.8 (3.6-4.1)	---	6.1 (3.3-10.7)	---	3.4 (3.3-3.5)	---	4.8 (3.3-10.7)

[1] Data for May 1992.
[2] Includes data from May through October, yearly.

10.2.3 BACTERIA

The coliform group of bacteria are found in the gut and feces of warm-blooded animals. This group of bacteria is used as an indicator of suitability of water for various uses (APHA *et al.* 1992). Coliform density is widely accepted as a criterion of the degree of pollution and sanitary quality of surface waters.

Water samples for total fecal coliform analysis were collected monthly at Lake George sampling stations 1 and 8 from June through August and again in October 1992 (Table 10-1). Samples were taken just under the water surface using a sterilized container. The container was then placed on ice and transported to laboratory facilities at Auburn University, Alabama for analysis. Total fecal coliform densities were determined using the membrane filter procedure (APHA *et al.* 1992).

Fecal coliform densities in Lake George were low during the summer of 1992 (Table 10-32). Only five samples, all taken in October, exceeded a density of 20 fecal coliform colonies per 100 ml and, in those cases, densities were below the limits established to maintain water quality to support designated water uses of the lake. The Alabama portion of Lake George is use-classified as Swimming and Fish and Wildlife from the dam to Cowikee Creek and Fish and Wildlife from Cowikee Creek to Phenix City, AL/Columbus, GA. The bacterial water quality is considered acceptable for both swimming and summertime (June through September) fishing if the geometric mean (at least five samples collected within a 30 day period) fecal coliform density does not exceed 200 colonies/100 ml.

Table 10-32. Fecal coliform bacterial densities (fecal coliform colonies/100ml) measured monthly during the growing season of 1992 in Lake W.F. George.

	Fecal Coliform Colonies per 100 ml				
	Date				
Station	5/26	6/16	7/14	8/4	10/5
1	*	*	*	*	*
2	*	*	*	*	40
3	*	*	*	*	*
4	*	*	*	*	*
5	*	*	*	*	20
6	*	*	*	*	90
7	*	*	*	*	100
8	*	*	*	*	140

* = <20 colonies/100ml.

10.2.4 MACROPHYTE SURVEY

A macrophyte survey of Lake George was conducted late in the growing season of 1993. The survey was conducted from shallow draft boats and was limited to the main body of the lake and larger tributary embayments. Initial reconnaissance revealed the most significant concentrations of macrophytes were in the upstream reach of the lake from about River Bend Park (13 miles upstream to station 8) downstream to Cowikee Creek (station 5) (Figure 10-1). However, scattered stands of macrophytes were noted all the way to the dam, particularly in coves and embayments.

A list of macrophytes identified during the survey appears in Table 10-33. All of the plants found were marginal emergents, rooted in the substrate and confined to shallow water (<1 m) areas. Two species, alligator-weed (*Alternanthera philoxeroides*) and water primrose (*Ludwigia peploides*), when growing in water, produce hollow stems that float on the water surface forming floating mats of vegetation. These species can become troublesome. The only submersed aquatics found during the survey were filamentous algae, however, no significant concentrations of algae were noted.

Dominant macrophytes included alligator-weed, water-willow (*Justicia americana*), grasses (mainly *Panicum hemitomon* and *P. repens*) and *Sesbania* spp. (mainly *S. macrocarpa*). These plants usually grew in scattered colonies along the shoreline in water <1.0 m deep. Full pool during the summer months is normally 190 feet above mean sea level (msl). During this survey conducted in October the lake elevation was 186.4 feet msl and virtually all of the plants were on exposed shorelines. The area of the lake exposed when the water level is at 187 feet msl is 1,799 ha (Personal Communication, Memphis Vaughan, U.S. Army Corps of Engineers). Given the plant taxa involved, this 1,799 ha-area

Table 10-33. Vascular aquatic plants identified in a survey conducted on Lake George 6 October 1993.

Species	Common Name
Alternanthea philoxeroides	alligator-weed
Alnus serrulata	alder
Amorpha fruiticosa	bastard-indigo
Ampelopsis arborea	pepper-vine
Arundanaria gigantea	cane
Baccharis halimifolia	groundsel-tree
Betula nigra	river birch
Campsis radicans	trumper-creeper
Cephalanthus occidentalis	button bush
Cuscuta sp.	dodder
Cyperus albomarginatus	sedge
Diodia virginiana	buttonweed
Echinochloa walteri	water grass
Eclipta alba	--
Erianthus sp.	plumegrass
Hemicarpha micrantha	--
Hibiscus militaris	halberd-leaved marshmallow
Hydrolea quadrivalvis	--
Juncus effusus	soft rush
Justicia americana	water-willow
Ludwigia decurrens	--
L. peploides	--
Mikania scandens	climbing hempweed
Myrica cerifera	wax myrtle
Panicum hemitomon	maidencane
P. repens	torpedo grass
Pluchea camphorata	stinkweed
Polygonum punctatum	smartweed
Rotala ramosior	toothcup
Sacciolepis striata	--
Salix nigra	black willow
Sesbania macrocarpa	--
S. punicea	rattlebox
S. vesicaria	bag pod

could be considered the maximum potential area of colonization for Lake George. Only a fraction (perhaps 10-20%) of this area is now colonized.

Alligator-weed is an aggressive exotic weed species forming floating mats of vegetation. The plant has the potential to spread and increase coverage in quiescent waters of Lake George. In most infested areas, alligator-weed was scattered in shoreline colonies some of which were up to 100 m in length and 1 to 3 m wide. The shoreline bordering the Eufaula National Wildlife Refuge on both sides of the lake was particularly well colonized. Alligator-weed and *Sesbania* spp. were usually found in relatively shallow (<0.7 m) areas.

Occupying slightly deeper (1.0 m) water were maiden cane and water-willow. These plants root in the substrate and grow erect and emergent, not forming floating mats at the surface. While none of these dominant plants are of particular value to wildlife (Fassett 1966), they do help stabilize shorelines and prevent erosion.

EPD (1993b) reported the presence of two potentially noxious aquatic plants not found in our survey. Relatively small stands of giant cutgrass, *Zizaniopsis miliacea*, and spiney leaf naiad, *Najas minor*, were found in a survey of Lake George conducted in 1991. COE personnel attempted to control these plants with herbicides following their discovery.

More recently two other potentially troublesome aquatic plants have been found. In June 1993 Florida elodea, *Hydrilla verticillata*, was located growing near the boat ramp at the East Bank Recreational Area (Personal Communication, Ron Puhr, U.S. Army COE). The colony covered an area of about one-eighth acre and apparently had not spread beyond the East Bank Recreational Area. A total of four herbicide treatments were applied during the 1993 growing season in hopes of eradicating or, at least, controlling the spread of this plant. Herbicides were also used to control small stands of waterweed, *Egeria densa*, at scattered locations in the lake. The herbicide treatments combined with the effects of the annual 1 m water-level fluctuation may prevent proliferation of these noxious weed species.

11.0 BIOLOGICAL RESOURCES

11.1 FISHERY

Lake George is nationally known for its largemouth bass fishery. Numerous fishery studies have been conducted on the lake since impoundment in 1962. Both the Alabama Department of Conservation and Natural Resources and the Georgia Department of Natural Resources have ongoing programs since both Alabama and Georgia border the lake. Table 11.1 lists fish species expected in the river and surrounding watershed prior to impoundment.

This reservoir has gone through several "boom and bust" years in largemouth bass harvest. Fisheries biologists feel that the cyclic nature of the shad populations control this cycling in bass abundance (Newman *et al.* 1993). This fluctuation in bass harvest caused concern among fishermen with the result being the installation of a 16 inch minimum size limit on bass in July, 1992. The purpose of this limit was to conserve the bass that are present and protect the young bass when the cycle trends upward again.

