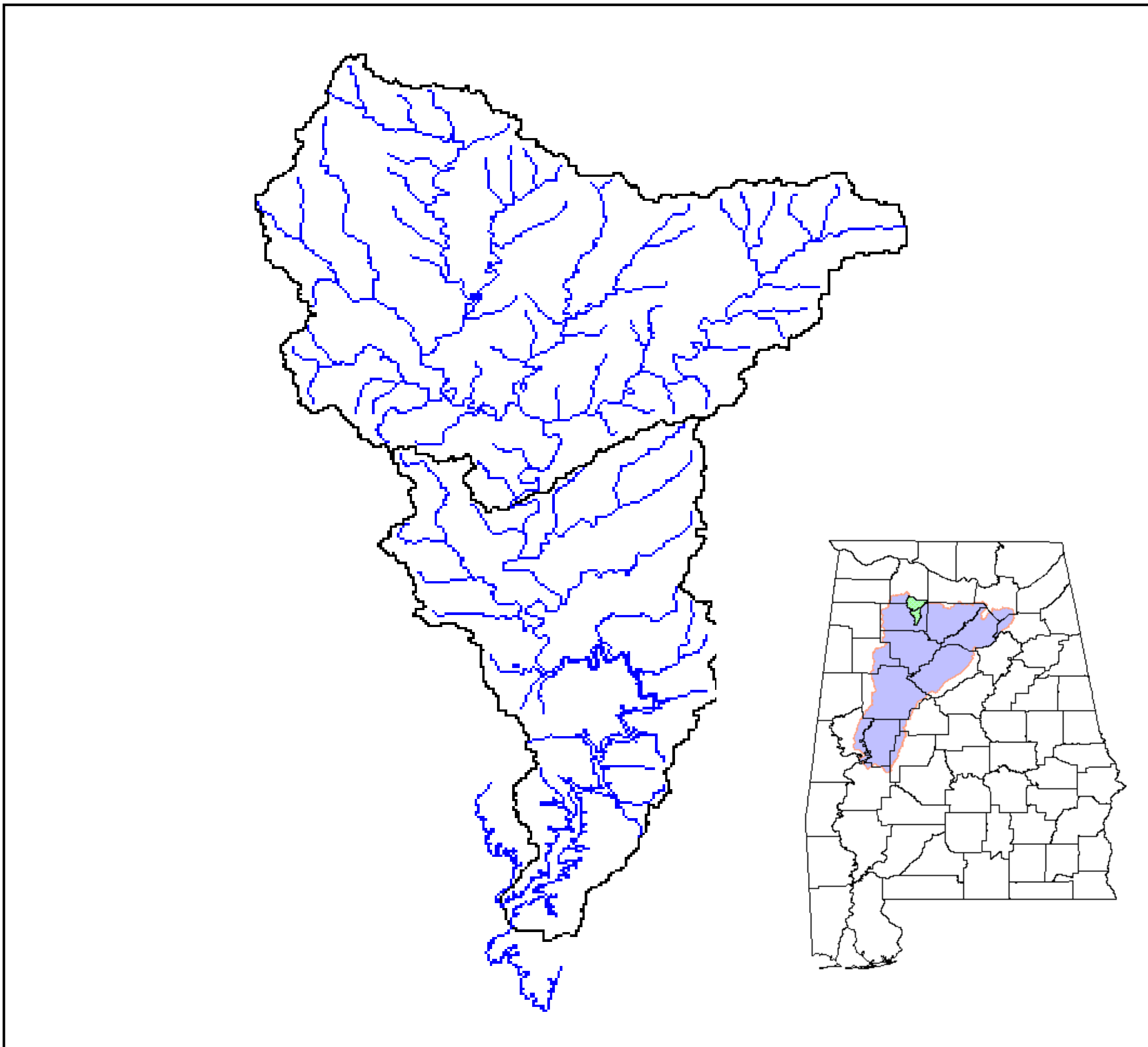
Brushy Creek Watershed Water Quality Assessment Report



Environmental Indicators Section
Field Operations Division
Alabama Department of Environmental Management

Brushy Creek Watershed
Water Quality Assessment
Report

January 14, 1999

Environmental Indicators Section
Field Operations Division
Alabama Department of Environmental Management

Brushy Creek Watershed
Water Quality Assessment

Preface

This project was funded or partially funded by the Alabama Department of Environmental Management utilizing a Clean Water Act Section 319(h) nonpoint source demonstration grant provided by the U.S. Environmental Protection Agency - Region 4.

Comments or questions related to this report should be addressed to:

Alabama Department of Environmental Management
Field Operations Division
Environmental Indicators Section
P.O. Box 301463
Montgomery, AL 36130-1463

Executive Summary

Brushy Creek is located in Lawrence County and Winston County, Alabama and is one of the major tributaries to Lewis Smith Reservoir. The drainage area of Brushy Creek is 227.4 km^2 (87.8 mi^2).

In recent years, concerns have developed among area residents concerning the lack of water quality data from Brushy Creek and it's embayment in Smith Reservoir, which serves as the water supply for the community of Arley, Alabama. Determinations of landuse as well as measurements of water quality and estimates of nutrient loading attempt to address those concerns. Tributary nutrient loading data for other major tributaries to Smith Reservoir was collected for ADEM by Auburn University during the Clean Lakes Program Phase I Diagnostic / Feasibility Study of Smith Reservoir. This report is intended to serve as a companion document to the Phase I study's final report (ADEM 1998).

Much of the Brushy Creek watershed lies within the Bankhead National Forest and is forested with an even mix of deciduous forest, evergreen forest, and mixed forest. Smaller percentages of landuse are comprised of overgrown clearcut areas (transitional barren) and pasture/hay fields with occasional occurrences of poultry and cattle operations. Therefore, silviculture was designated the primary nonpoint source pollutant within the Brushy Creek basin with impairment concentrated within the tributary drainages of Beech and Collier Creeks. Erosion of the gravel roads was also noted within Beech and Upper Brushy Creeks. Although the potential for nonpoint source pollution within the Brushy Creek watershed is high, it was measured to be slight within each of the tributaries.

Stream habitat quality in certain tributaries to Brushy Creek was impaired by sedimentation from nonpoint sources, though no impairment to the macroinvertebrate communities was detected. An assessment of the fish communities at these stations is recommended to further determine impairment to stream biological communities.

Mean annual total phosphorus (TP) concentrations of Brushy Creek were much higher than those of other tributaries to Smith Lake while mean annual TP concentrations

of Capsey Creek, a tributary to Brushy Creek, were similar to those of several other Smith Lake tributaries. Origins of Brushy Creek TP concentrations may be silvicultural and/or the agricultural activities in the watershed. Given their magnitude, the origins of the TP concentrations in Brushy Creek should be the subject of further research. Mean annual TN concentrations for Brushy and Capsey Creeks were lower than those of other tributaries to Smith Lake except Sipsey Fork.

Mean annual total suspended solids (TSS) concentrations of Brushy and Capsey Creeks were lower than those of other tributaries to Smith Lake.

Mean daily discharge from Brushy Creek during the study period was higher than that of all other tributaries measured during the 1995 Phase I Study of Smith Lake. Total loading of TP from Brushy Creek was below that of Rock and Clear Creeks but above that of Ryan Creek, Crooked Creek, and the Sipsey Fork. Total loading of TN from Brushy Creek was lower than that of all other tributaries except Sipsey Fork. Total loading of TSS from Brushy Creek was lower than that of all other tributaries.

Mean water temperature during the spring and summer season was lowest in the upper embayment and increased with each downstream station. Cooler temperatures likely prevail in the upper embayment due to its proximity to flowing water emerging from a heavily forested watershed. As the waters of the lower embayment slow and widen, exposure to solar radiation is greater and water temperatures increase. Thermal stratification developed at all lower embayment stations during the course of the summer season.

Mean spring and summer dissolved oxygen (DO) concentrations varied with each Brushy Creek embayment station. However, DO concentrations at each station were well above the ADEM Water Quality Criteria limit of 5.0 mg/l on all dates sampled. Chemical stratification occurred at all lower embayment stations during the course of the summer season with anoxic conditions developing only at Station 4.

Summer mean chlorophyll a concentrations were higher than spring mean values and with the exception of the uppermost embayment station, all within the eutrophic range.

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 souteastern lakes, with the exception of lakes in Florida (Raschke and Schultz 1987). Mean maximum dry weights above 10.0 mg/l indicate highly productive waters that may be subject to nuisance blooms. Growing season mean dry weights in the Brushy Creek embayment were well below 5.0 mg/l on all dates sampled.

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 the Brushy Creek embayment, phosphorus was the limiting or co-limiting nutrient at all sampling stations on all occasions with the exception of the mid-embayment stations during August. Internal phosphorus loading caused by the release of phosphorus from anaerobic sediments as the growing season progresses may be partly responsible for the increase in the influence of nitrogen later in the growing season.

Fecal coliform bacteria are defined as the bacteria of the coliform group that originate from the intestines of warm-blooded animals and serve as indicators of the presence of human or animal wastes. Fecal coliform density at all embayment stations was well within ADEM Water Quality Criteria limits on all dates sampled.

Table of Contents

List of Tables

List of Tables

List of Figures

Introduction

Brushy Creek is located in Lawrence and Winston County, AL and is one of the major tributaries to Lewis Smith Reservoir. Land use in the area is primarily agricultural and silvicultural. The drainage area of Brushy Creek at the Forest Service Rd. 255 bridge crossing is 227.4 km^2 (87.8 mi^2).

Objectives of the Brushy Creek water quality assessment were:

(a) to assess water quality in the flowing portion of Brushy Creek;

(b) to assess water quality in the nonflowing portion of Brushy Creek in its embayment in Lewis Smith Reservoir; and,

(c) to measure nutrient and sediment loading to Lewis Smith Reservoir from Brushy Creek.

In recent years, concerns have developed among area residents concerning the lack of water quality data from Brushy Creek and it's embayment in Smith Reservoir, which serves as the water supply for the community of Arley, AL (personal communication, Steve Foster, ADEM). Completion of these objectives addresses these concerns and completes tributary nutrient loading data collection for all major tributaries in the watershed of Lewis Smith Reservoir. Tributary nutrient loading data for other major tributaries to Smith Reservoir was collected for ADEM by Auburn University during the Clean Lakes Program Phase I Diagnostic / Feasibility Study of Smith Lake. This report is intended to serve as a companion document to the Lewis Smith Lake Phase I Diagnostic / Feasibility Study Final Report (ADEM 1998).

Lewis Smith Reservoir, the receiving waterbody for Brushy Creek, is an 8,580 hectare (33.11 square miles) impoundment of the Sipsey Fork of the Black Warrior River near Jasper, Alabama. Its watershed is 244, 340 hectares (943.7 square miles) and is located in Winston, Cullman, Walker, Lawrence, and Franklin counties. Impounded portions of the watershed extend into Winston, Walker, and Cullman counties. Considered to have very good water quality for a number of years following its impoundment and popular with the public for many recreational activities, public concern over the effects of nonpoint source (NPS) pollution to the water quality of the Smith Reservoir has increased in recent years. Land-use activities in the watershed having the potential to adversely affect Smith Reservoir and its tributaries include coal surface mining, forestry, agricultural operations, and residential development. The agricultural activities in the watershed include poultry and egg producers, swine producers, dairy and beef cattle producers, and row crop farms (ADEM 1987). A study conducted by Auburn University and the U.S. Soil Conservation Service (SCS) in 1988-1989 documented the impacts of nutrient loading on the water quality and aquatic communities in two Lewis Smith tributaries (Deutsch et al. 1990). Data from these and other ADEM studies (ADEM 1996) indicated that algal growth to Smith Reservoir is highly responsive to nutrient inputs from NPS, especially when rainfall is heavy during the growing season. The watershed's steep topography ensures that NPS runoff enters the lake quickly and the lack of aquatic macrophyte growth ensures that available nutrient input to the reservoir is used in algal production.

Materials and Methods

Landuse Estimates

Two methods were used to evaluate percent landuse within the Upper Brush Creek watershed (03160110030). The Environmental Indicators Section completed a roadside survey of landuse and potential nonpoint source impairments of the Upper Brushy Creek subwatershed March 18-19, 1997. Surveys were concentrated in areas where:

1. previous assessments have not been conducted recently; or,
2. no significant impairment from point sources was known.

It should be noted that concentrating surveys only in areas meeting these criteria will bias estimates of landuse and sources of impairment. Surveys were conducted in areas upstream of assessment stations and are therefore site specific. In addition, certain types of impairment may be concentrated around roads or access points.

In 1997, the US EPA completed an analysis of percent landuse within EPA Region IV. Estimates were based upon data satellite imagery data collected 1988, 1990, 1991, and 1993. This information was used in conjunction with the twelve digit cataloging unit codes by the Water Quality Section of the ADEM Water Division to estimate percent landuse by subwatershed. Percent landuse and nonpoint source impairments within the Sipsey Fork are currently being analyzed by Auburn University.

Watershed reconnaissance routes were designed to cover drainages of major tributaries and road crossings within each sub basin. Routes were plotted out on county maps prior to reconnaissance. Large sub basins were divided into separate reconnaissance areas in order to identify the tributaries where NPS pollutants are prevalent. Percent landuse was evaluated using a datasheet tally system. The prevalence of each landuse was determined by proportion of a mile: (S)mall = 0.1-0.3 mi./mile; (M)edium = 0.3-0.7 mi./mile; (L)arge = >0.7 mi./mile. For each one mile interval, an assessment was made of total contribution of each landuse to the one mile interval. Each side of the road located within the watershed was tallied as a separate mile.

The same tally system was used to evaluate the prevalence of nonpoint source pollutants. In order to assess the density and intensity of possible nonpoint source pollutants, each nonpoint source was tallied separately. Proximity of nonpoint sources to streams was also recorded, as well as presence and type of best management practices within the watershed.

To analyze reconnaissance data, tallies marked on each datasheet were converted into a score. Small, medium, and large sources received scores of three, six, and nine, respectively. Sources noted as adjacent to streams were scored an additional three points. In order to standardize scores across sub basins, scores were converted to score per mile surveyed. These scores were used to calculate percent landuse within each basin.

Nonpoint source impairment scores were also converted into score per mile surveyed. Impairment scores obtained for each category were summed to obtain the total impairment score. In general, scores < 6 indicate a slight potential for nonpoint source impairment to the waterbody; a score between 6 and 9 indicate moderate potential; and a score >9 indicates a high potential for impairment from nonpoint sources.

Sampling Locations

Sampling stations appear in Figure 1. Location data for macroinvertebrate, tributary loading, and embayment stations appears in Table 1 along with station descriptions.

Stream Habitat Assessment and Physical Characterization

Five stations in the Brushy Creek sub-watershed were selected for habitat and aquatic macroinvertebrate assessment. Stations BRUW-14 and BRSH-1 were located on Brushy Creek. Stations CPSY-1, RUSW-1, and BEEW-1 were located on Capsey, Rush, and Beech Creeks, respectively, each of which are tributaries to Brushy Creek.

