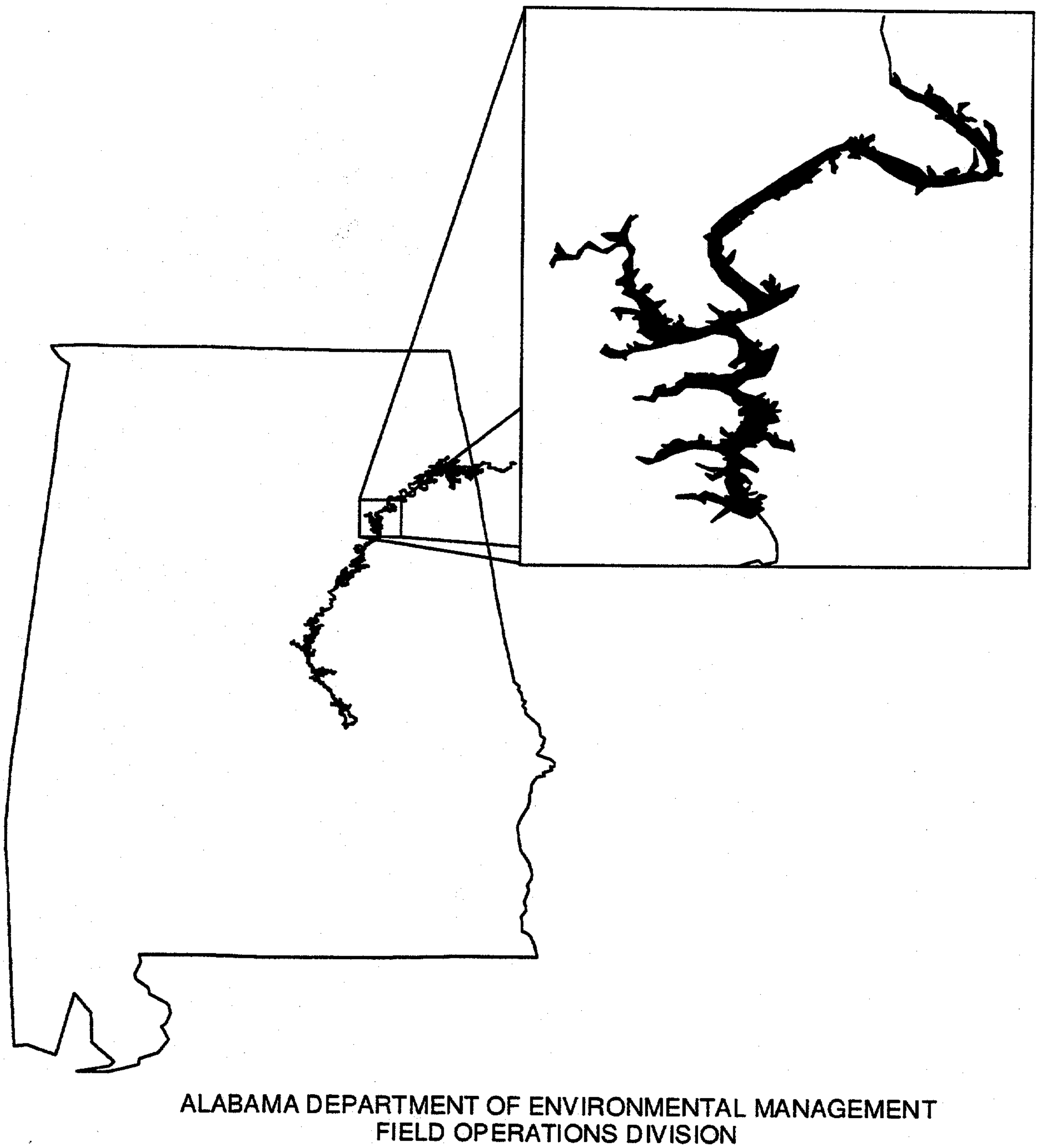
NEELY HENRY RESERVOIR
PHASE I DIAGNOSTIC/FEASIBILITY STUDY
FINAL REPORT



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FIELD OPERATIONS DIVISION
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LAKE H. NEELY HENRY

Phase I Diagnostic/Feasibility Study

FINAL REPORT

December, 1997

Preface

A 70% federal and 30% state matching grant to the state of Alabama provided funding for this study. This grant was 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 and Auburn University provided the matching funds through cooperative agreement with the Alabama Department of Environmental Management.

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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LAKE H. NEELY HENRY
PHASE I DIAGNOSTIC/FEASIBILITY STUDY

FINAL REPORT

8 December 1995

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EXECUTIVE SUMMARY

DIAGNOSTIC STUDY

Lake Neely Henry was chosen for a Phase I, Clean Lakes, Diagnostic/Feasibility Study based on the results of several previous studies that showed degraded water quality and toxic contamination of the lake from point and nonpoint sources of pollution. The objectives of this study were to gather historic and current data on Lake Henry, identify water quality problems and determine feasible solutions for their correction.

Neely Henry Dam was constructed on the Coosa River by Alabama Power Company for hydroelectric power generation during a period from 1962 to 1966. The lake has a surface area of 4,547 hectares at full pool and serves as a potable water supply, recreational (swimming and boating) resource, fishery and as flood protection. Studies conducted by ADEM, U.S. EPA and Auburn University have revealed water quality problems caused by excessive nutrient loading and the presence of toxic contaminants. As early as 1948, municipal and industrial pollution originating in the vicinity of Gadsden and Attalla, Alabama was causing serious water quality problems in Lake Henry.

Lake Henry is a relatively shallow reservoir (mean depth 3.3 m) with a mean hydraulic retention time (volume/mean discharge) of 5.8 days. The high flushing rate, particularly along the mainstem of the lake, weakened thermal stratification even in the deeper lacustrine areas. On the mainstem, classical thermoclines ($\Delta T \geq 1°C/m$ depth) were not found and water column temperature gradients seldom exceeded 3°C in 1993 or 2°C in 1994. Embayment stations were quite shallow (< 4.0 m) except for station 13 (confluence of Black Creek and Big Wills Creek) that was < 8 m deep. Stratification did occur at station 13 on occasion during both years.

Even though Lake Henry did not stratify thermally during the growing season (April through October) as is typical of warm monomictic lakes, chemical stratification did occur. Dissolved oxygen concentrations declined with depth and, at times, reached concentrations less than 1.0 mg/l. Lower D.O. concentrations were encountered under lower flow conditions in 1993 than under higher flow conditions of 1994. Similar trends were noted for embayment D.O. concentrations. D.O. concentrations measured at 2 m depth ranged between 3.6 and 11.0 mg/l and varied inversely with water temperature during the growing season. D.O. levels during the warmer months were frequently below saturation for existing temperature and atmospheric pressure.

The Coosa River is one of the more alkaline and naturally fertile rivers in Alabama. Some of the soils in the basin are rich in limestone yielding abundant $CO_3^{=}$ and HCO_3^{-} ions to surface waters. Specific conductance, a measure of the ionic content of water, ranged from a low of 88 μmhos/cm at some mainstem stations to a high of 351 μmhos/cm in Big Wills Creek Embayment at a depth of 2 m. Mainstem Alabama reservoirs were found to have specific conductance values ranging from about 23 μmhos/cm to 200 μmhos/cm. Lake Henry ranks in the upper half of the Alabama range indicating that it is one of the more fertile lakes in the state. Specific conductance at sampling stations in Black Creek and Big Wills Creek was always higher and usually much higher than conductance measured at mainstem and other embayment locations. This is apparently a result of municipal and industrial waste as well as urban runoff entering these tributaries from the cities of Fort Payne, Gadsden and other surrounding communities.

Nutrient enrichment of Lake Henry from point and nonpoint sources of pollution greatly increased lake fertility. Nitrogen and phosphorus are plant nutrients that are required in relatively high concentrations to support plant growth. Nitrogen concentrations in Lake Henry were excessive. Bioavailable nitrogen was abundant with seasonal mean concentrations in the headwaters usually exceeding 100 μg/l and lacustrine concentrations varying from about 30 - 200 μg/l. Of the macronutrients, phosphorus is usually in shortest supply and therefore is the element most often limiting to plant growth in freshwater ecosystems. In Lake Henry, however, phosphorus was so plentiful that nitrogen was the nutrient limiting algal growth. Seasonal mean total phosphorus concentration on the mainstem varied from about 50 μg/l to 140 μg/l. Bioavailable phosphorus concentrations varied from about 1.0 μg/l to 25.0 μg/l. Highest nutrient concentrations were always found downstream from Gadsden. Total phosphorus concentrations were always highest at locations in the Big Wills/Black Creek embayment.

The obvious response to nutrient enrichment of Lake Henry was excessive growth of plankton algae. Sixty four algal taxa were identified during the study. Phytoplankton communities were indicative of nutrient enriched, southeastern reservoirs. Corrected chlorophyll a concentrations in Lake Henry ranged from a high of 39.9 μg/l at the mouth of Big Wills/Black Creek in August 1994 to a low of 1.3 μg/l in the headwaters of the lake in July 1994. Mean spring concentrations were generally lower than mean summer or fall concentrations. Overall, chlorophyll a concentrations were higher in 1993 under relatively low flow conditions than during 1994 under higher flow conditions. On the mainstem, peak seasonal mean chlorophyll a concentrations always occurred at a point downstream from Gadsden. Mean chlorophyll a concentrations were consistently above the eutrophic threshold of 6.4 μg/l.

During 1993, phytoplankton primary productivity expressed on an areal basis was lowest in May and highest in September. Mean productivity ranged from a low of 831 mg C/m^2•day in June, 9.0 miles from the dam, to a high of 3,305 mg C/m^2•day in August, 2.0 miles downstream from Gadsden. Mean growing season productivity rates were well above the eutrophic threshold rate of 1,000 mg C/m^2•day.

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. Growing season mean dry weights on the mainstem of Lake Henry in 1993 were all above 5.0 mg/l (maximum desirable level) but below 10.0 mg/l (minimum problem level). Highest values occurred in May and lowest values in September. Dry weights above 10 mg/l were measured at five mainstem stations on at least one occasion. The effects of nutrient enrichment from point and nonpoint sources of pollution in the vicinity of Gadsden and surrounding communities were evident in the higher mean maximum dry weights of algae measured at stations downstream from Gadsden. The AGPT confirmed water chemistry results indicating that nitrogen, not phosphorus, was the essential nutrient limiting algal growth in the lake. Nitrogen limitation was caused by unusually high concentrations of phosphorus.

Total organic carbon (TOC) concentrations on the mainstem of the lake ranged from a low of 2.8 mg/l to a high of 18.2 mg/l. Seasonal mean concentrations were less variable with a low of 3.4 mg/l during the spring of 1993 and a high of 9.7 mg/l during summer 1994. Higher rainfall and runoff during 1994 produced higher concentrations of TOC during spring and summer than were measured in 1993. Fall concentrations were similar between years.

A macrophyte survey of Lake Henry was conducted from shallow-draft boats and was limited to the mainstem and larger tributary embayments. Dominant herbaceous macrophytes included water-willow (Justicia americana), soft rush (Juncus effusus), smartweed (Polygonum punctatum) and wool grass (Scirpus *cyperinus*). None of these plants are particularly noxious weeds but when growing in high-use areas of the lake may require management. Survey results revealed no serious aquatic plant problems in Lake Henry in 1994.

Duplicate sediment samples were collected at all sampling stations in Lake Henry on 9 August 1994. These samples were processed, preserved and submitted to ADEM's analytical laboratory facilities in Montgomery, Alabama. The sediment was tested for 29 organic contaminants and mercury. Polychlorinated biphenyls commonly known as PCB's (Arochlor 1254 and 1260) were found at seven mainstem stations and at four tributary embayment stations. The Coosa River has a history of PCB contamination dating back to 1971. The primary source of PCB contamination for this area has been identified as the General Electric Company in Rome, Georgia. The company is under a consent order to reduce PCB contaminated runoff from the plant site into the Coosa River. PCB level in fish tissues have declined through the years in both Georgia and Alabama, however, concentrations exceeding the 2 ppm FDA tolerance level for edible portions are still encountered in some fish species. There are no regulatory guidelines for PCB sediment levels.

Mercury was detected in Lake Henry sediments in concentrations ranging from 0.11 μg/g to 0.28 μg/g and was found at all sampling locations. There are no state or federal standards for sediment concentrations of heavy metals.

FEASIBILITY STUDY

The diagnostic study of Lake Henry revealed two basic problems; cultural eutrophication and toxic contamination. Both of these problems are caused by point and nonpoint source pollution from within the basin.

Eutrophication

This study, as well as others, has documented the cultural eutrophication of Lake Neely Henry that has occurred as a result of excessive nutrient enrichment of lake waters. Since records have been kept, Lake Henry has consistently ranked among the highest lakes in the state in terms of trophic status. The elevated trophic status of this lake was caused by the population growth and development in the Coosa River basin all the way to its headwaters in northwest Georgia. Point and nonpoint sources of pollution have increased through the years resulting in increased nutrient loading to the lake. These nutrients stimulate plant (usually plankton algae) growth in the receiving waters that, in turn, exerts an oxygen demand on the system. Excessive nutrient loading can be as damaging to an aquatic system as excessive organic matter loading. At present on the Coosa River NPDES permits issued by the Alabama and Georgia agencies require no limits on amounts of total phosphorus (TP) or total nitrogen (TN) that can be released. In addition, there are currently no requirements for permitted dischargers to monitor and report nutrient concentrations in their effluent on a regular (e.g. monthly) basis.

An increase in plankton algae biomass has been the predominant manifestation of nutrient enrichment of Lake Henry. In August 1989 corrected chlorophyll a concentration in the dam forebay was 21.0 μg/l. In August 1993 and 1994 at that location chlorophyll a concentrations were 22.6 μg/l and 23.1 μg/l, respectively. The highest mainstem chlorophyll a concentration measured during this study was 31.9 μg/l 4 miles from the dam in September 1993. Growing season (April - October) mean chlorophyll a concentrations in the dam forebay were 19.2 μg/l and 16.6 μg/l for 1993 and 1994, respectively. At a mid-reservoir location (Whorton Bend) the growing season mean chlorophyll a concentrations were 17.8

$\mu g/l$ and 14.8 $\mu g/l$ for 1993 and 1994, respectively. The higher concentrations measured in 1993 were likely caused by below normal rainfall which decreased discharge through the dam, decreased abiogenic turbidity and increased hydraulic retention time. The effects of cultural eutrophication in Lake Henry can be expected to worsen during periods of low discharge related to natural meteorological conditions or perhaps to increased upstream water demand.

Lake Henry is use-classified as Fish and Wildlife (F&W) throughout, with the exception of a portion of Black Creek lying between Highway 431 and Lake Gadsden that is classified as Agricultural and Industrial Water Supply. The upper reach of Lake Henry from the Weiss Dam Powerhouse downstream to the Gadsden Water Supply Intake is classified as Public Water Supply/F&W. The lower reach of the lake from the dam upstream to McCardney's Ferry (3 miles upstream of Big Canoe Creek) was classified Swimming/F&W. In the Water Quality Report to Congress covering the calendar years 1992 and 1993, ADEM (1994) found that Lake Henry only partially supported its Fish and Wildlife use classification because of chronic dissolved oxygen deficiencies. In addition, nutrient loading and elevated trophic status of the lake was reported to be threatening the water supply and recreational uses of the lake.

Recommended Action

Any steps taken to address the problem of cultural eutrophication of Lake Henry must include a consideration of all upstream portions of the Coosa River basin. This will involve upstream Lake Weiss as well as portions of the Coosa River basin in Georgia. A basinwide integrated approach, featuring maximum cooperation between the two states will be required to effectively and economically deal with this problem.

The following steps are recommended to assure that cultural eutrophication of Lake Henry is addressed and that lake waters will be safe and suitable for multiple uses.

1. Major point source dischargers (>0.5 MGD) into the Coosa River basin upstream of Lake Henry dam (Alabama and Georgia) should be requested to measure TP and TN in their effluent and report these findings in monthly discharge monitoring reports. Should this result in inaction, monitoring for TP and TN should be included as a condition of discharge through the National Pollutant Discharge Elimination System (NPDES).

   NOTE. This information will make it possible to identify significant point sources of plant nutrients entering the Coosa River. In addition, by subtracting point source nutrient loading from total nutrient loading (measured directly) it is possible to estimate nonpoint source loading. Once the sources of nutrients are known, actions can be taken to control nutrient additions to the system if necessary.

2. Chlorophyll a should be added to the list of water quality criteria used to protect, maintain and improve the quality of Lake Henry. Mean, photic zone chlorophyll a (corrected for phaeopigments) concentrations measured monthly during the growing season (April through October) in the dam forebay and at mid-reservoir (Whorton Bend) should not exceed 16 μg/l at either location. This criterion will be subject to the general conditions applicable to all water quality criteria as stated in section 335-6-10-.05 of the Alabama Water Quality Criteria (ADEM 1990).

   NOTE. Excessive chlorophyll a concentrations can be reduced by controlling nutrient additions through NPDES permitting (point sources) or use of best management practices (nonpoint sources). The following water quality improvements should result from this chlorophyll limit:

- greater water clarity;
- reduced oxygen demand caused by overproliferation and decomposition of organic matter (plankton algae);
- higher minimum and lower maximum pH and
- reduced probability that trihalomethane precursors will result from excessive phytoplankton blooms.

A chlorophyll a concentration of 16 μg/l during the growing season should be more than adequate to support a productive lake fishery.

Toxic Contamination

Excessive PCB concentrations in Coosa River fish were first reported by the Alabama Pesticide Laboratory in 1971. In 1976, the Georgia Environmental Protection Division reported high concentrations of PCB's in fish collected on the Coosa River between Rome, Georgia and the Georgia/Alabama state line. In 1979, the EPA banned the manufacture, processing, distribution and use of PCB's with the exception of that material existing in enclosed electrical equipment. Environmental PCB concentrations have decreased since the EPA ban went into effect, however, the stability of PCB's (50-300 times more persistent than DDT) will prolong the period of concern for these contaminants. A limited fish consumption advisory issued by the State Health Officer in 1989 is currently in effect for Lake Henry.

One sampling location was located in Lake Gadsden near the mouth of Black Creek downstream from the discharge and runoff from GSS. This station consistently had the lowest seasonal mean dissolved oxygen and highest temperature of all locations sampled. Waters at this station had the highest total nitrogen (usually high ammonia and total kjeldahl nitrogen) and highest or second highest seasonal mean total phosphorus concentrations measured at any location. An EPA study also reported depressed dissolved oxygen and elevated water temperature and nutrient concentration. In addition, the EPA study documented the presence of potentially toxic levels of organic compounds and metals in both water and sediment. Macroinvertebrate and fish data revealed a severely stressed aquatic fauna in the Black Creek reach downstream from the GSS discharge. Fish Health Assessment Indices reflected the poorest fish condition ever measured by TVA biologists. In October 1993, an estimated 43,000 fish were killed in a 3.0 mile (4.8 km) reach of Black Creek. GSS agreed to pay the state government $500,000 to settle claims related to the fish kill but did not admit any responsibility (F. R. Harders, Alabama Game and Fish).

Recommended Action

1. Annual monitoring of Lake Henry fish for the presence of PCB's should be continued to document any changes in residue levels. This sampling should include fish captured from the lake by state biologists as well as commercially caught fish from the lake that enter markets for sale to the public. Less frequent sampling can be conducted when PCB residue levels decline below FDA tolerance limits in fish for three consecutive years.
2. The portion of Black Creek downstream of the Gulf States Steel facility was documented to be in a degraded condition as a result of point and non-point source discharges, not even meeting the minimal water quality criteria of the Agricultural and Industrial Water Supply use classification. Gulf States Steel chronically fails to comply with NPDES permit limitations and as a result is subject to regulatory enforcement action. The segment is listed on Alabama's 1996 Draft 303(d) List of

impaired waters. Section 303(d) of the Clean Water Act requires the State to develop Total Maximum Daily Load (TMDL) estimates for the pollutants of concern. After the TMDL has been determined and the necessary corrective actions have been implemented, continued monitoring will be necessary to document improvements in water quality in Black Creek. The additional monitoring data will also be used in future use attainability analyses. The goal of the ADEM should be the upgrade of the segment to the Fish and Wildlife use classification so that Lake Neely Henry, in its entirety, could be expected to support multiple uses.

Monitoring

Lake Henry should be sampled each month during the growing season (April through October) to assure that water quality standards (including the new chlorophyll a standard) are being met. Lake Henry fish should be tested for PCB residues annually. Sampling of water and sediment from the reach of Black Creek downstream from GSS should be conducted annually.

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PART I. DIAGNOSTIC STUDY

1.0 LAKE IDENTIFICATION

Lake Neely Henry is located on the Coosa River in Northeast Alabama, southwest and downstream of Gadsden, near Ohatchee. Alabama Power Company constructed the dam for hydroelectric power generation which began in 1966. It is the second reservoir on the Coosa River System with the upstream reach of the reservoir meeting the tailwater of Weiss Lake. The reservoir is located in Calhoun and St. Clair Counties, Alabama. The nearest municipalities include Gadsden and Ohatchee.

Morphometric characteristics of Lake Henry appear in Table 1-1. Hydroelectric dam and turbine specifications for this lake appear in Table 1-2. Normal pool is maintained at 154.8 m. Drawdown elevation is 153.9 m, a drop of only 0.9 m. Reservoir volume at full pool is 14,882 ha-m and at drawdown approximately 11,141 ha-m. Average depth at full pool is 3.3 m and at drawdown 3.02 m. Drawdown begins after Labor Day and is usually completed by mid-December. Full pool is generally reached by mid-May depending on the amount of rainfall for the particular year.

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

a) Neely Henry Dam upstream to McCardney's Ferry:
Swimming/Fish and Wildlife

b) McCardney's Ferry to Gadsden water supply intake:
Fish and Wildlife

c) Gadsden water supply intake to Weiss Dam powerhouse:
Public Water Supply/Fish and Wildlife

Table 1-1. Morphometric characteristics of Lake Neely Henry.

Drainage area	17,093 km^2
Surface area	4,547 ha
Shoreline length	545 km
Full reservoir length	125 km
Maximum depth at dam	16 m
Average depth	3.3 m
Normal pool elevation	154.8 m NGVD
Normal pool volume	148.8×10^6 m^3
Drawdown pool elevation	153.9 m NGVD
Drawdown pool volume	111.4×10^6 m^3
Average depth at drawdown	3.0 m
Hydraulic retention time	5.78 days

Table 1-2. Lake Neely Henry hydroelectric dam and turbine specifications.

Location	
Town	Near Ohatchee, Alabama
County	Etowah
River	Coosa
Construction started	September 1, 1962
In-service date	June 2, 1966
Dam	
Type	concrete and earth fill
Maximum height	26 meters
Spillway gates	
Number	6
Size	12 meters X 9 meters
Capacity (ea.)	17,002 cfs
Hydraulic Turbines	
Number	3
Type	Propeller
Water discharge (ea.)	8,500 cfs @ effluent gate

2.0 BASIN GEOLOGY AND DRAINAGE

The Coosa River basin and specifically Lake Henry lie within the Valley and Ridge physiographic province in Alabama. This physiographic province is characterized by wide, gently rolling valleys and steep, rough ridges trending northeast-southwest. The Coosa Valley district of this province is composed of plains with varied relief characterized by parallelism of northeastward-trending valleys and ridges resulting from the erosion of extensively folded and faulted beds. The plain is formed on limestone and shale.

Soils in the area primarily consist of Hector, Holsten, Conasauga and Montevallo series (Table 2-1). These are shallow to moderately deep soils with brownish, shaley, loamy surface over brownish to reddish clayey subsoil. Depth to bedrock is usually in excess of sixty inches. The soils are moderately well drained and the surface layer is slightly acidic with the subsoil being slightly alkaline. Erosion potential is moderate dependent on slope and vegetation disturbances.

The Coosa River, formed by the confluence of the Oostanaula and Etowah Rivers in Rome, Georgia, is the major tributary to Lake Henry. Other tributaries include Big Canoe, Beaver, Shoal, Big Wills and Black Creek on the west side of the reservoir and Cove, Greens and O'Henry Creek on the east.

Table 2-1. Characteristics of soil associations surrounding Lake Neely Henry and their suitability/limitations for selected uses.

		Characteristics					Suitability/Limitations					
Soil Association	Soil and Landscape	Soil Series	Depth	Bedrock	Drainage	Surface Texture	Dominant Slope(%)	Cropland	Pasture	Septic Tanks	Roads	Building
Cobert-Conasauga-Firestone	level pasture, wooded valleys.	Cobert	Deep	Limestone	Well-drained	Loamy	1-6	Fair: to clayey	Good:	Severe: percs slowly	Severe: low strength, shrink-swell	Severe: low stremgth, shrink-swell
		Conasauga	Moderate	Shale	Well-drained	Loamy						
		Firestone	Moderate	Shale	Well-drained	Gravelly, loamy						
Conasauga-Firestone-Talbott	Wooded, rolling hills, pasture.	Conasauga	Moderate	Shale	Well-drained	Loamy	1-6	Fair: slope, to clayey	Good	Severe: percs slowly	Severe: low strength	Severe: low strength, shrink-swell
		Firestone	Moderate	Shale	Well-drained	Gravelly, loamy						
		Talbott	Moderate	---	Well-drained	Loamy						
Holston-McQueen-Chewacla	Large, level fields.	Holston	Deep	---	Well-drained	Loamy	0-6	Good	Good	Slight	Moderate: low strength	Moderate: low strength
		McQueen	Deep	---	Well-drained	Loamy						
		Chewacla	Deep	---	Poorly-drained	Loamy						
Minvale-Bodine-Fullerton	Rolling pasture, steep woodland.	Minvale	Deep	---	Well-drained	Cherty, loamy	6-35	Poor: slope, small stones droughty	Fair: slope, droughty	Severe: slope	Severe: slope	Severe: slope
		Bodine	Deep	---	Excessively drained	Cherty, loamy						
		Fullerton	Deep	---	Well-drained	Cherty, loamy						
Minvale-Fullerton	Hilly woodlands, pasture.	Minvale	Deep	---	Well-drained	Cherty, loamy	2-20	Fair: slope	Good	Moderate: slope	Moderate: slope, low strength	Severe: slope
		Fullerton	Deep	---	Well-drained	Cherty, loamy						
Hector-Rockland, Limestone-Allen	Steep, wooded slopes. Rock ledges, boulders.	Hector	Shallow	Sandstone	Well-drained	Gravelly, loamy	25-40	Poor: slope, depth to rock	Poor: slope	Severe: slope, depth to rock	Severe: slope, depth to rock	Severe: slope, depth to rock
		Allen	Deep	---	Well-drained	Loamy						

U.S. Army Corps of Engineers. 1981.

3.0 PUBLIC ACCESS

Public access to Lake Henry is provided through both free public access areas (3) and user fee access areas (8). These areas include boat ramps, picnic areas, camp grounds and one city park. Frequently utilized private boat launches include Willow Point Marina, Greensport Marina and Rainbow Marina. Tornado damage in 1994 forced the closing of one public access area near the dam, however the area was expected to reopen with improved facilities in 1995.

Visitation assessed by Alabama Power prior to 1982 was estimated at 465,100 per day and 1,085,300 overnight. This survey also indicated that facilities were adequate for the amount of visitation in 1982. Plans for continuing assessment of public access and recreation needs were also included in the Alabama Power Survey.

4.0 SIZE AND ECONOMIC STRUCTURE OF POTENTIAL USER POPULATION

Lake Henry is bordered by Etowah, St. Clair and Calhoun counties. Adjacent counties include Blount, Cherokee, DeKalb and Marshall counties. Gadsden is the largest municipality in the area and actually borders the lake. Ohatchee and Anniston are also in close proximity to the lake and other municipalities such as Jacksonville, Attalla and Oxford are well within traveling distance. Population and income data for each county in the vicinity of Lake Henry is presented in Table 4-1. Calhoun County had the highest population of the counties near the lake while Etowah County had the highest per capita income. Marshall County had the highest percentage of families with incomes below the poverty level and the second highest per capita income.

Business and employment data for counties in the vicinity of Lake Henry appear in Tables 4-2 and 4-3. Service and retail trade businesses comprised the largest number of business establishments in the area. Construction and manufacturing businesses followed, but were much lower in total number. Manufacturing employed by far the greatest number of people in the area followed by service and retail trade businesses.

Agricultural production data for each county in the vicinity of Lake Henry appear in Table 4-4. Etowah County did not rank among the top three counties in the vicinity of the lake in terms of farm acreage and agricultural production. However other counties in the area are heavily involved in various aspects of agricultural production. Cherokee and DeKalb counties, upstream of Lake Henry, are important producers of cotton, cattle, hogs, broilers, corn, wheat and soybeans.

Table 4-1. Total population and income characteristics of Alabama counties in the vicinity of Lake Neely Henry.

State County	Total Population	Per Capita Income	% Families with Income Below Poverty Level
Alabama			
Blount	39,248	10,168	11.4
Calhoun	116,034	10,704	11.7
Cherokee	19,543	9,915	14.2
DeKalb	54,651	9,604	14.2
Etowah	99,840	10,997	13.2
Marshall	70,832	10,793	14.5
St. Clair	50,009	10,596	12.1

U.S. Bureau of the Census. 1990.

Table 4-2. Number of business establishments of Alabama counties in the vicinity of Lake Neely Henry.

State	County	Total	Agricultural, Forestry, Fishing	Mining	Construction	Manufacturing	Transportation, Public Utilities	Wholesale Trade	Retail Trade	Finance, Insurance, Real Estate	Services	Unclassified Establishments
Alabama												
	Blount	515	6	4	74	47	20	35	145	30	136	18
	Calhoun	2,299	24	3	198	168	87	140	660	174	757	88
	Cherokee	288	5	2	20	32	14	18	96	18	67	16
	DeKalb	1,038	4	1	69	200	34	54	305	55	266	50
	Etowah	1,948	11	4	149	138	72	135	568	145	666	60
	Marshall	1,732	14	3	117	145	72	145	596	126	444	70
	St. Clair	715	16	2	83	71	37	54	209	32	179	32
	Total	8,535	80	19	710	801	336	581	2,579	580	2,515	334

U.S. Bureau of the Census. 1990.

Table 4-3. Number of employees for business establishments of Alabama counties in the vicinity of Lake Neely Henry.

State	County	Total	Agricultural, Forestry, Fishing	Mining	Construction	Manufacturing	Transportation, Public Utilities	Wholesale Trade	Retail Trade	Finance, Insurance, Real Estate	Services	Unclassified Establishments
Alabama												
	Blount	6,472	75	46	332	2,816	246	359	1,163	197	1,225	13
	Calhoun	33,433	155	81	1,477	11,426	1,366	2,200	7,973	1,192	7,439	124
	Cherokee	3,500	(B)	(A)	72	1,795	147	139	768	119	422	12
	DeKalb	16,422	(B)	(A)	552	8,973	556	821	2,817	405	2,188	(B)
	Etowah	31,219	29	65	1,382	11,129	1,285	1,601	6,785	1,268	7,614	61
	Marshall	26,089	64	(B)	795	12,993	825	1,703	5,931	723	2,944	(B)
	St. Clair	7,115	91	(B)	588	2,264	327	861	1,417	309	1,213	(B)
Total		124,250	---	---	5,198	51,396	4,752	7,684	26,854	4,213	23,045	---

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

U.S. Bureau of the Census. 1990.

Table 4-4. Agricultural production of Alabama counties in the vicinity of Lake Neely Henry.

State	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
Alabama											
	Blount	1,199	140,107	71,109	18.6	19.8	35,087	93	32	124	1,800
	Calhoun	685	90,474	41,055	6.5	1.5	10,209	87	36	128	500
	Cherokee	487	119,956	72,603	11.4	10.1	1,099	136	116	495	14,500
	DeKalb	2,047	213,440	122,392	25.7	50.3	55,565	1,169	100	412	900
	Etowah	928	100,517	47,478	10.4	4.1	15,491	82	27	143	1,700
	Marshall	1,582	136,599	78,497	18.8	16.3	44,252	348	20	318	400
	St. Clair	634	89,109	39,773	7.3	1.9	10,514	21	10	9	---
Total		7,562	890,202	472,907	98.7	104.0	172,217	1,936	341	1,629	19,800

U.S. Bureau of the Census. 1987.

