The Development of a Water Quality Monitoring Protocol at Caddo Lake, a Ramsar Wetland

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Roy Darville and Dwight Shellman
East Texas Baptist University and Caddo Lake Institute

Introduction

Caddo Lake, a forested bald cypress wetland, is located in northeast Texas and northwest Louisiana. In recent years the lake has enjoyed increased attention and protection. The lake has been classified as a Resource Category 1 Habitat by the U.S. Fish & Wildlife Service and in October, 1993, 6500 acres was declared the U.S.'s 13th Wetland of International Importance by the Ramsar Convention (Fig. 1). Caddo Lake Institute (the "Institute") supported the nomination of Caddo Lake as a Rarnsar wetland. The Rarnsar Convention is an intergovernmental treaty that provides a framework for international cooperation for the conservation of wetland habitats. Currently, 101 countries are members of the convention with 872 wetlands world-wide designated as Ramsar wetlands. The Caddo Lake Ramsar wetland is a wildlife management area managed by the Texas Parks and Wildlife Department.

Though Caddo Lake has a surface area of over 30,000 acres, it is shallow with an average depth of one meter and maximum depth of about three meters. There are three major habitat types at Caddo Lake -- riverine, wetland, and open water. Approximately one-third of the lake is dominated by a bald cypress swamp, while the remainder is more open water with interspersed baldcypress islands. The riverine habitat is represented by several major tributaries that enter the lake from the north (Kitchen Creek and James Bayou), west (Big Cypress Bayou), and south (Harrison Bayou), At the east end of the lake is a U.S. Army Corps of Engineers constructed dam which maintains the water at 168.5 feet above MSL. Recent studies of the lake and its watershed by the Texas Parks and Wildlife Department (Campo, 1986), U.S. Fish and Wildlife Service (Cloud, 1993) and the Institute (Shellman and Darville, 1995) suggest that the lake supports a very high biodiversity. The lake is also important in the region for economic benefits gained from tourism, nature-related activities, hunting, fishing, and other activities.

Monitoring of Caddo Lake

During the past 50 years sporadic ecological monitoring has occurred at Caddo Lake by state (Texas Natural Resources Conservation Commission, Louisiana Department of Environmental Quality), national agencies (U.S. Environmental Protection Agency, U S

Army Corps of Engineers, U.S. Geological Survey, National Wetlands Research Center), and universities (East Texas Baptist University, Wiley College, Stephen F. Austin State University, and Louisiana State University in Shreveport), and the institute. The only consistent monitoring by agencies has been water quality by the Texas Natural Resource Conservation Commission (TNRCC, 1995) but this is generally done only once per year at only one open water site.

In addition to water quality monitoring, personnel from the National Wetlands Research Center and the Institute began a bald cypress monitoring project three years ago at the lake (Keeland et al. 1996). Since the 1940s Texas Parks and Wildlife Department fisheries personnel have done fish species and creel surveys, but due to funding limitations, these are done on an irregular basis. Recently annotated checklists for the birds (Ingold, 1995) amphibians and reptiles (Hardy, 1995) have been prepared for the Caddo Lake watershed in Texas and Louisiana. Only in the past several years has an extensive floristic study of the lake been done. Botanists fi-om Stephen F. Austin State University identified 450 species of herbaceous and woody plants in Caddo Lake State Park and Wildlife Management Area (Hine and Van Kley, 1994) .

Monitoring of Ramsar wetlands to detect ecological change is recommended by the Ramsar Convention (Davis, 1994). Resolution VI. 1, adopted at Brisbane, Australia in March 1996, calls on contracting parties to support the development of early warning systems for detecting, and initiating action in response to change in ecological character of Ramsar wetlands, The resolution goes on to require that change in the ecological character of a listed site should be assessed against the baseline status presented in the Tnformation Sheet on Ramsar Wetlands. This assessment should be linked to the Ramsar criterion or criteria fulfilled by the site at the time of Ramsar designation. An effective monitoring program is a prerequisite for assessing whether or not a wetland has undergone a change in its ecological character, The Ramsar Convention does not specify how wetlands are to be monitored but does provide a framework for monitoring. The framework consists of a series of logical steps that can be used to design a monitoring program based on particular circumstances and needs. Additional guidance on monitoring is found in Ran-tsar Resolution 5.6 from the Kushiro Conference of the Parties in 1993.

A monitoring program that is designed to detect ecological change can be used to suggest that a wetland be placed on the Montreux Record of the Ramsar Convention. The Montreux Record, adopted in 1990 at the Fourth Conference of the Contracting Parties held in Montreux, Switzerland, is a register of wetland sites on the List of Wetlands of International Importance where changes in ecological character have occurred, are occurring, or are likely to occur as a result of technological developments, pollution or other human interference. The purpose of the list is to identify Ramsar sites that are in need of corrective action.

As can be seen from the history of Caddo Lake monitoring, governmental agencies can only sporadically monitor the Caddo Lake watershed due to limited funding and personnel.Therefore, other groups must take on this challenge. At the Sixth Conference of the Contracting Parties at Brisbane, Australia, Resolution VI 19 was adopted which supports the need for and enlargement of wetland education and public awareness. The resolution affirms that education and public awareness are essential instruments for successful and sustainable wetland management. Also during the Sixth Conference Recommendation 6.3 noted that the Technical Session on community-based management held in Brisbane disclosed several promising non-government organization models for active and informed participation of local people in the wise-use of their resources, such as those initiated by the Caddo Lake institute in the United States. Because of the monitoring mandate from the Ramsar Convention and the problem of sporadic monitoring, the Institute has decided to take a leadership role in the monitoring of Caddo Lake and in wetland education of the local public.

From its inception, the Institute has supported the creation of a basin-wide water quality monitoring network conducted by the academic members of the Institute. These members include Marshall High School, Karnack High School, Texarkana College, Panola College, East Texas Baptist University, Wiley College, and Louisiana State University in Shreveport. Initially this took the form of academic monitoring which used protocols capable of application in an education program. These protocols include: Texas Watch Program, Issac Walton League Save Our Streams Program, and Project GREEN.