Three stations (BRUW-14, CPSY-1, and RUSW-1) are characterized by riffle/run geomorphology. Habitat quality at these stations was therefore evaluated using the riffle/run habitat assessment form (Barbour and Stribling 1994). The two remaining

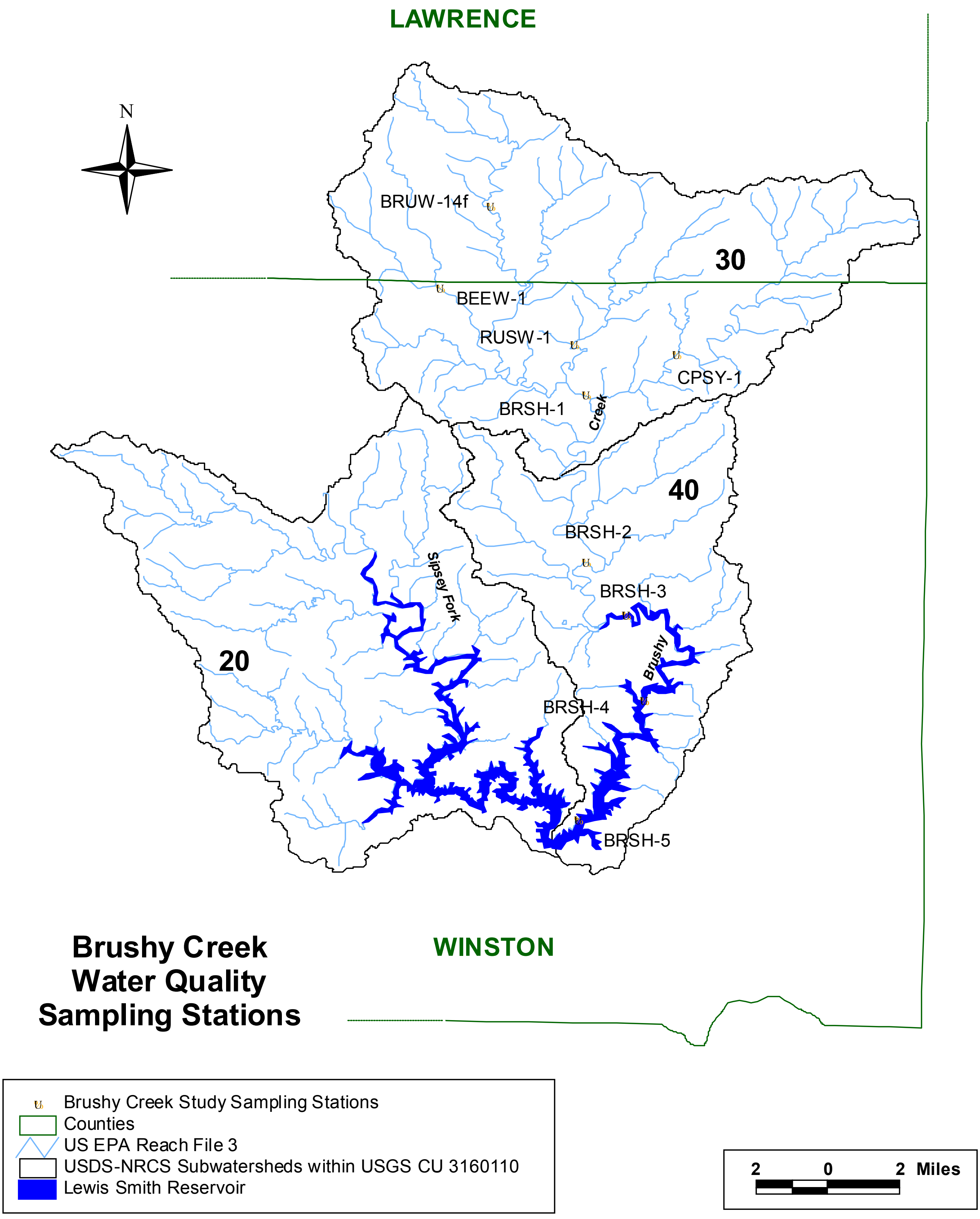

LAWRENCE
N
BRUW-14f
30
BEEW-1
RUSW-1
CPSY-1
BRSH-1
Creek
40
BRSH-2
BRSH-3
Sipsey Fork
20
Brushy
BRSH-4
BRSH-5
Brushy Creek
Water Quality
Sampling Stations
WINSTON
Brushy Creek Study Sampling Stations
Counties
US EPA Reach File 3
USDS-NRCS Subwatersheds within USGS CU 3160110
Lewis Smith Reservoir
2 0 2 Miles
ADEM-Water Quality Section 1998

Table 1. Station locations for the Brushy Creek watershed water quality assessment.

Study Phase	Waterbody	Station	Latitude/ Longitude	County	Section, Township, Range	Station Description
Tributary Loading						
	Brushy Creek	BRSH-1	34° 25' 26.34" 87° 24' 72.74"	Winston	NW1/4, Sec 23, T9S, R7W	Forest Service Rd. 255 bridge crossing of Brushy Creek.
	Capsey Creek	CPSY-1	34° 26' 94.14" 87° 21' 09.43"	Winston	NW1/4, Sec 18, T9S, R6W	Forest Service Rd. 266 bridge crossing of Capsey Creek.
Embayment Sampling	Smith Reservoir	BRSH-2	34° 18' 42.05" 87° 24' 71.84"	Winston	SW1/4, Sec 11, T10S, R7W	Approximately 1.5 miles upstream of U.S. Hwy. 278 bridge.
	Smith Reservoir	BRSH-3	34° 16' 20.94" 87° 23' 09.80"	Winston	NW1/4, Sec 24, T10S, R7W	Approximately 2.5 miles downstream of U.S. Hwy. 278 bridge.
	Smith Reservoir	BRSH-4	34° 12' 68.12" 87° 22' 38.24"	Winston	SE1/4, Sec 36, T10S, R7W	Approximately 1.5 miles upstream of Winston County Rd. 63 bridge.
	Smith Reservoir	BRSH-5	34° 07' 71.66" 87° 24' 97.92"	Winston	SW1/4, Sec 23, T11S, R7W	Approximately 0.5 miles upstream of Brushy Creek, Sipsey Fork confluence.
Macroinvertebrate Sampling	Brushy Creek	BRSH-1	34° 25' 26.34" 87° 24' 72.74"	Winston	NW1/4, Sec 23, T9S, R7W	Upstream of Forest Service Rd. 255 bridge crossing of Brushy Creek.
	Capsey Creek	CPSY-1	34° 26' 94.14" 87° 21' 09.43"	Winston	NW1/4, Sec 18, T9S, R6W	Upstream of Forest Service Rd. 266 bridge crossing of Capsey Creek.
	Beech Creek	BEEW-1	34° 29' 66.90" 87° 30' 55.60"	Winston	NE1/4, Sec 6, T9S, R7W	Upstream of Forest Service Rd. 245 bridge crossing of Beech Creek.
	Brushy Creek	BRUW-14f	34° 33' 07.20" 87° 28' 56.40"	Lawrence	SE1/4, Sec 20, T8S, R7W	Upstream of Forest Service Rd. 254 bridge crossing of Brushy Creek.
	Rush Creek	RUSW-1	34° 27' 35.60" 87° 25' 15.70"	Winston	SE1/4, Sec 10, T9S, R7W	Upstream of Forest Service Rd. 245 bridge crossing of Rush Creek.

stations (BRSH-1 and BEEW-1) are lower gradient and characterized by glide/pool geomorphology. Habitat quality at these sites was evaluated using the glide/pool habitat assessment form (Barbour and Stribling 1996). The glide/pool and riffle/run assessments evaluate different stream characteristics. However, both assessments are structured to evaluate three main habitat parameters: Instream habitat quality, bank stability, and riparian zone measurements. In order to compare habitat quality between stations, scores were converted into percent maximum score. Substrate composition was visually estimated at each site.

Macroinvertebrate Sampling Methodology

Five stations in the Brushy Creek sub-watershed were selected for habitat and aquatic macroinvertebrate assessment. Stations BRUW-14 and BRSH-1 were located on Brushy Creek. Stations CPSY-1, RUSW-1, and BEEW-1 were located on Capsey, Rush, and Beech Creeks, respectively, each of which are tributaries to Brushy Creek.

Macroinvertebrate bioassessments were conducted at each station using the Multihabitat Bioassessment (MB-I) methodology described in ADEM Field Operations Standard Operating Procedures and Quality Control Assurance Manual, Volume II – Freshwater Macroinvertebrate Biological Monitoring (1996). A three-member team conducted the ADEM's Multihabitat EPT screening method at each site. The Multihabitat EPT method is a screening technique used in watershed assessment studies. Because basin wide screening surveys entail assessments at multiple sites over a large area, the collection effort and analysis time were decreased by:

a) collecting samples from the four most productive habitats;
b) processing samples in the field; and,
c) focusing on the collection of pollution-sensitive taxa.

Collecting samples: The four most productive habitats at a site will differ naturally between riffle-run and glide-pool geomorphology streams. In riffle-run streams, the four habitats sampled were: 1) riffles, 2) leaf packs, 3) rootbanks, and 4) snags/logs and rocks. Glide-pool streams are characterized by low gradient, sandy substrates, a lack of riffle habitat, and meandering flows. The four habitats sampled in these streams were: 1) rootbanks, 2) leaf packs, 3) snags/logs, and 4) sand.

Nonpoint source impacts can degrade habitat quality and alter availability. In order to detect these impairments more effectively, the four habitats were sampled in proportion to their availability. In addition, the "quality" of the habitats sampled was representative of the quality of habitats available at the station. Prior to sampling, habitat availability was estimated and recorded on a biosurvey summary sheet. The estimate was used to determine how many samples were collected of each habitat type.

Process samples in the field: After each habitat was collected, the organic material was elutriated from the inorganic material. The inorganic material was visually inspected for organisms (esp. Trichoptera in stone cases, and relative abundance and voucher specimens of snails, bivalves, and mussels). The organic matter was washed down, and large debris was visually inspected and removed.

Collection of pollution-sensitive taxa: "EPT" organisms were removed from the sample in proportion to relative abundance and preserved in a pre-labeled vial. All rare EPT organisms (1-2 total specimens collected) were preserved for identification; 3-9 specimens of common organisms; ten specimens were preserved for identification for all abundant organisms. EPT organisms were identified to family level in the field. Relative abundance of EPT families was noted on the field-picking sheet. Relative abundance of "other organisms", especially dominant or abundant organisms, were also noted on the picking sheet. The remainder of each sample was preserved in a wide mouth container and returned to the laboratory.

Following analysis of the EPT data, each site was assessed as "unimpaired", "slightly impaired", "moderately impaired", or "severely impaired" based on the number of pollution-sensitive EPT families collected (ADEM 1997f).

Nutrient Loading

Water samples from nutrient loading stations were collected for a period of one year, monthly June through November and twice monthly December through May when rainfall was more frequent (Table 2). Water sample collections coincided with rainfall

Table 2. Brushy Creek watershed water quality assessment schedule.

Task	Year 1996	Year 1997										
	December	January	February	March	April	May	June	July	August	September	October	November
Tributary Loading	**XX**	**XX**	**XX**	**XX**	**XX**	**XX**	**X**	**X**	**X**	**X**	**X**	**X**
Water Quality - Nonflowing Stations					**X**	**X**	**X**	**X**	**X**			
Diel Measurements - Nonflowing Stations							**X**	**X**	**X**			
Chlorophyll a					**X**	**X**	**X**	**X**	**X**			
Algal Growth Potential Tests							**X**	**X**	**X**			
Macroinvertebrate Samples							**X**					

events whenever possible. In addition, samples were collected during two heavy rainfall events to further define tributary loading.

Upon arriving at each of the two flowing stations, stream discharge was determined by wading if possible or by suspension cable if stream depth prohibited wading.

Following stream discharge measurement, water was collected by grab sample for nutrient analysis (Table 3). A half-gallon plastic jug was filled from the grab sample and preserved with H_2SO_4 for nitrogen and total phosphorus analyses. Soluble reactive phosphorus samples were collected by vacuum filtering 250 ml of the grab sample through 0.45 micron Millipore membrane filters and collecting the filtrate in acid-washed 250 ml Nalgene containers. Samples were then preserved on ice until analyzed.

Separate samples for suspended sediment analysis were collected at cross-section intervals with a US Model DH-59 depth-integrating suspended sediment sampler using methods described by Glysson and Edwards (1988). The suspended sediment samples were composited into a half-gallon plastic jug and preserved on ice until analyzed.

Nutrient and suspended sediment data from Brushy and Capsey Creek stations together with stream discharge measurements from these stations and the Sipsey Fork of the Warrior River were used to estimate nutrient and sediment loading of Smith Lake from the Brushy Creek tributary.

Measured and calculated discharges from Brushy and Capsey Creeks were regressed against gaged discharge values of Sipsey Fork. Linear regressions ($y = a + bx$) were determined to estimate mean daily discharge for the two stations. SAS was used to perform regressions between stream discharge and TP, TN, and TSS concentrations to determine R^2 and probabilities (p) (SAS 1990).

Total loading for TP, TN, and TSS from Brushy Creek to Smith Reservoir was estimated using FLUX for the period December 1, 1996 through November 30, 1997. FLUX is an interactive data reduction program for estimating nutrient loading from grab sample nutrient concentration data, with associated instantaneous flow measurements,

Table 3. Analytical methods used in the water quality assessment of the Brushy Creek watershed.

Variable	Method	Reference
In situ		
Vertical illumination	Photometer, Secchi disk	Lind, 1979
Temperature	Thermistor	APHA et al. 1985
Dissolved oxygen	Membrane electrode	APHA et al. 1985
pH	Glass electrode	APHA et al. 1985
Specific conductance	Wheatstone bridge	APHA et al. 1985
Laboratory Analysis - Flowing Stations		
Ammonia	Automated phenate	EPA-600/4-79-020
Nitrite	Colorimetric	EPA-600/4-79-020
Nitrate	Cadmium reduction	EPA-600/4-79-020
Total organic nitrogen	Macro Kjeldahl	EPA-600/4-79-020
Soluble reactive phosphorus	Automated single reagent	EPA-600/4-79-020
Total phosphorus	Persulfate digestion	EPA-600/4-79-020
Total suspended solids	Filtration, drying	EPA-600/4-79-020
Laboratory Analysis - Nonflowing Stations		
Alkalinity	Potentiometric titration	EPA-600/4-79-020
Hardness	Titrametric, EDTA	EPA-600/4-79-020
Ammonia	Automated phenate	EPA-600/4-79-020
Nitrite	Colorimetric	EPA-600/4-79-020
Nitrate	Cadmium reduction	EPA-600/4-79-020
Total organic nitrogen	Macro Kjeldahl	EPA-600/4-79-020
Soluble reactive phosphorus	Automated single reagent	EPA-600/4-79-020
Total phosphorus	Persulfate digestion	EPA-600/4-79-020
Total organic carbon	Persulfate-ultraviolet	EPA-600/4-79-020
Total suspended solids	Filtration, drying	EPA-600/4-79-020
Turbidity	Nephelometer	APHA et al. 1985
Biological - Flowing Stations		
Macroinvertebrate	Multihabitat Bioassessment Protocol	ADEM 1992
Biological - Nonflowing Stations		
Chlorophyll a	Spectrophotometric	APHA et al. 1992
Algal Growth Potential Test	Printz Algal Assay Test	ADEM 1993

and continuous flow (mean daily discharge) data (Walker 1996). Continuous flow records were obtained from the United States Geological Survey (USGS) for Sipsey Fork.

Continuous flow was estimated for Brushy Creek and Capsey Creek as mentioned previously, then flow at the two sites was combined to give an overall value for Brushy Creek. Water quality data for Brushy and Capsey Creeks were from the 19 sampling dates from December 1996 through November 1997. Water quality data from Brushy and Capsey Creeks were entered into FLUX then combined for overall values for Brushy Creek.