5.0 HISTORY OF LAKE USES

Lake Henry was impounded by Alabama Power Company in 1966 for hydroelectric power generation. The town of Gadsden, Alabama uses the water as a public water supply. Much of the area around the lake is developed in permanent and semi-permanent residences.

The lake is popular with bass fishermen hosting numerous bass tournaments during the year. A commercial fishery (channel and blue catfish) also exists on the lake. Additional recreational activities include boating, skiing, swimming and camping.

6.0 USER POPULATION AFFECTED BY LAKE DEGRADATION

Lake Henry has been impacted by point and non-point source pollution since impoundment (AWIC 1949, EPA 1993, ADEM 1994). Fish kills have occurred as a result of chronic problems in Black Creek (EPA 1993). Additionally the upstream contamination of fish with polychlorinated biphenyls (PCBs) originating from an industrial source in Georgia (via Weiss Lake) was discovered in the 1970's. In May 1989, a limited fish consumption advisory was issued by the Alabama Department of Public Health pertaining to PCB contamination in catfish. The commercial fishery on Lake Henry involves only channel and blue catfish so this advisory negatively impacts this enterprise. The advisory extends from the Alabama-Georgia state line through Logan Martin Dam.

Lake Henry flows through the city of Gadsden and much of the urban population has some type of access to the lake. Since the lake is used for fishing, swimming, boating, skiing and as a public water supply, all users stand to be affected by these pollution impacts.

7.0 LAKE USE COMPARISON WITH NEARBY LAKES

Weiss Lake is located on the Coosa River near Centre, Alabama, approximately 30 miles upstream of Lake Henry. Impounded in 1961 by Alabama Power Company for hydroelectric power generation, the 12,222 hectare reservoir serves as a water supply for the town of Cedar Bluff. It is also one of the most popular recreational lakes in the state. Weiss is known for its outstanding crappie fishery which attracts fishermen from all over the southeast as well as several northern states. Bass tournaments also abound on the lake as well as various swimming, camping, boating and skiing activities. Concern over the effects of point and non-point source discharges into the lake and PCB contamination in the fish resulted in a Phase I Diagnostic/Feasibility Study which began in 1990.

Guntersville Lake is located northwest of Lake Henry on the Tennessee River. The lake was impounded by the Tennessee Valley Authority (TVA) in 1939 for hydroelectric power generation purposes and has a surface area of 27,114 hectares. The reservoir also serves as a public water supply and discharge point for several municipalities and industries. It is a reservoir that is popular for fishing, boating, skiing, swimming and other activities.

Logan Martin Lake is located on the Coosa River just below Lake Henry. It was impounded in 1964 prior to Lake Henry by Alabama Power Company for power generation. The lake is about 6,176 hectares in area and has been heavily utilized by the public for recreation and permanent residences. It is one of the most popular lakes in the state having numerous private clubs, golf courses and marinas. Recently the discovery of PCB contamination in the Choccolocco Creek arm of Logan Martin Lake has caused concern. A fish advisory was in existence due to upstream PCB contamination, however results from the Choccolocco Creek area have prompted a fish advisory on all species (ADEM 1994).

8.0 POINT SOURCE POLLUTION INVENTORY

An inventory of actual and permitted discharges was compiled for industrial, municipal and mining discharges in Alabama flowing into Lake Neely Henry between the Weiss Dam and the southern border of the Lake Henry watershed November 1992 through October 1994 (Tables 8-1 and 8-2). Data were obtained from discharge monitoring reports and compliance sampling inspections from the Alabama Department of Environmental Management. Annual point source loading estimates were calculated by expanding each monthly sampling value to a monthly load by multiplying the average daily load estimate by the average flow and number of days in the month then summing the monthly estimates. Nutrient data for municipalities obtained from compliance sampling inspections represents a single value rather than monthly values thus the resulting loading estimates are less accurate. Potential point source loading (Table 8-2) represents the amount of loading that would occur if permit limits for the various industry, municipal and mining interests were reached.

Twenty-four permitted dischargers were identified; nine industrial, ten municipal and five mining dischargers. Twelve of these facilities discharge directly into Lake Neely Henry at various points along the Coosa River. The 24 facilities released 69,314 million gallons of wastewater effluent annually. The industrial facilities Gulf States Steel and Alabama Power Co. Gadsden Steam Plant were responsible for 43% and 39% of the annual wastewater effluent.

Annual point source biochemical oxygen demand (BOD) was 1,122,143 lbs which represents 47% of the permitted BOD load. The municipal discharge of Gadsden Wastewater Treatment Plant West and East contributed 47% and 22%, respectively. Annual point source total suspended solids (TSS) load was 1,993,170 lbs which is 33% of the permitted TSS load. The Gadsden West WWTP contributed 32% and Gulf States Steel contributed 22%. Annual point source total nitrogen load was 1,289,513 lbs and total phosphorus load was 174,105 lbs.

Table 8-1. Annual 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 Neely Henry, November 1992 - October 1994.

Facility	NPDES No.	Fac	Receiving Stream	Permitted Flow (MGD)	Actual Flow (MGD)	Total Flow (MG/yr)	BOD Loading (lbs/yr)	TSS Load (kg/yr)	TN[1.6] Load (kg/yr)	TP[6] Load (kg/yr)
				Discharge directly into Neely Henry						
Alabama Power Co. Gadsden Steam Plant	AL0002887 DSN001	I	Coosa River	--	73.17	26,708	--	--	--	--
Alabama Power Co. Gadsden Steam Plant	AL0002887 DSN002	I	Coosa River	--	4.576	1,670	--	29,072	--	--
Emco, Inc.	AL0026484	I	Unnamed Trib to Coosa River	--	0.120	43.62	--	343	--	--
Goodyear Tire and Rubber Co.	AL0001007	I	Coosa River	--	6.617	2,415	--	88,773	--	--
Tyson Foods	AL0002119	I	Coosa River	--	1.244	454	42,164	31,261	6,010[1]	23,064
Attalla Lagoon	AL0057657	M	Coosa River	1.93	1.622	592	93,997	73,918	25,637[2]	6,717[3]
Gadsden East WWTP	AL0022659	M	Coosa River	3.50	6.214	2,268	207,678	93,220	103,037[2]	6,869[3]
Gadsden West WWTP	AL0053201	M	Coosa River	11.32	9.639	3,518	458,186	290,154	195,111[2]	23,041[3]
Glencoe Lagoon	AL0021334	M	Coosa River	0.45	0.334	122	24,794	19,120	--	--
Rainbow City Lagoon	AL0056839	M	Coosa River	0.741	0.455	166	29,408	26,190	13,570[3]	2,455[4]
Southside Lagoon	AL0055867	M	Coosa River	0.26	0.025	8.99	299	297	--	--
Calhoun Asphalt Sims Pit	AL0060585	Mn	Coosa River	--	--	--	--	--	--	--
Sagna, Inc.	AL0062472	Mn	Coosa River	--	--	--	--		--	----
Subtotal				18.201	104.016	37,965.61	856,525	652,346	343,363	62,145
					Big Wills Creek					
Cagles	AL0002241	I	Big Wills Cr	--	0.896	326.93	108,681	--	83,896[4]	--
Collinsville Lagoon	AL0024236	M	Big Wills Cr	0.30	0.233	85.02	8,619	4,073	4,32[2]	650[3]
Fort Payne WWTP	AL0023311	M	Big Wills Cr	4.0	2.340	854.30	39,345	34,640	20,625[2]	16,164[3]
Jordan Hatchery	AL0056103	I	Big Wills Cr	--	0.001	0.40	--	--	--	--
Subtotal				4.30	3.470	1,266.65	156,645	38,713	108,847	16,814

Table 8-1. (Cont.)

Facility	NPDES No.	Fac	Receiving Stream	Flow (MGD)	Permitted Flow (MGD)	Actual Flow (MG/yr)	Total Loading (lbs/yr)	BOD Load (kg/yr)	TSS Load (kg/yr)	TN[1,6] Load (kg/yr)
				TP[6]						
Black Creek										
Gulf States Steel	AL0055239	I	Black Cr	--	80.05	29,218	--	200,723	48,707[1]	--
Mountain View Baptist Hospital	AL0059544	M	Unnamed Trib to Black Cr	0.05	0.008	2.74	122	34	--	--
Subtotal				0.05	80.058	29,220.74	122	200,757	48,707	--
Little Wills Creek										
M & M Chemical	AL0054542	I	Unnamed Trib to Little Wills Cr	--	--	--	--	--	--	--
Dry Creek										
AAA Plumbing Pottery Corp.	AL0026042	I	Unnamed Trib to Dry Cr	--	0.013	4.75	--	305	--	--
Little Cove Creek										
Vulcan Mat. Glencoe Quarry	AL0002020 DSN001	Mn	Unnamed Trib to Little Cove Cr	--	1.231	449.5	--	10,553	--	--
Vulcan Mat. Glencoe Quarry	AL0002020 DSN002	Mn	Unnamed Trib to Little Cove Cr	--	0.019	7	--	197	--	--
Subtotal				--	1.25	456.5	--	10,750	--	--
Beaver Creek										
National Cement Co. Beaver Creek	AL0031534	Mn	Beaver Cr	--	0.193	70.61	--	939	--	--
Pole Creek										
West End Elementary School	AL0060089	M	Pole Cr	0.017	0.004	1.46	170	124	--	--
TOTAL				22.568	189.901	69,314	1,122,143	903,932	584,813	78,959

1 NH_3-N
2 Loading is based on utilizing actual flow (MGD) and concentration obtained from most recent ADEM compliance sampling inspection. TN value does not include nitrite-nitrogen.
3 Loading is based on utilizing actual flow (MGD) and concentration obtained from most recent ADEM compliance sampling inspection. TP value is PO_4-P.
4 Loading is based on utilizing actual flow (MGD) and concentration obtained from discharge monitoring report. TN value includes TKN and NH_3-N only.

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 Neely Henry, November 1992 - October 1994.

Facility	NPDES No.	Fac	Permitted Flow (MGD)	Permitted BOD (mg/l)	Permitted BOD (lbs/day)	Permitted BOD Load (lbs/yr)	Permitted TSS (mg/l)	Permitted TSS (kg/day)	Permitted TSS Load (kg/yr)	Permitted TN (mg/l)	Permitted TN Load (kg/yr)	Permitted TP (mg/l)	Permitted TP Load (kg/yr)
Discharge Directly into Neely Henry													
Alabama Power Co. Gadsden Steam Plant	AL0002887 DSN001	I	73.17[1]	--	--	--	--	--	--	--	--	--	--
Alabama Power Co. Gadsden Steam Plant	AL0002887 DSN002	I	4.576[1]	--	--	--	--	--	--	--	--	--	--
Emco, Inc.	ALA0026484	I	0.120[1]	--	--	--	30	--	4,973[2]	--	--	--	--
Goodyear Tire and Rubber Co.	AL0001007	I	6.617[1]	--	--	--	--	--	--	--	--	--	--
Tyson Foods	AL0002119	I	1.244[1]	--	331	120,815	--	202	73,730[2]	--	--	--	--
Attalla Lagoon	AL0057657	M	1.93	30	483	176,295	90	657	239,805	11.45[3]	30,530[4]	3.0[3]	7,999[4]
Gadsden East WWTP	AL0022659	M	3.50	30	1,547	564,655	30	702	256,230	12.0[3]	58,024[4]	0.80[3]	3,868[4]
Gadsden West WWTP	AL0053201	M	11.32	30	2,832	1,033,680	45	1,927	703,355	14.65[3]	229,109[4]	1.73[3]	27,055[4]
Glencoe Lagoon	AL0021334	M	0.45	30	113	41,245	90	153	55,845	--	--	--	--
Rainbow City Lagoon	AL0056839	M	0.741	30	185	67,525	90	252	91,980	21.56[3]	22,071[4]	3.90[3]	3,992[4]
Southside Lagoon	AL0055867	M	0.260	30	65	23,725	90	88	32,120	--		--	--
Calhoun Asphalt Sims Pit	AL0060585	Mn	--	--	--	--	35	--	--	--	--	--	--
Sagna, Inc.	AL0062472	Mn	--	--	--	--	--	--	--	--	--	--	--
Subtotal						2,027,940			1,458,038		339,734		42,914
Big Wills Creek													
Cagles	AL0002241	I	0.896[1]	30	--	81,698	--	--	--	--	--	--	--
Collinsville Lagoon	AL0024236	M	0.300	20	30	10,950	90	61	22,265	13.44[3]	5,570[4]	2.02[3]	837[4]
Fort Payne WWTP	AL0023311	M	4.000	15	500	182,500	30	454	165,710	6.38[3]	35,257[4]	5.00[3]	27,631[4]
Jordan Hatchery	AL0056103	I	0.001[1]	--	--	--	--	--	--	--	--	--	
Subtotal						275,148			187,975		40,827		28,468

Table 8-2. (Cont.)

Facility	NPDES No.	Fac	Permitted Flow (MGD)	Permitted BOD (mg/l)	Permitted BOD (lbs/day)	Permitted BOD Load (lbs/yr)	Permitted TSS (mg/l)	Permitted TSS (kg/day)	Permitted TSS Load (kg/yr)	Permitted TN (mg/l)	Permitted TN Load (kg/yr)	Permitted TP (mg/l)	Permitted TP Load (kg/yr)
						Black Creek							
Gulf States Steel	AL0055239	I	80.05[1]	--	--	--	9	--	995,320[2]	0.67[5]	74,096[2]	--	--
Mountain View Baptist Hospital	AL0059544	M	0.050	10	4.2	1,533	30	12.5	4,563	1.2[5]	--	--	--
Subtotal						1,533			999,883		74,096		--
						Little Wills Creek							
M & M Chemical	AL0054542	I	--	--	--	--	--	--	--	--	--	--	--
						Dry Creek							
AAA Plumbing Pottery Corp.	AL0026042	I	--	--	--	--	30	--	539[2]	--	--	--	--
						Little Cove Creek							
Vulcan Mat. Glencoe Quarry	AL0002020 DSN001	Mn	1.231[1]	--	--	--	25	--	42,516[2]	--	--	--	--
Vulcan Mat. Glencoe Quarry	AL0002020 DSN002	Mn	0.019[1]	--	--	--	25	--	656[2]	--	--	--	--
Subtotal						--			43,172		--		--
						Beaver Creek							
National Cement Co. Beaver Creek	AL0031534	Mn	0.193[1]	--	--	--	35	--	9,332[2]	--	--	--	--
						Pole Creek							
West End Elementary School	AL0060089	M	0.017	30	4.3	1,570	90	12.8	4,672	--	--	--	--
TOTAL						2,387,889			2,703,611		454,657		71,382

[1] Actual Flow
[2] Potential loading was estimated by utilizing actual average daily flow and permitted concentration.
[3] Facility is not required to monitor total phosphorus and total nitrogen in their effluent, values were obtained from the most recent ADEM compliance sampling inspection.
[4] Potential loading was estimated by utilizing permitted daily flow and concentration obtained from ADEM compliance sampling inspections.
[5] NH3-N

10.0 LAKE NEELY HENRY LIMNOLOGY

10.1 Lake Neely Henry Limnological History

The earliest water quality data available on that section of the Coosa River now impounded by Neely Henry Dam was published by the Alabama Water Improvement Advisory Commission (1949). Their studies conducted during the summer of 1948 revealed degraded water quality in the Coosa River and tributary streams receiving wastewater from municipal and industrial point sources located in the Gadsden, Alabama area. Untreated sewage from the Gadsden-Attalla area entered the river just downstream from the mouth of Big Wills Creek. In addition, Black Creek, a tributary of Big Wills Creek, received the wastewater from Republic Steel Corporation's Gadsden Works. This waste caused a substantial rise in water temperature (37°C), iron content (0.0-350 p.p.m.), BOD_5 (12.1 p.p.m.) and a decline in dissolved oxygen (3.1 p.p.m.) The Coosa River waters just downstream from the mouth of Big Wills Creek had the highest total fecal coliform counts of any location on the Coosa River. Noticeable recovery occurred downstream.

After completion of the Neely Henry Dam in 1966, water quality data on the lake were scarce until about 1971. During that year the Alabama Pesticide Laboratory (1971) reported findings of analytical studies conducted on the water, sediment and fish tissue collected at 76 aquatic sites in Alabama. One of the sampling sites was near the Southside Bridge over Lake Henry. All samples were screened for the presence of 17 pesticides (and metabolites) and the industrial chemical polychlorinated biphenyls (PCB). Edible portions (with bones) of fish were analyzed for toxic substances and reported in mg/kg wet weight. Largemouth bass from Lake Henry had 2.4 mg/kg DDT and 9.7 mg/kg PCB. Carp had 0.9 mg/kg DDT and 6.3 mg/kg PCB. At the time, FDA tolerance for both DDT and PCB in fish was 5.0 mg\kg.

In 1976, the Georgia Department of Natural Resources (DNR) Environmental Protection Division (EPD) collected fish from the Coosa River in Georgia and analyzed tissue samples for toxic substances. Some of the fish sampled had concentrations of polychlorinated biphenyls (PCB's), that exceeded the limit (5 mg/kg) established by the U.S. Food and Drug Administration (FDA) for human consumption (DNR 1976). A fish consumption advisory was issued for the lower Coosa River from Rome, Georgia downstream to the Alabama-Georgia state line. The advisory included all species of fish. A commercial fishing ban was imposed soon after (EPD 1991). The source of the contamination was identified as a General Electric Company plant at Rome, Georgia (DNR 1976 and EPD 1991). The plant manufactured electrical transformers that contained PCB's. When the company became aware of the environmental problems associated with this persistent industrial chemical in the early 1970's, they took action to minimize losses of spills of PCB's (DNR 1976). General Electric was later placed under a consent order to reduce PCB contaminated runoff from their plant site (EPD 1991).

DNR notified Alabama officials of the PCB problem in 1976 (DNR 1976). From 1976 until 1988, the Alabama Department of Environmental Management (ADEM) sampled fish in Weiss Lake and found that the PCB concentrations had declined below FDA action levels. However, in 1988 the Alabama Department of Agriculture and Industries tested filets of catfish allegedly caught in the Coosa River and found that almost one-half of the filets had PCB concentrations above the FDA tolerance level (revised to 2.0 mg/kg in 1979). As a result, in May 1989, the State Health Officer issued a health advisory recommending that women who were or may become pregnant; women who were breastfeeding or may breastfeed; and children under the age of 15 avoid eating large (>1.0 lb) catfish taken from the affected waters (ADPH 1989). The advisory covered a 160 mile stretch of the Coosa River from the Alabama-Georgia state line downstream to Logan Martin Dam and included lakes Weiss, Henry and Logan Martin (ADEM 1992).

In 1974, the Alabama Water Improvement Commission established a network of ambient water quality monitoring stations around the state. These stations are routinely sampled at regular intervals to detect long-term trends in water quality at select locations. A trend station (BW-1) was established on Big Wills

Creek at the DeKalb County Highway 52 bridge near Collinsville. This station was sampled routinely from July 1974 through May 1983.

In 1985, the paucity of information on water quality and trophic condition of Alabama reservoirs prompted ADEM, in a joint effort with the EPA, Region IV, to survey most of the public reservoirs in the state. Limited baseline water quality data were reported for Lake Henry and the trophic status of the lake was reported among the highest in Alabama (Raschke 1985). Four years later a more intensive reservoir assessment was conducted on 34 public lakes in Alabama with funds provided through an EPA Clean Lakes assessment grant. Auburn University, working through a Cooperative Agreement with ADEM, conducted the study during the 1989 growing season (Bayne *et al.* 1989). Once again Lake Henry proved to be a highly eutrophic system with D.O. concentrations well below saturation under late summer conditions.

The Reservoir Water Quality Monitoring Program was begun in 1990 by ADEM with funding in part provided by the EPA Clean Lakes grants. Under this program all public lakes are monitored every 2 years and certain use-impaired lakes are monitored yearly. Results of these studies are routinely published in biennial departmental reports and 305(b) reports submitted by ADEM to EPA (ADEM 1992a and 1994). Because of its excessive nutrient enrichment and advanced trophic state, Lake Henry only partially supports aquatic life (ADEM 1994). In addition, water supply (2,145 acres) and recreational (9,335 acres) uses of the lake are reported to be threatened by continued eutrophication of this lake (ADEM 1992a and 1994). Fish kills have been documented in Lake Henry tributaries receiving treated wastewater from municipal and industrial operations (ADEM 1992a and 1994).

Concern over water quality and waste load allocation to Lake Henry prompted ADEM to conduct a series of studies between 1991 and 1993. In July and September of both 1991 and 1992, intensive dissolved oxygen monitoring of the lake was carried out in order to characterize the D.O. dynamics of the system (ADEM 1992b and 1992c). This information was used to determine the need for additional studies to assure proper allocation of point source loads to the lake. Results of the 1992 study revealed several violations of the D.O. standard and led to the conclusion that Lake Henry was not supporting its water use classification for fish and wildlife (ADEM 1992b).

During the 1991 growing season, water quality in Big Wills Creek was monitored (ADEM 1992a and ADEM 1992d) and in July of 1993 a more intensive survey was conducted that included a time-of-travel dye study (ADEM 1994a). This work was done primarily to verify the 1990 wasteload allocation for Fort Payne, Alabama.

In 1993 the Ecological Support Branch of the EPA, Region IV, conducted an intensive investigation of the Big Wills/Black Creek embayment (EPA 1993). The investigation was prompted, in part, by the fact that Gulf States Steel, Inc. (GSS) located in Gadsden, Alabama had been in violation of their NPDES permit since it was issued in 1987. The plant discharges wastewater into Black Creek upstream of the embayment. The study included water quality, sediment quality, toxicity, bioaccumulation, macroinvertebrate community analysis, fish tissue residues and fish health assessment. Samples were taken in Big Wills Creek for comparison to conditions existing in Black Creek. Water quality downstream from the GSS discharge was degraded, with elevated temperature, depressed dissolved oxygen and concentrations of cyanide and copper above chronic effects levels. Sediments collected below the GSS discharge were toxic to test organisms. Seven organic compounds and eight metals were found in the sediment at potentially toxic concentrations. Only those benthic macroinvertebrates tolerant of polluted conditions were found downstream from GSS. Fish Health Assessment Indices were the highest (poorest condition) ever recorded by TVA investigators. Fish were scarce downstream from the GSS discharge with only stunted bluegill present in collections (EPA 1993).

In addition to the Phase I, Clean Lakes Study that is the subject of this report, Auburn University participated under cooperative agreement with ADEM in three intensive water quality surveys of Lake Henry during 1994 (Bayne *et al.* 1994b). These data will be used for calibration of a two-dimensional hydrodynamic and water quality model being applied by the Corps of Engineers as part of the ACT/ACF Comprehensive Study. Phytoplankton primary productivity was also measured on two occasions during the growing season of 1994.

10.2 Current Limnological Condition

From April 1993 through October 1994, as part of a Phase I, Clean Lakes, Diagnostic/Feasibility Study, Lake Neely Henry was examined to assess current limnological condition. The study was conducted by Auburn University (AU) under contract with the Alabama Department of Environmental Management (ADEM). Others providing data or information included in this lake assessment were: U.S. Environmental Protection Agency (EPA), Alabama Power Company, ADEM and the Alabama Public Health Department.

10.2.1 Lake Water Quality

Water quality variables were measured in Lake Henry monthly from April through October of both 1993 and 1994 (Table 10-1). In 1993, seventeen sampling stations were used and in 1994 the number of stations was reduced to seven (Table 10-2 and Figure 10-1). At each sampling station, in situ measurements of temperature, pH, dissolved oxygen (D.O.) and specific conductance were made throughout the water column with a Hydrolab® Surveyor II and Surveyor III (Table 10-3). Sampling was usually conducted between 0700 and 1300 hours. Secchi disk visibility was measured and the 1% incident light depth was determined with a submarine photometer at each sampling station.

A composite water sample was collected from the photic zone of the water column at each sampling station for additional water quality analyses. The photic zone depth was defined as four times the Secchi disk visibility depth (Taylor 1971). This estimate 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 onboard boat. Aliquots of this composite sample were poured into Nalgene® containers and stored on ice during transport to laboratory facilities at Auburn University. Samples

Table 10-1. Schedule of activities for the diagnostic study of Lake Neely Henry, 1993 and 1994.

TASK	JAN	FEB	MAR	APR	MAY	1993 JUN	JUL	AUG	SEP	OCT	NOV	DEC
Water Quality				X	X	X	X	X	X	X		
Chlorophyll a				X	X	X	X	X	X	X		
Phytoplankton				X	X	X	X	X	X	X		
Productivity					X	X	X	X	X			
AGP					X		X		X			

TASK	JAN	FEB	MAR	APR	MAY	JUN	1994 JUL	AUG	SEP	OCT	NOV	DEC
Water Quality				X	X	X	X	X	X	X		
Chlorophyll a				X	X	X	X	X	X	X		
Phytoplankton				X	X	X	X	X	X	X		
AGP				X	X	X	X	X	X	X		
Macrophyte ID								X				
Sediment								X				

Table 10-2. Lake Neely Henry sampling locations and activities during the diagnostic study conducted in 1993 and 1994.

Mainstem Station	Description	Water Quality		Chlorophyll *a*		Phytoplankton		Primary Prod.	AGPT	
		93	94	93	94	93	94	93	93	94
0	Tailrace	X								
1	Forebay (approx. RM 1.0)	X	X	X	X	X	X	X	X	X
2	RM 5.0	X	X	X	X	X	X		X	
3	RM 10.0	X		X		X		X	X	
4	RM 13.5	X		X		X			X	
5	RM 16.0 (77 Bridge @ Riverside)	X	X	X	X	X	X			X
6	RM 18.0	X		X		X		X	X	
7	RM 20.0	X	X	X	X	X	X		X	X
8	RM 22.0	X		X		X			X	
9	RM 24.5	X	X	X	X	X	X	X	X	X
10	RM 28.0	X	X	X	X	X	X		X	X
Tributaries										
11	Beaver Creek above Greensport Marina	X		X		X				
12	Big Canoe Cr.-Embayment downstream of Canoe Cr. Campground	X		X		X				
13	Confluence of Black Cr. & Big Wills Cr. (embayment) @ HWY 411	X	X	X	X	X	X	X		
14	Big Wills Cr. - embayment	X		X		X				
15	Big Wills Cr. - between Big Wills Ck embayment and first Hwy bridge	X		X		X				
16	Black Cr. - embayment	X		X		X				

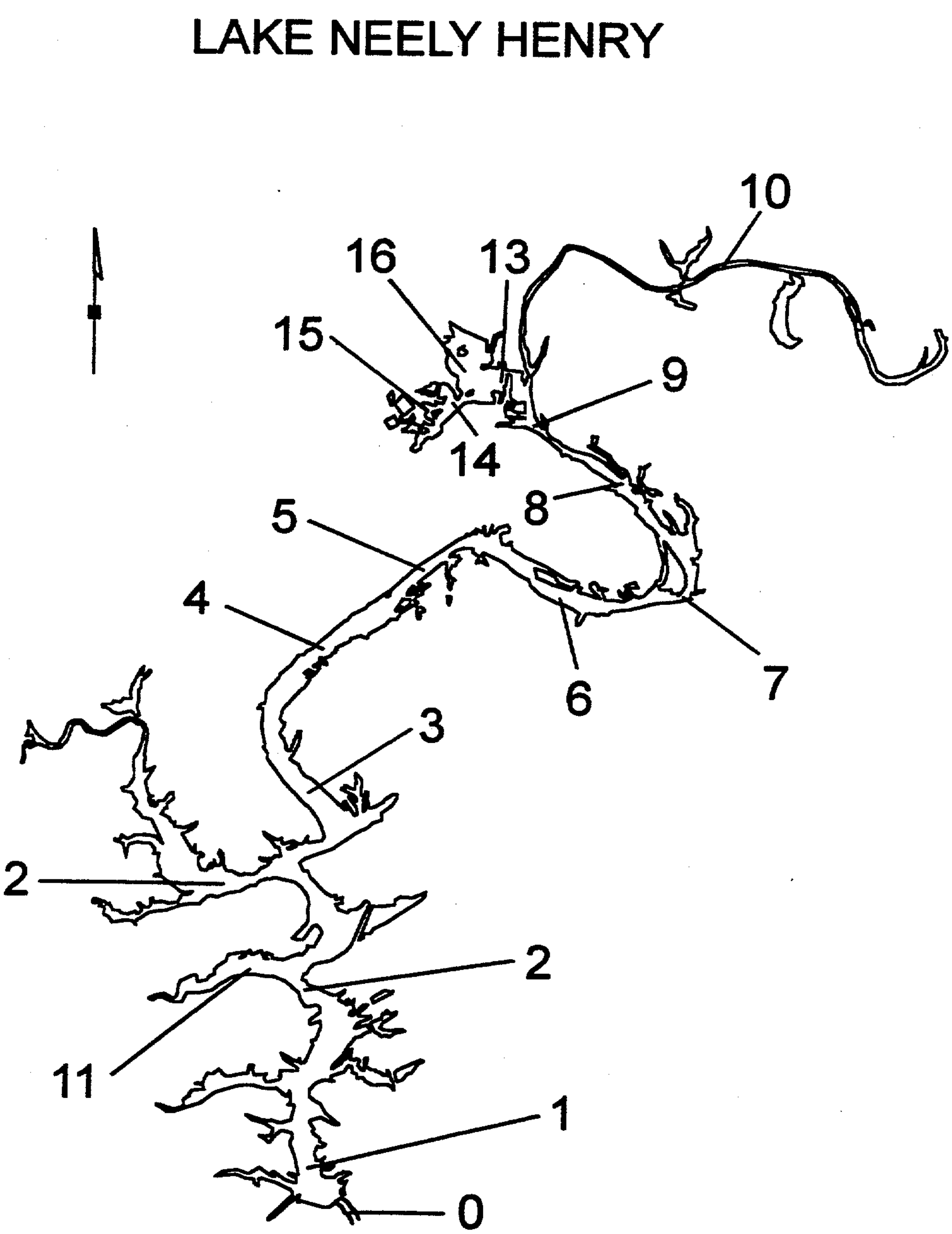

Figure 10-1. Map of Lake Neely Henry showing the locations of mainstem and embayment sampling stations during the diagnostic study, 1993-1994.

Table 10-3. Analytical methods used in measuring water quality in Lake Neely Henry, 1993 and 1994.

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
Hardness	EDTA titrimetric	Boyd 1979
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
Organic nitrogen	macro Kjeldahl	APHA 1992
Total phosphorus	persulfate digestion, ascorbic acid	APHA 1992
Soluble reactive phosphorus	ascorbic acid	APHA 1992
Total organic carbon	persulfate digestion, with Dohrmann DC-80	APHA 1992
Microbiological		
Chlorophyll a	spectrophotometric	APHA 1992
Phytoplankton enumeration	sedimentation chamber	APHA 1992
Algal Growth Potential Test	U.S.E.P.A. methodology	Athens, GA Lab
Phytoplankton primary productivity	Carbon 14 Method	APHA 1992

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 recommended holding times (APHA *et al.* 1992). Samples were collected monthly at mid-channel locations between 0700 and 1300 hours. Methods used to analyze water appear in Table 10-3.

Meteorological conditions can affect water quantity and water quality of reservoirs. Conditions existing from April through October 1993 were quite different from those existing from April through October 1994 (Table 10-4). Both years were warmer than normal (+0.34°C in 1993 and +0.60°C in 1994) but 1993 had a relatively dry growing season (April through October) with rainfall about 34 cm below normal. Growing season rainfall in 1994 was about 42 cm above normal. This much difference in rainfall and runoff into the lake altered the hydrology of the system resulting in greater mean monthly discharge through the dam (5,459 cfs in 1993 and 9,756 cfs in 1994) and decreased hydraulic retention time in 1994. To minimize water quality variations caused by seasonal changes in meteorological conditions, water quality data were grouped and examined by season. The seasons were defined as follows: spring (April and May), summer (June, July and August) and fall (September and October).

Lake Henry is a relatively shallow reservoir (mean depth 3.3 m) with a mean hydraulic retention time (volume/mean discharge)of 5.8 days. The high flushing rate, particularly along the mainstem of the lake, weakened thermal stratification even in the deeper lacustrine areas (Figures 10-2 and 10-3). On the mainstem, classical thermoclines ($\Delta T \geq 1$°C/m depth) were not found and water column temperature gradients seldom exceeded 3°C in 1993 or 2°C in 1994. Embayment stations were quite shallow (< 4.0 m) except for station 13 (confluence of Black Creek and Big Wills Creek) that was < 8 m deep. Stratification did occur at station 13 on occasion during both years.