Water Quality Monitoring: LAMOP and Texas Watch Program

In order to routinely monitor the water quality at Caddo Lake, the Institute began the Lake Monitoring Program (LAMOP) in 1994 under the direction of Mike Buttram, a chemistry professor at Texarkana College. He was responsible for setting up the water monitoring network, training volunteer monitors, and finding appropriate sites for monitoring. The first sites monitored were at Caddo Lake State Park and at various marinas and restaurants along the lake shore. Selection of sites was difficult because the area around the lake is almost completely privately owned. Also, at this time the Institute did not own a boat so monitoring the open water was not generally possible.

For routine water quality monitoring the Institute adopted the state sanctioned Texas Watch Program for chemical water testing, which is a state-wide volunteer program for the monitoring of all types of water bodies. Monitoring began in the summer of 1994 and LAMOP has now been conducted monthly for almost three years. Twenty-nine sites are currently monitored, however the number and location of sampling sites has varied over time depending on the number and interests of the volunteers. Recently, there has been increased attention paid to quality assurance/quality contro1 with the result that annual QA/QC workshops are held. The Institute financially supports LAMOP by providing the test kits, paying for the training of volunteers, reimbursing for travel expenses, and paying a minimum wage stipend for time spent monitoring.

The Texas Watch program uses field kits produced and sold by the LaMotte Chemical Company for $275. At each sampling site various observations are recorded and surface water is tested. Tests included in the kit include temperature, dissolved oxygen, pH, conductivity and the Secchi disk depth. These tests monitor key water quality parameters, but the number and quality of tests is limited. In order to have a more complete chemical monitoring program, the institute soon added several additional tests including alkalinity, carbon dioxide, nitrate, ammonia, phosphate, sulfide, zinc, copper, and turbidity. These water test kits are also purchased from LaMotte Chemical Company for approximately $ 40 per kit.

Table 1 shows a summary of the LAMOP data from 19 stations for July 1994 through June 1996. All stations are located along the lake's shore and not every station has received the same intensity of monitoring. These data are within natural ranges for water parameters in east Texas and reveal no specific water quality problems. One of the limitations with this approach is that most of the tests are based on the development of a color in a test solution and the subsequent comparison to a standard color chart. Color discrimination by different observers can be highly variable. Also, the natural level of many of these chemicals is very low, which in many cases (e.g. nitrate-nitrogen, sulfide, copper, and zinc) are often below the detection limits of the test kits. Thus, much of the water quality data would not be regarded as scientifically valid, although it has "presumptive" value. For example, it might provide data that suggests the need for a more rigorous monitoring program.

<u>LAMOP Biomonitorinq</u>

To complement the chemical monitoring program, the Institute has adopted two biomonitoring protocols: benthic biodiversity and fecal coliform bacteria. Benthic macroinvertebrates are monitored using a protocol from the Issac Walton's Save Our Streams; program. The protocol involves sampling of benthic macro-invertebrates using ' D' -frame nets at each sampling site four times per year The protocol requires the volunteer to sample the lake substrate and as randomly as possible pick out and identify as many organisms as possible in a 20 minute time period. The benthic biomonitoring results in the assignment of a semi-quantitative water quality index of excellent, good, fair, or poor to each site. Results from this biomonitoring program are shown in Table 1 and indicate that the sampled water reflects fair to good water quality. Two problems with this approach have been noticed: (1) the protocol was designed for use in streams, thus many of the organisms found in Caddo Lake were not on the Issac Walton water quality list; and (2) because there is no pre-determined number of organisms to sample, some volunteers put more effort into the work than others which results in uneven sampling efforts

Coliform bacteria monitoring, based on the scientifically rigorous protocol of the American Public Health Association, was begun in the fall of 1994 by Roy Darville and an undergraduate student at East Texas Baptist University of Marshall, Texas (Darville and Brock, 1995). Monitoring was done at 10 lake sites for total coliforms, fecal coliforms, and fecal streptococci. In order to meet State of Texas standards, each site was sampled five times within a 30 day time period. Personnel from Wiley College of Marshall, Texas, led by Alexandrine Randriamehefa took over this monitoring in the spring of 1995 (Randriamehefa, 1996) This protocol remained in place for over one year Results from Dr Randriamehefa' s work are show in Table 1 and in Figure 2. During this time period the mean of all stations except one exceeded the State of Texas criterion of 200 colonies per 100 ml Highest fecal coliform levels were found during the late summer and early fall, Fecal coliform monitoring indicates that a significant coliform problem exists in certain areas of the lake This type of monitoring is expensive, reflects only shoreline conditions, and is limited to the identification of only one type of pollution.

Specific chemical pollutants in the lake have been monitored recently by the Institute (1995) and by various agencies: Texas Natural Resource Conservation Commission (Crowe, 1997), Louisiana Department of Environmental Quality (Cormier, 1996) U.S. Geological Survey (1996), and the U.S. Army Corps of Engineers (1994). These groups examined surface water and/or sediment in Caddo Lake and in Harrison Bayou which empties into Caddo Lake. For example, the Texas Department of Health issued a fish consumption advisory for Caddo Lake during January, 1995. The advisory recommends that people do not consume largemouth bass greater than 18 inches in length, or freshwater drum of any size from Caddo Lake due to elevated mercury concentrations. Other chemicals of concern are: heavy metals such as arsenic, barium, cadmium, nickel, and zinc; organic compounds such as trichloroethene, dichloroethene, vinyl chloride, and acetone; and several pesticides. These studies suggest that chemical pollution of Caddo Lake may be a significant ecological and human health issue. Thus, over the past few years some data for chemical pollutants have become available for a few areas of Caddo Lake. However, there needs to be a more systematic, rigorous sampling approach so that all areas of the lake are examined and long-term trends can be identified.