Embayment Water Quality

Samples from the embayment stations were collected monthly April through August (Table 2) and analyzed for the variables listed in Table 3. Water samples from each station consisted of composited photic zone collections. Photic zone depth determinations were made by measuring the vertical illumination of the water column using an underwater photometer. The depth at which one percent of the surface illumination was measured by the photometer was considered the photic zone depth. A composited water sample of approximately twenty liters was collected from the photic zone. The sample was collected by raising and lowering a plastic submersible pump and hose apparatus repeatedly through the photic zone while collecting the sample in a plastic container. Withdrawal of individual samples from the composited water sample occurred in the order presented in the following paragraphs.

Chlorophyll a samples were collected by filtering a minimum of 500 ml of the composited photic zone sample through glass fiber filters immediately after collection of the composited sample. Immediately after filtering, each filter was folded once and placed in a 50 mm petri dish. Each petri dish was wrapped in aluminum foil, sealed in a ziploc bag, and placed on ice for shipment to the Field Operations Division to be frozen until analyzed.

Samples for Algal Growth Potential Tests (AGPT) were collected from the composited photic zone sample by filling a properly prepared plastic container and preserving on ice.

Soluble reactive phosphorus samples were collected by vacuum filtering 250 ml of the composited sample through 0.45 micron Millipore membrane filters and collecting the filtrate in acid-washed 250 ml Nalgene containers. Samples were then preserved on ice until analyzed.

Finally, two half-gallon portions of the composited sample were collected in plastic containers and properly preserved for laboratory analysis of other water quality variables listed in Table 3.

A Secchi disk measurement of visibility was also performed using a standard, 20 cm diameter, Secchi disk with attenuating black and white quadrants.

At each sampling site water temperature, dissolved oxygen, specific conductance, and pH were measured *in situ* at multiple depths in the water column with Hydrolab Surveyor III instruments. In addition, diel *in situ* measurements were conducted monthly June through August (Table 2) at certain embayment stations using a Hydrolab Datasonde III.

Quality Control / Quality Assurance

For quality control / quality assurance purposes, field duplicates of each sample type were collected during ten percent of the sampling events. Field duplicates were true duplicates of the complete collection process. At nonflowing stations, blanks were collected at the same frequency as duplicates by processing distilled water through the collection and filtration equipment in the same manner as regular samples. Measurements of water temperature, dissolved oxygen, specific conductance, and pH were replicated at sampling sites where duplicate samples were collected.

Results and Discussion

Landuse

Landuse within the Upper and Lower Brushy Creek watersheds was divided evenly between deciduous forest, evergreen forest, and mixed forest (Table 4) (Figure 2). Five percent of the Upper Brushy Creek watershed was comprised of transitional barren. Eight percent of the Lower Brushy Creek basin was comprised of pasture/ hay.

These estimates compare favorably with results of roadside surveys conducted within the Upper Brushy Creek subwatershed (Table 5). Although ADEM estimates did not include a category for mixed forest, total percent forest was ninety-six and eighty-five percent for USEPA and ADEM, respectively. Pasture comprised ten percent of total landuse estimated during the roadside survey. Poultry and cattle were also noted in Collier and Capsey Creeks.

The results of the nonpoint source survey are summarized in Table 6. Silviculture was the primary nonpoint source pollutant within the Brushy Creek basin. The impairment from silviculture was concentrated within the Beech Creek and Collier Creek drainages. Erosion of the gravel roads was also noted within Beech Creek and Upper Brushy Creek . Although potential within the Brushy Creek watershed is high, nonpoint source pollution was measured to be slight within each of the tributaries.

Habitat and Macroinvertebrate Assessment

Five stations in the Brushy Creek sub-watershed were selected for habitat and aquatic macroinvertebrate assessment. Stations BRUW-14 and BRSH-1 were located on Brushy Creek. Stations CPSY-1, RUSW-1, and BEEW-1 were located on Capsey, Rush, and Beech Creeks, respectively, each of which are tributaries to Brushy Creek.

Capsey Creek (CPSY-1), located within the Southwestern Appalachians, is characterized by riffle/run geomorphology. Stream substrate was composed of 35% bedrock with fairly even proportions of boulder, cobble, gravel and sand (Table 7). The

Table 4. Percent landuse of Upper and Lower Brushy Creeks estimated by EPA (1997). Estimates are based upon satellite imagery data collected during 1988, 1990, 1991, and 1993. Estimates of percent landuse in remaining Sipsey Fork subwatersheds are presented for comparison.

SubWatershed		Deciduous Forest	Evergreen Forest	Mixed Forest	Transitional Barren	Pasture/ Hay	Row Crops	Open Water
30	Upper Brushy Creek	32	32	32	5	0	0	0
40	Lower Brushy Creek	33	25	33	0	8	0	0
10	Sipsey Fork	41	28	31	0	0	0	0
20	Sipsey Fork	29	29	29	5	5	0	5
50	Right Fork, Clear Creek	33	24	29	5	10	0	0
60	Clear Creek	38	25	25	13	0	0	0
70	Sipsey Fork	30	20	25	5	5	5	10
80	Upper Rock Creek	41	14	18	0	18	9	0
90	Crooked Creek	33	13	20	0	27	7	0
100	Lower Rock Creek	40	13	20	0	13	7	7
110	Upper Ryan Creek	29	14	24	0	24	10	0
120	Lower Ryan Creek	36	16	20	0	12	4	12
130	Sipsey Fork, Black Warrior	54	8	23	0	8	8	0

Figure 2. Brushy Creek Watershed Landuse &
Location of macroinvertebrate sampling stations

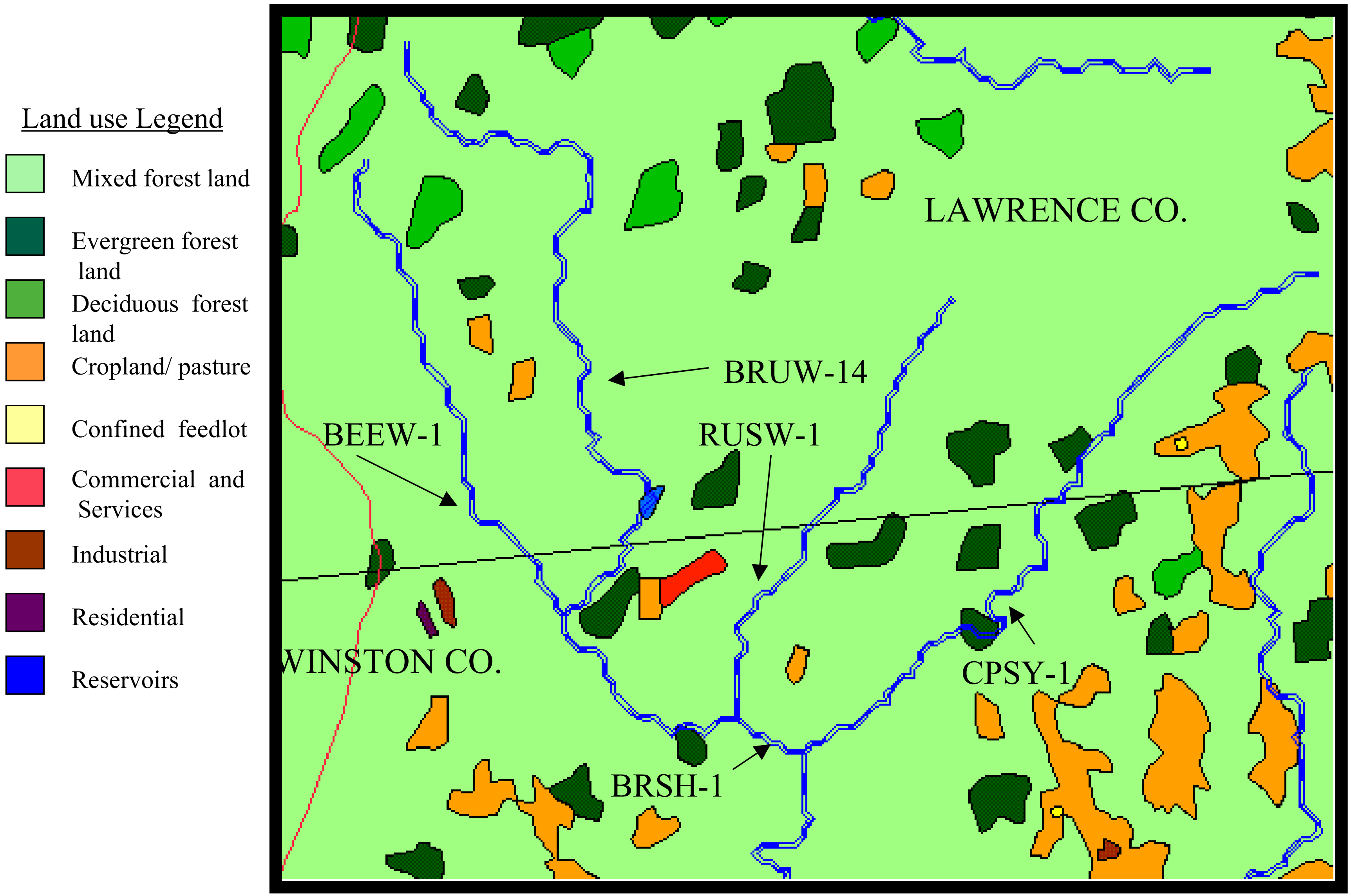


Table 5. Evaluation of percent landuse within the Upper Brushy Creek subwatershed. Estimates are based upon road surveys conducted by the EI Section, Mar. 18-19, 1997. Percents were calculated by dividing total landuse score by total number of miles surveyed. Upper Brushy Creek landuse was obtained by combining estimates of each of the five tributaries listed below.

	Forest		Animal Production			Residential
	Deciduous Forest	Monoculture Evergreen	Pasture	Poultry	Cattle	
Upper Brushy Creek	**39**	**46**	**10**	**1**	**1**	**3**
Collier Creek	33	30	27	7	0	9
E. Fork Beech Creek	56	37	5	0	0	2
Brushy Creek	55	39	5	0	0	1
Rush Creek	30	60	3	5	0	0
Capsey Creek	22	51	15	12	2	6

Table 6. Summary of roadside surveys conducted within the Brushy Creek watershed. Scores reflect both degree of nonpoint source impairment and number of impairments observed within the watershed. To standardize scores across sub basins, they are presented as score per mile surveyed. Scores obtained for each category were summed to obtain the total impairment score. Scores < 6 indicate a slight potential for nonpoint source impairment to the waterbody.

	Erosion		Agriculture	Animal Production		
Sub basin	Silviculture	Roadbank	Row Crops	Cattle Production	Poultry	Total Impairment Score
Brushy Creek						
Beech Creek	2.7	2.2	0.0	0.3	0.0	5.2
Collier Creek	3.0	0.0	0.0	0.8	0.5	4.3
Upper Brushy Creek	1.4	1.1	0.1	0.0	0.0	2.6
Rush Creek	1.7	0.4	0.0	0.0	0.4	2.5
Capsey Creek	0.8	0.2	0.0	0.3	0.5	1.8
Total impairment score	9.6	3.9	0.1	1.4	1.4	16.4

Table 7. Physical characteristics of sites in the upper Brushy Creek watershed.

	Station				
	BRUW-14f	CPSY-1	RUSW-1	BEEW-1	BRSH-1
Width	20	25	25	20	30
Basin area (sq. mi.)*	9	20	11	11	60
Stream Order	1	1	1	1	2
Depth (ft)					
Riffle	0.7	0.6	---	0.5	---
Run	1.0	1.0	1.0	2.0	2.5
Pool	1.5	3.0	1.5	3.5	3.0
Substrate (%)					
Bedrock	0	35	25	0	0
Boulder	25	10	15	15	35
Cobble	30	20	15	10	5
Gravel	6	10	2	15	5
Sand	30	15	35	53	45
Silt	5	5	2	5	2

*at sampling location

habitat was evaluated as “unimpaired”. Thirteen EPT families were collected indicating the aquatic macroinvertebrate community at CPSY-1 to be “unimpaired” (Table 8).

Beech Creek (BEEW-1), located within the Southwestern Appalachians, is characterized by glide/pool geomorphology. Stream substrate was composed of 53% sand overlying smaller proportions of boulder, cobble, and gravel (Table 7). Although the bottom substrate was embedded by sand, the habitat was evaluated as only “slightly impaired”. Thirteen EPT families were collected, indicating the aquatic macroinvertebrate community at BEEW-1 was “unimpaired” (Table 8).

Rush Creek, located within the Southwestern Appalachians, is characterized by riffle/run geomorphology. Stream substrate was composed of 35% sand overlying smaller proportions of boulder and cobble (Table 7). Although the bottom substrate was embedded by sand, the habitat was evaluated as only “slightly impaired”. Fourteen EPT families were collected, indicating the aquatic macroinvertebrate community at RUSW-1 was “unimpaired” (Table 8).

Brushy Creek at BRSH-1, located within the Southwestern Appalachians, is characterized by glide/pool geomorphology. The substrate at BRSH-1 was composed of 45% sand and 35% boulder with small amounts of cobble and gravel (Table 7). The substrate composition of BRUW-14f consisted of similar proportions of boulder, cobble, and sand with a small amount of gravel. Although the bottom substrate at both sites consisted of a substantial amount of sand, the habitat was evaluated as only “slightly impaired”. Twelve and sixteen EPT families were collected at BRSH-1 and BRUW-14f, respectively, indicating the aquatic macroinvertebrate communities to be “unimpaired” (Table 8).

Table 8. Habitat and aquatic macroinvertebrate assessments of sites in the upper Brushy Creek watershed. Scores given for each of three major habitat parameters are presented as percent of maximum score.

Parameter	BRUW-14	CPSY-1	RUSW-1		BEEW-1	BRSH-1
Habitat assessment form	Riffle/Run	Riffle/Run	Riffle/Run		Glide/Pool	Glide/Pool
Instream habitat quality	79	85	61		62	68
Sedimentation/ Deposition	70	80	63		55	60
% Sand	30	15	35		53	45
% Silt	5	5	2		5	2
Sinuosity	85	75	40		40	40
Bank and vegetative stability	48	70	65		68	60
Riparian zone measurements	93	90	93		90	88
% Canopy cover	90	90	90		30	70
% Maximum Score	73	80	64		66	65
Habitat Assessment Category	Good	Excellent	Good		Good	Good
EPT Taxa Collected	16	13	14		13	12
Aq. Macroinvertebrate Assess.	Unimpaired	Unimpaired	Unimpaired		Unimpaired	Unimpaired

Nutrient and Total Suspended Solids Loading

Nutrient and total suspended solids estimations for Brushy and Capsey Creeks were compared to loading estimations for other Smith Lake tributaries determined during the Lewis Smith Lake Diagnostic / Feasibility Study (1998).

Measured and calculated discharges from Brushy and Capsey Creeks were regressed against gaged discharge values of Sipsey Fork (R^2 = 0.97 and 0.75, respectively) (Table 9). Linear regressions (y = a + bx) were determined to estimate mean daily discharge for all stations. Total monthly discharge ($m^3 \times 10^6$) was calculated and plotted along with total phosphorus (TP), total nitrogen (TN), and total suspended solids (TSS) from December 1996 through November 1997 for Brushy Creek (Figure 3). Peak total monthly discharges occurred in May and June 1997. During the twelve month period of sampling, discharge was highest December 1996 through March 1997, and May through June 1997. Discharge was much lower in April 1997 and during the period July through November 1997.

Total monthly loading of TP, TN, and TSS was also estimated using FLUX (Figure 3). Loading estimate patterns for all variables were similar to total monthly discharge patterns for Brushy Creek. TP, TN, and TSS loading estimates were highest for June 1997 at Brushy Creek. During the twelve-month period, loading estimates were higher for December 1996 through March 1997, much lower during April 1997, reached their peak in June 1997, then dropped to their lowest levels August through November 1997.