Even though Lake Henry did not stratify thermally during the growing season (April through October) as is typical of warm monomictic lakes, chemical

Table 10-4. Meteorological conditions, river inflow and lake outflow measured during the diagnostic study of Lake Neely Henry, 1993 and 1994.

Year	Month	Temp[1] °C	DFN[2]	Rainfall[1] (cm)	DFN[2] (cm)	Mean[3] Daily Solar Radiation (Langleys)	Inflow[4] (CFS)	Outflow[4] (CFS)
1993	Apr	14.4	-1.43	6.8	-7.3	399	13,671	13,293
	May	19.6	-0.55	7.8	-4.1	465	8,873	8,740
	June	24.2	0.0	5.8	-3.8	486	4,735	4,769
	July	27.5	1.43	2.3	-10.5	543	3,803	4,051
	Aug	26.1	0.39	8.3	-0.3	438	2,774	2,837
	Sept	22.8	0.39	3.1	-5.9	389	2,247	2,352
	Oct	16.2	0.11	5.1	-2.2	278	2,241	2,168
	Nov	9.9	-0.88	5.6	-5.1	205	3,552	3,749
	Dec	6.2	0.22	9.9	-3.8	158	5,586	5,855
1994	Jan	3.8	-0.11	11.5	-2.1	151	11,138	11,122
	Feb	8.4	2.37	8.5	-4.3	237	14,548	14,657
	Mar	12.1	1.21	17.9	1.4	318	20,074	20,289
	Apr	15.7	0.61	9.6	-4.2	452	24,744	24,041
	May	19.3	-0.83	14.5	2.6	489	6,486	6,411
	June	25.4	1.27	28.5	18.9	452	5,385	5,448
	July	25.6	-0.50	17.2	4.4	431	9,320	9,268
	Aug	25.3	-0.39	8.9	0.3	521	5,953	5,965
	Sept	22.1	-0.39	18.4	9.5	466	6,224	6,222
	Oct	16.9	0.83	18.2	10.9	305	10,930	10,934

[1] Data from Gadsden Steam Plant, Gadsden, AL

[2] DFN = Deviation from normal

[3] Solar radiation data from Belle Mina, AL, April 1993 - July 1994, and from Nectar, AL, August - October 1994.

[4] Alabama Power Co.

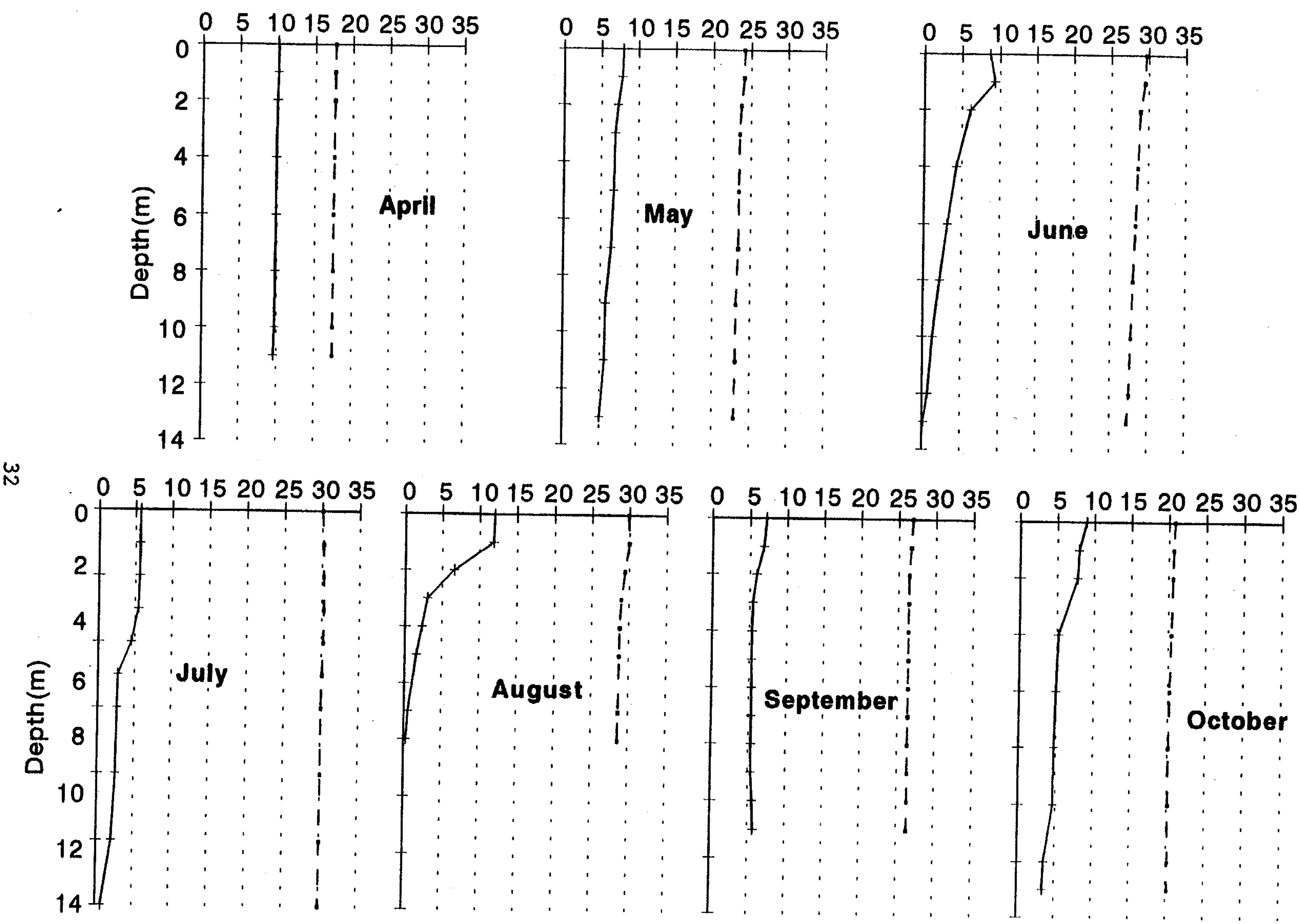

Figure 10-2. Dissolved oxygen (mg/l) (—+—) and temperature (C°) (– ▪ –) profiles at station 1 (dam forebay) on Lake Neely Henry, April 1993 through October 1993.

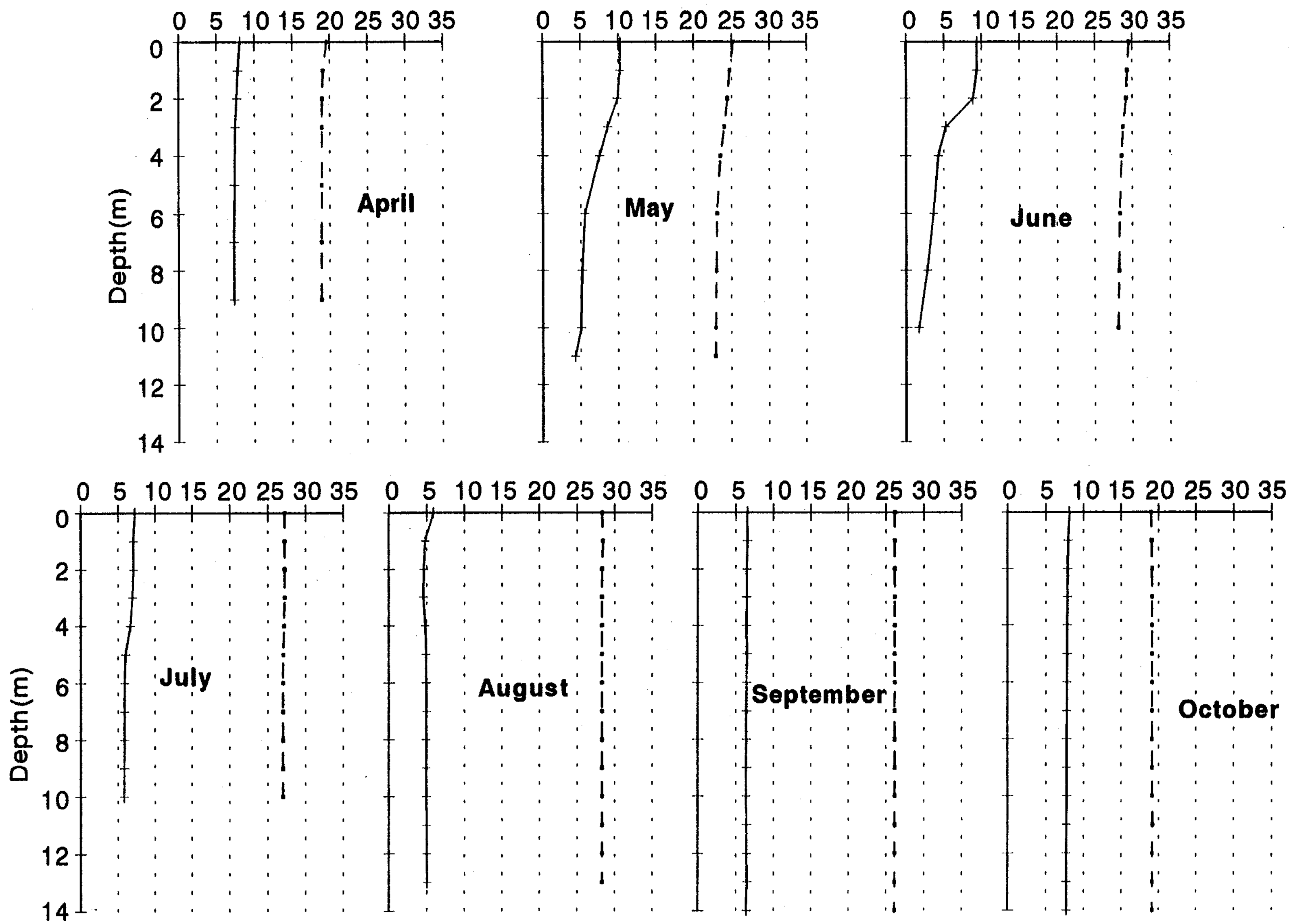

Figure 10-3. Dissolved oxygen (mg/l) (—+—) and temperature (C°) (– ▪ –) profiles at station 1 (dam forbay) on Lake Neely Henry, April 1994 through October 1994.

stratification did occur (Figures 10-2 and 10-3). D.O. concentrations declined with depth and, at times, reached concentrations less than 1.0 mg/l. Lower D.O. concentrations were encountered under lower flow conditions in 1993 than under higher flow conditions of 1994. Similar trends were noted for embayment D.O. concentrations. Specific conductance measured throughout the water column usually increased slightly with increasing depths (See electronic data set). Differences from top to bottom seldom exceeded 10.0 μmhos/cm even under the low flow conditions existing in 1993. Water movement in Lake Henry prevented the accumulation of decomposition products in the deeper waters during this study.

Water temperature measured at 2 m depth varied from a low of 16°C in Big Wills Creek Embayment (station 14) in April 1993 to 32°C in Black Creek Embayment (station 16) in 1993 (Tables 10-5, 10-6 and 10-7). D.O. concentrations measured at 2 m depth ranged between 3.6 and 11.0 mg/l and varied inversely with water temperature during the growing season. Highest mean D.O. concentrations occurred during spring and lowest during the summer.

Specific conductance, a measure of the ionic content of water, ranged from a low of 88μmhos/cm at mainstem sampling stations 9 and 10 to a high of 351 μmhos/cm in Big Wills Creek Embayment (station 14) at a depth of 2 m (Tables 10-5, 10-6 and 10-7). At mainstem sampling stations conductance varied between 88 μmhos/cm and 243 μmhos/cm at 2 m depth. Mean specific conductance was always higher in 1993 than in 1994 apparently as a result of lower flows and less dilution during 1993 (Figure 10-4). Specific conductance is a crude indicator of natural fertility since increases in ionic content are usually accompanied by increases in plant nutrients. Mainstem Alabama reservoirs were found to have specific conductance values ranging from about 23 μmhos/cm to 200 μmhos/cm (Bayne *et al.* 1989). Lake Henry ranks in the upper half of the Alabama range indicating that it is one of the more fertile lakes in the state. Other Coosa River impoundments were found to have relatively high specific conductance also (Bayne *et al.* 1993a and Bayne *et al.* 1993b). Specific conductance at sampling stations

Table 10-5. Mean (range) spring water temperature, dissolved oxygen and specific conductance measured at a depth of 2 m in Lake Neely Henry during the diagnostic study, 1993 - 1994.

Mainstem Stations	Temperature (°C)		Dissolved Oxygen (mg/l)		Conductivity (µmhos/cm)	
	1993	1994	1993	1994	1993	1994
0	20.7 (18-24)	--	8.6[1] (7.1-10.1)	--	131.3 (128-135)	--
1	20.6 (18-24)	21.7 (19-25)	8.6 (7.2-9.9)	8.8 (7.7-9.9)	129.5 (124-135)	107.4 (90-125)
2	20.6 (18-24)	21.3 (19-24)	8.6 (6.9-10.4)	7.6 (7.5-7.8)	131.5 (125-138)	110.0 (91-129)
3	20.6 (18-23)	--	8.7 (7.1-10.1)	--	128.6 (124-133)	--
4	20.6 (18-23)	--	8.9 (7.0-10.7)	--	127.9 (123-132)	--
5	20.5 (18-23)	21.3 (19-24)	8.6 (6.9-10.3)	7.9 (7.6-8.2)	131.0 (126-136)	114.2 (91-138)
6	20.5 (18-23)	--	8.8 (7.1-10.6)	--	131.3 (126-137)	--
7	20.4 (18-23)	21.1 (19-24)	8.5 (7.3-9.6)	7.6 (7.5-7.7)	128.2 (124-132)	118.3 (90-146)
8	20.6 (18-23)	--	8.8 (7.0-10.6)	--	125.8 (125-127)	--
9	20.5 (18-23)	21.1 (19-24)	8.5 (7.3-9.8)	7.5 (7.3-7.7)	130.8 (129-133)	114.3 (88-140)
10	20.0 (17-23)	20.9 (19-23)	8.3 (6.9-9.7)	7.5 (7.3-7.7)	119.5 (118-121)	109.4 (88-131)
Embayment Stations						
11	20.8 (18-24)	--	9.5 (7.6-11.4)	--	150.2 (141-160)	--
12	20.7 (18-24)	--	8.9 (8.5-9.6)	--	148.5 (148-149)	--
13	20.6 (18-23)	21.0 (18-24)	9.5 (9.1-9.9)	8.8 (7.5-10.2)	229.0 (223-235)	174.4 (122-227)
14	18.1[1] (16-20)	--	8.0[1] (7.2-8.7)	--	258.5 (249-268)	--
15	18.6[1] (18-20)	--	8.8[1] (7.8-9.8)	--	260.9 (254-268)	--
16	21.9 (20-24)	--	6.6[1] (4.9-7.0)	--	167.9 (152-184)	--

[1]Measured at 0.0 m.

Table 10-6. Mean (range) summer water temperature, dissolved oxygen and specific conductance measured at a depth of 2 m in Lake Neely Henry during the diagnostic study, 1993 - 1994.

Mainstem Stations	Temperature (°C) 1993	Temperature (°C) 1994	Dissolved Oxygen (mg/l) 1993	Dissolved Oxygen (mg/l) 1994	Conductivity (µmhos/cm) 1993	Conductivity (µmhos/cm) 1994
0	30.1 (29-31)	--	5.4[2] (4.5-6.5)	--	174.0 (149-193)	--
1	29.5 (29-30)	28.2 (27-29)	6.1 (5.6-6.6)	6.9 (4.6-8.9)	174.1 (150-192)	141.1 (128-159)
2	29.6 (29-31)	27.9 (27-29)	6.0 (5.7-6.4)	6.7 (5.7-7.7)	178.5 (157-193)	139.0 (122-163)
3	29.6 (28-31)	--	6.4 (5.9-6.7)	--	174.8 (152-187)	--
4	29.5 (28-31)	--	6.5 (5.5-7.8)	--	174.5 (153-186)	--
5	29.6 (28-31)	27.5 (26-28)	6.4 (5.6-7.0)	6.1 (5.5-7.0)	174.9 (154-186)	137.2 (113-162)
6	29.6 (28-31)	--	6.4 (5.6-7.2)	--	180.7 (170-186)	--
7	29.4 (28-31)	27.5 (26-28)	5.5 (5.0-6.0)	6.1 (5.8-6.5)	182.2 (158-196)	135.2 (111-171)
8	29.4 (28-31)	--	5.6 (4.7-6.5)	--	179.4 (154-196)	--
9	29.3 (28-31)	27.5 (26-29)	5.2 (5.0-5.4)	6.3 (5.8-7.0)	176.0 (157-186)	137.4 (118-171)
10	28.9 (28-30)	27.4 (26-28)	5.8 (5.6-6.3)	6.1 (5.3-6.8)	168.2 (148-179)	127.3 (103-162)
Embayment Stations						
11	29.6 (29-31)	--	6.0 (5.7-6.2)	--	183.7 (168-197)	--
12	29.7 (29-31)	--	5.1 (3.6-5.9)	--	175.8 (152-193)	--
13	29.9 (29-31)	26.7 (25-29)	7.3 (6.7-7.7)	8.0 (6.9-8.8)	269.9 (263-276)	169.8 (121-194)
14	28.2[1] (27-30)	--	7.4[1] (7.0-7.6)	--	286.9 (280-298)	--
15	28.5[2] (28-29)	--	8.2[2] (8.0-8.5)	--	289.7 (275-308)	--
16	30.9[1] (30-32)	--	5.2[1] (4.4-6.0)	--	250.1 (231-262)	--

[1]Measured at 1.0 m.
[2]Measured at 0.0 m.

Table 10-7. Mean (range) fall water temperature, dissolved oxygen and specific conductance measured at a depth of 2 m in Lake Neely Henry during the diagnostic study, 1993 - 1994.

Mainstem Stations	Temperature (°C) 1993	Temperature (°C) 1994	Dissolved Oxygen (mg/l) 1993	Dissolved Oxygen (mg/l) 1994	Conductivity (µmhos/cm) 1993	Conductivity (µmhos/cm) 1994
0	23.7 (21-27)	--	6.6[1] (5.9-7.2)	--	208.9 (189-229)	--
1	23.5 (21-26)	22.7 (19-26)	6.8 (5.9-7.7)	7.2 (6.5-7.9)	209.1 (188-230)	146.4 (140-153)
2	23.2 (20-26)	22.4 (19-26)	6.5 (6.0-6.9)	7.4 (6.7-8.1)	212.3 (191-234)	147.7 (144-151)
3	23.3 (21-26)	--	6.4 (6.3-6.4)	--	216.6 (195-238)	--
4	23.4 (21-26)	--	6.1 (5.9-6.3)	--	217.8 (197-239)	--
5	23.4 (20-27)	22.6 (19-26)	6.3 (6.3-6.4)	6.9 (6.0-7.7)	223.9 (213-235)	150.4 (147-154)
6	23.3 (20-26)	--	5.9 (5.9-6.0)	--	226.8 (217-237)	--
7	23.1 (20-26)	22.6 (19-26)	5.8 (5.5-6.2)	6.6 (5.6-7.7)	234.5 (226-243)	149.4 (141-158)
8	23.2 (20-26)	--	5.9 (5.3-6.5)	--	230.2 (220-241)	--
9	23.4 (20-27)	22.4 (19-26)	5.3 (4.6-6.0)	6.9 (5.8-8.0)	230.1 (225-235)	158.8 (158-160)
10	22.8 (20-26)	22.4 (19-26)	5.5 (4.9-6.1)	7.1 (6.3-8.0)	218.0 (207-229)	145.0 (136-154)
Embayment Stations						
11	22.8 (20-25)	--	7.9 (7.7-8.2)	--	210.4 (189-232)	--
12	22.9 (20-26)	--	7.1 (7.0-7.1)	--	209.5 (189-230)	--
13	23.2 (21-26)	21.1 (18-25)	7.3 (6.5-8.1)	8.5 (8.1-8.9)	305.3 (270-341)	220.5 (201-240)
14	21.2[1] (20-23)	--	8.6[1] (7.1-9.2)	--	347.5 (344-351)	--
15	--[2]	--	--[2]	--	--[2]	--
16	26.2[1] (25-28)	--	3.6[1] (3.6-3.6)	--	302.2 (286-318)	--

[1]Measured at 0.0 m.
[2]Station 15 not sampled, water depth too shallow to navigate channel.

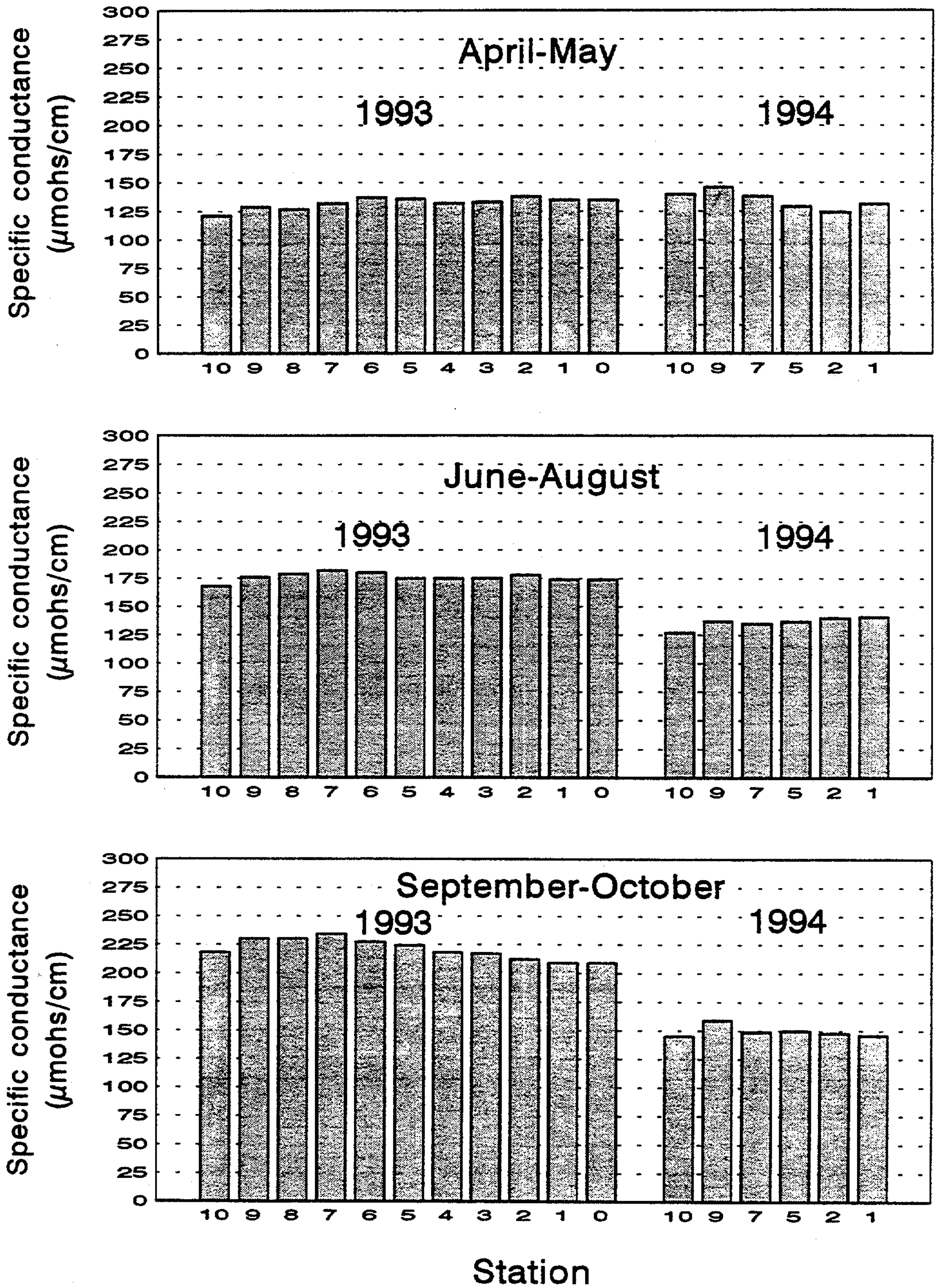

Figure 10-4. Seasonal mean specific conductance of the water column at mainstem sampling stations (headwaters at station 10 and dam at station 1) during the diagnostic study of Lake Neely Henry, April 1993 through October 1994.

(13, 14, 15 and 16) in Black Creek and Big Wills Creek was always higher and usually much higher than conductance measured at mainstem and other embayment locations. This is apparently a result of municipal and industrial waste as well as urban runoff entering these tributaries from the cities of Fort Payne and Gadsden, Alabama and other surrounding communities. Black Creek receives effluent (80.1 MGD) from Gulf States Steel and Big Wills Creek receives treated municipal waste (2.6 MGD) from the cities of Fort Payne and Collinsville and industrial waste from Cagles. The influence on these tributaries can be seen by comparing mean specific conductance at mainstem station 10 upstream of the Big Wills/Black Creek Embayment to values measured in the embayment (Tables 10-5, 10-6 and 10-7). On the mainstem, station 9 conductance was always higher than that measured at station 10. Highest mean specific conductance usually occurred at stations 7, 8 or 9, just downstream from Gadsden (Figure 10-4). The elevated conductance in this reach of the reservoir just downstream from the mouth of Big Wills Creek was apparently caused by the combined effects of several municipal wastewater treatment plants (WWTP) as well as flow from Big Wills Creek. Entering the mainstem of the lake near station 9 was the treated effluent from the Gadsden West WWTP (permit average flow 11.32 MGD), Attalla lagoon (1.93 MGD) and Rainbow City lagoon (0.741 MGD). Just upstream from station 8, effluent from Gadsden East WWTP (3.5 MGD) and Tyson Foods poultry processing plant enters the lake. Glencoe lagoon (0.45 MGD) discharges between stations 7 and 8 (Figure 10-1) and Southside lagoon (0.26 MGD) discharges just upstream from station 5 near the Rainbow City bridge. Urban runoff from the city of Gadsden and surrounding communities would also impact this area of Lake Henry.

In 1993, mean Secchi disk visibility and light penetration were similar among seasons at all mainstem stations (Tables 10-8, 10-9 and 10-10). However, in 1994 highest mean Secchi visibility and light penetration occurred during the spring with summer and fall values lower and more similar. The typical longitudinal gradient in suspended particles, from high levels in the relatively fast moving reservoir headwaters to lower levels in the more lacustrine areas

Table 10-8. Mean (range) spring Secchi disk visibility, 1% incident light depth, turbidity and total suspended solids measured during the Neely Henry diagnostic study, 1993 - 1994.

Mainstem Stations	Secchi (cm) 1993	Secchi (cm) 1994	1% Incident Light (cm) 1993	1% Incident Light (cm) 1994	Turbidity (NTU) 1993	Turbidity (NTU) 1994	Total Suspended Solids (mg/l) 1993	Total Suspended Solids (mg/l) 1994
0	--	--	--	--	13.2 (10-16)	--	9.8 (7-13)	--
1	107.0 (106-108)	125.0 (77-173)	296.0 (258-334)	283.5 (170-397)	9.0 (7-11)	13.4 (6-21)	7.9 (7-9)	9.3 (6-13)
2	104.5 (90-119)	109.5 (69-150)	247.5 (193-302)	249.0 (168-330)	13.1 (12-14)	19.1 (8-30)	9.4 (7-12)	11.8 (8-15)
3	101.0 (94-108)	--	249.5 (234-265)	--	11.5 (11-12)	--	11.6 (10-13)	--
4	91.0 (88-94)	--	254.5 (253-256)	--	10.9 (10-12)	--	12.5 (12-13)	--
5	95.5 (92-99)	89.5 (70-109)	301.5 (289-314)	189.5 (89-290)	9.3 (9-10)	15.8 (9-23)	10.2 (10-10)	11.8 (9-15)
6	95.0 (94-96)	--	252.5 (237-268)	--	11.8 (11-13)	--	10.1 (9-11)	--
7	107.0 (100-114)	93.0 (76-110)	277.5 (270-285)	229.0 (160-298)	9.2 (7-10)	17.0 (7-27)	10.2 (10-11)	15.4 (7-24)
8	101.5 (98-105)	--	278.5 (265-292)	--	8.9 (8-10)	--	12.0 (10-14)	--
9	108.5 (99-118)	98.5 (74-123)	277.0 (275-279)	314.0 (114-314)	9.2 (9-9)	17.5 (7-28)	13.4 (8-19)	19.3 (7-31)
10	112.0 (109-115)	97.5 (57-138)	308.0 (307-309)	238.5 (154-323)	8.6 (7-10)	17.1 (7-27)	13.0 (10-16)	13.8 (6-21)
Embayment Stations								
11	115.0 (102-128)	--	309.5 (277-342)	--	7.8 (7-8)	--	9.7 (7-13)	--
12	103.5 (93-114)	--	287.5 (244-331)	--	8.2 (6-10)	--	9.9 (7-13)	--
13	87.5 (61-114)	88.5 (82-95)	232.5 (188-277)	208.5 (192-225)	8.9 (7-11)	15.8 (12-20)	9.7 (9-11)	12.8 (11-15)
14	55.0	--	--[1]	--[1]	25.5 (23-28)	--	32.1 (17-48)	--
15	58.0	--	--[1]	--[1]	16.6 (12-21)	--	14.9 (13-17)	--
16	63.5 (49-78)	--	--[1]	--[1]	33.1 (16-50)	--	156.3 (13-299)	--

[1]Too shallow to measure.

Table 10-9. Mean (range) summer Secchi disk visibility, 1% incident light depth, turbidity and total suspended solids measured in Lake Neely Henry during the diagnostic study, 1993 - 1994.

Mainstem Stations	Secchi (cm) 1993	Secchi (cm) 1994	1% Incident Light (cm) 1993	1% Incident Light (cm) 1994	Turbidity (NTU) 1993	Turbidity (NTU) 1994	Total Suspended Solids (mg/l) 1993	Total Suspended Solids (mg/l) 1994
0	--	--	--	--	8.9 (5-14)	--	9.0 (6-12)	--
1	109.7 (101-119)	98.7 (81-132)	270.0 (238-295)	275.0 (201-350)	6.4 (4-8)	9.4 (6-13)	7.7 (7-8)	7.9 (5-10)
2	95.7 (86-104)	81.3 (73-97)	233.7 (215-258)	232.5 (193-272)	9.1 (8-11)	11.1 (9-15)	9.8 (9-11)	10.1 (8-11)
3	77.0 (75-81)	--	226.3 (218-238)	--	10.3 (8-13)	--	11.7 (10-13)	--
4	79.3 (69-86)	--	205.3 (189-215)	--	10.0 (9-11)	--	13.0 (11-16)	--
5	93.3 (84-103)	79.3 (71-87)	227.7 (218-237)	203.5 (186-221)	11.3 (11-12)	14.2 (11-19)	12.1 (10-13)	11.9 (10-13)
6	93.7 (81-104)	--	210.0 (190-235)	--	11.6 (11-12)	--	12.9 (9-16)	--
7	101.3 (89-112)	83.7 (77-90)	231.0 (227-234)	217.5 (213-222)	9.7 (9-10)	13.5 (10-19)	9.9 (8-11)	11.8 (11-13)
8	102.3 (101-103)	--	245.0 (233-261)	--	9.0 (9-10)	--	9.3 (8-10)	--
9	109.0 (98-123)	85.7 (78-95)	243.7 (213-275)	221.5 (210-233)	9.0 (8-10)	14.6 (10-22)	8.5 (8-10)	9.8 (8-12)
10	103.0 (89-118)	88.0 (69-98)	246.0 (220-267)	227.0 (218-238)	9.0 (7-11)	14.0 (10-20)	10.0 (8-12)	10.7 (9-13)
Embayment Stations								
11	100.0 (87-114)	--	265.3 (247-292)	--	10.4 (9-13)	--	11.1 (10-12)	--
12	104.7 (101-107)	--	249.3 (240-256)	--	11.8 (9-15)	--	13.1 (11-16)	--
13	86.7 (72-104)	74.0 (63-83)	200.7 (179-220)	189.0 (159-219)	13.6 (11-15)	19.3 (14-26)	13.9 (13-15)	13.7 (14-14)
14	65.0 (55-80)	--	151.5 (146-157)	--[1]	18.4 (15-22)	--	19.6 (14-28)	--
15	48.5 (43-54)	--	--[1]	--[1]	31.0 (18-39)	--	27.9 (23-32)	--
16	70.0 (62-84)	--	120.0	--[1]	22.3 (17-28)	--	30.2 (18-48)	--

[1]Too shallow to measure.