Conclusions Drawn from LAMOP

LAMOP has provided monthly water quality data for almost four years. This monitoring has been highly successful in the educational aspect in that over 100 local citizens have been trained to use the Texas Watch protocol throughout the Cypress Basin. DR. Buttram's efforts received special recognition in 1997 when the Texas Watch organization named rhe Institute as an "outstanding lead partner" and gave special recognition to two of the 1nstitute' s public school teachers. However, the utility of the data for determining water quality at Caddo Lake is limited. For instance, all of the sites that have been monitored so far are located along the shoreline. In a lake that is as large and as hydrologically complex as Caddo Lake, there is a significant need for sites located in the open water and in areas where specific water quality questions need to be answered. Second, many of the kits used in the chemical testing are not sensitive enough to detect small changes in surface water quality. In many cases the test results are below detection limits. More sensitive analytical methods for metals and nutrients were needed in order to more accurately monitor these chemicals of concern While the academic monitoring has presumptive value, there was a growing recognition by the Tnstitute that it is not comprehensive or rigorous enough to satisfy the requirements of Resolution VI. 1. Therefore, the Institute proceeded to develop a need for a more comprehensive, rigorous water quality monitoring approach.

Accordingly in 1996 the Institute assembled a discussion group of scientists for the purpose of designing a more comprehensive and rigorous monitoring protocol. Participants included, Dwight K. Shellman, President of the Institute, Roy Darville of

East Texas Baptist University, Alexandrine Randriamehefa of Wiley College, Mike Buttram of Texarkana College, James B. Johnston and Carroll Cordes of the National Wetlands Research Center, Virginia Engel of USGS-BRD, and Tom Hardaway of the Louisiana Department of Environmental Quality. As a result of this dialog an initial design was created for the first Caddo Lake Institute Protocol (CLIP) for Rapid Intensive Biomonitoring (RIB).

Development of CLIP/RIB

In order to address these concerns a more advanced intensive monitoring protocol (CLIP/RIB) has been developed. Two chemical sampling programs have been designed with the assistance of Virginia Engel of the USGS-BRD. The first sampling program was designed to answer the question: How does the water quality of Caddo Lake vary seasonally and how can we identify long-term trends in improvement or degradation of water quality at representative sites within Caddo Lake? Starting in February 1997, four open water sites are being sampled monthly (Fig. 3). These sites were chosen based on prior knowledge of the sites' ecology, limnology, and pollution status. Big Cypress Bayou and James Bayou were chosen because they represent the largest inflows into the lake. Harrison Bayou has several known pollution problems, and the mid-lake site represents the deepest area of the lake. In addition all of these sites have on at least one previous occasion been sampled by the Texas Natural Resources Conservation Commission, which allows for some data comparison.

The second program is attempting to answer the question: What is the overall condition or health of Caddo Lake from a water quality perspective? In order to answer this question all areas of the lake will be sampled using a design similar to that of the Environmental Monitoring and Assessment Protocol (EMAP). EMAP was originally developed by the USEPA to provide improved information on the current status of, and long-term trends in the condition of the nation's ecological resources. EMAP for surface waters incorporated the random selection of lakes in a specific region of the country and the intensive monitoring of those lakes. From the monitoring of these lakes, conclusions could be drawn about the environmental status of lakes in the entire region (Larsen and Christie, 1993).

In the case of Caddo Lake we are monitoring only one lake and its wetlands, so we modified EMAP to accommodate our specific needs. Using a LANDSAT base map of Caddo Lake and National Wetlands Inventory data, a geographical information system (GIS) was used to divide the lake into three habitat types: riverine, wetland, and open water (Figs 4,5,6,7). Within each habitat type equal-sized hexagons were created where each habitat type used a different sized hexagon. From the hexagons thirty random generated sampling points were derived for each habitat type The sampling stations were then superimposed over the base map and plotted These ninety sites will be monitored during a two or three week period this summer, typically the time when a lake's water quality is at a minimum.

For both the monthly monitoring program and the intensive summer monitoring program, the following water quality parameters will be tested at the surface and bottom of each site: water temperature, dissolved oxygen, carbon dioxide, pH, alkalinity, conductivity, chloride, total solids, suspended solids, dissolved solids, hardness, nitrate, ammonia, total phosphorus, reactive phosphorus, Secchi disk depth, true color, apparent color, turbidity, chlorophyll a, and biological oxygen demand (BOD). All sampling and testing will follow USEPA. or APHA approved methodology with appropriate QA/QC procedures. Appropriate blanks and standards are run monthly. Sample preservation follows APHA guidelines, which includes cooling the water samples to 4°C and in some cases preservation with sulfuric acid. All tests are run within 48 hours of sampling.

Biomonitoring

CLIP/RIB will now use the USEPA's Rapid Biomonitoring Protocol (Plafkin et al. 1995), instead of the Issac Walton League's protocol. This will result in a much better estimation of water quality using benthic macroinvertebrates. Five benthic samples are being taken quarterly at the same four open water sites using a petite Ponar dredge. Samples are preserved with formalin until analyzed in the laboratory.

Biomordtoring using fecal coliform bacteria will continue with monthly sampling at the surfaceland bottom of each site. The protocol will follow rigorous APHA methods.

Data Management and Analysis

Data will be entered into an Excel spreadsheet, mapped into a GIS (ArcView 2), and subjected to statistical analysis by SPSS, a statistical software package. Differences among the four monthly sites and between the surface and bottom will be determined, Seasonally and long-term trends will be analyzed following an USEPA method (Recklow et al. 1995). Also, the Project GREEN water quality index (WQI), derived from the National Sanitary Foundation, will be calculated for each site (Mitchell and Stapps, 1995). Nine tests are conducted: dissolved oxygen, fecal coliforms, pH, 5-day biochemical oxygen demand (BOD), change in water temperature, total phosphate, nitrate, turbidity, and total solids. The index results in a water quality assessment of excellent, good, fair, or poor. This index is used nationwide by many volunteer groups which allows for easy comparison and communication of results.