Annual mean concentrations of TP, TN, and TSS were estimated for Brushy Creek and Capsey Creek stations from the 19 samples collected from December 1996 through November 1997 (Table 9). Annual mean TP concentrations were 16 ug/l for Brushy Creek and 50 ug/l for Capsey Creek. TP concentrations were negatively correlated (p = 0.61 and 0.04) with instantaneous stream discharge at Brushy and Capsey Creeks (R^2 = -0.12 and -0.46, respectively). Annual mean TP concentrations of Brushy Creek were much higher than those of other tributaries to Smith Lake while concentrations of Capsey Creek were similar to those of several other Smith Lake

Table 9. Mean (range) daily discharge and annual mean (range) concentration of total phosphorus, total nitrogen, and total suspended solids at Brushy Creek and Capsey Creeks from December 1996 through November 1997. Data from all other tributaries collected November 1994 through October 1995 for Diagnostic Study of Smith Lake.

Station	Mean Daily Discharge		Total Phosphorus		Total Nitrogen		Total Suspended Solids	
	(cfs)	R^2(p)	(ug/l)	R^2(p)	(ug/l)	R^2(p)	(mg/l)	R^2(p)
Brushy Creek	152.6	0.97	160	-0.12	270	-0.12	2.39	0.89
	(30-3154)	(<0.01)	(2-1860)	(0.61)	(110-1080)	(0.62)	(0.15-16)	(<0.01)
Capsey Creek	47.2	0.75	50	-0.46	530	0.29	2.70	0.88
	(13-873)	(<0.01)	(2-140)	(0.04)	(280-1410)	(0.22)	(0.5-16)	(<0.01)
Ryan Creek[a]	100.7	0.75	67	0.34	1616	0.72	12.11	0.52
	(0-2048)	(<0.01)	(20-251)	(0.01)	(861-2987)	(<0.01)	(1.17-91.05)	(<0.01)
Crooked Creek[a]	69.6	0.93	50	0.48	1204	0.82	9.68	0.64
	(0-1422.9)	(<0.01)	(11-236)	(<0.01)	(315-2600)	(<0.01)	(0.01-59.35)	(<0.01)
Rock Creek[a]	139.9	0.95	69	0.08	1490	0.45	11.54	0.48
	(4.5-6020.3)	(<0.01)	(12-322)	(0.23)	(440-2821)	(<0.01)	(0.95-89.15)	(<0.01)
Sipsey Fork[a]	195.6	0.97	18	0.46	185	0.13	6.34	0.75
	(0-8960.1)	(<0.01)	(6-69)	(<0.01)	(77-512)	(0.14)	(0.17-38.02)	(<0.01)
Clear Creek[a]	199.7	0.93	46	0.62	592	0.54	31.84	0.85
	(0-4299.2)	(<0.01)	(10-280)	(<0.01)	(331-1175)	(<0.01)	(0.91-259.9)	(<0.01)
Tailwaters[a]	1548.9	---	15	0.14	781	0.006	2.54	0.02
(Alabama Power Dam)	(0-7449)		(5-42)	(0.16)	(463-1219)	(0.77)	(0.78-6.570)	(0.58)

[a] data from Lewis Smith Lake Phase I Diagnostic / Feasibility Report, 1998.

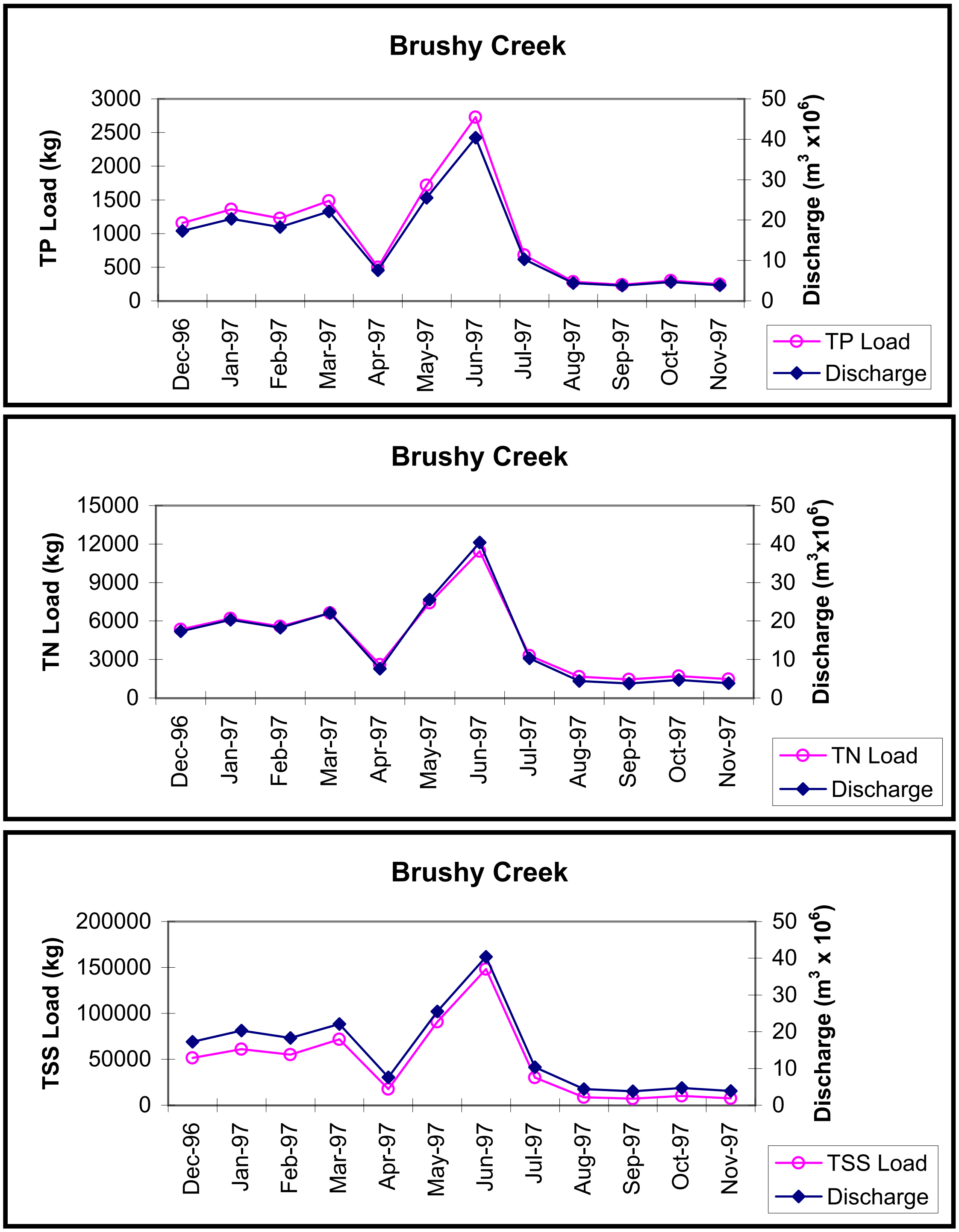


Figure 3. Total monthly loading at Brushy Creek for total phosphorus (TP), total nitrogen (TN), and total suspended solids (TSS) as determined by FLUX, plotted with estimates of total monthly discharge, December 1996 through November 1997.

tributaries. The TP concentration recorded from an April sampling event of Brushy Creek (1860 ug/l) were much higher than those of other months and greatly influenced the annual mean value. Review of analytical records with ADEM Central Laboratory personnel confirmed the values, resulting in their acceptance into the database. Exclusion of this April TP value results in an annual mean concentration of 69 ug/l, a value that remains higher than that of all tributaries except Rock Creek. Origins of Brushy Creek TP concentrations may be silvicultural or the limited agricultural activities in the watershed. Discussions with US Forest Service personnel in the Bankhead National Forest (personal communication James Ramey) indicated that forest management activities were unlikely to be the source of the TP. Given their magnitude, however, the origins of the TP concentrations in Brushy Creek should be the subject of further research.

Annual mean TN concentrations were 0.27 mg/l for Brushy Creek and 0.53 mg/l for Capsey Creek (Table 9). TN concentrations were negatively correlated ($p = 0.62$) with instantaneous stream discharge at Brushy Creek ($R^2 = -0.12$). TN concentrations were positively correlated ($p = 0.22$) with instantaneous stream discharge at Capsey Creek ($R^2 = 0.29$). Annual mean TN concentrations for Brushy and Capsey Creeks were, with the exception of Sipsey Fork, lower than those of other tributaries to Smith Lake.

Annual mean TSS concentrations were 2.39 mg/l for Brushy Creek and 2.70 mg/l for Capsey Creek (Table 9). TSS concentrations were positively correlated ($p < 0.01$) to a high degree with instantaneous stream discharge at Brushy Creek ($R^2 = 0.89$). TSS concentrations were positively correlated ($p < 0.01$) to a high degree with instantaneous stream discharge at Capsey Creek ($R^2 = 0.88$). Annual mean TSS concentrations of Brushy and Capsey Creeks were lower than those of other tributaries to Smith Lake.

Total loading for TP, TN, and TSS from Brushy Creek to Smith Reservoir was estimated using FLUX for the period December 1, 1996 through November 30, 1997 (Table 10). Mean daily discharge from Brushy Creek during the study period was higher than that of all other tributaries measured during the Phase I Study of Smith Lake. Total loading of TP from Brushy Creek was below that of Rock and Clear Creeks but above that of Ryan Creek, Crooked Creek, and the Sipsey Fork. Total loading of TN from

Table 10. Estimated total loading using FLUX for total phosphorus (TP), total nitrogen (TN), and total suspended solids (TSS) from Brushy Creek, December 1996 through November 1997. All other tributary loading data collected November 1994 through October 1995 for Diagnostic/Feasibility Study of Smith Lake.

Station	Watershed Area[a] (miles^2)	Mean Daily Discharge (cfs)	TP Loading (mt/yr)[b]	TN Loading (mt/yr)[b]	TSS Loading (mt/yr)[b]
Brushy Creek	88	199.8	12	53	540
Ryan Creek	49	100.7	11	187	2825
Crooked Creek	46	69.6	7	110	1448
Rock Creek	79	139.9	20	241	5561
Sipsey Fork	89	195.6	7	47	3785
Clear Creek	90	199.7	20	145	18709
Tailwaters (Alabama Power Dam)	944	1548.9	28	1086	3410
Total Stream Load			77	783	32868

[a] Watershed area in square miles above the point of sampling.

[b] mt/yr = metric tons per year.

Brushy Creek was lower than that of all other tributaries except Sipsey Fork. Total loading of TSS from Brushy Creek was lower than that of all other tributaries.

Total loading of TP, TN, and TSS from the six tributary streams into Lewis Smith Lake was 77 metric tons, 783 metric tons, and 32,868 metric tons, respectively. Of these total amounts, Brushy Creek, Crooked Creek, and the Sipsey Fork contributed the least (Figures 4 and 5). Brushy Creek accounted for 16% of the TP, 7% of the TN, and 2% of the TSS. Crooked Creek accounted for 9% of the TP, 14% of the TN, and 4% of the TSS. Sipsey Fork accounted for 9% of the TP, 6% of the TN, and 12% of the TSS. Clear Creek contributed the majority of the TSS load (58%). Rock and Clear Creek contributed a significant portion of the TP loading (31% and 31%). Rock and Ryan Creeks contributed a significant portion of the TN load (30% and 24%, respectively).

Embayment Water Quality

Water quality variables are grouped according to relationship or method of sampling. To minimize water quality variations caused by seasonal changes in meteorological conditions, variables were also grouped and examined by season. The seasons were spring (April and May), and summer (June, July, and August). Mean temperature, dissolved oxygen, pH, and conductivity values are from a depth of five feet (1.5m), at which ADEM Water Quality Criteria (1997) are set.

Brushy Creek embayment water quality data were collected at a lower embayment station during the 1995 Lewis Smith Lake Phase I Diagnostic / Feasibility Study and compared with that of mainstem locations and other tributary embayments in the study report. Therefore, embayment water quality data collected during this study will not be compared with that of other tributary embayments in this report and will serve only as indicators of water quality in the embayment portion of the watershed during the course of this study.

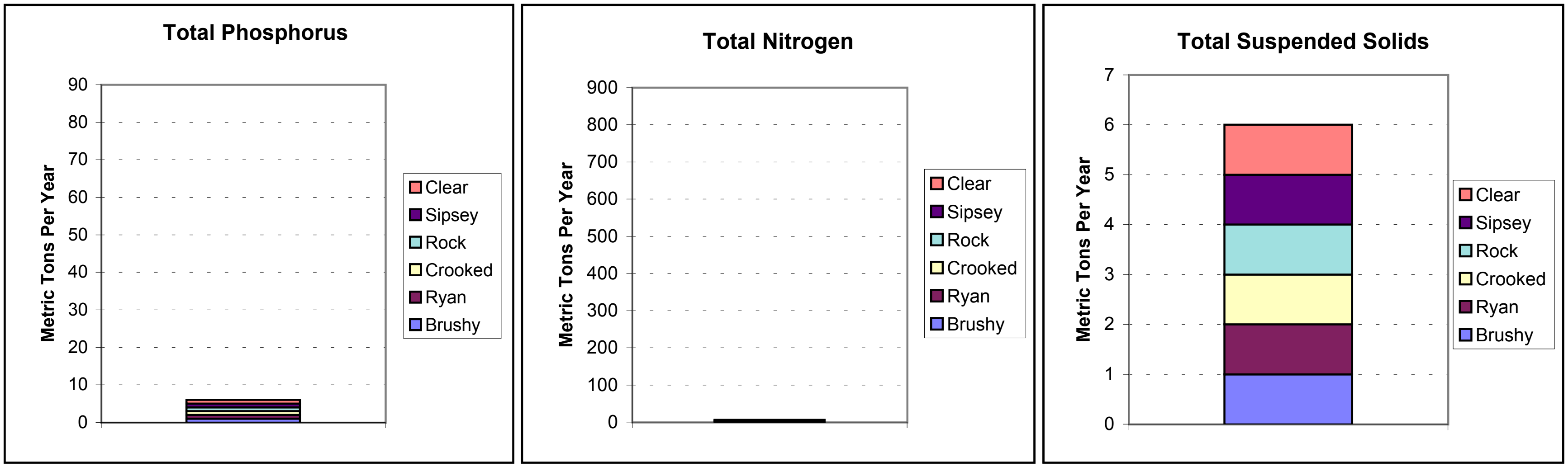


Figure 4. Total annual loading (point and nonpoint source) of total phosphorus, total nitrogen, and total suspended solids from each tributary, as determined by FLUX. Brushy Creek data collected December 1996 through November 1997. All other tributary data collected November 1994 through October 1995 for Diagnostic Study of Smith Lake.