Table 10-10. Mean (range) fall Secchi disk visibility, 1% incident light depth, turbidity and total suspended solids measured in Lake Neely Henry during the diagnostic study, 1993 - 1994.

Mainstem Stations	Secchi (cm) 1993	Secchi (cm) 1994	1% Incident Light (cm) 1993	1% Incident Light (cm) 1994	Turbidity (NTU) 1993	Turbidity (NTU) 1994	Total Suspended Solids (mg/l) 1993	Total Suspended Solids (mg/l) 1994
0	--	--	--	--	18.5 (14-23)	--	22.6 (18-27)	--
1	100.0 (95-105)	84.5 (77-92)	252.5 (223-282)	197.0 (179-215)	7.2 (5-9)	12.3 (12-12)	10.7 (8-13)	11.7 (10-13)
2	93.0 (92-94)	77.0 (76-78)	227.0 (216-238)	185.5 (176-195)	9.3 (9-10)	14.8 (14-15)	14.1 (10-18)	13.8 (14-14)
3	89.0 (84-94)	--	245.0 (200-290)	--	10.1 (9-11)	--	10.2 (8-12)	--
4	91.5 (84-99)	--	223.0 (221-225)	--	9.6 (8-11)	--	11.7 (12-12)	--
5	113.0 (110-116)	78.0	258.5 (247-270)	155.0 (97-213)	8.0 (7-9)	13.4 (13-14)	9.5 (9-10)	12.8 (12-14)
6	120.0 (117-123)	--	267.5 (246-289)	--	7.6 (7-9)	--	9.8 (9-11)	--
7	114.0 (108-120)	93.5 (93-94)	261.0 (245-277)	208.5 (207-210)	8.3 (7-9)	12.1 (12-12)	10.1 (9-11)	11.0 (10-12)
8	123.0 (110-136)	--	275.5 (249-302)	--	7.8 (7-9)	--	10.0 (10-10)	--
9	125.5 (105-146)	92.0 (88-96)	280.0 (218-342)	210.0 (208-212)	8.3 (7-9)	12.7 (12-14)	10.3 (9-12)	11.3 (11-12)
10	120.5 (108-133)	92.5 (89-96)	261.5 (237-286)	208.0 (203-213)	8.2 (7-9)	12.8 (13-13)	8.5 (8-9)	11.8 (11-13)
Embayment Stations								
11	87.5 (85-90)	--	223.0 (215-231)	--	9.7 (9-10)	--	10.5 (9-12)	--
12	75.0 (68-82)	--	195.0 (179-211)	--	11.9 (11-13)	--	13.8 (12-16)	--
13	89.5 (83-96)	75.5 (68-83)	183.5 (179-188)	162.5 (159-166)	17.5 (17-18)	19.6 (18-21)	18.5 (17-20)	17.3 (17-18)
14	53.0 (33-73)	--	--[1]	--[1]	35.6 (17-54)	--	38.9 (17-61)	--
15	--[2]	--	--[2]	--[1]	--[2]	--	--[2]	--
16	62.0	--	--[1]	--[1]	20.0 (19-21)	--	15.6 (13-18)	--

[1] Too shallow to measure.

[2] Station 15 not sampled, water depth too shallow to navigate channel

downstream was not observed in Lake Henry. Such patterns were apparently obscured by the relatively rapid flow of water through the lake. The Big Wills/Black Creek Embayment stations had lower light transmission and greater quantities of suspended particles than other embayment and mainstem stations (Tables 10-8, 10-9 and 10-10). Conditions in Beaver Creek Embayment (station 11) and Big Canoe Creek Embayment (station 12) were similar to nearby mainstem sampling stations 2 and 3.

Total alkalinity, the concentration of bases in water (expressed as mg/l $CaCO_3$), primarily composed of bicarbonate (HCO^-) and carbonate ($CO^=$) ions, usually increases as basin soil fertility increases. In a recent study, total alkalinity of large mainstream impoundments of Alabama varied from a low of 7 mg/l to a high of 67 mg/l (Bayne *et al.* 1989). At the mainstem sampling stations in Lake Henry, total alkalinity varied from a low of 29 mg/l (as $CaCO_3$) during the spring of 1994 to a high of 97 mg/l in the fall of 1993 (Tables 10-11, 10-12 and 10-13). In the summer of 1948, prior to impoundment of the Coosa River to form Lake Henry, total alkalinity at a point 2 miles upstream of the highway bridge at Gadsden ranged between 42 mg/l and 63 mg/l (Alabama Water Improvement Advisory Commission 1949). The Coosa River is one of the more alkaline and naturally fertile rivers in Alabama. Some of the soils in the basin are rich in limestone yielding abundant $CO_3^=$ and HCO_3^- ions to surface waters (Lineback 1973).

Total alkalinity in tributary embayments varied greatly with highest values measured in Big Wills Creek (136 mg/l) and the lowest value (33 mg/l) measured at station 13, the mouth of the Big Wills/Black Creek embayment (Tables 10-11, 10-12 and 10-13). Big Wills Creek (stations 14 and 15) consistently had seasonal mean total alkalinity values in excess of 100 mg/l.

Total hardness is a measure of the divalent, alkaline earth metal content of water. Calcium (Ca^{++}) and magnesium (Mg^{++}) are normally the most abundant metals

Table 10-11. Mean (range) spring concentrations of total alkalinity, pH and hardness measured in Lake Neely Henry during the diagnostic study, 1993 - 1994.

Mainstem Stations	Total Alkalinity (mg/l as $CaCO_3$) 1993	1994	pH[1] (SU) 1993	1994	Hardness (mg/l as $CaCO_3$) 1993	1994
0	51.9 (49-55)	--	7.8 (7.7-8.0)	--	52.9 (52-54)	--
1	50.6 (48-54)	36.8 (29-45)	7.9 (7.6-8.4)	7.4 (7.1-8.6)	51.6 (50-53)	43.8 (37-51)
2	48.9 (48-50)	40.0 (31-49)	7.8 (7.6-8.2)	7.3 (7.1-8.0)	51.5 (49-54)	43.8 (37-51)
3	48.1 (46-50)	--	7.8 (7.6-8.2)	--	51.1 (50-52)	--
4	50.3 (49-51)	--	7.7 (7.6-8.5)	--	51.4 (49-54)	--
5	49.6 (48-51)	40.0 (31-49)	7.9 (7.5-8.3)	7.4 (7.2-7.8)	51.5 (51-52)	48.4 (44-53)
6	52.9 (49-57)	--	7.8 (7.7-8.4)	--	52.7 (49-56)	--
7	52.9 (52-54)	44.3 (32-56)	7.8 (7.7-8.1)	7.5 (7.3-7.8)	53.1 (51-55)	46.9 (36-58)
8	53.8 (51-56)	--	7.8 (7.6-8.4)	--	51.7 (49-54)	--
9	54.1 (52-56)	42.8 (31-55)	7.8 (7.7-8.2)	7.5 (7.3-7.7)	52.8 (53-53)	46.9 (39-55)
10	49.1 (46-52)	41.3 (31-51)	7.6 (7.4-7.9)	7.8 (7.7-7.8)	47.8 (47-48)	40.4 (40-41)
Embayment Stations						
11	66.4 (59-74)	--	8.3 (8.0-8.9)	--	63.5 (56-71)	--
12	65.0 (64-66)	--	8.1 (8.0-8.1)	--	64.3 (64-65)	--
13	89.4 (86-93)	62.5 (44-81)	8.3 (8.2-8.5)	8.0 (7.8-8.8)	95.0 (87-103)	77.7 (59-96)
14	117.6 (115-121)	--	7.7[2] (7.7-7.7)	--	115.0 (109-121)	--
15	116.8 (115-118)	--	7.8[3] (7.7-8.1)	--	117.7 (108-127)	--
16	47.8 (45-51)	--	7.3[2] (7.3-7.3)	--	58.3 (55-61)	--

[1] Measured at 2 m, [2] Measured at 1 m, [3] Measured at 0 m

Table 10-12. Mean (range) summer concentrations of total alkalinity, pH and hardness measured in Lake Neely Henry during the diagnostic study, 1993 - 1994.

Mainstem Stations	Total Alkalinity (mg/l as $CaCO_3$) 1993	1994	pH[1] (SU) 1993	1994	Hardness (mg/l as $CaCO_3$) 1993	1994
0	68.4 (57-76)	--	7.2 (7.0-7.7)	--	66.0 (59-74)	--
1	68.1 (57-76)	58.7 (54-64)	7.9 (7.7-8.4)	7.7 (7.4-8.6)	65.1 (58-72)	53.9 (51-60)
2	70.1 (59-80)	58.3 (54-64)	7.9 (7.6-8.4)	7.5 (7.3-8.2)	65.5 (60-71)	54.5 (51-61)
3	69.9 (60-75)	--	7.9 (7.6-8.2)	--	64.1 (60-67)	--
4	68.1 (62-74)	--	7.9 (7.5-8.3)	--	64.0 (58-68)	--
5	68.2 (62-74)	56.3 (50-66)	7.9 (7.6-8.3)	7.4 (7.1-7.8)	64.3 (61-66)	52.9 (45-59)
6	71.4 (64-75)	--	7.9 (7.7-8.2)	--	67.2 (65-69)	--
7	69.8 (59-76)	55.1 (47-66)	7.7 (7.5-7.8)	7.4 (7.1-7.7)	66.9 (62-70)	50.3 (41-62)
8	69.4 (58-76)	--	7.7 (7.6-8.0)	--	64.0 (57-69)	--
9	72.5 (62-83)	55.3 (41-68)	7.6 (7.5-7.7)	7.5 (7.3-7.9)	64.4 (60-67)	50.6 (43-60)
10	68.2 (60-73)	50.0 (39-64)	7.7 (7.6-7.8)	7.4 (7.1-7.9)	60.7 (56-64)	48.3 (40-57)
Embayment Stations						
11	75.3 (73-81)	--	8.0 (7.9-8.3)	--	72.2 (69-78)	--
12	70.5 (63-81)	--	7.9 (7.8-8.3)	--	68.8 (60-75)	--
13	100.2 (96-108)	61.3 (33-78)	8.4 (8.3-8.5)	7.7 (7.3-8.5)	98.2 (96-101)	63.6 (41-80)
14	117.3 (113-126)	--	8.2[2] (8.1-8.3)	--	116.1 (112-122)	--
15	119.3 (111-132)	--	8.3[3] (8.3-8.4)	--	117.8 (110-128)	--
16	84.3 (83-85)	--	8.2[2] (8.1-8.3)	--	87.3 (86-89)	--

[1] Measured at 2 m, [2] Measured at 1 m, [3] Measured at 0 m

Table 10-13. Mean (range) fall concentrations of total alkalinity, pH and hardness measured in Lake Neely Henry during the diagnostic study, 1993 - 1994.

Mainstem Stations	Total Alkalinity (mg/l as $CaCO_3$) 1993	1994	pH[1] (SU) 1993	1994	Hardness (mg/l as $CaCO_3$) 1993	1994
0	84.4 (78-91)	--	7.5 (7.4-7.6)	--	77.4 (72-83)	--
1	83.6 (79-88)	56.3 (50-62)	8.0 (7.8-8.1)	7.6 (7.4-7.8)	75.6 (75-76)	53.6 (50-58)
2	83.5 (77-91)	57.8 (57-59)	7.8 (7.8-7.9)	7.6 (7.5-7.8)	73.4 (70-76)	52.7 (49-56)
3	80.3 (75-86)	--	7.8 (7.8-7.9)	--	73.9 (71-77)	--
4	81.0 (77-85)	--	7.7 (7.6-7.7)	--	73.7 (70-77)	--
5	81.3 (74-89)	55.0 (50-60)	7.8 (7.7-8.0)	7.5 (7.4-7.6)	75.2 (73-78)	54.4 (51-57)
6	82.0 (80-85)	--	7.8 (7.7-7.8)	--	75.2 (74-77)	--
7	82.6 (78-88)	54.1 (48-61)	7.7 (7.7-7.7)	7.4 (7.3-7.6)	76.0 (74-78)	52.3 (49-56)
8	83.9 (77-91)	--	7.7 (7.7-7.7)	--	75.4 (73-78)	--
9	90.5 (85-97)	58.4 (55-62)	7.6 (7.5-7.6)	7.6 (7.5-7.7)	73.1 (71-76)	56.6 (57-57)
10	80.0 (77-83)	51.5 (45-58)	7.6 (7.5-7.6)	7.6 (7.5-7.8)	70.9 (71-71)	48.1 (42-55)
Embayment Stations						
11	86.6 (80-94)	--	8.3 (8.2-8.5)	--	78.3 (76-81)	--
12	85.8 (79-93)	--	8.0 (7.9-8.2)	--	78.6 (77-80)	--
13	102.0 (92-113)	86.4 (79-94)	8.3 (8.1-8.6)	8.0 (7.7-8.7)	101.5 (93-110)	83.9 (78-90)
14	131.4 (127-136)	--	8.0[2] (8.0-8.0)	--	125.5 (121-130)	--
15	--[3]	--	--[3]	--	--[3]	--
16	99.9 (97-103)	--	8.1[4] (7.9-8.3)	--	97.3 (96-99)	--

[1] Measured at 2 m, [2] Measured at 1 m, [3] Station 15 not sampled, water depth too shallow to navigate channel, [4] Measured at 0 m

in soils of the eastern United States and they are generally associated with carbonate minerals responsible for alkalinity of water. Therefore, total alkalinity (expressed as mg/l $CaCO_3$) and total hardness (as mg/l CaCO) concentrations in water are usually similar and tend to vary together. Such was the case in Lake Henry (Table 10-11, 10-12 and 10-13). Seasonal means and ranges of total hardness at a given sampling station were quite similar to alkalinity means and ranges. In the 1948 pollution study, water hardness measured 2 miles upstream of the highway bridge at Gadsden ranged from 58 mg/l to 66 mg/l (Alabama Water Improvement Advisory Commission 1949). Both total alkalinity and hardness values were higher under the relatively dry conditions of 1993 compared to the wetter conditions that existed in 1994. This was apparently a result of greater dilution under higher flows that occurred in 1994.

Carbonate minerals function as natural chemical buffers that prevent wide fluctuations in pH of lake water. The pH of Lake Henry waters was relatively stable ranging between 7 and 9 (Tables 10-11, 10-12 and 10-13). This stability is a result of the relatively high alkalinity of the system.

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 and therefore is the element most often limiting to plant growth in freshwater ecosystems. In some cases, phosphorus concentrations, relative to nitrogen, are high and nitrogen availability becomes limiting. This usually occurs at total nitrogen to total phosphorus ratios < 16:1 (Porcella and Cleave 1981).

Nitrogen is available to plants as nitrates ($NO_3^=$) or as the ammonium ion (NH_4^+). On the mainstem of Lake Henry, seasonal mean NO_3-N concentrations were higher during the wet 1994 growing season than during the dry 1993 growing season (Tables 10-14, 10-15 and 10-16). Inorganic nitrogen compounds are very soluble and rainfall and runoff from surrounding watersheds typically increase nitrogen loading to streams and lakes. During both years, highest concentrations occurred during the spring and lowest concentrations were found during the summer. Fall concentrations were usually intermediate. NH_3-N concentrations measured during the spring and fall seasons of 1993 were generally higher than 1994 values, however, during the summer season, concentrations were higher in 1994. Bioavailable nitrogen concentrations were usually highest just downstream of Gadsden (stations 7, 8 or 9) and progressively declined at sampling locations downstream toward the dam (Figure 10-5). Concentrations upstream of Gadsden (station 10) were always lower than concentrations measured just downstream of Gadsden.

Seasonal mean bioavailable nitrogen concentrations in tributary embayments were quite variable (Tables 10-14, 10-15 and 10-16). Concentrations in Beaver and Big Canoe creeks were much lower than concentrations measured in the Big Wills/Black Creek Embayments (stations 13, 14, 15 and 16) and were generally lower than levels measured at nearby mainstem stations 2 and 3. Highest seasonal mean NH_3-N concentrations were consistently found in the Black Creek Embayment (station 16). NO_3-N concentrations were always higher in the Big Wills/Black Creek Embayment than in Beaver Creek Embayment or Big Canoe Creek Embayment. One of the four sampling stations in Big Wills/Black Creek Embayment usually had the highest mean NO_3-N concentration among all stations. The only exception was in the fall of 1993 (Table 10-16).

Seasonal mean total Kjeldahl nitrogen (TKN) concentrations were similar between years at comparable locations and increased from spring to summer and from summer to fall (Tables 10-14, 10-15 and 10-16). TKN includes the organic

Table 10-14. Mean (range) spring concentrations of nitrite-nitrogen, nitrate-nitrogen, ammonia-nitrogen and total Kjeldahl nitrogen measured in Lake Neely Henry during the diagnostic study, 1993 - 1994.

Mainstem Stations	NO_2-N (µg/l) 1993	NO_2-N (µg/l) 1994	NO_3-N (µg/l) 1993	NO_3-N (µg/l) 1994	NH_3-N (µg/l) 1993	NH_3-N (µg/l) 1994	TKN (µg/l) 1993	TKN (µg/l) 1994
0	4.0 (4-4)	--	62.5 (30-95)	--	99.0 (87-111)	--	421.5 (400-443)	--
1	3.5 (3-4)	2.0 (1-3)	47.0 (25-69)	117.0 (22-212)	68.5 (50-87)	48.0 (42-54)	418.5 (380-457)	482.5 (441-524)
2	3.5 (3-4)	2.5 (0-5)	34.0 (30-38)	134.0 (30-238)	54.0 (27-81)	45.0 (34-56)	405.5 (371-440)	521.0 (518-524)
3	4.0 (3-5)	--	46.0 (35-57)	--	49.5 (35-64)	--	408.5 (371-446)	--
4	4.0 (3-5)	--	39.0 (34-44)	--	51.0 (35-67)	--	498.5 (457-540)	--
5	7.0 (5-9)	2.5 (1-4)	58.5 (58-59)	139.0 (28-250)	72.0 (43-101)	37.0 (27-47)	358.5 (343-374)	457.5 (447-468)
6	8.5 (5-12)	--	72.0 (62-82)	--	78.5 (40-117)	--	421.5 (343-500)	--
7	4.5 (4-5)	4.0 (4-4)	77.0 (61-93)	157.0 (79-235)	32.5 (10-55)	53.0 (39-67)	432.5 (394-471)	483.0 (403-563)
8	4.0 (4-4)	--	69.0 (69-69)	--	79.5 (78-81)	--	420.0 (397-443)	--
9	5.0 (5-5)	2.5 (2-3)	72.0 (58-86)	141.0 (44-238)	78.5 (76-81)	39.0 (33-45)	428.5 (400-457)	460.5 (409-512)
10	3.0 (3-3)	2.5 (1-4)	49.5 (36-63)	124.5 (32-217)	56.5 (20-93)	43.5 (40-47)	357.0 (357-357)	422.5 (421-424)
Embayment Stations								
11	0.5 (0-1)	--	4.5 (0-9)	--	29.0 (22-36)	--	405.5 (380-431)	--
12	1.5 (1-2)	--	16.0 (12-20)	--	37.0 (17-57)	--	437.0 (437-437)	--
13	10.0 (7-13)	6.0 (2-10)	348.0 (345-351)	413.0 (111-715)	19.0 (0-38)	54.0 (44-64)	415.5 (374-457)	570.5 (415-726)
14	7.0 (4-10)	--	523.0 (487-559)	--	56.5 (53-60)	--	321.5 (300-343)	--
15	6.0 (3-9)	--	558.5 (467-650)	--	52.0 (42-62)	--	260.0 (197-323)	--
16	19.5 (19-20)	--	149.5 (139-160)	--	262.5 (247-278)	--	775.5 (751-800)	--

Table 10-15. Mean (range) summer concentrations of nitrite-nitrogen, nitrate-nitrogen, ammonia-nitrogen and total Kjeldahl nitrogen measured in Lake Neely Henry during the diagnostic study, 1993 - 1994.

Mainstem Stations	NO_2-N (µg/l) 1993	NO_2-N (µg/l) 1994	NO_3-N (µg/l) 1993	NO_3-N (µg/l) 1994	NH_3-N (µg/l) 1993	NH_3-N (µg/l) 1994	TKN (µg/l) 1993	TKN (µg/l) 1994
0	5.3 (3-9)	--	80.3 (36-159)	--	81.7 (31-119)	--	463.7 (357-534)	--
1	0.3 (0-1)	6.0 (3-12)	7.7 (2-15)	48.3 (0-145)	33.7 (25-38)	82.7 (71-95)	567.0 (545-585)	591.3 (541-652
2	4.3 (0-12)	5.0 (2-11)	3.7 (0-7)	63.0 (0-189)	37.3 (25-59)	75.3 (18-150)	499.7 (414-557)	567.3 (548-588
3	2.7 (0-7)	--	3.0 (0-7)	--	24.3 (7-44)	--	572.0 (471-700)	--
4	4.0 (0-11)	--	7.3 (0-12)	--	27.0 (0-63)	--	596.7 (471-714)	--
5	4.7 (0-12)	6.3 (4-9)	13.0 (3-18)	73.7 (18-178)	58.7 (5-129)	121.3 (96-148)	605.7 (557-637)	569.3 (551-594
6	3.3 (2-5)	--	18.7 (3-39)	--	68.3 (10-146)	--	667.3 (623-728)	--
7	7.7 (2-11)	6.7 (5-8)	34.7 (24-53)	75.0 (32-147)	120.7 (100-137)	155.7 (123-198)	637.7 (443-785)	595.0 (510-668
8	6.3 (2-10)	--	26.0 (13-33)	--	111.0 (39-162)	--	579.7 (471-645)	--
9	8.7 (2-17)	6.3 (4-8)	20.7 (12-27)	72.3 (8-185)	106.0 (69-148)	89.0 (73-106)	564.7 (460-671)	559.3 (518-609
10	6.7 (1-16)	5.0 (3-7)	18.7 (10-23)	58.0 (3-145)	64.7 (31-98)	76.0 (62-103)	538.7 (414-648)	571.0 (518-603
Embayment Stations								
11	0.7 (0-1)	--	2.7 (0-8)	--	43.7 (18-57)	--	569.3 (506-617)	--
12	2.0 (0-6)	--	0.7 (0-1)	--	49.7 (11-84)	--	556.7 (471-628)	--
13	2.0 (1-3)	5.7 (3-10)	22.3 (3-36)	81.0 (0-212)	60.0 (9-98)	73.7 (28-115)	773.0 (728-814)	702.3 (527-810
14	2.3 (1-5)	--	47.7 (7-121)	--	78.7 (7-118)	--	776.7 (671-871)	--
15	2.3 (1-3)	--	34.3 (5-62)	--	98.7 (49-124)	--	751.0 (634-871)	--
16	30.7 (14-44)	--	106.3 (65-141)	--	293.7 (139-425)	--	1015.0 (891-1200)	--

Table 10-16. Mean (range) fall concentrations of nitrite-nitrogen, nitrate-nitrogen, ammonia-nitrogen and total Kjeldahl nitrogen measured in Lake Neely Henry during the diagnostic study, 1993 - 1994.

Mainstem Stations	NO_2-N (µg/l) 1993	NO_2-N (µg/l) 1994	NO_3-N (µg/l) 1993	NO_3-N (µg/l) 1994	NH_3-N (µg/l) 1993	NH_3-N (µg/l) 1994	TKN (µg/l) 1993	TKN (µg/l) 1994
0	9.0 (8-10)	--	70.5 (69-72)	--	109.5 (82-137)	--	628.5 (543-714)	--
1	3.5 (3-4)	3.0 (2-4)	52.0 (0-104)	84.0 (0-168)	47.5 (34-61)	18.5 (0-37)	621.5 (600-643)	610.0 (527-693
2	2.5 (1-4)	4.0 (1-7)	11.5 (3-20)	96.0 (0-192)	67.0 (19-115)	22.5 (0-45)	690.0 (663-717)	582.0 (462-702
3	11.5 (7-16)	--	35.0 (15-55)	--	83.5 (39-128)	--	671.0 (671-671)	--
4	13.5 (10-17)	--	39.5 (12-67)	--	135.5 (98-173)	--	684.0 (677-691)	--
5	10.0 (5-15)	5.0 (5-5)	42.5 (11-74)	133.5 (59-208)	114.0 (60-168)	36.0 (30-42)	630.0 (617-643)	519.5 (435-604
6	8.5 (5-12)	--	50.5 (37-64)	--	135.5 (92-179)	--	678.0 (628-728)	--
7	11.0 (7-15)	4.0 (4-4)	76.5 (49-104)	121.5 (33-210)	190.5 (185-196)	59.5 (37-82)	757.0 (757-757)	610.5 (504-717
8	11.0 (4-18)	--	76.5 (40-113)	--	171.0 (152-190)	--	674.0 (663-685)	--
9	5.5 (4-7)	4.5 (4-5)	38.0 (9-67)	125.5 (30-221)	209.5 (198-221)	67.0 (37-97)	660.0 (657-663)	592.0 (512-672
10	3.0 (3-3)	2.0 (1-3)	38.0 (27-49)	76.0 (8-144)	162.5 (117-208)	40.0 (27-53)	520.0 (503-537)	578.0 (489-667
Embayment Stations								
11	0.5 (0-1)	--	5.5 (0-11)	--	96.0 (33-159)	--	602.5 (585-620)	--
12	2.0 (0-4)	--	10.0 (3-17)	--	118.5 (101-136)	--	671.0 (657-685)	--
13	22.0 (5-39)	4.5 (1-8)	22.5 (0-45)	202.0 (0-404)	194.5 (110-279)	38.5 (27-50)	902.5 (877-928)	675.5 (462-889
14	13.0 (3-23)	--	45.5 (11-80)	--	200.5 (167-234)	--	531.0 (514-548)	--
15	--	--	--	--	--	--	--	--
16	75.5 (58-93)	--	62.0 (0-124)	--	547.5 (447-648)	--	1251.0 (1220-1282)	--

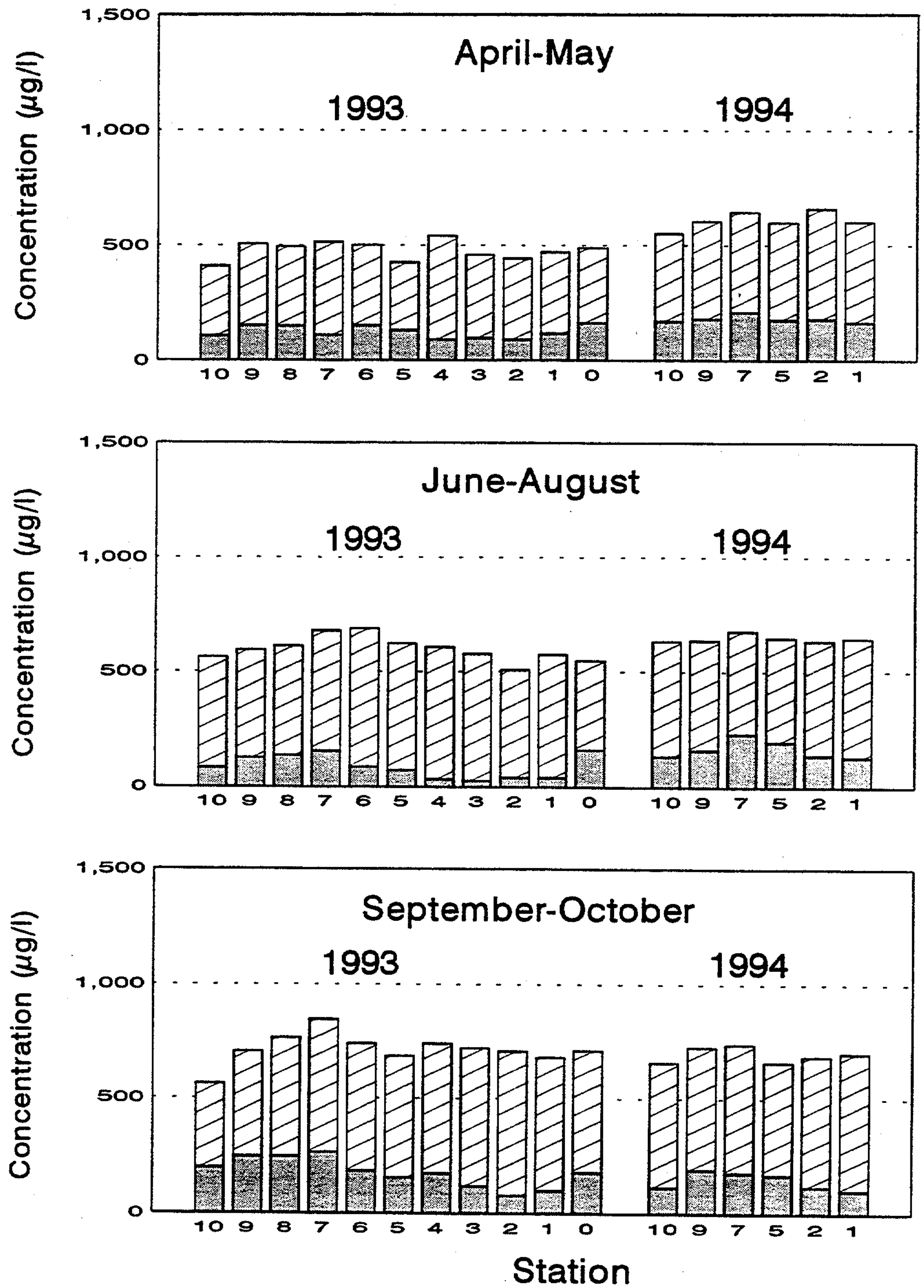

Figure 10-5. Seasonal mean bioavailable nitrogen (▩) and total nitrogen (▨+▩) concentrations at mainstem sampling stations (headwaters at station 10 and dam at station 1) during the diagnostic study of Lake Neely Henry, April 1993 through October 1994.

nitrogen fraction and this generally increases as plankton algae production increases during the growing season. TKN was consistently higher in the Black Creek Embayment (station 16) than at any other location. On the mainstem of the reservoir TKN concentrations were usually lowest at sampling station 10 upstream from Gadsden and highest at some downstream lacustrine location. Mid-reservoir, lacustrine areas usually support maximum algal biomass (Thornton *et al.* 1990).

Phosphorus in water is routinely reported as total phosphorus (all forms of phosphorus expressed as P) and soluble reactive phosphorus the major component of which is orthophosphate ($PO_4^{=}$ expressed as P), the most common and abundant form of phosphorus available to plants. On the mainstem of the reservoir, seasonal mean concentrations of both orthophosphate (PO_4-P) and total phosphorus (TP) were generally higher at comparable locations during 1994 than 1993 (Figure 10-6). This difference was most pronounced during the spring season. With few exceptions, TP and PO_4-P peaked at station 7 or 6 and declined downstream toward the dam (Tables 10-17, 10-18 and 10-19). Station 10 upstream from Gadsden usually had as low or lower TP and PO_4-P levels than any other downstream station (except for the tailwater station 0). Point and nonpoint sources of pollution in the Gadsden area produced a rise in both nitrogen and phosphorus compounds just downstream from the city (Figures 10-5 and 10-6).