Results from the first three months of CLIP

Monitoring has been completed at the four fixed stations for the months of February through April Results for water quality parameters are summarized in Table 2. Virginia Engel of USGS-BRD has assisted with some of the statistical analysis. One-way ANOVAs performed on the physicochemical parameters found that 10 of the 25 parameters measured were statistically significant between the stations at the a = 0.05 level. Independent samples t-tests comparing the surface and bottom means for all parameters across all four months resulted in no statistical differences, thus the water column during February - April was fairly homogenous. This result was expected because the region has experienced above normal rainfall and winds during these months which serves to thoroughly mix the water column. Bonferroni's multiple range test of the parameters by site shows that the Harrison Bayou site is significantly different from the other three sites. Most of the statistically significant parameters are indicators of poor water quality: low dissolved oxygen, high ammonia, high nitrates, high color, and high fecal califorms. In addition, several parameters exceed State of Texas or federal surface water quality criteria. After more data is collected, trend analysis will be conducted to examine for long-term trends.

The first benthic sampling was conducted in April at all four open water sites. Tdentificarion of the benthic macroinvertebrates resulted in the identification of 30 taxa and 564 individuals (Table 2). The fauna was dominated by tolerant species of oligochaetes, leeches,. amphipods, and chironomids. Preliminary results suggest that the water quality at Harrison Bayou is significantly worse than at the other three sites. Additional analyses of this data will occur at a later date.

Monitoring Costs

The Institute has made a substantial financial investment in the design and implementation of this intensive monitoring design. The data below shows most of the costs incurred to date.

16' Go-Devil boat, trailer, 25 hp motor, accessories	$7200
multiparameter water quality meter (Yellow Springs Instrument Co.)	$3000
water test kit (model DREL/2010, Hach Company)	$2300
turbidimeter (model 21OOP, Hach Company)	$ 900
fecal coliform equipment: oven, filtration apparatus, vacuum pump, and supplies (Hach Company)	$2500
Ponar dredge and benthic sampling supplies (Forestry Suppliers Co.)	$ 600
water and benthic sample bottles (Hach Company)	$ 500
water sampler (Forestry Suppliers Co.)	$ 200
chemicals, glassware, etc.	$ 500
	$17,700

labor (field work, lab analysis, and data management and analysis): 30 hours/month

Future Monitoring

In addition to chemical and biological monitoring of water quality, future CLIP plans call for the idetermination of specific pollutant concentrations including endocrine disrupters, monitoring of the bird life, and monitoring the unique ecological features of Caddo Lake. in water, sediment, fish, and possibly other biota. This monitoring of toxic chemicals is based on Ramsar Recommendation 6.14 on toxics in wetlands. This recommendation calls on contracting parties to determine how these chemicals are effecting the ecological character of the wetland. Sampling of these chemicals will follow EPA or APHA approved procedures. Specific chemicals (heavy metals, pesticides, priority pollutants) will be chosen based on the results of prior screening by various agencies. The laboratory analysis; for these pollutants is beyond the present capabilities of the Institute, therefore this analysis will be contracted out to agency partners or private laboratories. In addition, because: Caddo Lake was designated as a Ramsar wetland because of its bird life and unique ecological character, the Institute will develop monitoring protocols in support of Resolution VI. **1.**

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List of Figures
(figures available upon request)

List of Tables.