Tables 11.2 - 11.3 present some results of 1992 and 1993 fishery studies conducted by the Alabama Department of Conservation and Natural Resources. Table 11.4 presents a comparison of the harvest of dominant fish species over recent years. Fluctuations are particularly evident in bass, shad and bluegill. Success of the 16 inch length limit on largemouth bass harvest will be evaluated in subsequent years.

Alabama initiated a hybrid bass stocking program in Lake George in 1975. This program has been continued by both Alabama and Georgia to the present and has produced an excellent fishery both in the reservoir and the tailwaters (Newman *et al.* 1994).

Table 11.1. A checklist of warm-water fish species believed to be present in Walter F. George Lake, separated into game (G), commercial (C), and other groupings (O).

Scientific Name	Category	Common Name
Ichthyomyzon gagei	(O)	Southern Brook Lamprey
Lepisosteus occulatus	(O)	Spotted gar
Lepisosteus osseus	(O)	Longnose gar
Amia calva	(O)	Bowfin
Anguilla rostrata	(C)	American eel
Alosa chrysochloris	(O)	Skipjack herring
Dorosoma cepedianum	(O)	Gizzard shad
Dorosoma petenense	(O)	Threadfin shad
Cyprinella callitaenia	(O)	Bluestripe shiner
Cyprinella venustus	(O)	Blacktail shiner
Cyprinus carpio	(O)	Carp (introduced)
Luxilus zonistius	(O)	Bandfin shiner
Lythrurus atrapiculus	(O)	Blacktip shiner
Nocomis leptocephalus	(O)	Bluehead chub
Notemigonus chrysoleucas	(O)	Golden shiner
Notropis buccatus	(O)	Silverjaw minnow
Notropis euryzonus	(O)	Broadstripe shiner
Notropis hypsilepis	(O)	Highscale shiner
Notropis longirostris	(O)	Longnose shiner
Notropis maculatus	(O)	Taillight shiner
Notropis texanus	(O)	Weed shiner
Notropis winchelli	(O)	Clear chub
Opsopoeodus emiliae	(O)	Pugnose minnow
Semotilus atromaculatus	(O)	Creek chub
Carpiodes cyprinus	(O)	Quillback
Erimyzon sucetta	(O)	Lake chubsucker
Minytrema melanops	(O)	Spotted sucker
Moxostoma duquesnei	(O)	Black redhorse
Moxostoma lachneri	(O)	Greater jumprock
Moxostoma poecilurum	(O)	Blacktail redhorse
Ameiurus brunneus	(C)	Snail bullhead
Ameiurus catus	(C)	White catfish
Ameiurus natalis	(C)	Yellow bullhead
Ameiurus nebulosus	(C)	Brown bullhead
Ameiurus serracanthus	(C)	Spotted bullhead
Ictalurus punctatus	(C)	Channel catfish
Noturus gyrinus	(O)	Tadpole madtom
Noturus leptacanthus	(O)	Speckled madtom
Esox americanus	(G)	Redfin pickerel
Esox niger	(G)	Chain pickerel
Aphredoderus sayanus	(O)	Pirate perch
Strongylura marina	(O)	Atlantic needlefish
Fundulus olivaceus	(O)	Blackspotted topminnow
Gambusia holbrooki	(O)	Mosquitofish
Labidesthes sicculus	(O)	Brook silverside
Morone chrysops	(G)	White bass (introduced)
Centrarchus macropterus	(G)	Flier
Elassoma zonatum	(O)	Banded pygmy sunfish
Lepomis auritus	(G)	Redbreast sunfish

Table 11.1. (Cont.)

Scientific Name	Category	Common Name
Lepomis cyanellus	(G)	Green sunfish
Lepomis gulosus	(G)	Warmouth
Lepomis humilis	(G)	Orangespotted sunfish (introduced)
Lepomis macrochirus	(G)	Bluegill
Lepomis marginatus	(G)	Dollar sunfish
Lepomis megalotis	(G)	Longear sunfish
Lepomis microlophus	(G)	Red-ear sunfish
Lepomis punctatus	(G)	Spotted sunfish
Micropterus coosae	(G)	Redeye bass
Micropterus salmoides	(G)	Largemouth bass
Pomoxis annularis	(G)	White crappie (introduced)
Pomoxis nigromaculatus	(G)	Black crappie
Etheostoma edwini	(O)	Brown darter
Etheostoma fusiforme	(O)	Swamp darter
Etheostoma parvipinne	(O)	Goldstripe darter
Etheostoma swaini	(O)	Gulf darter
Perca flavescens	(G)	Yellow perch
Percina nigrofasciata	(O)	Blackbanded darter

Table 11.2. Number of fish species collected by gear type in Lake Eufaula 1992.

Species: Common Name	Species: Scientific Name	Electrofishing No.	Electrofishing CPE	Electrofishing Tot.E	Gillnetting No.	Gillnetting CPE	Gillnetting Tot.E	Seining No.	Seining CPE	Seining Tot.E
Largemouth Bass	*Micropterus salmoides*	113	80.1	1.41				389	21.6	18
Largemouth Bass*	*Micropterus salmoides*	142	74.3	1.91	18	4.5	4			
Bluegill sunfish	*Lepomis macrochirus*	107	209.8	0.51				121	6.72	18
Bluegill sunfish*	*Lepomis macrochirus*	105	79.0	1.33				284	12.4	23
Black crappie	*Pomoxis nigromaculatus*	101	34.4	2.94						
Black crappie*	*Pomoxis nigromaculatus*				45	11.2	4			
Gizzard shad	*Dorosoma cepedianum*	100	36.4	2.75						
Gizzard shad*	*Dorosoma cepedianum*	100	75.2	1.33	83	20.8	4			
Threadfin shad	*Dorosoma petenense*	139	53.2	2.61						
Threadfin shad*	*Dorosoma petenense*	100	112.4	0.89	1	0.2	4			
Hybrid striped bass	*Morone chrysops* x *M. saxatilis*	1	0.9	1.17						
Hybrid striped bass*	*Morone chrysops* x *M. saxatilis*				111	27.8	4			
Redbreast sunfish	*Lepomis auritus*	4	3.4	1.17						
Redbreast sunfish*	*Lepomis auritus*	19	33.3	0.57	1	0.2	4			
Longear sunfish	*Lepomis megalotis*	2	1.7	1.17				3	0.17	18
Longear sunfish*	*Lepomis megalotis*	2	3.5	0.57						
Redear sunfish	*Lepomis microlophus*	26	22.2	1.17				4	0.22	18
Redear sunfish*	*Lepomis microlophus*	27	47.3	0.57						
Green sunfish	*Lepomis cyanellus*	1	0.9	1.17						
Green sunfish*	*Lepomis cyanellus*	1	1.8	0.57						
White catfish	*Ameiurus catus*	4	3.4	1.17						
White catfish*	*Ameiurus catus*				5	1.2	4			

Table 11.2. (Cont.)

Species: Common Name	Species: Scientific Name	Electrofishing No.	Electrofishing CPE	Electrofishing Tot.E	Gillnetting No.	Gillnetting CPE	Gillnetting Tot.E	Seining No.	Seining CPE	Seining Tot.E
Yellow perch	*Perca flavescens*	7	6.0	1.17						
Yellow perch*	*Perca flavescens*	7	12.2	0.57	2	0.5	4			
Warmouth	*Lepomis gulosus*	5	4.3	1.17						
Warmouth*	*Lepomis gulosus*									
Channel catfish	*Ictalurus punctatus*									
Channel catfish*	*Ictalurus punctatus*				64	16.0	4			
Golden shiner	*Notemigonus crysoleucas*	8	6.8	1.17				200	11.1	10
Bullhead catfish	*Ameiurus spp.*				2	0.5	4			
Bullhead catfish*	*Ameiurus spp.*									
Skipjack herring*	*Alosa chrysochloris*				32	8.0	4			
Flier	*Centrarchus macropterus*									
Carp*	*Cyprinus carpio*	5	8.8	0.57	6	1.5	4			
Spotted Bass*	*Micropterus punctulatus*									
Spotted sucker	*Minytrema melanops*	24	20.5	1.17						
Spotted sucker*	*Minytrema melanops*	9	15.8	0.57	1	0.2	4			
Blacktail redhorse*	*Moxostoma poecilurum*									
Blacktail shiner	*Cyprinella venusta*							233	12.9	18
Blacktail shiner*	*Cyprinella venusta*	32	56.1	0.57						
Brook Silversides	*Labidesthes sicculus*	2	1.7	1.17				235	13.1	18
Brook Silversides*	*Labidesthes sicculus*	4	7.0	0.57						
Chain Pickerel*	*Esox niger*	1	1.8	0.57						
Gambusia	*Gambusia holbrooki*							231	12.8	18

*Fall sample

Table 11.3. Number of fish species collected by gear type in Lake Walter F. George 1993.