With more rainfall and runoff in 1994, TP concentrations were usually higher at all stations. Phosphorus adsorbs onto surfaces of suspended inorganic particles, and therefore, increases in abiogenic turbidity are frequently accompanied by increased phosphorus concentrations. During the growing season of 1993 at station 2, near the dam, TP concentrations ranged from 52 μg/l to 80 μg/l. During 1994 the range was from 56 μg/l to 163 μg/l. In the spring of 1994 the range among all mainstem sampling stations was 96 μg/l to 165 μg/l (Table 10-17). These are high TP levels. TP concentrations > 100 μg/l are indicative of highly eutrophic waters (Wetzel 1983). At station 10, the headwaters of Lake Henry, TP concentrations varied between 50 μg/l and 112 μg/l during the two

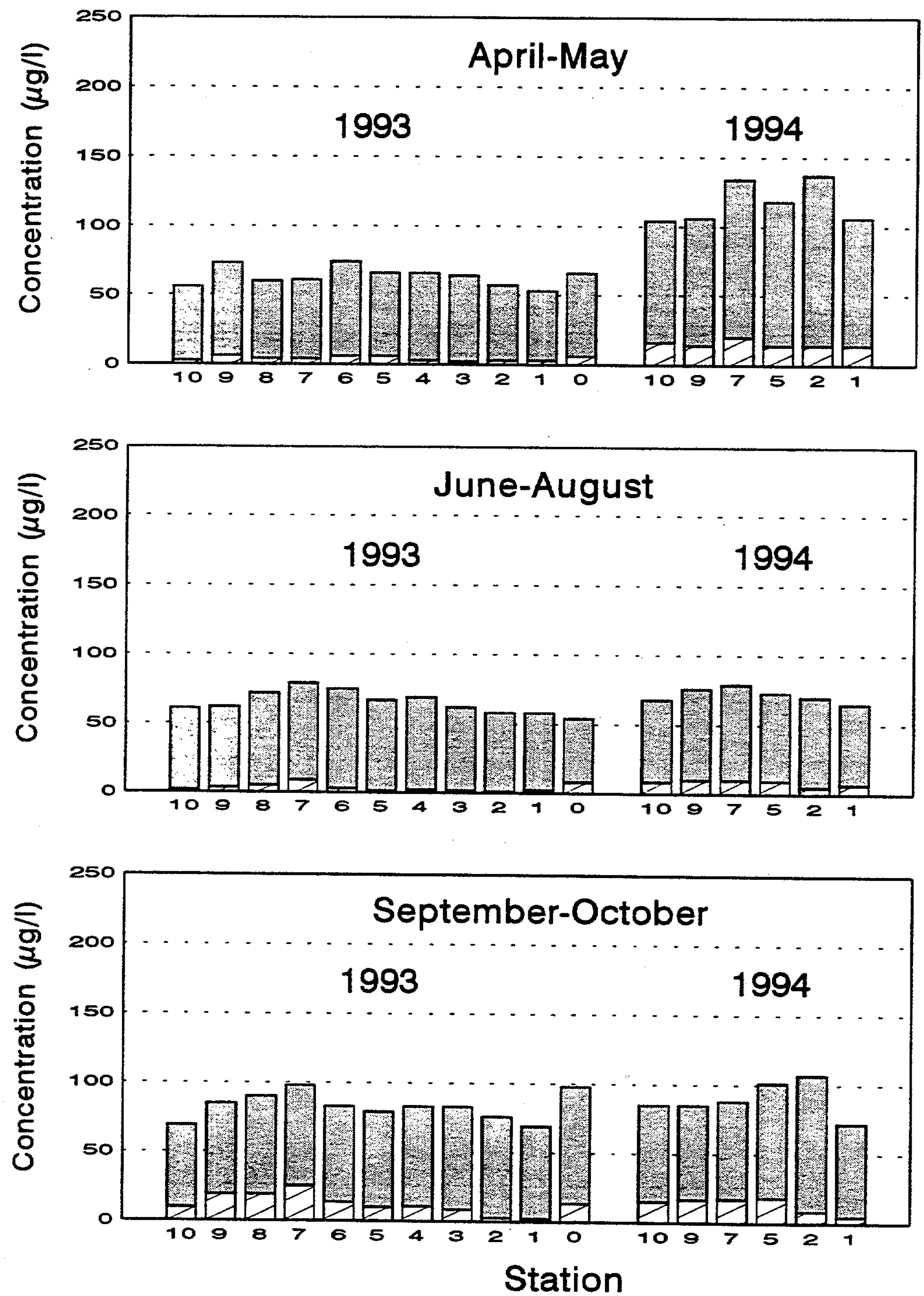

Figure 10-6. Seasonal mean total phosphorus (+) and soluble reactive phosphorus ( ) concentrations at mainstem sampling stations (headwaters at station 10 and dam forebay at station 1) during the diagnostic study of Lake Neely Henry, April 1993 through October 1994.

Table 10-17. Mean (range) spring concentrations of orthophosphate and total phosphorus measured in Lake Neely Henry during the diagnostic study, 1993 - 1994.

Mainstem Stations	Orthophosphate (µg/l) 1993	1994	Total Phosphorus (µg/l) 1993	1994
0	6.0 (5-7)	--	66.0 (54-78)	--
1	3.0 (3-3)	14.0 (3-25)	53.0 (50-56)	106.0 (98-114)
2	2.5 (1-4)	14.0 (2-26)	57.0 (53-61)	136.5 (110-163)
3	2.0 (1-3)	--	64.0 (63-65)	--
4	2.5 (2-3)	--	65.5 (65-66)	--
5	5.5 (3-8)	14.0 (2-26)	65.5 (64-67)	118.0 (106-130)
6	5.5 (3-8)	--	73.5 (67-80)	--
7	4.0 (3-5)	19.5 (12-27)	61.0 (59-63)	134.0 (103-165)
8	4.0 (2-6)	--	60.0 (60-60)	--
9	6.0 (5-7)	13.5 (4-23)	72.5 (64-81)	105.5 (101-110)
10	2.5 (1-4)	15.5 (6-25)	56.5 (55-58)	104.0 (96-112)
Embayment Stations				
11	1.0 (1-1)	--	45.5 (43-48)	--
12	0.0 (0-0)	--	43.5 (41-46)	--
13	13.0 (2-24)	17.0 (3-31)	88.5 (78-99)	126.5 (87-166)
14	44.0 (40-48)	--	123.0 (116-130)	--
15	53.5 (47-60)	--	109.0 (87-131)	--
16	7.5 (2-13)	--	138.5 (77-200)	--

Table 10-18. Mean (range) summer concentrations of orthophosphate and total phosphorus measured in Lake Neely Henry during the diagnostic study, 1993 - 1994.

Mainstem Stations	Orthophosphate (µg/l) 1993	Orthophosphate (µg/l) 1994	Total Phosphorus (µg/l) 1993	Total Phosphorus (µg/l) 1994
0	8.0 (6-11)	--	53.7 (48-60)	--
1	2.0 (1-4)	6.7 (4-10)	57.7 (54-63)	64.7 (48-77)
2	1.0 (0-2)	5.0 (2-10)	58.0 (52-63)	69.7 (56-83)
3	1.7 (1-2)	--	62.3 (57-66)	--
4	2.0 (0-4)	--	68.7 (65-72)	--
5	1.3 (0-2)	9.3 (1-18)	67.0 (55-74)	73.0 (69-77)
6	3.0 (1-6)	--	75.0 (72-80)	--
7	8.7 (3-19)	10.0 (5-15)	79.3 (62-96)	79.0 (68-90)
8	5.0 (4-6)	--	71.7 (61-81)	--
9	3.3 (0-6)	10.0 (0-18)	62.0 (54-68)	75.7 (69-87)
10	1.7 (1-3)	8.3 (1-17)	61.0 (50-70)	68.0 (60-79)
Embayment Stations				
11	1.0 (0-2)	--	62.0 (60-64)	--
12	1.0 (0-2)	--	58.3 (51-63)	--
13	1.0 (0-2)	5.0 (0-5)	90.0 (89-92)	92.7 (86-98)
14	15.7 (11-19)	--	119.0 (116-125)	--
15	19.3 (6-26)	--	150.7 (117-180)	--
16	5.7 (3-7)	--	126.3 (111-151)	--

Table 10-19. Mean (range) fall concentrations of orthophosphate and total phosphorus measured in Lake Neely Henry during the diagnostic study, 1993 - 1994.

Mainstem Stations	Orthophosphate (µg/l) 1993	Orthophosphate (µg/l) 1994	Total Phosphorus (µg/l) 1993	Total Phosphorus (µg/l) 1994
0	13.0 (10-16)	--	98.0 (82-114)	--
1	2.0 (1-3)	4.5 (1-8)	69.0 (61-77)	193.5 (72-315)
2	2.5 (2-3)	8.5 (3-14)	76.0 (72-80)	107.0 (81-133)
3	8.5 (4-13)	--	83.0 (83-83)	--
4	10.5 (7-14)	--	82.5 (82-83)	--
5	10.0 (4-16)	18.0 (10-26)	79.0 (76-82)	100.5 (87-114)
6	13.5 (8-19)	--	83.0 (83-83)	--
7	25.0 (20-30)	17.0 (9-25)	97.5 (94-101)	87.5 (87-114)
8	19.0 (12-26)	--	90.0 (80-100)	--
9	19.0 (18-20)	16.5 (11-22)	85.0 (81-89)	85.0 (83-87)
10	9.5 (8-11)	15.0 (8-22)	68.5 (66-71)	85.0 (82-88)
Embayment Stations				
11	2.5 (2-3)	--	72.5 (70-75)	--
12	2.0 (2-2)	--	74.5 (73-76)	--
13	10.5 (3-18)	15.0 (0-30)	124.0 (123-125)	110.5 (106-115)
14	75.5 (57-94)	--	191.5 (142-241)	--
15	--[1]	--	--[1]	--
16	65.5 (59-72)	--	183.0 (168-198)	--

[1] Station 15 not sampled, water depth too shallow to navigate.

growing seasons. EPA (1986) suggested a limit of 50 μg/l TP at the point where a stream enters a lake or reservoir to avoid excessive nutrient loading.

PO_4-P and TP concentrations in Beaver Creek and Big Canoe Creek Embayments were similar to or somewhat less than concentrations at nearby mainstem sampling stations 2 and 3 (Tables 10-17, 10-18 and 10-19). Sampling stations in the Big Wills/Black Creek Embayment had PO_4-P and TP concentrations much higher than Big Canoe and Beaver creeks and usually higher than levels measured at the nearest upstream mainstem station 10. The highest PO_4-P concentrations occurred at station 15 in Big Wills Creek. This stream received treated municipal waste from the Collinsville and Fort Payne, Alabama WWTP, industrial waste from Cagles, as well as runoff from agricultural lands. TP levels were usually higher in Big Wills Creek (station 14 and 15) or Black Creek (station 16) than at any other sampling station. Black Creek received treated wastewater from Gulf States Steel as well as urban runoff from the city of Gadsden (EPA 1993).

In reservoirs, phosphorus associated with suspended particles tends to sink if water movement subsides sufficiently in lentic areas of the lake. The 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 losses of 61% and 75% in Lakes Seminole and Walter F. George, respectively, two lakes located on the Chattahoochee River on the border between Alabama and Georgia. Under certain 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 releases soluble phosphorus to the overlying water column. The relatively high flushing rate of Lake Henry (5.8 day mean retention time) prevents rigid thermal and chemical stratification decreasing the incidence of internal phosphorus loading.

During the summer growing seasons the ratio of total nitrogen (TN) to total phosphorus (TP) at mainstem sampling stations varied from 8.5 to 10.0 in 1993 and from 8.4 to 10.0 in 1994 (Table 10-20). Tributary embayment ratios ranged from 5.2 to 9.6. Optimum TN to TP ratios for phytoplankton growth is in the range of 11 to 16 (Porcella and Cleave 1981). Phytoplankton growth in Lake Henry was nitrogen limited because of the high concentrations of phosphorus entering the lake primarily by way of the Coosa River and wastewater entering the lake in the vicinity of Gadsden. Waters receiving treated municipal waste often have relatively low (2-5) TN:TP (Raschke and Schultz 1987). Upstream Coosa River (station 10) had ratios of 9.2 in 1993 and 9.3 in 1994. Lowest ratios occurred downstream from Gadsden and in the Big Wills/ Black Creek embayment. Any increases in bioavailable nitrogen to Lake Henry will increase, perhaps dramatically, phytoplankton production. Controlling phosphorus loading of the lake is the only practical solution to the problem of algal growth in the lake (EPA 1990) but the low TN to TP ratio means that much phosphorus must be removed just to force the lake into phosphorus limitation of phytoplankton growth.

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 analysis of phytoplankton related variables. Aliquots of the composite sample were separated for total organic carbon (TOC) analyses, phytoplankton identification and enumeration, chlorophyll a analyses and Algal Growth Potential Tests (AGPT) (Table 10-21). Phytoplankton enumeration, chlorophyll a analysis and TOC analysis was conducted monthly April

Table 10-20. Summer mean total nitrogen (μg/l TN), total phosphorus (μg/l TP) and the ratio of TN to TP at all mainstem and tributary embayment stations in Lake Neely Henry, 1993 - 1994.

Mainstem Stations	1993 TN	1993 TP	1993 TN:TP	1994 TN	1994 TP	1994 TN:TP
0	549	54	10.2	--	--	--
1	575	58	10.0	646	65	10.0
2	508	58	8.8	635	70	9.1
3	578	62	9.3	--	--	--
4	608	69	8.9	--	--	--
5	623	67	9.3	649	73	8.9
6	689	75	9.2	--	--	--
7	680	79	8.6	677	79	8.6
8	612	72	8.5	--	--	--
9	594	62	9.6	638	76	8.4
10	564	61	9.2	634	68	9.3
Embayment Stations						
11	573	62	9.2	--	--	--
12	559	58	9.6	--	--	--
13	797	90	8.6	789	93	8.5
14	827	119	6.9	--	--	--
15	788	151	5.2	--	--	--
16	1152	126	9.1	--	--	--

Table 10-21. Analytical methods used in measuring microbiological variables in Lake Neely Henry, during the diagnostic study 1993 - 1994.

Variable	Method	Reference
Chlorophyll a	Spectrophotometric	APHA, 1989
Algal Growth Potential Test	U.S.E.P.A. Methodology	Athens, GA Lab.
Phytoplankton Enumeration	Sedimentation Chamber	APHA, 1989
Phytoplankton Primary Productivity	Carbon 14 Method	APHA, 1989

through October during both 1993 and 1994 (Table 10-3). Phytoplankton primary productivity was measured May through September of 1993 at mainstem stations 1, 3, 6 and 9 (Table 10-2 and Figure 10-1). The carbon-14 method of estimating net productivity was used (Table 10-3). 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 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 mean daily productivity (mgC/m^2•day) using solar radiation data obtained at the site during the exposure and total daily radiation measured in Calhoun, Georgia by a cooperative observer for the National Oceanic and Atmospheric Administrations (NOAA) (Table 10-4).

Phytoplankton densities ranged from a low of 1,533 organisms/ml at station 15 during the spring 1993 (Table 10-22) to 6,477 organisms/ml at station 13 during the fall 1993 (Table 10-24). Highest densities occurred during the summer and fall and lowest densities during the spring (Figure 10-7). Highest phytoplankton densities usually occurred at lacustrine stations 1 and 2 downstream near the dam. Lowest densities usually occurred downstream from Gadsden (stations 7, 8 and 9). Tributary embayments supported algal densities that were similar to densities measured at nearby mainstem stations, however, Big Wills Creek (station 14 and 15) had relatively low densities in the spring of 1993 (Tables 10-22, 10-23 and 10-24).

Numerical dominance was shared by green algae (Division Chlorophyta) and diatoms (Division Chrysophyta) at mainstem sampling stations (Figure 10-8). Diatoms were generally more abundant in spring months and green algae more

Table 10-22. Mean (range) spring total organic carbon and chlorophyll a concentrations and phytoplankton densities in Lake Neely Henry during the diagnostic study, 1993 - 1994.

Mainstem Stations	Total Organic Carbon (mg/l) 1993	Total Organic Carbon (mg/l) 1994	Chlorophyll a (µg/l) 1993	Chlorophyll a (µg/l) 1994	Phytoplankton Density (Organisms/ml) 1993	Phytoplankton Density (Organisms/ml) 1994
0	3.4 (3-4)	--	11.41 (6-17)	--	2302.5 (2061-2544)	--
1	3.5 (3-4)	5.4 (5-6)	11.55 (9-14)	9.55 (9-11)	2992.5 (2411-3574)	2796.0 (2551-3042)
2	4.1 (3-5)	4.7 (4-5)	11.55 (5-18)	9.55 (9-10)	3353.0 (2780-3926)	2976.0 (2687-3265)
3	3.9 (3-4)	--	13.88 (7-21)	--	2953.0 (2215-3691)	--
4	4.8 (4-6)	--	16.09 (8-24)	--	3234.0 (2978-3490)	--
5	4.1 (4-4)	6.5 (6-7)	14.15 (7-21)	10.21 (10-10)	3309.0 (3294-3324)	2484.0 (1894-3074)
6	5.1 (5-5)	--	17.09 (10-24)	--	3040.0 (2457-3623)	--
7	3.4 (3-4)	5.0 (5-5)	16.42 (9-24)	9.61 (8-11)	2811.5 (2442-3201)	2496.0 (2179-2813)
8	3.4 (3-4)	--	16.95 (8-26)	--	2455.0 (2174-2736)	--
9	3.7 (3-4)	4.9 (5-5)	13.55 (10-17)	9.08 (7-11)	3002.0 (2969-3035)	2369.5 (2361-2378)
10	3.6 (3-4)	5.0 (5-5)	12.35 (7-18)	8.01 (6-10)	3167.0 (2615-3719)	2524.5 (2269-2780)
Embayment Stations						
11	3.9 (3-5)	--	7.21 (5-9)	--	2960.0 (1973-3947)	--
12	4.7 (4-5)	--	10.81 (8-14)	--	2524.5 (2126-2923)	--
13	4.0 (3-5)	4.6 (4-5)	9.08 (7-12)	12.22 (5-20)	2799.5 (2302-3297)	2455.5 (1574-3337)
14	3.7 (3-5)	--	1.67 (0-3)	--	1874.0 (1827-1921)	--
15	2.8 (2-3)	--	1.40 (0-3)	--	1653.0 (1533-1773)	--
16	4.0 (4-5)	--	7.88 (7-9)	--	3465.5 (2713-4218)	--

Table 10-23. Mean (range) summer total organic carbon and chlorophyll a concentrations and phytoplankton densities in Lake Neely Henry during the diagnostic study, 1993 - 1994.

Mainstem Stations	Total Organic Carbon (mg/l) 1993	Total Organic Carbon (mg/l) 1994	Chlorophyll a (µg/l) 1993	Chlorophyll a (µg/l) 1994	Phytoplankton Density (Organisms/ml) 1993	Phytoplankton Density (Organisms/ml) 1994
0	4.8 (4-6)	--	8.99 (8-10)	--	3584.0 (2304-4240)	--
1	5.0 (4-6)	7.2 (5-12)	20.87 (19-23)	19.40 (17-23)	5110.7 (4099-5711)	3190.3 (2710-3440)
2	4.7 (4-6)	6.3 (5-9)	18.65 (13-23)	21.18 (14-29)	5074.0 (4493-5935)	3721.7 (2857-5413)
3	5.9 (4-10)	--	19.00 (13-23)	--	3915.7 (3279-4800)	--
4	4.7 (3-6)	--	20.65 (14-25)	--	4291.7 (3779-4846)	--
5	4.4 (3-6)	6.5 (4-10)	19.36 (14-25)	18.87 (12-24)	4064.7 (2883-5440)	3096.3 (2410-4065)
6	4.8 (3-6)	--	21.58 (15-28)	--	4614.3 (3913-5093)	--
7	4.3 (3-6)	7.1 (4-9)	18.29 (14-22)	18.02 (13-21)	4276.0 (3963-4462)	3680.3 (2716-4270)
8	4.3 (3-6)	--	17.58 (13-21)	--	3086.3 (2483-3619)	--
9	4.4 (3-5)	9.7 (5-18)	14.51 (10-21)	16.29 (7-24)	3723.7 (2553-5377)	2910.7 (1970-3589)
10	4.6 (3-6)	6.6 (4-11)	18.69 (13-23)	14.37 (1-23)	3500.3 (1790-5017)	3295.0 (2258-3903)
Embayment Stations						
11	6.6 (5-8)	--	18.33 (14-21)	--	3662.0 (3533-3864)	--
12	5.0 (4-7)	--	15.84 (11-19)	--	4344.3 (3535-5210)	--
13	5.3 (4-7)	7.0 (6-9)	22.92 (22-24)	24.03 (6-40)	4034.3 (3709-4284)	3185.3 (2224-4545)
14	4.7 (4-7)	--	20.47 (18-22)	--	3918.3 (2964-5035)	--
15	4.2 (3-5)	--	20.11 (18-22)	--	4042.7 (3326-4549)	--
16	5.4 (5-7)	--	15.80 (13-21)	--	3289.7 (2765-4175)	--

Table 10-24. Mean (range) fall total organic carbon and chlorophyll a concentrations and phytoplankton densities in Lake Neely Henry during the diagnostic study, 1993 - 1994.

Mainstem Stations	Total Organic Carbon (mg/l) 1993	Total Organic Carbon (mg/l) 1994	Chlorophyll a (µg/l) 1993	Chlorophyll a (µg/l) 1994	Phytoplankton Density (Organisms/ml) 1993	Phytoplankton Density (Organisms/ml) 1994
0	5.7 (5-6)	--	16.80 (16-18)	--	3846.0 (3582-4110)	--
1	4.3 (4-5)	4.5 (4-5)	24.32 (20-29)	19.42 (13-26)	4399.0 (4050-4748)	4171.0 (3883-4459)
2	5.3 (5-6)	4.2 (4-5)	28.97 (26-32)	15.35 (13-18)	4773.0 (4648-4898)	5690.5 (4939-6442)
3	5.0 (4-6)	--	21.34 (16-26)	--	2824.0 (2583-3065)	--
4	4.9 (4-6)	--	20.96 (15-27)	--	3623.5 (2233-5014)	--
5	5.0 (5-5)	4.4 (4-5)	21.32 (16-27)	12.82 (10-15)	4184.0 (3936-4432)	3906.0 (2232-5580)
6	4.9 (5-5)	--	21.36 (17-25)	--	4541.5 (3389-5694)	--
7	5.6 (5-7)	4.0 (4-4)	18.29 (15-22)	15.02 (12-18)	3330.5 (2288-4373)	3693.5 (3426-3961)
8	5.2 (4-6)	--	19.51 (17-22)	--	3663.0 (3117-4209)	--
9	5.7 (5-6)	4.7 (4-5)	15.33 (14-17)	14.55 (13-16)	4111.5 (3390-4833)	4317.5 (3391-5244)
10	5.1 (4-6)	4.1 (4-4)	13.02 (12-14)	14.22 (13-15)	3099.0 (3022-3176)	4695.5 (4028-5363)
Embayment Stations						
11	5.9 (6-6)	--	19.56 (19-20)	--	4900.0 (4809-4991)	--
12	5.7 (6-6)	--	22.41 (22-23)	--	3881.5 (2472-5291)	--
13	5.6 (5-7)	4.9 (5-5)	28.61 (25-32)	18.42 (8-29)	5399.0 (4321-6477)	4120.0 (2626-5614)
14	3.7 (3-5)	--	15.69 (15-16)	--	2439.5 (1807-3072)	--
15	--[1]	--	--[1]	--	--[1]	--
16	7.6 (7-8)	--	9.57 (8-11)	--	3003.0 (2675-3331)	--

[1] Station 15 not sampled, water depth too shallow to navigate channel.

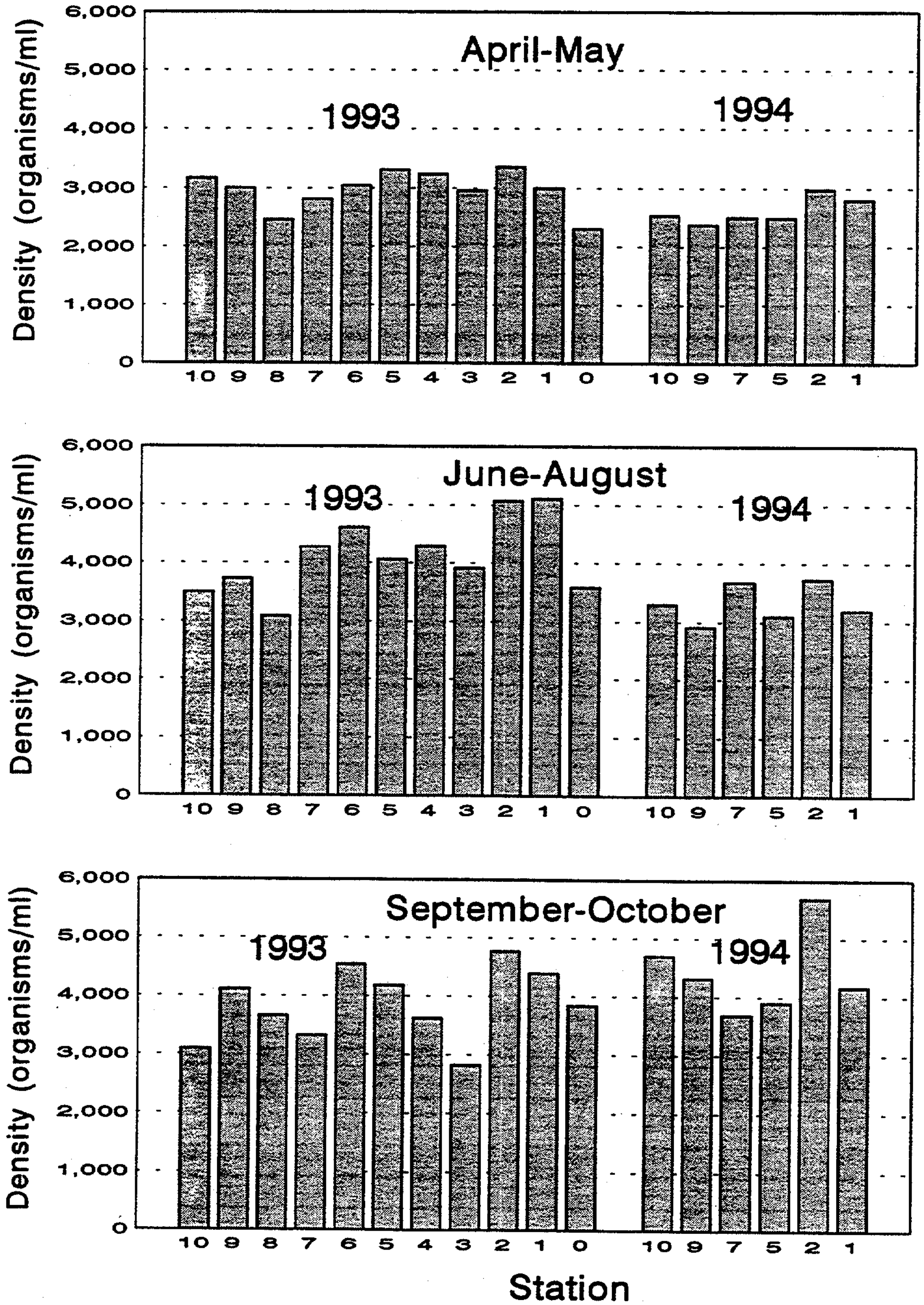

Figure 10-7. Seasonal mean phytoplankton densities at mainstem sampling stations (headwaters at station 10 and dam forebay at station 1) during the diagnostic study of Lake Neely Henry, April 1993 through October 1994.

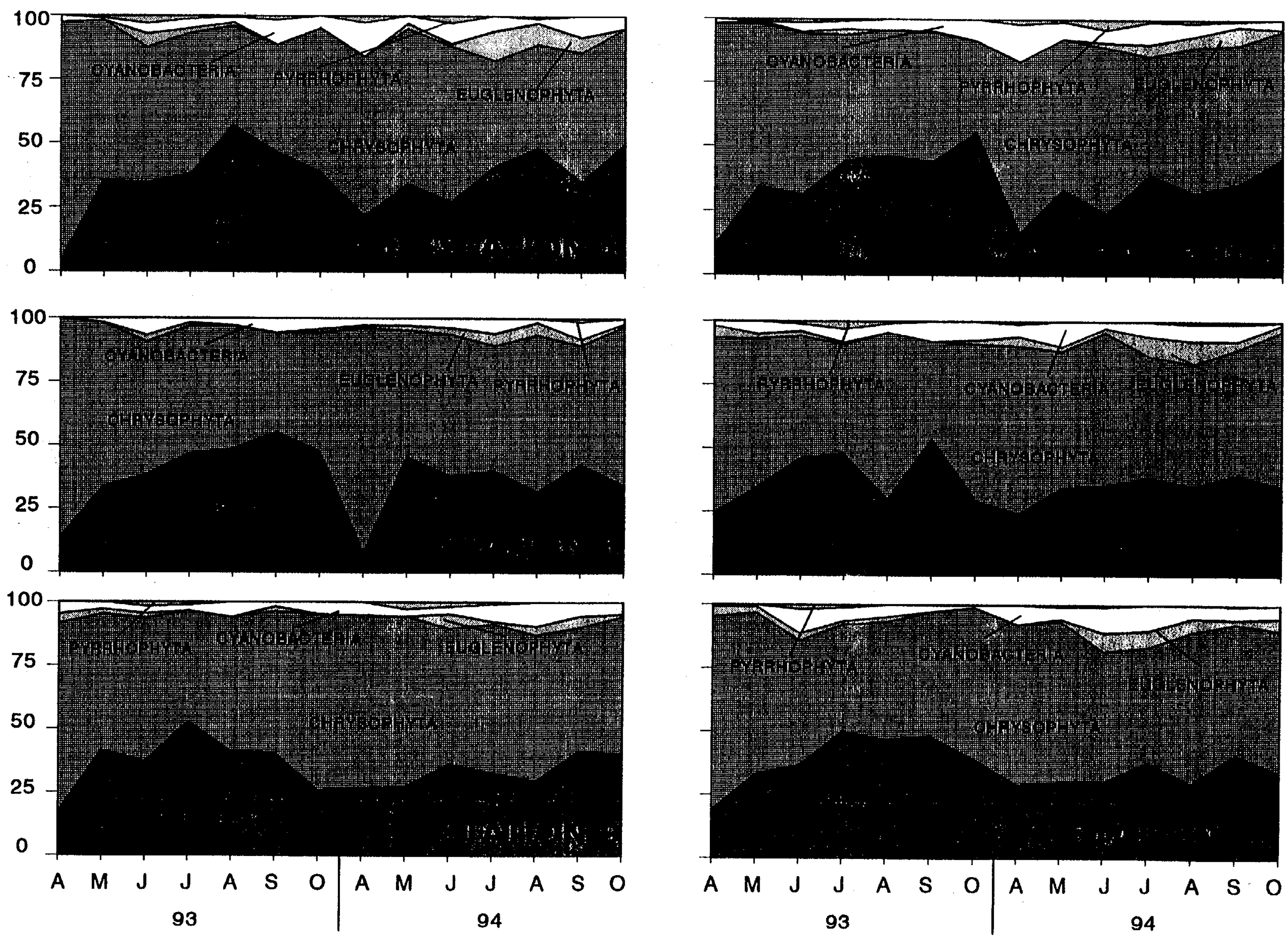

Figure 10-8. Percent composition of phytoplankton communities by algal Division during the diagnostic study of Lake Neely Henry, April 1993- October 1994.

abundant in summer and fall months. The blue-green algae (Division Cyanobacteria) were the third most abundant algal group followed by euglenoids (Division Euglenophyta) and dinoflagellates (Division Pyrrhophyta) (Figure 10-8). Bayne *et al.* (1993b) reported similar community composition of Weiss Lake phytoplankton during the growing seasons (April - October) of 1991 and 1992.

Sixty-three algal taxa were identified from samples taken from Lake Henry (Table 10-25). These taxa are generally common constituents of lake phytoplankton communities in this region (Taylor *et al.* 1979). Green algal taxa were most numerous although diatoms were not always identified to genus.

Pennate and centric diatoms were common and abundant throughout the reservoir and, in aggregate, were numerically dominant on most sampling occasions (Table 10-26). The most commonly encountered pennate diatoms that could be identified without special preparation were Tabellaria spp. and Asterionella formosa. The centric diatoms, Melosira distans and M. granulata were common and abundant. M. distans was frequently the dominant alga. Dominant green algae included Ankistrodesmus convolutus, Chlamydomonas spp and Crucigenia sp. (Table 10-26).

Among the dominant phytoplankton genera, all occur with great frequency in reservoirs of the southeastern United States (Taylor *et al.* 1979). Palmer (1969) listed Ankistrodesmus, Chlamydomonas and Melosira as genera of algae tolerant of organic pollution. In addition, each of the dominant genera listed in Table 10-26 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 of Lake Henry were indicative of a typical nutrient enriched southeastern reservoir.