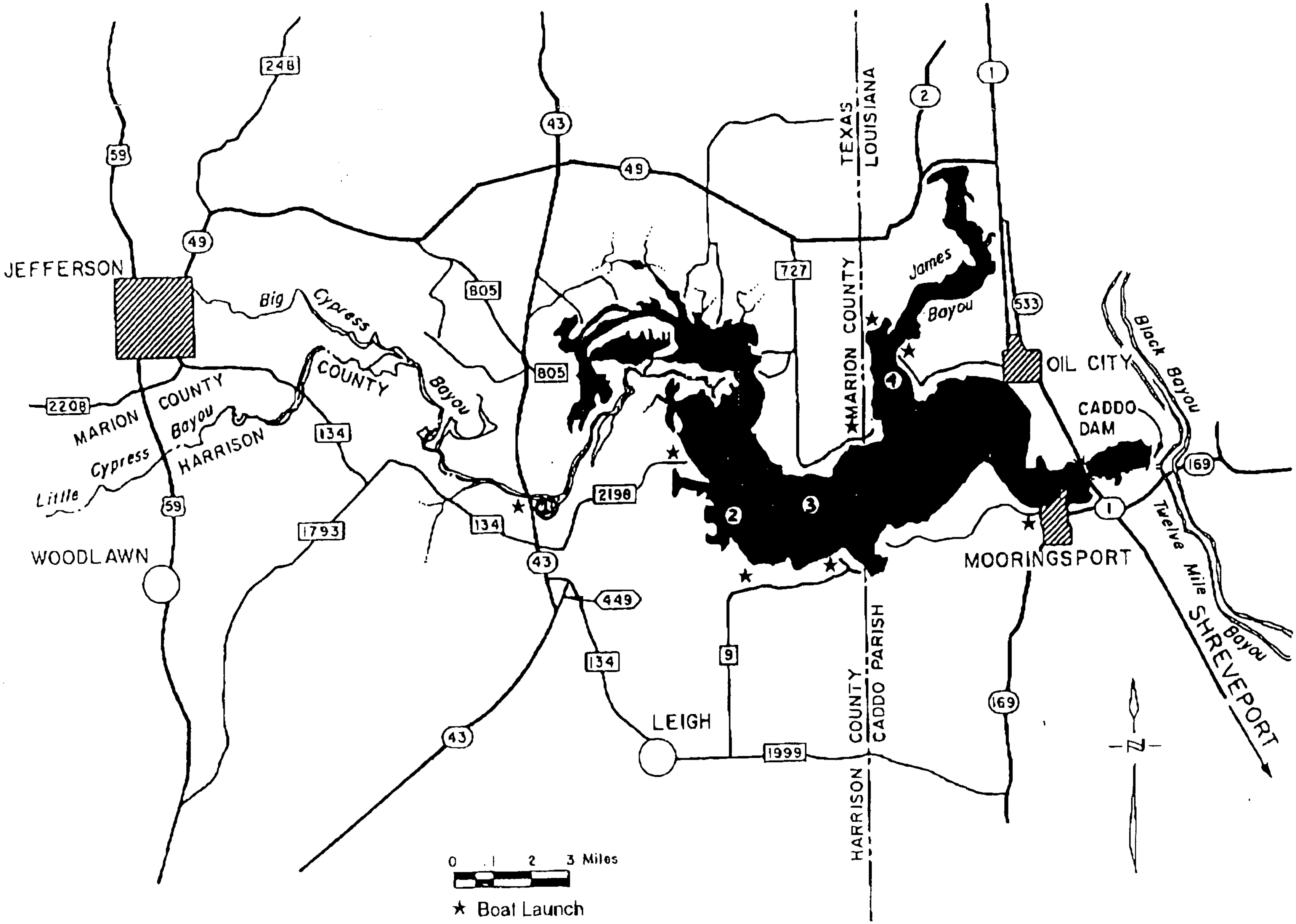
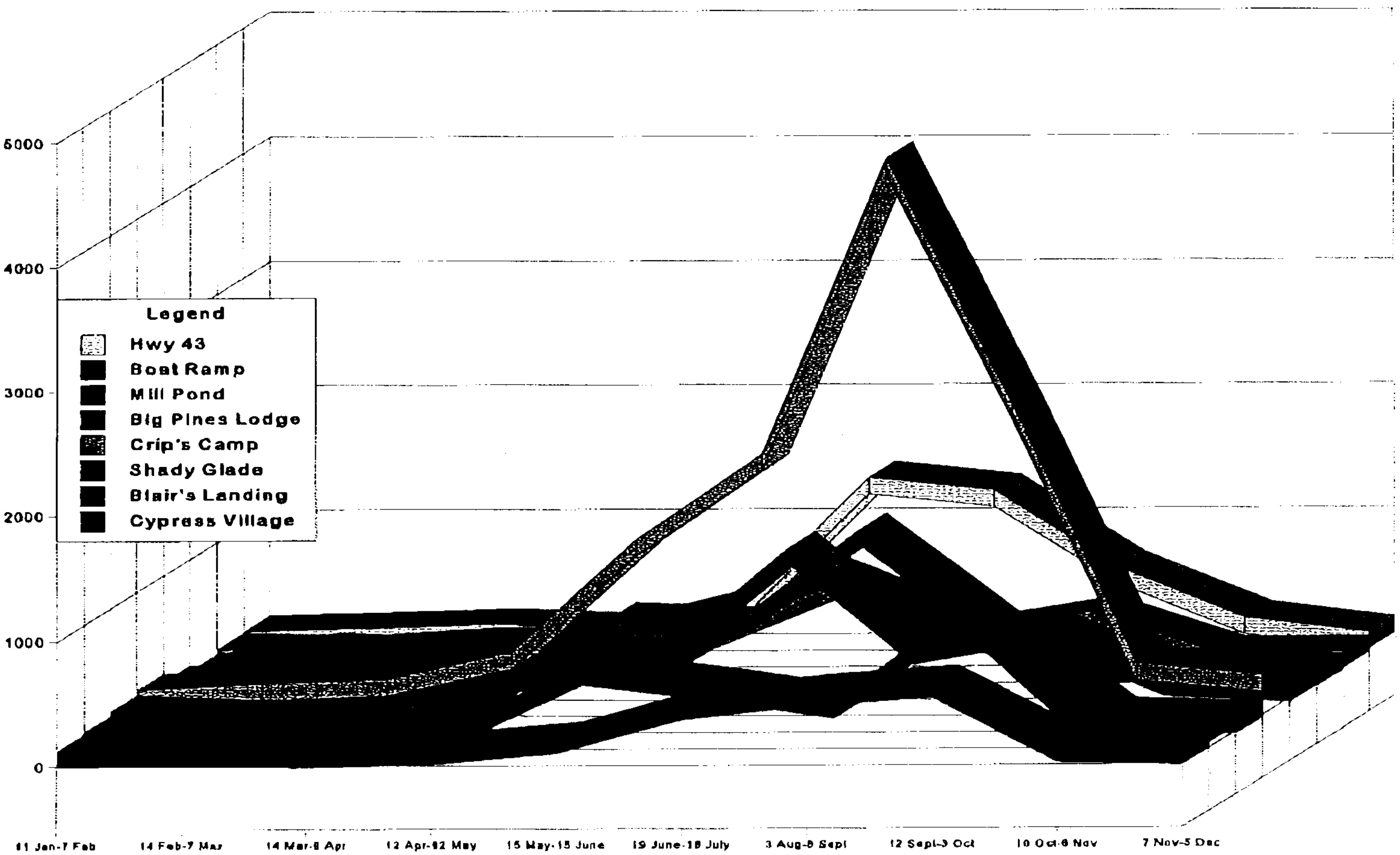


Figure 2. Vicinity and site location map for Caddo Lake.