Species: Common Name	Scientific Name	Electrofishing No.	CPE	Tot.E		Gillnetting No.	CPE	Tot.E		Seining No.	CPE	Tot.E
Largemouth Bass	Micropterus salmoides	111	95.7	1.16		4	1.0	4		214	9.3	23
Largemouth Bass*	Micropterus salmoides	112	64.0	1.75		4	1.0	4				
Bluegill sunfish	Lepomis macrochirus	100	68.6	1.46								
Bluegill sunfish*	Lepomis macrochirus	102	67.0	1.52						284	12.4	23
Black crappie	Pomoxis nigromaculatus		15	30.0	0.5							
Black crappie*	Pomoxis nigromaculatus		13	19.7	0.66		10	2.5	4			
Gizzard shad	Dorosoma cepedianum	100	294.1	0.34								
Gizzard shad*	Dorosoma cepedianum	100	77.5	1.29		52	13.0	4				
Threadfin shad	Dorosoma petenense	100	80.0	1.25								
Threadfin shad*	Dorosoma petenense	100	56.8	1.76								
Hybrid striped bass	Morone chrysops x M. saxatilis											
Hybrid striped bass*	Morone chrysops x M. saxatilis						110	27.5		4		
Redbreast sunfish	Lepomis auritus		10	20.0	0.5							
Redbreast sunfish*	Lepomis auritus		13	19.7	0.66							
Longear sunfish	Lepomis megalotis	7	14.0	0.5								
Longear sunfish*	Lepomis megalotis	2	3.0	0.66						11	0.48	23
Redear sunfish	Lepomis microlophus	16	32.0	0.5								
Redear sunfish*	Lepomis microlophus	25	37.9	0.66						10	0.43	23
Green sunfish	Lepomis cyanellus											
Green sunfish*	Lepomis cyanellus											

Table 11.3. (Cont.)

Species: Common Name	Species: Scientific Name	Electrofishing No.	Electrofishing CPE	Electrofishing Tot.E	Gillnetting No.	Gillnetting CPE	Gillnetting Tot.E	Seining No.	Seining CPE	Seining Tot.E
White catfish	Ameiurus catus									
White catfish*	Ameiurus catus				5	1.2	4			
Yellow perch	Perca flavescens	6	12.0	0.5						
Yellow perch*	Perca flavescens	2	3.0	0.66						
Warmouth	Lepomis gulosus									
Warmouth*	Lepomis gulosus	2	3.0	0.66						
Channel catfish	Ictalurus punctatus									
Channel catfish*	Ictalurus punctatus				25	6.2	4			
Golden shiner	Notemigonus crysoleucas									
Bullhead catfish	Ameiurus spp.									
Bullhead catfish*	Ameiurus spp.				1	0.3	4			
Skipjack herring*	Alosa chrysochloris				45	11.2	4			
Flier	Centrarchus macropterus									
Carp	Cyprinus carpio	20	44.0	0.5						
Carp*	Cyprinus carpio				3	0.8	4			
Spotted Bass*	Micropterus punctulatus	1	0.6	1.75						
Spotted sucker	Minytrema melanops	4	8.0	0.5						
Spotted sucker*	Minytrema melanops	11	16.7	0.66	3	0.8	4			
Blacktail redhorse*	Moxostoma poecilurum	1	1.5	0.66						
Blacktail shiner	Cyprinella venusta	20	40.0	0.5						
Blacktail shiner*	Cyprinella venusta	3	4.6	0.66				80	3.48	23

Table 11.3. (Cont.)

Species		Electrofishing			Gillnetting			Seining		
Common Name	Scientific Name	No.	CPE	Tot.E	No.	CPE	Tot.E	No.	CPE	Tot.E
Brook Silversides	*Labidesthes sicculus*	2	4.0	0.5						
Brook Silversides*	*Labidesthes sicculus*	2	3.0	0.66				49	2.13	23
Chain Pickerel*	*Esox niger*							1	0.04	23
Gambusia	*Gambusia holbrooki*							21	0.91	23
White Bass*	*Morone chrysops*	1	1.5	0.66	1	0.3	4			
American Eel*	*Anguilla rostrata*									

*Fall sample

Table 11.4. A comparison of the standing stocks of selected species in Lake Walter F. George from 1986 through 1992.

	1986 kg/ha	1987 kg/ha	1988 kg/ha	1989 kg/ha	1990 kg/ha	1991 kg/ha	1992 kg/ha
Predatory Game Fish							
Largemouth Bass	12.7	21.7	16.4	38.7	72.5	31.3	23.3
Black Crappie	1.1	0.1	1.7	64.4	29.5	8.8	3.2
Totals	19.0	33.2	80.5	63.8	108.6	42.9	26.8
Non-Predatory Game Fish							
Bluegill Sunfish	40.5	40.8	60.0	76.5	56.1	75.2	37.8
Redear Sunfish	4.1	5.3	3.1	10.8	12.6	8.6	2.3
Totals	83.1	81.4	89.0	124.0	88.1	98.6	56.6
Non-Predatory Food Fish							
Spotted Sucker	10.4	10.0	20.8	6.9	95.8	8.0	13.9
Carp	121.0	133.3	69.0	95.6	78.8	72.1	39.2
Totals	133.4	145.2	94.8	104.6	139.6	83.8	58.1
Predatory Food Fish							
Channel Catfish	2.1	3.2	6.1	14.4	21.1	7.6	18.6
White Catfish	5.2	5.9	7.1	13.7	165.2	3.7	24.8
Totals	6.4	9.7	13.2	28.5	183.2	12.2	43.5
Forage Fish							
Gizzard Shad	65.8	75.0	78.2	117.6	109.7	143.0	123.4
Threadfin Shad	49.6	80.2	12.9	113.5	34.6	31.4	94.6
Totals	120.2	162.4	96.0	227.2	166.7	174.8	224.3
Grand Total	359.2	431.9	355.0	530.3	645.4	412.2	409.2

11.2 WILDLIFE

The Eufaula National Wildlife Refuge was established in October, 1964. The refuge contains aquatic, wetland and terrestrial habitats which support a diverse flora and fauna. The refuge offers hunting for both deer and various birds during their respective seasons with the greater emphasis going to waterfowl. A list of common and transient bird species is presented in Table 11.5. Reptiles and amphibians expected in and around Lake George are present in Table 11.6. Endangered species known to occur in the area include the American alligator *Alligator mississippiensis*, bald eagle *Haliaeetus leucocephalus*, wood stork *Mycteria americana* and peregrine falcon *Falco peregrinus* (ACDNR 1972).

Table 11.5. Checklist of birds expected in and around Lake Water F. George and its surrounding watershed.