Table 10-25. Phytoplankton taxa by major group indicating occurrence at selected stations in Lake Neely Henry, April 1993-October 1994.

Division	Algal Taxa	Station																
		00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
CHLOROPHYTA	<u>Actinastrum</u> sp.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	<u>Ankistrodesmus</u> <u>convolutus</u>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	<u>Ankistrodesmus</u> <u>falcatus</u>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	<u>Ankistrodesmus</u> <u>fusiformis</u>			X														
	<u>Ankistrodesmus</u> <u>nannoselene</u>	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	
	<u>Arthrodesmus</u> sp.	X																
	<u>Chlamydomonas</u> sp.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	<u>Chodatella</u> sp.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
	<u>Closteriopsis</u> sp.	X					X	X	X		X	X	X	X	X	X		X
	<u>Closterium</u> sp.	X	X	X	X		X			X	X	X	X	X	X	X	X	
	<u>Coelastrum</u> sp.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	<u>Cosmarium</u> sp.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	<u>Crucigenia</u> sp.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	<u>Desmidium</u> sp.										X		X					
	<u>Dictyosphaerium</u> sp.	X	X	X		X	X		X	X	X	X	X	X	X	X	X	
	<u>Elakatothrix</u> sp.								X									X
	<u>Euastrum</u> sp.	X	X	X	X	X	X	X	X		X	X		X	X			X
	<u>Eudorina</u> sp.										X				X			

Table 10-25. (cont.)

Division	Algal Taxa	Station																
		00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
CHLOROPHYTA	*Franceia* sp.		X		X		X	X					X	X	X	X	X	X
	Gloeocystis sp.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Golenkinia sp.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
	Kirchneriella sp.			X						X			X		X			
	Micrasterias sp.		X	X	X					X					X			X
	Micratinium sp.	X							X	X	X	X						
	Oocystis sp.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Pachycladon sp.				X				X	X								
	Pandorina sp.	X		X		X	X	X	X	X	X	X	X	X	X	X	X	X
	Pediastrum sp.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Polyedriopsis sp.					X												
	Scenedesmus abundans	X		X	X	X		X	X		X	X	X	X	X	X	X	X
	Scenedesmus acuminatus	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Scenedesmus armatus	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Scenedesmus bicaudatus			X								X						
	Scenedesmus denticulatus					X	X		X			X				X	X	
	Scenedesmus quadricauda	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Scenedesmus sp.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 10-25. (cont.)

Division	Algal Taxa	Station 00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
CHLOROPHYTA	*Schroederia* sp.		X	X				X	X			X		X	X			X
	Selenastrum sp.		X	X	X	X	X	X	X		X			X	X	X		X
	Sphaerocystis sp.	X	X	X			X	X	X	X	X	X	X		X	X		X
	Staurastrum sp.	X		X	X							X	X			X		X
	Tetraedron minimum	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Tetraedron sp.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Tetrastrum sp.	X	X	X	X	X	X	X	X		X	X	X		X	X		X
	Treubaria sp.		X	X	X		X		X			X	X		X	X		X
CHRYSOPHYTA	*Asterionella* sp.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Melosira distans	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Melosira granulata	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Tabellaria sp.							X										
	Centric diatom		X	X			X		X	X	X	X		X	X	X		
	Pennate diatom	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
CYANOBACTERIA	*Anabaena* sp.		X				X	X	X	X	X							
	Aphanocapsa sp.		X									X						
	Chroococcus sp.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
	Gloeocapsa sp.									X	X							

Table 10-25. (cont.)

Division	Algal Taxa	Station 00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
CYANOBACTERIA	Gomphosphaeria sp.		X	X		X	X	X	X	X	X	X	X		X	X		
	Merismopedia sp.	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X
	Microcystis sp.			X					X									
	Oscillatoria sp.				X			X	X	X	X	X	X	X				X
	Raphidiopsis sp.		X	X		X	X	X	X		X	X	X	X	X			X
	Spirulina sp.		X	X			X		X		X	X			X			
EUGLENOPHYTA	Euglena sp.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Phacus sp.	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X
	Trachelomonas sp.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
PYRRHOPHYTA	Peridinium sp.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X

Table 10-26. Dominant algal taxa collected at selected sampling stations on Lake Neely Henry during the diagnostic study, 1993 - 1994.

Station→ Season Year↓	Mainstem Stations 1	 2	 5	 7	 9	 10	Embayment 13
SPRING 1993	1. Melosira distans 2. Melosira granulata 3. Pennate diatoms	1. Melosira distans 2. Pennate diatoms 3. Melosira granulata	1. Melosira distans 2. Pennate diatoms 3. Melosira granulata	1. Melosira distans 2. Melosira granulata 3. Pennate diatoms	1. Melsoira distans 2. Melosira granulata 3. Pennate diatoms	1. Melosira distans 2. Melosira granulata 3. Pennate diatoms	1. Pennate diatoms 2. Ankistrodesmus convolutus 3. Melosira distans
SUMMER 1993	1. Pennate diatoms 2. Melosira distans 3. Chlamydomonas sp.	1. Melosira distans 2. Pennate diatoms 3. Chlamydomonas sp.	1. Pennate diatoms 2. Melosira distans 3. Chlamydomonas sp.	1. Pennate diatoms 2. Melosira distans 3. Chlamydomonas sp.	1. Pennate diatoms 2. Melosira distans 3. Chlamydomonas sp.	1. Pennate diatoms 2. Chlamydomonas sp. 3. Melosira distans	1. Pennate diatoms 2. Chlamydomonas sp. 3. Melosira distans
FALL 1993	1. Melosira distans 2. Melosira granulata 3. Pennate diatoms	1. Melosira distans 2. Melosira granulata 3. Pennate diatoms	1. Melosira distans 2. Ankistrodesmus convolutus 3. Pennate diatoms	1. Melosira distans 2. Chlamydomonas sp. 3. Melosira granulata	1. Melosira distans 2. Melosira granulata 3. Ankistrodesmus convolutus	1. Melosira distans 2. Melosira granulata 3. Pennate diatoms	1. Melosira distans 2. Pennate diatoms 3. Ankistrodesmus convolutus
SPRING 1994	1. Melosira distans 2. Pennate diatoms 3. Melosira granulata	1. Melosira distans 2. Melosira granulata 3. Pennate diatoms	1. Melosira distans 2. Pennate diatoms 3. Melosira granulata	1. Pennate diatoms 2. Melosira distans 3. Chlamydomonas sp.	1. Melosira distans 2. Melosira granulata 3. Pennate diatoms	1. Pennate diatoms 2. Melosira granulata 3. Melosira distans	1. Pennate diatoms 2. Ankistrodesmus convolutus 3. Chlamydomonas sp.
SUMMER 1994	1. Melosira distans 2. Pennate diatoms 3. Chlamydomonas sp.	1. Pennate diatoms 2. Melosira distans 3. Melosira granulata	1. Pennate diatoms 2. Melosira distans 3. Melosira granulata	1. Pennate diatoms 2. Melosira distans 3. Melosira granulata	1. Pennate diatoms 2. Melosira granulata 3. Melosira distans	1. Pennate diatoms 2. Melosira distans 3. Melosira granulata	1. Pennate diatoms 2. Chlamydomonas sp. 3. Melosira distans
FALL 1994	1. Melosira distans 2. Pennate diatoms 3. Melosira granulata	1. Melosira distans 2. Pennate diatoms 3. Melosira granulata	1. Melosira distans 2. Melosira granulata 3. Pennate diatoms	1. Pennate diatoms 2. Melosira distans 3. Melosira granulata	1. Melosira distans 2. Pennate diatoms 3. Melosira granulata	1. Pennate diatoms 2. Melosira distans 3. Melosira granulata	1. Pennate diatoms 2. Crucigenia sp. 3. Melosira distans

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 and 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 μg/l are indicative of eutrophic waters (Carlson 1977). Waters having concentrations > 56.0 μg/l are considered hypereutrophic. Chlorophyll a concentrations in Lake Henry ranged from a low of 0.0 μg/l at embayment stations 14 and 15 in the spring of 1993 to a high of 39.9 μg/l at station 13 in August 1994 (See electronic data set). Seasonal mean chlorophyll a concentrations varied considerably, with highest values occurring during summer and fall and lowest values during the spring (Tables 10-22, 10-23 and 10-24). Chlorophyll a concentrations were generally higher in 1993 than in 1994 probably because of the longer hydraulic retention time and improved light conditions under lower flows that existed in 1993 (Table 10-4 and Figure 10-9). Bayne and Maceina (1992) reported higher chlorophyll a levels in Weiss Lake during the relatively dry 1990 growing season (41 μg/l) than levels measured during the wetter 1989 growing season (27 μg/l).

The relatively short mean hydraulic retention time of Lake Henry (5.8 days) results in strong unidirectional downstream (advective) currents that transport nutrients and phytoplankton rapidly toward the dam. The absence of thermal stratification, particularly in the mainstem of the reservoir, results in rather uniform nutrient dispersal throughout the water column. These conditions typically produce minimal longitudinal gradients of physicochemical and biological

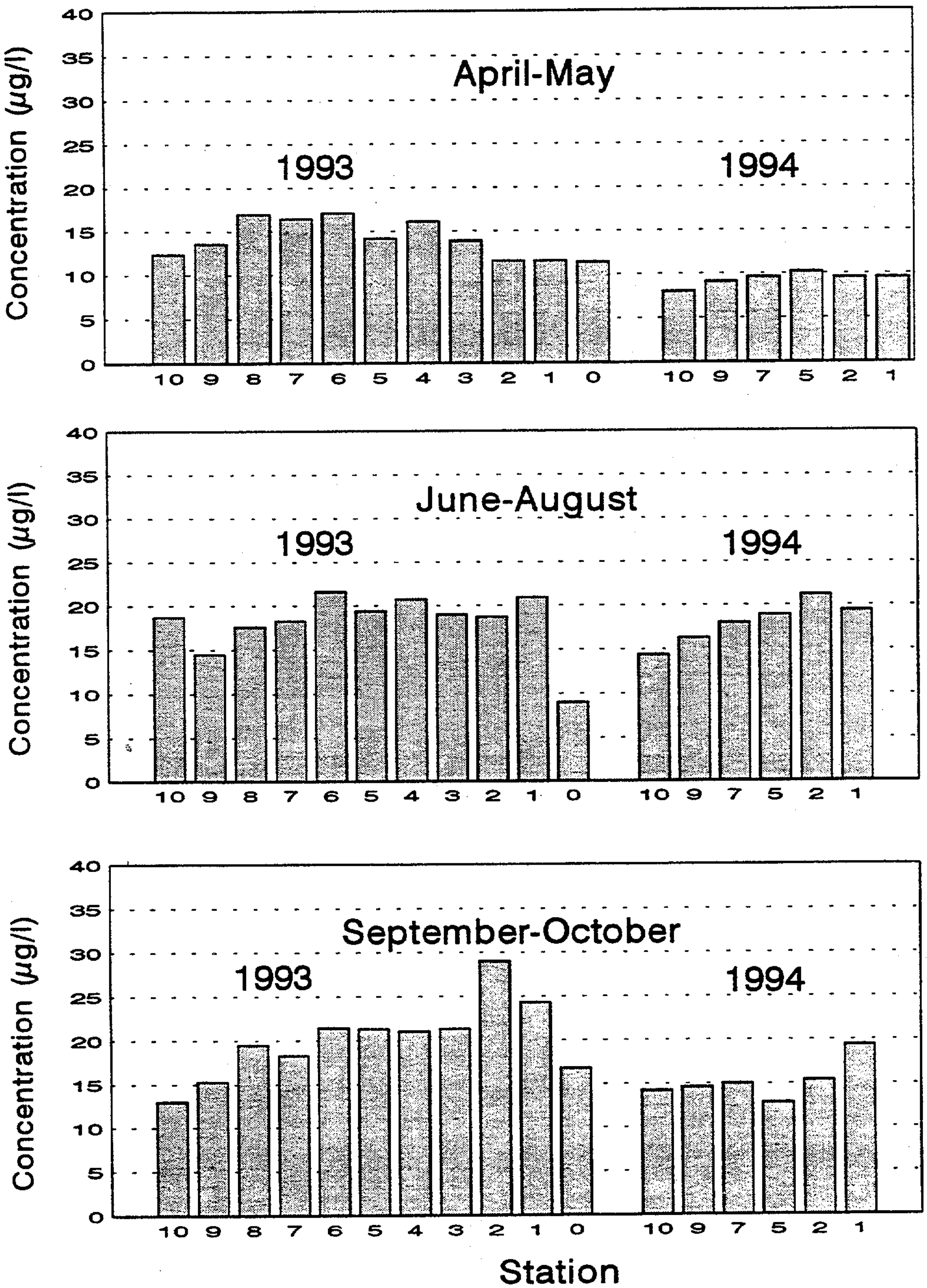

Figure 10-9. Seasonal mean chlorophyll a concentrations at mainstem sampling stations (headwaters at station 10 and dam at station 1) during the diagnostic study of Lake Neely Henry, April 1993 through October 1994.

variables (Thorton *et al.* 1990). Seasonal mean chlorophyll a levels at lacustrine sampling stations (stations 1-8) were similar throughout (Figure 10-9). Upstream station 10 usually had the lowest mean chlorophyll a concentrations. Highest mean concentrations were measured at stations 1, 2, 5 and 6 (Figure 10-9).

Among the tributary embayment stations, station 13 at the mouth of the Big Wills Creek/Black Creek embayment usually had the highest mean chlorophyll a concentrations (Tables 10-22, 10-23 and 10-24). Stations 13 chlorophyll a levels were usually higher than station 10, the nearest upstream mainstem sampling station. Lowest mean chlorophyll a levels were measured during the spring at embayment stations 14 and 15 (Big Wills Creek). High turbidity and low Secchi visibility at these stations as well as at station 16 (Table 10-8) suggest light limitation of the plankton algae at these locations. Chlorophyll a levels in Beaver and Big Canoe creeks (stations 11 and 12) were usually lower than, but similar to, levels measured at the nearest upstream mainstem station 3 (Tables 10-22, 10-23 and 10-24).

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 considered eutrophic (Wetzel 1983).

Mean growing season (May-September) primary productivity measured in 1993 exceeded levels considered eutrophic (1,000 mgC/m^2•day) at all sampling stations (Table 10-27 and Figure 10-10). Seasonal mean productivity was also consistently above the eutrophic level at all sampling stations (Table 10-27 and Figure 10-11). Mean growing season productivity of Lake Henry in 1993 was considerably higher than productivity measured in upstream Lake Weiss during the growing seasons of 1991 and 1992 (Bayne *et al.* 1993b). Measuring productivity of Lake Henry during a relatively dry growing season probably resulted in higher estimates of productivity than would occur under more normal weather conditions. Higher productivity under 1993 low flow conditions was likely caused by increased retention time and improved light conditions favoring algal photosynthesis in the lake. In general, turbidity was lower and light penetration deeper in Lake Henry in 1993 than in 1994 (Tables 10-8, 10-9 and 10-10). Bayne and Maceina (1992) documented the effects of extreme growing season rainfall/runoff on Weiss Lake primary productivity. In 1989, unusually heavy rainfall during the growing season resulted in light-limited conditions (high abiogenic turbidity) and increased discharge (shortened retention time) that suppressed mean algal productivity below the 1000 mgC/m^2•day. The 1990 mean growing season productivity under more normal

Table 10-27. Mean (range) phytoplankton primary productivity measured at five sampling stations on Lake Neely Henry during the diagnostic study conducted in 1993.

	Year	Station	Primary Productivity ($mgC/m^3/hr$)	Primary Productivity ($mgC/m^2/day$)
Spring	1993	1	15.8	1675.9
		3	26.4	1598.6
		6	38.4	1511.4
		9	25.3	1178.3
		13	33.3	1670.4
Summer	1993	1	58.4 (36-88)	1774.6 (1290-2718)
		3	63.0 (30-101)	1570.2 (831-2618)
		6	79.6 (63-110)	1831.0 (1237-2805)
		9	89.5 (50-128)	2185.0 (1356-3305)
		13	93.0 (68-113)	1949.1 (1447-2258)
Fall	1993	1	56.9	3134.7
		3	52.0	1583.7
		6	67.6	2362.4
		9	65.9	3096.7
		13	52.9	1880.4
Growing Season[1]	1993	1	49.6 (16-88)	2026.9 (1290-3135)
		3	53.5 (26-101)	1578.6 (831-2618)
		6	69.0 (38-110)	1873.4 (1237-2805)
		9	72.0 (25-128)	2166.0 (1178-3305)
		13	73.0 (33-113)	1880.0 (1447-2258)

[1] Growing Season = May through September 1993.

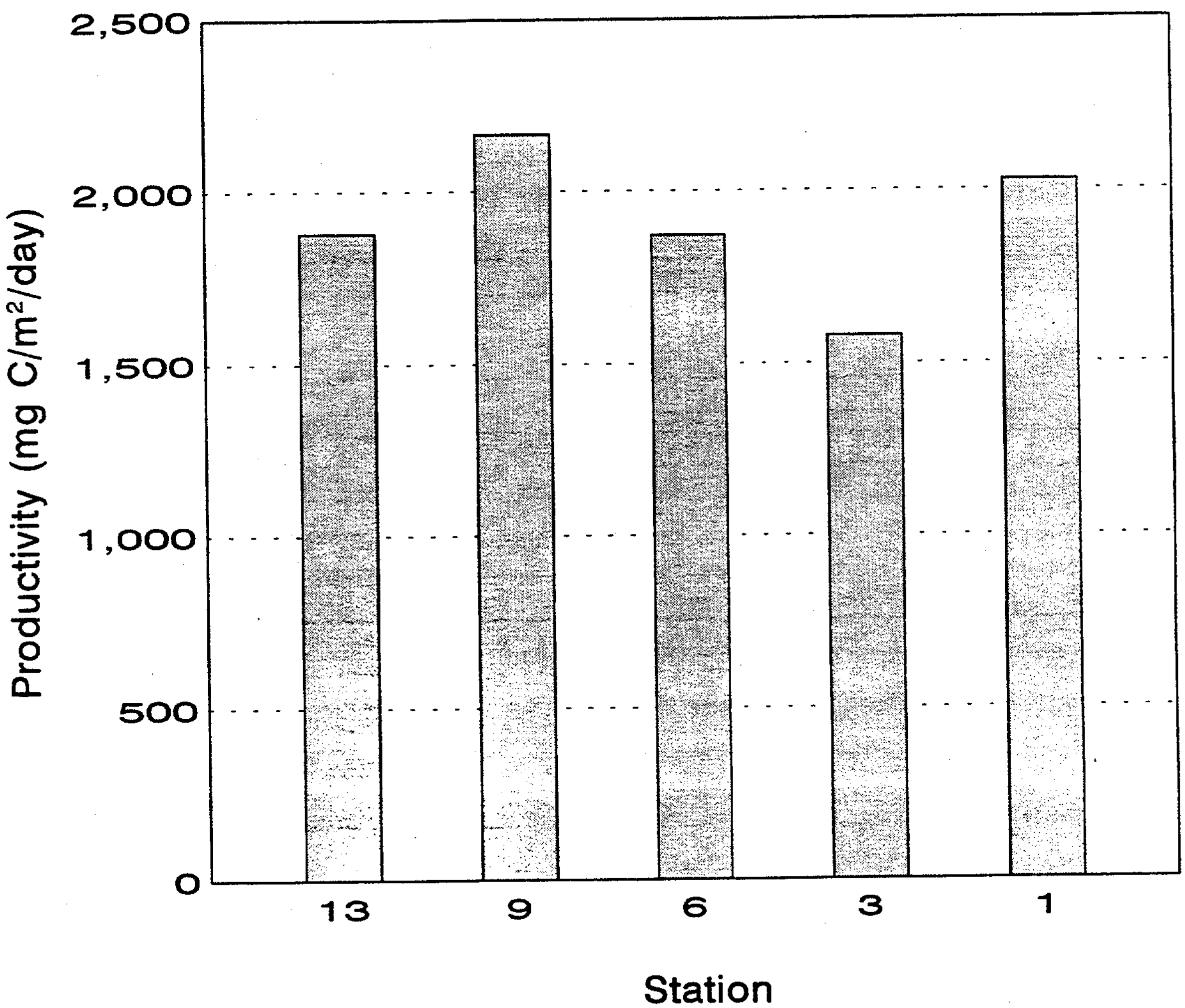

Figure 10-10. Phytoplankton primary productivity measured at stations 1 (dam forebay), 3, 6, 9 and 13 during the diagnostic study of Lake Neely Henry conducted in 1993. Values are growing season mean estimates of productivity.

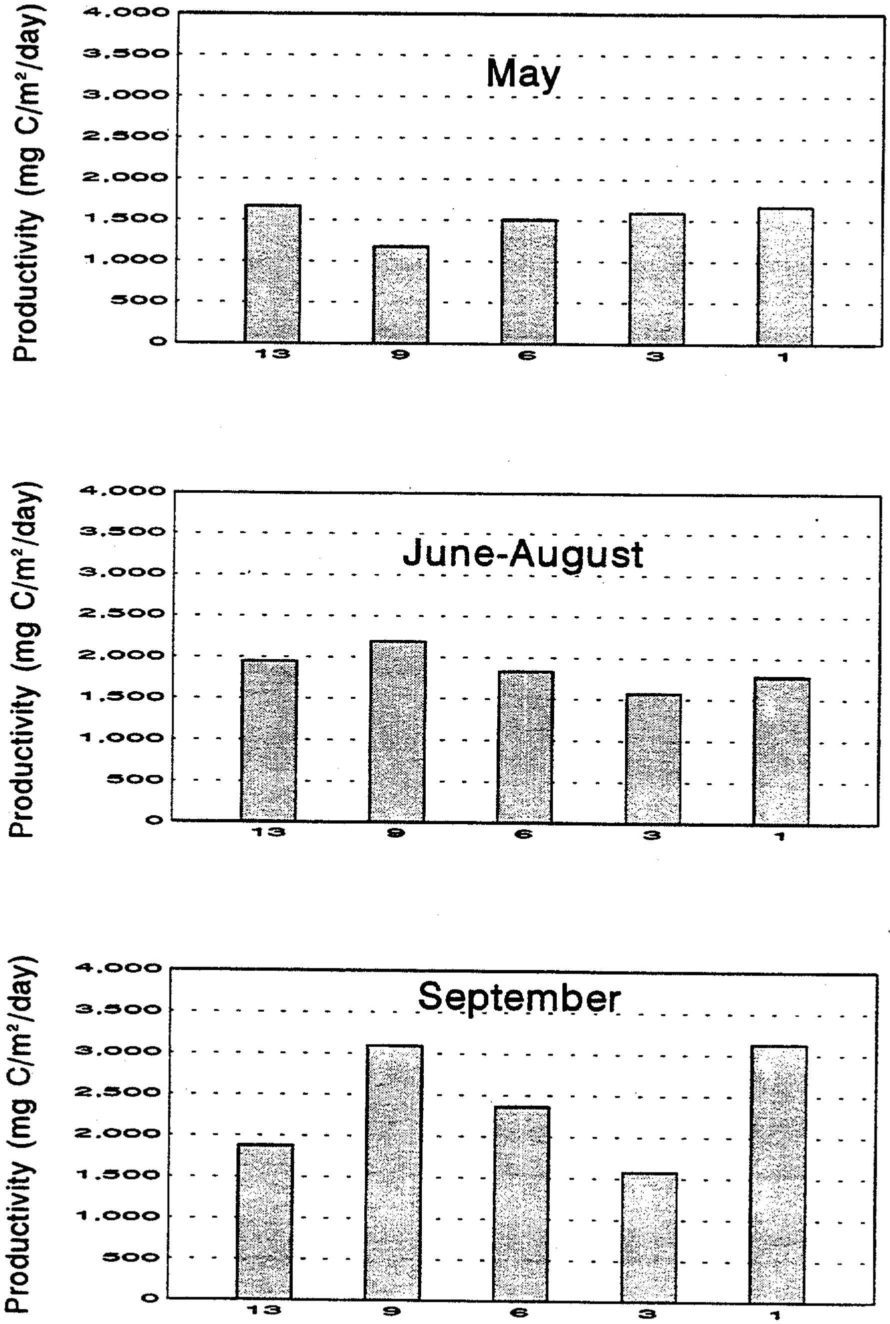

Figure 10-11. Phytoplankton primary productivity measured at sampling stations 1(dam forebay), 3, 6, 9, and 13 during the diagnostic study of Lake Neely Henry concluded in 1993. Values represent seasonal trends in productivity.

rainfall conditions averaged 1,554 mgC/m^2•day (excluding outlying data gathered at one station in July 1990).

There was no consistent pattern in seasonal mean primary productivity among mainstem stations (Figure 10-11). For the growing season highest productivity occurred at station 9 and lowest productivity at station 3 (Figure 10-10). Embayment station 13 was similar to nearby mainstem station 9.

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). Maximum algal dry weights below 5.0 mg/l are thought to assure protection from nuisance phytoplankton blooms and fish-kills in southeastern lakes, excluding Florida (Raschke and Schultz 1987). Mean maximum dry weights above 10.0 mg/l indicate highly productive waters that may be subjected to nuisance blooms. Growing season mean dry weights on the mainstem of Lake Henry in 1993 were all above 5.0 mg/l but below 10.0 mg/l (Table 10-28). Highest values occurred in May and lowest values in September. Dry weights above 10 mg/l were measured at stations 2, 3, 6, 8 and 9 on at least one occasion. The effects of nutrient enrichment (Table 10-20) from point and nonpoint sources of pollution in the vicinity of Gadsden and surrounding communities were evident in the higher mean maximum dry weights of algae measured at stations 6, 8 and 9 all just downstream from Gadsden (Table 10-28). Frequently, highest algal growth potential occurs at the most upstream riverine sampling station having relatively high nutrient content (Bayne *et al.* 1993a, Bayne *et al.* 1993b and Bayne *et al.* 1994a). On Lake Henry, the upstream-most station 10 (Figure 10-1) did not have the highest algal dry weights (Table 10-28). This is further evidence of the strong influence of the Gadsden area on Lake Henry.

Table 10-28. Mean maximum dry weight (mg/l) of Selenastrum capricornutum cultured in Lake Neely Henry waters[1]. A growing season mean weight for each station is also presented.

Sta.	Year	April	May	June	July	August	September	October	Mean
1	1993		8.69		5.86		5.27		6.61
	1994	22.07	2.91	4.47	17.71	3.94		5.67	8.98
2	1993		11.01		3.54		0.67		5.07
3	1993		10.48		5.86		2.53		6.29
4	1993		9.57		5.09		4.69		6.45
5	1994	11.78	2.54	9.14	14.12	2.79		1.98	7.06
6	1993		14.41		10.36		4.65		9.81
7	1994	20.03	7.35	13.47	12.88	4.06		5.78	10.60
8	1993		12.46		8.87		8.22		9.85
9	1993		11.20		11.37		4.68		9.08
	1994	17.69	3.51	7.50	12.53	7.08		2.27	8.43
10	1993		9.63		6.65		4.57		6.95
	1994	20.11	2.69	4.86	11.20	2.13		2.18	7.20

[1] Results of Algal Growth Potential Tests conducted by the Ecological Support Branch, U.S. Environmental Protection Agency, Region IV.

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 waste (Raschke and Schultz 1987). The AGPT is helpful in identifying these common growth limiting nutrients. In Lake Henry nitrogen was the limiting nutrient at all stations except at station 2 in May where co-limitation (N and P) occurred (Table 10-29). Weiss Lake, the impoundment just upstream from Lake Henry, was also reported to be nitrogen limited (Bayne *et al.* 1993b), so nitrogen limitation at upstream station 10 in Lake Henry was expected. The relatively high concentrations of bioavailable phosphorus entering the lake headwaters along with treated municipal wastewater just downstream from Gadsden assured continued nitrogen limitation all the way downstream to the dam (Tables 10-17, 10-18 and 10-19). Water chemistry data showing TN:TP ratios well below the 11-16 range (Table 10-20) considered optimum for phytoplankton growth (Porcella and Cleave 1981) support the AGPT findings of nitrogen limitation.

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). The overwhelming influence of 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 (Tables 10-22, 10-23 and 10-24). At mainstem sampling stations in Lake Henry individual TOC concentrations ranged from a low of 2.8 mg/l to a high of 18.2 mg/l. Seasonal mean concentrations were less variable with a low of 3.4 mg/l at stations 0, 7 and 8 during the spring of 1993 and a high of 9.7

Table 10-29. Temporal and spacial variation in nutrient limitation based on results of Algal Growth Potential Tests[1] conducted during the growing season of 1993.

	Limiting Nutrient							
Mainstem Station	1	2	3	4	6	8	9	10
DATE								
May 1993	N[2]	N and P[3]	N	N	N	N	N	N
July 1993	N	N	N	N	N	N	N	N
September 1993	N	N	N	N	N	N	N	N

[1] AGPT conducted by the Ecological Support Branch, U.S. Environmental Protection Agency, Region IV

[2] N = Nitrogen

[3] P = Phosphorus

mg/l at station 9 during the summer of 1994. Since much of the TOC is allochthonous carbon, increases in rainfall and surface runoff are expected to increase TOC of lake waters. Bayne and Maceina (1992) reported mean growing season (May through September) TOC concentrations in Weiss Lake of 11.9 mg/l in 1989 and 4.1 mg/l in 1990. The large difference between years was attributed to unusually heavy rainfall during the 1989 growing season that affected TOC in all four lakes being studied. In Lake Henry, TOC concentrations were higher during the spring and summer of 1994 than during the relatively dry 1993 (Tables 10-22 and 10-23). However, fall concentrations were a bit higher in 1993 than in 1994 (Table 10-24).

TOC concentrations in Lake Henry tributary embayments were similar to concentrations measured at the nearest upstream sampling station on the mainstem (Tables 10-22, 10-23 and 10-24). Beaver, Big Canoe and Black creeks (stations 11, 12 and 16) usually had TOC levels somewhat higher than those measured on the mainstem and Big Wills Creek (stations 14 and 15) usually had values somewhat lower than those measured on the mainstem.

10.2.3 Macrophyte Survey

A macrophyte survey of Lake Henry was conducted from shallow-draft boats and was limited to the mainstem and larger tributary embayments. Initial reconnaissance revealed the most significant stands of aquatic vegetation were marginal emergent forms found between station 5 near Rainbow City and station 10 upstream of Gadsden (Figure 10-1). Shallow water along the shoreline and around islands in overbank areas of the mainstem and in large embayments were the sites of the most extensive stands of emergent macrophytes. However, scattered stands of macrophytes were found all the way to the dam, particularly in coves and embayments.

A list of macrophytes identified during the survey appears in Table 10-30. Trees, shrubs and woody vines were common along shorelines and on islands. Most of the herbaceous plants were marginal emergent types, rooted in the substrate and confined to shallow water (<1.0 m) areas. Alligator-weed, (Alternanthera philoxeroides), when growing in the water, can produce hollow stems that float on the water surface forming floating mats of vegetation. This exotic species can become weedy but at Lake Henry only relatively small stands of alligator-weed were found. The only submersed aquatic plants observed during the study were filamentous algae, however, no significant stands of algae were found.

Dominant herbaceous macrophytes included water-willow (Justicia americana), soft rush (Juncus effusus), smartweed (Polygonum punctatum) and wool grass (Scirpus cyperinus). None of these plants are particularly noxious weeds but when growing in high-use areas of the lake may require management. Survey results revealed no serious aquatic plant problems in Lake Henry in 1994.

10.2.4 Toxic Contaminants in Sediment

Duplicate sediment samples were collected at sampling stations 1 through 16 (Table 10-2) in Lake Henry on 9 August 1994. Samples were collected with a KB® 2-inch diameter, core sampler equipped with a cellulose-acetate-butyrate (CAB) liner tube. The tubes, containing sediment, were sealed and placed on ice for transport to laboratory facilities at Auburn University where they were frozen. The frozen sediment was removed from the tubes, wrapped in aluminum foil, placed in individual plastic bags and transported, frozen, to ADEM's analytical laboratory facilities in Montgomery, Alabama. The upper 5 cm of each core sample was removed for analysis. Preparation of the samples and analytical procedures used appear in Appendix 2. The sediment was tested for an array of organic chemicals and mercury (Table 10-31).