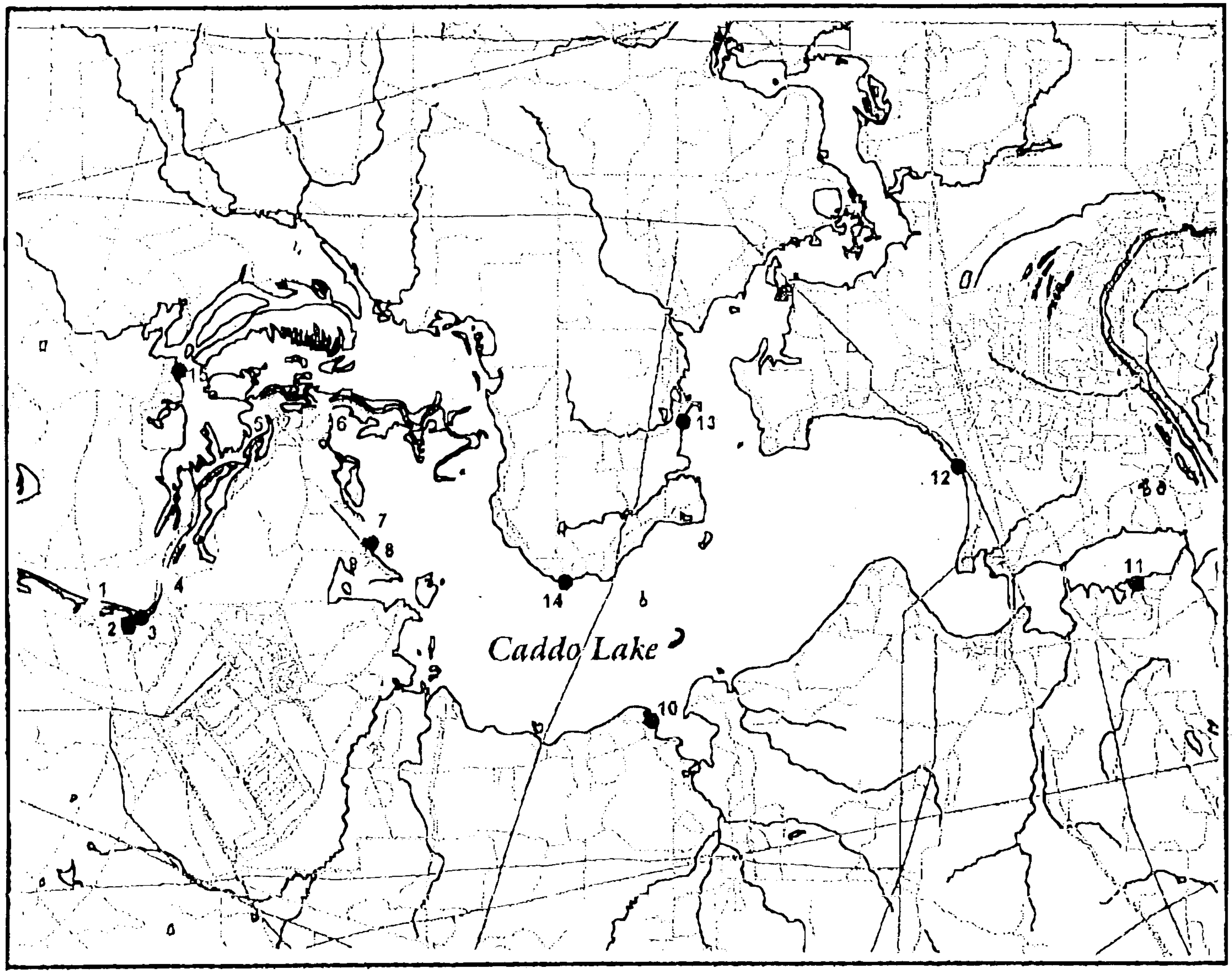
Geometric Mean of Fecal Coliforms

From January 11 to December 7, 1995

Number of Colonies/100 ml



Composite Analysis of Benthic Macroinvertebrates at Caddo Lake
July 1994 through May 1996



SAMPLING SITES
1 Highway 43 Bridge
2 Caddo Lake State Park – Mill Pond
3 Caddo Lake State Park – Boat Ramp
4 Big Pine Lodge
5 Blair's Landing
6 Cypress Village Boat Ramp
7 Shady Glade Marina and Restaurant
8 Bayou Landing Restaurant
9 Crip's Camp
10 Collier's Landing
11 Summer Point landing
12 Earl G. Williamson Park
13 Pelican Lodge
14 Potter's Point
15 Pine Needle Lodge

Analysis Values
Poor
Fair
Good

Features
Hydrology
Roads
Railways
Pipelines

Note: All sites were sampled once in each season for at least a 1 year period. Sites 12,13,14 and 15 were not sampled in 1996. Sampling for sites 1,4,5,6,7 and 9 was begun in March 1995.

0 2 4 Miles

Map by Becky Gullette, Panola College; July 1996
Analysis by Dr. Roy Darville, East Texas Baptist University
Sample site coverages created by John Bryan, Panola College
Other coverages courtesy of The National Biological Service
and The Caddo Lake Institute

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Summary of Results for LAMOP at Caddo Lake, July1994 - June1996 [1]