BIRDS

Family	Scientific Name	Common Name
Gaviidae	Gavia immer	common loon
Podicipedidae	Podiceps auritus horned grebe	
	Podilymbus podiceps	pied-billed grebe
Phalacrocoracidae	Phalacrocorax auritus	double-crested cormorant
Anhingidae	Anhinga anhinga anhinga	
Ardeidae	Ardea herodias great blue heron	
	Butorides virescens	green heron
	Florida caerulea little blue heron	
	Bubulcus ibis	cattle egret
	Casmerodius albus	great egret
	Egretta thula	snowy egret
	Hydranassa tricolor	Louisiana heron
	Nycticorax nycticorax	black-crowned night heron
	Nyctanassa violacea	yellow-crowned night heron
	Dichromanassa rufescens	reddish egret
	Botaurus lentiginosus	American bittern
Ciconiidae	Mycteria americana	wood stork
Threskiornithidae	Plegadis falcinellus	glossy ibis
	Plegadis chihi white-faced ibis	
	Eudocimus albus white ibis	
	Eudocimus ruber scarlet ibis	
	Ajaia ajaja	roseate spoonbill
Anatidae	Olor columbianus whistling swan	
	Branta canadensis	Canada goose
	Anser albifrons white-fronted goose	
	Chen caerulescens	snow goose
	Dendrocygna bicolor	fulvous tree duck
	Anas platyrhynchos	mallard
	Anas rubripes	black duck
	Anas strepera	gadwall
	Anas acuta	pintail
	Anas crecca	green-winged teal

Table 11.5. (Cont.)

Family	Scientific Name	Common Name
Anatidae	Anas discors	blue-winged teal
	Anas americana american wigeon	
	Anas cylpeata	northern shoveler
	Aix sponsa	wood duck
	Aythya americana redhead	
	Aythya collaris ring-necked duck	
	Aythya valisineria	canvasback
	Aythya marila	greater scaup
	Aythya affinis lesser scaup	
	Bucephala clangula	common goldeneye
	Bucephala albeola	bufflehead
	Clangula hyemalis	oldsquaw
	Melanitta deglandi	white-winged scoter
	Oxyura jamaicensis	ruddy duck
	Lophodytes cucullatus	hooded merganser
	Mergus merganser common merganser	
	Mergus serrator red-breasted merganser	
Cathartidae	Cathartes aura turkey vulture	
	Coragyps atratus black vulture	
Accipitridae	Elanoides forficatus	swallow-tailed kite
	Ictinia misisippiensis	Mississippi kite
	Accipiter striatus	sharp-shinned hawk
	Accipiter cooperii	Cooper's hawk
	Buteo jamaicensis	red-tailed hawk
	Buteo lineatus red-shouldered hawk	
	Buteo platypterus	broad-winged hawk
	Buteo swainsoni Swainson's hawk	
	Buteo lagopus	rough-legged hawk
	Aquila chrysaetos	golden eagle
	Haliaeetus leucocephalus	bald eagle
	Circus cyaneus marsh hawk	
Pandionidae	Pandion haliaetus	osprey
Falconidae	Falco peregrinus peregrine falcon	
	Falco columbarius	merlin
	Falco sparverius American kestrel	
Phasianidae	Colinus virginianus	bobwhite
Meleagrididae	Meleagris gallopavo	turkey

Table 11.5. (Cont.)

Family	Scientific Name	Common Name
Gruidae	Grus canadensis sandhill crane	
Rallidae	Rallus elegans king rail	
	Rallus limicola Virginia rail	
	Porzana carolina sora	
	Coturnicops noveboracensis	yellow rail
	Porphyrula martinica	purple gallinule
	Gallinula chloropus	common gallinule
	Fulica americana American coot	
Charadriidae	Charadrius semipalmatus	semipalmated plover
	Charadrius melodus	piping plover
	Charadrius vociferus	killdeer
	Pluvialus dominica	American golden plover
	Pluvialus squatarola	black-bellied plover
Scolopacidae	Arenaria interpres	ruddy turnstone
	Philohela minor American woodcock	
	Capella gallinago	common snipe
	Numenius phaeopus	whimbrel
	Bartramia longicauda	upland sandpiper
	Actitis macularia	spotted sandpiper
	Tringa solitaria solitary sandpiper	
	Tringa melanoleuca	greater yellowlegs
	Tringa flavipes lesser yellowlegs	
	Catoptrophorus semipalmatus	willet
	Calidris canutus red knot	
	Calidris melanotos	pectoral sandpiper
	Calidris fuscicollis	white-rumped sandpiper
	Calidris minutilla	least sandpiper
	Calidris alpina dunlin	
	Calidris pusilla semipalmated sandpiper	
	Calidris mauri western sandpiper	
	Calidris alba	sanderling
	Limnodromus griseus	short-billed dowitcher
	Celidris himantopus	stilt sandpiper
	Tryngites subruficollis	buff-breasted sandpiper
	Limosa fedoa	marbled godwit
	Philomachus pugnax*	ruff
Recurvirostridae	Recurvirostra americana	American avocet
	Himantopus mexicanus	black-necked stilt
Phalaropodidae	Phalaropus fulicarias	red phalarope
	Lobipes lobatus northern phalarope	

* = accidental

Table 11.5. (Cont.)

Family	Scientific Name	Common Name
Laridae	Larus argentatus herring gull	
	Larus delawarensis	ring-billed gull
	Larus atricilla	laughing gull
	Larus philadelphia	Bonaparte's gull
	Sterna nilotica* gull-billed tern	
	Sterna forsteri	Forster's tern
	Sterna hirundo	common tern
	Sterna fuscata	sooty tern
	Sterna antillarum	least tern
	Sterna sandvicensis*	sandwich tern
	Sterna caspia	caspian tern
	Chlidonias niger black tern	
Rynchopidae	Rynchops niger*	black skimmer
Columbidae	Columba livia	rock dove
	Zenaida asiatica white-winged dove	
	Zenaida macroura mourning dove	
	Columbina passerina	ground dove
Cuculidae	Cocczus americanus	yellow-billed cuckoo
	Coccyzus erythropthalmus	black-billed cuckoo
Tytonidae	Tyto alba	barn owl
	Otus asio	screech owl
	Bubo virginianus great horned owl	
	Strix varia	barred owl
	Asio otus	long-eared owl
	Asio flammeus	short-eared owl
	Aegolius acadicus	saw-whet owl
Caprimulgidae	Caprimulgus carolinensis	chuck-will's-widow
	Caprimulgus vociferus	whip-poor-will
	Chordeiles minor common nighthawk	
Apodidae	Chaetura pelagica	chimney swift
Trochilidae	Archilochus colubris	ruby-throated hummingbird
Alcedinidae	Ceryle alcyon	belted kingfisher
Picidae	Colaptes auratus common flicker	
	Dryocopus pileatus	pileated woodpecker

* = accidental

Table 11.5. (Cont.)

Family	Scientific Name	Common Name
Picidae	Melanerpes carolinus	red-bellied woodpecker
	Melanerpes erythrocephalus	red-headed woodpecker
	Sphyrapicus varius	yellow-bellied sapsucker
	Picoides villosus	hairy woodpecker
	Picoides pubescens	downy woodpecker
	Picoides borealis	red-cockaded woodpecker
	Campephilus principalis	ivory-billed woodpecker
Tyrannidae	Tyrannus tyrannus	eastern kingbird
	Tyrannus verticalis	western kingbird
	Muscivora forficata	scissor-tailed flycatcher
	Myiarchus crinitus	great crested flycatcher
	Myiarchus stolidus*	stolid flycatcher
	Sayornis phoebe eastern phoebe	
	Empidonax flaviventris	yellow-bellied flycatcher
	Empidonax virescens	acadian flycatcher
	Contopus virens	eastern wood-pewee
	Nuttallornis borealis	olive-sided flycatcher
	Pyrocephalus rubinus	vermilion flycatcher
Alaudidae	Eremophila alpestris	horned lark
Hirundinidae	Tachycineta bicolor	tree swallow
	Riparia riparia	bank swallow
	Stelgidopteryx serripennis	rough-winged swallow
	Hirundo rustica	barn swallow
	Hirundo pyrrhonota	cliff swallow
	Progne subis	purple martin
Corvidae	Cyanocitta cristata	blue jay
	Corvus brachyrhynchos	American crow
	Corvus ossifragus	fish crow
Paridae	Parus carolinensis	Carolina chickadee
	Parus bicolor	tufted titmouse
Sittidae	Sitta carolinensis	white-breasted nuthatch
	Sitta canadensis red-breasted nuthatch	
	Sitta pusilla	brown-headed nuthatch
Certhiidae	Certhia americana	brown creeper
Troglodytidae	Troglodytes aedon	house wren
	Troglodytes troglodytes	winter wren

* = accidental

Table 11.5. (Cont.)