Table 10-30. Vascular aquatic plants identified in a survey conducted on Lake Neely Henry 19 September 1994.

Species	Common Name
Acer rubrum	red maple
Acer saccharinum	silver maple
Alnus serrulata	alder
Alternanthera philoxeroides	alligator-weed
Amorpha fruticosa	bastard-indigo
Arundinaria gigantea	cane
Betula nigra	river birch
Campsis radicans	trumpet-creeper
Cephalanthus occidentalis	button bush
Cornus amomum	--
Cuscuta sp.	dodder
Hibiscus militaris	halberd-leaved marshmallow
Juncus effusus	soft rush
Justicia americana	water-willow
Mikania scandens	climbing hempweed
Nyssa sp.	--
Polygonum punctatum	smartweed
Salix nigra	black willow
Scirpus cyperinus	wool grass
Typha latifolia	common cattail

Table 10-31. List of contaminants and their detection limits analyzed in sediment collected from Lake Neely Henry in 1994.

Contaminant	Detection Limit
4,4'-DDD	0.0042 µg/g
4,4'-DDE	0.0025 µg/g
4,4'-DDT	0.0036 µg/g
Arochlor 1016	0.050 µg/g
Arochlor 1221	0.050 µg/g
Arochlor 1232	0.050 µg/g
Arochlor 1242	0.050 µg/g
Arochlor 1248	0.050 µg/g
Arochlor 1254	0.050 µg/g
Arochlor 1260	0.050 µg/g
a-BHC	0.0019 µg/g
Aldrin	0.0022 µg/g
b-BHC	0.0033 µg/g
Chlordane	0.0015 µg/g
d-BHC	0.0011 µg/g
Dieldrin	0.0050 µg/g
Dursban in Soil	0.01 µg/g
Endosulfan I	0.0021 µg/g
Endosulfan II	0.0024 µg/g
Endosulfan Sulfate	0.0036 µg/g
Endrin	0.0036 µg/g
Endrin Aldehyde	0.0016 µg/g
g-BHC	0.0020 µg/g
Heptachlor	0.0020 µg/g
Heptachlor Epoxide	0.0021 µg/g
Mercury in Soil	0.1000 µg/g
Methoxychlor	0.0057 µg/g
Mirex	0.0300 µg/g
Toxaphene	0.0500 µg/g

The only contaminants found in concentrations above detection limits of the analytical procedures were Arochlor 1254, Arochlor 1260 and mercury (Table 10-32). Polychlorinated biphenyls commonly known as PCB's (Arochlor 1254 and 1260) were found at seven mainstem stations and at four tributary embayment stations. On the mainstem, concentrations were < 0.60 μg/g and in embayments, concentrations were < 0.90 μg/g. PCB's were found in sediments of upstream Weiss Lake in 1992 at concentrations < 0.20 μg/g (Bayne *et al.* 1993b). PCB's were not detected in sediments collected from West Point Lake in 1990 and 1991 (Bayne *et al.* 1994a). The Coosa River has a history of PCB contamination dating back to 1976 (DNR 1976). Health officials in Alabama and Georgia posted fish consumption advisories for the Coosa River and lakes Weiss and Henry. The primary source of PCB contamination for this area has been identified as the General Electric Company in Rome, Georgia (EPD 1991). The company is under a consent order to reduce PCB contaminated runoff from the plant site into the Coosa River. PCB levels in fish tissues have declined through the years in both Georgia (EPD 1993) and Alabama, however, concentrations exceeding the 2 ppm FDA tolerance level for edible portions are still encountered in some fish species. There are no regulatory guidelines for PCB sediment levels.

Mercury was detected in Lake Henry sediments in concentrations ranging from 0.11 μg/g to 0.28 μg/g and was found at all sampling stations (Table 10-32). Mercury concentrations in lake sediments are quite variable. Lawrence (1972) reported mercury levels varying from 0.8 μg/g to 2.5 μg/g in sediments taken from Coosa River impoundments. He found no detectable mercury in core samples from Lake Henry but hydrosol (water/sediment interface) samples contained 0.15 μg/g mercury. More recent studies of sediments taken from West Point Lake on the Chattahoochee River revealed mercury concentrations of from < 0.02 μg/g to 0.20 μg/g (Bayne *et al.* 1994a). There are no state or federal standards for sediment concentrations of heavy metals.

Table 10-32. Contaminants detected in Lake Neely Henry sediment collected in August 1994. Concentrations are expressed as $\mu g/g$.

Station	Rep	Arochlor 1260	Arochlor 1254	Mercury
1	A	0.23	U	0.19
	B	0.12	U	0.16
2	A	U	0.07	0.11
	B	U	0.12	0.24
3	A	U	0.09	0.25
	B	U	0.15	0.18
4	A	U	0.15	0.26
	B	U	U	0.20
5	A	U	0.51	0.18
	B	U	U	0.20
6	A	U	U	0.21
	B	U	0.13	0.17
7	A	U	0.13	0.13
	B	U	U	0.26
8	A	U	U	0.16
	B	U	U	0.25
9	A	U	U	0.12
	B	U	U	0.18
10	A	U	U	0.17
	B	U	U	0.15
11	A	U	U	0.17
	B	U	U	0.19
12	A	U	0.42	0.11
	B	U	U	0.12
13	A	U	U	0.22
	B	0.60	U	0.28
14	A	U	U	0.18
	B	U	U	0.19
15	A	U	0.14	0.14
	B	U	0.30	0.13
16	A	0.84	U	0.26
	B	U	U	0.26

U = less than instrument detection limit

11.0 BIOLOGICAL RESOURCES

11.1 Fishery

Lake Henry is a popular fishing lake as are the upstream and downstream reservoirs Lakes Weiss and Logan Martin. Numerous bass tournaments have been held on the lake (15 in 1993, 23 in 1994) and Lake Henry compared favorably to Lakes Weiss and Logan Martin (Tables 11.1 - 11.2). A list of fish species collected from Lake Henry and the watershed surrounding the lake is presented in Table 11.3. The fisheries section of the Alabama Department of Conservation and Natural Resources assessed the sport fishery during 1988, 1993 and 1994. The Department has collected baseline data on the lake and assessed the lake at intervals depending on the amount of public concern. Electrofishing, gillnetting and seining were all utilized to determine the composition and condition of the sportfish and other species in the lake. Some results from electrofishing for largemouth bass, spotted bass, white crappie, black crappie and bluegill are presented in Tables 11.4 - 11.7. Sampling involved electrofishing for 30 minutes at each of 10 randomly selected sites. RSD (incremental relative stock density) was summarized for the different size categories of the targeted species; S = stock, Q = quality, P = preferred and M = memorable. Black and white crappie were collected by trap net during fall, 1994. Seining was utilized to verify bass reproduction and gill netting targeted striped, hybrid and white bass.

Additionally, the state has stocked hybrid striped bass, striped bass and Florida largemouth bass since the early 1980's. Stocking records of these additional species in Lake Henry are presented in Table 11.8.

Growth in the largemouth bass was described as slow during 1988 for fish aged III and IV. Growth improved during 1993 and 1994 for the entire black bass

Table 11-1. Ranking by quality indicators for all reservoirs with five or more tournament reports in the 1993 B.A.I.T. program.

Rank	Percent Success	Average Weight	Bass per Man-day	Pounds per Man-day	Hours per Bass > 5lb	Overall	Value
1	Harris	Eufaula	Martin	Jordan	Eufaula	Wheeler	104
2	Millers Ferry	West Point	Harris	Jones Bluff	Wheeler	Jones Bluff	101
3	Mitchell	Jordan	Jones Bluff	Wheeler	Harding	Millers Ferry	96
4	Martin	Aliceville	Wheeler	Lay	Guntersville	Jordan	94
5	Demopolis	Millers Ferry	Mitchell	Mitchell	Wilson	Harding	88
6	Weiss	Jones Bluff	Lay	Millers Ferry	West Point	Lay	88
7	Jones Bluff	Wheeler	Demopolis	Harding	Aliceville	Mitchell	81
8	Lay	Lay	Jordan	Martin	Weiss	Weiss	79
9	**Neely Henry**	Guntersville	**Neely Henry**	Demopolis	Millers Ferry	Demopolis	78
10	Wheeler	Harding	Gainesville	**Neely Henry**	Gainesville	Martin	74
11	Harding	Weiss	Harding	Logan Martin	Jones Bluff	Logan Martin	66
12	Jordan	Mitchell	Millers Ferry	Weiss	Jordan	Harris	65
13	Logan Martin	Logan Martin	Logan Martin	Harris	Demopolis	**Neely Henry**	64
14	Gainesville	Pickwick	Weiss	Gainesville	Logan Marin	Guntersville	63
15	Warrior	Mobile Delta	Wilson	Wilson	Warrior	Gainesville	62
16	Holt	Warrior	Warrior	Guntersville	Lay	Aliceville	58
17	Smith	**Neely Henry**	Guntersville	Warrior	Pickwick	Wilson	58
18	Wilson	Demopolis	Holt	West Point	Smith	Eufaula	55
19	Aliceville	Wilson	Coffeeville	Holt	Martin	West Point	55
20	Coffeeville	Gainesville	Pickwick	Aliceville	Coffeeville	Warrior	51
21	Guntersville	Holt	Mobile Delta	Pickwick	**Neely Henry**	Pickwick	36
22	Pickwick	Coffeeville	Aliceville	Coffeeville	Holt	Holt	34
23	Mobile Delta	Smith	Smith	Mobile Delta	Harris	Coffeeville	27
24	Eufaula	Martin	West Point	Eufaula	Mitchell	Smith	24
25	West Point	Harris	Eufaula	Smith	Mobile Delta	Mobile Delta	23

Table 11-2. Ranking by quality indicators for all reservoirs with five or more tournament reports in the 1994 B.A.I.T. program.

Rank	Percent Success	Average Weight	Bass per Man-day	Pounds per Man-day	Hours per Bass > 5lb	Overall	Value
1	Martin	Eufaula	Martin	Jordan	Wheeler	Jordan	112
2	Weiss	Guntersville	Jones Bluff	Jones Bluff	Wilson	Gainesville	98
3	Harding	Wilson	Jordan	Lay	Eufaula	Logan Martin	98
4	Jones Bluff	West Point	Logan Martin	Logan Martin	Cedar Creek	Jones Bluff	96
5	Logan Martin	Pickwick	Millers Ferry	Millers Ferry	Aliceville	Wheeler	96
6	Jordan	Jordan	Gainesville	Gainesville	Gainesville	Lay	94
7	**Neely Henry**	Lay	Lay	Martin	Pickwick	Millers Ferry	92
8	Aliceville	Wheeler	Demopolis	Wheeler	Guntersville	Weiss	89
9	Mobile Delta	Weiss	**Neely Henry**	**Neely Henry**	Harding	Aliceville	86
10	Lay	Jones Bluff	Harding	Mitchell	Holt	**Neely Henry**	85
11	Millers Ferry	Mitchell	Aliceville	Wilson	Weiss	Martin	84
12	Gainesville	Gainesville	Mitchell	Demopolis	Jordan	Harding	79
13	Warrior	Logan Martin	Wheeler	Weiss	Millers Ferry	Wilson	77
14	Wheeler	Millers Ferry	Holt	Aliceville	Warrior	Pickwick	71
15	Tuscaloosa	**Neely Henry**	Little Bear	Holt	**Neely Henry**	Eufaula	67
16	Holt	Aliceville	Weiss	Harding	Logan Martin	Holt	66
17	Demopolis	Harris	Tuscaloosa	Pickwick	Tuscaloosa	Demopolis	63
18	Little Bear	Demopolis	Mobile Delta	Little Bear	Harris	Mitchell	58
19	Smith	Holt	Warrior	Eufaula	Lay	Guntersville	51
20	Pickwick	Mobile Delta	Pickwick	Tuscaloosa	West Point	Tuscaloosa	50
21	Harris	Tuscaloosa	Cedar Creek	Mobile Delta	Martin	Warrior	48
22	Cedar Creek	Little Bear	Smith	Warrior	Demopolis	Mobile Delta	45
23	Wilson	Harding	Harris	Harris	Little Bear	Little Bear	44
24	Mitchell	Warrior	Wilson	Smith	Smith	Cedar Creek	41
25	Eufaula	Smith	Eufaula	Cedar Creek	Mitchell	Harris	38
26	West Point	Martin	Guntersville	Guntersville	Jones Bluff	West Point	36
27	Guntersville	Cedar Creek	West Point	West Point	Mobile Delta	Smith	26

Table 11-3. A checklist of fish species collected from Lake Neely Henry and the surrounding watershed.

Scientific Name	Common Name
Lepisosteidae	
Lepisosteus osseus	longnose gar
Lepisosteus oculatus	spotted gar
Clupeidae	
Dorosoma cepedianum	gizzard shad
Dorosoma petenense	threadfin shad
Esocidae	
Esox niger	chain pickerel
Cyprinidae	
Campostoma oligolepis	largescale stoneroller
Cyprinus carpio	carp
Carassius auratus	goldfish
Cyprinella callistia	Alabama shiner
Cyprinella trichroistia	tricolor shiner
Cyprinella venusta	blacktail shiner
Luxilus chrysocephalus	striped shiner
Lythrurus lirus	mountain shiner
Notemigonus crysoleucas	golden shiner
Notropis chrosomus	rainbow shiner
Notropis xaenocephalus	Coosa shiner
Phaencobius catostomus	riffle minnow
Pimephales vigilax	bullhead minnow
Semotilus atromaculatus	creek chub
Catastomidae	
Hypentelium etowanum	Alabama hogsucker
Ictiobus bubalus	smallmouth buffalo
Minytrema melanops	spotted sucker
Moxostoma duquesnei	black redhorse
Moxostoma erythrurum	golden redhorse
Moxostoma poecilurum	blacktail redhorse
Ictaluridae	
Ameiurus catus	white catfish
Ameiurus melas	black bullhead
Ameiurus natalis	yellow bullhead
Ameiurus nebulosus	brown bullhead
Ictalurus furcatus	blue catfish
Ictalurus punctatus	channel catfish
Noturus leptacanthus	speckled madtom
Pylodictis olivaris	flathead catfish
Cyprinodontidae	
Fundulus olivaceus	blackspotted topminnow
Fundulus stellifer	southern studfish
Poeciliidae	
Gambusia affinis	mosquito fish

Table 11-3. (Cont.)

Scientific Name	Common Name
Cottidae	
Cottus carolinae	banded sculpin
Percichthyidae	
Morone chrysops	white bass
Morone saxatilis	striped bass
Morone saxatilis x M. chrysops	hybrid striped bass
Centrarchidae	
Lepomis auritus	redbreast sunfish
Lepomis cyanellus	green sunfish
Lepomis gulosus	warmouth
Lepomis humilis	orangespotted sunfish
Lepomis macrochirus	bluegill
Lepomis megalotis	longear sunfish
Lepomis microlophus	redear sunfish
Lepomis punctatus	spotted sunfish
Micropterus coosae	redeye bass
Micropterus punctulatus	spotted bass
Micropterus salmoides	largemouth bass
Pomoxis annularis	white crappie
Pomoxis nigromaculatus	black crappie
Percidae	
Etheostoma coosae	Coosa darter
Etheostoma jordani	greenbreast darter
Etheostoma stigmaeum	speckled darter
Percina caprodes	logperch
Percina nigrofasciata	black-banded darter
Percina shumardi	river darter
Stizostedion vitreum	walleye
Sciaenidae	
Aplodinotus grunniens	freshwater drum

Table 11-4. Number of fish species collected by gear type in Lake Neely Henry, 1988.

Species	Electrofishing			Netting			Seining		
	No.	CPE	Tot.E	No.	CPE	Tot.E	No.	CPE	Tot.E
Spotted Gar				1	0.10	12			
Gizzard Shad	108	83.10	1.30	88	7.30	12			
Threadfin Shad	102	32.90	3.10						
Carp				25	2.10	12			
Blacktail Shiner	42	24.70	1.70				53	4.40	12
Minnow	1	0.60	1.70						
Smallmouth Buffalo				3	0.30	12			
Spotted Sucker	9	5.30	1.70	13	1.10	12			
Black Redhorse	1	0.60	1.70	3	0.30	12			
Blacktail Redhorse	3	1.80	1.70						
White Catfish				2	0.20	12			
Blue Catfish				22	1.80	12			
Channel Catfish	5	2.90	1.70	29	2.40	12			
Flathead Catfish				13	1.10	12			
White Bass	1	0.60	1.70	18	1.50	12			
Striped Bass				3	0.30	12			
Hybrid Striped Bass				5	0.40	12			
Green Sunfish	10	5.90	1.70				1	0.10	12
Warmouth Sunfish	2	1.20	1.70						
Bluegill Sunfish	100	98.00	1.02				5	0.40	12
Longear Sunfish	32	18.80	1.70				3	0.30	12
Spotted Bass	113	47.10	2.40	3	0.30	12			
Largemouth Bass	185	97.30	1.90	3	0.30	12	5	0.40	12
White Crappie	28	5.50	5.10	19	1.60	12			
Black Crappie	21	4.10	5.10	8	0.70	12			
Freshwater Drum	8	4.70	1.70	50	4.20	12			

Table 11-5. Total number, CPE and percent of sample of target species collected by electrofishing in Lake Neely Henry, 1988. RSD-S = relative stock density (stock size), RSD-Q = relative stock density (quality size), RSD-P = relative stock density (preferred size), RSD-M = relative stock density (memorable size).

Species	Number of Samples	RSD-S			RSD-Q			RSD-P			RSD-M			RSD-T			TOTAL	
		no.	cpe	pct	no.	cpe	pct	no.	cpe	pct	no	cpe	pct	no.	cpe	pct	no.	cpe
Spotted Bass	5	47	19.60	48	35	14.60	36	14	5.80	14	1	0.40	1	0	0	0	97	40.40
Largemouth Bass	4	52	27.40	46	35	18.40	31	21	11.10	19	5	2.60	4	0	0	0	113	59.50
Bluegills	2	72	70.60	71	29	28.50	29	0	0	0	0	0	0	0	0	0	101	101
Black Crappie	10	0	0	0	3	0.60	15	10	2	50	7	1.40	35	0	0	0	20	3.90
White Crappie	10	0	0	0	3	0.60	10	18	3.50	62	8	1.60	28	0	0	0	29	5.70

Table 11-6. Number of fish species collected by gear type in Lake Neely Henry, 1994.

Species	Electrofishing			Trap Netting		
	No.	CPE	Tot.E	No.	CPE	Tot.E
Gizzard shad	108	98.2	1.1	12	0.30	40
Threadfin shad	112	53.3	2.1	3	0.10	40
Carp				3	0.10	40
Blacktail shiner	9	7.5	1.2			
Golden shiner	1	0.8	1.2			
Spotted sucker	3	2.5	1.2	2	0.05	40
Black redhorse	1	0.8	1.2	1	0.03	40
Blacktail redhorse	4	3.3	1.2	1	0.03	40
Channel catfish	4	3.3	1.2	26	0.70	40
Flathead catfish				1	0.03	40
White bass				5	0.13	40
Striped bass						
Hybrid striped bass						
Green sunfish	2	1.7	1.2			
Warmouth	1	0.8	1.2	17	0.41	40
Orangespotted sunfish	3	2.5	1.2			
Bluegill sunfish	93	77.5	1.2			40
Longear sunfish	6	5.0	1.2	11	0.30	40
Redear sunfish	19	15.8	1.2	25	0.63	40
Spotted bass	111	35.8	3.1	1	0.03	40
Largemouth bass	125	52.1	2.4	1	0.03	40
White crappie	7	5.8	1.2	55	1.40	40
Black crappie	17	14.2	1.2	116	2.90	40
Log perch	1	0.8	1.2	2	0.05	40
Freshwater drum	4	3.3	1.2			

Table 11-7. Total numbers, effort, catch-per-effort (CPE) and percent of samples by RSD size categories, 1988, 1993 and 1994. RSD-S = relative stock density (stock size), RSD-Q = relative stock density (quality size), RSD-P = relative stock density (preferred size), RSD-M = relative stock density (memorable size).

				SUBSTOCK			RSD-S				RSD-Q				RSD-P				RSD-M				TOTAL		PSD
Species	Date	No. of samples	Total effort	No.	CPE	Pct[1]	No.	CPE	Pct	Wr[2]	No.	CPE	Pct	Wr	No.	CPE	Pct	Wr	No.	CPE	Pct	Wr	No.	CPE	
	Spring 1988	4	1.9	5	2.6	5	52	27.4	46	92	35	18.4	31	93	21	11.1	19	104	5	2.6	4	107	113	59.5	54
Largemouth Bass	Spring 1993	7	3.5	3	0.8	3	34	9.7	32	101	33	9.4	31	106	32	9.1	30	111	6	1.7	6	104	108	30.9	68
	Spring 1994	5	2.4	22	9.0	21	44	18.1	43	92	28	11.5	27	95	27	11.1	26	102	4	1.6	4	99	125	52.1	57
	Spring 1988	5	2.4	9	3.7	9	47	19.6	48	97	35	14.6	36	95	14	5.8	14	105	1	0.4	1	115	97	40.4	53
Spotted Bass	Spring 1993	7	3.5	1	0.2	1	27	7.7	40	99	27	7.7	40	115	9	2.5	13	124	5	1.4	7	119	69	19.7	60
	Spring 1994	7	3.1	9	2.9	9	25	8.1	25	100	51	16.6	50	103	17	5.5	17	110	9	2.9	9	116	111	36.0	75
White Crappie	Fall 1994	40 n.n	40n.n	3	0.08	5.7	19	0.5	37	65	18	0.5	35	88	12	0.3	23	97	3	0.08	6	92	55	1.4	
Black Crappie	Fall 1994	40 n.n	40n.n	1	0.03	0.8	13	0.03	11	64	34	84.4	30	84	59	1.5	51	92	9	0.2	8	96	116	2.9	
	Spring 1994	7	1.2	3	2.5	3	70	60.0	78	84	20	17.1	22	79									93	77.5	22
Bluegill	Fall 1994	40 n.n	40 n.	228	5.7	100	195	4.9	86	78	33	0.8	14	75									456	11.4	14

[1] Substock Pct. is substock: number of substock size fish collected for every 100 fish of stock size and larger.
[2] Wr = relative weight.

Table 11-8. Fish stocking in Lake Neely Henry, 1984-1994.

Species	Date	Rate	Size Group (in)	Total*
Striped bass	1984	4.9/A	1-2	55,100
	1985	4.9/A	1-2	55,000
	1992	4.0/A	1-2	42,110 G
				155,210
Hybrid striped bass	1984	5.0/A	1-2	55,695
	1985	5.0/A	1-2	55,352
	1986	5.3/A	1-2	59,031
	1988	5.4/A	1-2	60,752
	1989	4.0/A	1-2	44,940
	1990	5.0/A	1-2	56,100
	1991	2.0/A	1-2	22,084
	1992	3.0/A	1-2	33,806
				387,760
Florida largemouth bass	1984	2.3/A	1-2	25,800
	1986	2.7/A	1-2	30,032
	1987	1.0/A	1-2	11,400
	1988	2.0/A	1-2	22,470
	1989	4.0/A	1-2	45,000
	1990	0.9/A	1-2	10,555
	1991	2.0/A	1-2	22,446
	1992	2.0/A	1-2	22,240
	1993	2.0/A	1-2	22,240
				212,183

* G denotes Gulf Coast strain

population. Intraspecific competition for food among the more numerous, smaller bass was thought to be the reason for the slower growth during 1988.

11.2 Wildlife

A checklist of birds, amphibians and reptiles expected in the Lake Henry watershed appears in Table 11.9. The watershed was 77 percent forested with the remaining area urban, primarily developed into permanent and semi-permanent residences. There was little agriculture present on the watershed (Floyd 1988). The urban areas tend to limit wildlife, however the undeveloped forested areas provide good habitat for some species. There have been sightings of the bald eagle *Haliaeetus leucocephalus* near the Neely Henry dam during the winter months. The Black Creek-Big Wills Creek embayment is also utilized by migratory waterfowl during winter months.

Table 11-9. Checklist of birds, amphibians and reptiles expected in and around Lake Neely Henry and its surrounding watershed.

Family	Scientific Name	Common name
BIRDS		
Gaviidae		
	Gavia immer	common loon
Podicipedidae		
	Podiceps auritus	horned grebe
	Podiceps nigricollis	eared grebe
	Podilymbus podiceps	pied-billed grebe
Pelecanidae		
	Pelecanus erythrorhynchos	white pelican
Phalacrocoracidae		
	Phalacrocorax auritus	double-crested cormorant
Anhingidae		
	Anhinga anhinga	anhinga
Ardeidae		
	Ardea herodias	great blue heron
	Butorides virescens	green heron
	Florida caerula	little blue heron
	Bubulcus ibis	cattle egret
	Casmerodius albus	great egret
	Egretta thula	snowy egret
	Hydranassa tricolor	Louisiana heron
	Nycticorax hycticorax	black-crowned night heron
	Nyctanassa violacea	yellow-crowned night heron
	Ixobrychus exilis	least bittern
	Botaurus lentiginosus	American bittern
Ciconiidae		
	Mycteria americana	wood stork
Threskiornithidae		
	Plegadis falcinellus	glossy ibis
	Eudocimus albus	white ibis
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
	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

Table 11-9. (Continued)

Family	Scientific Name	Common name
	Aythya valisineria	canvas back
	Aythya marila	greater scaup
	Aythya affinis	lesser scaup
	Bucephala clangula	common goldeneye
	Bucephala albeola	bufflehead
	Clangula hyemalis	oldsquaw
	Melanitta delglandi	white-winged scoter
	Melanitta perspicillata	surf 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
	Accipter striatus	sharp-shinned hawk
	Accipter 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 perigrinus	peregrin falcon
	Falco columbarius	merlin
	Falco sparverius	American kestrel
Tetraonidae		
	Bonasa umbellus	ruffed grouse
Phasianidae		
	Colinus virginianus	bobwhite
Meleagrididae		
	Meleagris gallopavo	turkey
Gruidae		
	Grus canadensis	sandhill crane
Rallidae		
	Rallus elegans	kingrail
	Rallus limicola	Virginia rail
	Porzana carolina	sora
	Porphyrula martinica	purple gallinule

Table 11-9. (Continued)

Family	Scientific Name	Common name
	Gallinula chloropus	common gallinule
	Fulica americama	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 yellow legs
	Tringa flavipes	lesser yellow legs
	Catoptraphorus semipalmatus	willet
	Calidris melanotus	pectoral sandpiper
	Calidris fuscicollis	white-rumped sandpiper
	Calidris bairdii	Baird's sandpiper
	Calidris minutilla	least sandpiper
	Calidris alpina	dulin
	Calidris pusilla	semipalmated sandpiper
	Calidris mauri	western sandpiper
	Calidris alba	sanderling
	Limnodromus griseus	short-billed dowitcher
	Limnodromus scolopaceus	land-billed dowitcher
	Micropalama himantopus	stilt sandpiper
	Tryngites subruficollis	buff-breasted sandpiper
	Limosa fedoa	marbled godwit
Recurvirostridae		
	Recurvirostra americama	American avocet
Phalaropodidae		
	Phalaropus fulicarius	red phalarope
	Steganopus tricolor	Wilson's phalarope
	Lobipes lobatus	northern phalarope
Laridae		
	Larus argentatus	herring gull
	Larus delawarensis	ring-billed gull
	Larus artricilla	laughing gull
	Larus philadelphia	Bonaparte's gull
	Sterna forsteri	Forster's tern
	Sterna hirundo	common tern
	Sterna albifrons	least tern
	Thalasseus maximus*	royal tern
	Hydroprogne caspia	caspian tern
	Chlidonias niger	black tern

Table 11-9. (Continued)

Family Scientific Name	Common name
Columbidae	
Columba livia	rock dove (pigeon)
Zenaida asiatica	white-winged dove
Zenaida macroura	mourning dove
Columbina passerina	ground dove
Cuculidae	
Cocoyzus americanus	yellow-billed cuckoo
Cocoyzus erythropthalmus	black-billed cuckoo
Tytonidae	
Tyto alba	barn owl
Otus asio	screech owl
Bubo virginianus	great horned owl
Strix varia	barred 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	
Megacerle alcyon	belted kingfisher
Picidae	
Colaptes auratus	common flicker
Dryocopus pileatus	pileated woodpecker
Centurus carolinus	red-bellied woodpecker
Melanerpea erythrocephalus	red-headed woodpecker
Sphyrapicus varius	yellow-bellied sapsucker
Dendrocopos villosus	hairy woodpecker
Dendrocopos pubescens	downy woodpecker
Picoides borealis	red-cockaded woodpecker
Tyrannidae	
Tyrannus tyrannus	eastern kingbird
Tyrannus verticalis	western kingbird
Muscivora forficata	scissor-tailed flycatcher
Myiarchus crinitus	great creasted flycatcher
Sayornis phoebe	eastern phoebe
Empidonax flaviventris	yellow-bellied flycatcher
Empidonax virescens	acadian flycatcher
Empidonax traillii	willow flycatcher
Empidonax alnorum	alder flycatcher
Empidonax minimus	least flycatcher
Contopus virens	eastern wood pewee
Nuttallornis borealis	olive-sided flycatcher

Table 11-9. (Continued)

Family Scientific Name	Common name
Alaudidae	
Eremophila alpestris	horned lark
Hirundinidae	
Iridoprocne bicolor	tree swallow
Riparia riparia	bank swallow
Stelgidopteryx ruficollis	rough-winged swallow
Hirundo rustica	barn swallow
Petrochelidon pyrrhonota	cliff swallow
Progne subis	purple martin
Corvidae	
Cyanocitta cristata	blue jay
Corvus brachyrhynchos	common 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
Certhidae	
Certhia familiaris	brown creeper
Troglodytidae	
Troglodytes aedon	house wren
Troglodytes troglodytes	winter wren
Thryomanes bewickii	Bewick's wren
Thryothorus ludovicianus	carolina wren
Telmatodytes palustris	long-billed marsh wren
Cistothorus platensis	short-billed marsh wren
Mimidae	
Mimus polyglottos	mocking bird
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 caerula	blue-gray gnatcatcher
Regulus satrapa	golden-crowned kinglet
Regulus calendula	ruby-crowned kinglet
Motacillidae	
Anthus spinoletta	water pipit

Table 11-9. (Continued)

Family Scientific Name	Common name
Anthus spragueii	Sprague's pipit
Bombycillidae	
Bombycilla cedrorum	cedar waxwing
Laniidae	
Lanius ludovicianus	loggerhead shrike
Sturnidae	
Sturnus vulgaris	starling
Vireonidae	
Vireo griseus	white-eyed vireo
Vireo bellii	Bell's 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
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 kirtlandii	Kirtland's warbler
Dendroica discolor	prairie warbler
Dendroica palmarum	palm warbler
Seiurus aurocapillus	ovenbird
Seiurus noveboracensis	northern waterthrush
Seiurus motacilla	Louisiana waterthrush
Oporornis formosus	Kentucky warbler
Oporornis agilis	Connecticut warbler
Oporornis philadelphia	mourning warbler
Geothypis trichas	common yellowthroat
Icteria virens	yellow-breasted chat

Table 11-9. (Continued)

Family	Scientific Name	Common name
	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 meadowlark
	Sturnella neglecta	western meadowlark
	Agelaius phoeniceus	red-winged blackbird
	Icterus spurius	orchard oriole
	Icterus galbula	northern oriole
	Euphagus carolinus	rusty blackbird
	Euphagus cyanocephalus	Brewer's blackbird
	Quiscalus quiscula	common crackle
	Molothrus ater	brown-headed cowbird
Thraupinae		
	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
	Hesperiphona vespertina	evening grosbeak
	Carpodacus purpureus	purple finch
	Spinus pinus	pink siskin
	Spinus tristis	american goldfinch
	Loxia curvirostra	red crossbill
	Piplio erythrophthalmus	rufous-sided towhee
	Passerculus sandwichensis	Savannah sparrow
	Ammondramus savannarum	grasshopper sparrow
	Ammondramus henslowii	Henslow's sparrow
	Ammospiza leconteii	Le Conte's sparrow
	Ammospiza caudacuta	sharp-tailed sparrow
	Pooecetes gramineus	vesper sparrow
	Aimophila aestivalis	Bachman's sparrow
	Junco hyemalis	dark-eyed junco
	Spizella passerina	chipping sparrow
	Spizella pallida	clay-colored sparrow
	Spizella pusilla	field sparrow
	Zonotrichia querula	Harris' sparrow
	Zonotrichia leucophrys	white-crowned sparrow
	Zonotrichia albicollis	white-throated sparrow
	Passerella iliaca	fox sparrow
	Melospiza lincolnii	Lincoln's sparrow
	Melospiza georgiana	swamp sparrow
	Melsopiza melodi	song sparrow