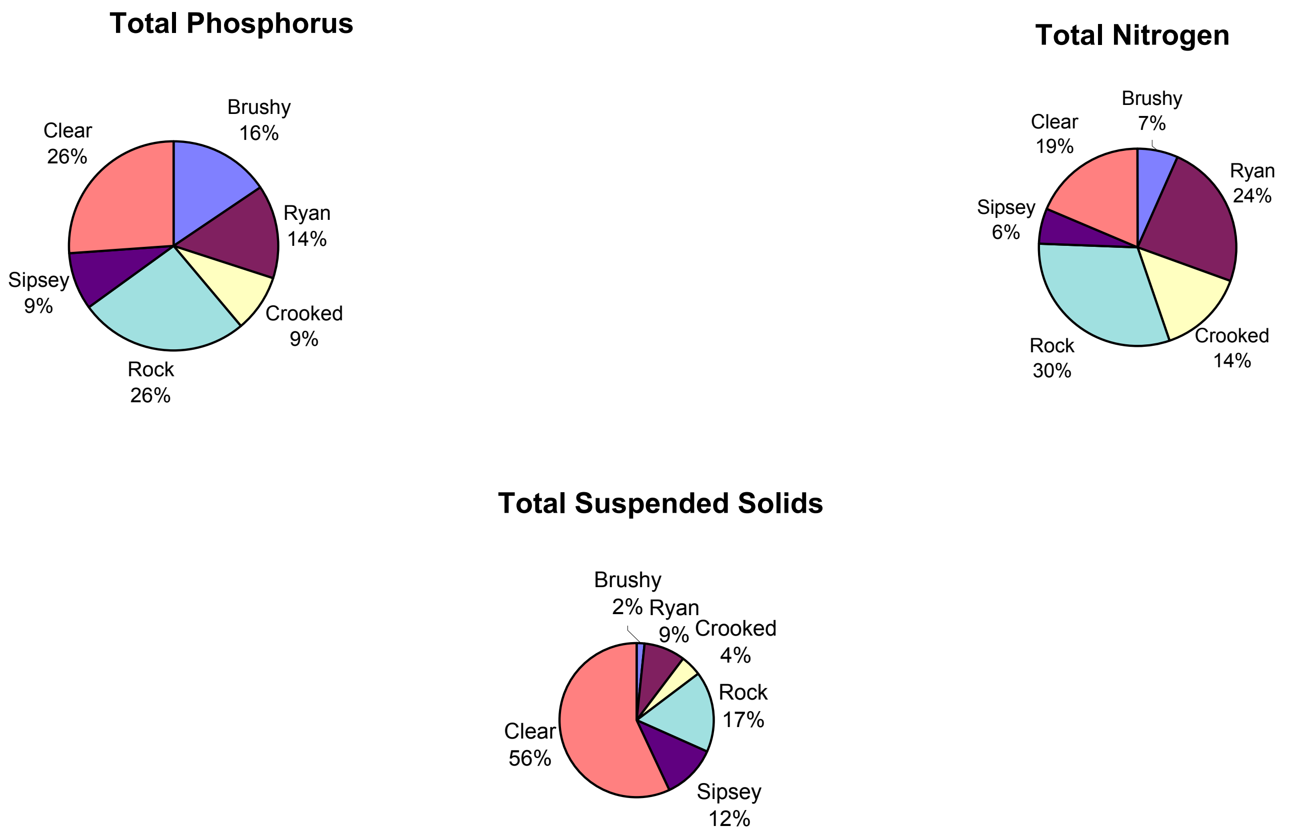


Figure 5. Total annual loading (point and nonpoint source) of total phosphorus, total nitrogen, and total suspended solids from each tributary, as determined by FLUX. Brushy Creek data collected December 1996 through November 1997. All other tributary data collected November 1994 through October 1995 for Diagnostic Study of Smith Lake.

Temperature-Dissolved Oxygen-Conductivity

Mean temperature during the spring and summer season was lowest in the upper embayment and increased with each downstream station (Tables 11, 12). Cooler temperatures likely prevail in the upper embayment due to its proximity to flowing water emerging from a heavily forested watershed. As the waters of the lower embayment slow and widen, exposure to solar radiation is greater and water temperatures increase. As expected with the increase in air temperature, water temperatures were several degrees higher at each station from spring to summer.

Mean spring and summer DO concentrations varied with each embayment station (Tables 11, 12). However, DO concentrations at each station were above the ADEM Water Quality Criteria (1997) limit of 5.0 mg/l on all dates sampled. Mean DO concentrations decreased from spring to summer at all locations.

Mean conductivity values during the spring increased at lower embayment stations (Table 11). Mean conductivity values during the summer were similar at all locations (Table 12). Mean values decreased at all stations from spring to summer.

Diel and Profile Graphs

Diel water quality measurements were made at each station during the months of June, July, and August by placing a Hydrolab Datasonde III at a depth of 1.5m (5ft).

During June (Figure 6), diel water temperatures changed little at each station. Temperatures in the upper embayment (Station 2) were lowest while those in the lower embayment (Stations 4, 5) were generally 6-8^{o}C higher. Diel DO concentrations remained between 8 and 10 mg/l at all stations. Measurements of pH were lowest in the upper embayment with values generally between 6 and 7 standard units. Diel pH measurements in the lower embayment were generally between 7 and 9 standard units.

During July (Figure 7), diel water temperatures increased 3-5 degrees over those of June and all stations showed much the same pattern as before. Diel DO concentrations were lower at all stations than in June and were between 5 and 8 mg/l at all stations at all times. The patterns of diel pH measurements were similar to those of June at all stations.

Table 11. Mean (range) temperature (Temp), dissolved oxygen (DO), and conductivity (Cond) for Brushy Creek embayment stations during spring (April, May) 1997.

Stations	Temp** (^{0}C)	DO** (mg/l)	Cond** (mmhos/cm)
2	14.02 (14.40 - 13.83)	9.25 (9.39 - 9.07)	0.037 (0.043 - 0.026)
3	15.19 (15.97 - 14.41)	8.74 (9.20 - 8.28)	0.037 (0.050 - 0.024)
4	17.94 (18.88 - 16.99)	9.26 (9.53 - 8.98)	0.040 (0.047 - 0.032)
5	18.16 (19.39 - 16.92)	9.05 (9.11 - 8.98)	0.043 (0.046 - 0.039)

** measured at a depth of 1.5m (5ft).

Table 12. Mean (range) temperature (Temp), dissolved oxygen (DO), and conductivity (Cond) for Brushy Creek embayment stations during summer (June, July, August) 1997.

Stations	Temp** (^{0}C)	DO** (mg/l)	Cond** (mmhos/cm)
2	23.45 (26.43 - 20.11)	7.27 (8.40 - 6.28)	0.036 (0.042 - 0.030)
3	26.18 (29.49 - 20.09)	7.87 (8.43 - 7.18)	0.034 (0.037 - 0.028)
4	29.68 (30.49 - 28.44)	8.09 (8.26 - 7.93)	0.035 (0.038 - 0.033)
5	30.03 (30.81 - 28.80)	7.94 (8.14 - 7.65)	0.037 (0.039 - 0.035)

** measured at a depth of 1.5m (5ft).

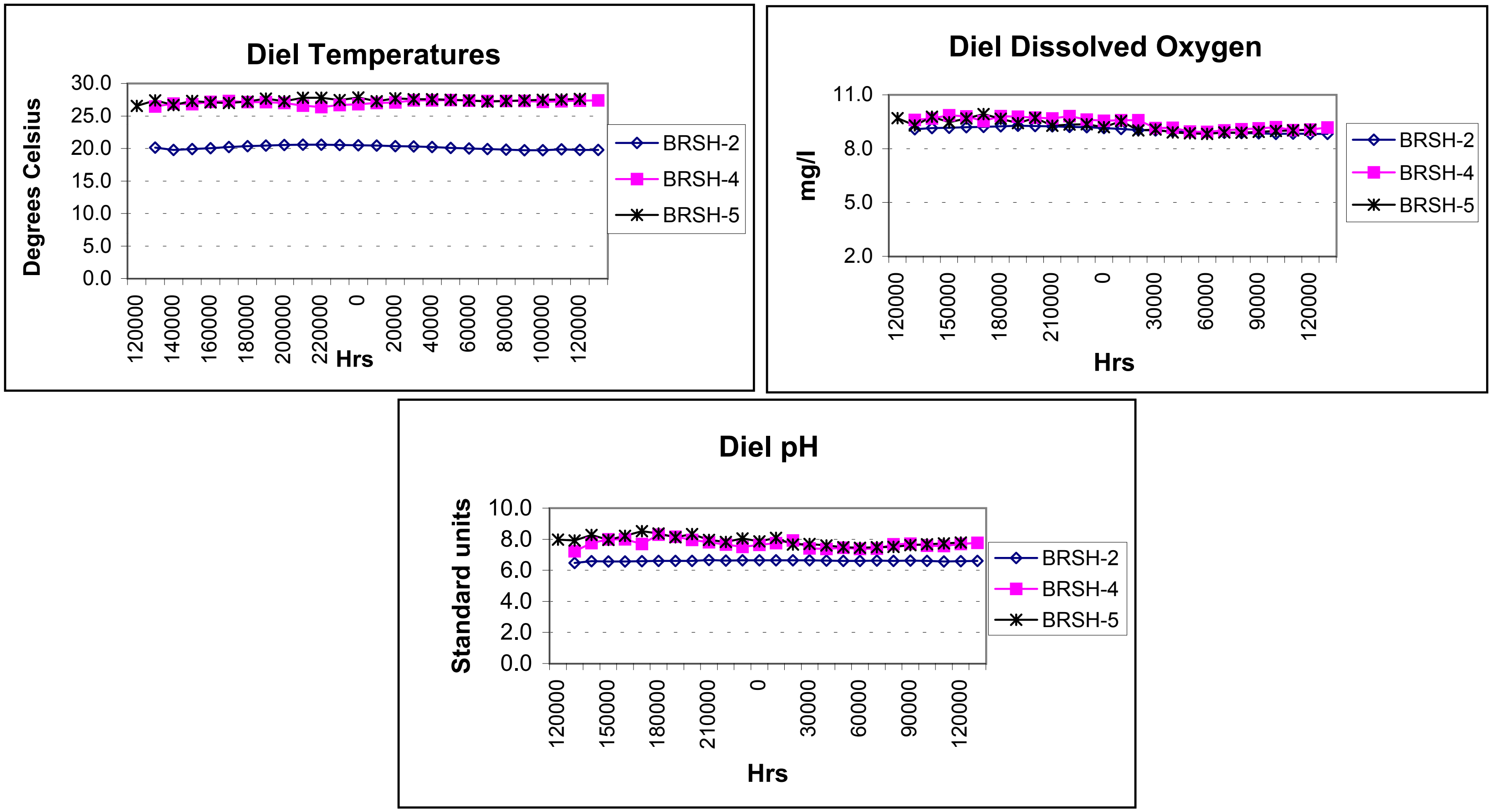


Figure 6. Diel temperature, dissolved oxygen, and pH measurements at a depth of 1.5m (5 ft.) at Brushy Creek embayment stations 2, 4, and 5 on June 24-25, 1997.

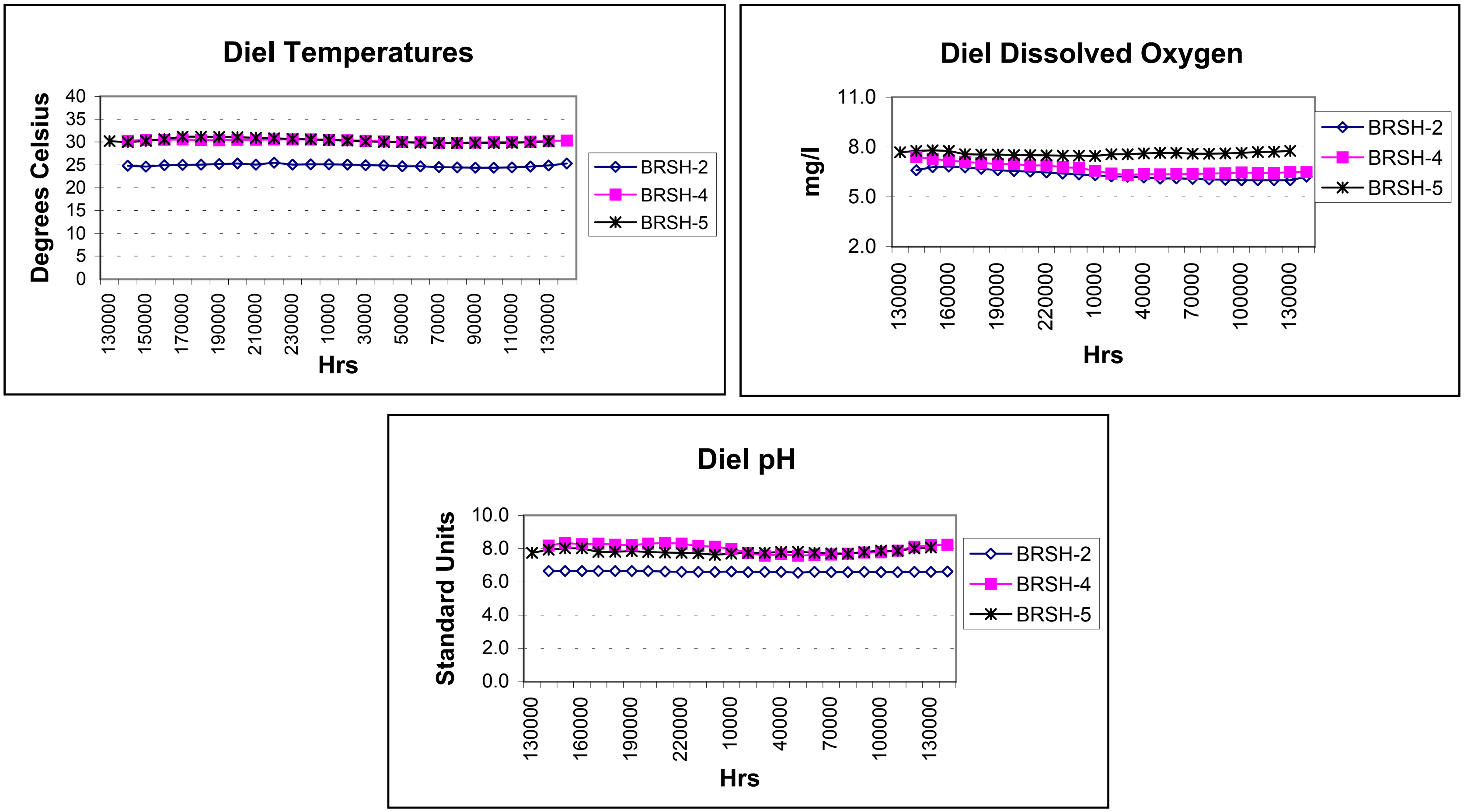


Figure 7. Diel temperature, dissolved oxygen, and pH measurements at a depth of 1.5m (5 ft.) at Brushy Creek embayment stations 2, 4, and 5 on July 15-16, 1997.

During August (Figure 8), diel water temperatures were very similar to those of July. However, diel DO concentrations at Station 5 were above 9 mg/l at all times and were higher in August than July. Diel DO concentrations at Station 4 were similar to those of July and were above 7 mg/l at all times. In the upper embayment, diel DO concentrations were slightly lower overall than in July but remained above the criterion limit of 5 mg/l at all times. Diel pH measurements in the upper embayment were similar to those of July while those of the lower embayment were slightly lower than July measurements.

Temperature and dissolved oxygen (DO) profile graphs were developed from *in situ* measurements for Brushy Creek embayment stations 3-5 (Figures 9-11). No profiles were developed for Station 2, downstream of the creek's inflow, because of the shallow depth and essentially isothermal and isochemical conditions on all sampling dates. The water column at Station 2 remained well oxygenated on all sampling dates.

Profiles for upper embayment Station 3 indicate essentially isothermal and isochemical conditions through the spring and into the summer seasons (Figure 9). Thermal stratification developed at Station 3 in July and August while chemical stratification, as indicated by DO concentrations, developed in August 1997. DO concentrations at Station 3 remained above criterion limits of 5 mg/l at all times. The entire water column remained oxygenated though DO concentrations near the bottom generally declined in the months sampled.