Family	Scientific Name	Common Name
Troglodytidae	Thryomanes bewickii	Bewick's wren
	Thryothorus ludovicianus	carolina wren
	Cistothorus palustris	long-billed marsh wren
	Cistothorus platensis	sedge wren
Mimidae	Mimus polyglottos	mockingbird
	Dumetella carolinensis	gray catbird
	Toxostoma rufum	brown thrasher
Turdidae	Turdus migratorius	American robin
	Hylocichla mustelina	wood thrush
	Catharus guttatus	hermit thrush
	Catharus ustulatus	Swainson's thrush
	Catharus minimus gray-cheeked thrush	
	Catharus fuscescens	veery
	Sialia sialis	eastern bluebird
Sylviidae	Polioptila caerule	blue-gray gnatcatcher
	Regulus satrapa	golden-crowned kinglet
	Regulus calendula	ruby-crowned kinglet
Motacillidae	Anthus spinoletta	water pipit
	Anthus spragueii Sprague's pipit	
Bombycillidae	Bombycilla cedrorum	cedar waxwing
Laniidae	Lanius ludovicianus	loggerhead shrike
Sturnidae	Sturnus vulgaris European starling	
Vireonidae	Vireo griseus	white-eyed vireo
	Vireo flavifrons yellow-throated vireo	
	Vireo solitarius solitary vireo	
	Vireo olivaceus	red-eyed vireo
	Vireo philadelphicus	Philadelphia vireo
	Vireo gilvus	warbling vireo
Parulidae	Mniotilta varia	black-and-white warbler
	Protonotaria citrea	prothonotary warbler
	Limnothlypis swainsonii	Swainson's warbler
	Helmitheros vermivorus	worm-eating warbler
	Vermivora chrysoptera	golden-winged warbler
	Vermivora pinus	blue-winged warbler
	Vermivora bachmanii	Bachman's warbler
	Vermivora peregrina	Tennessee warbler

Table 11.5. (Cont.)

Family	Scientific Name	Common Name
Parulidae	Vermivora celata orange-crowned warbler	
	Vermivora ruficapilla	Nashville warbler
	Parula americana northern parula	
	Dendroica petechia	yellow warbler
	Dendroica magnolia	magnolia warbler
	Dendroica tigrina	Cape May warbler
	Dendroica caerulescens	black-throated blue warbler
	Dendroica coronata	yellow-rumped warbler
	Dendroica virens black-throated green warbler	
	Dendroica cerulea	cerulean warbler
	Dendroica fusca	blackburnian warbler
	Dendroica dominica	yellow-throated warbler
	Dendroica pensylvanica	chestnut-sided warbler
	Dendroica castanea	bay-breasted warbler
	Dendroica striata	blackpoll warbler
	Dendroica pinus	pine warbler
	Dendroica discolor	prairie warbler
	Dendroica palmarum	palm warbler
	Seiurus aurocapillus	ovenbird
	Seiurus noveboracensis	northern waterthrush
	Seiurus motacilla	Louisiana waterthrush
	Oporornis formosus	Kentucky warbler
	Geothypis trichas	common yellowthroat
	Icteria virens	yellow-breasted chat
	Wilsonia citrina hooded warbler	
	Wilsonia pusilla Wilson's warbler	
	Wilsonia canadensis	Canada warbler
	Setophaga ruticilla	American redstart
Ploceidae	Passer domesticus	house sparrow
Icteridae	Dolichonyx oryzivorus	bobolink
	Sturnella magna	eastern meodowlark
	Sturnella neglecta	western meodowlark
	Xanthocephalus xanthocephalus	yellow-headed blackbird
	Agelaius phoeniceus	red-winged blackbird
	Icterus spurius	orchard oriole
	Icterus galbula	northern oriole
	Euphagus carolinus	rusty blackbird
	Euphagus cyanocephalus	Brewer's blackbird
	Quiscalus guiscula	common crackle
	Molothrus ater	brown-headed cowbird

Table 11.5. (Cont.)

Family	Scientific Name	Common Name
Thraupidae	Piranga olivacea scarlet tanager	
	Piranga rubra	summer tanager
Fringillidae	Cardinalis cardinalis	cardinal
	Pheucticus ludovicianus	rose-breasted grosbeak
	Pheucticus melanocephalus	black-headed grosbeak
	Guiraca caerulea blue grosbeak	
	Passerina cyanea indigo bunting	
	Passerina ciris	painted bunting
	Spiza americana	dickcissel
	Coccothraustes vespertina	evening grosbeak
	Carpodacus purpureus	purple finch
	Cerduelis pinus	pine siskin
	Cerduelis tristis	American goldfinch
	Loxia curvirostra	red crossbill
	Piplio erythrophthalmus	rufous-sided towhee
	Calamospiza melanocorys	lark bunting
	Passerculus sandwichensis	Savannah sparrow
	Ammodramus savannarum	grasshopper sparrow
	Ammodramus henslowii	Henslow's sparrow
	Ammodramus leconteii	Le Conte's sparrow
	Pooecetes gramineus	vesper sparrow
	Chondestes grammacus	lark sparrow
	Aimophila aestivalis	Bachman's sparrow
	Junco hyemalis	dark-eyed junco
	Spizella passerina	chipping sparrow
	Spizella pusilla field sparrow	
	Zonotrichia leucophrys	white-crowned sparrow
	Zonotrichia albicollis	white-throated sparrow
	Passerella iliaca	fox sparrow
	Melospiza lincolnii	Lincoln's sparrow
	Melospiza georgiana	swamp sparrow
	Melospiza melodia	song sparrow
	Calcarius lapponicus	Lapland longspur
	Calcarius pictus Smith's longspur	

Table 11.6. Checklist of amphibians and reptiles expected in and around Lake Water F. George and its surrounding watershed.

Family	Scientific Name	Common Name
AMPHIBIANS		
Bufonidae	Bufo quercicus oak toad	
	Bufo terrestris southern toad	
	Bufo woodhousei fowleri	Fowler's toad
Hylidae	Acris crepitans crepitans	northern cricket frog
	Acris gryllus gryllus	southern cricket frog
	Acris gryllus dorsalis	Florida cricket frog
	Hyla avivoca	bird-voiced treefrog
	Hyla cinerea	green treefrog
	Hyla crucifer crucifer	northern spring peeper
	Hyla femoralis pine woods treefrog	
	Hyla gratiosa	barking treefrog
	Hyla squirella squirrel treefrog	
	Hyla versicolor gray tree frog	
	Limnaoedus ocularis	little grass frog
	Pseudacris brachyphona	mountain chorus frog
	Pseudacris nigrita nigrita	southern chorus frog
	Pseudacris ornata	ornate chorus frog
	Pseudacris triseriata feriarum	upland chorus frog
Micorhylidae	Gastrophryne carolinensis	eastern narrow-mouthed toad
Pelobatidae	Scaphiopus holbrooki holbrooki	eastern spadefoot toad
Ranidae	Rana areolata sevosa	dusky gopher frog
	Rana catesbeiana bullfrog	
	Rana clamitans clamitans	bronze frog
	Rana grylio	pig frog
	Rana heckscheri river frog	
	Rana palustris pickerel frog	
	Rana pipiens sphenocephala	southern leopard frog
Ambystomatidae	Ambystoma cingulatum	flatwoods salamander
	Ambystoma maculatum	spotted salamander
	Ambystoma opacum marbled salamander	
	Ambystoma talpoideum	mole salamander
	Ambystoma texanum	small-mouthed salamander
	Ambystoma tigrinum tigrinum	eastern tiger salamander
Amphiumidae	Amphiuma means	two-toed amphiuma
	Amphiuma tridactylum	three-toed amphiuma

Table 11.6. (Cont.)