Test	N100	N200	N300	N400	S020	S090	S100	S190	S200	S210	S215	S220	S300	S305	S380	S400	S410	S500	S600
Temp (°C)	19.9	21.3	22.3	20.1	19.7	22..3	19.5	20.7	19.0	19.8	22.5	19.8	20.9	19.9	19.9	22.1	21.1	21.6	20.6
D.O. (mg/l)	5.1	7.6	9.3	8.7	7.5	7.6	7.0	7.7	7.3	7.5	7.1	7.6	7.6	6.4	6.7	5.9	5.7	8.4	8.45
Conductivity (uS/cm)	105	109	119	116	102	109	110	104	111	101	118	108	113	104	104	107	140	114	116
Secchi Disc (m)[3]	0.58	0.64	0.37	0.65	0.35	0.35	0.67	0.72	0.85	0.80	0.86	0.55	0.95	0.24	0.70	0.62	0.75	0.69	0.79
pH	6.3	6.7	7.3	7.1	6.5	6.5	6.5	6.5	6.4	6.5	6.7	6.5	6.6	6.6	6.4	6.2	6.3	6.9	7.1
CO2 (mg/l)	11.64	5.8	3.1	3.2			13.7		14.5		7.6		7.8			10.2		5.0	14
Alkalinity (mg/)									28				28			33		29	
NH3-N (mg/l)	0.48	1.33 (85%)	0.28 (75%)	0.2 (89%)			0.2 (86%)		ND (100%)		0.15 (94%)		0.5 (95%)			0.47 (72%)		2.0 (87%)	0.6 (83%)
NO3-N (mg/l)	0.7	ND[2] (100%)	ND (100%)	ND (100%)			ND (100%)		0.5 (95%)		ND (100%)		ND (100%)			ND (100%)		ND (100%)	ND (100%)
PO4 (mg/l)	0.4	0.6 (32%)	0.3 (36%)	0.58 (5%)			0.26 (59%)		0.35 (82%)		0.23 (76%)		0.25 (39%)			0.31 (17%)		0.23 (48%)	0.30 (36%)
Sulfide (mg/l)	---	.2 (95%)	ND (100%)	ND (100%)	---	---	0.7 (95%)	---	0.2 (95%)		ND (100%)		0.2 (96%)			0.2 (89%)		0.2 (91%)	ND (100%)
Copper (mg/l)							ND (100%)		ND (100%)		1.0 (75%)		0.05 (67%)			ND (100%)		0.07 (50%)	
Zinc (mg/l)							ND (100%)		ND (100%)		ND (100%)		0.75 (67%)			ND (100%)		0.5 (83%)	
Benthic macro-invertebrate [4]	fair	fair	poor	fair			fair		fair							good		fair	fair
Fecal coliform (colonies/100 ml) [5]					336		221		182	286		298	212		465		1186		

1. Not all stations were sampled an equal number of times; numbers in parenthesis are percent of samples below detection limit of the test method.
2. ND = No samples had results above the detection limit.
3. Minimum depth due to many months when Secchi disc depth exceeded total depth.
4. Issac Walton Save Our Streams Protocol; four water quality categories: excellent, good, fair, poor
5. Mean of ten geometric means based on five samples in 30 day periods during January - December, 1995.

Table 2: Benthic Biomonitoring at Caddo Lake, April 1997

Taxon	SP1	SP2	SP3	SP4	SP5	HB1	HB2	HB3	HB4	HB5	ML1	ML2	ML3	ML4	ML5	JB1	JB2	JB3	JB4	JB5	TOTAL
Cnidaria																					
Hydridae																					
Hyrda																			1		1
Platyhelminthes																					
Planariidae																					
Dugesia tigrina														1		7	2	2	6		18
Annelida																					
Oligochaeta																					
Tubificidae																					
Branchiura sowerbyi																	2	2		1	5
Limnodrilus	20	10	9		10				14	9	1					11	2	2	43		131
Naididae																					
Dero digitata											1						1	2			4
Pristina				1	2												2		1		6
Pristinella									1												1
Stylaria fossularis	1			2	2											3		1	1		10
Hirudinea																					
Erpobdellidae																					
Erpobdella														1							1
Glossiphoniidae																					
Helobdella elongata	1	1	4																4		10
Helobdella stagnalis											5	4		1					3	1	14
Piscicolidae																					
Myzobdella lugubris																	1		1		2
Mollusca																					
Gastropoda																					
Ancylidae																					
Hebetancylus excentricus					1																1
Viviparidae																					
Lioplax		1							9												10
Pelecypoda																					
Unionidae																					
Ligumia		2																			2
Sphaeridae																					
Musculium									1							1				1	3
Arthropoda																					
Crustacea																					

Table 2: Benthic Biomonitoring at Caddo Lake, April 1997

Amphipoda																					
Talitridae																					
Hyallela azteca		1		2							5	6	10	2	3	6	16	64	7	42	164
Insecta																					
Trichoptera																					
Polycentropodidae																					
Neureclipsis		1																			1
Ephemeroptera																					
Caenidae																					
Caenis		1															1				2
Ephemeridae																					
Hexagenia limbata	1	2			1																4
Odonata																					
Coenagrionidae																					
Enallagma													1			1	1			1	4
Diptera																					
Chironomidae																					
Coelotanypus														1							1
Chironomus																	1		4	3	8
Cryptochironomus																			1		1
Polypedilum			12	15	2											7	3		3	1	43
Tanypus	3	3		2	3						10	18	26	15	13		1				94
Chaoboridae																					
Chaoborus	1	2							1		2	2	4	1	1		3		3		20
Megaoptera																					
Sialidae																					
Sialis					1																1
Lepidoptera																		1			1
Hydracarina										1											1
TOTAL INDIVIDUALS	27	24	25	22	22	0	0	0	26	10	24	30	41	22	17	36	36	74	78	50	564
TOTAL TAXA	6	10	3	5	8	0	0	0	5	2	6	4	4	7	3	7	13	7	13	7	