Profiles for lower embayment Station 4 indicate the development of thermal and chemical stratification in April 1997 that persisted through August (Figure 10). DO concentrations were above criterion limits on all dates sampled. Anoxic conditions existed near the bottom in June and July. In August, anoxic conditions initially developed below six meters depth. DO concentrations then increased with depth to approximately fourteen meters. Anoxic conditions were reestablished at 15 meters depth and existed to the bottom depth of 21 meters.

Profiles for lower embayment Station 5 indicate the development of thermal and chemical stratification in April 1997 that persisted through August (Figure 11). DO concentrations were above criterion limits on all dates sampled. The water column

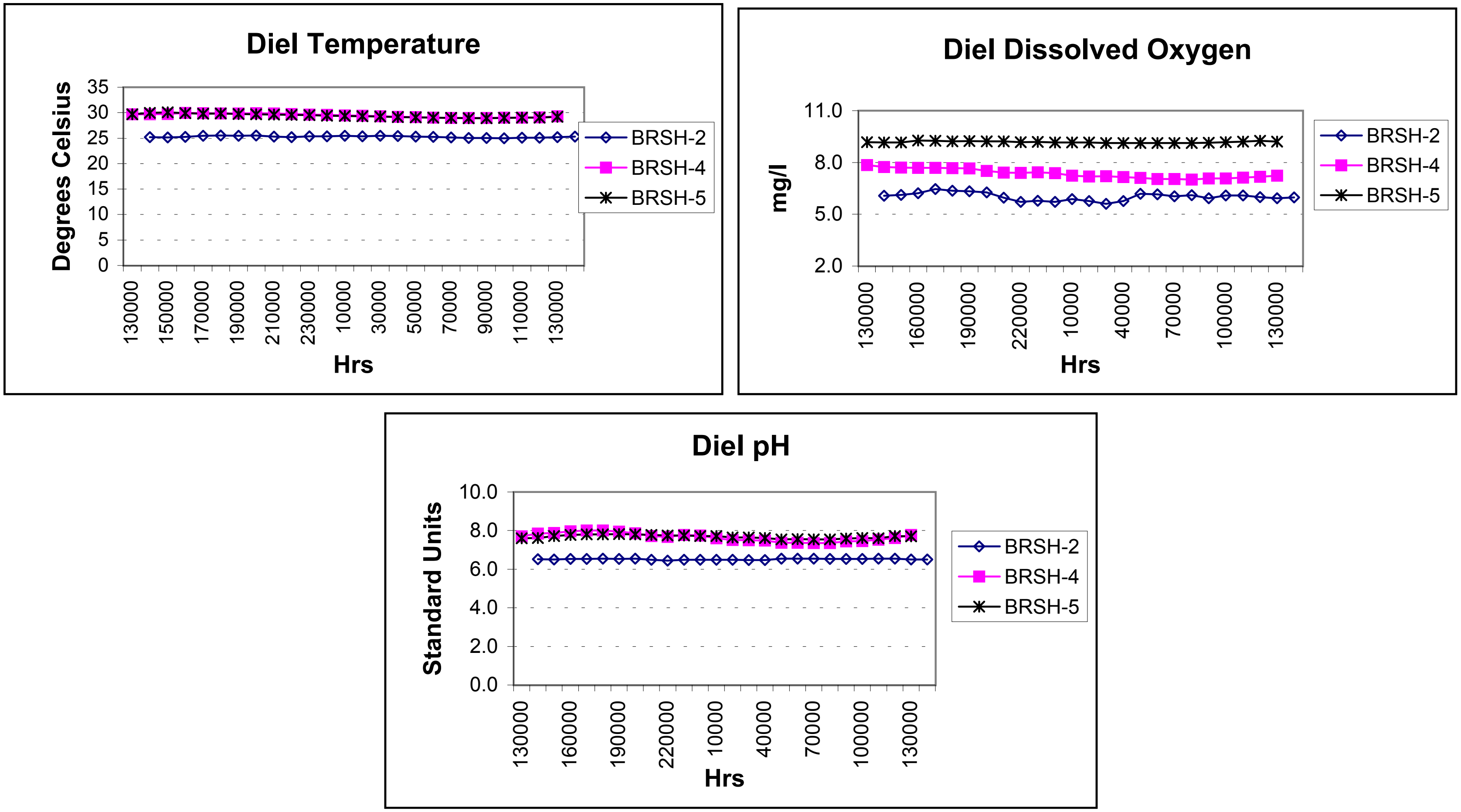


Figure 8. Diel temperature, dissolved oxygen, and pH measurements at a depth of 1.5m (5 ft.) at Brushy Creek embayment stations 2, 4, and 5 on August 5-6, 1997.

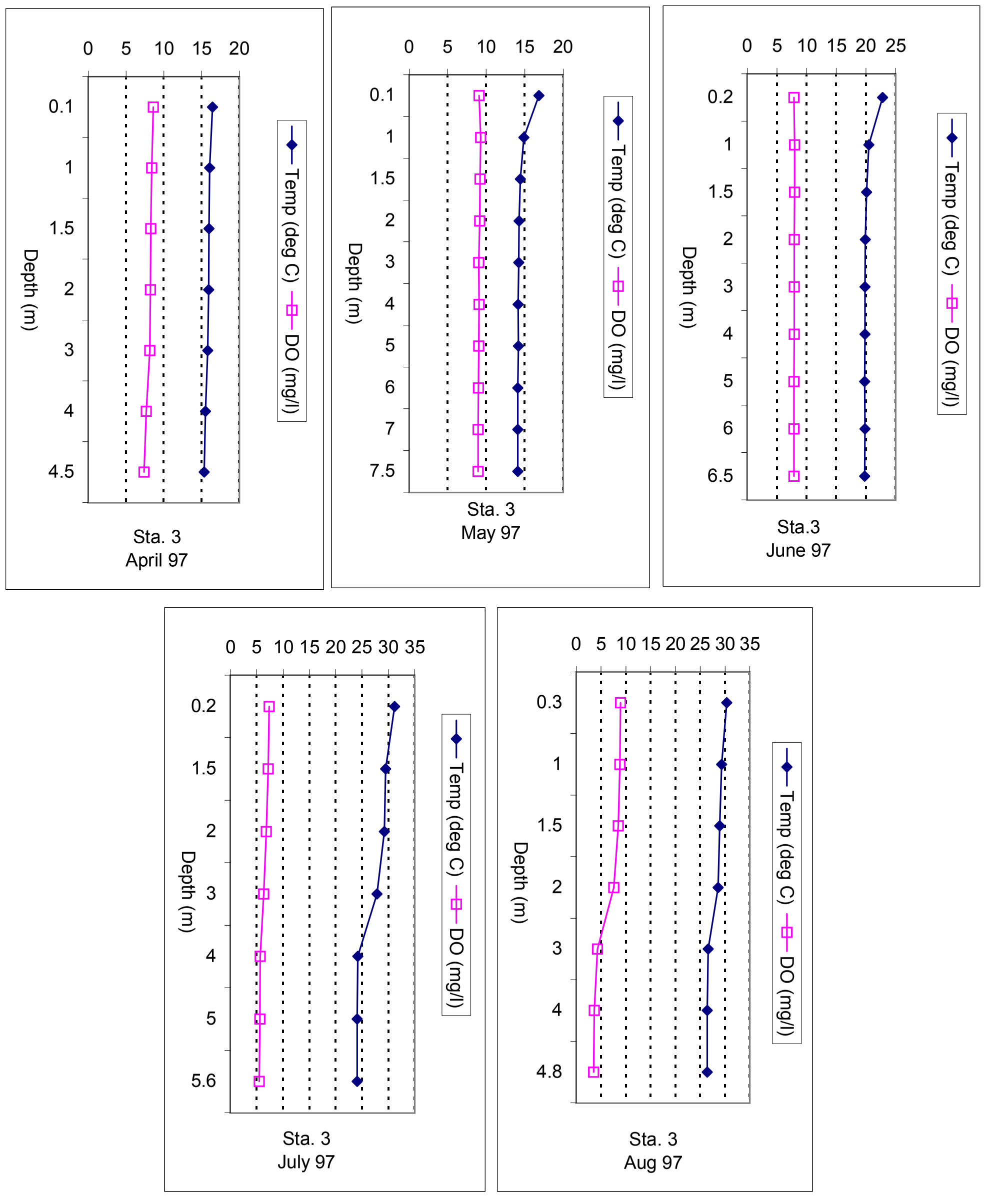


Figure 9. Temperature (Temp) and dissolved oxygen (DO) profile graphs for Brushy Creek embayment Station 3, April - August 1997.

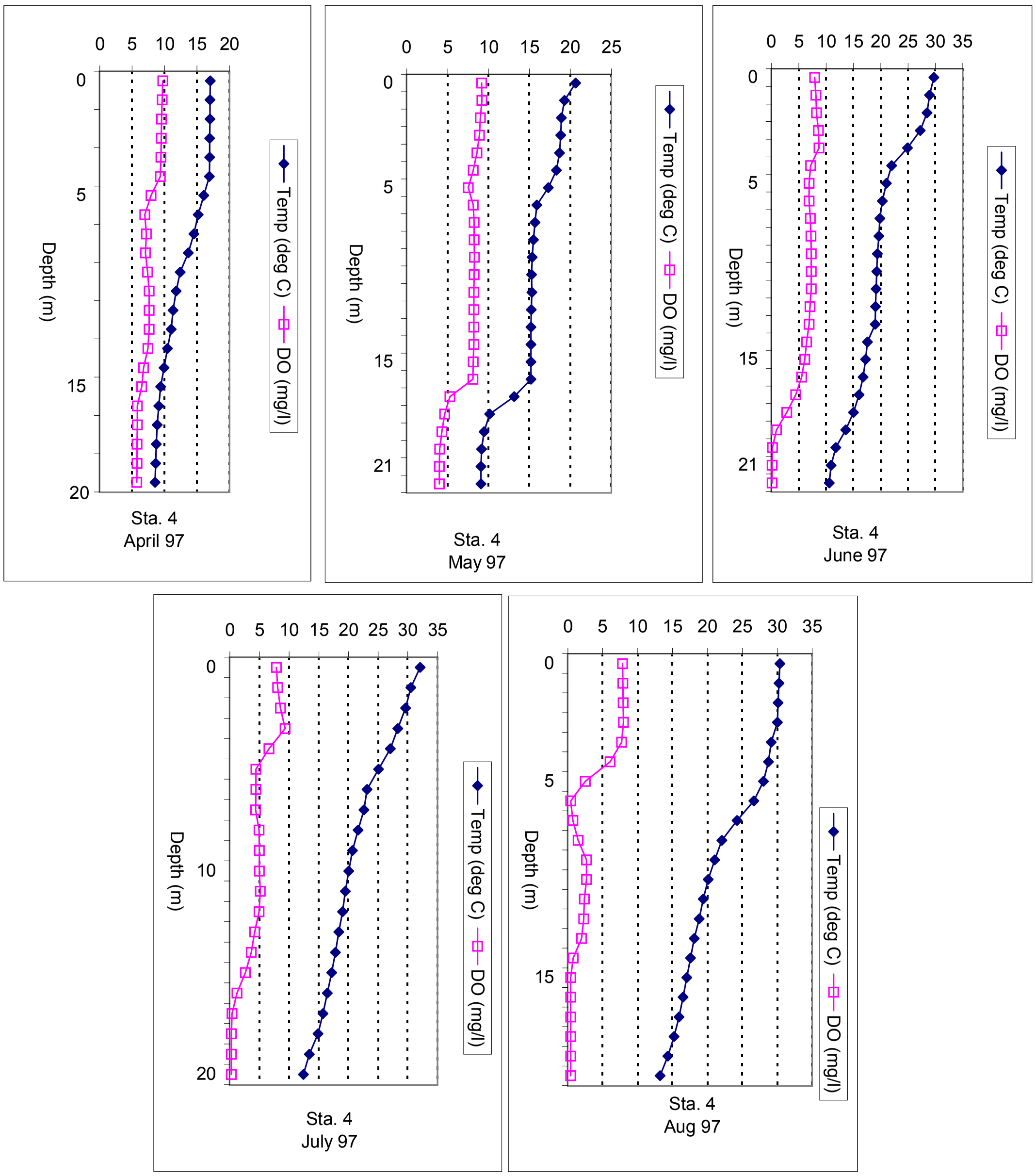


Figure 10. Temperature (Temp) and dissolved oxygen (DO) profile graphs for Brushy Creek embayment Station 4, April - August 1997.

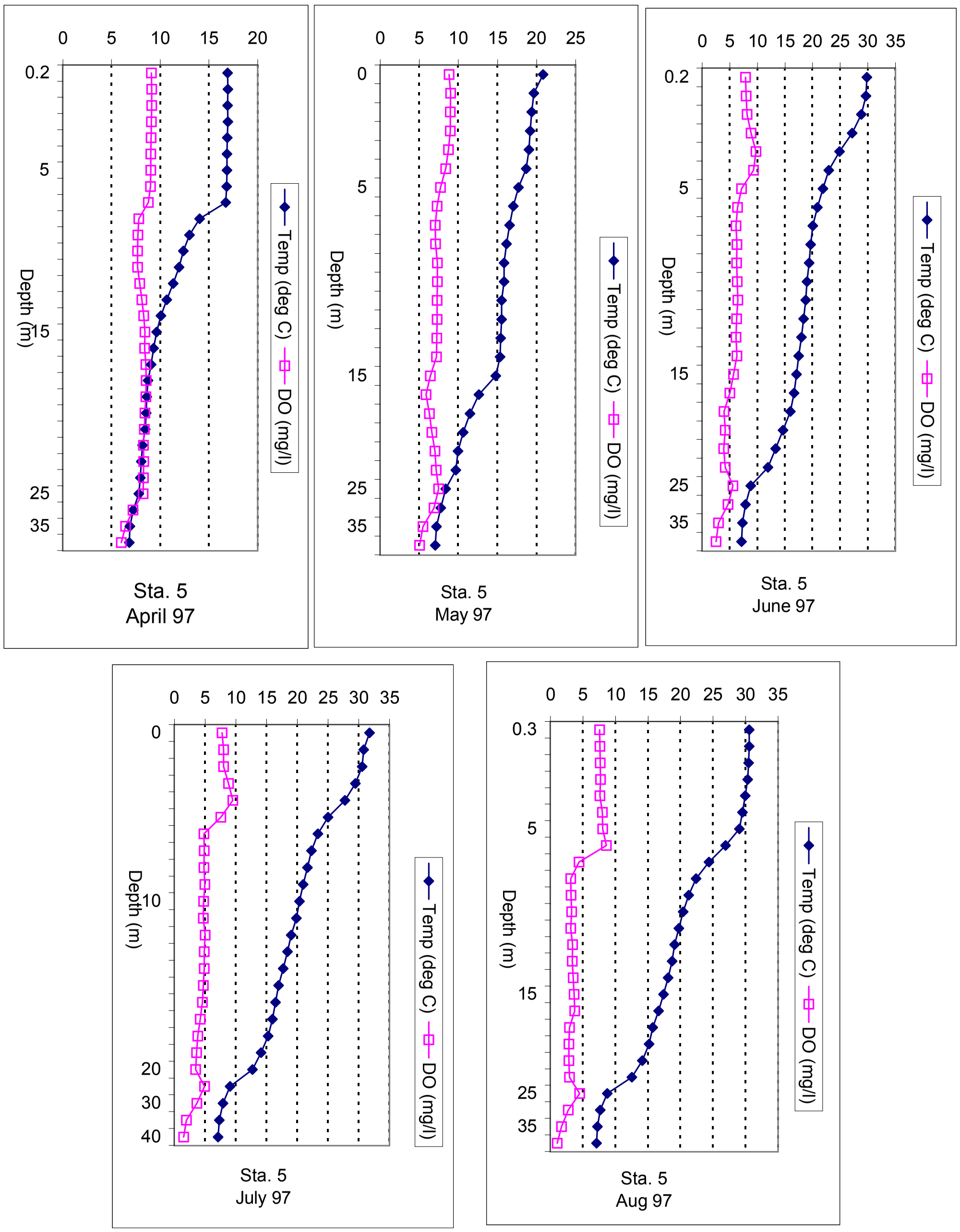


Figure 11. Temperature (Temp) and dissolved oxygen (DO) profile graphs for Brushy Creek embayment Station 5, April - August 1997.

remained oxygenated on all dates sampled with DO concentrations at 35 meters depth dropping below 2 mg/l from July through August.