Family	Scientific Name	Common Name
Plethodontidae	Desmognathus aeneus	seepage salamander
	Desmognathus fuscus auriculatus	southern dusky salamander
	Desmognathus monticola ssp.	seal salamander
	Eurycea bislineata	two-lined salamander
	Eurycea longicauda guttolineata	three-lined salamander
	Hemidactylium scutatum	four-toed salamander
	Manculus quadridigitatus	dwarf salamander
	Phaeognathus hubrichti	red hills salamander
	Plethodon dorsalis dorsalis	zigzag salamander
	Plethodon glutinosus glutinosus	slimy salamander
	Pseudotriton montanus flavissimus gulf coast mud salamander	
	Pseudotriton ruber vioscai	southern red salamander
Proteidae	Necturus beyeri	Beyer's waterdog
Salamandridae	Notopthalmus viridescens louisianensis	central newt
Sirenidae	Siren intermedia intermedia	eastern lesser siren
	Siren intermedia nettingi	western lesser siren
	Siren lacertina	greater siren
REPTILES		
Alligatoridae	Alligator mississippensis	american alligator
Anguidae	Ophisaurus attenuatus longicaudus eastern slender glass lizard	
	Ophisaurus ventralis	eastern glass lizard
Iguanidae	Anolis carolinensis carolinensis	green anole
	Sceloporus undulatus undulatus	southern fence lizard
Scincidae	Eumeces anthracinus anthracinus	northern coal skink
	Eumeces anthracinus pluvialis	southern coal skink
	Eumeces egregius similis	northern mole skink
	Eumeces fasciatus	five-lined skink
	Eumeces inexpectatus	southeastern five-lined skink
	Eumeces laticeps broad-headed skink	
	Scincella laterale	ground skink

Table 11.6. (Cont.)

Family	Scientific Name	Common Name
Teidae	Cnemidophorus sexlineatus sexlineatus	eastern six-lined racerunner
Colubridae	Carphophis amoenus helenae	midwest worm snake
	Cemophora coccinea copei	northern scarlet snake
	Coluber constrictor priapus	southern black racer
	Diadophis punctatus punctatus	southern ringneck snake
	Diadophis punctatus stictogenys	Mississippi ringneck snake
	Drymarchon corais couperi	eastern indigo snake
	Elaphe guttata guttata	corn snake
	Elaphe obsoleta spiloides	gray rat snake
	Farancia abacura abacura	eastern mud snake
	Farancia abacura reinwardti	western mud snake
	Farancia erytrogramma erytrogramma	rainbow snake
	Heterodon platyrhinos	eastern hognose snake
	Heterodon simus	southern hognose snake
	Lampropeltis calligaster rhombomaculata	mole snake
	Lampropeltis getulus getulus	eastern kingsnake
	Lampropeltis getulus holbrooki	speckled kingsnake
	Lampropeltis triangulum elapsoides	scarlet kingsnake
	Masticophis flagellum flagellum	eastern coachwhip
	Nerodia cyclopion cyclopion	greenwater snake
	Nerodia cyclopion floridana	Florida green water snake
	Nerodia erythrogaster erythrogaster	red-bellied water snake
	Nerodia erythrogaster flavigaster	yellow-bellied water snake
	Nerodia fasciata fasciata	banded water snake
	Nerodia fasciata clarki	gulf salt marsh water snake
	Nerodia fasciata confluens	broad-banded water snake
	Nerodia fasciata pictiventris	Florida water snake
	Nerodia rhombifera rhombifera	diamond-backed water snake
	Nerodia rigida sinicola	gulf glossy water snake
	Nerodia septemvittata	queen snake
	Nerodia sipedon pleuralis	midland water snake
	Nerodia taxispilota	brown water snake
	Opheodrys aestivus	rough green snake
	Pituophis melanoleucus melanoleucus	northern pine snake
	Pituophis melanoleucus lodingi	black pine snake
	Pituophis melanoleucus mugitus	Florida pine snake
	Rhadinaea flavilata	pine woods snake

Table 11.6. (Cont.)

Family	Scientific Name	Common Name
Colubridae	Seminatrix pygaea pygaea	north Florida black swamp snake
	Storeria dekayi limnetes	marsh brown snake
	Storeria dekayi wrightorum	midland brown snake
	Storeria occipitomaculata occipitomaculata	northern red-bellied snake
	Tantilla coronata coronata	southeastern crowned snake
	Thamnophis sauritus sauritus	eastern ribbon snake
	Thamnophis sirtalis sirtalis	eastern garter snake
	Virginia striatula	rough earth snake
	Virginia valeriae valeriae	eastern smooth earth snake
	Virginia valeriae elegans	western smooth earth snake
Elapidae	Micrurus fulvius fulvius	eastern coral snake
Viperidae	Agkistrodon contortrix contortrix	southern copperhead
	Agkistrodon piscivorus piscivorus	eastern cottonmouth
	Agkistrodon piscivorus conanti	Florida cottonmouth
	Agkistrodon piscivorus leucostoma	western cottonmouth
	Crotalus adamanteus	eastern diamondback rattlesnake
	Crotalus horridus	timber rattlesnake
Viperidae	Sistrurus miliarius barbouri	dusky pigmy rattlesnake
	Sistrurus miliarius streckeri	western pigmy rattlesnake
Cheloniidae	Caretta caretta caretta	Atlantic loggerhead
	Chelonia mydas	green turtle
	Eretmochelys imbricata imbricata	Atlantic hawksbill
	Lepidochelys kempi	Atlantic ridley
Dermochelidae	Dermochelys coriacea coriacea	Atlantic leatherback
Chelydridae	Chelydra serpentina serpentina	common snapping turtle
	Macroclemys temmincki	alligator snapping turtle
Emydidae	Chrysemys picta dorsalis	southern painted turtle
	Deirochelys reticularia reticularia eastern chicken turtle	
	Graptemys barbouri	Barbour's map turtle
	Graptemys nigrinoda nigrinoda	northern black-knobbed sawback
	Graptemys nigrinoda delticola	southern black-knobbed sawback

Table 11.6. (Cont.)

Family	Scientific Name	Common Name
Emydidae	Graptemys pulchra	Alabama map turtle
	Malaclemys terrapin pileata	Mississippi diamondback terrapin
	Pseudemys alabamensis	Alabama red-bellied turtle
	Pseudemys concinna concinna	river cooter
	Pseudemys floridana floridana	Florida cooter
	Pseudemys scripta scripta	yellow-bellied pond slider
	Pseudemys scripta elegans	red-eared pond slider
	Terrapene carolina major	gulf coast box turtle
	Terrapene carolina triunguis	three-toed box turtle
Kinosternidae	Kinosternon subrubrum subrubrum	eastern mud turtle
	Kinosternon subrubrum hippocrepis	Mississippi mud turtle
	Sternotherus minor minor	loggerhead musk turtle
	Sternotherus minor peltifer	stripe-necked musk turtle
	Sternotherus odoratus	common musk turtle
Testudinidae	Gopherus polyphemus	gopher tortoise
Trionychidae	Trionyx ferox	Florida softshell
	Trionyx muticus calvatus	gulf coast smooth softshell
	Trionyx spiniferus asper	gulf coast spiny softshell