Sheet1

Site #	SiteName	Depth	SiteType	Date	TotDepth	WatTemp	DO	OxySat	BOD	CO2	Alkalin	pH	Conduct	Hardness	Turbidity
					m	C	mg/l	%	mg/l	mg/l	mg/l	SU	uS/cm	mg/l	NTU
1	SP	S	riverine	2/21/97	1.19	12.5	8.80	83	ND	7.0	23	6.2	70	24	31.5
1	SP	B	riverine	2/21/97		12.6	8.70	82	ND	7.5	22	6.1	70	40	50.8
2	HB	S	wetland	2/21/97	1.01	14.4	6.40	63	ND	8.0	35	6.3	82	56	44.1
2	HB	B	wetland	2/21/97		14.2	3.90	38	ND	8.0	32	6.3	82	64	155
3	ML	S	lake	2/21/97	4.07	12.7	9.70	91	ND	6.0	22	6.2	57	48	32
3	ML	B	lake	2/21/97		12.2	ND	84	ND	6.0	22	6.2	57	100	89.7
4	JB	S	riverine	2/21/97	2.09	12.9	9.40	89	ND	6.0	21	5.9	59	20	13.6
4	JB	B	riverine	2/21/97		12.3	8.65	81	ND	5.0	21	5.9	58	32	34.2
1	SP	S	riverine	3/16/97	2.09	16.1	7.31	74	ND	5.0	11	6.6	77	56	17.7
1	SP	B	riverine	3/16/97		16.1	4.89	50	ND	10.0	12	6.6	78	60	1190
2	HB	S	wetland	3/16/97	1.12	16.4	6.08	63	ND	11.0	18	6.7	65	56	700
2	HB	B	wetland	3/16/97		16.4	5.31	55	ND	11.0	17	6.6	68	56	1140
3	ML	S	lake	3/16/97	3.03	16.6	7.56	78	ND	8.0	10	6.6	82	60	300
4	ML	B	lake	3/16/97		16.6	6.50	67	ND	8.5	10	6.7	84	56	1510
4	JB	S	riverine	3/16/97	2.32	17.3	7.33	76	ND	10.0	8	6.4	69	52	450
4	JB	B	riverine	3/16/97		17.3	3.57	37	ND	9.0	9	6.4	70	52	620
1	SP	S	riverine	4/11/97	2.45	17.3	8.84	92	3.3	6.0	14	6.61	94	30	9
1	SP	B	riverine	4/11/97		17.4	8.40	87	0	7.5	13	6.56	93	30	8
2	HB	S	wetland	4/11/97	1.73	17.6	2.80	29	2.8	27.5	29	6.43	74	32	16
2	HB	B	wetland	4/11/97		15.8	3.64	26	1.4	29.0	24	6.38	96	24	23
3	ML	S	lake	4/11/97	2.51	17.8	8.84	96	0	9.0	14	6.93	94	24	7
3	ML	B	lake	4/11/97		17.8	8.90	97	0	9.0	13	6.97	97	22	10
4	JB	S	riverine	4/11/97	1.71	18.7	9.00	99	0	7.0	11	7.09	82	24	9
4	JB	B	riverine	4/11/97		18.7	9.00	99	0	8.0	11	6.96	82	24	10
FebMean					2.09	12.975	7.935714	76.375		6.6875	24.75	6.1375	66.875	48	56.3625
MarMean					2.14	16.6	6.06875	62.5		9.0625	11.875	6.575	74.125	56	740.9625
AprMean					2.1	17.6375	7.4275	78.125		12.875	16.125	6.74125	89	26.25	11.5
TotMean					2.11	15.7375	7.109565	72.33333		9.541667	17.58333	6.484583	76.66667	43.41667	269.6083

Sheet1

Secchi	TotSolids	SusSolids	DisSolids	TruColor	AppColor	NH3	NO3-N	NO3	TotP	ReactP	TotPO4	ReactPO4	Cl	FC
m	mg/l	mg/l	mg/l	CU	cU	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	#/100ml
0.47	148	28	128	30	195	0.4	0.8		0.17	0.13			2.5	500
	309	144	165	83	313	0.47	0.7		0.15	0.11			3	1460
0.17	208	60	148	117	395	0.52	1.1		0.17	0.14			2.5	4500
	580	202	382	107	944	0.55	1.2		0.24	0.19			3	5120
0.38	188	40	148	99	284	0.43	0.7		0.18	0.13			2.5	180
	315	238	77	104	491	0.49	0.8		0.21	0.17			2.5	320
0.7	137	24	113	21	262	0.43	0.8		0.18	0.14			3	240
	155	66	89	84	217	0.42	0.6		0.19	0.13			3.5	140
0.6	510	7	503	136	208	0.51	0.6	2.6	0.14	0.11	0.25	0.32	1.5	1420
	1190	26	1164	150	240	0.53	0.6	2.4	0.1	0.04	0.23	0.11	1.5	1380
0.45	700	6	694	237	328	0.69	1	4.5	0.11	0.09	0.25	0.28	1.5	1840
	1140	22	1118	250	406	0.67	1	4.3	0.13	0.1	0.24	0.3	1.5	2260
0.95	300	2	298	101	104	0.34	0.3	1.4	0.11	0.07	0.23	0.21	1.5	140
	1510	86	1424	108	252	0.32	0.4	1.6	0.1	0.05	0.21	0.14	1.5	140
0.71	450	1	449	120	176	0.45	0.3	1.4	0.14	0.1	0.31	0.32	1	500
	620	7	613	127	186	0.44	0.5	1.9	0.11	0.05	0.3	0.14	2	420
0.89	116	0	116	107	138	0.54	0.3	1.2	0.04	0.04	0.17	0.13	15	110
	102	2	100	95	142	0.54	0.3	1.5	0.02	0.03	0.1	0.09	15	80
0.61	150	3	147	205	252	1	0.6	2.7	0.01	0.01	0.03	0.02	10	100
	163	0	163	180	228	1.2	0.9	3.8	0.03	0.03	0.1	0.09	15	13400
0.95	134	0	134	124	251	0.54	0.3	1.3	0.02	0.01	0.06	0.02	10	900
	127	2	125	104	130	0.52	0.3	1.2			0.02	0.01	10	70
0.75	100	3	97	99	147	0.63	0.1	0.6	0.04	0.02	0.11	0.01	15	120
	43	12	31	93	151	0.71	0.1	1.6	0.04	0.03	0.11	0.01	15	330
0.43	255	100.25	156.25	80.625	387.625	0.46375	0.8375	#DIV/0!	0.18625	0.1425	#DIV/0!	#DIV/0!	2.8125	1557.5
0.6775	802.5	19.625	782.875	153.625	237.5	0.49375	0.5875	2.5125	0.1175	0.07625	0.2525	0.2275	1.5	1012.5
0.8	116.875	2.75	114.125	125.875	179.875	0.71	0.3625	1.7375	0.028571	0.024286	0.0875	0.0475	13.125	1888.75
0.635833	391.4583	40.875	351.0833	120.0417	268.3333	0.555833	0.595833	2.125	0.114348	0.083478	0.17	0.1375	5.8125	1486.25