Turbidity-Total Suspended Solids-Light Penetration

Turbidity and total suspended solids (TSS) were highest in the upper embayment during the spring and summer seasons (Tables 13, 14). Turbidity at all locations was higher in spring than summer. TSS was similar or higher in summer than spring at all locations.

Light penetration as measured by mean Secchi disk measurements was generally greater in the lower embayment during the spring and summer seasons (Tables 15, 16). Light penetration increased from spring to summer at all but the uppermost embayment location. The lower limit of the photic zone was usually two to three times the Secchi visibility depth at all locations.

Alkalinity-Hardness-pH

Total alkalinity, the concentration of bases in water that are primarily composed of bicarbonate (HCO_3^-) and carbonate ($CO3^=$) ions, usually increases as basin soil fertility increases. In a recent study, total alkalinity of large reservoirs in Alabama varied from a low of 7 mg/l to 67 mg/l (Bayne et al. 1989). Total alkalinity concentrations of Brushy Creek embayment stations ranged from 8 mg/l during the spring to 18 mg/l during the summer indicating that the soils of the watershed are relatively infertile and low in soluble forms of carbonates. Mean spring alkalinity concentrations were lowest in the upper embayment and increased with each downstream station (Table 17). Mean summer alkalinity concentrations were highest in the upper embayment and decreased downstream (Table 18).

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 in soils of the United States and are generally associated with carbonate minerals responsible for alkalinity of water. Therefore, total alkalinity and total hardness concentrations in water

Table 13. Mean (range) turbidity and total suspended solids (TSS) measured at each Brushy Creek embayment station during spring (April, May) 1997.

Stations	Turbidity NTU	TSS mg/l
2	9.0 (11.3 - 7.8)	2.0 (2.0 - 2.0)
3	13.2 (13.7 - 12.7)	5.5 (6.0 - 5.0)
4	7.77 (11.9 - 3.6)	2.5 (4.0 - 1.0)
5	4.38 (5.4 - 3.4)	0.5 (0.5 - 0.5)

Table 14. Mean (range) turbidity and total suspended solids (TSS) measured at each Brushy Creek embayment station during summer (June, July, August) 1997.

Stations	Turbidity NTU	TSS mg/l
2	7.8 (10.3 - 5.8)	6.8 (11.0 - 2.0)
3	10.4 (16.9 - 6.6)	5.7 (8.0 - 3.0)
4	3.5 (4.2 - 3.0)	2.3 (5.0 - 1.0)
5	2.8 (3.4 - 2.3)	1.2 (2.0 - 0.5)

Table 15. Mean (range) Secchi disk visibility and 1% incident light depth at each Brushy Creek embayment station during spring (April, May) 1997.

Stations	Secchi (m)	Photic zone (m)
2	1.57 (1.82 - 1.11)	2.88 (3.98 - 2.33)
3	0.90 (0.90 - 0.89)	3.00 (3.52 - 2.48)
4	1.97 (2.75 - 1.18)	4.74 (6.16 - 3.32)
5	2.12 (2.69 - 1.55)	6.61 (7.53 - 5.68)

Table 16. Mean (range) Secchi disk visibility and 1% incident light depth at each Brushy Creek embayment station during summer (June, July, August) 1997

Stations	Secchi (m)	Photic zone (m)
2	1.48 (1.99 - 1.15)	2.98 (4.10 - 1.80)
3	1.37 (1.55 - 1.11)	3.48 (3.75 - 3.12)
4	2.61 (2.72 - 2.41)	5.98 (6.85 - 5.34)
5	3.05 (3.33 - 2.82)	6.90 (7.49 - 6.10)

Table 17. Mean (range) pH, alkalinity, and hardness measured at each Brushy Creek embayment station during spring (April, May) 1997.

Stations	pH** (s.u.)	Alkalinity mg/l	Hardness mg/l
2	6.32 (6.46 - 6.05)	9.7 (11.0 - 8.0)	9.6 (10.3 - 8.4)
3	6.07 (6.21 - 5.92)	10.0 (12.0 - 8.0)	9.5 (11.2 - 7.8)
4	6.42 (6.43 - 6.40)	10.5 (11.0 - 10.0)	10.2 (10.9 - 9.5)
5	6.48 (6.57 - 6.39)	12.5 (14.0 - 11.0)	12.35 (13.6 - 11.1)

** measured at a depth of 1.5m (5ft).

Table 18. Mean (range) pH, alkalinity, and hardness measured at each Brushy Creek embayment station during summer (June, July, August) 1997.

Stations	pH** (s.u.)	Alkalinity mg/l	Hardness mg/l
2	6.45 (6.57 - 6.40)	14.2 (18.0 - 10.0)	11.5 (15.0 - 8.7)
3	6.78 (7.58 - 6.37)	12.3 (14.0 - 10.0)	10.7 (12.5 - 8.4)
4	7.47 (7.54 - 7.35)	12.7 (13.0 - 12.0)	11.7 (12.4 - 11.2)
5	7.42 (7.84 - 7.17)	12.3 (13.0 - 12.0)	11.5 (12.4 - 10.6)

** measured at a depth of 1.5m (5ft).

are usually similar and tend to vary together. Mean spring total hardness values generally followed this pattern and increased at downstream embayment stations, as did total alkalinity (Table 17). Mean summer total hardness concentrations did not follow the pattern of total alkalinity and were more variable (Table 18).

Carbonate minerals function as natural chemical buffers that prevent wide fluctuations in pH of lake water. The low alkalinity of waters in the Brushy Creek embayment resulted in a pH range of 5.92 to 6.57 during the spring and 6.37 to 7.84 inthe summer (Tables 17, 18). Mean spring pH values were generally similar at all locations. Mean summer pH values were generally higher at the lower embayment stations. Values increased from spring to summer at each station.

Nutrients

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 the element most often limiting to plant growth in freshwater ecosystems.

Nitrogen is available to plants as nitrates (NO_3^-) or as the ammonium ion (NH_4^+). Spring mean ammonia concentrations in the Brushy Creek embayment were generally higher at the upper embayment stations (Table 19). Summer mean ammonia concentrations were similar at all embayment stations (Table 20). Summer mean ammonia concentrations at the upper embayment stations were much lower than those of the spring season.

Total Kjeldahl nitrogen (TKN) is the sum of organic nitrogen and ammonia. In unpolluted lakes, density of plankton communities largely determines the amount of organic matter present in surface waters. Mean TKN concentrations in the Brushy Creek embayment were much lower in the spring season than in the summer season (Tables 19, 20) as were measurements of algal biomass (chlorophyll a). Highest summer mean TKN concentrations occurred in the upper embayment.

Table 19. Mean (range) ammonia (NH_3-N), nitrate+nitrite (NO_3+NO_2), total Kjeldahl nitrogen (TKN), total phosphorus, and dissolved reactive phosphorus measured at each Brushy Creek embayment station during spring (April, May) 1997.

Stations	NH_3-N mg/l	NO_3+NO_2 mg/l	TKN mg/l	Total Phosphorus mg/l	Dissolved Phosphorus mg/l
2	0.045 (0.120 - 0.008)	0.150 (0.150 - 0.150)	0.075 (0.075 - 0.075)	0.038 (0.090 - 0.004)	0.005 (0.009 - 0.003)
3	0.024 (0.040 - 0.008)	0.192 (0.233 - 0.150)	0.075 (0.075 - 0.075)	0.080 (0.100 - 0.060)	0.008 (0.011 - 0.005)
4	0.008 (0.008 - 0.008)	0.115 (0.140 - 0.090)	0.075 (0.075 - 0.075)	0.085 (0.090 - 0.080)	0.007 (0.007 - 0.006)
5	0.008 (0.008 - 0.008)	0.116 (0.141 - 0.090)	0.075 (0.075 - 0.075)	0.075 (0.080 - 0.070)	0.008 (0.009 - 0.007)

Table 20. Mean (range) ammonia (NH_3-N), nitrate+nitrite (NO_3+NO_2), total nitrogen, total phosphorus, and dissolved reactive phosphorus measured at each Brushy Creek embayment station during summer (June, July, August) 1997.

Stations	NH_3-N mg/l	NO_3+NO_2 mg/l	TKN mg/l	Total Phosphorus mg/l	Dissolved Phosphorus mg/l
2	0.008 (0.008 - 0.008)	0.104 (0.130 - 0.040)	0.135 (0.250 - 0.075)	0.069 (0.140 - 0.002)	0.003 (0.005 - 0.001)
3	0.008 (0.008 - 0.008)	0.060 (0.100 - 0.030)	0.257 (0.620 - 0.075)	0.058 (0.140 - 0.014)	0.003 (0.005 - 0.002)
4	0.008 (0.008 - 0.008)	0.043 (0.050 - 0.040)	0.103 (0.160 - 0.075)	0.067 (0.140 - 0.021)	0.003 (0.004 - 0.002)
5	0.008 (0.008 - 0.008)	0.047 (0.060 - 0.040)	0.152 (0.200 - 0.075)	0.069 (0.140 - 0.016)	0.003 (0.004 - 0.002)

Phosphorus in water is commonly reported as total phosphorus (TP) (all forms of phosphorus expressed as P) and dissolved reactive phosphorus (DRP). The major component of DRP is orthophosphate (PO_4^{3-} expressed as P), the most common and available form of phosphorus available to plants. During the spring season, mid-embayment stations had the highest TP concentrations with little difference between stations apparent in summer mean concentrations (Tables 19, 20). With the exception of the uppermost embayment station, spring mean TP and DRP concentrations were higher than summer mean concentrations.

Algal Biomass

Phaeophytin-corrected chlorophyll a concentration is an indicator of algal, or phytoplankton, biomass and is a variable often used to determine the trophic status of lakes in the absence of macrophytes (Carlson 1977 and USEPA 1990). It is a variable that integrates the physical, chemical, and biological environmental components into one expression of biotic response. Therefore, chlorophyll a concentration is superior to simple physical (water transparency) or chemical (nutrients) variables used to characterize trophic status (Hern et al. 1981). Corrected chlorophyll a concentrations of about 6.4 to 56 ug/l are indicative of eutrophic waters (Carlson 1977). Waters with concentrations > 56.0 ug/l are considered hypereutrophic while waters with concentrations of 1.0 to < 6.4 ug/l are classified as mesotrophic.

Spring mean chlorophyll a concentrations for all except the uppermost embayment stations were within the mesotrophic range (Table 21). Summer mean chlorophyll a concentrations were higher than in spring and with the exception of the uppermost embayment station, all within the eutrophic range (Table 22). During the spring season, highest mean concentrations occurred in the lower embayment. During the summer season highest mean concentrations were more centrally located.

Total organic carbon (TOC) concentrations are composed of dissolved and particulate fractions with the ratio of dissolved to particulate ranging from 6:1 to 10:1 in most unpolluted lakes (Wetzel 1983). Most of the particulate fraction is composed of

Table 21. Mean (range) total organic carbon, chlorophyll a, trophic state index, and fecal coliforms measured at each Brushy Creek embayment station during spring (April, May) 1997.

Stations	Total Organic Carbon mg/l	Chlorophyll a ug/l	Fecal coliforms per 100ml
2	1.74 (1.87 - 1.62)	0.30 (0.80 - 0.05)	29 (38 - 20)
3	2.15 (2.42 - 1.87)	1.61 (2.14 - 1.07)	59 (63 - 55)
4	1.90 (2.30 - 1.50)	5.07 (7.74 - 2.40)	22 (43 - 1)
5	2.04 (2.27 - 1.80)	3.87 (4.54 - 3.20)	5 (9 - 1)

Table 22. Mean (range) total organic carbon, chlorophyll a, trophic state index, and fecal coliforms measured at each Brushy Creek embayment station during summer (June, July, August) 1997.

Stations	Total Organic Carbon mg/l	Chlorophyll a ug/l	Fecal coliforms per 100ml
2	1.36 (2.62 - 0.25)	1.19 (2.14 - 0.05)	21 (48 - 1)
3	1.49 (2.96 - 0.25)	7.88 (15.7 - 0.05)	5 (13 - 1)
4	1.37 (2.37 - 0.67)	7.09 (7.83 - 5.61)	1 (1 - 1)
5	1.23 (2.37 - 0.50)	6.73 (7.01 - 6.41)	1 (1 - 1)

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 temporally and spatially. TOC concentrations in the Brushy Creek embayment varied only slightly from station to station in either season though mean concentrations in the summer were lower than those of the spring (Tables 21, 22).

Algal Growth Potential Tests

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). In control samples, maximum algal standing crop (MSC) dry weights that are below 5.0 mg/l are thought to assure protection from nuisance phytoplankton blooms and fish-kills in southeastern lakes, with the exception of lakes in Florida (Raschke and Schultz 1987). Mean maximum algal standing crop dry weights above 10.0 mg/l indicate highly productive waters that may be subject to nuisance blooms.

Growing season mean maximum algal standing crop dry weights in the Brushy Creek embayment were well below 5.0 mg/l on all dates sampled (Table 23). Highest overall mean dry weights occurred at the mid-embayment stations.

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 the Brushy Creek embayment, phosphorus was the limiting or co-limiting nutrient at all sampling stations on all occasions with the exception of the mid-embayment stations during August (Table 23). Internal phosphorus loading caused by the release of phosphorus from anaerobic sediments as the growing season progresses may be partly responsible for the increase in the influence of nitrogen later in the growing season.

Table 23. Algal Growth Potential Testing (AGPT) of Brushy Creek Embayment.

Station	Date	Mean MSC (mg/l) C	C+N	C+P	Limiting Nutrient
BRSH-2	6/26/97	2.33	2.32	**6.16**	Phosphorus
BRSH-2	7/17/97	1.34	**1.81**	**9.38**	Phosphorus
BRSH-2	8/7/97	1.31	1.25	**7.34**	Phosphorus
BRSH-3	6/26/97	1.6	1.74	**6.17**	Phosphorus
BRSH-3	7/17/97	3.05	1.96	1.93	Co-limiting
BRSH-3	8/7/97	3.45	**10.62**	3.29	Nitrogen
BRSH-4	6/26/97	1.78	1.79	**3.46**	Phosphorus
BRSH-4	7/17/97	2.91	1.44	2.22	Co-limiting
BRSH-4	8/7/97	1.83	**2.47**	1.87	Nitrogen
BRSH-5	6/26/97	1.46	1.67	**1.78**	Phosphorus
BRSH-5	7/17/97	1.93	1.27	**3.01**	Phosphorus
BRSH-5	8/7/97	1.22	1.16	**1.75**	Phosphorus

MSC = Maximum Standing Crop
C = Control; C+N = Control + Nitrogen; C+P = Control + Phosphorus
Values in **bold** print are significantly different from control.