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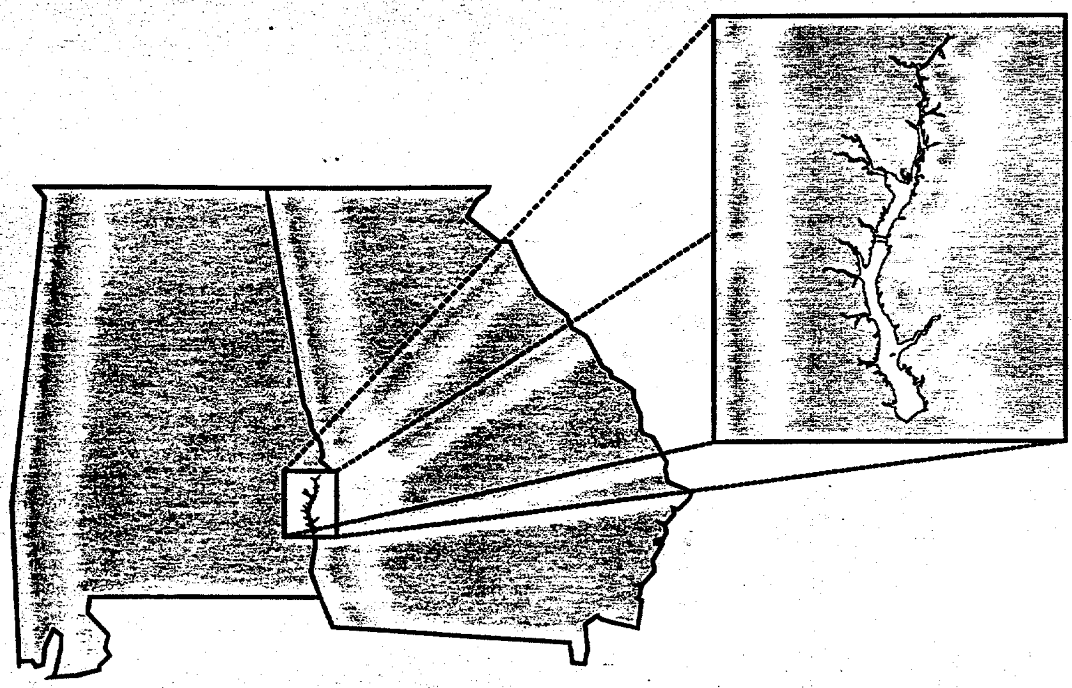
PART 3

WALTER F. GEORGE RESERVOIR

ALABAMA/GEORGIA FEASIBILITY STUDY



1.0 FEASIBILITY STUDY

1.1 INTRODUCTION

Lake Walter F. George Phase I Diagnostic studies were conducted in 1991, 1992, and 1993 and the lake was found to be in relatively good condition. No water use (i.e. recreation or fishing) impacts were documented. The trophic status was documented as eutrophic (characterized by an accumulation of nutrients that support elevated algal productivity without the problems associated with hypereutrophic overproduction). Therefore, the management of nutrient loading, particularly phosphorus, is an important long-term objective in maintaining the water quality of Lake Walter F. George.

The studies identified several additional potential issues of concern. Lead and mercury were detected in water samples, organic chemicals were detected in lake sediments, and chlordane was detected in fish samples in the headwaters of the lake. Small populations of nuisance aquatic plants were documented. Two additional long-term concerns, not specifically dealt with the 1991-1993 diagnostic studies, were noted. These concerns were sediment inputs to the lake and floating trash and debris which collect on the banks of the lake.

Environmental management goals for Lake Walter F. George are to protect and maintain the current quality of the lake and to monitor and manage factors that could impact the water resource in the future. The following paragraphs discuss methods proposed to achieve these goals.

1.2 PROTECTION OBJECTIVES

To protect the existing water quality of Lake Walter F. George, watershed management and continued lake monitoring is recommended. The following objectives are proposed to accomplish this goal:

- Adopt lake water quality standards for pH, chlorophyll a, total nitrogen, total phosphorus loading, fecal coliform bacteria, dissolved oxygen, and temperature.

- Establish nutrient limits for major tributaries to the lake.

- Monitor water quality in the lake and major tributaries to assess compliance with water quality standards.

- Monitor and manage nutrient inputs from point and nonpoint sources, including combined sewer overflows, in the lake watershed.

- Collect and analyze fish tissue samples and issue fish consumption guidelines based on assessment of risk.

- Monitor and control nuisance aquatic plants.

- Continue and encourage lake shore cleanup programs.

- Control sediment input through implementation and enforcement of existing erosion and sedimentation laws.

1.2 LAKE AND TRIBUTARY WATER QUALITY STANDARDS

O.C.G.A. 15-5-20 of the Georgia Water Quality Control Act, passed by the Georgia General Assembly in 1992, requires that the Georgia Environmental Protection Division (GAEPD) perform comprehensive studies of major, publicly owned lakes and reservoirs in Georgia. The law also requires that the GAEPD establish water quality standards for the lakes and nutrient standards for major tributaries based on the comprehensive study results. The water quality standards proposed below provide for the protection of Lake Walter F. George and implement the provisions of the Georgia law.

- **pH:** Within the range of 6.0 to 9.5 (standard units).

- **Chlorophyll *a*:** For the months of April through October, the average of monthly photic zone composite samples shall not exceed 18 µg/l at mid-river at U.S. Highway 82 or 15 µg/l at mid-river in the dam forebay.

- **Total Nitrogen:** Not to exceed 3.0 mg/l as nitrogen in the photic zone.

- **Total Phosphorus:** Total lake loading shall not exceed 2.4 pounds per acre-foot of lake volume per year.

- **Fecal Coliform Bacteria:** Fecal coliform bacteria shall not exceed the Specific Criteria for Classified Water Usage presented in the Georgia Environmental Protection Division Rules and Regulations for Water Quality Control, Chapter 391-3-6-.03(6).
  - From Georgia Hwy 39 to Cowikee Creek, fecal coliform bacteria shall not exceed the Fishing criteria, Chapter 391-3-6-.03(6)(c)(iii).
  - From Cowikee Creek to the Walter F. George Dam, fecal coliform bacteria shall not exceed the Recreation criteria, Chapter 391-3-6-.03(6)(b)(I).

- **Dissolved Oxygen:** A minimum daily average of 5.0 mg/l and no less than 4.0 mg/l at all times at the depth specified in Chapter 391-3-6-.03(5)(f) of the Georgia Environmental Protection Division Rules and Regulations for Water Quality Control.

- **Temperature:** Water temperature shall not exceed the Recreation criteria presented in the Georgia Environmental Protection Division Rules and Regulations for Water Quality Control, Chapter 391-3-6-.03(6)(b)(iv).

- **Major Lake Tributary:** The annual total phosphorus loading to Lake Walter F. George, monitored at the Chattahoochee River at Georgia Highway 39, shall not exceed 2,000,000 pounds.

Monitoring to verify compliance with lake standards will be conducted once per month, April through October, at two locations as follows: (1) mid-river in the dam forebay and (2) mid-river at U. S. Highway 82. Monitoring of the Chattahoochee River total phosphorus concentration at Georgia Highway 39 will be conducted once per month, January through December. Responsibility for this monitoring will be shared by Alabama and Georgia environmental management agencies.

Tributary flow for the Chattahoochee River at Georgia Highway 39 will be calculated by summing the following:

1. Monthly mean discharge at the USGS gage on the Chattahoochee River at Columbus, Georgia;
2. Monthly mean discharge at the USGS gage on Upatoi Creek in Georgia;
3. Monthly mean discharge at the USGS gage on Uchee Creek in Alabama;
4. Monthly discharge from the non-gaged watershed area between Columbus and Georgia Highway 39, estimated using a monthly average productivity factor (cfs per square mile) calculated from the Upatoi Creek watershed and Uchee Creek watershed discharge data; and
5. Monthly mean discharge from the Columbus South WPCP.

Monthly Chattahoochee River tributary flows and monthly total phosphorus concentration data will be multiplied to calculate monthly loadings at Georgia Highway 39. These will be summed to produce an annual loading of total phosphorus.

1.4 NUTRIENT CONTROL

The Cities of Columbus, Phenix City, and Eufaula and other areas in the Walter F. George watershed are experiencing development and population increases. This growth generates additional flows to water pollution control plants which may result in increased point source nutrient loading to the lake. Population growth may also cause an increase in nonpoint nutrient loading. To insure compliance with the proposed lake standards, point source dischargers and local governments should monitor and manage the lake's watersheds. An increase in point source loadings could be offset by an equal or greater reduction in nonpoint nutrient loading. Where applicable, NPDES permitted point sources in the watershed, between the Lake Oliver and Lake Walter F. George dams, should be required to monitor effluent phosphorus and total nitrogen concentrations.