Table 11-9. (Continued)

Family Scientific Name	Common name
Calcarius lapponicus	lapland longspur
Calcarius pictus	Smith's longspur
AMPHIBIANS	
Bufonidae	
Bufo americanus americanus	american toad
Bufo quercicus	oak toad
Bufo terrestris	southern toad
Bufo woodhousei	Fowler's toad
Hylidae	
Acris crepitans crepitans	northern cricket frog
Acris gryllus gryllus	southern cricket frog
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 treefrog
Pseudacris brachyphona	mountain chorus frog
Pseudacris triseriata feriarum	upland chorus frog
Microrhylidae	
Gastrophyryne carolinensis	eastern narrow-mouthed toad
Pelobatidae	
Scaphiopus holbrooki holbrooki	eastern spadefoot toad
Ranidae	
Rana areolata sevosa	dusky gopher frog
Rana catesbeiana	bullfrog
Rana clamitans melaneta	green frog
Rana palustris	pickerel frog
Rana pipiens sphenocephala	southern leopard frog
Ambystomatidae	
Ambystoma maculatum	spotted salamander
Ambystoma opacum	marbled salamander
Ambystoma talpoideum	mole salamander
Ambystoma tigrinum tigrinum	eastern tiger salamander
Cryptobranchidae	
Cryptobranchus alleganiensis	hellbender
Plethodontidae	
Aneides aeneus	green salamander
Desmognathus aeneus	seepage salamander
Desmognathus fuscus fuscus	northern dusky salamander
Desmognathus monticola spp.	seal salamander
Desmognathus ochrohaeus	mountain dusky salamander
Eurycea aquatica	brown-backed salamander
Eurycea bislineata	two-lined salamander
Eurycea longicauda longicauda	long-tailed salamander
Eurycea longicauda guttolineata	three-lined salamander

Table 11-9. (Continued)

Family	Scientific Name	Common name
	Eurycea lucifuga	cave salamander
	Gryinophilus palleucus palleucus	Tennessee cave salamander
	Gryinophilus palleucus necturoides	no common name
	Gryinophilus porphyriticus porphyriticus	northern spring salamander
	Gryinophilus porphyriticus dunni	carolina spring salamander
	Gryinophilus porphyriticus duryi	Kentucky spring salamander
	Hemidactylium scutatum	four-toed salamander
	Plethodon dorsalis dorsalis	zigzag salamander
	Plethodon glutinosus glutinosus	slimy salamander
	Pseudotriton montanus flavissumus	gulf coast mud salamander
	Pseudotriton ruber ruber	northern red salamander
Proteidae		
	Necturus beyeri	Beyer's waterdog
	Necturus maculosus	mudpuppy
Salamandridae		
	Notopthalmus viridescens viridenscens	red-spotted newt
REPTILES		
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
	Sceloporus undulatus hyacinthus	northern 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
	Spincella laterale	ground skink
Teidae		
	Cnemidophorus sexlineatus sexlineatus	eastern six-lined racerunner
Colubridae		
	Carphophis amoenus amoenus	eastern worm snake
	Cemophora coccinea copei	northern scarlet snake
	Coluber constrictor constrictor	northern black racer
	Diadophis punctatus punctatus	southern ringneck snake
	Diadophis punctatus edwardsi	northern ringneck snake
	Diadophis punctatus stictogenys	Mississippi ringneck snake
	Elaphe guttata guttata	corn snake
	Elaphe obsoleta obsoleta	black rat snake
	Elaphe obsoleta spiloides	gray rat snake
	Farancia abacura reinwardti	western mud snake
	Heterodon platyrhinos	eastern hognose snake
	Heterodon simus	southern hognose snake

Table 11-9. (Continued)

Family Scientific Name	Common name
Lampropeltis calligaster rhombomaculata	mole snake
Lampropeltis getulus niger	black kingsnake
Lampropeltis triangulum triangulum	eastern milksnake
Lampropeltis triangulum elapsoides	scarlet kingsnake
Lampropeltis triangulum syspila	red milk snake
Masticophis flagellum flagellum	eastern coachwhip
Nerodia erythrogaster erythrogaster	red-bellied water snake
Nerodia erythrogaster flavigaster	yellow-bellied water snake
Nerodia septemvittata	queen snake
Nerodia sipedon pleuralis	midland water snake
Opheodrys aestivus	rough green snake
Pituophis melanoleucus melanoleucus	northern pine snake
Storeria dekayi dekayi	northern brown snake
Storeria wrightorum	midland brown snake
Storeria occipitomaculata occipitomaculata	northern red-bellied snake
Tantilla coronata	southeastern crowned snake
Thamnophis sauritus sauritus	eastern ribbon snake
Thamnophis sauritus sirtalis	eastern garter snake
Virginia striatula	rough earth snake
Virginia valeriae valeriae	eastern smooth earth snake
Elapidae	
Micrurus fulvius fulvius	eastern coral snake
Viperidae	
Agkistrodon contortrix mokeson	northern copperhead
Agkistrodon piscivorus piscivorus	eastern cottonmouth
Crotalus horridus	timber rattlesnake
Sistrurus miliarius miliarius	carolina pigmy rattlesnake
Chelydridae	
Chelydra serpentina serpentina	common snapping turtle
Macroclemys temmincki	alligator snapping turtle
Emydidae	
Chrysemys picta marginata	midland painted turtle
Deirochelys reticularia reticularis	eastern chicken turtle
Graptemys geographica	map turtle
Graptemys nigrinoda nigrinoda	northern black-knobbed sawback
Graptemys pseudogeographica ouachitensis	ouachita map turtle
Graptemys pulchra	Alabama map turtle
Pseudemys concinna concinna	river cooter
Pseudemys scripta elegans	red-eared pond slider
Terrapene carolina carolina	eastern box turtle
Terrapene carolina triungis	three-toed box turtle
Kinosternidae	
Kinosternon subrubrum subrubrum	eastern mud turtle
Sternotherus minor depressus	flattened mud turtle
Sternotherus minor peltifer	stripe-necked musk turtle
Sternotherus odoratus	common musk turtle
Trionychidae	
Trionyx muticus muticus	midland smooth softshell
Trionyx spiniferus spiniferus	eastern spiny softshell
Trionyx spiniferus asper	gulf coast spiny softshell

PART II. FEASIBILITY STUDY

LAKE RESTORATION ALTERNATIVES

PROBLEM: Cultural Eutrophication

PRIMARY CAUSES:

Municipal and industrial point source dischargers

Elevated fertility of upstream Weiss Lake

Nonpoint source discharge of nutrients

This study, as well as others, has documented the cultural eutrophication of Lake Neely Henry that has occurred as a result of excessive nutrient enrichment of lake waters. Since records have been kept, Lake Henry has consistently ranked among the highest lakes in the state in terms of trophic status (ADEM 1994). The elevated trophic status of this lake is caused, in part, by the natural fertility of the Coosa River which drains portions of the Valley and Ridge Physiographic Province. Limestone valleys of this region yield waters high in dissolved solids as is evidenced by specific conductance and total alkalinity levels that are among the highest measured in Alabama rivers. The cultural eutrophication problem of Lake Henry, however, is the result of human population growth and development in the Coosa River basin all the way to its headwater in northwest Georgia. Point and nonpoint sources of pollution have increased through the years resulting in increased nutrient loading to the lake. Traditionally regulatory agencies in both Alabama and Georgia have addressed the eutrophication problem by controlling, through permitting, the organic matter (BOD) content of treated wastewater. Treatment to reduce organic matter content of wastewater removes a relatively small portion of the plant nutrients present in the effluent. These nutrients stimulate plant (usually plankton algae) growth in the receiving waters that, in turn, exerts an oxygen demand on the system. Excessive nutrient loading can be as damaging to an aquatic system as excessive organic matter loading. At present on the Coosa River NPDES permits issued by the Alabama and Georgia agencies require no limits on amounts of total phosphorus (TP) or total nitrogen (TN) that can be released. In addition, there are currently no requirements for permitted dischargers to monitor and report nutrient concentrations in their effluent on a regular (e.g. monthly) basis.

Weiss Lake just upstream from Lake Henry on the Coosa River is also highly eutrophic and suffers from nutrient pollution (Bayne *et al.* 1993b). Therefore, the headwaters of Lake Henry contain seasonal mean TP concentrations that always exceed and sometimes more than double the maximum amount of TP (50 μg/l) recommended by EPA for streams entering lakes. As high as these headwater concentrations are, they are among the lowest for the entire lake because of the point and nonpoint source pollution entering the lake downstream from Gadsden, Alabama (Figure 10-5). TN concentrations were also high (Figure 10-20), comparable to those measured in Weiss Lake, but because of the excessive amount of TP, algal growth in Lake Henry was nitrogen limited. Additional sources of bioavailable nitrogen could cause dramatic increases in algal biomass in the lake as was indicated by the Algal Growth Potential Test results. But since nitrogen control is generally considered impractical in combatting eutrophication (EPA 1990), reduction of TP loading will have to be undertaken in order to force the lake into phosphorus limitation and make it possible to control, through phosphorus manipulation, the trophic status of the lake.

An increase in plankton algae biomass has been the predominant manifestation of nutrient enrichment of Lake Henry. In August 1989 corrected chlorophyll a concentration in the dam forebay was 21.0 μg/l (Bayne *et al.* 1989). In August 1993 and 1994 at that location chlorophyll a concentrations were 22.6 μg/l and 23.1 μg/l, respectively. The highest mainstem chlorophyll a concentration measured during this study was 31.9 μg/l at station 2 during September 1993. Growing season (April - October) mean chlorophyll a concentrations in the dam forebay (station 1) were 19.2 μg/l and 16.6 μg/l for 1993 and 1994, respectively. At a mid-reservoir location (station 7) the growing season mean chlorophyll a concentrations were 17.8 μg/l and 14.8 μg/l for 1993 and 1994, respectively. The higher concentrations measured in 1993 were likely caused by below normal rainfall which decreased discharge through the dam (Table 10-4) decreased abiogenic turbidity (Tables 10-8, 10-9 and 10-10) and increased hydraulic retention time. Alabama reservoirs with retention times of less than 30 days (Lake Henry retention is 5.8 days) responded with increased chlorophyll a concentrations as retention times increased (Bayne *et al.* 1994c). The effects of cultural eutrophication in Lake Henry can be expected to worsen during periods of low discharge related to natural meteorological conditions or perhaps to increased upstream water demand.

Recreational users, particularly skiers and swimmers, prefer clearer waters for aesthetic and safety reasons. A Secchi disk visibility of 1.2 m (4 feet) or greater is recommended for swimming waters to allow sufficient visibility for rescue of a submerged drowning victim (National Academy of Sciences 1973). During the growing season, an increase in water clarity would require a decrease in plankton algae abundance. These algae are the primary producers of food for other aquatic organisms living in the lake and some anglers believe the more food available to the fish the better the fishing. Fishery scientists have expressed concern that improvements in lake water quality (i.e., reduced phosphorus, reduced algae and increased water clarity) will result in an unacceptable decline in the quality of the sport and commercial fisheries (Yurk and Ney 1989). While it is clear that oligotrophic lakes will not support as large a fish biomass as eutrophic lakes, recent studies conducted at Auburn University suggest that an increase in algal biomass beyond certain limits does not enhance sport fishing (Bayne *et al.* 1994c). Their study of four mainstem reservoirs spanning the trophic range of Alabama lakes revealed that increases in phytoplankton chlorophyll a (uncorrected for phaeopigments) concentrations in excess of 10 to 15 μg/l did not improve sportfish (primarily black bass and crappie) growth and abundance or the quality of the fishery. It appears, therefore, that improvement of water quality from near hypereutrophic condition to a moderately eutrophic state would not adversely affect the sport fishery in Lake Henry.

Increased organic matter content in surface waters can cause problems in potable water supply lakes. Chlorination of the water during the treatment process forms organohalides called trihalomethanes (THM's) that threaten human health (Cooke *et al.* 1986). Four organic compounds comprise THM's: trichloromethane (chloroform), bromodichloromethane, dibromochloromethane and tribromomethand (bromoform). These compounds are known or suspected of being carcinogenic and/or mutagenic agents and the U.S. Environmental Protection Agency has established a maximum contaminant level of 100 μg/l in finished drinking water (Vogt and Regli 1981). Increasing THM levels in drinking water supplies across the country have raised concern about sources and control of organic THM precursor molecules entering treatment plants (EPA 1990). Although watershed sources, like marshes, are known to be important sources of organic precursors, within-lake production of organic matter by algae and higher plants also contributes. Palmstrom *et al.* (1988) demonstrated that 30% of the precursors entering a treatment plant withdrawing water from an Ohio water supply reservoir was generated within the lake, primarily by algae. Proliferation of algae in potable water supply lakes can also cause taste and odor problems in finished drinking water.

Lake Henry is use-classified as Fish and Wildlife (F&W) throughout, with the exception of a portion of Black Creek lying between Highway 431 and Lake Gadsden that is classified as Agricultural and Industrial Water Supply. The upper reach of Lake Henry from the Weiss Dam Powerhouse downstream to the Gadsden Water Supply Intake is classified as Public Water Supply/F&W. The lower reach of the lake from the dam upstream to McCardney's Ferry (3 miles upstream of Big Canoe Creek) was classified Swimming/F&W (ADEM 1990). In the Water Quality Report to Congress covering the calendar years 1992 and 1993, ADEM (1994) found that Lake Henry only partially supported its Fish and Wildlife use classification because of chronic dissolved oxygen deficiencies. In addition, nutrient loading and elevated trophic status of the lake was reported to be threatening the water supply and recreational uses of the lake.

RECOMMENDATIONS

Any steps taken to address the problem of cultural eutrophication of Lake Henry must include a consideration of all upstream portions of the Coosa River basin. This will involve upstream Lake Weiss as well as portions of the Coosa River basin in Georgia. A basinwide integrated approach, featuring maximum cooperation between the two states will be required to efficiently and economically deal with this problem. A Phase I report on Lake Weiss is nearing completion (Bayne *et al.* 1993b).

The following steps are recommended to assure that cultural eutrophication of Lake Henry is addressed and that lake waters will be safe and suitable for multiple uses.

1. Major point source dischargers (>0.5 MGD) into the Coosa River basin upstream of Lake Henry dam (Alabama and Georgia) should be requested to

measure TP and TN in their effluent and report these findings in monthly discharge monitoring reports. Should this result in inaction, monitoring for TP and TN should be included as a condition of discharge through the National Pollutant Discharge Elimination System (NPDES).

NOTE. This information will make it possible to identify significant point sources of plant nutrients entering the Coosa River. In addition, by subtracting point source nutrient loading from total nutrient loading (measured directly) it is possible to estimate nonpoint source loading. Once the sources of nutrients are known, actions can be taken to control nutrient additions to the system if necessary.

2. Chlorophyll a should be added to the list of water quality criteria used to protect, maintain and improve the quality of Lake Henry. Mean, photic zone chlorophyll a (corrected for phaeopigments) concentrations measured monthly during the growing season (April through October) in the dam forebay and at mid-reservoir (station 7 - Whorton Bend) should not exceed 16 μg/l at either location. This criterion will be subject to the general conditions applicable to all water quality criteria as stated in section 335-6-10-.05 of the Alabama Water Quality Criteria (ADEM 1990).

NOTE. Excessive chlorophyll a concentrations can be reduced by controlling nutrient additions through permitting (point sources) or use of best management practices (nonpoint sources). The following water quality improvements should result from this chlorophyll limit:

- greater water clarity;
- reduced oxygen demand caused by overproliferation and decomposition of organic matter (plankton algae);
- higher minimum and lower maximum pH;

- reduced probability that trihalomethane precursors will result from excessive phytoplankton blooms and
- reduced probability of taste and odor problems developing in potable water supplies taken from the lake.

A chlorophyll a concentration of 16 μg/l during the growing season should be more than adequate to support a productive lake fishery.

PROBLEM: Toxic Contamination

PRIMARY CAUSES:

Persistent PCB residues originating from a General Electric transformer plant located near Rome, Georgia.

Release of toxic substances from Gulf States Steel, Inc. (GSS) near Gadsden, Alabama.

Excessive PCB concentrations in Coosa River fish were first reported by the Alabama Pesticide Laboratory (1971) in 1971. In 1976, the Georgia Environmental Protection Division reported high concentrations of PCB's in fish collected on the Coosa River between Rome, Georgia and the Georgia/Alabama state line. In 1979, the EPA banned the manufacture, processing, distribution and use of PCB's with the exception of that material existing in enclosed electrical equipment (Laws 1993). Environmental PCB concentrations have decreased since the EPA ban went into effect, however, the stability of PCB's (50-300 times more persistent than DDT) will prolong the period of concern for these contaminants (Laws 1993). A limited fish consumption advisory issued by the State Health Officer in 1989 is currently in effect for Lake Henry.

Station 16 was located in Lake Gadsden near the mouth of Black Creek (Figure 10-1) downstream from the discharge and runoff from GSS. This station consistently had the lowest seasonal mean dissolved oxygen and highest temperature of all locations sampled. Waters at this station had the highest total nitrogen (usually high ammonia and total kjeldahl nitrogen) and highest or second highest seasonal mean total phosphorus concentrations measured at any location. An EPA (1993) study also reported depressed dissolved oxygen and elevated water temperature and nutrient concentration. In addition, the EPA study documented the presence of potentially toxic levels of organic compounds and metals in both water and sediment. Macroinvertebrate and fish data revealed a severely stressed aquatic fauna in the Black Creek reach downstream from the GSS discharge. Fish Health Assessment Indicies reflected the poorest fish condition ever measured by TVA biologists. In October 1993, an estimated 43,000 fish were killed in a 3.0 mile (4.8 km) reach of Black Creek (ADEM 1994). GSS agreed to pay the state government $500,000 to settle claims related to the fish kill but did not admit any responsibility (F. R. Harders, Alabama Game and Fish).

RECOMMENDATIONS

1. Annual monitoring of Lake Henry fish for the presence of PCB's should be continued to document any changes in residue levels. This sampling should include fish captured from the lake by state biologists as well as commercially caught fish from the lake that enter markets for sale to the public. Less frequent sampling can be conducted when PCB residue levels decline below FDA tolerance limits in fish for three consecutive years.
2. The portion of Black Creek downstream of the Gulf States Steel facility was documented to be in a degraded condition as a result of point and non-point source discharges, not even meeting the minimal water quality criteria of the Agricultural and Industrial Water Supply use classification. Gulf

States Steel chronically fails to comply with NPDES permit limitations and as a result is subject to regulatory enforcement action. The segment is listed on Alabama's 1996 Draft 303(d) List of impaired waters. Section 303(d) of the Clean Water Act requires the State to develop Total Maximum Daily Load (TMDL) estimates for the pollutants of concern. After the TMDL has been determined and the necessary corrective actions have been implemented, continued monitoring will be necessary to document improvements in water quality in Black Creek. The additional monitoring data will also be useful in future use attainability analyses. The goal of the ADEM should be the upgrade of the segment to the Fish and Wildlife use classification so that Lake Neely Henry, in its entirety, could be expected to support multiple uses.

PHASE II MONITORING PROGRAM

Lake Henry should be monitored annually during the growing season (April through October) to assure that water quality standards (including the new chlorophyll a standard) are being met. Sampling should be conducted monthly in the dam forebay, at Whorton bend, in the mouths of Black Creek, Big Wills Creek and under the Highway 411 bridge at the junction of Lakes Gadsden and Lake Henry. At each location water column profile measurements of temperature, dissolved oxygen, pH and conductivity should be made. A photic zone composite sample should be collected at each location for the measurement of turbidity and chlorophyll a (corrected for phaeopigments). A surface water sample should be collected for determination of fecal coliform organism density. In May, July and September, composite water samples from the two mainstem sampling locations should be collected for Algal Growth Potential Tests.

Lake Henry fish should be tested for PCB residues annually. Fish collected from the lake using electrofishing techniques as well as fish collected in markets or from commercial fisherman should be analyzed. Findings should be reported to the Alabama Department of Public Health. Annual sampling of water and sediment from the reach of Black Creek downstream from GSS should be conducted. These samples should be analyzed for the presence of toxic organic compounds and heavy metals.

ENVIRONMENTAL EVALUATION

The following questions and answers pertain to suggested restoration activities to address water quality problems identified in the Phase I Diagnostic/Feasibility Study of Lake Henry.

1. Will the proposed projects displace any people? NO
2. Will the proposed projects deface existing residences or residential areas? NO
3. Will the proposed projects be likely to lead to a change in established land use patterns such as increased development pressure near the lake? NO
4. Will the proposed projects adversely affect a significant amount of prime agricultural land or agricultural operations on such land? NO
5. Will the proposed projects result in a significant adverse effect on parkland, other public land or lands of recognized scenic value? NO
6. Will the proposed projects result in a significant adverse effect on lands or structures of historic, architectural, archaeological or cultural value? NO

7. Will the proposed projects lead to a significant long-range increase in energy demands? NO

8. Will the proposed projects result in significant and long range adverse changes in ambient air quality or noise levels? NO

9. Do the proposed projects involve use of in-lake chemical treatment? NO

10. Will the proposed projects involve construction of structures in a floodplain? YES

11. Will dredging be employed as part of the restoration procedures, and if so, where will the dredge material be deposited? NO

12. Will the proposed projects have a significant adverse effect on fish and wildlife, or on wetlands or any other wildlife habitat, especially those of endangered species? NO

13. Are there additional feasible alternatives to the proposed restoration projects, and why were they not chosen? The recommended changes in regulatory data collection, lake water quality standards and use-classification of Black Creek will necessitate numerous restoration activities by municipalities, industries and nonpoint source polluters. Feasible alternatives for restoration will be evaluated on a case by case basis.

14. Are there additional adverse environmental impacts from the proposed restoration projects that were not addressed in the previous questions? NO

Literature Cited

ADEM. 1990. Water quality criteria. Water Quality Program - Water Division Chapter 335-6-10. Alabama Department of Environmental Management. 41 pp.

ADEM. 1992a. Water quality report to congress for calendar years 1990 and 1991. Alabama Department of Environmental Management, Montgomery, Alabama.

ADEM. 1992b. Lake Neely Henry dissolved oxygen study, July, September 1991. Alabama Department of Environmental Management, Montgomery, Alabama.

ADEM. 1992c. Neely Henry Reservoir dissolved oxygen study 1992. Alabama Department of Environmental Management, Montgomery, Alabama.

ADEM. 1992d. Alabama Clean Water Strategy-Water Quality Assessment Report. Alabama Department of Environmental Management. Montgomery, Alabama.

ADEM. 1994. Water quality report to congress for calendar years 1992 and 1993. Alabama Department of Environmental Management, Montgomery, Alabama.

ADPH. 1989. News Releases-Health Advisory. Alabama Department of Public Health. Montgomery, Alabama.

Alabama Pesticide Laboratory. 1971. Pesticide residue content (including PCB) of fish, water and sediment collected in 1971 from aquatic sites in Alabama. Alabama Department of Agriculture and Industries, Montgomery, Alabama.

Alabama Water Improvement Advisory Commission. 1949. Studies of pollution in streams of Alabama. Alabama Water Improvement Commission, Montgomery, Alabama.

American Public Health Association, American Water Works Association and Water Pollution Control Federation. 1992. Standard methods for the examination of water and wastewater. 18th ed. Washington, D.C. 1268 pp.

Bayne, D. R., W. C. Seesock and L. D. Benefield. 1989. Water quality assessment Alabama public lakes 1989. Alabama Department of Environmental Management. Montgomery, Alabama. 178 pp.

Bayne, D. R., W. C. Seesock, E. C. Webber and J. A. McGuire. 1990. Cultural eutrophication of West Point Lake - a 10-year study. Hydrobiologia 199:143-156.

Bayne, D. R. and M. J. Maceina. 1992. Investigations of management techniques for public fishing lakes, Study XII Key limnological factors related to fish management in large impoundments. Job Performance Report. Project F-40. Alabama Department of Conservation and Natural Resources. Montgomery, Alabama.

Bayne, D. R., E. M. Reutebuch, W. C. Seesock and P. P. Emmerth. 1993a. Limnological study of Lay Lake. Kimberly-Clark Corporation, Childersburg, Alabama.

Bayne, D. R., W. C. Seesock, P. P. Emmerth, E. Reutebuch and F. Leslie. 1993b. Weiss Lake Phase I, Diagnostic/Feasibility Study, Draft Report. Alabama Department of Environmental Management, Montgomery, Alabama.

Bayne, D. R., P. Bush, V. Blazer, W. C. Seesock, P. P. Emmerth, E. Reutebuch and F. Leslie. 1994a. West Point Lake Phase I Diagnostic/Feasibility Study. Final Report. Alabama Department of Environmental Management, Montgomery, Alabama.

Bayne, D. R., W. C. Seesock, A. Watson and E. Reutebuch. 1994b. Lake Neely Henry water quality and primary productivity data. Electronic data set. Alabama Department of Environmental Management, Montgomery, Alabama.

Bayne, D. R., M. J. Maceina and W. C. Reeves. 1994c. Zooplankton, fish and sport fishing quality among four Alabama and Georgia reservoirs of varying trophic status. Lake and Reservoir Management 8(2):153-163.

Boyd, C. E. 1979. Water quality in warmwater fish ponds. Auburn University Agricultural Experiment Station, Auburn, Alabama. 359 pp.

Carlson, R. E. 1977. A trophic state index. Limnology and Oceanography 22(2):361-369.

Catchings, E. D. and S. M. Smith. 1994. Neely Henry Reservoir Managment Report (Draft). Alabama Department of Conservation and Natural Resources, Fisheries Section. Montgomery, Alabama. 11 pp.

Cooke, R. E., E. B. Welch, S. A. Peterson and P. R. Newroth. 1986. Lake and reservoir restoration. Butterworths, Boston, Massachusetts. 392 pp.

DNR. 1976. News Release. Georgia Department of Natural Resources. Atlanta, Georgia.

EPA. 1986. Quality criteria for water 1986. Office of Water Regulations and Standards. U.S. Environmental Protection Agency. Washington, D.C.

EPA. 1990. The lake and reservoir restoration guidance manual, 2nd edition. EPA-440/4-90-006. U.S. Environmental Protection Agency. Washington, D.C.

EPA. 1993. Ecological assessment Black Creek Gadsden, Alabama, August-September, 1993. Ecological Support Branch, Environmental Services Division, U.S. Environmental Protection Agency, Region IV, Athens, GA.

EPD. 1991. Water quality in Georgia, 1990-1991. Georgia Department of Natural Resources, Environmental Protection Division. Atlanta, Georgia. 69 pp.

EPD. 1993. Lake assessment project fish tissue results, March 1993. Environmental Protection Division, Georgia Department of Natural Resources, Atlanta, Georgia.

Floyd, K. B. and E. D. Catchings. 1988. Neely Henry Reservoir Management Report. Alabama Department of Conservation and Natural Resources, Fisheries Section. Montgomery, Alabama. 14 pp.

Fogg, G. E. 1965. Algal cultures and phytoplankton ecology. University of Wisconsin Press, Madison, Wisconsin. 126 pp.

Hern, S. C., V. W. Lambou, L. R. Williams and W. D. Taylor. 1981. Modifications of models predicting trophic state of lakes. Project summary. EPA-600/3-81-001. Environmental Monitoring Systems Laboratory, U.S. Environmental Protection Agency, Las Vegas, Nevada.

Lambou, V. W., W. D. Taylor, L. R. Williams and S. C. Hern. 1981. Relationship of common phytoplankton genera to nutrients in eastern and southeastern lakes. Pages 328-364 in M. W. Lorenzen, (ed.). Phytoplankton-environmental interactions in reservoirs. Technical Report E-81-13. Office, Chief Engineers, U.S. Army, Washington, D.C.

Lawrence, J. M. 1970. Fertility and aquatic biomass in southeastern impoundments. Pages 115-126 in W. G. Weist and P. E. Greeson (eds.) Hydrobiology: Bioresources of shallow water environments. American Water Resources Association, Urbana, Illinois.

Lawrence, J. M., P. B. Wyatt, W. T. Dumas, J. Moss and J. Denton. 1972. Report on heavy metal content of fish, water and sediments collected in 1971 from selected aquatic sites in Alabama. Fisheries Division, Alabama Department of Conservation and Natural Resources.

Laws, E. A. 1993. Aquatic pollution. An introductory text, 2nd ed. John Wiley & Sons, Inc. New York, New York. 611 pp.

Lind, O. T. 1985. Handbook of common methods in limnology. 2nd Ed. Kendall/Hunt Publishing Co., Dubuque, Iowa. 199 pp.

Lineback, N. G. (ed). 1973. Atlas of Alabama. University of Alabama Press, University, Alabama. 138 pp.

McHugh, J. J. and W. C. Reeves. 1993. Bass anglers information team. Annual Report. Alabama Department of Conservation and Natural Resources, Fisheries Section. Montgomery, Alabama.

McHugh, J. J. and W. C. Reeves. 1994. Bass anglers information team. Annual Report. Alabama Department of Conservation and Natural Resources, Fisheries Section. Montgomery, Alabama.

Palmer, C. M. 1969. A composite rating of algae tolerating organic pollution. Journal of Phycology 5:78-82.

Palmstrom, N. S., R. E. Carlson and G. D. Cooke. 1988. Potential links between eutrophication and the formation of carcinogens in drinking water. Lake and Reservoir Management 4(2):1-15.

Porcella, D. B. and M. L. Cleave. 1981. The use of bioassay approaches for assessing phytoplankton growth in lakes and reservoirs. Pages 276-314 in M. W. Lorenzen, (ed.). Phytoplankton-environmental interactions in reservoirs. Technical report E-81-13. Office, Chief of Engineers, U.S. Army, Washington, D.C.

Raschke, R. L. 1985. Alabama lakes--trophic classification. Ecological Support Branch, Environmental Services Division, U.S. Environmental Protection Agency, Athens, Georgia. 23 pp.

Raschke, R. L. and D. A. Schultz. 1987. The use of algal growth potential test for data assessment. Journal Water Pollution Control Federation 59(4):222-227.

Reeves, W. C. and J. J. McHugh. 1993. B.A.I.T. bass anglers information team 1993 annual report. Alabama Department of Conservation and Natural Resources, Fisheries Section, Montgomery, Alabama. 13 pp.

Reeves, W. C. and J. J. McHugh. 1994. B.A.I.T. bass anglers information team 1994 annual report. Alabama Department of Conservation and Natural Resources, Fisheries Section, Montgomery, Alabama. 13 pp.

Smith, S. M. 1994. Investigation of a fish kill in Black Creek, a tributary to the Coosa River in Etowah County from November 3-5, 1993. Alabama Department of Conservation and Natural Resources, Fisheries Section, Montgomery, Alabama. 12 pp.

Taylor, M. P. 1971. Norris Reservoir fertilizer study. II. Effects of thermal stratification and nutrient availability on the productivity of reservoir phytoplankton. Journal of Tennessee Academy of Science 46:90-97.

Taylor, W. D., S. C. Hern, L. R. Williams, V. W. Lambou, M. K. Morris and F. A. Morris. 1979. Phytoplankton water quality relationships in U.S. lakes Part IV: The common phytoplankton genera from eastern and southeastern lakes. Working paper No. 710. Office of Research and Development. U.S. Environmental Protection Agency. Washington, D.C. 81 pp.

Thornton, K. W., B. L. Kimmel and F. E. Payne (eds.). 1990. Reservoir limnology, ecological perspectives. John Wiley and Sons, Inc. New York, New York. 246 pp.

Wetzel, R. G. 1983. Limnology 2nd edition. Saunders College Publishing, Philadelphia, Pennsylvania. 858 pp.

Yurk, J. J. and J. J. Ney. 1989. Phosphorus-fish community biomass relationships in southern Appalachian Reservoirs: can lakes be too clean? Lake and Reservoir Management 5:83-90.