Fecal Coliform Concentrations

Fecal coliform bacteria are defined as the bacteria of the coliform group that originate from the intestines of warm-blooded animals (Welch 1992) and serve as indicators of the presence of human or animal wastes.

Waters of the Brushy Creek embayment are use-classified Public Water Supply (PWS)/Fish and Wildlife (F&W) from the Brushy Creek embayment confluence with the Sipsey Fork to US Hwy. 278 (ADEM 1997). This area of the Brushy Creek embayment encompasses Stations 3-5. From Hwy. 278 to its source, Brushy Creek is use-classified Fish and Wildlife. Station 2 lies within this portion of the Brushy Creek embayment.

ADEM Water Quality Criteria for PWS use-classifications require that bacteria of the fecal coliform group not exceed a geometric mean of 2,000/100ml on a monthly average value nor exceed a maximum of 4,000/100 ml in any sample. ADEM Criteria for F&W use-classifications require that bacteria of the fecal coliform group not exceed a geometric mean of 1,000/100ml on a monthly average nor a maximum of 2,000/100 ml in any sample. From June through September, geometric mean fecal coliform density cannot exceed 200/100ml in PWS or F&W use-classifications.

Fecal coliform density at all embayment stations was well within ADEM Criteria limits on all dates sampled with a high value of 63 recorded at Station 3 during the spring (Tables 21, 22). Spring mean fecal coliform density was higher at all locations than summer mean values, as was expected with heavier rainfall and runoff during the spring season.

Literature Cited

Alabama Department of Environmental Management (ADEM). 1987. Water quality study of Lewis Smith Lake. 140 pp.

Alabama Department of Environmental Management (ADEM) Field Operations Division. 1992 b. Standard operating procedures and quality control assurance manual - vol. II. Freshwater macroinvertebrate biological monitoring.

Alabama Department of Environmental Management (ADEM) Field Operations Division. 1993b. Standard operating procedures and quality control assurance manual - vol. V. Algal growth potential testing.

Alabama Department of Environmental Management (ADEM) Field Operations Division. 1996. ADEM Reservoir Water Quality Monitoring Program Report 1990-1995. 307 pp.

Alabama Department of Environmental Management (ADEM) Field Operations Division. 1996. ADEM Field Operations Standard Operating Procedures and Quality Control Assurance Manual, Volume II – Freshwater Macroinvertebrate Biological Monitoring.

Alabama Department of Environmental Management (ADEM) Water Division. 1997. Water Quality Criteria. Water Quality Program. Chapter 335-6-10. 54pp.

Alabama Department of Environmental Management (ADEM). 1997f. Analysis criteria for the MB-EPT aquatic macroinvertebrate bioassessment technique (Draft). Field Operations Division, Alabama Department of Environmental Management, Montgomery, AL.

Alabama Department of Environmental Management (ADEM) Field Operations Division. 1998. Lewis Smith Lake Phase I Diagnostic/Feasibility Study Final Report. 166 pp.

American Public Health Association, American Water Works Association and Water Pollution Control Federation. 1985. Standard methods for the examination of water and wastewater. 16th ed. APHA, Washington, D.C.

Barbour, M.T. and J.B. Stribling. 1994. A technique for assessing stream habitat structure. Conference proceedings, Riparian ecosystems in the humid U.S.: Functions, values, and management. National Association of Conservation Districts. Washington, D.C. March 15-18, 1993, Atlanta, GA. Pages 156-178.

Literature Cited (cont'd)

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

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

Deutsch, W.G., W.C. Seesock, E.C. Webber, and D.R. Bayne. 1990. The impact of poultry rearing operations on water quality and biological communities of second order streams in Cullman and Winston counties, Alabama, 1988-89. Department of Fisheries and Allied Aquacultures, Auburn University, Alabama.

Glysson, D.G. and T.K. Edwards. 1988. Field methods for measurement of fluvial sediment. Open-File report 86-351, United States Geological Survey. Reston, Virginia.

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.

Lind, O.T. 1979. Handbook of common methods in limnology. The C.V. Mosby Co., St. Louis, Missouri. 199 pp.

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

SAS. 1990. SAS/STAT user's guide. Version 6. 4th edition. SAS Institute Inc. Cary, North Carolina.

U.S. Environmental Protection Agency. 1983. Methods for the chemical analysis of water and wastes. Environmental Monitoring and Support Laboratory, Cincinnati, Ohio. EPA-600/4-79-020.

U.S. Environmental Protection Agency. 1990. The lake and reservoir restoration guidance manual. 2nd edition. EPA-440/4-90-006. U.S.E.P.A. Office of Water. Washington, D.C. 326 pp.

Literature Cited (cont'd)

Walker, W.W. 1996. Simplified procedures for eutrophication assessment and prediction: User manual, Instruction Report W-96-2. U.S. Army Corps of Engineers Waterways Experiment Station. Vicksburg, Mississippi.

Welch, E.B. 1992. Ecological Effects of Wastewater. 2nd edition. Chapman and Hall Publishers. London, England. 425 pp.

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

Appendix

Appendix Table 1. Taxa lists of samples collected at Beech Creek (BEEW-1), Brushy Creek (BRUW-14f and BRSH-1), Capsey Creek (CPSY-1), and Rush Creek (RUSW-1), July 15-16, 1997.

	Station				
	BEEW-1	BRSH-1	BRUW-14f	CPSY-1	RUSW-1
ARTHROPODA					
INSECTA					
EPHEMEROPTERA					
Baetidae					
Acentrella	6		6	108	6
Acerpenna	26				
Apobaetis					1
Baetis		12		102	
Centroptilum	10	9		11	3
Fallceon	30	17	12	28	6
Paracloeodes	1			1	
Baetidae UNID dif			6	8	
Baetidae UNID	9	11	19		25
Ephemerellidae					
Ephemerella		4			
Eurylophella	2	7	12	1	17
Ephemeridae					
Ephemera		1			
Hexagenia		2			
Heptageniidae					
Cinygmula				2	
Stenacron		17	1	3	4
Stenonema	160	22	65	32	74
Heptageniidae UNID	1	1	7	6	
Isonychidae					
Isonychia	36		12		
Leptophlebiidae					
Habrophlebiodes	2		17		
Paraleptophlebia					2
Tricorythidae					
Tricorythodes		2			
PLECOPTERA					
Leuctridae					
Leuctra	48	8	58	1	4

Appendix Table 1. Taxa lists of samples collected at Beech Creek (BEEW-1), Brushy Creek (BRUW-14f and BRSH-1), Capsey Creek (CPSY-1), and Rush Creek (RUSW-1), July 15-16, 1997.

	Station				
	BEEW-1	BRSH-1	BRUW-14f	CPSY-1	RUSW-1
Perlidae					
Acroneuria	24	39	50	13	91
Neoperla		4		6	12
Perlesta	12	1			
Perlidae Unid dif			1		
TRICHOPTERA					
Brachycentridae					
Brachycentrus			1		6
Calamoceratidae					
Anisocentropus			6		8
Heteroplectron					2
Glossosomatidae					
Glossosoma			2	18	21
Helicopsychidae					
Helicopsyche				2	
Hydropsychidae					
Ceratopsyche/Symphit	1	30	33	130	24
Cheumatopsyche	253	34	18	100	42
Diplectrona	24		6		6
Hydropsyche	42	13	24	25	36
Hydropsychidae UNID	12		17		78
Lepidostomatidae					
Lepidostoma	1				
Leptoceridae					
Mystacides		2		12	1
Nectopsyche		1			
Oecetis	1				
Limnephilidae					
Pycnopsyche		4	5	6	3
Limnephilidae UNID			8		
Philopotamidae					
Chimarra	6	9	7	24	6
Dolophilodes			24	30	

Appendix Table 1. Taxa lists of samples collected at Beech Creek (BEEW-1), Brushy Creek (BRUW-14f and BRSH-1), Capsey Creek (CPSY-1), and Rush Creek (RUSW-1), July 15-16, 1997.

	Station				
	BEEW-1	BRSH-1	BRUW-14f	CPSY-1	RUSW-1
Polycentropodidae					
Cernotina		14			
Paranyctiophylax	1				
Phylocentropus	1	2			
Polycentropus	1		4	4	
Polycentropodidae UNID dif				6	
Psychomyiidae					
Lype	3		3	1	2
Rhyacophilidae					
Rhyacophila			6		
DIPTERA					
CHIRONOMIDAE					
Chironominae					
Chironomini					
Cryptochironomus	2	2			1
Cryptotendipes	1				
Dicrotendipes	3	2			
Microtendipes	11	4	12	2	2
Nilothauma	7	2	3		
Omnisus			1	4	
Paracladopelma	3	1	10		
Paralauterborniella				1	1
Phaenopsectra	3	3	9	104	2
Polypedilum	85	69	216	171	132
Stenochironomus	2	1			1
Stictochironomus	2			1	1
Tribelos		9	5	9	
Xenochironomus		1			
Chironomini UNID	2	1		4	
Pseudochironomini					
Pseudochironomus			1		

Appendix Table 1. Taxa lists of samples collected at Beech Creek (BEEW-1), Brushy Creek (BRUW-14f and BRSH-1), Capsey Creek (CPSY-1), and Rush Creek (RUSW-1), July 15-16, 1997.

	Station				
	BEEW-1	BRSH-1	BRUW-14f	CPSY-1	RUSW-1
Tanytarsini					
Cladotanytarsus	8	1	3	6	
Microspectra	1		66	12	30
Rheotanytarsus	282	114	120	177	53
Stempellinella	1			2	1
Sublettea	8				
Tanytarsus	54	21	38	9	
Orthocladinae					
Brillia	5	2	1	1	8
Cardiocladius		39		12	
Corynoneura			6		
Cricotopus	11	18	7	14	
Cricotopus/Orthocladi	25	5	12	27	
Limnophyes		1			
Lopescladius		21	18	7	30
Nanocladius	1	2	6		
Parachaetocladius	13	1	6		12
Parametriocnemus	45	18	193	13	26
Psectrocladius	1				
Rheocricotopus	75	51	184	7	37
Rheosmittia	1		7	1	
Stilocladius	3				
Symposiocladius	1	1	2	2	
Thienemanniella	2	14	42	15	
Tvetnia	13	21	21	27	6
Xylotopus	1	1	1		1
Orthocladinae UNID	1		6		
Tanypodinae					
Ablabesmyia	6	14	11	7	13
Djalmabatista				1	
Natarsia				1	
Paramerina	1				
Pentaneura			6		
Procladius		1			
Thienemannimyia Grp	39	21	47	16	1
Tanypodinae UNID				4	

CHIRONOMIDAE UNID					1
Athericidae					

Appendix Table 1. Taxa lists of samples collected at Beech Creek (BEEW-1), Brushy Creek (BRUW-14f and BRSH-1), Capsey Creek (CPSY-1), and Rush Creek (RUSW-1), July 15-16, 1997.

	Station				
	BEEW-1	BRSH-1	BRUW-14f	CPSY-1	RUSW-1
Atherix	6		4	11	18
Ceratopogonidae					
Bezzia	1	4			
Dixidae					
Dixa	1	1	3	1	1
Dixella		1			
Empididae					
Chelifera	1				
Hemerdromia	8			6	
Empididae UNID dif	1				
Simulidae	49	60	11	306	37
Tabanidae					
Tabanidae UNID dif	6	1			
Tipulidae					
Antocha	8		7	24	
Dicranota	12		1	6	
Hexatoma			6		
Pilaria	6				
Pseudolimnophila					1
Tipula					1
Tipulidae UNID dif			6		
COLEOPTERA					
Dryopidae					
Helichus	10		8		4
Dytiscidae					
Agabus		1			
Copelatus				2	
Hydroporus		1	1	1	
Laccophilus	2			2	
Lioporeus	4	5		6	4
Dytiscidae UNID	4				

Appendix Table 1. Taxa lists of samples collected at Beech Creek (BEEW-1), Brushy Creek (BRUW-14f and BRSH-1), Capsey Creek (CPSY-1), and Rush Creek (RUSW-1), July 15-16, 1997.

	Station				
	BEEW-1	BRSH-1	BRUW-14f	CPSY-1	RUSW-1
Elmidae					
Ancyronyx	9	7	1		1
Dubiraphia	39	29	46	32	33
Macronychus	1	12	3	5	1
Microcylloepus		5	1	24	
Optioservus	135	40	169	178	304
Oulimnius			30	6	18
Stenelmis	116	44	174	94	217
Elmidae UNID			6		
Gyrinidae					
Dineutus	18	11	4	38	7
Gyrinus	7	4		7	
Haliplidae					
Haliplus	1	1			
Peltodytes	3				1
Hydrophilidae					
Berosus		3			1
Enochrus	2				
Hydrobius	1				
Hydrochus		3		5	
Psephenidae					
Ectopria	10	4	6	1	
Psephenus			6	1	6
Ptilodactylidae					
Anchytarsus		19	4	4	43
HEMIPTERA					
Gerridae					
Trepobates			1		
Nepidae					
Ranatra		2			
Veliidae					
Microvelia		3		1	2
Rhagovelia					1

Appendix Table 1. Taxa lists of samples collected at Beech Creek (BEEW-1), Brushy Creek (BRUW-14f and BRSH-1), Capsey Creek (CPSY-1), and Rush Creek (RUSW-1), July 15-16, 1997.

	Station				
	BEEW-1	BRSH-1	BRUW-14f	CPSY-1	RUSW-1
MEGALOPTERA					
Corydalidae					
Corydalus		9		9	
Nigronia	41		6	15	19
Corydalidae UNID		4			
Sialidae					
Sialis	5	11	1	1	
ODONATA					
Aeshnidae					
Basiaeschna		2			
Boyeria	17	7	8	8	7
Calopterygidae					
Hetaerina	5	3		1	3
Coenagrionidae					
Argia	2				2
Ischnura	1	1			
Coenagrionidae UNID dif		3		2	
Coenagrionidae UNID	1				
Cordulegastridae					
Cordulegaster			6		3
Corduliidae					
Macromia	2	3		2	1
Neurocordulia	1	4	1		2
Corduliidae/Libellulidae					
Corduliidae/Libellulidae Unid dif					7
Corduliidae/Libellulidae UNID		1	3		
Gomphidae					
Dromogomphus		22		13	3
Gomphus				52	
Hagenius		1	1		
Progomphus			2		
Stylurus	61		2		2
Gomphidae UNID dif					37
Gomphidae UNID		4	23	1	

Appendix Table 1. Taxa lists of samples collected at Beech Creek (BEEW-1), Brushy Creek (BRUW-14f and BRSH-1), Capsey Creek (CPSY-1), and Rush Creek (RUSW-1), July 15-16, 1997.

	Station				
	BEEW-1	BRSH-1	BRUW-14f	CPSY-1	RUSW-1
CRUSTACEA					
AMPHIPODA					
Talitridae					
Hyalella			5	10	
DECAPODA					
Cambaridae	1	4		2	2
ISOPODA					
Asellidae					
Lirceus	6	1	2	7	
ANNELIDA		4		1	
HIRUDINEA					
HIRUDINEA UNID dif		5			
OLIGOCHAETA	3	2	26	6	2
MOLLUSCA					
GASTROPODA					
LIMNOPHILA					
Ancylidae					
Laevapex	1				
Planorbidae					
Helisoma				1	
Planorbella	1				
MESOGASTROPODA					
Pleuroceridae	4	68	13	67	63
PELECYPODA					
HETERODONTA					
Corbiculidae					
Corbicula		25			6
Sphaeriidae	12		4	1	6
Unionidae				1	