The management of nonpoint source nutrient inputs should be considered in any plan to manage the water quality of Lake Walter F. George. Best management practices should be encouraged throughout the watershed to address nonpoint source inputs from agriculture, forestry, and urban areas.

1.5 COMBINED SEWER OVERFLOWS

Combined sewer overflows (CSOs) are a national concern and the elimination or mitigation of CSO discharges is a major water quality initiative. In 1991 there were 15 CSOs in Columbus, Georgia, which discharged into the Chattahoochee River upstream of Lake Walter F. George. The Georgia General Assembly passed Senate Bill 196 in January 1991 requiring municipalities to address the CSO problem.

In March, 1991, Georgia DNR issued the City of Columbus NPDES permits and an administrative order with a compliance schedule requiring actions to mitigate their CSO discharges. All construction activities were completed by their scheduled deadline of December 31, 1995. Columbus separated out sanitary sewage from stormwater where feasible. This accounted for about fifty percent of the CSO drainage area, eliminating five of the 15 CSOs. This sewage is now sent to existing WPCP facilities. The remaining CSOs discharge through on-site treatment facilities during rain events which result in an overflow. The largest of the remaining CSOs has a vortex separator which removes solids. The rest of the CSOs use screening for solids removal. All CSO facilities now have chlorine disinfection. CSO discharges are monitored and monthly compliance reports are submitted to Georgia DNR.

1.6 EROSION/SEDIMENTATION CONTROL

The Georgia Environmental Protection Division addresses sediment problems through implementation of the Erosion and Sedimentation Act and through recent implementation of a stormwater management strategy. The Erosion and Sedimentation Act (ESA) was signed into law in April 1975 and became effective in April 1977. The ESA established a statewide comprehensive program for erosion and sedimentation control in order to protect water and land resources of the State. The ESA provides a mechanism for erosion and sedimentation control through regulation of certain land disturbing activities, primarily those associated with construction. Implementation of the ESA involves local governments and state agencies. The ESA provides for counties and municipalities to become local certified issuing authorities for land disturbing activity permits.

During the 1985 Session at the General Assembly, the ESA was amended to give the Georgia Environmental Protection Division the authority to review the actions and progress of certified counties and municipalities. Local issuing authorities should place emphasis on aggressive implementation of programs on a continuous basis and provide educational opportunities such as workshops, seminars, and technical assistance. Efforts should be continued to enforce erosion and sedimentation laws.

The Alabama Department of Environmental Management (ADEM) addresses erosion and sediment control through the Stormwater Program and through the state's Nonpoint Source Management Program. The Stormwater Program as applied in Alabama requires construction sites of 5 acres or greater to obtain permit coverage and implement Best Management Practices (BMPs) to control erosion and sedimentation. Construction sites of less than 5 acres and other types of land use activities are regulated through provision's of the Nonpoint Source Management Program and pollution control regulations established pursuant to the Alabama Water Pollution Control Act.

ADEM continues to pursue improvements in regulatory and non-regulatory programs to provide for enhanced protection of State waters from the effects of erosion and sedimentation

1.7 URBAN STORMWATER REGULATION

Stormwater controls will be implemented by the Georgia Environmental Protection Division in the Columbus metropolitan area through the enforcement of the stormwater permit program. The City of Columbus and Muscogee County have submitted a joint permit application. Based on this application, EPD will issue a stormwater permit. This permit will require the following items:

1. Identification of major stormwater discharges.
2. Elimination of illegal discharges to storm sewers.
3. Sampling of selected stream and stormwater discharges.
4. Implementation of best management practices to control stormwater runoff.

5. Assessment of the effectiveness of the controls over time.

The stormwater management strategy is a long term approach to deal with pollution associated with stormwater runoff in the Columbus metro area. The implementation of the controls associated with this program will ultimately reduce the nutrient and sediment loading to Lake Walter F. George.

The Georgia Environmental Protection Division will also be issuing general permits for stormwater discharges associated with industrial and construction activities. Issuance of baseline general permits for stormwater from construction activities will provide an enhanced enforcement mechanism beyond that presently provided by the Erosion and Sedimentation Act. Civil and criminal penalties as provided by the Water Quality Control Act can be sought for failure to comply with local ordinances, the Erosion and Sedimentation Act, or best management practices.

The best management practices provision of the baseline general construction permit will include two significant features. First, a working document titled "Stormwater Pollution Prevention Plan" will be required of each permittee. This document would detail what measures the permittee (owner/operator) would take to eliminate any stormwater pollution (i.e., sedimentation). This plan would be prepared prior to starting any construction activity. The plan, at a minimum, would identify the location and describe all stabilization and structural controls which would be used to eliminate or remove sediment. A plan approved under the Erosion and Sedimentation Act will satisfy this requirement. The second feature would require the owner/operator to conduct and certify routine inspections of the site to insure compliance with the plan and to perform corrective actions if necessary.

Urban stormwater controls in the Alabama watershed are not regulated through the ADEM Stormwater Program because of population densities less than the federal minimum for MS4 Stormwater permits. Accordingly, stormwater controls are addressed through the voluntary and regulatory mechanisms found in the State's Nonpoint Source Management Program and through implementation of general permits for the discharge of stormwater from construction sites greater than 5 acres and industrial activities regulated under the Stormwater Program.

When applicable, the ADEM issues industry specific general permits for industrial stormwater discharges. The permits require sampling and analysis of stormwater discharges. All permits require that a BMP Plan be prepared and implemented by the facility. The BMP Plan describes measures that the facility will take to prevent pollution of stormwater and provides for daily inspection of the facility.

1.8 TOXIC SUBSTANCES

Additional monitoring of the lake will provide data to determine if mercury and lead concentrations noted in the initial sampling can be substantiated. Samples should be collected and handled in accordance with clean sampling and analysis techniques. The "clean lab techniques" were not established when water samples showing lead and mercury were collected in April 1991. Guidance methodology was issued by the U.S. Environmental Protection Agency in February 1994 that included recommendations for sampling and analysis for trace metal concentrations.

One set of lake water samples should be collected at four or more sites along the Chattahoochee River channel to isolate possible sources. These sites should include the Cowikee Creek confluence, the river at the U.S. Highway 82 bridge, the Cheneyhatchee Creek confluence, and the dam forebay. Alabama and Georgia agencies will share responsibility for this monitoring effort. The need for further action will be determined based on mercury and lead concentrations in these samples.

Sediment sampling should be considered in the future to further evaluate the concentration of organic compounds in lake sediments. At the present time there are no standards for use in evaluating sediment data. The U. S. Environmental Protection Agency has initiated work on developing national sediment criteria. At such time as these standards have been promulgated, the data from the 1991 samples will be reviewed to determine the need for additional monitoring of lake sediments.

Fish will be collected from the lake and the Chattahoochee River upstream for ongoing monitoring of toxic substances. Fish consumption guidelines will be issued as appropriate using accepted risk-based assessment methods.

1.9 NUISANCE AQUATIC PLANTS

The U. S. Army Corps of Engineers currently monitors and controls nuisance aquatic plants in Lake Walter F. George. This work should be continued. Education of lake users is an important part of this control effort. Inventories of lake aquatic plant populations should be made at regular intervals (every five years is recommended). Population maps should be compared to determine growth trends of problem plants. The introduction of nuisance aquatic plants should be restricted to the maximum extent possible.

2.0 TRASH AND FLOATING DEBRIS EXCLUSION

Lake Walter F. George should be protected from the inundation of floating trash, tree parts, and other debris coming from the upstream Chattahoochee River. Methods to reduce this problem should be investigated. The U. S. Army Corps of Engineers and the Walter F. George Lake Advisory Committee currently sponsor an annual shoreline cleanup project. This effort should be continued and possibly expanded to include the upper, riverine areas of the lake.